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Abstract

This deliverable document describes the infrastructure update done in the three European local testbeds: i2CAT, UEssex and UTH. The document is divided in an introductory section about the architecture of the OFELIA-type islands (section 4) and three sections, one for each testbed (sections 5 to 7).

Each of the last three sections provides details on the characteristics of the new hardware added to each testbed, its deployment configuration and how it is connected to the existing infrastructure at each site.

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1 Acronyms

AM	Aggregate Manager
AP	Access Point
ASN	Access Service Network
CF	Control Framework
CSM	Collaborative Spatial Multiplexing
DANA	Distributed Applications and Networks Area (i2CAT's department)
DoW	Document of Work
EIRP	Equivalent Isotropically Radiated Power
EU	European Union
FI	Future Internet
FIBRE	Future Internet testbeds / experimentation between Brazil and Europe
FFR	Fractional Frequency Reuse
Gbps	Gigabits per second
GW	Gateway
NFS	Network File System
NITOS	Network Implementation Testbed using Open Source platforms
OCF	OFELIA Control Framework
OF	OpenFlow
OFELIA	OpenFlow in Europe: Linking Infrastructure and Applications
OMF	cOntrol and Management Framework (NITOS CF)
ORBIT	Open-Access Research Testbed for Next-Generation Wireless Networks
OS	Operating System
RAID	Redundant Array of Independent Disks
SDR	Software Defined Radio
SFP	Small Form-factor Pluggable
SOFDMA	Scalable Orthogonal Frequency Division Multiplexing Access
TB	Terabytes
TBD	To Be Defined
UHD	Ultra High Definition
VLAN	Virtual LAN
VM	Virtual Machine
VPN	Virtual Private Network
WDM	Wavelength Division Multiplexing
Wi-Fi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access
WP	Work Package

2 Scope

This document is the outcome of the task 3.2 *Infrastructure Update* of the WP3 of the FIBRE Project. For each of the three testbeds – i2CAT, UEssex and UTH – the infrastructure update will be reported as well as the characteristics of the new hardware added to the testbed, its deployment configuration and how it is connected to the existing infrastructure at each site.

3 Reference Documents

[FIBRE D3.1] "FIBRE Deliverable D3.1 Use case analysis and requirements specifications". Available at "Deliverables" section in the FIBRE's Project Webpage. http://www.fibre-ict.eu/, last view on 26/06/2012

[ICARUS] http://nitlab.inf.uth.gr/NITlab/index.php/testbed/hardware/wireless-nodes/icarus-nodes, last view on 26/06/2012

[Intel] http://ark.intel.com/products/47925/Intel-Xeon-Processor-E5620-(12M-Cache-2_40-GHz-5_86-GTs-Intel-QPI), last view on 26/06/2012

[Linksys] http://homestore.cisco.eu/store/ciscoeu/en_IE/pd/productID.241269400, last view on 26/06/2012

[NITOS-Scheduler-FlowVisor] http://nitlab.inf.uth.gr/NITlab/papers/Integrating%20FlowVisor%20access%20control%20in%20a%20publicly%20available%20OpenFlow%20testbed%20with%20slicing%20support.pdf, last view on 26/06/2012

[OFELIA D4.1] https://alpha.fp7-ofelia.eu/cms/assets/Public-Deliverables/OFELIAD41.pdf, last view on 26/06/2012

[OpenWRT] https://openwrt.org/, last view on 26/06/2012

[PRONTO] http://tamnetworks.com/1ge-10ge-solution, last view on 26/06/2012

[SuperMicro] http://www.supermicro.com/products/system/1U/6016/SYS-6016T-T.cfm, last view on 26/06/2012

4 Network architecture of OFELIA-type Islands

This section gives some information about the network architecture inside OFELIA-type islands of the FIBRE project, that is, UEssex and i2CAT islands. The first part describes the logical network architecture of the islands, how they are divided in three logical networks (control, management and experimental) and the function of each of the logical networks. The second part explains the addressing scheme of the islands.

More detailed information can be found on the public deliverable D4.1 of the OFELIA project [OFELIA D4.1].

4.1 Logical network architecture

Experimental or Data Network. This is an OpenFlow network that connects the OpenFlow switches with the users' VMs available for experimenting.

Control Network. This network gives users access to the several services hosted in the servers to control and use the facility. Apart from the specific services of the CF (web portal, expedient, opt-in manager, VT-AM and FlowVisor), and the possible general services to be implemented as required like LDAP, DNS, NFS. This control network also provides access to the users to their experiments (slices) and allows them to connect to the VMs through SSH.

Management network. This network is not intended to be accessible by users. Management network allows the Island Managers to manage the infrastructure of their island by interconnecting servers or/and virtual machines where control framework's modules are hosted, as well as the management interfaces of the switches.

4.2 Addressing scheme

To facilitate the routing inside the control and management networks, a common addressing scheme is used. This scheme is based on the one used in OFELIA project so further federation between FIBRE and OFELIA islands will be eased.

Both i2CAT and UEssex islands network addresses fall in the range 10.10.0.0/15. The 16th bit indicates if the range belongs to Control Network (10.10.0.0/16) or Management Network (10.11.0.0/16). Bits from 17th to 21st identify the island and the last 11 (22nd to 32nd) bits identify the host.

This scheme allows 32 different IDs for islands and 2048 hosts for each of the islands.

00001010.0000101Z.XXXXXYYY.YYYYYYYY

16th bit Z:	0 = Control Network
	1 = Management Network
17th – 21st bits XXXXX:	00001 = i2CAT island
	00010 = UEssex island
22nd – 32nd bits YYYYYYYYYYY:	host ID

5 UEssex

UEssex FIBRE island is co-located with the OFELIA testbed but with detached infrastructure. The island facility mainly comprises of OpenFlow enabled switches, servers to host control framework, Xen virtual machines and optical equipment to support technology pilot and sub-lambda investigation. The details of the testbed are as follows.

5.1 Equipment specifications

5.1.1 Network equipment

The UEssex FIBRE Island currently comprises of one OF-enabled 10Gig Extreme summit switch along with servers & optical equipment. Optical equipment consists of 3 ADVA ROADMS & one Calient fibre switch which will be used to showcase technology pilots and also investigating sub-lambda capabilities.

The Extreme Summit X650 is a high density 10 Gigabit Ethernet switch with 24 10GBASE-T and 8 SFP+ port which accommodates the needs for both copper twisted pair cable and optical fibre-based 10 Gigabit Ethernet.

Important features include

- 24-port 10 Gigabit Ethernet non-blocking switching with 363 million packets per second forwarding rate in a 1RU form factor
- 24 ports of 10 Gigabit Ethernet per 1RU height with optional 8-port 10 Gigabit WDM interface
- Optical WDM(1550nm) module to support FIBRE technology pilots
- Ultra low latency switching for High Performance Cluster Computing (HPCC)

Table 1 summarises its specifications:

	Extreme Summit X650
Ports	24-port 10GBASE-T with one VIM1 slot with 8 WDM optical ports
Layer 2/3/4 throughput	363 Million Packets Per Second (24-port 10GbE wire rate) and up to 506 Million Packets Per Second aggregated throughput (with VIM1-10G8X)
L2 Switching	IEEE 802.D, IEEE 802.1W, IEEE 802.1S, EAPSv2, ESRP
L3 Routing	Static, RIPv1,RIPv2,OSPFv2,OSPFv3, IS-IS, BGP4
VLANs	4,094 VLANs with Port, 802.1Q tag, Protocol, MAC-based VLAN
MAC entries	32K

	Extreme Summit X650	
Network interface	1G/10G BASE-T RJ45 ports	24
	10Gbps SFP+ ports	8
	10/100/1000 BASE-T management ports	2
Host route table	IPv6	3K
	IPv4	6K
LPM route table	IPv6	6K
	IPv4	12K
Forwarding mode	Store-and-forward	

Table 1: Extreme Summit X650 specification

UEssex is in process of acquiring 2 more OpenFlow enabled Pronto 3290 switches which will be included in the FIBRE testbed shortly.

5.1.2 Servers

Four servers have been deployed and distributed as the following list shows:

- 1 - Hosting the different modules of the OCF (Clearinghouse, AMs, databases, etc.)
- 2 - Hosting users VMs.
- 1 – Technology Pilot development.

The hardware for end host virtual machines will be deployed on 2 servers, 1 server for control framework both on Dell PowerEdge R610 supplied with a 10GE Dual SPF+ NIC extending their networking capabilities to 6 interfaces each. Another R610 server will be dedicated to run Technology pilot use cases housing the software modules needed for the use case. In addition to the virtual machines for the end users, there are dedicated server boxes used for UHD applications coders and decoders along with 6TB hard-drive for storage. The storage RAID device will act as NFS hosting VMs, UHD video content etc. required for the FIBRE project.

Features of the Dell PowerEdge R610 servers are shown in Table 2:

	Dell PowerEdge R610
CPU	Intel® 64-bit Xeon®E5620 processor: • 4 cores • 2.4 GHz • 12 MB smart cache • 5.86 GT/s QPI Speed • Hyper Threading support
RAM	6 GB DDR3-1066MHz
Hard Disk	146GB SAS
Network Controllers	• Broadcom® NetXtreme II 57711 Dual Port SFP+ DA 10GbE NIC with TOE and iSCSI Offload, PCIe-8 • Embedded Broadcom Gigabit Ethernet LOM with 4P TOE

Table 2: Dell PowerEdge specifications

5.2 Inventory

Inventory of OpenFlow switches in UEssex island:

Manufacturer	Model	Datapath ID	Status
Extreme	Summit X650	TBD	Up and running

Table 3: Inventory of OpenFlow switches in UEssex island

Inventory of the servers in UEssex island:

Model	Host Name	Operating System	RAM	Duties	Status
Dell PowerEdge R610	cseepetra	Debian Squeeze 64-bit	6Gb	Control Framework & FlowVisor	Up and running
Dell PowerEdge R610	cseeniagara	Debian Squeeze 64-bit	6Gb	Production XEN Server Hosting VMs	Up and running
Dell PowerEdge R610	cseeely	Ubuntu 12.04 64bit	6Gb	Production XEN Server (XCP based) Hosting VMs	Installation in progress
Dell PowerEdge R610	cseenanjing	Ubuntu 10.04 64-bit	6Gb	Technology pilot use-case trials	Installation in progress

Table 4: Inventory of servers in UEssex Island

5.3 Topology and network configuration

This Section describes the connectivity of the switches and the servers in details.

As explained in section 4.1, the UEssex FIBRE topology allows defining three separated logical networks, in the same way as the OFELIA Island. Two of the logical networks, Control Network and Management Network, are defined over VLANs. **Control Network** uses VLAN 4093 and **Management Network** uses VLAN 4094. Both networks are allocated in eth1 interface on servers.

All servers' eth0 ports are connected to Internet via the university network.

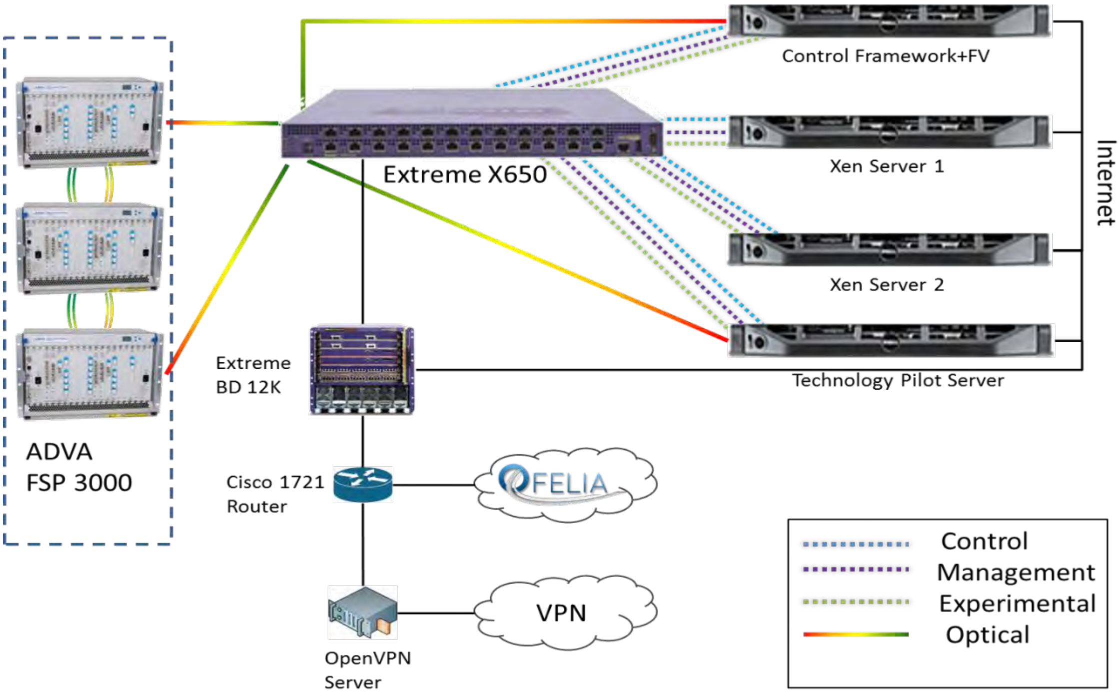

Figure 1: Current UEssex FIBRE Infrastructure

University of Essex has a very good connectivity to the GEANT through JANET network which connects it to a wide range of Universities across the world and within the UK. Currently UEssex is connected to i2CAT via GEANT over 1Gig VLAN circuit which will be used for federated experiments. UEssex is also connected (1Gig) to Brazil & USA via Internet2 for which it has a dedicated Extreme Black Diamond switch.

Future Plans:
UEssex is in the process of getting 2 more OpenFlow enabled Pronto switches which are planned to be integrated by August 2012. UEssex is also investigating sub-lambda capable switches for OpenFlow deployment which would be used in the FIBRE use case trials.

5.4 Existing infrastructure mapping

This section describes the shared infrastructure between OFELIA & FIBRE for connectivity purposes. There are two ways of connecting to OFELIA UEssex Island

- VPN over Internet
- GEANT Connectivity

UEssex is planning to use the same OFELIA connectivity for FIBRE as well.

For VPN connection a dedicated VPN server along with a router is available which will be used to segregate FIBRE & OFELIA traffic to their respective networks. UEssex Island is connected to GEANT Network with 10GE connectivity. The resources dedicated for this connectivity is an Extreme 12804 BlackDiamond carrier grade switch which is used to connect to Janet which in-turn connects us to GEANT & Internet2 on separate circuits.

Overall Topology is shown in Figure 2:

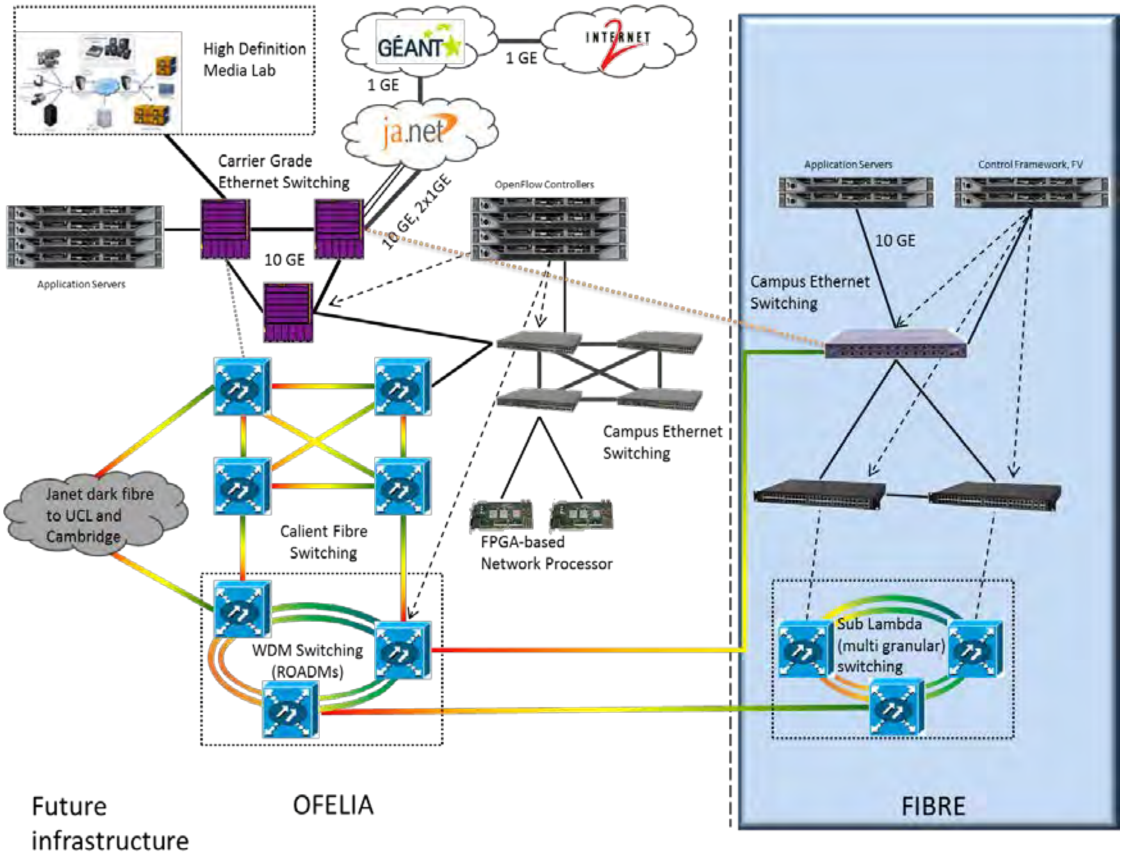

Figure 2: UEssex Future topology

5.5 Addressing

According to the addressing scheme presented in section 4.2, the following parameters are applied to the UEssex island:

- Management Network
  - VLAN id 4094
  - IP subnet range 10.11.16.0/21 network
  - Switch management (Within UEssex Island)

Mgmt IP	Node
10.11.16.100	Extreme Switch
10.11.16.2	XEN server cseeniagara
10.11.16.3	XEN Server cseeely
10.11.16.4 - 10.11.16.255	Reserved for other servers & switches

Table 5: IP addresses for Management network

- Control Network
  - OpenVPN tunnelled
  - GEANT connection for Federation experiments
  - VLAN id 4093
  - IP subnet range 10.10.16.0/21

Control IP	Node
10.10.16.2	Reserved for LDAP
10.10.16.3	FlowVisor
10.10.16.4	Control Framework
10.10.16.5 - 10.10.16.100	Reserved for future use

Table 6: IP addresses for Control network

- Experimental/Data Network
  - OpenVPN tunnelled
  - GEANT connection for Federation experiments
  - no restriction imposed to experimentation

6 i2CAT

This section describes the infrastructure that i2CAT has deployed for FIBRE facility testbed.

i2CAT FIBRE island has been placed in an independent rack in the same premises than OFELIA testbed at mediaCAT, the i2CAT lab in Castelldefels, although they both will be interconnected, most probably following the intra-federation method decided at OFELIA using the OFELIA CF.

Specific configuration of this interconnection will be studied and detailed in the near future. Meanwhile focus is on independent deployment and functioning of the FIBRE part of the facility.

6.1 Equipment specifications

6.1.1 Network equipment

The i2CAT FIBRE island is composed by three OF-enabled PRONTO switches model TN3290 [PRONTO]. This equipment also includes four SFP+ ports, two of them are provided with a SFP+ Dual LC 10G 300m 850nm optical transceivers in each of the switches. The goal of these connectors is still in a discussion and study status. The physical interconnection of the switches forms a meshed OpenFlow network topology.

The Pronto 3290 is wire-speed layer 2/3 switch platform, with non-blocking performance of 48 GE ports and 4 10GE uplinks. It is embedded with 4MB of packet buffers, 32K of MAC entries and up to 16K of routing rules. It is capable of handling both IPv4 and IPv6 traffic and is equipped with a storm control feature to avoid Broadcast or Multicast storms in a data centre.

Table 7 shows some other specifications:

		TN3290
Bandwidth		176Gbps
MAC entries		128K
Network interface	10/100/1000 BASE-T RJ45 ports	48
	10Gbps SFP+ ports	4
	10/100/1000 BASE-T management ports	2
Host route table	IPv6	4K
	IPv4	8K
LPM route table	IPv6	8K
	IPv4	16K
Forwarding mode		Store-and-forward
System memory		512MB DDR
Packet buffer		4MB
Mean Time Between Failure (MTBF)		175,699 hours

Table 7: PRONTO TN3290 Switch specifications

The FIBRE facility will also include four Linksys WRT54GL Wi-Fi routers [Linksys]. The goal is to extend the switching capacity using the Ethernet ports available at the access points, but in addition, experiment with the process of adding OpenFlow capabilities to the equipment, which are not present by default. The other point is to provide the testbed with some minimal wireless capabilities. To do so, there is a possible collaboration being discussed between i2CAT and a professor from the UPC. The plan is to distribute these APs together with 3/4 others provided by him among one of the floors of a building in the Castelldefel's UPC campus where i2CAT lab premises are located. This wireless mini-testbed will be connected to the wired structure allowing wireless experimentation and also being a source of real traffic for the testbed.

The original firmware of the routers does not support OpenFlow but through OpenWRT [OpenWRT], this will be updated by installing the whole OpenFlow stack.

Table 8 shows more specifications of the routers:

	Linksys WRT54GL
Bands	2.4 GHz
Standards	IEEE 802.3, IEEE 802.3u, IEEE 802.11g, IEEE 802.11b
Antennas	2 external
Ethernet ports	4 x 10/100

Table 8: Linksys WRT54GL APs specifications

6.1.2 Servers

Five servers have been deployed and distributed as the following list shows:

- 1 – Guimera: Hosting the different modules of the OFELIA CF (Clearinghouse, AMs, databases, etc.)
- 3 – Serafi, Papasseit, Martorell: Hosting users VMs.
- 1 – Desclot: Development, testing, integration.

The installed model is SuperMicro SuperServer 6016T-T [SuperMicro]. Each server has 2 Intel Xeon E5620 processors [Intel], with 48GB RAM memory, 2TB of hard disk capacity and a 4-port 10/100/1000 Ethernet card to extend it to a total of 6 interfaces. This is a similar configuration to the OFELIA servers, which have shown a good performance for the purpose of the project, but improved in the processor's frequency and the RAM memory.

The five servers run Debian Squeeze distribution and are XEN enabled.

The servers have been named Desclot, Serafi, Papasseit, Martorell and Guimera, following DANA's common practice of name servers as Catalan writers.

Table 9 shows the specifications of each server:

	SuperServer 6016T-T
Motherboard	Super X8DTL-i

CPU	Two Intel® 64-bit Xeon®E5610 processors: • 4 cores • 2.4 GHz • 12 MB smart cache • 5.86 GT/s QPI Speed
QPI	Up to 6.4 GT/s
RAM	48GB
Hard Disk	2 TB
Expansion Slots	One PCI-E 2.0 x8 (in x16 slot)
Network Controllers	• 2x Intel® 82574L Gigabit Ethernet Controllers • Supports 10BASE-T, 100BASE-TX, and 1000BASE-T, RJ45 output

Table 9: SuperServer 6016T-T specifications

6.2 Inventory

In this section all the equipment deployed in i2CAT's island and its actual status are listed.

Inventory of OpenFlow switches in the testbed:

Manufacturer	Model	Name	Datapath ID	Status
Pronto	TN3290	PRONTO1	TBD	Up and running
Pronto	TN3290	PRONTO2	TBD	Up and running
Pronto	TN3290	PRONTO3	TBD	Up and running

Table 10: Inventory of OpenFlow switches in the i2CAT island

Inventory of the servers in the island:

Model	Host Name	Operating System	RAM	Duties	Status
SuperMicro SuperServer 6016T-T	Desclot	Debian Squeeze 64-bit	48Gb	Development XEN Server	Up and running
SuperMicro SuperServer 6016T-T	Serafi	Debian Squeeze 64-bit	48Gb	Production XEN Server Hosting VMs	Up and running
SuperMicro SuperServer 6016T-T	Papasseit	Debian Squeeze 64-bit	48Gb	Production XEN Server Hosting VMs	Up and running
SuperMicro SuperServer 6016T-T	Martorell	Debian Squeeze 64-bit	48Gb	Testing XEN Server	Installed (testing)
SuperMicro SuperServer 6016T-T	Guimera	Debian Squeeze 64-bit	48Gb	Deployment of the CF - Expedient - Optin - Flowvisor - MySQL engine	Up and running

Table 11: Inventory of the servers in the i2CAT island

6.3 Topology and network configuration

As commented in previous sections, i2CAT testbed is composed of three Pronto switches and five SuperMicro servers and divided into three logical networks. Next figure show a schema of how the components are interconnected in two separated planes (Data network and Control and Management networks):

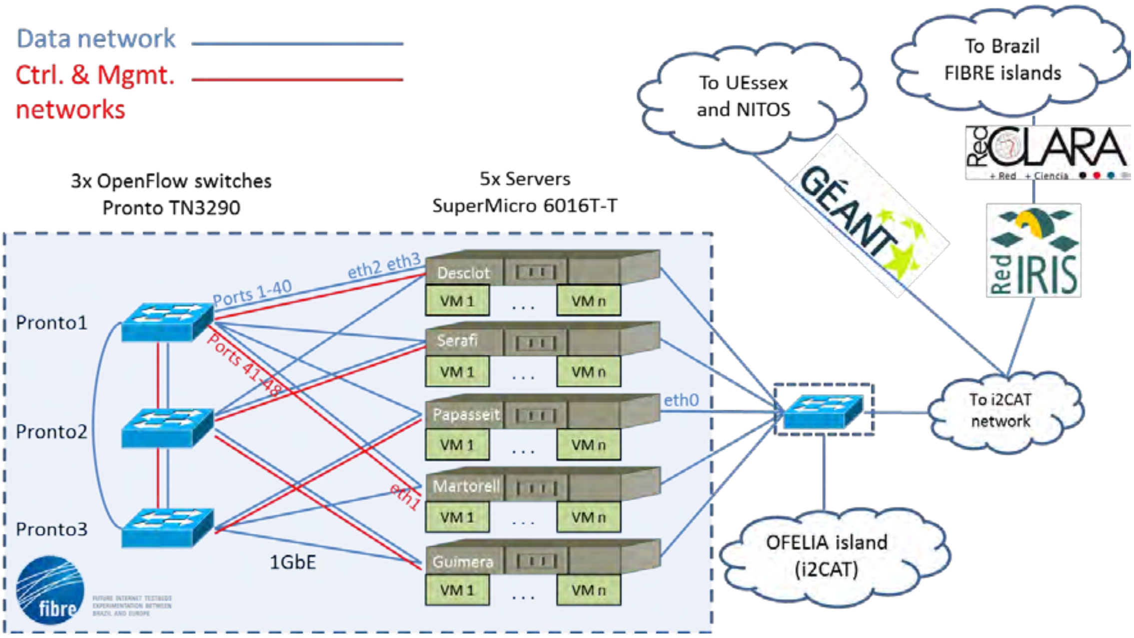

Figure 3: Current i2CAT FIBRE Infrastructure

This topology is divided in three separated logical networks, as explained in section 4.1. Ports 1 to 40 of the switches are configured to use OpenFlow and ports 41 to 48 are used as legacy ports.

Control Network and Management Network are defined over VLANs. **Control Network** is defined over VLAN 4093 and **Management Network** over VLAN 4094 and both networks use interfaces eth1 of the servers.

The **Data Network** is defined over interfaces eth2 and eth3 of all five servers, which are connected to the three switches to some of the OpenFlow ports. These interfaces are shared between the VMs through a bridge.

The island is connected to i2CAT's network that gives direct access to i2CAT's OFELIA testbed, and connects to UEssex FIBRE island, and probably NITOS testbed, through GEANT network and to the Brazilian FIBRE islands through RedIRIS and RedCLARA networks.

Tables below show details of connections between switches and servers (Table 12), and between switches (Table 13).

Switch	Datapath ID	Port	Server	VM interface
Pronto1	TBD	9	Desclot	eth2
Pronto1	TBD	10	Serafi	eth2
Pronto1	TBD	11	Papasseit	eth2
Pronto1	TBD	12	Martorell	eth2
Pronto2	TBD	10	Guimera	eth2
Pronto2	TBD	11	Desclot	eth3
Pronto2	TBD	12	Serafi	eth3
Pronto3	TBD	10	Papasseit	eth3
Pronto3	TBD	11	Martorell	eth3
Pronto3	TBD	12	Guimera	eth3

Table 12: OpenFlow domain connections switches – servers

Switch	Port	Connected to	Switch	Port
Pronto1	2	→	Pronto2	1
Pronto1	3	→	Pronto3	1
Pronto2	1	→	Pronto1	2
Pronto2	3	→	Pronto3	2
Pronto3	1	→	Pronto1	3
Pronto3	2	→	Pronto2	3

Table 13: OpenFlow domain connections between switches

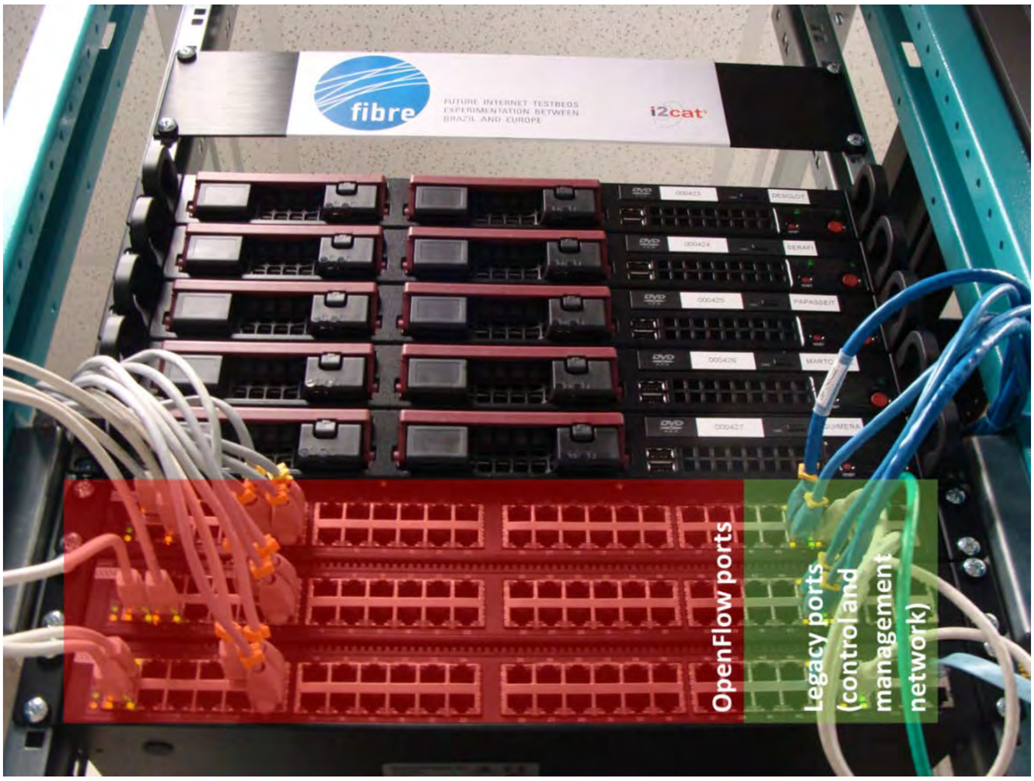

Figure 4: i2CAT equipment in place

6.4 Infrastructure mapping

This section describes the shared infrastructure between OFELIA & FIBRE islands in i2CAT for connectivity purposes.

The link between both testbeds will be established through a switch in each of the testbeds. As shown in Figure 5, there will be a link for the Data Network (OpenFLow Network) and the Control and Management networks.

The Control and Management networks will link the AMs in Guimera and Llull servers allowing experimenters from each side to add resources of both testbeds to their experiment. Later, these resources can be used through the data link (OpenFlow network).

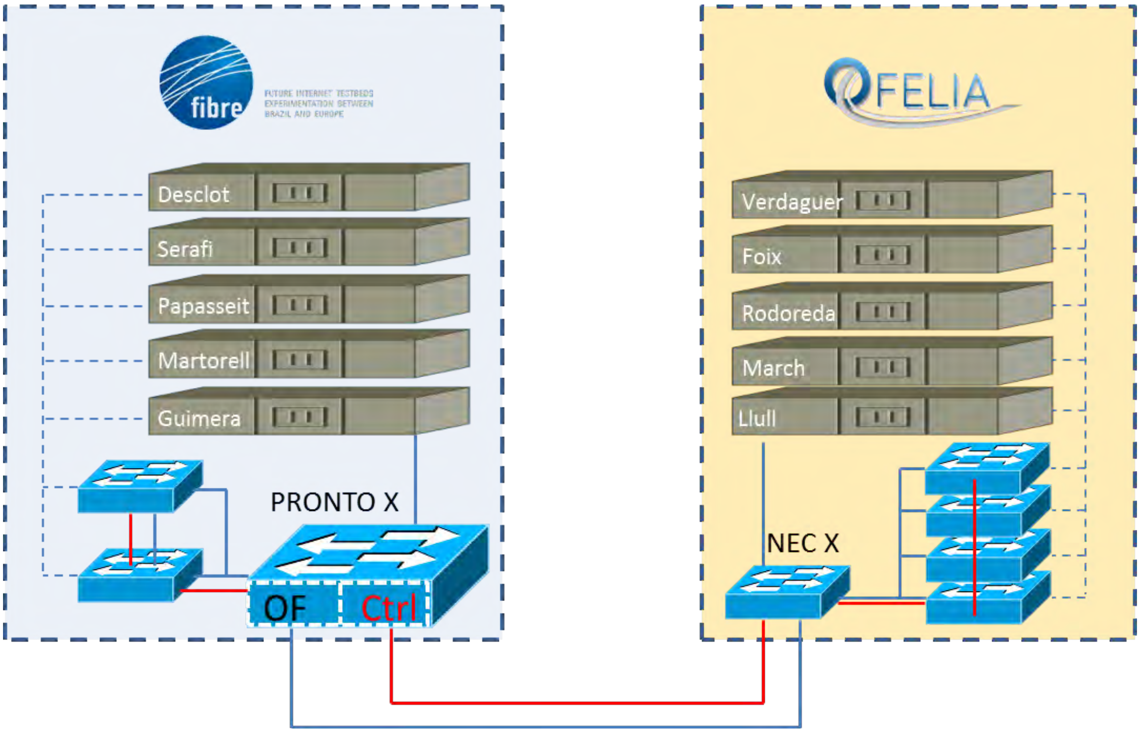

Figure 5: i2CAT Future topology

6.5 Addressing

According to the addressing schema shown in section 4.2, the following ranges are being used at the moment:

- Control network (VLAN 4093): 10.10.8.0/21 (10.10.8.0 - 10.10.15.255)
- Management network (VLAN 4094): 10.11.8.0/21 (10.11.8.0 - 10.11.15.255)
- Data network: no restriction imposed to experimentation

Next subsections show the currently allocated addresses.

6.5.1 Management plane traffic (VLAN=4094)

IP range: 10.11.8.0/24 (10.11.8.0 - 10.11.8.255)

IP	Machine	Type	Alive
10.11.8.1	Guimera	Assigned	Yes
10.11.8.2	Desclot	Assigned	Yes
10.11.8.3	Serafi	Assigned	Yes
10.11.8.4	Papasseit	Assigned	Yes
10.11.8.5	Martorell	Assigned	Yes
10.11.8.6		FREE	
10.11.8.7	CF VM	Assigned	Yes
10.11.8.8	Database VM	Assigned	Yes
10.11.8.9	Flowvisor 1	Assigned	Yes
10.11.8.10	Flowvisor 2	Assigned	No
10.11.8.11	PreProduction CF	Assigned	Yes
10.11.8.12 - 10.11.8.20		RESERVED (New Hosts)	
10.11.8.21	PRONTO1	Assigned	Yes
10.11.8.22	PRONTO2	Assigned	Yes
10.11.8.23	PRONTO3	Assigned	Yes
10.11.8.24 - 10.11.8.50		Reserved (New switches)	
10.11.8.51 - 10.11.15.255		FREE	

Table 14: IP addresses for Control plane traffic

6.5.2 Control (user) plane traffic (VLAN=4093)

IP range: 10.10.8.0/21 (10.10.8.0-10.10.15.255)

IP	Machine	Type	Alive
10.10.8.1	Local gateway (Guimera)	Assigned	Yes
10.10.8.2		Reserved for LDAP if needed	
10.10.8.3	Flowvisor	Assigned	Yes
10.10.8.4	Control Framework	Assigned	Yes
10.10.8.5	PreProduction (CF)	Assigned	Yes
10.10.8.6 - 10.10.8.25		RESERVED (Local services)	
10.10.8.26 - 10.10.15.255	Users VMs	FREE	

Table 15: IP addresses for User plane traffic

7 UTH

According to the DoW, UTH's testbed extension comprises two major components:

i. An OpenFlow extension, with the acquisition of two OpenFlow switches and their integration in the NITOS testbed, to form an additional wired (Ethernet) network among the wireless-enabled testbed nodes.

ii. Extension with a meso-scale (WiMAX/LTE/3G) base-station and programmable client devices.

The first extension is already in place and functional. Regarding the second extension, UTH has ordered one WiMAX Base Station and some WiMAX network cards (USB and mini-PCI), which are expected to arrive within the next couple of months. UTH has also applied to the national spectrum regulatory authorities for license to use the WiMAX band, the application is currently pending.

7.1 Equipment specifications

7.1.1 Network equipment

The OpenFlow equipment of NITOS comprises 2 Pronto 3290 Switches. It is the same type of switches as the ones acquired by the i2CAT island, so the reader can refer to Table 7 in section 6.1.1 for specifications. The switches feature standard Broadcom switch fabric BCM5653.x and each one supports one OpenFlow instance (datapath).

Figure 6: Pronto 3290 Switch

The WiMAX Base Station ordered is the MacroMAXe 802.16e Mobile WiMAX Base Station of the AirSpan company. MacroMAXe is a compact, lightweight "all-outdoor, all-in-one" form-factor. It includes MIMO (multiple input/multiple output) Matrix A/B and CSM, a unique implementation of Fractional Frequency Reuse (FFR), and Multi-carrier operation.

Below are listed the most important features of the MacroMAXe base station:

- Supports 802.16e-2005 SOFDMA
- All-in-one single outdoor unit
- Employs SDR technology
- Dual 37 dBm radios in 3.3-3.8 GHz bands and dual 40dBm radios in 2.3 and in 2.5 GHz bands
    - 60dBm EIRP with front-mounted antennas

- Four (4) receivers for improved uplink link budget
- MIMO support: Matrix A & Matrix B
- Supports 3.5 MHz, 5MHz, 7MHz, 10MHz, 2x7MHz and 2x10MHz channels
- Supports interoperable reference points defined by NRM (Network Reference Model)
    - Supports interoperable R6 reference point
- Supports standalone mode for fixed application with no need for ASN GW
- Supports IP & Ethernet CS (including VLANs)
- Giga Ethernet interface for backhaul
    - Fibre and copper interfaces
- Compact and light form factor
- <20 litre, <17 kg all-outdoor package
- Very low power consumption
    - 200W typical for fully loaded sector

Figure 7: View of the AirSpan MacroMAXe WiMAX Base Station to be deployed in NITOS

For completeness of the presentation, below are listed the specifications for the two types of nodes currently used in NITOS, although these nodes already existed at FIBRE beginning. A new set of nodes, developed by NITlab (the group behind NITOS) will soon form an additional indoor testbed (less susceptible to external interference than the current testbed), which is expected to be deployed by the end of the year and will also be made available within FIBRE. Details and specifications for those nodes can be found in [ICARUS].

ORBIT Nodes	
Motherboard	VIA MB770
CPU	VIA C3 processor 1GHz
Memory	512MB RAM
Storage	40GB
Wired Network Interfaces	2 Ethernet ports
Wireless Interfaces	2 Wistron CM9 a/b/g Wi-Fi cards with Atheros 5213 chipsets

Table 16: Specifications for the older NITOS nodes, the ORBIT nodes

Commell Nodes	
Motherboard	Commell LV-67B
CPU	Intel Core 2 Duo P8400 2,26GHz
Memory	1GB RAM
Storage	80GB
Wired Network Interfaces	2 Ethernet ports
Wireless Interfaces	AR5006XS a/b/g with Atheros AR5414 (some nodes also feature the MIMO AR5008 card with AR5418 chipset)

Table 17: Specifications for the newer, Commell-based, nodes of NITOS

7.1.2 Servers

For the moment, UTH has not deployed any new server machines for FIBRE purposes, apart from these already existent in NITOS at the beginning of the project. There are some discussions for moving the OpenFlow-related functionalities (FlowVisor, NOX controller instances) to a new dedicated server. As some of the servers among UTH's overall research infrastructure are currently underutilized or used for in large part obsolete purposes, a rearrangement of UTH's servers is expected to take place soon and one powerful machine is going to be assigned with the FIBRE OpenFlow-related tasks.

It is reminded here, that NITOS is featuring standalone nodes, therefore there are no servers hosting VMs (e.g. XEN servers). The addition of one or more such servers in the future is something that UTH is considering, but it is not by any means necessary for FIBRE purposes or for the operation of NITOS in general.

7.2 Inventory

This section summarizes the NITOS equipment currently available in FIBRE:

OpenFlow switches inventory:

Manufacturer	Model	Name	Status
Pronto	TN3290	PRONTO1	Up and running
Pronto	TN3290	PRONTO2	Up and running

Table 18: Inventory of NITOS OpenFlow switches

Nodes inventory:

Name	Type	Status
Node001	ORBIT node	Available
Node002	ORBIT node	Available
.....	.....	.....
Node010	ORBIT node	Available
Node011	Diskless node	Available, but not used with OMF. To be replaced in the future
Node012	Diskless node	Available, but not used with OMF. To be replaced in the future
Node013	Diskless node	Available, but not used with OMF. To be replaced in the future
Node014	Formerly ORBIT node	Currently unavailable, soon to be replaced with new node
Node015	Formerly ORBIT node	Currently unavailable, soon to be replaced with new node
Node016	Commell node	Available
Node017	Commell node	Available
.....	.....	.....
Node028	Commell node	Available
Node029	Commell node (MIMO capable, GNU radio)	Available
Node030	Commell node (MIMO capable, GNU radio)	Available
Node031	Commell node	Available
Node032	Commell node (MIMO capable, GNU radio)	Available
.....	.....	.....
Node035	Commell node (MIMO capable, GNU radio)	Available

Table 19: Inventory of NITOS OpenFlow nodes

It is noted here that there are also some other nodes (Commell-based), which are currently being used by UTH for pilot features (mobile nodes mounted on robots, node moving on rails, etc.), which are not currently offered publicly (as the respective software frameworks are under development), but are expected to be integrated in the future.

7.3 Topology and network configuration

The overall topology of the NITOS testbed is depicted in the figure below:

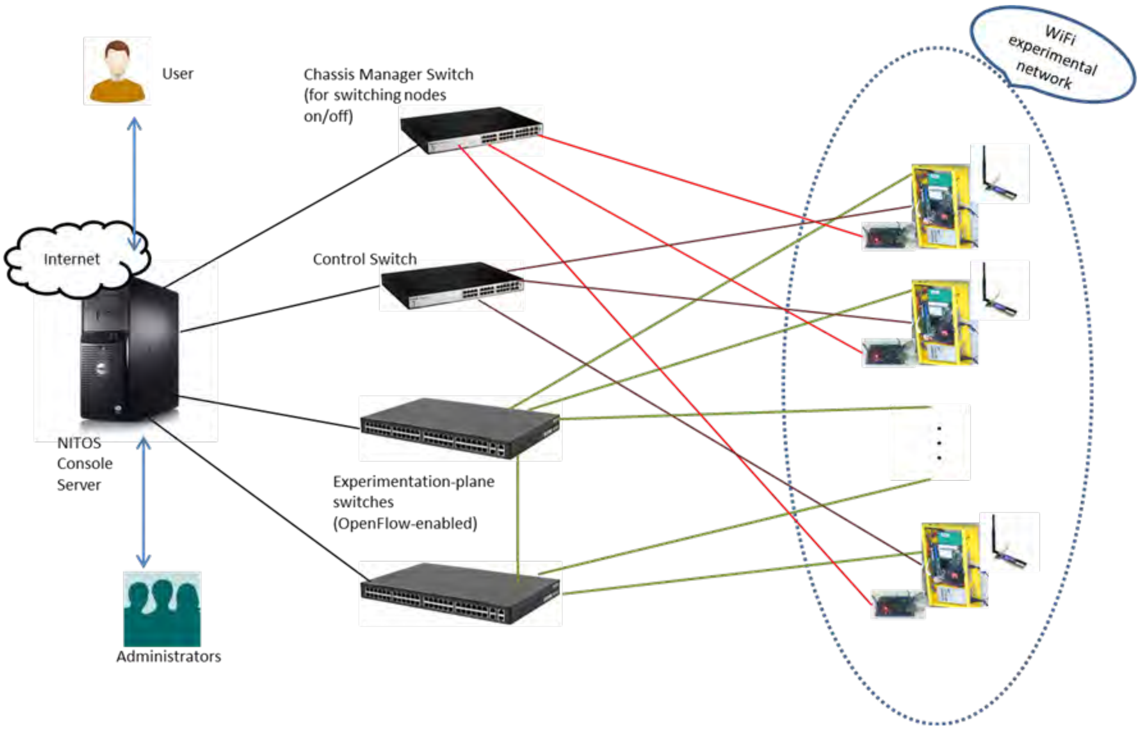

Figure 8: NITOS topology

The two OpenFlow switches are physically connected together, while all of the existing NITOS nodes are physically connected to the switches, forming a programmable wired experimental network.

Approximately half of the NITOS nodes are connected to the first Pronto switch and the rest of them to the second Pronto switch.

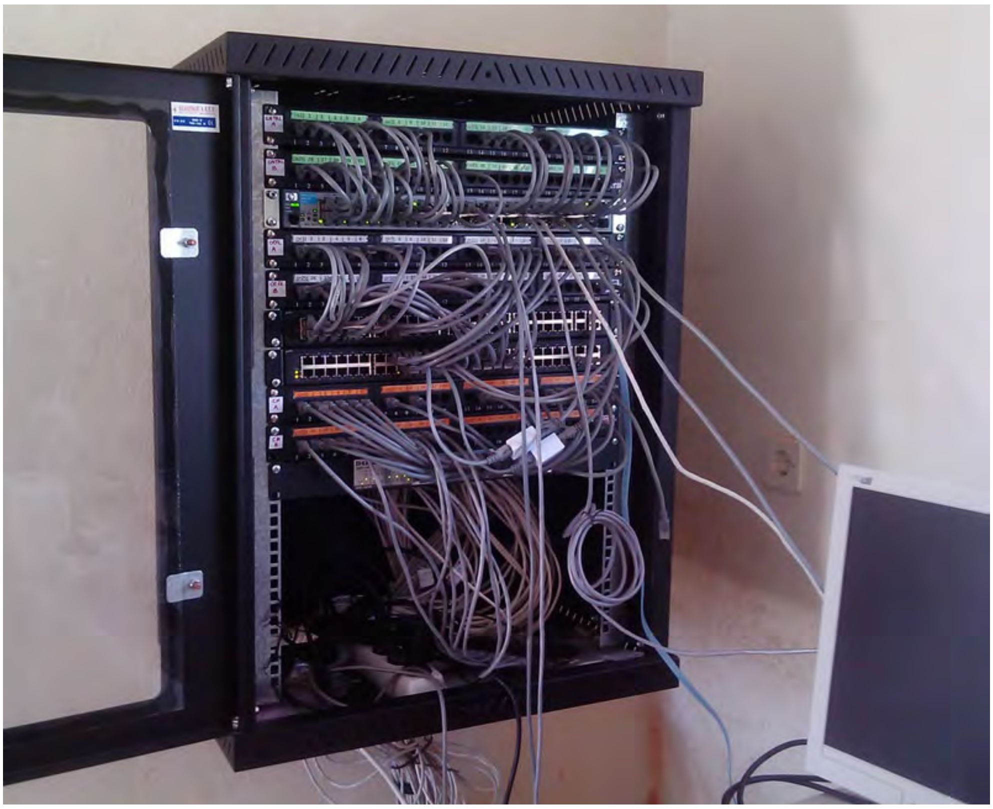

Figure 9: The NITOS rack. The two OF switches have been deployed in the middle part. The rack also hosts the control network switch and the Chassis Manager card network switch

The OpenFlow switches have been flashed with Stanford Indigo Image V1.0. On the server side it is used FlowVisor version 0.8.0 to create user slices and allocate switch resources.

These slices are created for each slice in NITOS automatically, and assignment of flowspaces to a given slice is managed by the NITOS Scheduler software, according to user reservations. The idea is that when a user reserves a set of nodes, he/she also reserves the associated set of OpenFlow switch physical ports (with the entire IP and TCP/UDP port range) for the same time interval. See [NITOS-Scheduler-FlowVisor] for a demo paper recently presented in TridentCom describing this setup.

By default, a default NOX controller is assigned to each slice, instructing its associated flowspace to operate normally, i.e. as a standard switch. However, each user can redirect control of his flowspace to another OpenFlow controller instance running on his home folder in the NITOS server or even on his local PC.

Topology and network configuration details for the WiMAX extension of the testbed are not yet available, as UTH is waiting for the equipment to arrive (expected within the next couple of months). The plan, however, is that the WiMAX BS be placed in a spot where the current outdoor NITOS nodes are in its range. In this way, a subset of the nodes featuring both Wi-Fi and WiMAX interfaces can be utilized for experiments combining both technologies.

7.4 Addressing

NITOS features four local wired (Ethernet) networks:

i. The control network (used for sending configuration commands to the nodes via OMF, but also for ssh into the nodes)

ii. The CM (Chassis Manager) card network, which is used by OMF's CM service, in order to power on/off the nodes, monitor their power state, retrieve some sensor measurements from CM-card-mounted sensors, etc.

iii. The OpenFlow control network used to connect the OpenFlow controllers hosted at the NITOS server to the FlowVisor and also the FlowVisor to the management ports of the switches.

iv. The experimental OpenFlow network.

The control IP addresses are in the range 10.0.1.0/24 and can be seen in the table below. These addresses are automatically allocated to the nodes by the testbed's local DHCP server, based on the MAC addresses of their control network interfaces.

Control IP	Node
10.0.1.1	Node001
10.0.1.2	Node002
....	....
10.0.1.35	Node035

Table 20: Control IP address allocation for NITOS nodes

The CM card addresses, which are statically written in the CM cards firmware, and are in the range 10.1.0.0/24, can be seen in the table below.

Control IP	Node
10.1.0.1	Node001
10.1.0.2	Node002
....	....
10.1.0.35	Node035

Table 21: CM card address allocation for NITOS nodes

There are no predefined IP addresses for the experimental OpenFlow network, as the users have full flexibility of choosing these addresses for their resources. The only restriction, imposed by the FlowVisor, is to not direct traffic towards physical OpenFlow switch ports that do not correspond to nodes they have reserved.

END OF DOCUMENT