034115

PHOSPHORUS

Lambda User Controlled Infrastructure for European Research

Integrated Project

Strategic objective:
Research Networking Testbeds

Deliverable reference number: D.7.3.3

Annual Report on EU and Non-EU Collaboration and Technical Liaison Activities

Due date of deliverable: 2009-06-30
Actual submission date: 2009-06-30
Document code: Phosphorus-WP7-D.7.3.3

Start date of project:
October 1, 2006

Duration:
33 Months

Organisation name of lead contractor for this deliverable: **University of Essex (UESSEX)**

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract

The PHOSPHORUS project aims to co-operate with European partners, however, the full success can be achieved only by global collaboration of all interested partners working on dynamic grid and network service provisioning. Partnership with them make opportunity of share the experience and technical knowledge, achieve synergy between all similar projects by collaboration in the common areas of interest. This document is a detailed report on all liaison activities during the Phosphorus project.

This is the third release of an evolving deliverable document.

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0 Executive Summary

This document describes co-operation between PHOSPHORUS projects and other European and non-European organisations. From the beginning, collaboration activities were an important part of the PHOSPHORUS project. Some partners in the Consortium were specially chosen to enable easy and effective cooperation. During the the PHOSPHORUS project, there were established collaboration with seven international projects and several NRENs. Most of the collaborations were very helpful to take choices during PHOSHORUS architecture and its particular layers design. These choices enabled the implementation cooperation with other projects and some standardization efforts. A lot of interest has been generated for the PHOSPHOROUS prototypes outcomes which were transformed into strong and focused collaboration.

Section 1 contains description of collaboration with European NRENs and projects.

Section 2 contains information about cooperation with non-European organizations.

1 Collaborations with EU Partners

1.1 Collaboration with GN2 project

The PHOSPHORUS project has intended to closely cooperate with GÉANT2 activities in order to achieve a synergy effect and improve future network services. Due to PHOSPHORUS objectives, the JRA3 Bandwidth on Demand (BoD) activity was selected as the liaison point and common benefits are expected to be visible before projects ends. The AutoBAHN system designed and developed by GN2 JRA3 activity is aimed to implement an automatic bandwidth provisioning system for heterogeneous multi-domain NREN environments. Its objectives involve possible deployment of the BoD service over various network technologies, depending on NRENs requirements. The main focus of GN2 JRA3 research was placed on the most common technologies used as data planes in Europe, in particular Ethernet and SDH. Network equipment can be managed directly by AutoBAHN, indirectly through vendor's NMS, or even with applications developed internally for particular NREN needs.

AutoBAHN architecture is comparable with the PHOSPHORUS one. There are some similarities that may by pointed out. According to figure 1.1 AutoBAHN is built on two main entities, the Inter-Domain Manager (IDM) and the Domain Manager (DM), which control complementary responsibility areas. Both IDM and DM must be deployed in a domain, which is expected to operate under AutoBAHN control. The IDM performs activities affecting inter-domain aspects of bandwidth reservation, which includes:

- inter-domain communication – only IDM modules are allowed to communicate each other at multi-domain level; DM modules are not contacting each other and are focused on single domain activities,
- common network configuration negotiation – some attributes (e.g. common VLAN identifiers) must be agreed for inter-domain circuit creation; this process requires a common agreement between all domains, and this negotiation process is managed by the IDMs,
- user access to the system – the IDM is equipped with sub-module for user/application access, which allows to submit reservation, cancel it, or check its current state.

1.1.1 GN2 AutoBAHN and Phosphorus Harmony interoperability

The IDM scope is similar to Network Service Plane (NSP) module of PHOSPHORUS. Initially, at the beginning of the PHOSPHORUS project, it was considered to use full AutoBAHN IDM module or reuse most of the source

code, instead of starting an independent design and implementation process from scratch. The representatives of both projects had declared a cooperation in such activity, however further PHOSPHORUS work discovered some important differences in assumptions and requirements between NSP and IDM. Reuse of the IDM source code became more complicated than starting new implementation. Moreover, the IDM maturity was not at the production level and both requirements and architecture were continuously the subject of changes.

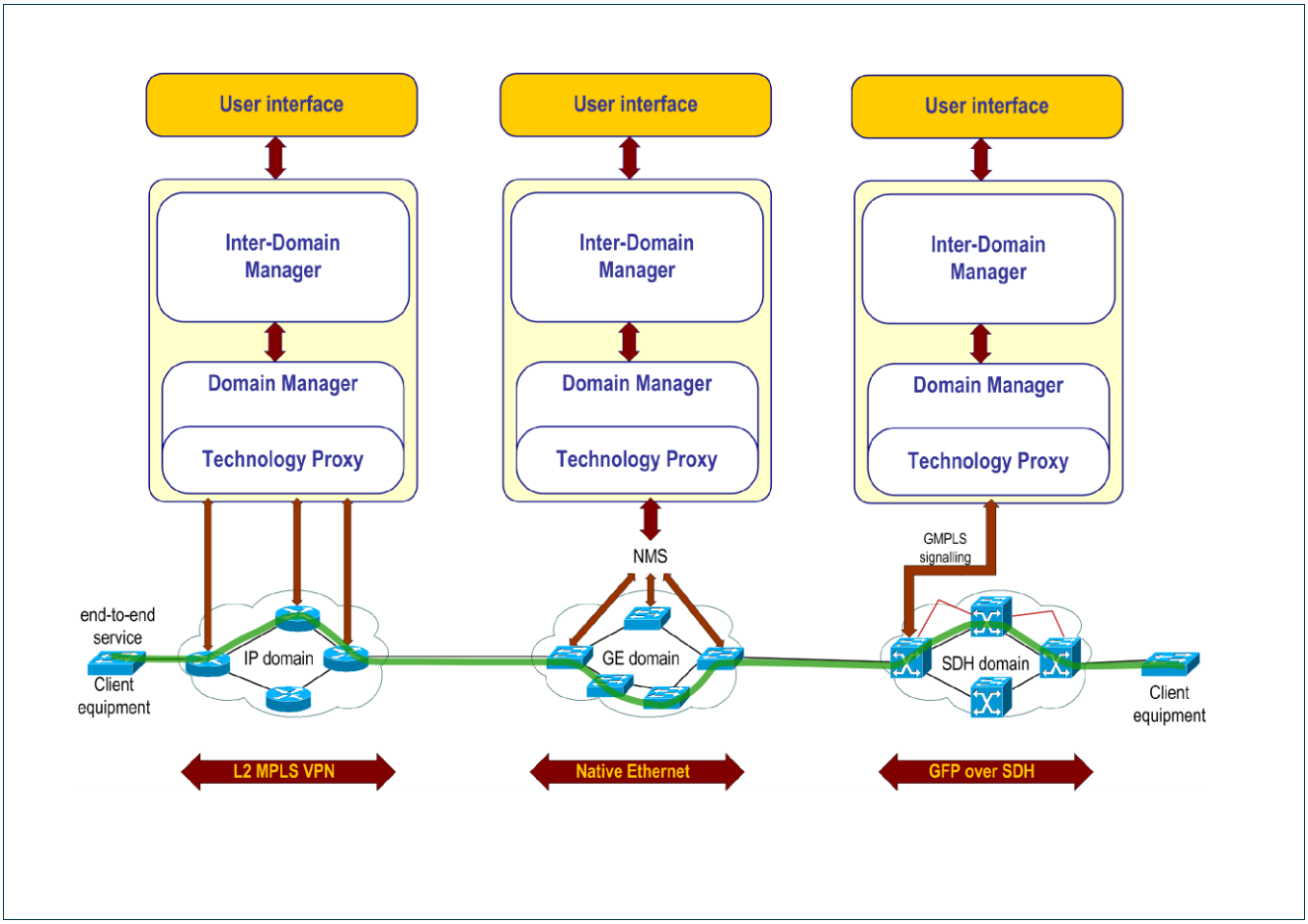

Figure 1.1: AutoBAHN architecture

The decision of not using IDM source code was inevitable and thus lead to the concept of AutoBAHN-PHOSPHORUS peering. Despite of differences in the design, priorities and objectives, both systems are designed as BoD services, which are able to operate within multi-domain environment. It is just a matter of time when two neighbour domains will be controlled by AutoBAHN on one side and PHOSPHORUS on the other side. Having in mind users satisfaction and effectiveness of network services, the best option to follow was to create an interface between both systems, so that reservations can be realized in collaborative environment. In order to make the two systems interoperable several conditions had to be met:

- a common way of topology advertisement must be agreed and implemented,

- a common way of reservation management messages mechanism must be agreed and implemented,
- a common way of signalling must be agreed and implemented ("signalling" in the meaning of network equipment configuration).

It was agreed that both systems would create a proxy box (IDC translator presented on Figure 1.2), which enable messaging translation. The work plan to implement full collaboration was established during the PHOSPHORUS meeting in Zakopane, Poland in June 2007. The plan was based on on-going cooperation between AutoBAHN and DRAGON/OSCARS BoD system developed by Internet2 and ESNet organizations. It consists of 3 steps, which represents 3 stages of reservation process (exchange topology, book resources, create circuit):

1. exchange, analyze, and agree protocols for network topology advertisement,
2. exchange, analyze, and agree protocols for reservations,
3. exchange, analyze, and agree protocols for signalling.

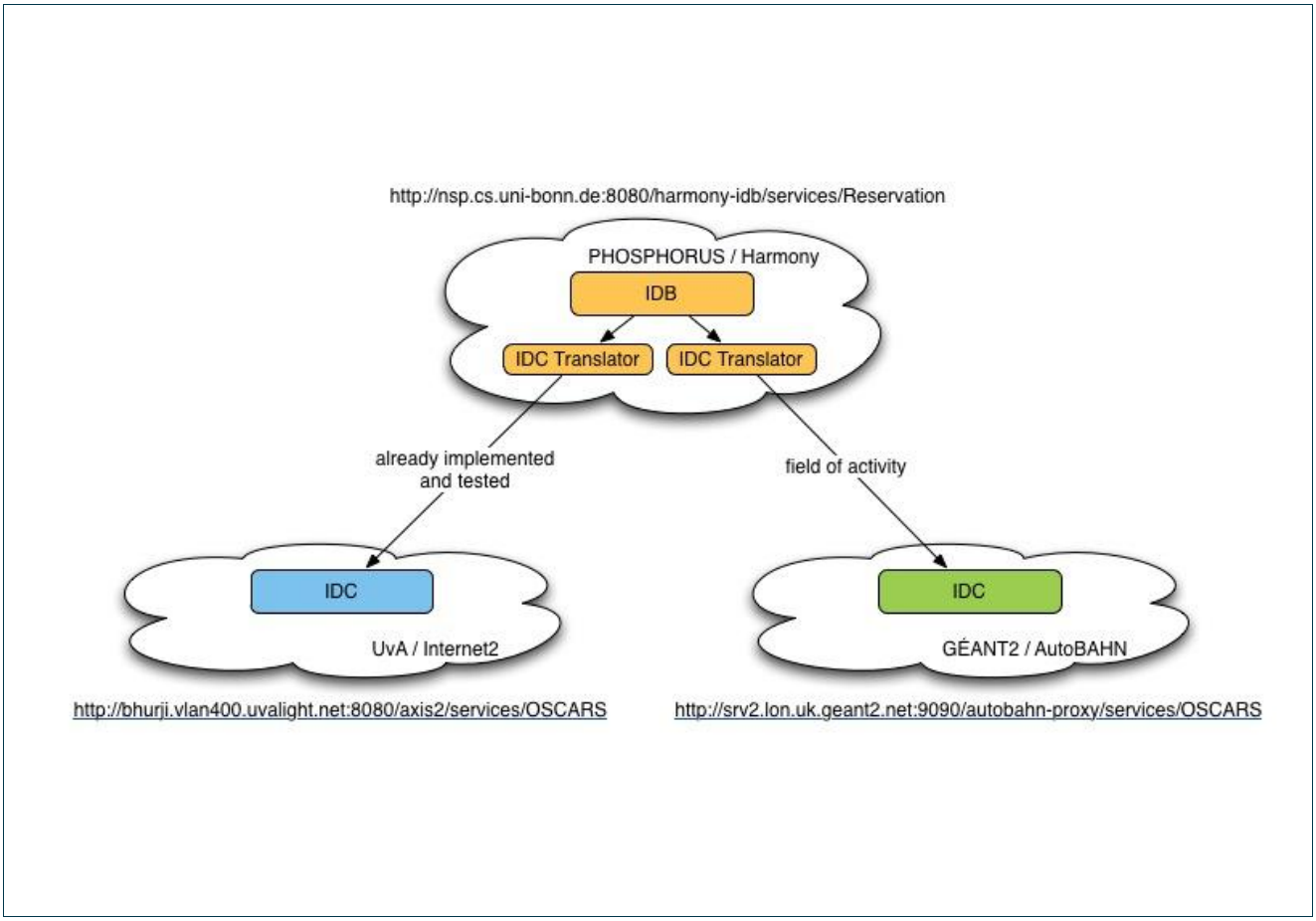

Figure 1.2: Abstract overview of the AutoBAHN/Harmony test-bed

The IDC proxy was finally implemented by Phosphorus WP1 team and successfully tested during reservation requests going between Harmony testbed and AutoBAHN testbed.

In GN3 JRA3 activity (AutoBAHN), there is a discussion about possibility of Harmony system usage within AutoBAHN. Harmony is capable to provide for AutoBAHN a GMPLS domain directly controlled by Harmony system with additional features like advanced reservation, topology abstraction and inter-domain features.

1.1.2 GN2 AutoBAHN and Phosphorus G^{2}MPLS interoperability

The DM and AutoBAHN as a whole is incapable of GMPLS domain support, due to limited presence of GMPLS capable equipments in European NRENs. Moreover, GMPLS Control Plane was not planned for the short term deployment by any NREN participating in the GÉANT2 project, even though some preparation studies and guidance for future work have been explored. In this context, the interoperation between GÉANT2 and PHOSPHORUS were capable of many potential benefits:

1. it will enable AutoBAHN systems to perform reservation in PHOSPHORUS managed domains, and thus it will be able to indirectly operate in GMPLS enabled domains,

2. it will enable G^{2}MPLS domain to progress its reservations in wider scale topologies, and with the potentiality of peering with other far-end technologies such as Internet2

3. it will open and share PHOSPHORUS research results in the GMPLS and Grid fields, with a potential take up of integrated solutions and know how,

4. it will allow the GÉANT network to plan future research on the early assessment by PHOSPHORUS of the issues for integrating the networks and the Grids through Control Plane technologies.

Supported by these benefits, the collaboration between PHOSPHORUS and GÉANT2 research teams has been strengthen through ad hoc meetings on specific technical issues. Some PHOSPHORUS WP2 representatives have been invited to the 5th GN2 Technical Workshop, held in Rome (Italy) on January 21st-25th 2008, and during this event a dedicated meeting took place between the two teams with the following main objectives:

a. to discuss and assess the PHOSPHORUS Control Plane architecture (Grid-GMPLS) for the integrated and seamless control of Grid and network resources in the operational and service perspective of the network operators,

b. to assess at a more deep and detailed level the compatibilities between the two control approaches (AutoBAHN and G^{2}MPLS) in terms of routing and signalling models,

c. to analyse the functional requirements of a module located at the boundary between the G^{2}MPLS and AutoBAHN domains, aimed to let the two control technologies interoperate automatically,

d. to agree on the procedures for communication and exchange of information between the two teams.

As a result of this meeting, many commonalities in terms of procedures and models have been found between the two systems and a preliminary solution of interoperability between AutoBAHN and G^{2}MPLS domains has been sketched. It is based on the use of a boundary G.E-NNI proxy capable of terminating the (signalling and routing) protocol sessions on the G^{2}MPLS side and bridging their sematics towards the AutoBAHN system through Web-Service technologies, and viceversa. In order to re-use the existing solutions just developed by the GN2 team for other interoperability events (Internet2 in particular), the Inter-Domain Communication (IDC) Web Service has been evaluated as the more effective solution for interfacing the G.E-NNI proxy to AutoBAHN.

Finally, the G^{2}MPLS-AutoBAHN interface was established using G^{2}MPLS-Harmony gateway. The AutoBAHN implemented the client for Harmony-Reservation web-service. The successful provisioning within AutoBAHN and G^{2}MPLS CP was established.

Futher, there is an option to use G^{2}MPLS software within GN3 AutoBAHN activity where it can be used as a standard GMPLS Control Plane managed by AutoBAHN GMPLS Technology Proxy module. This can be done because part of Phosphorus G^{2}MPLS team is starting working in new GN3 AutoBAHN activity.

1.2 Collaboration with Alcatel and France Telecom

Alcatel-Lucent is one of the largest research, technology and innovation organization in the telecommunications industry. It provides solutions that enable service providers, enterprises and governments worldwide, to deliver voice, data and video communication services to end-users. **France Telecom** is the main telecommunication company in Europe and one of the largest in the world.

The partnership with European Industrials and achievement of the commercial exploitation of the PHOSPHORUS technologies is one of the goals of the PHOSPHORUS project. The main scope of collaboration with Alcatel-Lucent and France Telecom will concentrate in the following topics:

- End-to-End on demand service delivery,
- Development and deployment of Grid enabled network control planes,
- Building the European-wide test-beds and facilities,
- Evaluation of the applicability of the concept of a combined grid/network control plane for the commercial sector.

The collaboration will involve active exchange of researchers and relevant know how. A set of common workshops with panel discussions and live demonstrations is foreseen in order to allow the knowledge exchange and open the discussion on relevant subjects.

The rationale for the collaboration is to demonstrate the viability of the end-to-end on demand service delivery in multi-domain environment, involving different provisioning technology and heterogeneous network equipment integrated with Grid middleware. Together with leading telecommunication companies the PHOSHPORUS project will have a chance to demonstrate the latest research developments with strong support from the industry.

The collaboration brings also extra benefits to the project. Through the industrial partners the PHOSPHORUS consortium will have a possibility to cooperate with the CARIOCAS project, in which both, France Telecom and Alcatel-Lucent, play a major role. A similar background of PHOSPHORUS and CARIOCAS, the same rationales and similar approaches to the Grid enabled network control planes might have a strong influence not only on the project achievements. It was expected that the results of the cooperation may have a strong impact on the research activities in Europe and even beyond it.

Through **Alcatel-Lucent** collaboration on Grid User Network Interface (GUNI) standardization activities in OGF driven by PHOSPHORUS project, Telecom Operator requirements and considerations towards network

resources management for connectivity services delivered for Open Grid Service Architecture are identified. Interactions with network operators through GUNI are identified to support a number of services such as dynamic SLA Negotiation and service contract establishment. From Telco's perspective, it is interesting if network services can be part of bundled service elements to automate service management and business level agreements without exposing network operator infrastructure information. This can be achieved by considering network resources as elements of Grid Services creating virtual network configurations. However, the network resources abstraction needs to be limited to avoid automation problems such as a complex network planning or scheduling. This collaboration aids PHOSPHORUS efforts on the standardisation work in GHPN-RG informational draft and engage more Telco operators.

1.2.1 Co-operation with Carriocas project

CARRIOCAS studies and implements an ultra high bit rate (up to 40Gb/s per channel) optical fiber core network to meet the scientific and industrial needs in remote usage of computing and storage resource for high performance interactive/collaborative simulations and virtual prototyping.

The main goals of the Carriocas project are:

- to develop cost-effective and reliable 40Gb/s transmission systems,
- to adapt network architecture, management, protocols, algorithms to distributed application requirements (high connectivity dynamics, stringent quality of service),
- to implement high performance applications: high resolution interactive visualization on a remote picture wall and distributed massive data storage system,
- to test and validate the approaches on an experimental network.

The project is coordinated by Alcatel-Lucent France and the consortium is composed of over 20 French academic and commercial partners.

Due to similar main objectives and related scope of the research carried out in Carriocas and PHOSPHORUS, the PHOSPHORUS consortium decided to explore the possibilities of a cooperation with the Carriocas project.

As a measurable result of the discussions between the project leaders, Alcatel-Lucent Bell Labs France had hosted a two-day workshop in Paris, France, 15-16 July 2008, conducted by the IST project PHOSPHORUS and the System@atic project CARRIOCAS with the main focus on defining the specifications for network service interfaces over heterogeneous infrastructures such as networks and Grids.

Using the background of two ongoing collaborative projects, the Workshop aimed at designing new network architectures supporting well-specified network service interfaces. The participants constituted a balanced mix of experts from Telecom industries, universities, and national laboratories, all representing various Grid technology areas as well as scientific applications.

The workshop was composed of a series of presentations interspersed with discussion sessions. In the earlier session (Day 1 session), the participants of the two projects made presentations to communicate their views to the other participants. During the Day 2 sessions, the connections between topics are identified and discussed. Finally, the discussions were further refined and converted into the Workshop Report.

Workshop Agenda

Tuesday July 15th	
14:00h – 16:00h	Introductions and project presentations - CARRIOCAS (20') (**Dominique Verchere, Alcatel-Lucent Bell Labs France**) - Phosphorus (20') (**Dimitra Simeonidou, University of Essex**)
16:00h – 18:00h	East-West Network Service Interface - Phosphorus – HARMONY (**Sergi Figuerola, i2CAT**) - Phosphorus – G.E-NNI (**Gino Carrozzo, Nextworks**) - CARRIOCAS – Multi-domain network services over PCE (**Richard Douville, Alcatel-Lucent Bell Labs France**)
18:00h – 19:00h	North-South Network Service Interface - Phosphorus approach – G.OUNI (30') (**Eduard Escalona, University of Essex**)
Wed. July 16th	
9:30h – 11:00h	CARRIOCAS Service architecture - Scheduling, Reconfiguration,Virtualization (SRV) services (**Pascale Primet, INRIA**) Phosphorus G2MPLS Architecture (**Gino Carrozzo, Nextworks**) - G.E-NNI and G²MPLS architecture discussions
11:00h – 11:15h	Break
11:15h – 13:15h	Standard references to address network services - OGF (GNI-DMNR) (**Georges Zervas, Universiry of Essex**) - IETF (**Gino Carrozzo, Nextworks**) - ETSI-Grid (**Bela Berde, Alcatel-Lucent Bell Labs France**) - IPSphere (**Sergi Figuerola, i2CAT**) - ITU-T (**Dominique Verchere, Alcatel-Lucent Bell Labs France**)
13:15h – 14:00h	Lunch Break
14:00h – 16:30h	Partner Presentation for Network services definitions - A scenario of data exchanges and contracts between customers, GSP and SRV in CARRIOCAS **(Dominique Barth, PRiSM)** - NREN's roles in Research Projects with example of PIONER (**Bartosz Belter, PSNC**) - IaaS infrastructure (**Sergi Figuerola, i2CAT**) - Grid computing users / Orange clouds (**Xialong Kong, Orange Labs**) - Computing/Networks combination resources reservation (**Maurice Gagnaire, Telecom-Paristech**)
16:30h – 17:30h	Discussions: - User/Server, Grid application, Virtual organizations - Network operators → Infrastructure operators - Service Providers: Network service providers and their positions with other IT service providers e.g. Storage as a Service, Scientific Instruments, Computational services, etc. SLA template: language. Business context considerations for different types of actors.
17h30 – 18h00	Objective definitions,

	Discussions and Plan of next steps.

1.3 Collaboration with FEDERICA project

The FEDERICA project will create a European wide "technology agnostic" infrastructure made of Gigabit circuits, transmission equipment and computing nodes capable of virtualization to host experimental activities on new Internet architectures and protocols.

The FEDERICA network is based on the Research & Education multi-gigabit networks footprint. Circuits are terminated in Points of Presence (PoPs) of NRENs and GÉANT2, hosting FEDERICA nodes capable of virtualising hosts e.g. open source routers and end nodes. Virtual slices of FEDERICA's infrastructure may be allocated to network researchers for testing even with disruptive experiments within a large production substrate. The researchers will have full control on the allocated virtual nodes and network slice and access network monitoring information. Internal project research is focused on understanding and producing initial solutions for monitoring, management and control of parallel virtual networks.

FEDERICA Kick off meeting - The project's official kick-off meeting was held in Rome on 17-18 January 2008. During the event the Phosphorus's Coordinator Artur Binczewski was presenting main assumptions of the Lambda User Controlled Infrastructure For European Research. More information is available at http://www.fp7-federica.eu/events.php

During the 18th of May 2008 in Burges (Brugge), Belgium, the Phosphorus and Federica projects organized together a tutorial and workshop. This workshop discussed architectural solutions for network and IT service integration over high speed network infrastructure. In particular, the workshop presented various implementations of network control and service plane architectures to support the emerging infrastructure-as-a-service model. The main goal was to share the collective experiences gained by major research projects and initiatives around the globe and explore common vision, outcomes and synergies.

The two projects can obtain major benefits from this collaboration. On the one hand, PHOSPHORUS would be provided the computing facilities needed for running stress tests and performance analysis of the Harmony system over a wide scenario, with a high amount of IDB, HNA and NRPS entities interworking each other, following the several models studied in WP1. This testing scenario can be provided in a FEDERICA slice, as a set of computing resources (virtual machines, from now on VM) and a normal IP connectivity among them.

On the other hand, FEDERICA project would get a real user that is interested in using its virtualization capabilities. This way, FEDERICA project would test both its administrative procedures for giving a virtualized slice of its test-bed to users and, at the same time, test the stability and performance of its appliances, both software and hardware.

Finally, The Memorandum of Understanding and The Cooperation Agreement between the two projects has been signed by the project coordinators of each project.

1.4 Collaboration with RINGrid project

Remote Instrumentation in Next-generation Grids is a 18 months project co-funded by the EC under FP6. The main objectives of the RINGrid project include: the systematic identification of instruments and corresponding user communities, a definition of their requirements as well as careful analysis of the synergy between Remote Instrumentation and next-generation high speed communications networks and grid infrastructure as a basis for the definition of recommendations for designing next-generation Remote Instrumentation Services. The dissemination of project results among scientific, industrial and business groups of users will promote egalitarian access to the European e-Infrastructure and increase awareness of benefits from using next-generation Remote Instrumentation Systems [6].

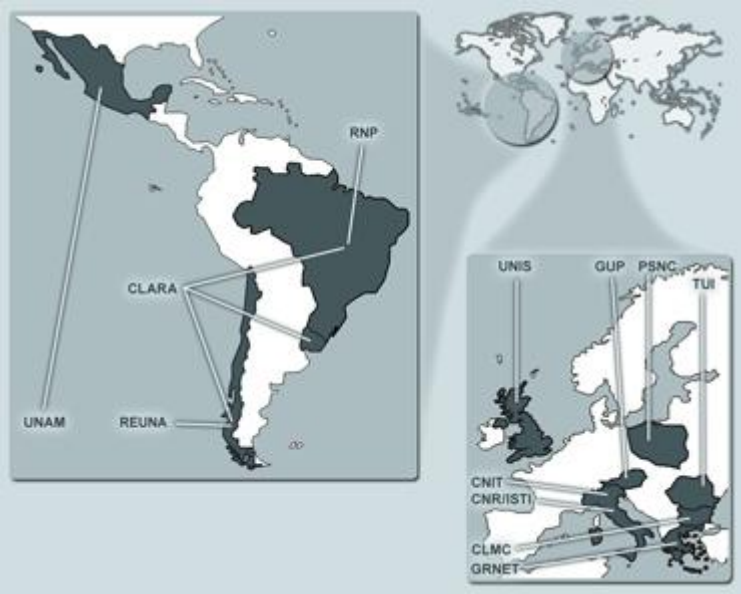

Figure 1.2: RINGrid participants [6]

PHOSPHORUS project and its objectives were presented during "3rd Technical Meeting on Remote Instrumentation in Next−generation" Grids organized in frames of IMEKO'07 on 20-21 September 2007 in Iasi, Romania. Participants of the meeting expressed interest in PHOSPHORUS activities, especially in usability of PHOSPHORUS' G^{2}MPLS implementation in Grids.

More information on RINGrid project can be obtained online at http://www.ringrid.eu

1.5 Collaboration with EGEE project

The Enabling Grids for E-sciencE (EGEE) project is funded by the European Commission and aims to build on recent advances in grid technology and develop a service grid infrastructure which is available to scientists 24 hours-a-day. The project aims to provide researchers in academia and industry with access to major computing resources, independent of their geographic location. The EGEE project will also focus on attracting a wide range of new users to the Grid. The project will primarily concentrate on three core areas:

- The first area is to build a consistent, robust and secure Grid network that will attract additional computing resources,
- The second area is to continuously improve and maintain the middleware in order to deliver a reliable service to users,
- The third area is to attract new users from industry as well as science and ensure they receive the high standard of training and support they need.

The EGEE Grid will be built on the EU Research Network GÉANT and exploit Grid expertise generated by many EU, national and international Grid projects to date [5].

PHOSPHORUS' WP3 recently started to explore the possibilities of a cooperation with the EGEE SA2 activity. Some years ago EGEE had an own activity on interaction of the Grid middleware and the network layer, including research on co-allocation issues. However, this activity was stopped due to other activities considered more important. Thus, as a first approach for the exploration of possible topics for a cooperation with EGEE we selected Grid middleware and network interoperation as the environment for the current discussions on potential topics. Moreover, we started exchanging the objectives and the state of the respective activities in PHOSPHORUS and EGEE.

2 Collaborations with non-EU Partners

The main aim of the PHOSPHORUS project is related to European partners co-operation however the full success can be achieved only by global collaboration of all interested partners. To fulfil this idea some non-European partners participate in the PHOSPHORUS project: MCNC(USA), Nortel(USA), CRC(Canada). However, there are many others organisations working on dynamic service provisioning using network and computing resources. Partnership with them make opportunity of share the experience and technical knowledge, achieve synergy between all similar projects by collaboration in the common areas of interest. There is also the possibility to run some set of services between networks and solutions developed by different projects which is a very practical kind of co-operation. Common meetings and workshops give a great possibility to promotion of the projects results in research communities.

The PHOSPHORUS project collaborates with the following organizations/projects:

- CANARIE,
- Internet2/Dragon,
- ESnet/OSCARS,
- National LambdaRail/Enlightened Computing,
- Japan Gigabit Network/G-Lambda,
- Korea Institute of Science and Technology Information.

2.1 CANARIE Inc.

2.1.1 About CANARIE

It is Canada's advanced Internet development organization - is a not-for-profit corporation supported by its members, project partners and the Canada Federal Government. CANARIE's mission is to accelerate Canada's advanced Internet development and use by facilitating the widespread adoption of faster, more efficient networks and by enabling the next generation of advanced products, applications and services to run on them. More information on CANARIE organization can be obtained online at http://www.canarie.ca/. CANARIE organization is national optical Internet research and education network CAnet 4 network operator.

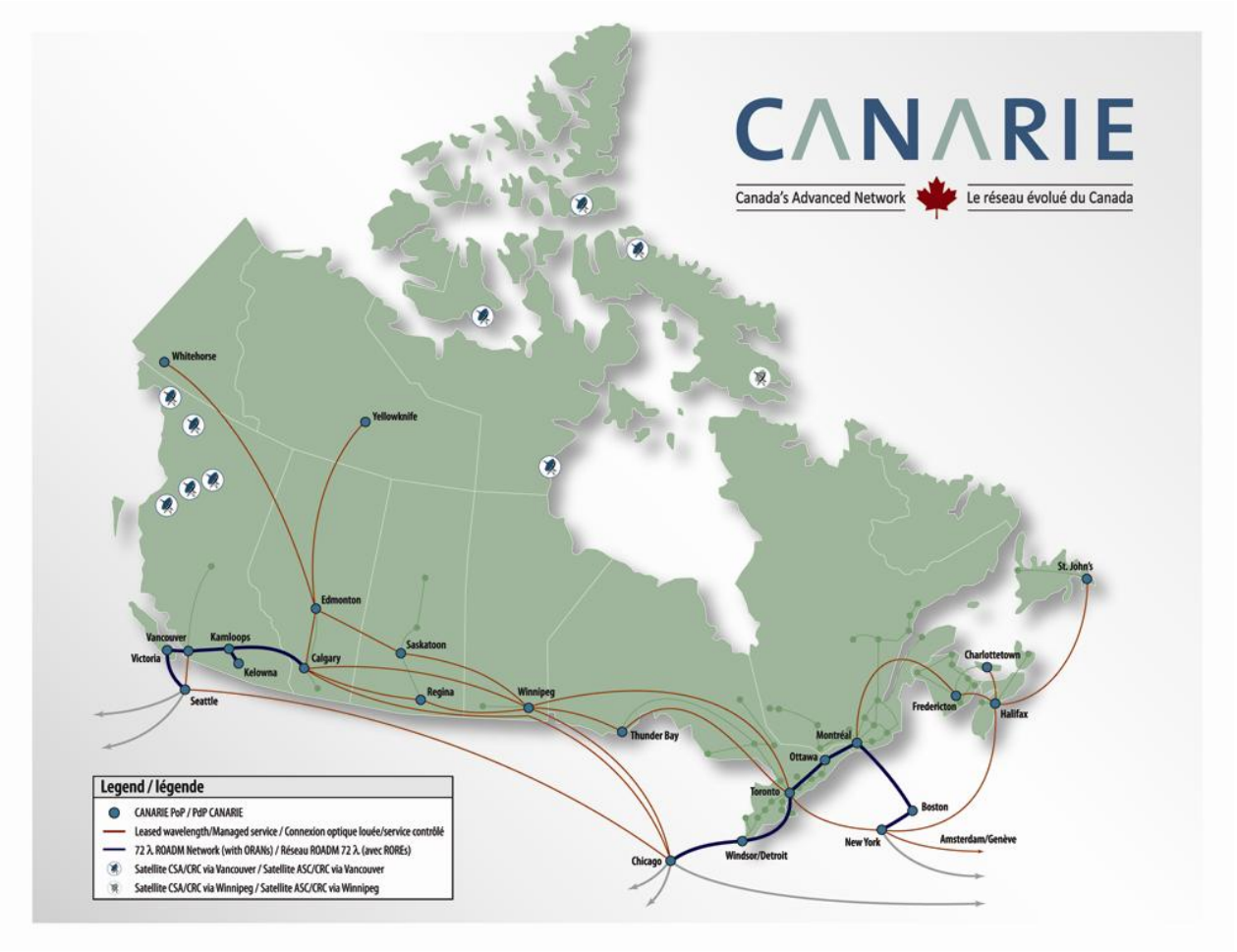

Figure 2.1: CAnet network map

2.1.2 UCLP project

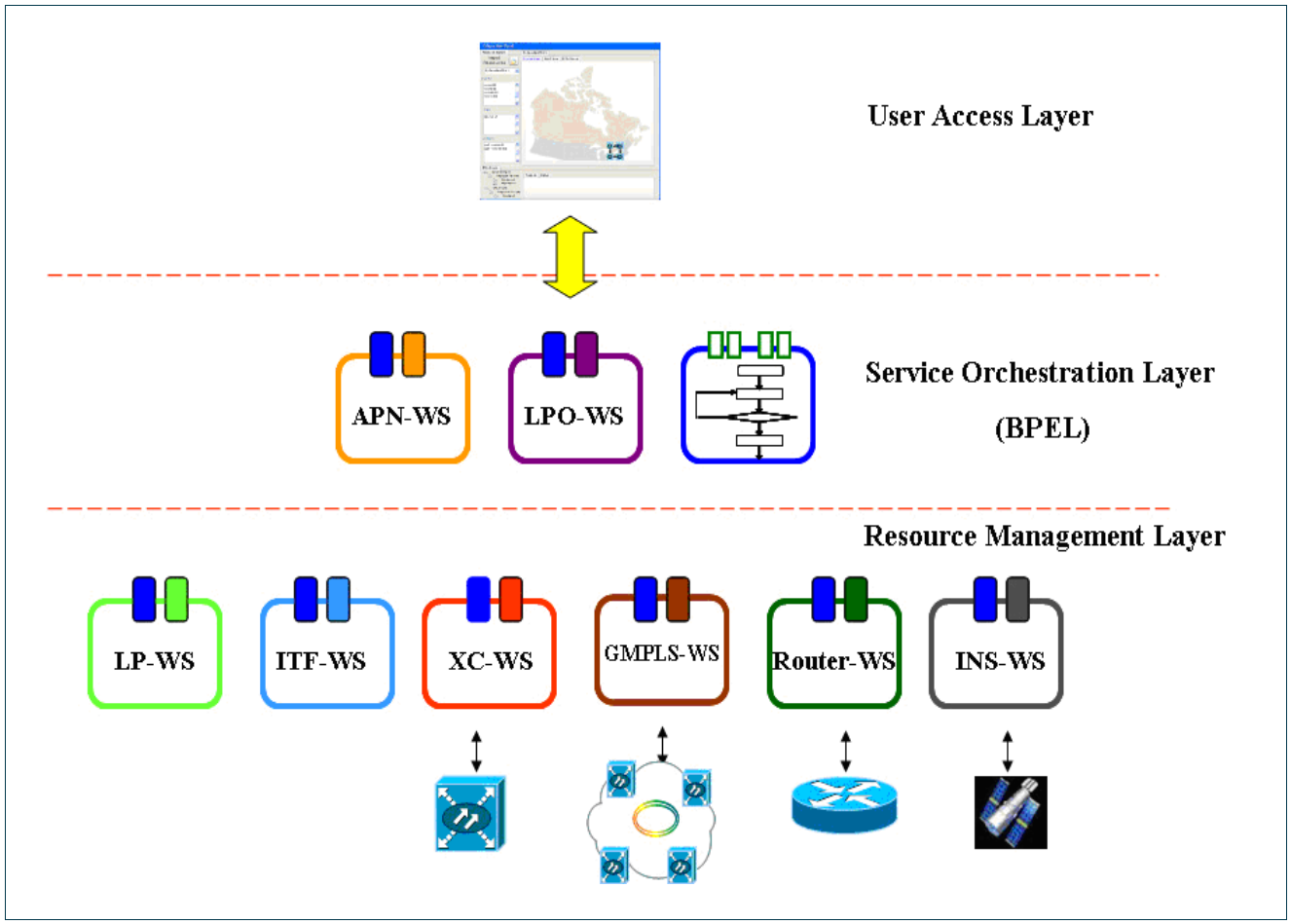

Figure 2.2: UCLPv2 System Architecture

One of the CANARIE projects is User Controlled LightPath (UCLP) which allows end-users, either people or sophisticated applications, to treat network resources as software objects and provision and reconfigure lightpaths within a single domain or across multiple, independently managed, domains. The UCLP architecture is presented on **Figure 2.2**. Users can also join or divide lightpaths and hand off control and management of these larger or smaller private sub-networks to other users. The UCLPv2 project is funded under CANARIE's Directed Research Program and is being performed in collaboration with the Communications Research Centre, the i2CAT Foundation in Barcelona, Spain, Inocybe Technologies Inc., and the University of Ottawa. The goal of the project it to create a set of virtualized network resources that can be orchestrated into BPEL workflows to create Articulated Private Networks as described above. End users will be able to control and managed their APNs using a Graphical User Interface built on Eclipse RCP technology that is both familiar and very easy to use and will never have to see or write any BPEL workflow source code. More information on UCLP project can be obtained online at http://www.canarie.ca/canet4/uclp/uclp_software.html.

2.1.3 HSVO project

This project is funded by Canarie's Network Enabled Platforms (NEP) program. The HSVO aims to create a sustainable research platform for experimental development of shared ICT-based health services. This includes support for patient treatment planning as well as team and individual preparedness in the operating room, emergency room, general practice clinics, and patients' bedsides. In the context of the Network-Enabled Platforms program, the project seeks to offer such support to distributed communities of learners and health-care practitioners. Achieving these goals entails the development of tools for simultaneous access to the following training and collaboration resources: remote viewing of surgical procedures (or cadaveric dissections show on **Figure 2.3**), virtual patient simulation involving medical mannequins and software simulators, access to 3D anatomical visualization resources, and integration of these services with the SAVOIR middleware along with the Argia network resource management software.

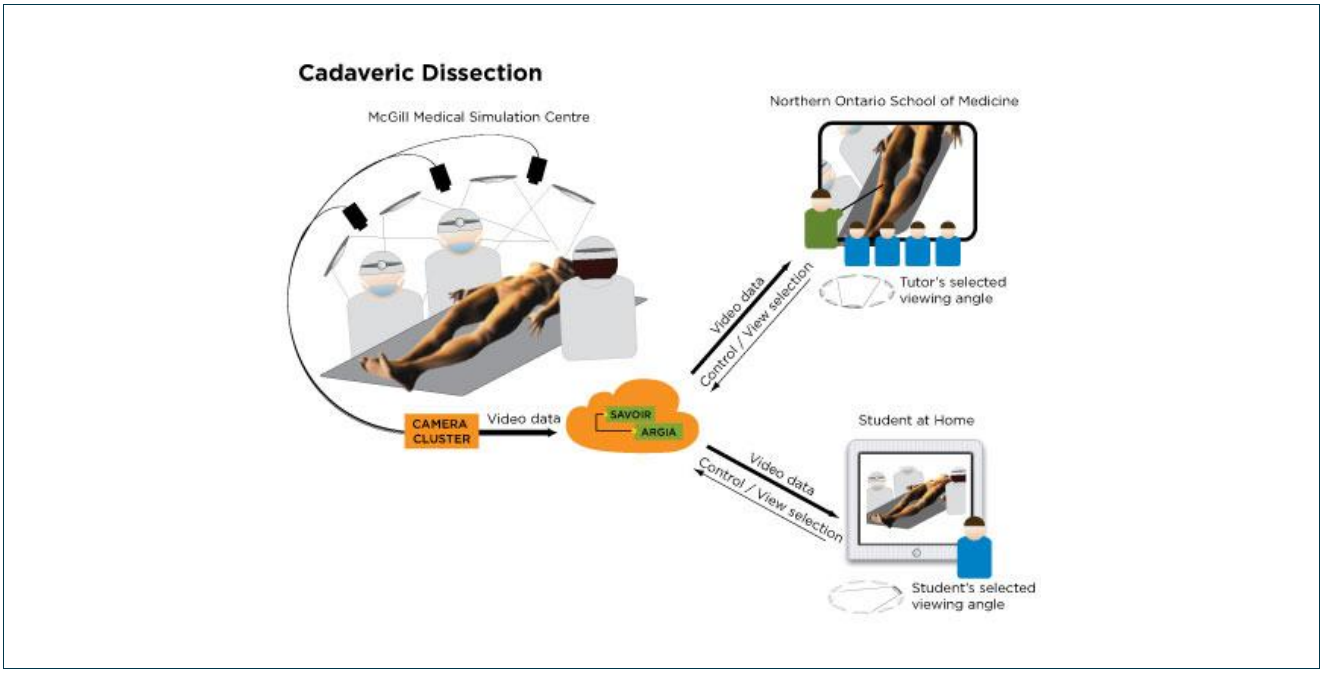

Figure 2.3: Cadaveric dissection – HSVO makes an autopsy view available remotely

2.1.4 PHOSPHORUS and CANARIE co-operation

2.1.4.1 *Step 1: Interconnecting Phosphorus test-bed*

As can be seen on **Figure 2.4**, Canarie participated in the project by providing the required connectivity between Canada and other Phosphorus partners using CAnet 4 network.

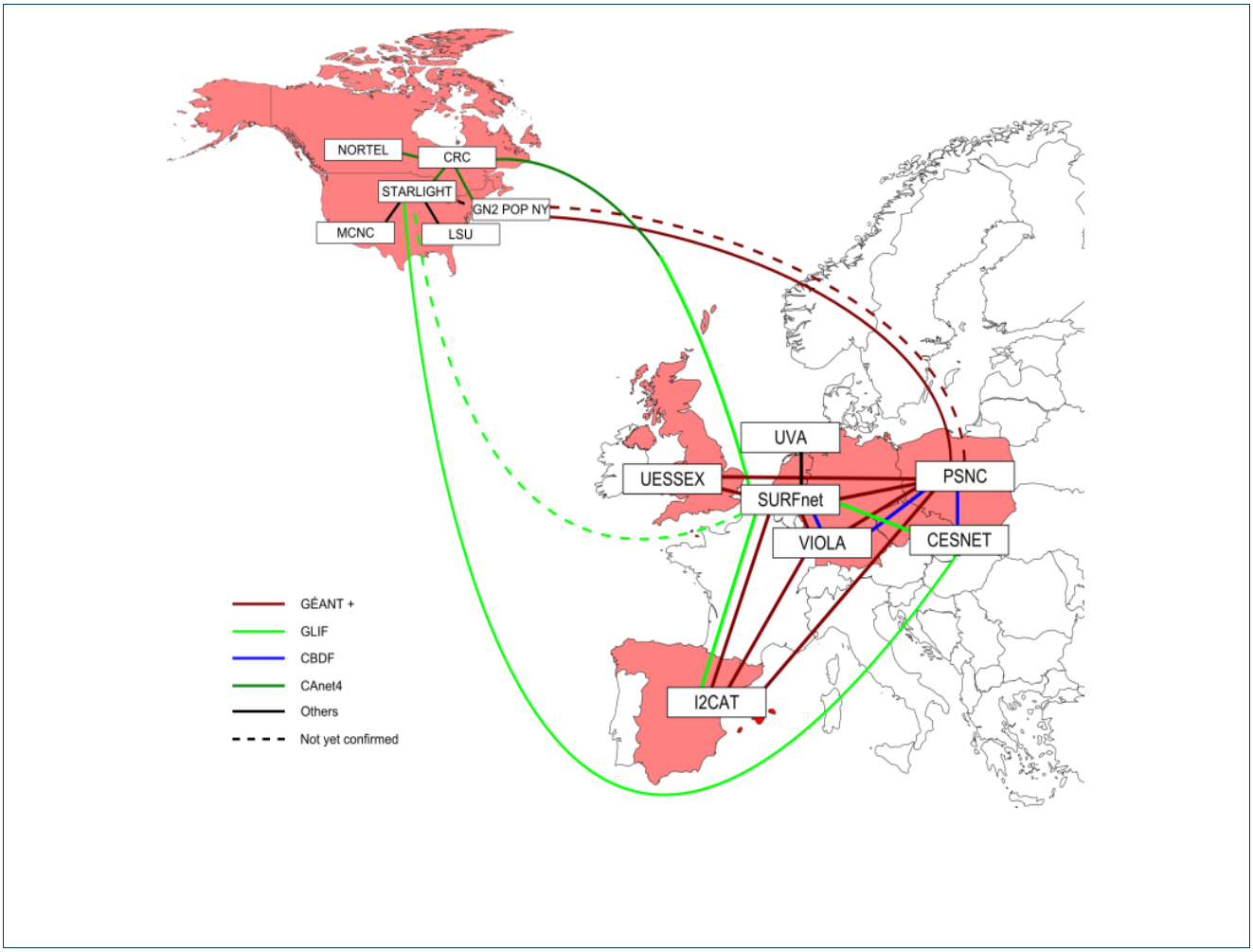

Figure 2.4: CAnet4 data-links interconnecting the PHOSPHORUS test-bed

2.1.4.2 *Step 2: UCLP integration to Harmony system*

Communications Research Centre(CRC) and i2CAT were participating in the PHOSPHORUS Project and they were working on the UCLPv2 interaction to PHOSPHORUS architecture aspects within PHOSPHORUS WP1 activity. This work aims to create seamless interoperability between UCLP, DRAC, ARGON and GMPLS Control Plane under Harmony system umbrella. CRC and i2CAT were enhancing of UCLPv2 to achieve the required PHOSPHORUS functionality. To enable UCLP integration with other PHOSPHORUS Harmony system, the PHOSPHORUS WP6 implemented proper test-bed structure and installed UCLPv2 in PHOSPHORUS partners local test-beds: CRC, UESSEX, I2CAT [4]. There were appointed and configured connections between all these test-beds, where the most important are between Europe and Canada.

2.1.4.3 *Step 3: Harmony – HSVO Collaboration*

The goal of Harmony – HSVO Collaboration is to show how external applications, such as HSVO, can achieve the inter-operability with Harmony. The SAVOIR middleware coordinates the infrastructure and resources associated with the HSVO facilities. This collaboration has been demonstrated in one local event in Barcelona: “Internet del Futur. Jornada de Recerca: Projecte TRILOGY”. In the demonstration, SAVOIR middleware called the Harmony Inter-domain Broker in order to establish a path from HSVO to i2CAT. The user in the conference venue was able to view rendered 3D data sets based on the Basset Collection.

Moreover, this collaboration were demonstrated also in the TERENA Networking Conference (June 09), which took place in Málaga, Spain. The test-bed were extended with one new domain located in the conference venue and directly connected to the i2CAT local test-bed. This deployment allowed the client to establish a path between Sunnyvale and Málaga (going through Canada and Barcelona) using the Harmony system and visualize anatomical 3D rendered data (**Figure 2-5**).

Finally, the demonstration of the inter-operability between Harmony and HSVO will also be demonstrated locally in Barcelona, where i2CAT will perform one special demonstration to the e-Health community of the city, including as well some medical employees, in order to show the commercial benefits of this collaboration.

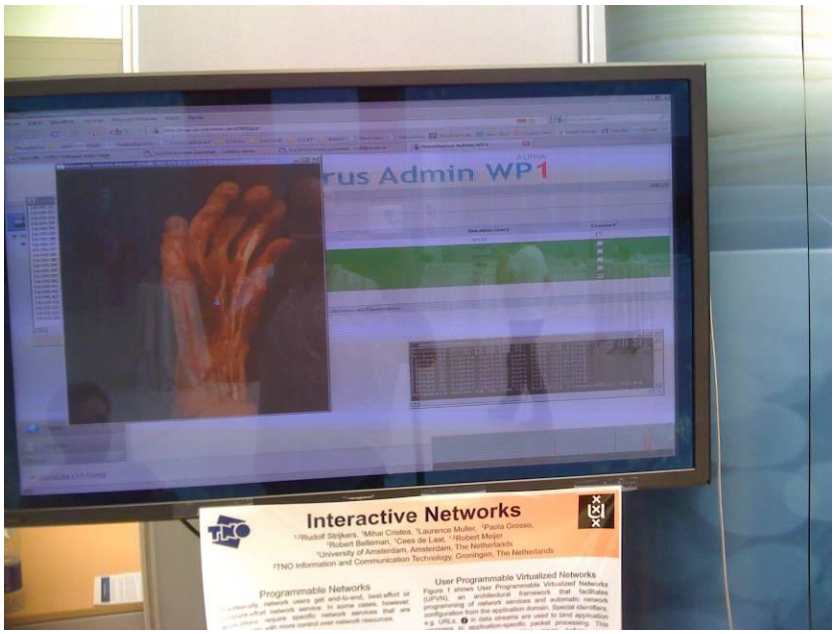

Figure 2-5: HSVO working with Harmony in TNC'09 conference

2.2 Internet2/Dragon and ESnet/OSCARS

2.2.1 About Internet2

Internet2 (University Corporation for Advanced Internet Development) is a non-profit consortium which develops and deploys advanced network applications and technologies, for education and high-speed data transfer purposes. Its goal is accelerating the creation of tomorrow's Internet. It is led by 208 U.S. universities and partners with 60 companies in areas from the networking (Cisco Systems), publishing (Prous Science) and technology industries such as Comcast, Intel and Sun Microsystems. Internet2 network is presented on **Figure 2.6**. More information on Internet2 organization can be obtained online at http://www.internet2.org.

Figure 2.6: Internet2 network map

2.2.2 Dragon project

The DRAGON (Dynamic Resource Allocation via GMPLS Optical Networks) project, funded by USA National Science Foundation (NSF), is conducting research and developing technologies to enable dynamic provisioning of network resources on an interdoman basis across heterogeneous network technologies. A DRAGON network architecture and control plane is defined which aims to leverage the maturing of network technologies (such as WDM, Ethernet, and Next-Generation SONET) to demonstrate the power and flexibility of a "hybrid" packet and circuit switched network infrastructure. A key element is the extension of the GMPLS IP control plane to enable multi-domain, multi-layer, multi-service provisioning with robust levels of authentication, authorization, and accounting. DRAGON's architecture is presented on **Figure 2.7**. More information on DRAGON project can be obtained online at http://dragon.maxgigapop.net/twiki/bin/view/DRAGON/WebHome.

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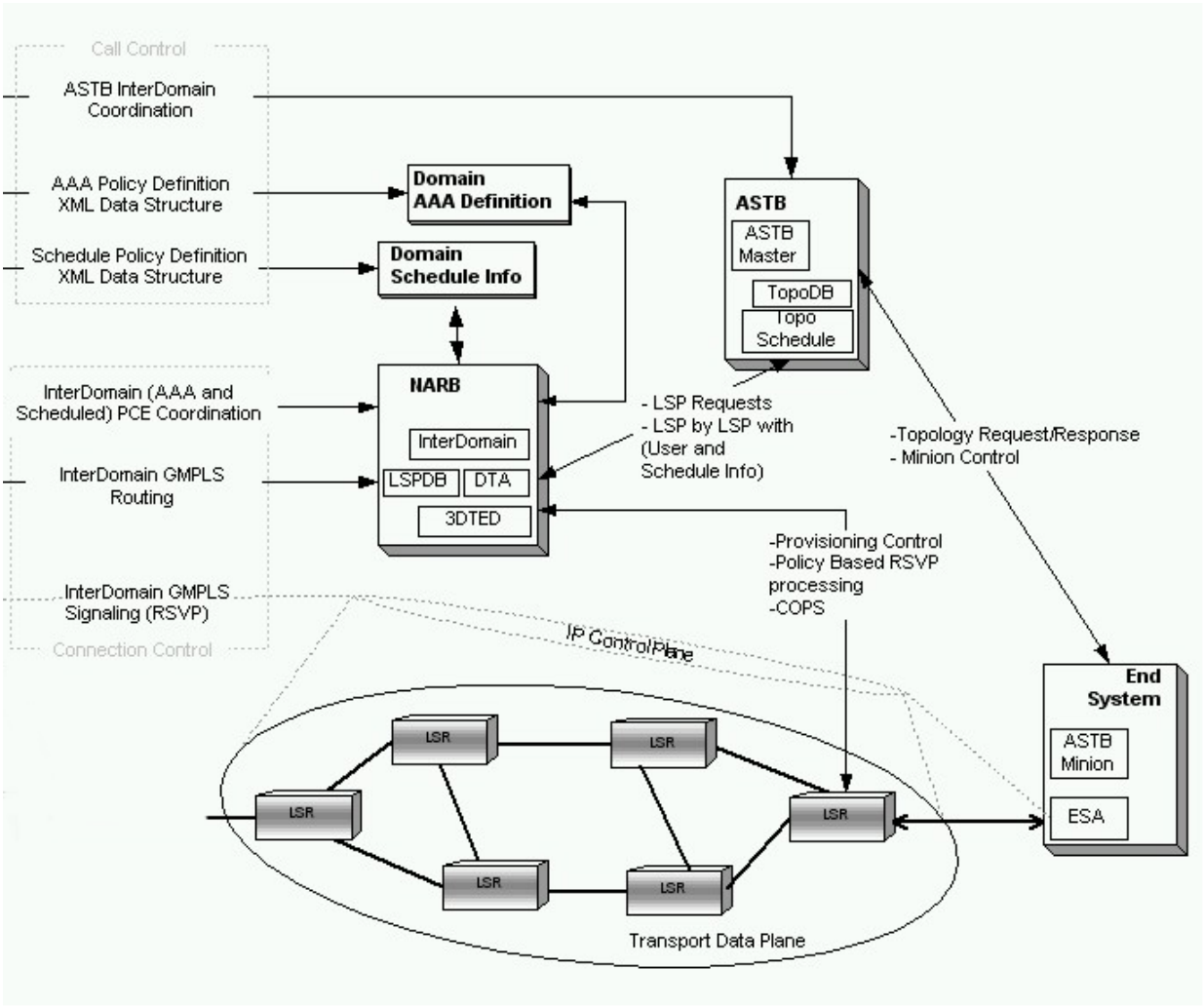

Figure 2.7: Dragon's architecture

2.2.3 About ESnet

Energy Sciences Network is a high-speed network serving thousands of Department of Energy scientists and collaborators worldwide. A pioneer in providing high-bandwidth, reliable connections, ESnet enables researchers at national laboratories, universities and other institutions to communicate with each other using the collaborative capabilities needed to address some of the world's most important scientific challenges.

Managed and operated by the ESnet staff at Lawrence Berkeley National Laboratory, ESnet provides direct connections to all major DOE sites (site list) with high performance speeds, as well as fast interconnections to

more than 100 other networks. Funded principally by DOE's Office of Science, ESnet services allow scientists to make effective use of unique DOE research facilities and computing resources, independent of time and geographic location. More information on ESnet organization can be obtained online at http://www.es.net/.

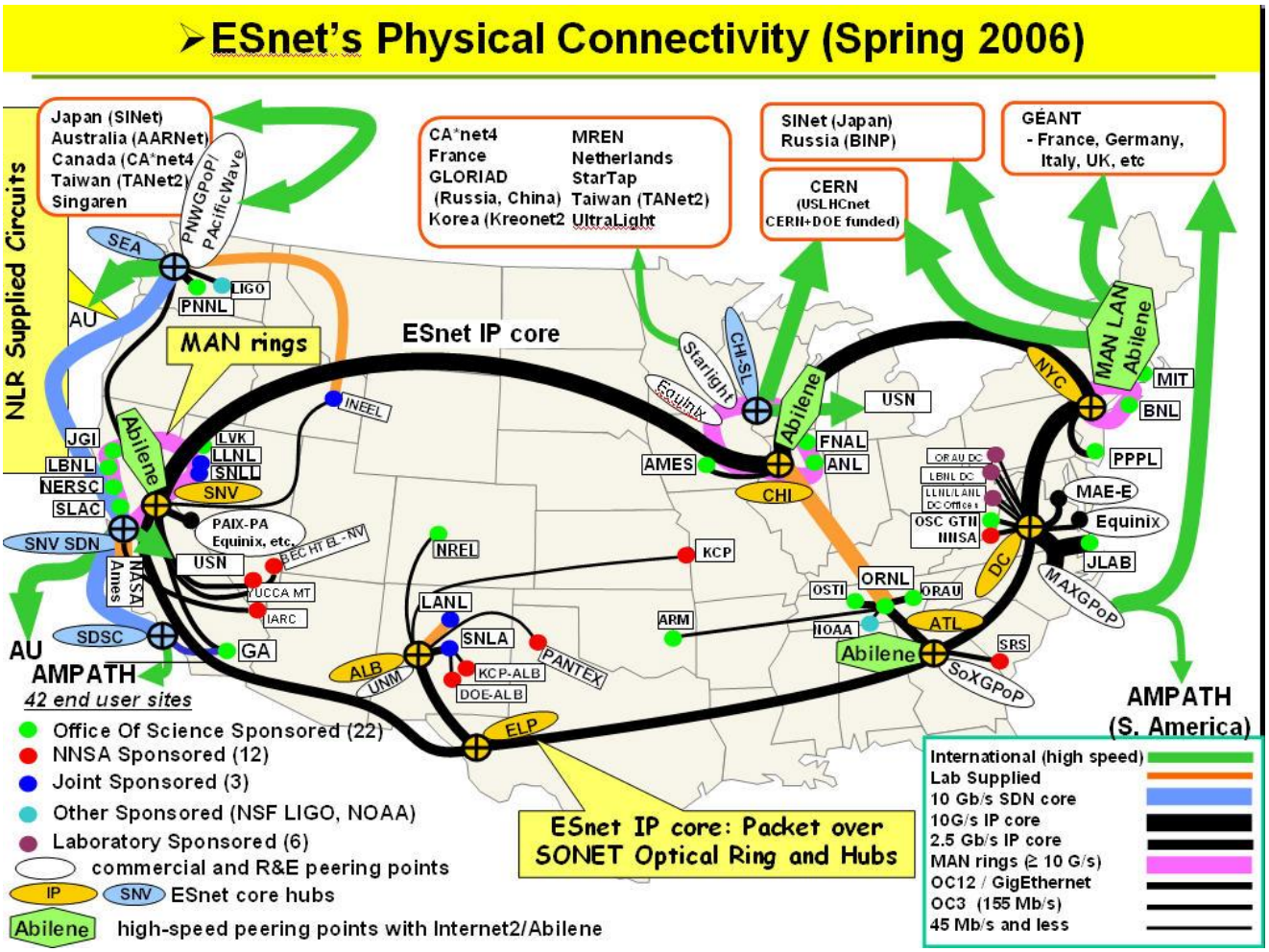

Figure 2.8: ESnet's physical connectivity network map

2.2.4 OSCARS Project

The focus of the ESnet On-Demand Secure Circuits and Advance Reservation System (OSCARS) is to develop and deploy a prototype service that enables on-demand provisioning of guaranteed bandwidth secure circuits within ESnet. OSCARS will leverage existing (or in development) products, services, and code (both from the industry and academia) to accomplish its goals. OSCARS will utilize the existing DOEGrids certificate infrastructure and modify Virtual Organization Membership Services (VOMS) software to implement its authentication and authorization schemes. The management and operation of end-to-end circuits (using Label Switched Paths (LSPs)) within the network will be supported using Multi-Protocol Label Switching (MPLS) and Resource Reservation Protocol (RSVP). Quality of Service (QoS) will be used to provide bandwidth

guarantees. OSCARS is implementing a multi-domain control plane implementing functions such as path finding and path reservations. More information on OSCARS project can be obtained online at http://www.es.net/OSCARS/.

2.2.5 PHOSPHORUS, Internet2 and ESnet co-operation

2.2.5.1 *Step 1: Phosphorus AAA for OSCAR/DRAGON*

The Internet2 consortium is working together with ESnet (Energy Sciences Network) on the implementation of the Dynamically Controlled Network architecture (DCN) that define a Control- and Data- plane architecture for multi-domain, multi-layer hybrid networks .

Cooperation between Internet2/ESnet and UvA in the framework of the Phosphorus project started from the beginning of the project. At the initial stage in 2006-2007 WP4 was actively involved into joint development of the authorisation service for interdomain lightpath provisioning that should be capable of integrating network resource provisioning systems developed both in the Internet2/ESnet and in the Phosphorus project: OSCARS and NSP/Harmony. This cooperation was resulted in the development of the token based interdomain-signalling concept and the definition of Token Validation Service (TVS) functionality. The TVS code developed by WP4 was integrated into OSCARS middleware and now is a part of the OSCARS/DRAGON release, it was jointly being tested by connecting the Phosphorus AAA test-bed in Amsterdam and the Internet2 HOPI testbed interconnected via Netherlight and MANLAN. A joint demo as presented at SuperComputing 2007 in Reno.

2.2.5.2 *Step 2: IDC/OSCARS, AAA and Harmony interoperability*

At the second stage since 2008, the cooperation was primary focused on achieving interoperability between OSCARS/DCN and Harmony/NSP systems to provide cross-domain lightpaths. The UvA testbed has been integrated into the Harmony infrastructure to allow setting up connections in the UvA testbed by requesting them from the Harmony NSP. For this purpose, a Harmony NSP Adapter (HNA) has been created (**Figure 2.10**) and deployed in the UvA testbed. To achieve interoperability with Internet2, an Inter-Domain Controller (IDC) has been deployed in the UvA testbed and a Harmony-IDC request translator was developed and deployed. In this way it became possible to set up connections going through the Internet2 and Phosphorus domains by sending requests to the Harmony NSP. The Phosphorus-DCN interoperability was demonstrated at SC08, and described in more detail in the next section.

The most important event where this collaboration has been shown is the SuperComputing 08 event (SC 08), held in Austin, Texas, US at the end of November. Next figures (**Figure 2.9** and **Figure 2.10**) depict the Dutch booth where the inter-operability on-demand demonstrations were performed and the abstract overview of the IDC/OSCARS translator. The combined Phosphorus/Internet2 setup realized one of the possible demo scenarios to request a path from the Harmony NSP running from a host in the I2CAT domain to the demonstrator host on the SC08 showfloor. The actual demo consisted of showing the setup of a path to a VIOLA, I2CAT and Internet2 host by making requests in the Harmony NSP web GUI.

Figure 2.9: Dutch booth at SC 08 (Austin, Texas) where the Harmony-IDC inter-operability demonstrations were performed

The demonstrator booth was visited frequently and the feedback positive as useful technical feedback were received. This provided an input to further development of the Harmony/NSP system and the generic Authorisation framework for multi-domain/cross-domain lightpath provisioning.

The cooperation between Internet2/ESnet and Phosphorus was presented in a number of presentation at different international events such as: Internet2 Day Event in 2007, 2008, 2009; GLIF meeting in 2007, 2008, and 2009.

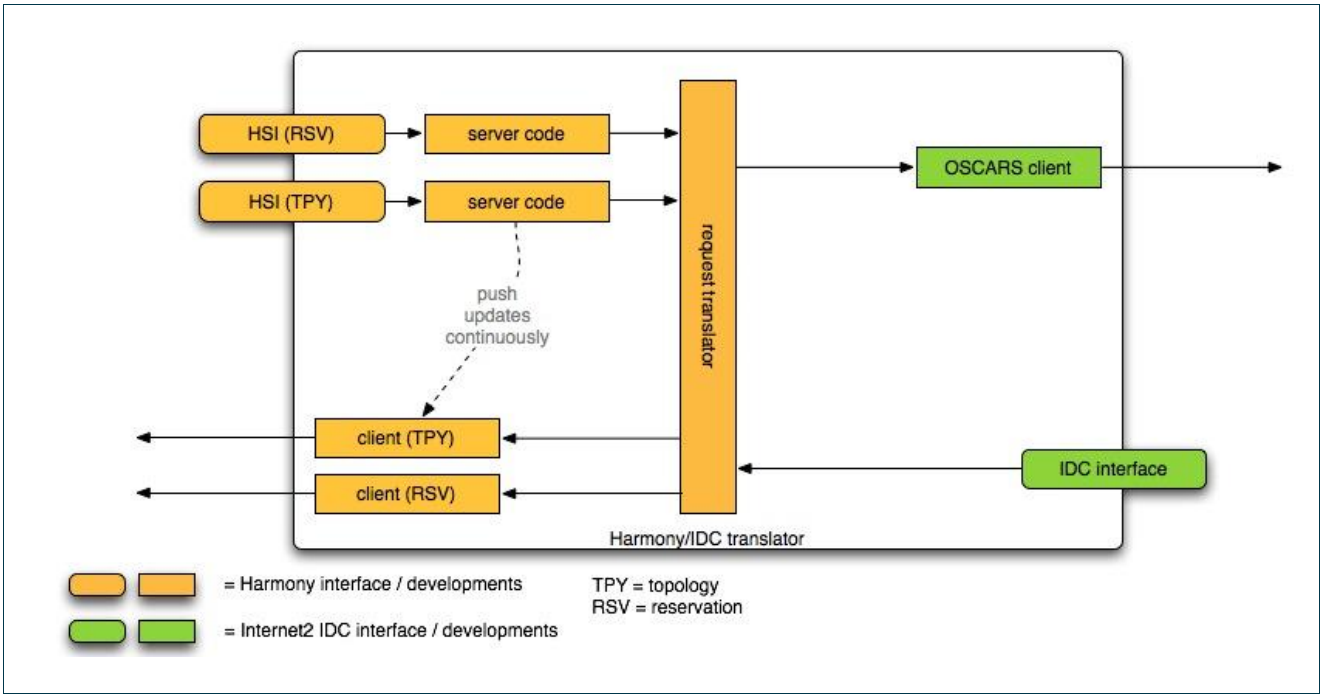

Figure 2.10: Abstract overview of the IDC/OSCARS translator

2.3 National LambdaRail/Enlightened Computing and Japan Gigabit Network/G-Lambda

2.3.1 About National LambdaRail network

National LambdaRail (NLR) is a high-speed national computer network (see **Figure 2.11**) in the United States that runs over fiber-optic lines, and is the first transcontinental Ethernet network. The name is shared by the organization of research institutions that developed the network, and, to date, plans to continue developing it. More information on NLR organization can be obtained online at http://www.nlr.net.

Figure 2.11: The NLR network map

2.3.2 Enlightened Computing project

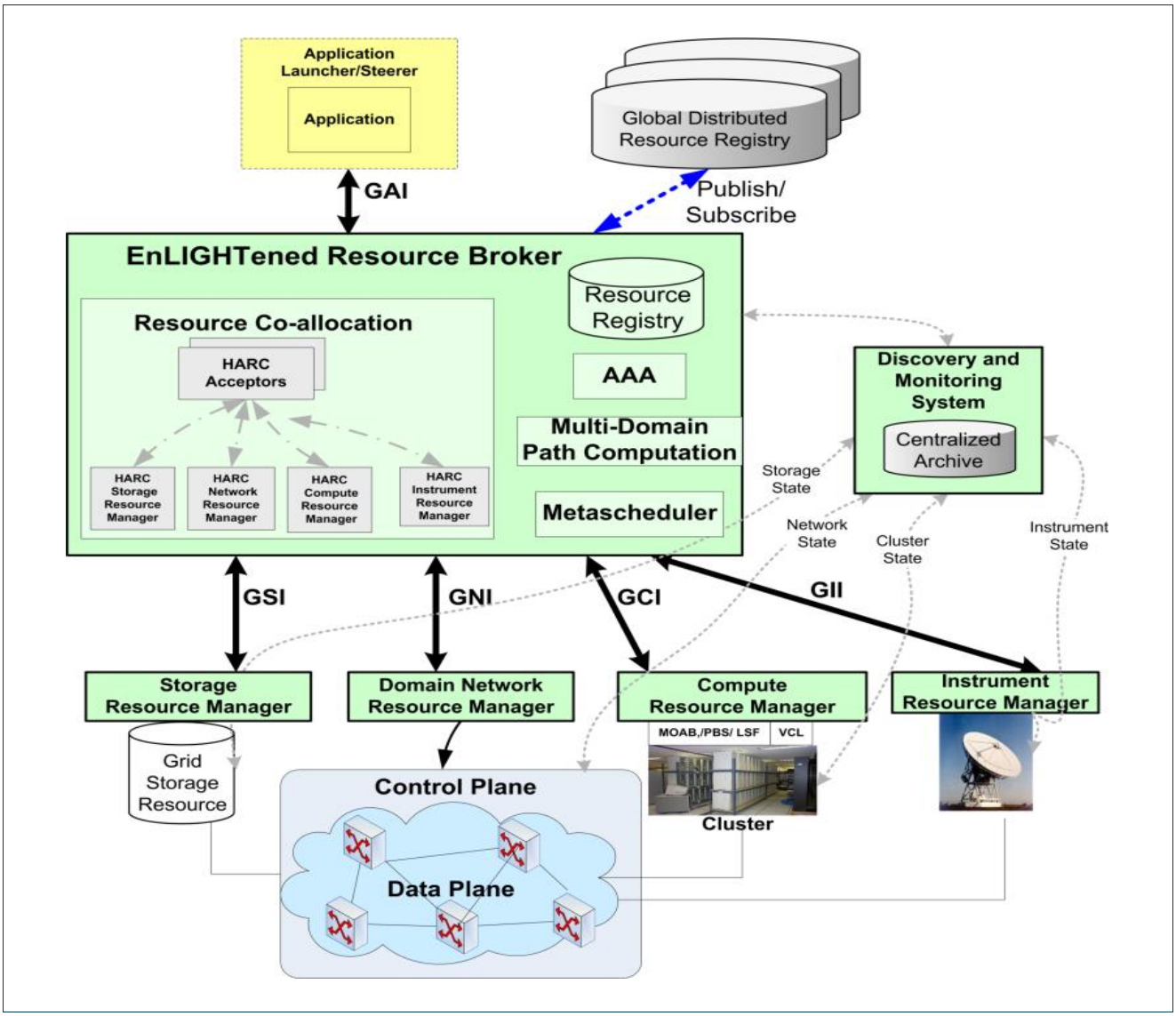

Figure 2.12: Enlightened Computing Architecture

The focus of the Enlightened Computing project is on developing dynamic, adaptive, coordinated and optimized use of networks connecting geographically distributed high-end computing resources and scientific instrumentation. A critical feedback-loop consists of resource monitoring for discovery, performance, and SLA compliance, and feed back to co-schedulers for coordinated adaptive resource allocation and co-scheduling (see **Figure 2.12**). Enlightened Computing network research is driven by concrete application projects in astrophysics, coastal modeling, and atmospheric research, currently underway, all of which critically require progress in network technologies and tools that utilize them. The research carried out, the developed tools, and the applications that use them will be deployed across regional and nationwide 10Gbps bandwidth test-beds

running over National LambdaRail(NRL) and Louisiana Optical Network Initiative(LONI), connected via four all-photonic Calient switches, all using GMPLS control plane technologies. More information on Enlightened Computing project can be obtained online at http://www.enlightenedcomputing.org.

2.3.3 About Japan Gigabit Network

Japan Gigabit Network (JGN) is a nationwide, next generation, high-speed telecommunications network that is made widely available for use at Japan universities, research institutions, venture businesses, local governments. The JGN is expected to be widely used for research and development of very high-speed networking and high-performance application technologies. The JGN is also expected to create business opportunities and telecommunications services. More information on JGN organization can be obtained online at http://www.jgn.nict.go.jp/english/index.html.

2.3.4 G-Lambda project

The goal of G-lambda is to establish a standard web services interface to network resource manager provided by network operators (Telecom operators). This interface should be used by application service providers (Grid resource managers / Grid brokers) or by end users to make the most of network operators service available. Define a standard web service interface, which is acceptable for both ASP and commercial network operators (see **Figure 2.13**). G-Lambda optical test-bed was established using JNG network. More information on G-Lambda project can be obtained online at http://www.g-lambda.net.

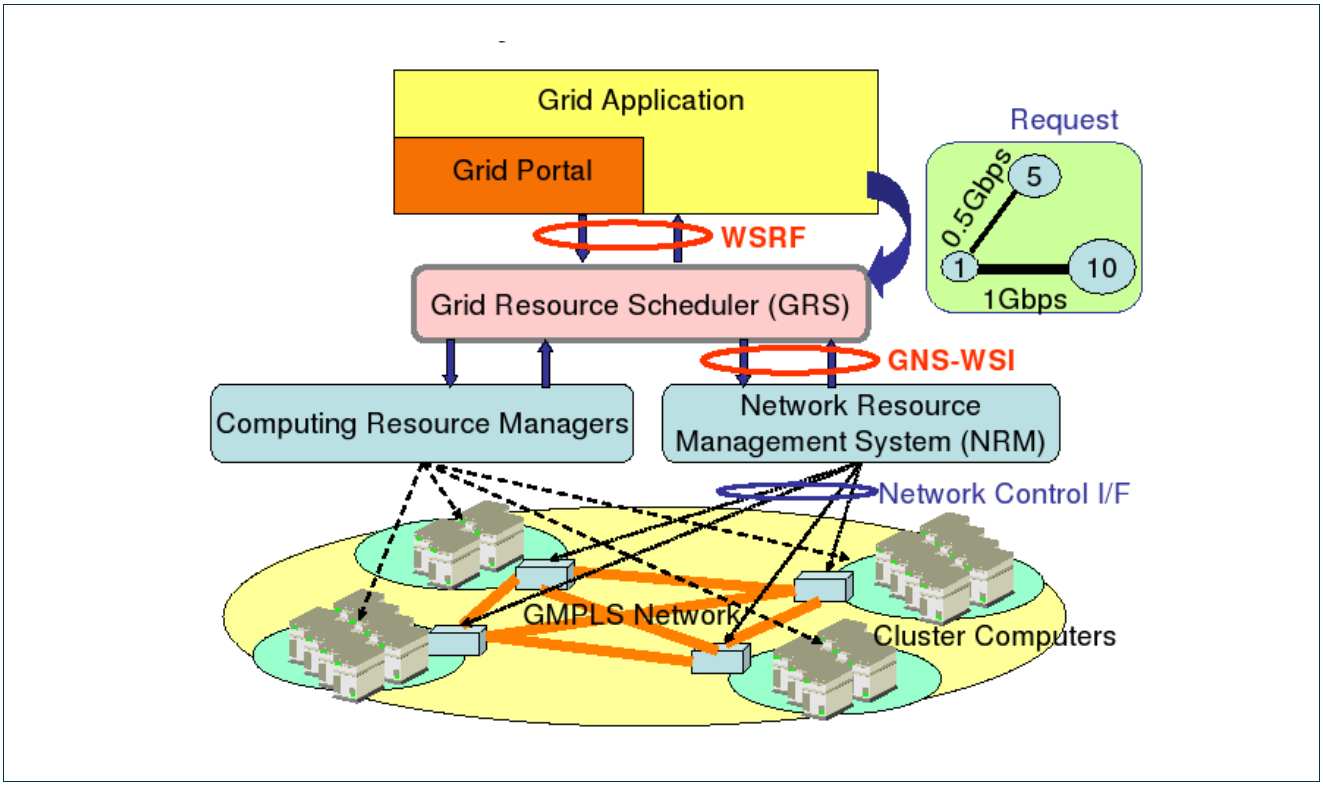

Figure 2.13: G-lambda's system overview

2.3.5 PHOSPHORUS, Enlightened Computing and G-Lambda co-operation

The one of the main participants of Enlightened Computing is MCNC which also is participated in the PHOSPHORUS project and National LambdaRail organisation. MCNC (represented by Gigi Karmous Edwards) in the PHOSPHORUS project is participating in testing and demonstration activities in order to extend the EU test-bed to the USA for international demonstrations for the PHOSPHORUS project. MCNC increases the global awareness of the PHOSPHORUS project and its developments.

First cooperation planes between these three projects began during Supercomputing 2006 (Tampa, Florida, USA from the 11th – 17th November 2006) where University of Essex organised a BOF session: "Delivery of Network Services across Heterogeneous Optical Domains". All three projects were concerned with interoperability issues between heterogeneous network domains. The BOF targeted wider community awareness and participation in the main common technical challenges concerning these projects.

Next very important event was Collaboration Across Three Continents Meeting (from January 31st to February 2nd 2007). It was organized by MCNC where G-Lambda, PHOSPHORUS and Enlightened Computing research teams discussed in face-to-face meeting about collaboration plans (see **Figure 2.14**). During this meeting all participants gained an understanding of the three research project, established a work plan for 3-way collaboration. The objectives of the meeting were threefold to provide an update on the on-going

concentration efforts on networks and grids and to discuss the trends and critical issues related to the future of research networking test-beds and to explore creation of synergies between projects, to explore plans for future actions (in particular, within the context of the upcoming FP7) and to pursue efforts to maximize synergy with other similar concentration initiatives.

Figure 2.14: G-Lambda, PHOSPHORUS and Enlightened Computing research teams during Collaboration Across Three Continents Meeting

During the meeting, the three teams formulated an action technical plan for collaboration of optical networks and grid middleware across three continents:

- Develop two common interfaces to request resources:
    - An API for all grid resources,
    - An API to request Lightpaths from domain network managers,
- Interconnect all test-beds.

One of the co-operation effects is providing the OGF Grid User Network Interface (GUNI) draft which defines, describes and provides extensions to existing UNI standardization documents required to support Grid service requirements and functionalities over GMPLS or Network Resource Provisioning Systems. This document describes an interface for Grid Users, Applications and Resources which could be used in G-lambda,

enlightened, PHOSPHORUS or any other Grid middleware in the future. GUNI draft contribution are PHOSPHORUS (EU), Enlightened (USA), G-Lambda (JAPAN), 3TNET (CHINA), e-Photon/One+ (EU) and GLIF.

The last PHOSPHORUS, Enlightened Computing and G-Lambda project meeting were hold during 7th LambdaGrid Workshop, 17-18 September 2007 in Prague where Control Plane Working Group discussions were placed.

The main goal of the PHOSPHORUS, Enlightened Computing and G-Lambda is collaboration of optical networks and grid middleware across three continents. All three projects are currently working on establishing standard and open interfaces which can be used for connecting different Bandwidth on Demand system components especially preparing a connection between G-Lambda, Enlightened Computing and PHOSPHORUS test-beds and demonstrating together an advance network and computing service delivery demonstrations.

2.4 Korea Institute of Science and Technology Information (KISTI)

2.4.1 About KISTI

KISTI, organized in 1962, is a government supported research institute dedicated to the promotion of national competitiveness through the establishment of a science and technology information (STI) R&D infrastructure. As a national core institute for STI infrastructure, KISTI collects, analyzes, and provides scientific, technological and industrial information. In addition, the organization builds and operates R&D supporting infrastructures, such as supercomputing and research networks.

The KISTI Supercomputing Center is the largest provider of supercomputing resources and high performance networks in Korea. Its missions are to advance the national information infrastructure by providing leading-edge computational resources and networks, to advance computational science and computational techniques, and to assist scientific communities and industry in exploiting the computational resources for the growth of their competitiveness worldwide.

2.4.2 PHOSPHORUS and KISTI collaboration

In year 2008, KISTI organization decided to interconnect the data plane of KISTI's dedicated network to the data plane of the test-bed used by Harmony in the Phosphorus project and deploy Argia as a Network Resource Provisioning System at KISTI's dedicated network. KISTI signed the collaboration agreement with the Phosphorus project. In the beginning of 2009, the test-beds were interconnected and Argia were installed by WP1 team. To allow KISTI join the Network Service Plane of Harmony in the Phosphorus project, the Harmony NRPS Adapter for Argia were set up at KISTI.

During Terena conference 2009 in Malaga (Spain), the joint demonstrations of Harmony system managing many Phosphorus local-testbeds and also KISTI network were presented. WP1 team presented setup a network path in purpose of transmiting a demanding HD video streaming from Korea towards the conference venue.

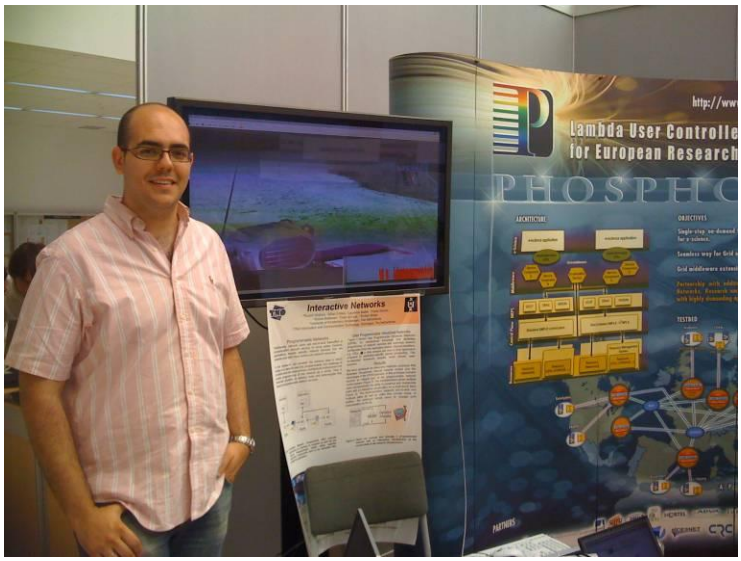

Figure 2-15: HD video streamed from KISTI domain. TNC 09.

3 Summary

The direct collaboration with other EU and non-EU projects and organizations was focused on follow up of new technological achievements mainly inter-domain, multi-technology BoD systems such as the Harmony system and the G^{2}MPLS Control Plane but also G.AAA framework for optical networks. In particular, the great success was installation of Harmony system and ARGIA-NPRS in Korean NREN (KISTI) and showing HSVO project applications using HARMONY system for creation of the optical path for health media connect.

These achievements will be presented after the end of the Phosphorus project during two international events: Supercomputing'09 (November'09, Portland) and IBC'09 (September'09, Amsterdam) in order to disseminate of Phosphorus project great outcomes.

4 Acronyms

AAA	Authentication, Authorisation, Accounting
APN	Access Point Name
ASP	Application Service Providers
ARGON	Allocation and Reservation in Grid-enabled Optic Networks
BoD	Bandwidth on Demand
BPEL	Business Process Execution Language
DM	Domain Manager
DOE	Department of Energy
DRAC	Dynamic Resource Application Controller
DRAGON	Dynamic Resource Allocation via GMPLS Optical Networks
IDM	Inter-Domain Manager
JNG	Japan Gigabit Network
GEANT2	Pan-European Gigabit Research Network
GEANT+	the point-to-point service in GEANT2
GMPLS	Generalized MultiProtocol Label Switching
G^{2}MPLS	Grid-GMPLS (enhancements to GMPLS for Grid support)
GHPN-RG	Grid High Performance Networking Research Group
NREN	National Research and Education Network
NRL	National LambdaRail
NRPS	Network Resource Provisioning System
NSP	Network Service Plane
OGF	Open Grid Forum
OGSA	Open Grid Service Architecture
OSCARS	On-Demand Secure Circuits and Advance Reservation System
QoS	Quality of Service
RPC	Rich Client Platform
RSVP	Resource Reservation Protocol
SoA	Service-oriented Architeture
SDH	Synchronous Digital Hierarchy
TVS	Token Validation Service
UCLP	User Controlled LigthPath
UNI	User Network Interface
VLAN	Virtual Local Area Network

5 References

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