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EXPERIMENTATION BETWEEN
BRAZIL AND EUROPE



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Abstract

The aim of the WP5 is to develop local and federated technology pilots and validate the deployed FIBRE facilities through showcases, which have been pre-selected from a number of use cases (UCs): Seamless Mobility, High Definition Content Delivery and Bandwidth on Demand through OpenFlow and GMPLS. The D5.1 and D5.2 deliverables [14, 15] present a global and homogeneous view of these UCs, mainly focusing on their goals and objectives, on the involved technologies, on the developed building blocks and on the integration of these modules taken as a whole.

On the other hand, this deliverable only recalls the UC-3 (“Bandwidth on Demand through OpenFlow and GMPLS in the FIBRE facility”) giving further information on the software dependencies and prerequisites, on the building blocks configuration and on the steps to be done in order to install the components into the FIBRE infrastructure.

Notes:

1. The WP5 partners decided to follow a SDN approach in this UC, that means that we have a unique and centralized SDN controller for the OpenFlow-based network resources which belong to a single “slice” of the FIBRE facility. On top of this controller, several components have been built with different purposes, e.g. discovery the underlying topology, retrieve statistic information, install or remove the end-to-end flow-entries, etc. One of these components is the GMPLS Flow-aware PCE (F-PCE) based on the IETF PCE architecture, [10]. This module is in charge of path computation using the available virtual network information and the composition of the network services related to the end-to-end flow routes. For this reason, we do not have a whole distributed GMPLS control plane stack in our use case environment, but “only” an enhanced version of its PCE sub-component that realizes a PCE-as-a-service concept.
2. Generally speaking, the previous point is not a strong constraint in our architecture. Indeed, we integrated the EsNet OSCARS framework as a top level component of the SDN controller to manage and control the BoD services. This project has a strictly relationship with the DRAGON software, that is a full open source implementation of the GMPLS stack. That said, we could consider as an extension of this UC the possibility to have two different domains of the FIBRE facility both managed by the OSCARS Inter-Domain Controller (IDC) and connected using its IDC-protocol. In one of these domains we could use the SDN controller as a network Resource Manager and in the other we could use the DRAGON GMPLS control plane to manage the multiple data-plane technologies. In such a way, we

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could realize the interoperability between control planes: a distributed GMPLS control plane and a centralized SDN controller. The Figure 1 gives an overview of the proposed scenario.

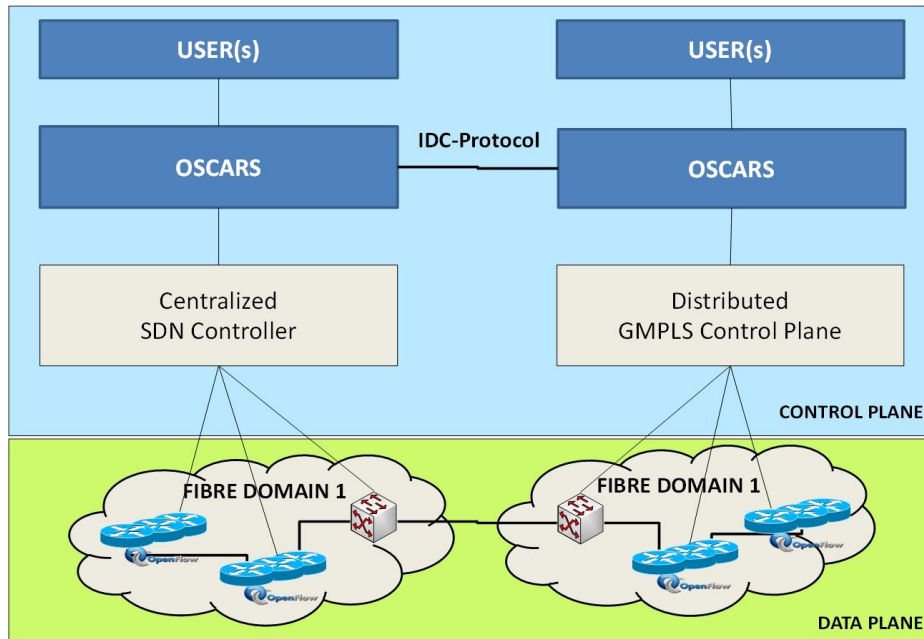


Figure 1: Multiple FIBRE domains, interoperability between GMPLS and SDN through OSCARS



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1 Acronyms

AM	Aggregate Manager
API	Application Programming Interface
BoD	Bandwidth on Demand
CDN	Content Delivery Network
CDS	Content Delivery Server
CLI	Command Line Interface
CORBA	Common Object Request Broker Architecture
CRUD	Create, Read, Update and Delete
CP	Control Plane
DPID	DataPath IDentifier
DPS	Discovery Packet Switches
E-OFC	Extended-OpenFlow Controller
FIBRE	Future Internet testbeds / experimentation between Brazil and Europe
F-PCE	Flow-aware Path Computation Element
FPGA	Field-Programmable Gate Array
FV	FlowVisor
GMPLS	Generalized Multi-Protocol Label Switching
GUI	Graphical User Interface
HTTP	HyperText Transfer Protocol
IM	Island Manager
LLDP	Link Layer Discovery Protocol
LSP	Label Switched Path
MS	Milestone
NE	Network Element
NMI	Network Management Interface
NOX	OpenFlow Controller
OCF	OFELIA Control Framework
OF	OpenFlow
OFELIA	OpenFlow in Europe: Linking Infrastructure and Applications
OFV	Optical FlowVisor
OMF	cOntrol, Management and Measurement Framework
OML	ORBIT Measurement Library
OSPF-TE	Open Shortest Path First - Traffic Engineering
OSS	Open Source Software
p.	Page
QoS	Quality of Service
ROADM	Reconfigurable Optical Add-Drop Multiplexer
RSVP-TE	Resource Reservation Protocol - Traffic Engineering
SDN	Software Defined Networking

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SFA	Slice-based Federation Architecture
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
TED	Traffic Engineering Database
UDP	User Datagram Protocol
UNI	User Network Interface
VLAN	Virtual Local Area Network
VM	Virtual Machine
VON	Virtual Optical Network
VT	Virtualization Technology
WP1	Project Management
WP2	Building and operating the Brazilian facility
WP3	Building and operating the European facility
WP4	Federation of facilities
WP5	Development of technology pilots and showcases
WP6	Dissemination and collaboration



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2 Scope

This deliverable presents the Bandwidth on Demand through OpenFlow and GMPLS in the FIBRE facility use case. The document gives a brief high-level overview of the UC, focusing on its objectives and on its architecture. The main part of the deliverable is the software description, in terms of developed modules and technical specifications. Moreover, some details on the package dependencies and on the installation procedure are introduced. Finally ending with the user workflow which describes the various steps to be taken by a experimenter to run the use case over the FIBRE control framework.

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3 Reference Documents

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4 Technology Pilot 3: Bandwidth on Demand through OpenFlow and GMPLS in the FIBRE facility


This use-case exploits the flexibility of the OpenFlow (OF) protocol and the potentiality of the FlowVisor (FV), the F-PCE and OSCARS systems in order to implement an open and generalized Bandwidth on Demand (BoD) service for the OF-enabled devices in the FIBRE infrastructure.

The NOX control framework, using its southbound OF protocol, implements the SDN paradigm which decouples control plane from data plane, allowing for remote software to take over the control and management of the underlying network resources. Moreover, the FV acting as a transparent proxy between the physical OF-enabled switches and one or more OF controllers, allows the creation of a sophisticated virtual topology composed of multiple “slices” of the network resources, by delegating the control of each slice to a different controller. The NOX controller can be easily extended with several new components providing advanced functionalities, e.g.

- discovery the virtual underlying topology (discovery packet/circuit component);
- retrieve the flows/ports monitoring statistics (monitoring component);
- enhance the supported protocol in the core framework (STP component);
- perform the end-to-end path computation and flow-route installation (F-PCE component);
- on-demand and advance reservation scheduling (OSCARS component).

4.1 Functional Description

The FIBRE infrastructure provides a large-scale and distributed facility composed of OpenFlow enabled switches and computing resources. The enhanced version of NOX controller (e-NOX) is installed to control and manage the virtual “slice” of the network resources. It can discover the overall network topology, i.e. packet and optical devices, and update the F-PCE system and OSCARS framework with useful information on the nodes and links.

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OSCARS provides a web interface to request the end-to-end path computation introducing bandwidth, VLAN and time constraints. OSCARS performs a first validation on the request parameters using the topology information available through the SDN controller. Then, it send the request to the lower layer.

The e-NOX controller manages the request using the F-PCE module to compute the best available path (Dijkstra algorithm) between the 2 endpoints. The path is replayed to OSCARS which offers the resource scheduling.

Based on time constraints, OSCARS request the VLAN based circuit setup to e-NOX which is in charge to install the proper flow-entries in the physical switches of the path. So, the circuit is created for a certain amount of time and can be used by tools or media application depending on the user objective.

4.2 Software Architecture

The Figure 2 gives an overview of the use case architecture and the interfaces between the different modules.

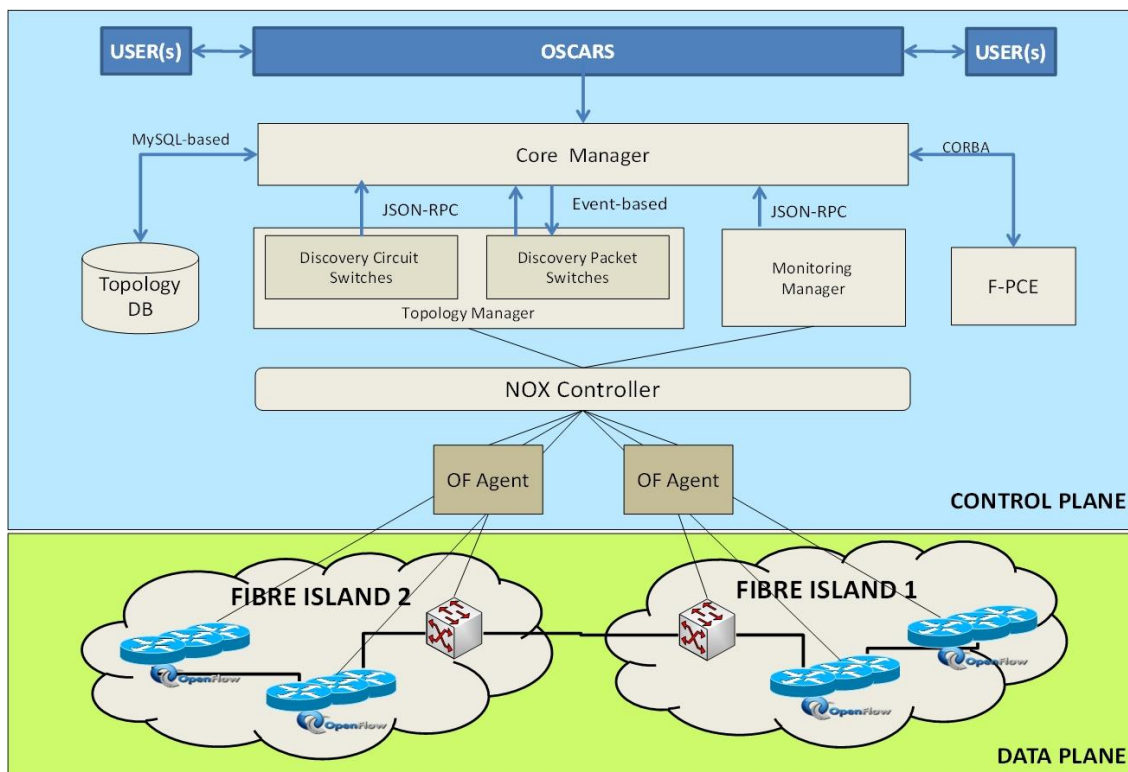



Figure 2: Use Case Architecture and Modules Interfaces

The following section describes the depicted building blocks.

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4.2.1 Modules description

OSCARS. This module provides dynamically provisioned and guaranteed bandwidth secure circuits both within ESnet, and between ESnet and other network domains. The On-Demand Secure Circuits and Advance Reservation System (OSCARS) project prototype develops a web user interface to schedule circuits creation and reservation with bandwidth, time and VLAN constraints.


Core Manager. The Core Manager is a python NOX component used to update the topology information of the F-PCE data model and the Topology DB tables. It interacts with other components (Discovery Packet Switches and Discovery Circuit Switches) to retrieve a full-mesh network graph (nodes and links). Furthermore, the Core Manager can update the Topology DB tables with the statistics meters such as the number of active flow entries, the bit/frame error rate of OF ports, etc. Moreover, the Core Manager can install or remove flow entries from the physical switches (packet or optical) controlling OF parameters as ingress or egress datapath identifiers, source or destination port numbers, etc.

Discovery Packet Switches (DPS). The DPS is a python NOX application used to discover the underlying packet-domain topology and to expose the physical/virtual infrastructure information to the Core Manager component. The topology information includes the OpenFlow switches and ports capabilities, the inter-switches physical links (through LLDP), the authenticated hosts, etc.

Discovery Circuit Switches (DCS). The DCS is a C++ NOX application based on the OpenFlow circuit switching addendum extensions (v0.3). The DCS retrieves the WDM network information which includes device characteristics (e.g. fixed/flexible WDM grid), module or port or wavelengths details, switching constraints associated with the node, etc.

Flow Monitoring Manager. The Flow Monitoring Manager is a python NOX component used to collect statistic information of the controlled OF-enabled packet switches. The meters are stored into the Topology DB tables. The information includes several details of the switch ports (e.g. number of received/transmitted bytes) or tables (e.g. number of active entries).

Topology Database. The Topology DB is a MySQL-based transactional database. It stores the topology information (switches, ports, links and hosts) and the statistic parameters (ports and tables) into relational tables.

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Flow-aware Path Computation Engine (F-PCE). The F-PCE module is a centralized application based on the IETF PCE architecture, [10]. It can be used to compute the end-to-end paths into a virtualized network environment composed of OpenFlow-enabled packet switches and optical devices. Moreover, the F-PCE supports a hierarchical approach based on proper iterations between child and parent F-PCE elements.

4.2.2 Technical specifications

These are the technologies involved on the implementation:

Experiment Side:

FIBRE Control Framework

User Side:

NOX OpenFlow controller
F-PCE module
OSCARS framework
MySQL Database
Python REST API

4.2.3 Installation instructions

Following are the steps to follow to install the OSCARS framework, [16]:


Step 1: Install the dependencies

```
# Mysql sever
sudo apt-get install mysql-server

# Java Development Kit (JDK)
wget http://java.sun.com/javase/downloads/index_jdk5.jsp
sudo mv jdk1.5.0_x /usr/local/java5
export JAVA_HOME=/usr/local/java5

# Tomcat 5.5
wget http://tomcat.apache.org/download-55.cgi
sudo mv apache-tomcat-5.5.X /usr/local/tomcat
export CATALINA_HOME=/usr/local/tomcat

# Ant version 1.7
```

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```
wget http://ant.apache.org/bindownload.cgi
unzip apache-ant-1.7.0-bin.zip
sudo mv apache-ant-1.7.0 /usr/local/ant
export ANT_HOME=/usr/local/ant
```

Step 2: Install the Inter-Domain Controller (IDC) software, customizing the building and the installation procedures


```
wget https://wiki.internet2.edu/confluence/display/DCNSS
gunzip dcn-software-suite-0.5.X.tar.gz
tar -xvf dcn-software-suite-0.5.X.tar
# IDC software
cd dcn-software-suite-0.5.X/idc
./do_build.sh
./do_install.sh
# TERCE software
cd dcn-software-suite-0.5.X/terce
./do_install.sh
```

Step 3: Configure the OSCARS installation

```
cd dcn-software-suite-0.5.X/idc/tools/utis
# Creating the First User Account
./idc-orgadd
./idc-useradd
# Defining Your Local Domain
./idc-domainadd
# Changing Keystore Passwords
./idc-kpasswd
```

Step 4: Start OSCARS

```
cd dcn-software-suite-0.5.X/idc
./oscars.sh
```

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Due to the complexity to reproduce the previous steps, the WP5 partners decided to release the OSCARS software into a pre-installed (and ready-to-use) virtual-machine with all the packets dependencies already satisfied. The VM is delivered as a single file in the OVA format. Currently, the last available version is “*OSCARS_disk2.ova*” (26 February 2014).

Following are the steps to follow to install the F-PCE module:

Step 1: Install the dependencies

```
sudo apt-get install gawk libreadline-dev flex bison make unifdef g++
sudo apt-get install omniidl omniidl-python omniorb omniorb-idl python-omniorb
libomniorb4-dev
sudo apt-get install libboost-all-dev
sudo apt-get install autogen autotools-dev autoconf libtool
sudo apt-get install git
```


Step 2: Install the F-PCE software, that is a NXW proprietary code

```
# obtain the code from NXW
git clone <nwx git server address>/gmpls-build
cd gmpls-build
./bootstrap
./configure --prefix=/opt/fpce
./builder --bootstrap fibre
./builder --build
```

Following are the steps to follow to install the e-NOX controller:

Step 1: Install the dependencies

```
cd /etc/apt/sources.list.d/
wget http://openflowswitch.org/downloads/debian/nox.list
sudo apt-get update
sudo apt-get install nox-dependencies
```


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Step 2: Install the e-NOX software

```
git clone https://github.com/rmonno/ENOX-controller
cd ENOX-controller/src/nox-classic
./boot.sh
mkdir build/
cd build/
../configure
make
```

Due to the complexity to reproduce these steps, the WP5 partners decided to release the E-NOX controller and F-PCE software into a pre-installed (and ready-to-use) virtual-machine with all the packets dependencies already satisfied. The VM is delivered as a single file in the OVA format. Currently, the last available version is “*ENOX-10.04-controller_v0.6.ova*” (10 February 2014). The VM includes the Core Manager, Discovery Packet Switches (DPS), Discovery Circuit Switches (DCS), Flow Monitoring Manager, Topology DB and Flow-aware Path Computation Engine (F-PCE) applications.

4.3 User Workflow

In the following sections we give further details on the steps that an experimenter can follow to reproduce the use case into the FIBRE infrastructure.


Some assumptions are taken here:

1. the reference control and management framework (CMF) is an enhanced version of OCF developed for the FIBRE project;
2. the experimenter has already received the credentials to access the user portal;
3. the role of the experimenter is “administrator”.

4.3.1 Create a slice using the CMF

The experimenter can point the browser to the server address and can access using the provided username and password. Then:

- create a new project giving a name and a short description
- add the aggregate managers to the project. At least we need:
 - a VT Aggregate Manager (computing resources)
 - an OpenFlow Aggregate Manager (network resources)
- create a slice giving a name and a short description
- add the aggregate managers to the slice

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4.3.2 Configure the test environment

The experimenter can choose the resources and can create the desired topology. E.g.:

- create 3 VMs in the managed physical servers
 - 1 VM can be used to install the e-NOX controller and the OSCARS framework
 - 2 VM can be used as different hosts
- choose the physical and virtual ports of the managed OpenFlow switches
- create and grant the flow-space
 - use a VLAN identifier = n (e.g. n=2)
 - redirect the network management traffic to the e-NOX VM created previously
- access to the hosts VMs and configure the data interface to send VLAN tagged traffic with VLAN identifier = n (e.g. n=2)

4.3.3 Deploy e-NOX and OSCARS

The experimenter can deploy the e-NOX and OSCARS software following the instructions given in 4.2.3

After that, the experimenter can start all the components:

- (F-PCE) `cd /opt/fpce/bin && sudo ./fibreCtrl start`
- (e-NOX) `cd <path>/eufibre/src/nox-classic/build/src && ./nox_core -i ptcp:6633 discovery_packet core_manager`
- (OSCARS) `cd <path>/dcn-software-suite-0.5.X/idc && ./oscars.sh`


4.3.4 Setup a circuit using the OSCARS interface

The experimenter can access to the hosts VMs and can try pinging each other. At this stage, the ping should fail because there isn't any active circuit between the two endpoint.

It is also possible to retrieve the e-NOX acquired topology using the curl utility:

- `curl -X GET http://10.1.0.28:8080/topology`

It should show the addresses of the hosts VMs, the allocated switches details, the ports and the links with a decimal representation of the data-path identifiers.

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Now the experimenter can access the OSCARS web interface through the browser using the username and password. Then, he/she can go to the “create reservation” page and fill the form:


- paste the link identifier for the source and destination, e.g.
 - urn:ogf:network:domain=cpqd.com.br:node=switch4099:port=10:link=11.2.2
 - urn:ogf:network:domain=cpqd.com.br:node=switch4097:port=10:link=11.2.1
- don't specify any path
- specify a bandwidth (e.g. 200 Mbps)
- give a short description
- specify a source VLAN = n (e.g. n=2)
 - make sure that “same VLAN on source and destination” is checked
 - make sure that source and destination VLAN type are “tagged”
- specify a start-time and an end-time for the reservation
 - the default values are start-time=now and end-time=4 minutes

Then, the experimenter can click on the “create reservation” button.

4.3.5 Verify the circuit installation

In a few seconds, the experimenter can verify that the ping will start working between the two hosts. That means that the circuit is up and running.

Moreover, the experimenter might wait for 4 minutes (or the configured timeout) to verify the automatic teardown of the circuit.


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5 Conclusion

In this deliverable the Bandwidth on Demand through OpenFlow and GMPLS in the FIBRE facility use case has been presented.

It is important to note that this use case has been also used to demonstrate the FIBRE infrastructure during two public events:

- 2nd FIBRE open workshop, premises of UPC in Barcelona on 5 November 2013.
- FIA meeting, International Conference Center in Athens on 18-20 March 2014.

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