



034115

PHOSPHORUS

Lambda User Controlled Infrastructure for European Research

Integrated Project

Strategic objective:
Research Networking Test-beds



Deliverable D.6.3 Test-bed functionality report

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Project:	Phosphorus
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Abstract

PHOSPHORUS addresses some of the key technical challenges to enable on-demand e2e network services across multiple domains. The PHOSPHORUS network concept will make applications aware of their complete Grid resources (computational and networking) environment and capabilities, and able to make dynamic, adaptive and optimized use of heterogeneous network infrastructures connecting various high-end resources. PHOSPHORUS will enhance and demonstrate solutions that facilitate vertical and horizontal communication among applications middleware, existing Network Resource Provisioning Systems (NRPS), and the proposed Grid-GMPLS Control Plane (G²MPLS).

One of the main assumptions of PHOSPHORUS is that the project propositions and developments should be validated and demonstrated in a real advanced optical network. To achieve this, the project has built a distributed test-bed in which the project outcome will be demonstrated with a set of real scientific applications in a set of real-life scenarios.

The project demonstrates an incremental approach to the test-bed construction. The first version of the test-bed has already been built and validated. It is based mostly on the solutions available before PHOSPHORUS while the project developments will be incrementally introduced to the test-bed when they are available from other project activities.

This document summarises the functionality of the test-bed after the first phase of developments as a base for integration of the project outcomes. The description of functionality is limited to the features which have vital meaning for the tests and demonstrations envisaged for the test-bed. More information about the particular elements of the test-bed can be found in other PHOSPHORUS documents, mostly generated by workpackages 1, 2 and 3.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Table of Contents

0	Executive Summary	6
1	Applications	8
1.1	KoDaVis (Distributed Collaborative Visualisation)	8
1.2	Distributed Data Storage Systems (DDSS)	9
1.3	TOPS	10
2	Grid middleware	11
2.1	Meta Scheduling Service	11
2.2	UNICORE	12
3	Switching inside local test-beds	14
3.1	PSNC local test-bed	14
3.2	CESNET local test-bed	15
3.3	I2CAT local test-bed	17
3.4	SURFnet local test-bed	18
3.5	UvA local test-bed	19
3.6	UESSEX local test-bed	19
3.7	VIOLA local test-bed	21
3.8	CRC local test-bed	23
4	Connections between local test-beds	24
4.1	Physical connections	24
4.2	Logical connections	27
5	Control plane and NRPSes	29
5.1	GMPLS and G ² MPLS	29
5.2	UCLP	35
5.3	DRAC	36
5.4	ARGON	37
6	Conclusions	41
7	References	42
8	Acronyms	43

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



List of Figures

Figure 1. Topology and resources of the CESNET test-bed	16
Figure 2. Topology of long-distance connections inside CESNET test-bed	17
Figure 3. DRAC web interface at SURFnet	19
Figure 4: Topology of the VIOLA local test-bed	22
Figure 5: Current VLANs in the PHOSPHORUS test-bed	28
Figure 6: GMPLS driver system design	30
Figure 7: Thin NRPS and other PHOSPHORUS modules	33
Figure 8: GMPLS Test Environment of the VIOLA PHOSPHORUS Test-bed	34
Figure 9. DRAC interface	37
Figure 10: Structure of the ARGON resource reservation system	38
Figure 11: MPLS Test Environment of the VIOLA PHOSPHORUS Test-bed	40

List of Tables

Table 1: VLAN connections in the PHOSPHORUS test-bed	27
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Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



0 Executive Summary

PHOSPHORUS addresses some of the key technical challenges to enable on-demand e2e network services across multiple domains. The PHOSPHORUS network concept will make applications aware of their complete Grid resources (computational and networking) environment and capabilities, and able to make dynamic, adaptive and optimized use of heterogeneous network infrastructures connecting various high-end resources. PHOSPHORUS will enhance and demonstrate solutions that facilitate vertical and horizontal communication among applications middleware, existing Network Resource Provisioning Systems (NRPS), and the proposed Grid-GMPLS Control Plane(G²MPLS)..

One of the main assumptions of PHOSPHORUS is that the project propositions and developments should be validated and demonstrated in a real advanced optical network. To achieve this, the project has built a distributed test-bed in which the project outcome will be demonstrated with a set of real scientific applications in a set of real-life scenarios.

The test-bed is constructed from communications equipment (optical switches, TDM switches, Gigabit Ethernet switches, transmission equipment) and advanced GRID resources (like computing nodes, visualisation and storage resources). The communications equipment is the platform of the project's developments and implementations in order to allow applications to utilise the functionality of an advanced optical network and assure seamless cooperation of various test-bed equipment. The different types of resources (communications, computing etc) correspond to the elements of an advanced GRID system in which GRID resources are distributed over a communications network. The structure of the test-bed is also compatible with the PHOSPHORUS paradigm of integration between traditional GRID and the communications infrastructure. The GRID resources do not only include the hardware but also GRID middleware software which controls the resources and acts as an interface between the applications and the infrastructure.

The project demonstrates an incremental approach to the test-bed construction. The first version of the test-bed has already been built and validated. It is based mostly on the solutions available before PHOSPHORUS while the project developments will be incrementally introduced to the test-bed when they are available from other project activities.

This document summarises the functionality of the test-bed after the first phase of developments as a base for integration of the project outcomes. The description of functionality is limited to the features which have vital meaning for the tests and demonstrations envisaged for the test-bed. More information about

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

the particular elements of the test-bed can be found in other PHOSPHORUS documents, mostly generated by workpackages 1, 2 and 3.

The summary of the functionality covers several layers of the PHOSPHORUS test-bed: applications, GRID middleware, switching infrastructure, connections between local test-beds, control plane and NRPSes. The functionality was verified in tests, which confirmed that the test-bed works properly and is ready for integration of the project developments.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



1 Applications

This chapter depicts the current status of installation and the functionality of applications which will be used to verify and demonstrate the PHOSPHORUS developments. The applications have been provided by Workpackage 3 and installed on the resources (GRID nodes) of PHOSPHORUS local test-beds.

1.1 KoDaVis (Distributed Collaborative Visualisation)

Short application description

KoDaVis is an application that deals with the collaborative visualisation of data in distributed teams. It provides remote access to huge atmospheric simulation data using a data server. This server is connected to a number of visualisation systems. To allow a collaborative workflow, the visualisation systems are coupled by an interaction server, which distributes the user interactions among them in order to synchronize the visualised scene.

The functionality to be tested in PHOSPHORUS test-bed

The use case to be tested in PHOSPHORUS test-bed aims to make scheduled synchronous reservations of resources via the UNICORE middleware. These resources are namely compute capacity on the data server, the visualisation clients and network bandwidth and QoS between server and clients. Furthermore, the client-triggered transfer of huge amounts of data from the data server to the visualisation clients is conducted, exposing the high bandwidth and QoS property of the PHOSPHORUS lambda services.

The functionality available in the test-bed (verified by preliminary tests)

Both the visualisation client and the data server have been installed in the PHOSPHORUS test-bed. The connection between client and server is established interactively through an ssh-tunnel. The transfer of data takes place in both directions: requests for datasets are sent from the visualisation client to the data server, and in response to these requests datasets are sent back to the visualisation.

The functionality to be implemented/deployed in following months

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

Within the next months, scheduled synchronous reservations of resources are going to be performed by the UNICORE middleware.

Moreover, the collaboration of visualisation clients is going to be tested.

1.2 Distributed Data Storage Systems (DDSS)

Short application description

DDSS are used to transport, exchange, share, store, backup/archive and restore data in scientific and commercial applications. Test scenarios for PHOSPHORUS test-bed include two DDSS use cases: data transfers performed with use of GridFTP application and backup/archive/restore operations made by a backup/archive application.

The functionality to be tested in PHOSPHORUS test-bed (*describe in the relation to use-cases*)

Two use cases are to be tested in PHOSPHORUS test-bed: GridFTP data transfers and backup/archive/restore operations. In the former scenario GridFTP server stores or retrieves the data from/to single or multiple clients (many-to-one). The single client can collaborate with many servers at the same time (one-to-many). Data transmission between client-server pair can be done over 1-128 parallel streams (stripes).

In the latter scenario, the end-user data is collected on client machines by a client B/A modules and send through TCP/IP connections to B/A server module. B/A server manages storage pools that can include disks, tapes and other storage media and stores user data in these pools, according to the defined policy. Typical setup contain single B/A server and multiple B/A clients.

The functionality available in the test-bed (verified by preliminary tests)

(describe in the relation, what use-cases can be run in the test-bed)

Both use-cases have been tested in PHOSPHORUS test-bed. As far, one-to-one Grid FTP scenarios (one client, one server) were tested for various number of threads (1-16), and thus possibility of performing these scenarios in the test-bed is confirmed. Also one-to-one backup/archive application scenarios were successfully run, so this functionality is available in the test-bed.

In addition to applications, a tool for collecting and visualising the test results was developed. It collects the DDSS test results, i.e. the performance obtained during the tests, and prepares graphs that are put on the web site, and can be used for later analysis.

The functionality to be implemented/deployed in following months

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

In following months, more complicated DDSS test scenarios are going to be performed, including many-to-one and one-to-many use-cases.

1.3 TOPS

Short application description

TOPS is used to access, stream and display very large datasets with both scientific and commercial origins. In the coming period focus will be laid on streaming views on a 50 TB climatology dataset, maintained by Dutch researchers from the University of Utrecht.

For the test-bed, we will be focusing on the performance of each of the different components, from the data retrieval to the streaming portion.

The functionality to be tested in PHOSPHORUS test-bed (describe in the relation to use-cases)

The typical use case that will be explored is a researcher at a display facility, that selects a subset of the total dataset and desired display parameters, and either immediately starts viewing the resulting display, or gets a time slot for later when the content is ready to be viewed.

Because waiting time is perceived as lost time, most efforts will go into measuring and minimizing waiting time, in each of the different stages of the TOPS pipeline.

The functionality available in the test-bed (verified by preliminary tests)

Currently, the necessary patches for getting the lightpath from SARA to IAIS have not yet been laid. Network testing so far have taught us that large MTUs (9000) are not supported on all machines in the path. This is an issue that is still pending.

The functionality to be implemented/deployed in following months

In the following months, a version of TOPS that is suitably modular for use on a grid will be deployed and tested. Using this version, performance measurements will be taken.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



2 Grid middleware

This chapter depicts the current status of installation and the functionality of GRID middleware which will be used to verify and demonstrate the PHOSPHORUS developments. The GRID middleware has been provided by Workpackage 3 and installed on the resources (GRID nodes) of PHOSPHORUS local test-beds.

2.1 Meta Scheduling Service

Name of the middleware component:

MetaScheduling Service (MSS)

Short middleware description

MMS is a co-allocation and reservation service in the PHOSPHORUS test-bed. It allows a user to reserve and co-allocate multiple resource including network connections for an application. In the first phase of the project the user specifies the resources needed to run a specific application. In the second phase applications are annotated with their respective resource demand and the user only needs to specify the application while the selection of the appropriate resources is done automatically based on the annotated data.

The functionality to be tested in PHOSPHORUS test-bed

Functionality of the MSS with respect to two use-cases will be tested:

- Reservation of a single network connection, e.g. to do experiments with GridFTP, or to transfer the results of WISDOM simulations from the executing PHOSPHORUS site to the results data-base.
- Reservation and co-allocation of multiple resources for one application, e.g. reserving the compute nodes and network for the WISDOM workflow, or reservation of compute resources and network for the KoDaVis application.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

The functionality available in the test-bed (verified by preliminary tests)

Both types of reservation have been tested. However, no tests with network resources have been done so far as the integration of the NSP to the MSS is not yet available. Also, no tests with applications have been performed as the applications still have been in development.

The functionality to be implemented/deployed in following months

The Interface to the PHOSPHORUS network resource provisioning system ARGON will be implemented and tested. Also, reservation of compute resources operated by other PHOSPHORUS partners will be tested.

2.2 UNICORE

Name of the middleware component:

UNICORE

Short middleware description

UNICORE is the main Grid middleware system used in the PHOSPHORUS test-bed. It offers seamless and secure access to Grid resources. The new version 6 of UNICORE has been released in August and is used in the project. It is based on OGF Web-Service standards. With an UNICORE client extension of the, users will be able to specify their CPU and networking resource demands. These are handled by the MetaScheduling Service (MSS). The current production version 5 of UNICORE which is already integrated with the MSS, is used for parts of the tests within the first phase of the project. The full integration of UNICORE 6 with the MSS will take place in the beginning of the second phase.

The functionality to be tested in PHOSPHORUS test-bed

Functionality of UNICORE with respect to two use-cases will tested:

- Starting and managing complex distributed applications, e.g. multiple KoDaVis visualization clients connecting to central data- and collaboration-servers
- Preperation of the middleware in a mixed environment, where some connections are made over internet and some over dedicated PHOSPHORUS test-bed lines.

The functionality available in the test-bed (verified by preliminary tests)

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

Starting and managing the so called UNICORE 6 extended services (e.g. the KoDaVis data-server) has been tested over the Internet. Performance and functionality tests based on dedicated PHOSPHORUS connections have just started.

The functionality to be implemented/deployed in following months

The integration of the UNICORE 6 system with the MSS is the major next step planned for the following months. These developments include the extension of UNICORE server components as well as providing access to MSS functionality through the UNICORE Client user interface.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



3 Switching inside local test-beds

This chapter shows the current functionality of the PHOSPHORUS local test-bed. As each of the local test-beds offers different functionality and serves different purposes, each of them is described separately.

3.1 PSNC local test-bed

The switching infrastructure in the PSNC local test-bed consists of one optical switch (Calient DiamondWave FiberConnect) and three Gigabit Ethernet switches (Foundry XMR). PSNC plans to expand the switching infrastructure to three optical switches on the same type as well as lease three lambda capable switches for temporary use at the test-bed.

The Calient optical switch is capable of switching fibres and supports optical multicast functions (copying an optical signal to multiple output ports). The switch works in the optical domain without converting the signals to electrical domain. Thus, it is fully transparent and independent of the transmission technology. It can switch optical signal carrying one wavelength only as well as DWDM signals carrying multiple wavelengths in a single fibre. However, it is not capable of switching wavelengths in a DWDM multiplexed signal.

The insertion loss of the switch equals 2dB, which is in the power budget of the interfaces connected to the switch. Even in scenarios in which a signal passes three optical switches (all the switches planned for the test-bed) the total insertion loss (6dB) will stay in the power budget so no amplifiers are needed in the test-bed.

The switch offers a TL1 command line interface which can be used by its PC-based G²MPLS controller to communicate with the switch.

The Ethernet switches are used to switch Ethernet frames between Gigabit Ethernet interfaces. In the PSNC local test-bed these are used to switch traffic between GRID nodes and aggregate traffic originated in the GRID nodes before reaching the optical domain.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

Using both optical and Ethernet switches in the test-bed gives the Phosphorus consortium the flexibility to verify the project developments in both domains – optical and Ethernet. Accordingly to the test scenarios each transmission between GRID nodes can be switches in any of the domains as well as simultaneously in both domains.

One of the Ethernet switches is also used to multiplex and demultiplex VLANs on the connections to other local test-beds to emulate multiple parallel links. This switch also allows for creating connections (VLANs) between local test-beds which are not directly connected – they can be connected via PSNC using a direct VLAN.

The Ethernet switches support MPLS, Layer 2 VPN and VPLS. These features are not used in the test-bed now but can be introduced to the test-bed later when the G²MPLS stack for the switches is available and supports MPLS. The switches offer a range of features related to Layer 2 which can be used when requested by GRID middleware and applications, e.g. guaranteed bandwidth, bandwidth policing, address filtering and others.

The switches offer a command line interface with SNMP access which can be used by their PC-based G²MPLS controllers to communicate with the switches.

The switching infrastructure at PSNC is not controlled by a control plane or NRPS yet. PSNC plans to introduce the G²MPLS stack for both optical and Ethernet switches when it is available from Workpackage 2.

3.2 CESNET local test-bed

3.2.1 Switching and transmission resources in the local test-bed and their connections

There are two main PoPs in Praha and Brno. The core network is based on Cisco 15454 MSPP (3 boxes in Praha, 1 in Brno), building a core triangle. These SONET crossconnects are connected via 10 G DWDM lambdas (ie lambdas with OC-192c framing) and are able to aggregate 1 GE signals.

In addition to SONET equipment, 1GE, 10G LAN and WAN PHYs GE switching and routing platforms from Cisco (Catalyst 6503), Force10 (E300) and Foundry (BigIron, Edgelron, SuperX) are available. All equipment supports DWDM pluggable optics (XENPAK, XFP, GBIC, SFP), Cisco 15454 support full tuneable (32 channels in C band) transponders. CzechLight 8x8 hit-less optical switches (crossconnects) are available both in Praha and Brno allowing pure optical switching.

There are no dedicated core/edge routers or switches, rather they can be deployed and used as needed.

The topology of the test-bed as well as all the test-bed resources is shown in Figure 1.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3

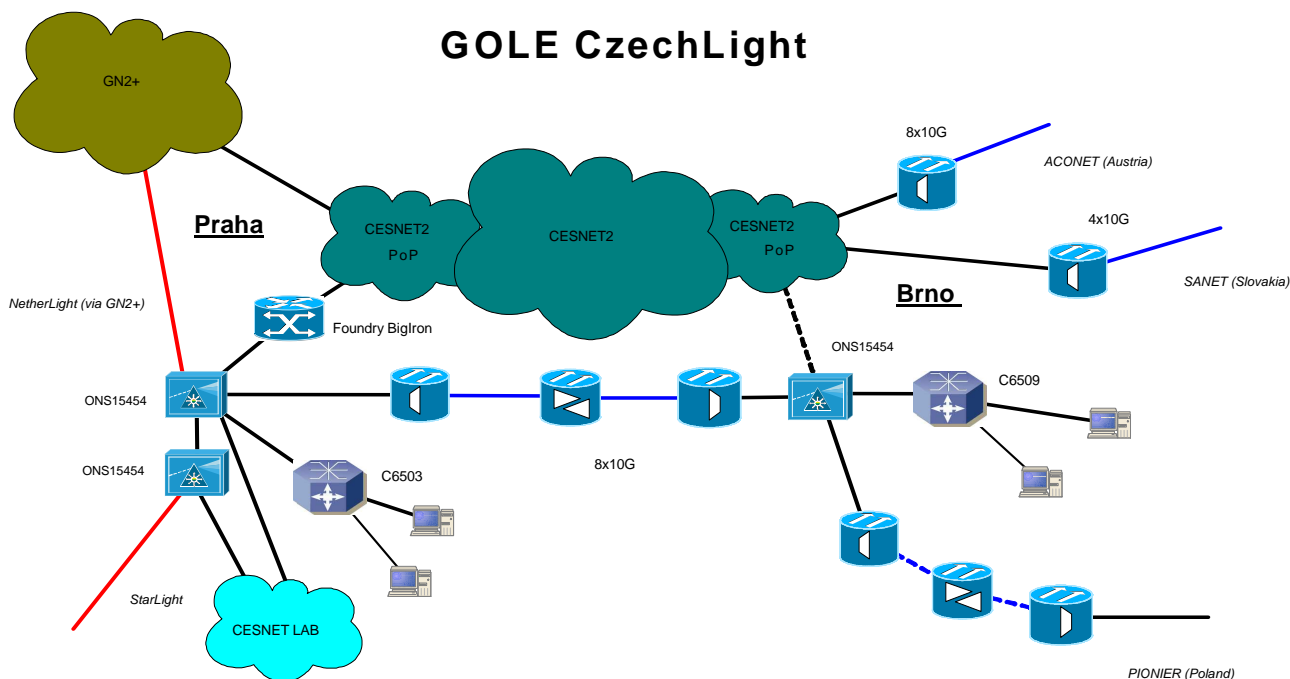


Figure 1. Topology and resources of the CESNET test-bed

3.2.2 Control and provisioning plane in the local test-bed

The optical crossconnect offers command line interface, SONET crossconnects offer TL1 and routers/switches offer CLI and SNMP. GMPLS is not supported.

The CESNET local test-bed infrastructure does not use any control plane or NRPS yet. CESNET is planning to use and deploy G²MPLS stack for all equipment when the stack is available from Workpackage 2.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

3.2.3 Interconnections with other local test-beds

The CESNET local test-bed have two direct connections to other Phosphorus local test-beds: SURFnet and PSNC. The 1GE link to SURFnet has already been established through GN2+ infrastructure (Ethernet over SONET). Two connections to PSNC are available. The first is non-dedicated 1GE link via GÉANT and the second one is dedicated dark fibre which can be used for lambda services providing 10G capacity and allow upgrade to 8 times 10G (this dark fibre link has been successfully established up to Czech-Polish borders).

The interconnection topology is shown in Figure 2:

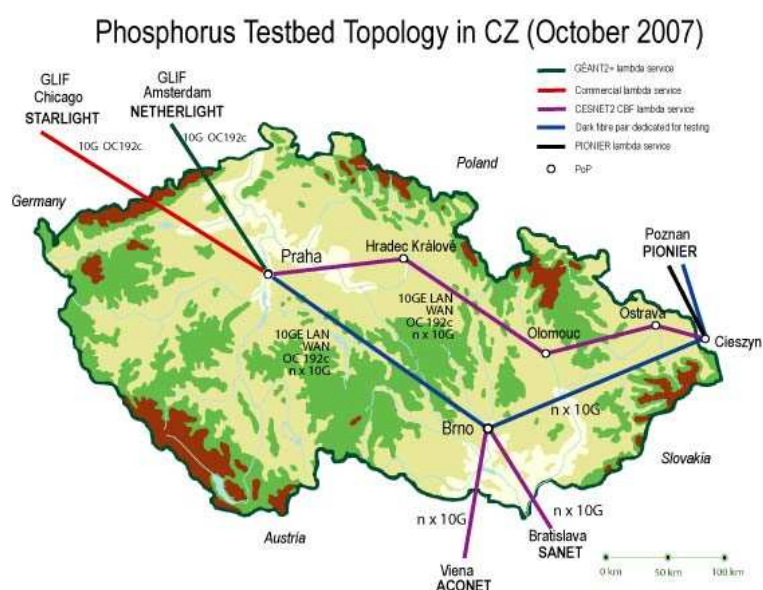


Figure 2. Topology of long-distance connections inside CESNET test-bed

3.3 I2CAT local test-bed

The switching infrastructure at the i2CAT local test-bed is composed by the following equipment:

- 1 x Alcatel 1850TSS-320 Transport Service Switch
- 2 x Nortel OPTera Metro 5200 Multiservice Platform
- 3 x Cisco Catalyst Gigabit Ethernet Switches

The Alcatel 1850TSS-320 is a multiservice node, with a commutation capacity up to 320Gbps and with matrix, control units and power supply redundancy. The applications for which it is designed are MSPP (Multi Service Provisioning Platform), MSTP (Multi Service Transport Platform) and also can be used as Ethernet/RPR/MPLS aggregation node. It supports several protocols for packet and circuit traffic. It also

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

counts with several mechanisms of QoS and failure tolerance. This device includes an agnostic matrix (universal) which is able to commute indistinctively frames (Ethernet, RPR, MPLS) and circuits (SDH/SONET/LCAS/VCAT), as well as to incorporate support for WDM and OTN. Inside the test-bed, this node is used to multiplex/demultiplex 3 VLANs (7xVC-4 each one) received through a 10Gbps SDH link connected to the GLIF, and sends each one of them to a port of a switch, connected to the OPTeras core and the application switch.

The Optical Metro 5200 is a DWDM multi-service platform that delivers 32 wavelengths of bandwidth, 10G scalability and sub-rate multiplexing capabilities that simplify the deployment of efficient DWDM metropolitan networks. The open and modular architecture of the Optical Metro 5200 delivers network scalability, per-wavelength manageability, bit-rate and protocol independence, and ring survivability. In the test-bed, these devices are connected between them, creating a DWDM ring. Each one of them is connected to 2 switches to achieve the required connectivity capabilities of the test-bed. These 2 devices are the ones that will be configured by UCLP via TL1 protocol, offering several interconnection possibilities between the connected partners and the local applications.

The Catalysts are used to commute the VLANs received from the remote partners and to offer connection to the local applications. These switches will have static configurations (since they are not controlled by UCLP yet), although they will offer the needed interconnection possibilities. All of them are connected to the OPTera core network, that will be the one that will enable/disable the connections.

3.4 SURFnet local test-bed

SURFnet implements a local test-bed using DRAC and the OME6500 nodes that are available for test-bed purposes. The 3 nodes are connected to the Phosphorus L2 hub switch, with an interdomain port to CRC, i2CAT and Viola – the other partners in WP1 that have an active test-bed. Additionally a local host node is connected to allow checking local connectivity and end-to-end connectivity. Between the nodes a network with 10 Gbps links exists, however all external connectivity is currently on GE ports. In the future the existing link from the test-bed to NetherLight may be used as well, to create direct end-to-end L1 circuits.

Once integration with other Work Packages occurs more client ports can easily be added to the setup. With this functionality the SURFnet test-bed emulates a real network, using the same equipment as what would be used in the actual production network.

Currently all partners in WP1 have access to the control of the network via the publicly accessible website <http://drac.surfnet.nl/> that is running on a DELL server that accesses both the test-bed and the public internet. All partners have user accounts that allows creation of circuits between the ports that are allocated to DRAC, including access to the web services interface.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

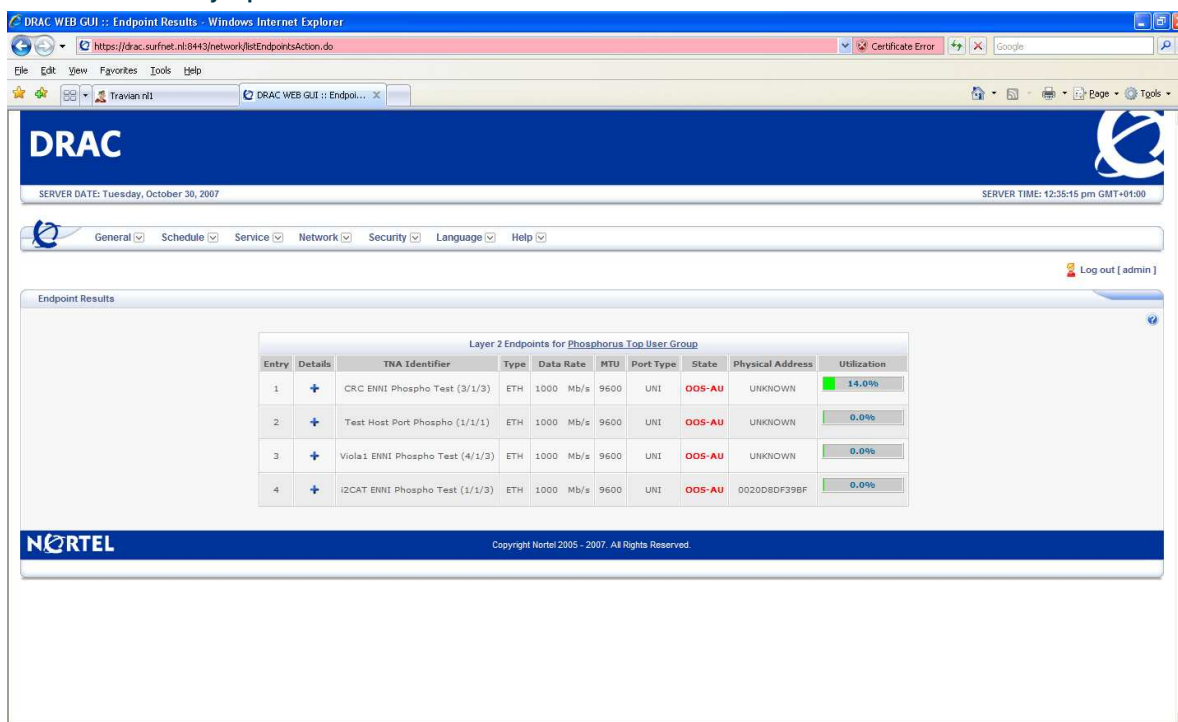


Figure 3. DRAC web interface at SURFnet

3.5 UvA local test-bed

In its Lighthouse test-bed facility in Amsterdam, UvA created an AAA test-bed, comprising of 9 IBM 330x CPUs and 6 24-port Gigabit Ethernet Dell PowerConnect 5324 802.1Q VLAN switches. This facility is logically configured as 3 clusters of 3 hosts and 2 switches. One cluster represents a domain. Domains can interconnect via UTP or SMF using 4 available SFP fibre ports. One host is considered as management plane host and the two other hosts as are considered as control plane hosts, each driving one Dell gigabit switch. Using dark-fibre inter-connections, this test-bed can be connected to Netherlight, a facility from SURFnet (see 3.4), which is co-located with Lighthouse. Netherlight offers international connectivity to Lambdas connecting several of our project partners as presented in chapter 4. The purpose of this test-bed is to allow various control and management plane implementations to operate and inter-operate in a multi-domain scenario's. The Lighthouse test-bed also include 3 Intel NPU development platforms. This test-bed is used to implement and test the FORCES based token-switch, created by WP4.

3.6 UESSEX local test-bed

University of Essex (UEssex) switching infrastructure for Phosphorus test-bed is made up of a single Calient DiamondWave FiberConnect Optical Switch, a single Ethernet Foundry FastIron Edge Switch

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

(X424HF Premium), two Dell 2716 PowerConnect Gigabit Ethernet switches and one Dell 6248 PowerConnect layer 3 managed switched with 10Gigabit and 1Gigabit Ethernet interfaces.

The Optical switch is the core switching node of the UEssex local test-bed and it is a carrier class switch with the capability to terminate 192 fibres per shelf (i.e. 96 X 96 switch matrix). The switch also supports 1-to-2 multicasting on selected ports. The switch dimension can be increased with an increment of 8 connections up to 320 X 320 which makes it highly scalable. This allows the test-bed to be able to easily and quickly adapt-to and also accommodate more fibre services/applications in the future. With its Remote and Dynamic Fiber Management properties, other partners can be given access to optical switch to allow them manage and provision their own connections adequately. It also has a low insertion loss of 2dB and less than 20ms configuration time. The optical switch has been partitioned into four independent 24X24 switches comprising 4 core optical switches in the UEssex local test-bed. These switches are operated independently as four separate optical switches. The optical switch supports the TL1 command interface that allows it to be easily interfaced with the available control plane protocols and Network Resource Provisioning Systems (NRPS) in Phosphorus. At the moment UEssex is working on interfacing it with the User Controlled Light Path (UCLP) NRPS Software.

The FastIron edge Ethernet switch provides connectivity between UEssex local test-bed and other test-beds in Phosphorus. It is used primarily on our test-bed to multiplex, demultiplex and switch between Gigabit Ethernet interfaces. It has a switching performance of up to 88Gbps with 24 100/1000 SFP interfaces, four Combo-port which supports 10/100/1000 and two 10G XFP ports which supports 10G Ethernet. The edge Ethernet switch also supports a wide range of Layer-2 and Layer-3 protocols such as VLAN tagging and Priority, VLAN Q-in-Q, VSRP, SNMP, RIP and OSPF. With its support for VLAN and Q-in-Q, it is used to multiplex and demultiplex VLANs on the connections to other local test-beds to simulate multiple parallel links. This switch also allows for creating connections (VLANs) between local test-beds which are not directly connected to UEssex.

Dell 6248 PowerConnect layer 3 managed switched in the UEssex local test-bed is used to switch traffic between Grid computing resources and the optical domain. It supports 48 ports 1Gigabit Ethernet switching ports, 4 SFP combo ports and two 10 Gigabit Ethernet ports. It has also switch capacity of 232Gbps. This switch also supports VLAN tagging and VLAN Q-in-Q.

The Local Area Network Switching (LAN) within our test-bed is achieved using two Dell 2716 PowerConnect Gigabit Ethernet switches which support VLAN and link aggregation technologies. Each switch also has a switching capacity of 32Gbps. These switches form the control plane network and also they are used to connect the application test-clients to the test-bed.

All the switches in the test-bed have TL1 or SNMP interface for control and management. The optical switch is controlled by four PC-based controllers (i.e. one per switch partition) and each Ethernet switch is controlled by one PC-based controller. UEssex is working to install UCLP NRPS software on the optical switch controllers. They will also be used in order to run G²MPLS stack when it is available.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

At present, all the switches are installed and the initial functionality self tests have been carried out. At the moment UEssex is working on interfacing these switches and also expecting the dedicated links to connect our test-bed to other Phosphorus nodes.

3.7 VIOLA local test-bed

The connections inside the local test-bed as well as all links to the other Phosphorus local test-beds use Gigabit Ethernet as the transmission technology. This way the local test-bed uses the same transmission technologies as most modern GRIDs. Gigabit Ethernet transmissions are switched in the test-bed in two layers – on layer one by SDH cross connects and on layer two by Gigabit Ethernet switches using MPLS.

The core of the local test-bed is built from three SDH cross connects, which switch SDH connections by using GMPLS. The SDH cross connects are Alcatel 1678 MCC systems. The cross connects are connected via 10 Gbps SDH links, building a triangle. Each of the SDH cross connects has at least 12 Gigabit Ethernet ports and will be able to switch each GbE port to any other GbE port using SDH connections. The Alcatel cross connects can be connected to OIF UNI 2.0 clients, which can be used for creating user initiated end-to-end connections. Three Proxy UNI 2.0 clients from Alcatel are available within the test-bed.

Each SDH cross connect is connected via two Gigabit Ethernets to a Riverstone 15008 Gigabit Ethernet switch. Four Gigabit Ethernet ports on each SDH cross connect are reserved to connect directly applications. Between the three Riverstone 15008 Gigabit Ethernet switches services based on MPLS tunnels can be defined. The Ethernet switches build the MPLS domain and add an additional layer to the heterogeneous Phosphorus network. The connections between the Ethernet switches themselves are 10 GbE links. The SDH cross connects will be controlled by Thin NRPS (GMPLS web service) and the Gigabit Ethernet switches will be controlled by the NRPS adapter ARGON.

The Riverstone Gigabit Ethernet switches aggregate traffic from GRID resources which are connected to them. The Alcatel 7750 Ethernet switches are used for connecting the VIOLA test-bed to the other PHOSPHORUS test-beds (see chapter “Interconnections with other local test-beds”).

All Gigabit Ethernet Switches, SDH cross connects and Proxy UNI systems are connected to a common control network (DCN network). This network is used for local management and configuration of the network devices.

The topology of the test-bed as well as all the test-bed resources is shown in Figure 4.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

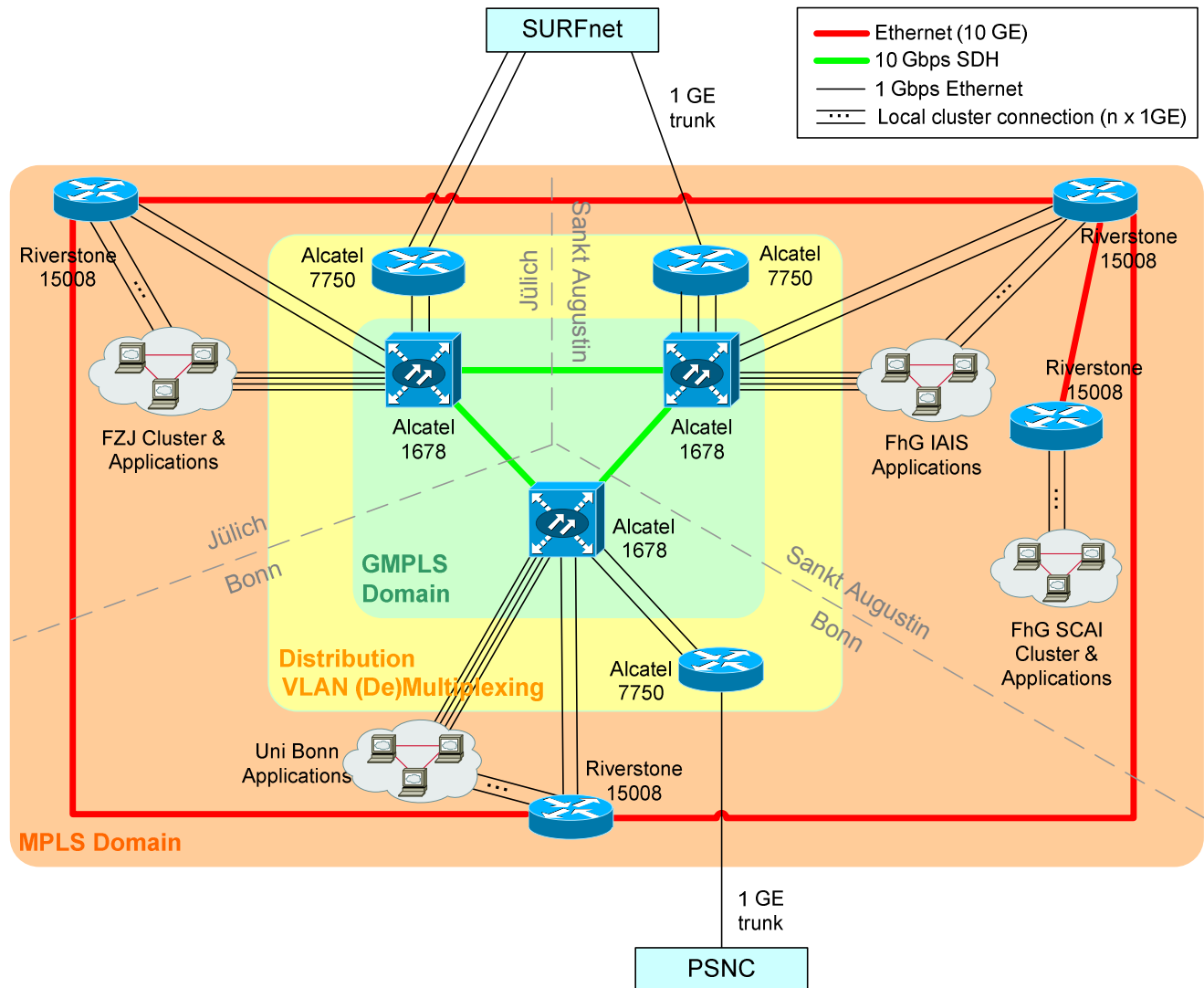


Figure 4: Topology of the VIOLA local test-bed

The VIOLA local test-bed has direct connections to Phosphorus local test-beds at SURFnet (3 physical links and PSNC (1 link)). One of the links to SURFnet has already been established. The other links will be provided until the end of October 2007. Via these test-beds other Phosphorus test-beds like CRC, i2CAT and PSNC can be reached. Multiple VLANs are used for simulating light paths on a single physical link. The links are terminated in one of the Alcatel 7750 Gigabit Ethernet switches in order to de/multiplex the VLANs. The Alcatel 7750 switches are connected to the Alcatel SDH cross connects. These cross connects can switch the connections from the other Phosphorus test-beds to local applications or to connections to other Phosphorus test-beds.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



3.8 CRC local test-bed

The CRC test-bed comprises equipment located in the Broadband Applications and Demonstration Laboratory (BADLAB™) and the Optical Networking Laboratory (ONL) facilities and extends across CANARIE, Canada's advanced network. The CANARIE network elements assigned to the Phosphorus project can be managed and controlled via the UCLP NRPS associated with the CRC domain.

A total of 6 network elements (5 Nortel OME 6500s and one Nortel HDXc) across CANARIE will be managed and controlled by the UCLP-CRC NRPS to manipulate the four LightPaths (LPs) allocated to the Phosphorus project. The Nortel Optical Multiservice Edge (6500) and Optical Cross Connect (HDXc) platforms support SONET switching and have OC-192 interfaces and line cards with dedicated GbE ports. All LPs end points facing the CRC BADLAB facility are terminated on GbE ports which connect to a Cisco 3750 switch co-located with the CANARIE Ottawa POP. The Cisco 3750 switch is connected to the BADLAB's core switch/router, a Cisco Catalyst 6509, via an 8-channel CWDM infrastructure. A Nortel OPTera Metro 5200 is also available as part of the Optical Networking Laboratory (ONL) adjacent to the BADLAB and supports GbE interfaces which can be connected to the Catalyst 6509 and/or PC's.

The resources across CANARIE for the 4 LPs assigned to the Phosphorus project have been given access rights by the UCLP-CRC NRPS. The 4 LPs have been manually provisioned and successfully tested. The two LPs originating from CRC and terminating on the PSNC and SURFnet L2 switches have been provisioned using VCAT containers which currently aren't supported by the UCLP NRPS. A request was issued to CANARIE to reconfigure these LPs using STS24c circuits. The CANARIE NOC was to initiate the changes during the week of September 16th following the GLIF '07 workshop but we have received no indication that the changes have been made. The LP from CRC to MCNC/LSU is only an STS3c circuit. This will be increased to a full STS24c circuit when more resources become available following the completion of the CAnet 4 transition to CAnet 5.

The L2 switches are also used to multiplex and demultiplex VLANs on the connections to other local test-beds to simulate multiple parallel links. This switch also allows for creating connections (VLANs) between local test-beds which are not directly connected – they can be connected via PSNC and SURFnet using a direct VLAN.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



4 Connections between local test-beds

This chapter shows the current status and functionality of connections between local test-beds.

4.1 Physical connections

1. PSNC – SURFnet
 - Technology – Gigabit Ethernet over SDH
 - Infrastructure used – GÉANT+
 - Status – running and tested
 - Capacity – 1Gbps
 - Jumbo frames transmission – yes
 - VLAN transmission – yes (using Q-in-Q)

2. PSNC – VIOLA
 - Technology – Gigabit Ethernet (L2VPN)
 - Infrastructure used – Cross Border Fibre, Layer 2 VPN in PIONIER and X-WiN Layer 2 tunnel (DFN)
 - Status – running and tested
 - Capacity – limited to 700Mbps, can be increased on demand for demos to 1Gbps.
 - Jumbo frames transmission – yes
 - VLAN transmission – yes

3. PSNC – i2CAT
 - Technology – Gigabit Ethernet (L2VPN)
 - Infrastructure used – GÉANT+
 - Status – running and tested
 - Capacity – 1Gbps
 - Jumbo frames transmission – yes
 - VLAN transmission – not tested

4. PSNC – CRC

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

- Technology – Gigabit Ethernet over SDH
 - Infrastructure used – GÉANT+, CANet 4
 - Status – running and tested
 - Capacity – 1Gbps
 - Jumbo frames transmission – yes
 - VLAN transmission – yes
5. VIOLA – SURFnet
- Technology – Gigabit Ethernet over SDH
 - Infrastructure used – GÉANT+ and X-WiN Layer 2 tunnel (DFN)
 - Status – running and tested
 - Capacity – 1Gbps
 - Jumbo frames transmission – yes
 - VLAN transmission – yes
6. VIOLA – SURFnet
- Technology – Gigabit Ethernet (L2VPN)
 - Infrastructure used – Cross Border Fibre (SURFnet) and private fibre (FZJ)
 - Status – to be implemented until end of October 2007
 - Capacity – 2x1Gbps
 - Jumbo frames transmission – to be determined
 - VLAN transmission – to be determined
7. CRC – SURFnet
- Technology – Gigabit Ethernet over SONET
 - Infrastructure used – CANet 5, SURFnet
 - Status – running and tested
 - Capacity – 1Gbps
 - Jumbo frames transmission – yes
 - VLAN transmission – yes (using Q-in-Q)
8. CRC – NORTEL
- Technology – Gigabit Ethernet over SONET
 - Infrastructure used – CANet 5
 - Status – running and tested
 - Capacity – 1Gbps
 - Jumbo frames transmission – yes
 - VLAN transmission – yes (using Q-in-Q)
9. CRC – MCNC
- Technology – Gigabit Ethernet over SONET
 - Infrastructure used – CANet 5, STARLIGHT
 - Status – running and tested

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

- Capacity – Currently limited to 155 Mbps and will be upgraded to 1Gbps when additional resources become available
- Jumbo frames transmission – yes
- VLAN transmission – yes (using Q-in-Q)

10. UEssex – PSNC

- Technology – Gigabit Ethernet over SDH
- Infrastructure used – GÉANT+
- Status – to be tested
- Capacity – 1Gbps
- Jumbo frames transmission – yes
- VLAN transmission – yes (using Q-in-Q)

11. UEssex – SURFNET

- Technology – Gigabit Ethernet over SDH
- Infrastructure used – GÉANT+
- Status – to be tested
- Capacity – 1Gbps
- Jumbo frames transmission – yes
- VLAN transmission – yes (using Q-in-Q)

12. i2CAT – CRC

- Technology – Gigabit Ethernet over SDH
- Infrastructure used – GLIF
- Status – running and tested
- Capacity – 1Gbps (7xVC-4)
- Jumbo frames transmission – Yes
- VLAN transmission – Yes

13. i2CAT – SURFnet

- Technology – Gigabit Ethernet over SDH
- Infrastructure used – GLIF
- Status – running and tested
- Capacity – 1Gbps (7xVC-4)
- Jumbo frames transmission – Yes
- VLAN transmission – Yes

14. UvA – SURFnet

- Technology – Dark fiber
- Infrastructure used – none (co-located)
- Status – operational
- Capacity – multiple 1-GE as offered by Netherlight.
- Jumbo frames transmission – Yes
- VLAN transmission – Yes

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

15. CESNET – SURFnet

- Technology – Gigabit Ethernet over SONET
- Infrastructure used – GÉANT+
- Status – available on request
- Capacity – 1Gbps
- Jumbo frames transmission – yes
- VLAN transmission – yes

4.2 Logical connections

On the physical connections described in 4.1 several logical connections are realized. Table 1 and Figure 5 give an overview about the logical connections and the defined VLANs.

VLAN id	between		Links used	Type of Connection
	Site A	Site B		
934	i2CAT	SURFnet	i2CAT - SURFnet	direct
947	SURFnet	VIOLA	SURFnet - VIOLA	direct
948	SURFnet	CRC	SURFnet - CRC	direct
937	i2CAT	VIOLA	i2CAT - PSNC, PSNC - SURFnet, SURFnet - VIOLA	stitched
938	i2CAT	CRC	i2CAT - SURFnet, SURFnet - CRC	stitched
978	VIOLA	CRC	VIOLA - PSNC, PSNC - CRC	stitched
903	SC 2007	i2CAT	SC 2007 - PSNC, PSNC - i2CAT	application
908	SC 2008	CRC	SC 2007 - PSNC, PSNC - CRC	application
917	PSNC	VIOLA	PSNC - VIOLA	application
957	SARA	VIOLA	SARA - SURFnet, SURFnet - VIOLA	application

Table 1: VLAN connections in the PHOSPHORUS test-bed

Further logical connections will be configured depending on the different test scenarios. The tests already executed proved that it is possible to create logical layer 2 connections between local test-beds which are not connected by a direct link. The logical connections are provisioned as VLANs and use switches in intermediate local test-beds.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

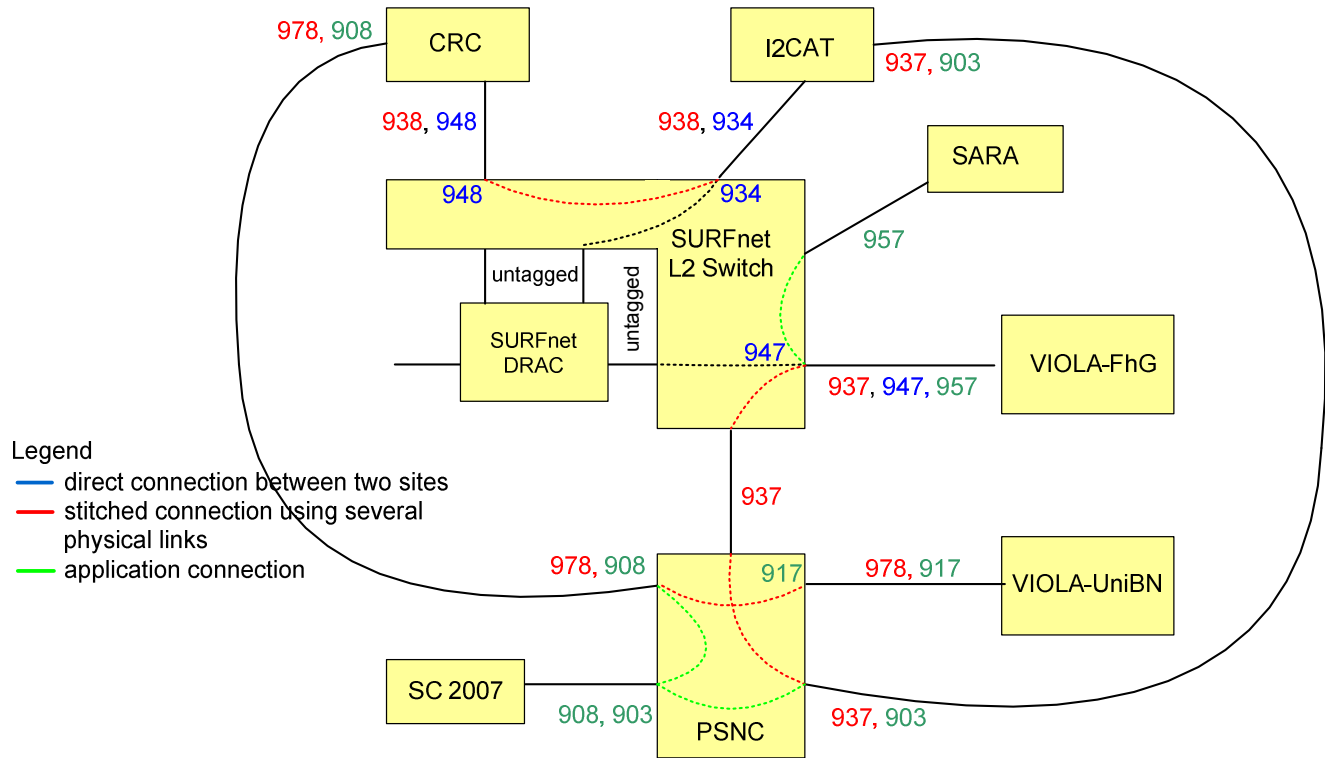


Figure 5: Current VLANs in the PHOSPHORUS test-bed

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



5 Control plane and NRPSes

There is one control plane – GMPLS – and several NRPSes (Network Resource Provisioning Systems) deployed in the test-bed now. Their current functionality is described briefly in this chapter. New versions of the control planes and NRPSes will be installed in the test-bed when available from Workpackages 1 and 2.

5.1 GMPLS and G²MPLS

5.1.1 VIOLA

A Thin NRPS and a GMPLS driver are currently developed and tested within work package 1. A first demo is planned for the SC 2007 conference.

5.1.1.1 GMPLS driver

The GMPLS driver acts as an interface between NRPS and the GMPLS control plane. It provides the following services:

Path creation service	This service creates a point-to-point path between two endpoints specified by TNA addresses.
Path termination service	This service tears down a point-to-point path which has been set up by a NRPS.
Path monitoring service	This service provides status information about the specified path.
Path discovery service	This service retrieves any established point-to-point connection in the controlled network. It is basically needed to refresh the NRPS view on the network in case of memory losses through system failures or maintenance reboots.
Endpoint discovery	This service retrieves information about any endpoint in the controlled network.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

service	It is needed to deliver the available endpoints to the NRPS during system initialization and to refresh the NRPS view on the available endpoints in case of memory losses through system failures or maintenance reboots.
Registration service	This service registers the NRPS to receive messages from the web service in case of path status changes or endpoint changes.

Additionally there are notifications which inform registered NRPS about changes concerning paths and endpoints.

Path delete notification	The event driven path delete service informs all registered and authenticated systems, if a path is no longer available.
Endpoint update notification	The event driven endpoint update service provides all registered and authenticated systems when endpoints have been removed from or added to the controlled network domain.

The overall system design is shown in Figure 6:

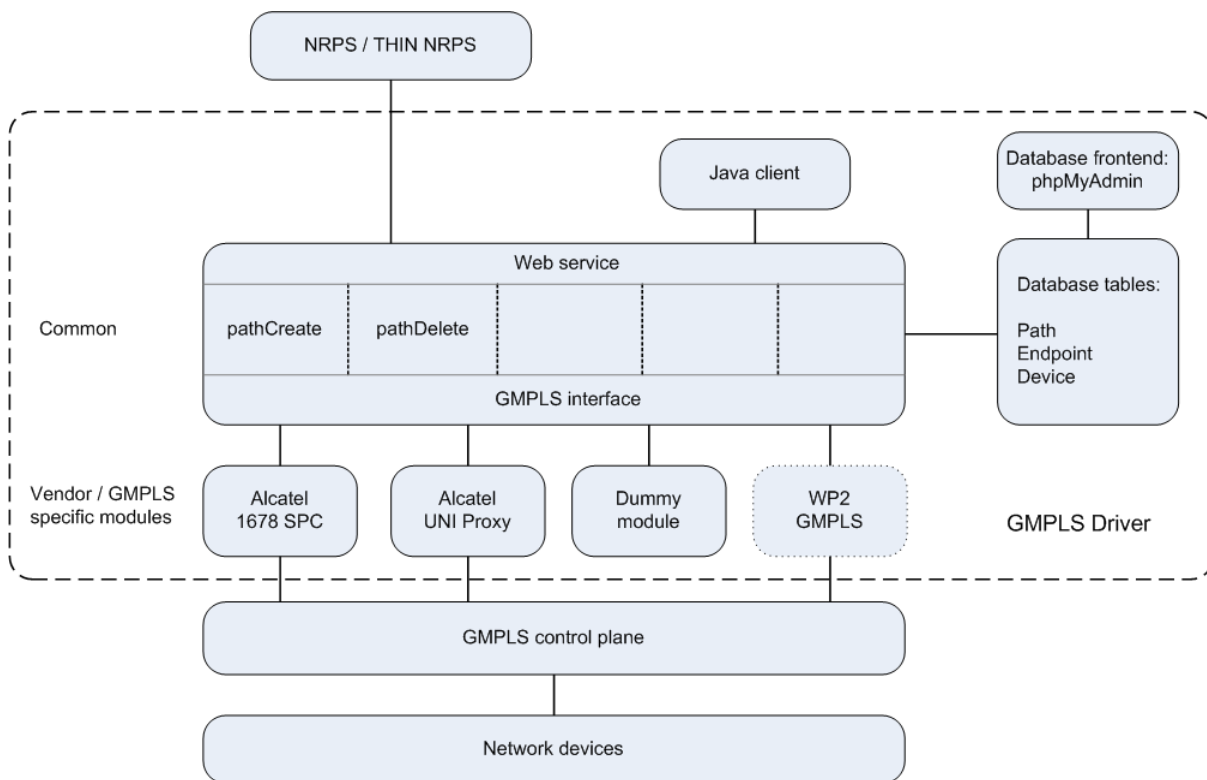


Figure 6: GMPLS driver system design

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

The GMPLS services are offered via a web service to the clients. A client could be a NRPS or for test purposes a user, who can access the services via a JAVA application. Information about paths, endpoints and devices is kept within an internal database, which can be accessed from all GMPLS driver modules or from a database frontend, like phpMyAdmin. GMPLS operations are initiated and controlled by vendor specific modules. Currently there are three modules available for creating and deleting paths:

- The Alcatel 1678 SPC module is used for managing the Gigabit Ethernet over SDH and SDH connections within the VIOLA test-bed. This module is based on the Alcatel GMRE command line interface, which allows the creation and deletion of Soft Permanent Connections (SPC).
- The Alcatel UNI Proxy module can be used for signalling Gigabit Ethernet over SDH and SDH connections between two UNI clients. Within the VIOLA test-bed three clients are available, which can be connected to any SDH cross connect.
- The Dummy module does not create any real GMPLS signalled connections. It simulates the creation and deletion of connections within a simulated domain. Besides this, it can act as a sample module for implementing new GMPLS modules.

After the WP2 GMPLS protocol implementation has been finished, a module can be added for this control plane, too.

5.1.1.2 *Thin NRPS*

The Thin NRPS is a network resources provisioning system for domains with a GMPLS control plane. Its relationship to the other PHOSPHORUS modules is show in Figure 7. The Thin NRPS

- provides a reservation web service, which is used by the NSP to reserve, create and delete network connections. It uses the same web service interface as the NRPS adapters.
- provides a notification receiver interface, which enables the GMPLS driver to send update information about endpoints and paths. Besides this, the GMPLS driver can register via this interface at the Thin NRPS driver.
- acts as a client to the topology manager web service of the NSP, e.g. it will add a domain and provide information about endpoints.
- acts as a client to the GMPLS driver web service for creating and deleting network connections and for obtaining information about endpoints and existing connections.

Internally, Thin NRPS provides the following functions:

- handles reservation requests from the NSP; checks, if the reservation can be granted and keeps track of the reservations in a database.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

- As the Thin NRPS currently only gets endpoint information from the underlying GMPLS driver, it has no knowledge about internal links and their usage. This means, that in case of advance reservation no checks for availability of bandwidth on the internal links can be performed. Therefore the Thin NRPS will only check, if endpoints are available and if there are conflicts concerning the usage of endpoints within overlapping reservations.
- schedules creation and termination of network connections using the GMPLS driver.
- registers its domain at the NSP domain manager, retrieves user and border endpoints from the GMPLS driver and forwards border endpoints to the NSP domain manager.
- handles endpoint updates from the GMPLS driver and informs the NSP domain manager.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3

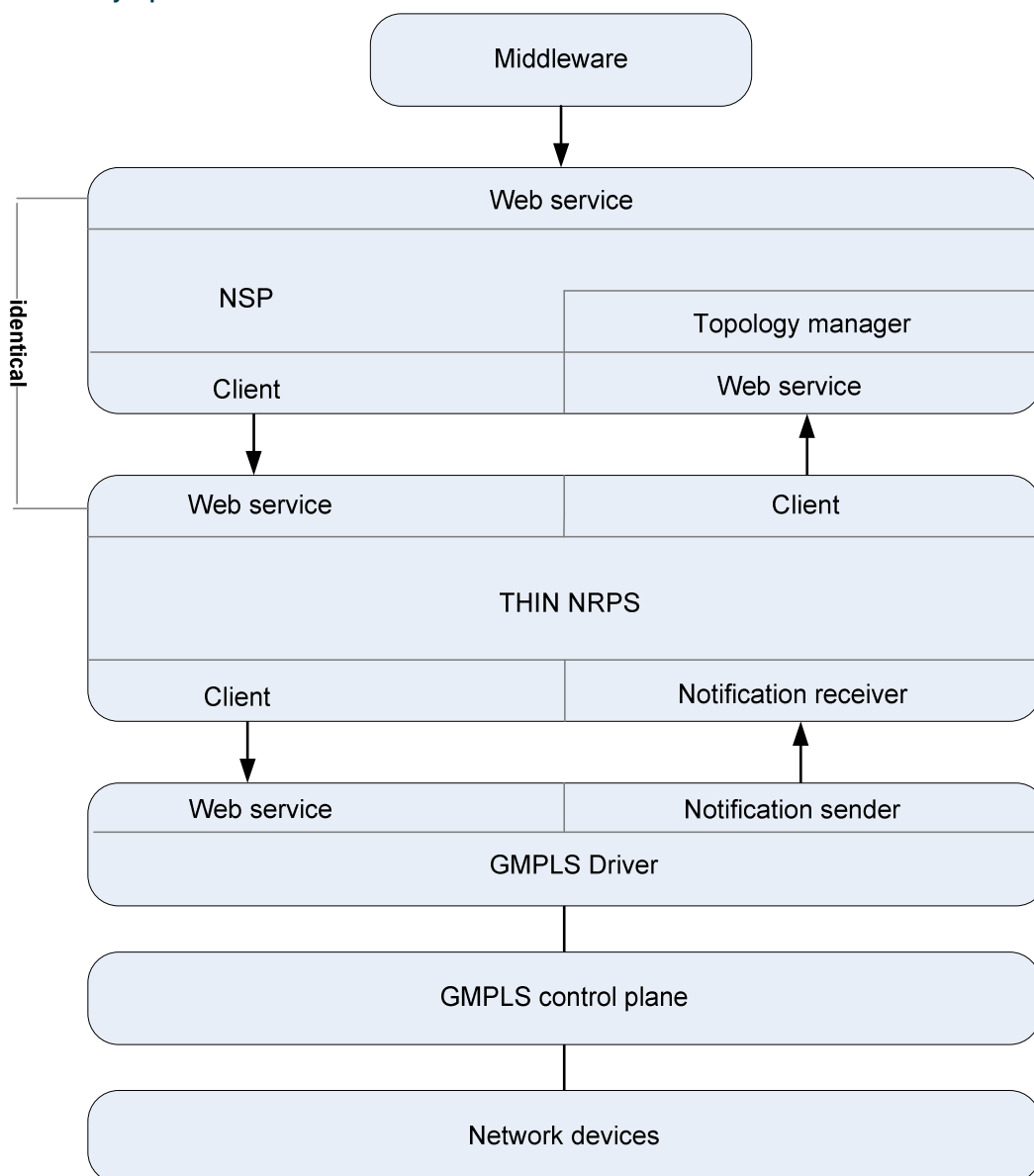


Figure 7: Thin NRPS and other PHOSPHORUS modules

In contrast to a normal NRPS adapter the Thin NRPS has only a limited functionality. Only fixed reservations are currently supported, because no topology information about links and their usage is available. Therefore the following functions are currently not supported:

- Deferrable reservations
- Malleable reservations
- Unidirectional or point-to-multipoint connections

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

- MaxDelay
- DataAmount

5.1.1.3 Test of Thin NRPS and GMPLS driver within the GMPLS domain

The Thin NRPS tests have been performed within the GMPLS domain of the VIOLA PHOSPHORUS test-bed, which is shown in Figure 8. Alcatel 1678 cross connects are controlled by the Alcatel GMPLS implementation GMRE. Via the Thin NRPS and the GMPLS driver Soft Permanent Connections (SPC) between the Gigabit Ethernet endpoints were created, monitored and terminated.

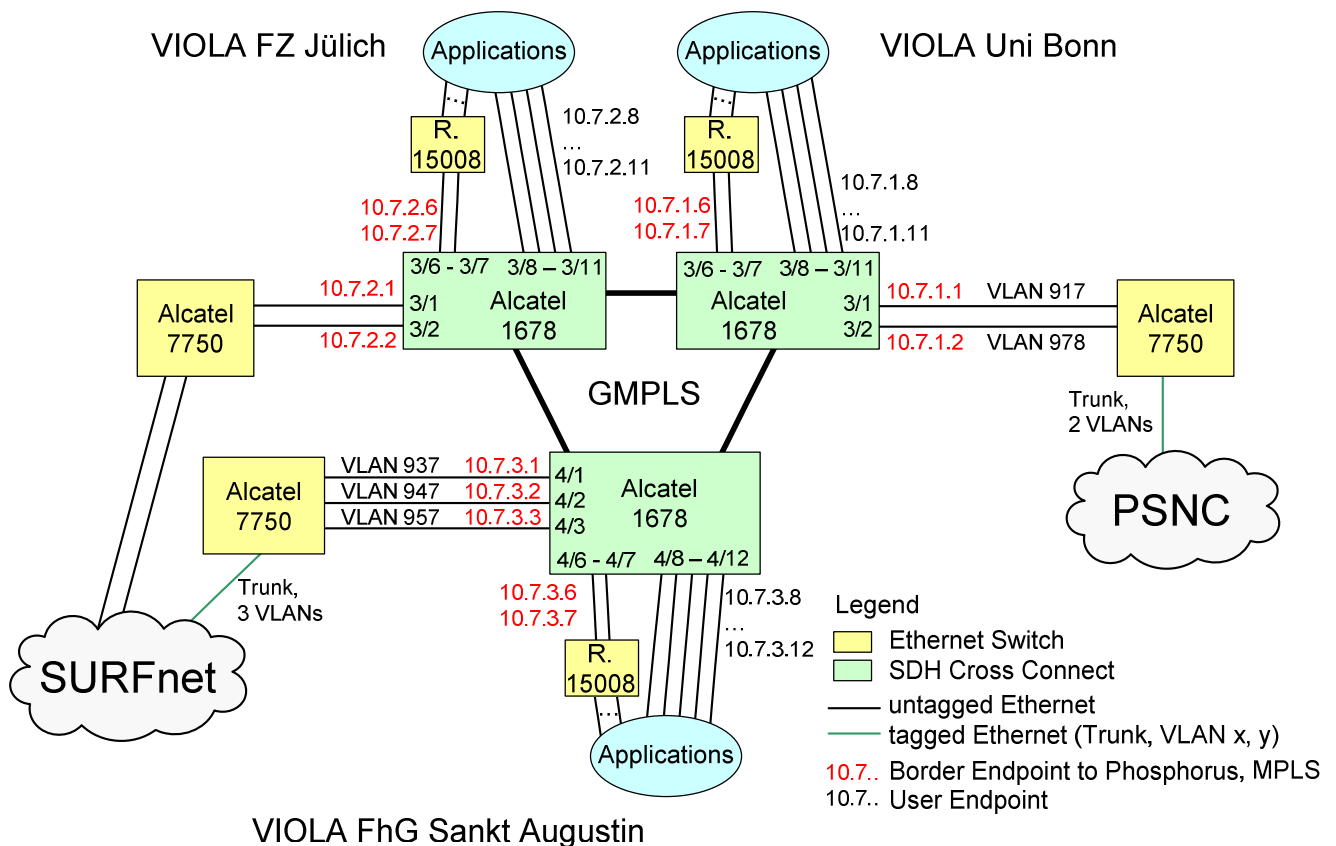


Figure 8: GMPLS Test Environment of the VIOLA PHOSPHORUS Test-bed

5.1.2 CRC

CRC - It is expected that the software to be made available through WP-2 will be used to implement a GMPLS (and later G²MPLS) based control plane running on a number of PCs in the BADLAB. It is assumed that this control plane will be used to control a subset of the network elements comprising the

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

local test-bed which extends across CANARIE. Initially, this would be done by making use of networking resources assigned to the UCLP Virtual Lab on CANARIE in order to perform the first round of tests and achieve some level of confidence with the control plane software. This will be tackled only after the UCLP NRPS for the CRC domain is fully operational and has successfully been tested with WP-1 partners.

5.2 UCLP

5.2.1 CRC

CRC is configuring a host for an instance of the UCLP NRPS associated with the CRC/CANARIE domain. The host will include the UCLP NRPS, the NRPS Adapter and the Advanced Reservation software. The NRPS Adapter will access the NSP Server located at UniBonn via a VPN established using tinc. Testing of the VPN has been successfully completed between: CRC and VIOLA; and CRC and UniBonn. An instance of the NSP has been set up at CRC for local testing. It is expected that by the week of October 15th we will have a fully configured UCLP server (NRPS + Adapter + Advanced Reservation) for the CRC/CANARIE domain that will be communicating via a VPN with the NSP Server located at UniBonn.

5.2.2 UESSEX

At the University of Essex we have just deployed the bundled version of UCLP on 4 different nodes and currently working on interfacing these nodes to our optical switch using the UCLP software. Our Optical switch supports TL1 commands but there are no current provisions for TL1 commands in the UCLP software. We are currently working on integrating this property into the UCLP software on our test-bed. Our aim is to partition our optical switch in four separate and individual optical switches in which each of the partition is managed by a UCLP node. The UCLP software will help reveal existing and available network resources on our optical switch as objects using service oriented technologies. These will allow light paths to be easily provisioned and configured both within our local test-bed and also within the PHOSPHORUS test-bed as a whole by any interested partner. At the moment no tests have been carried out but we will perform various tests as soon as the UCLP integration becomes functional.

5.2.3 I2CAT

i2CAT will have available some host resources to run the UCLP software (the public NRPS Adapter and the UCLP Server). They can be executed separately (i.e. each one in a different machine) or both in the same machine. The host that executes the UCLP Adapter will be connected via VPN (tinc) with the public NSP available in UniBonn to allow the secure communication between them. In the joint tests between all the partners, the NSP will contact the UCLP server at i2CAT in order to configure the resources of the local test-bed to materialize the required connections.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

UCLP will be capable of configuring the Nortel OPTera Metro devices of the test-bed to offer the different connection possibilities. The trunk DWDM ring will be static (interconnection of the 2 OPTeras), and there will be 4 OCI ports configurable by UCLP.

The UCLP configuration tests to control the equipment have just started and the communication tests (Adapter-UCLP and NSP-Adapter) are going to be started soon.

5.3 DRAC

The SURFnet test-bed currently runs DRAC as an NRPS. All currently required functionalities for WP1 are supported, both through the web services interface and the web GUI at <http://drac.surfnet.nl/>. Testing has happened to verify that users get access to the correct ports, are allowed to provision connections within their policy and that all edge ports can effectively be used. In testing DRAC creates connections between all ports – be it L1 or L2 – that are allocated to the PHOSPHORUS user group, at the bandwidth that is requested by the user. Ethernet frames are transported transparently, thus making the test-bed a proper sub-part of end to end connections.

The web services interface is currently being used via the NRPS adapter developed in WP1, where all required functionalities for connection provisioning are provided. In the next release – that is already running on the non-public part of the test-bed – additional functionality for more advanced scheduling is available. This functionality will be integrated into the adapter after basic testing has happened.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

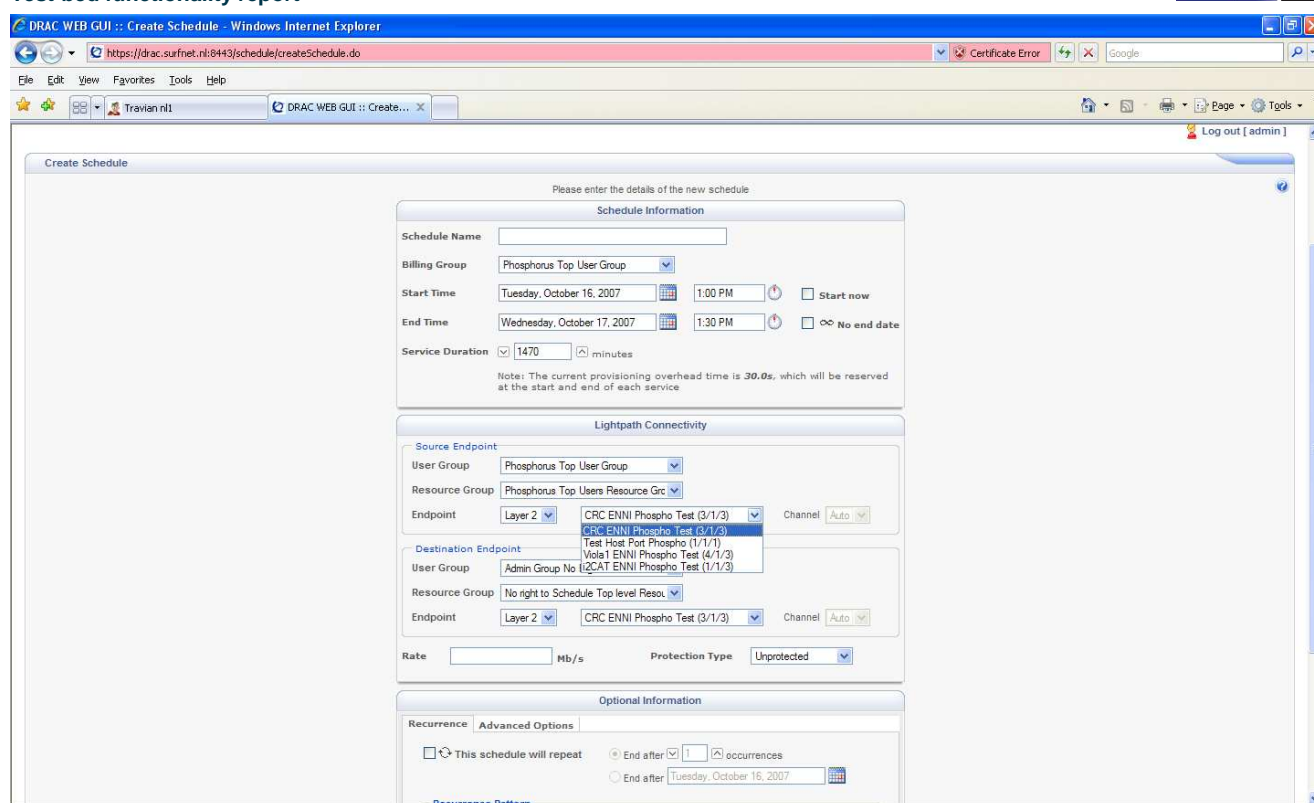


Figure 9. DRAC interface

5.4 ARGON

5.4.1 Functional description

The original ARGON resource reservation system was developed within the BMBF VIOLA project. The ARGON core system supports the reservations with fixed bandwidth requirements, the reservation and computation of suitable configurations for the transmission of data amounts under defined constraints, as well as the modification and cancellation of such reservations. The system itself was redesigned in 2007 to support further requirements associated with the developments in the PHOSPHORUS project.

The interface and the processing of requests are designed in a way to permit an efficient collaboration with the MetaScheduling Service (MSS) as described in [MSS]. The main challenge of a MSS is to coordinate the reservation of different independent resources, such as the computation power of cluster nodes and network resources, for example. Such coordination is required to implement a premium service for end users. In general, a sufficient way to coordinate such resources is to check their availability for the requested point in time first. Therefore, the ARGON core system offers an availability request to check whether required network resources are available or not. If the requested resources are not available, the

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

system determines an alternative point in time at which the requested reservation would be realizable. This helps the MSS to find sufficient alternatives to provide the requested service. Note that the availability check provided by ARGON reflects only the availability of resources at the point in time the request is processed – pre-reservation of any kind is not provided. This means that resources may be unavailable, even if an availability check was confirmed before.

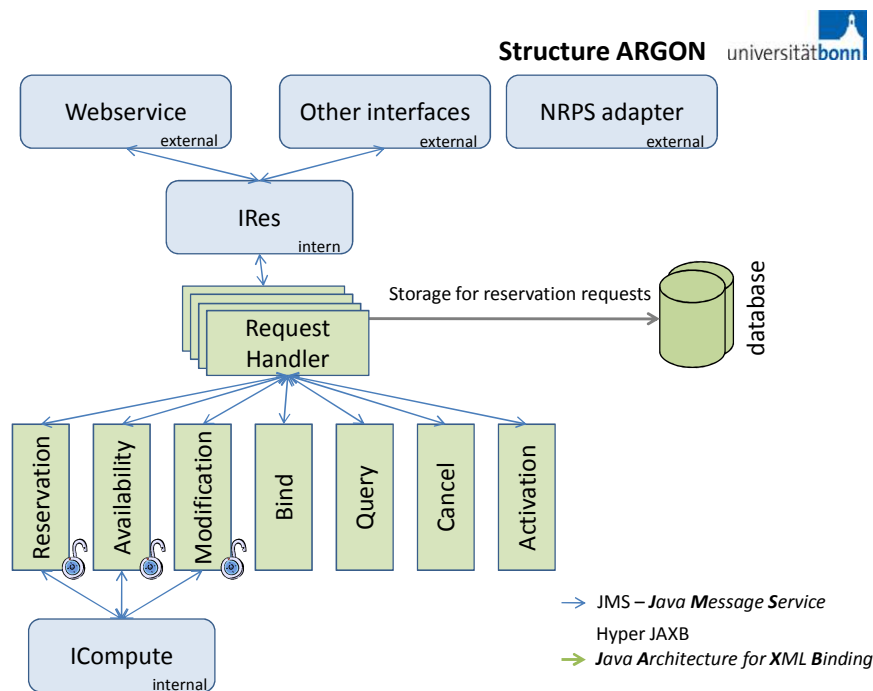


Figure 10: Structure of the ARGON resource reservation system

From the point of view of the end-users, reservations of resources often depend on each other, as they are part of workflows. A simple example for such a workflow is given by sensor data, which are to be analyzed by several clusters. In case of ARGON, workflows are supported by combining several connections to a single request. If at least one connection specified in a request is not feasible, the entire request is rejected. This behaviour represents the fact that a single reservation is worthless in general, if the other reservations of the same workflow are unfeasible. This design also minimizes the complexity for requests from the point of view of the MSS.

Reservations and other requests are transmitted to ARGON through an asynchronous interface, implemented via a Java Message Services. This interface is denoted as IRes. The structure of ARGON is depicted in Figure 10. If a reservation request is accepted by the ARGON core system, it determines a unique ID and transmits it back to the user. This ID can be used to refer to the reservation in subsequent requests. Such requests can be modifications or cancellations, for example. These requests can be interpreted as a delayed transmission of additional information. Another important aspect requiring the

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

delayed transmission of additional information for a request is involved with layer 3 services. For such services, the ARGON system requires information about the IP addresses and transport layer ports which are to be mapped on a tunnel between the endpoints of a connection. However, especially if reservations are made by the MSS, this information is not available at the point in time a reservation request is transmitted. Using the ID of a request, the addresses and ports can be imparted to ARGON using bind requests, if they are available.

Using the IRes interface as an internal interface to transmit requests to the ARGON core system, allows the usage of different user interfaces on top of the core as depicted in Figure 10. The main interface which is used by the MSS in the VIOLA project is implemented by a separate webservice. The webservice forwards incoming requests to the core system. In case of the PHOSPHORUS use case, the user interface is given by the NRPS adapter working on the same level as the webservice used in the VIOLA project.

Reservations which are accepted by the network resource reservation system are to be enforced on the routers in the test-bed at the right point in time. ARGON supports both the configuration in MPLS and GMPLS domains, using Riverstone 15008 and Alcatel 1678 cross connects. (Note that in the PHOSPHORUS test-bed however, the Alcatel 1678 devices comprise a separate domain under control of the Thin NRPS for GMPLS domains.) As the Riverstone routers have no knowledge about time, events such as path setup and teardown are triggered by a scheduler which is part of the core system. The routers themselves are configured in parallel through their CLI interface using a telnet component in the core system. Once a path is set up, the requested bandwidth is guaranteed between the endpoints and therefore for the reserved reservations.

5.4.2 Test of ARGON NRPS Adapter and ARGON NRPS within the MPLS domain

The tests have been performed within the MPLS domain of the VIOLA PHOSPHORUS test-bed, which is shown in Figure 11. Riverstone 15008 routers are controlled via CLI by the ARGON NRPS. Via the ARGON NRPS Adapter and the ARGON NRPS connections between the Gigabit Ethernet endpoints were created, monitored and terminated.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



Test-bed functionality report

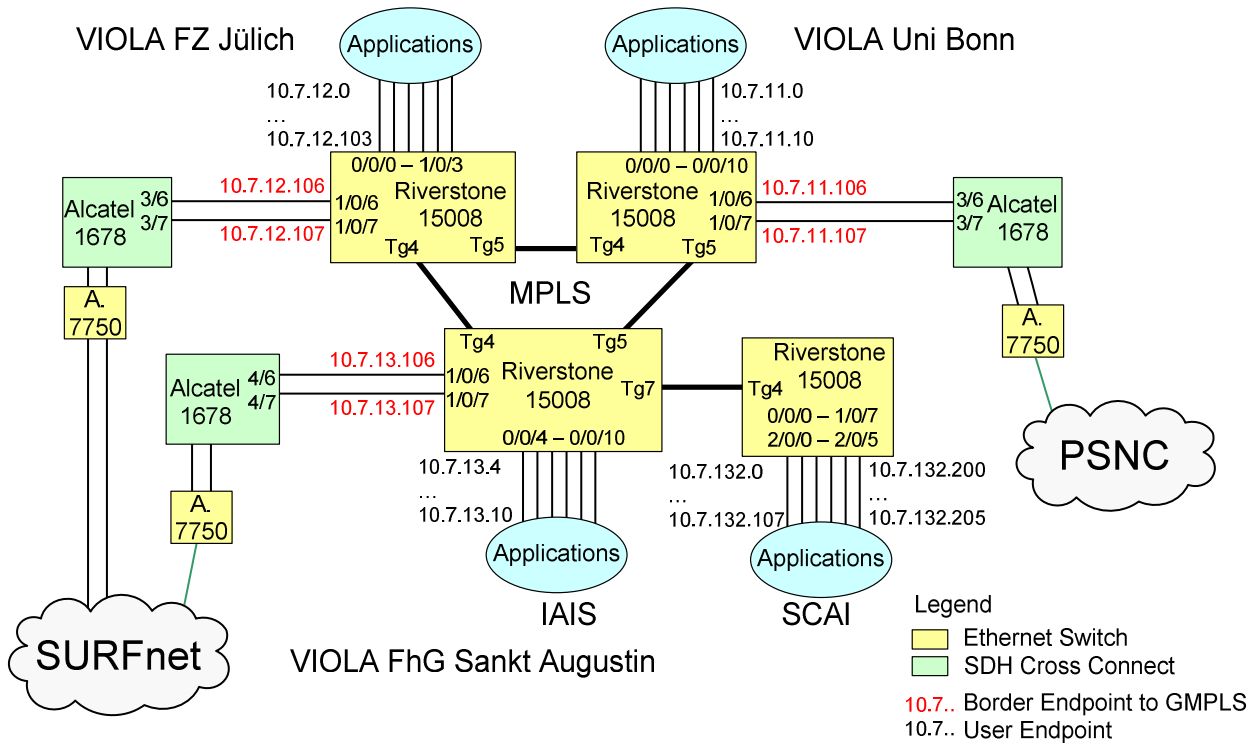


Figure 11: MPLS Test Environment of the VIOLA PHOSPHORUS Test-bed

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



6 Conclusions

This document summarises the functionality of the test-bed after the first phase of its development as a base for integration of the project outcomes. The description of functionality is limited to the features which have vital meaning for the tests and demonstrations envisaged for the test-bed. More information about the particular elements of the test-bed can be found in other PHOSPHORUS documents, mostly generated by workpackages 1, 2 and 3.

The summary of the functionality covers several layers of the PHOSPHORUS test-bed: applications, GRID middleware, switching infrastructure, connections between local test-beds, control plane and NRPSes. The functionality was verified in tests, which confirmed that the test-bed works properly and is ready for integration of the project developments.

Tests conducted before preparing this document showed that the test-bed works properly and is ready for integration of the project developments.

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



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Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



8 Acronyms

B/A	backup/archive
BADLAB	Broadband Applications and Demonstration Laboratory
CANET 4	The Canadian NREN
CAVE	Cave Automatic Virtual Environment
DDSS	Distributed Data Storage Systems
DWDM	Dense Wavelength Division Multiplexing
GÉANT2	Pan-European Gigabit Research Network
GÉANT+	the point-to-point service in GÉANT2
GLIF	Global Lambda Integrated Facility
GMPLS	Generalized MPLS (MultiProtocol Label Switching)
G ² MPLS	Grid-GMPLS (enhancements to GMPLS for Grid support)
GN2	GÉANT2
IP	Internet Protocol
MPI	Message Passing Interface, see http://www-unix.mcs.anl.gov/mpi
MPLS	MultiProtocol Label Switching
MSS	MetaScheduling Service
NIL	Nothing In Line
NREN	National Research and Education Network
NRPS	Network Resource Provisioning System
ONL	Optical Networking Laboratory
PoP	Point of Presence
SNMP	Simple Network Management Protocol
TL1	Transaction Language 1
TOPS	Technology for Optical Pixel Streaming
UCLP	User Controlled Light Paths
UNI	User to Network Interface
VLAN	Virtual LAN (as specified in IEEE 802.1p)
VPN	Virtual Private Network

Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3



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Project:	Phosphorus
Deliverable Number:	D.6.3
Date of Issue:	30/09/07
EC Contract No.:	034115
Document Code:	Phosphorus-WP6-D.6.3