



ABSTRACTION LAYER FOR IMPLEMENTATION OF EXTENSIONS IN PROGRAMMABLE NETWORKS

Collaborative project co-funded by the European Commission within the Seventh Framework Programme

Grant agreement no: 317880
Project acronym: ALIEN
Project full title: "Abstraction Layer for Implementation of Extensions in programmable Networks"
Project start date: 01/10/12
Project duration: 24 months

Deliverable D5.3

Experimental-driven research - Appendix III (TBAM integration and demonstration with Multicast and IPv6 traffic experiment results)

Version 7.9

Due date: 30/10/2014
Submission date: 12/11/2014
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Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



Table of Contents

Executive Summary	7
1 TBAM integration and demonstration with Multicast and IPv6 traffic experiment	9
1.1 Testing Scenario	9
1.2 Experiment results	9
1.2.1 Slice configuration	9
1.2.2 Multicast experiments	13
1.2.3 Controller logs	14

Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



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Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



Figure summary

Figure 1-1 List of the aggregates visible from the ACF Expedient GUI	10
Figure 1-2 Representation of the physical topology of the slice	10
Figure 1-3 CREATE-NET's OFELIA OpenFlow resources	11
Figure 1-4 i2CAT's OFELIA OpenFlow resources	11
Figure 1-5 CREATE-NET's ALIEN OpenFlow resources	12
Figure 1-6 Time-slot configuration mask	12
Figure 1-7 i2CAT's virtualization resources	12
Figure 1-8 Experiments overview.	13



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Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



Executive Summary

This document complements deliverable D5.3 “Experimental-driven research” with details about testing scenario steps and all materials like logs, screenshots, packet dumps collected during performing of experimentation tests. We highly encourage to read first D5.3 which contains overview of the experiment, goals to be achieved, experiment environment and also discussion about experiment validation.

Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



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Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



1 TBAM integration and demonstration with Multicast and IPv6 traffic experiment

1.1 Testing Scenario

- ALIEN island (4 ALIEN switches) located at the CREATE-NET premises and connected to the CREATE-NET's OFELIA island
- ACF installed to manage the ALIEN switches and connected to the OCF instances running on 5 OFELIA islands
- Slice composed of switches of 3 OFELIA islands (CREATE-NET, i2CAT and iMinds) plus the ALIEN island
- Two different controllers: FloodLight for the OFELIA switches using OpenFlow v1.0 and Ryu for the ALIEN switches using OpenFlow v1.2
- IPv4 and IPv6 multicast applications running on top of FloodLight and Ryu
- VLC [VLC] software running on the virtual machines and acting as multicast server and client

1.2 Experiment results

As anticipated in the "Experiments goals" section, the experimentation is basically divided in two different phases: the first consists in the configuration of the experiment with the inclusion of all the needed resources using the Expedient GUI. This phase validates the ACF implementation and the ability of its components to interact with the OCF instances running on the OFELIA islands to configure the experiment setup (slice configuration and start-up processes). The second phase consists of the execution of two different experiments on the same slice: one IPv4 multicast video streaming involving both ALIEN and OFELIA islands and another IPv6 multicast video streaming confined within the ALIEN Island.

The results of the experimentation are described in the following sections.

1.2.1 Slice configuration

Configuration and start-up of an experiment through the ACF's Expedient GUI. Once the slice is created, the CREATE-NET ALIEN aggregate plus several OFELIA aggregates can be selected from the list exposed by the GUI (see Figure 1-1). This demonstrates that the ACF's instance of Expedient has been successfully connected to the Opt-Ins of the OFELIA islands.

Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014

Name	Type	Location	Description	Size	Managers	Status	Actions
Create-Net Island ALIEN AM	Alien Resource Aggregate	Trento - Alien	via alla Cascata 56/d, Create-Net, Povo (IT)	4	root	✓	remove
Create-Net island OpenFlow AM	OpenFlow Aggregate	Trento	via alla Cascata 56/d, Create-Net, Povo (IT)	79	root	✓	remove
Create-Net island Virtualization AM	Virtualization Aggregate	Trento	via alla cascata 56/d, Create-Net, Povo (IT)	3	root	✓	remove
ETH Island Virtualization AM	Virtualization Aggregate	Zurich	Gloriastrasse 35, ETZ building, 8092 Zurich, Switzerland	2	root	✓	remove
ETHZ Island OpenFlow AM	OpenFlow Aggregate	Zurich	Gloriastrasse 35, ETZ building, 8092 Zurich, Switzerland	53	root	✓	remove
i2cat OpenFlow AM	OpenFlow Aggregate	Barcelona	C. Gran Capita 2-4 Edifici Nexus I, 2 planta, desp. 203 08034 Barcelona	85	root	✓	remove
i2cat Virtualization AM	Virtualization Aggregate	Barcelona	C Gran Capita 2-4 Edifici Nexus I, 2 planta, desp. 203 08034 Barcelona	3	root	✓	remove
iMinds Island OpenFlow AM	OpenFlow Aggregate	Ghent	Zuiderpoort Office Park Gaston Crommenlaan 8 (box 102) B-9050 Ghent-Ledeberg Belgium	58	root	✓	remove
TUB Island Virtualization AM	Virtualization Aggregate	Berlin	Strasse des 17. Juni 135, 10623 Berlin, Germany	2	root	✓	remove
TUB Island Openflow AM	OpenFlow Aggregate	Berlin	Strasse des 17. Juni 135, 10623 Berlin, Germany	69	root	✓	remove

Figure 1-1 List of the aggregates visible from the ACF Expedient GUI

Once all the needed aggregates are included into the experiment, the Expedient GUI shows an overview of the physical topology (see Figure 1-2). In particular, the ALIEN island, labelled as "Trento - Alien", is connected to the switch 02:08:02:08:00:00:00:01 of the CREATE-NET's OFELIA island.

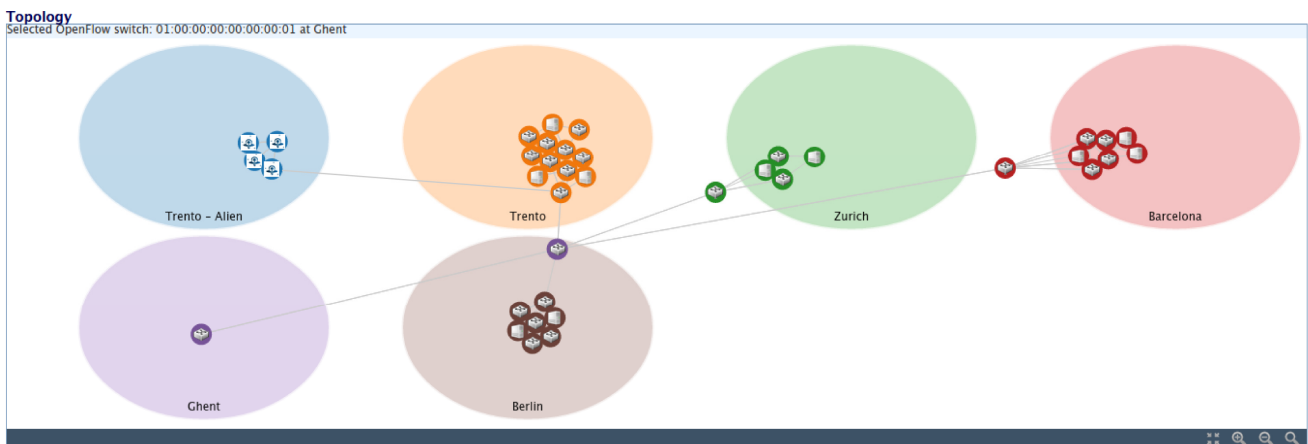


Figure 1-2 Representation of the physical topology of the slice

The next step is the selection of the resources needed for the experiments. In particular, for OFELIA OpenFlow aggregates we select the ports of the switches we want to use and we enter the IP address and TCP port on which the FloodLight controller is listening to. Furthermore, for the ALIEN resources, we user define the time-slot, the Ryu controller's IP address/TCP port and the VLAN ID (see the Deliverable [D4.2] for more details about the VLAN ID remapping process). Finally, we instantiate the virtual machines that act as multicast servers and clients on the Virtualization aggregates (see the screenshots of the Expedient UI in Figure 1-3, Figure 1-4, Figure 1-5, Figure 1-6 and Figure 1-7).

Experimental-driven research – Appendix III

• OpenFlow Aggregate: Create-Net island OpenFlow AM ▲

Name: Create-Net island OpenFlow AM
 Status: ✔
 Physical location: Trento
 Resources:

Requested Flowspace (1) [More information ▼](#)
 Granted Flowspace (1) [More information ▲](#)

Flowspace	Associated OpenFlow Interfaces
VLAN ID: 623 - 623	OpenFlow Switch: 02:08:02:08:00:00:00:08 - Port 3
	OpenFlow Switch: 02:08:02:08:00:00:00:01 - Port 1
	OpenFlow Switch: 02:08:02:08:00:00:00:01 - Port 3
	OpenFlow Switch: 02:08:02:08:00:00:00:01 - Port 4
	OpenFlow Switch: 02:08:02:08:00:00:00:01 - Port 8
	OpenFlow Switch: 02:08:02:08:00:00:00:01 - Port 12
	OpenFlow Switch: 02:08:02:08:00:00:00:01 - Port 25
	OpenFlow Switch: 02:08:02:08:00:00:00:02 - Port 12
	OpenFlow Switch: 02:08:02:08:00:00:00:02 - Port 4
	OpenFlow Switch: 02:08:02:08:00:00:00:02 - Port 3
	OpenFlow Switch: 02:08:02:08:00:00:00:03 - Port 26
	OpenFlow Switch: 02:08:02:08:00:00:00:03 - Port 12
	OpenFlow Switch: 02:08:02:08:00:00:00:01 - Port 26
	OpenFlow Switch: 02:08:02:08:00:00:00:02 - Port 25
	OpenFlow Switch: 02:08:02:08:00:00:00:07 - Port 1
	OpenFlow Switch: 02:08:02:08:00:00:00:07 - Port 3
	OpenFlow Switch: 02:08:02:08:00:00:00:06 - Port 1
	OpenFlow Switch: 02:08:02:08:00:00:00:06 - Port 3
	OpenFlow Switch: 02:08:02:08:00:00:00:09 - Port 3
	OpenFlow Switch: 02:08:02:08:00:00:00:09 - Port 1
OpenFlow Switch: 02:08:02:08:00:00:00:08 - Port 1	

Openflow controller: tcp:10.216.32.15:6666

Actions:

Remove from slice:

Figure 1-3 CREATE-NET's OFELIA OpenFlow resources

• OpenFlow Aggregate: i2cat OpenFlow AM ▲

Name: i2cat OpenFlow AM
 Status: ✔
 Physical location: Barcelona
 Resources:

Requested Flowspace (1) [More information ▼](#)
 Granted Flowspace (1) [More information ▲](#)

Flowspace	Associated OpenFlow Interfaces
VLAN ID: 623 - 623	OpenFlow Switch: 00:10:00:00:00:00:00:03 - Port 1
	OpenFlow Switch: 00:10:00:00:00:00:00:02 - Port 12
	OpenFlow Switch: 00:10:00:00:00:00:00:02 - Port 1
	OpenFlow Switch: 00:10:00:00:00:00:00:03 - Port 12
	OpenFlow Switch: 00:10:00:00:00:00:00:05 - Port 12
	OpenFlow Switch: 00:10:00:00:00:00:00:05 - Port 11
	OpenFlow Switch: 00:10:00:00:00:00:00:05 - Port 1
	OpenFlow Switch: 00:10:00:00:00:00:00:04 - Port 12
	OpenFlow Switch: 00:10:00:00:00:00:00:04 - Port 1
	OpenFlow Switch: 00:10:00:00:00:00:00:06 - Port 12
	OpenFlow Switch: 00:10:00:00:00:00:00:01 - Port 11
	OpenFlow Switch: 00:10:00:00:00:00:00:01 - Port 7
	OpenFlow Switch: 00:10:00:00:00:00:00:01 - Port 5
	OpenFlow Switch: 00:10:00:00:00:00:00:01 - Port 4
	OpenFlow Switch: 00:10:00:00:00:00:00:01 - Port 3
OpenFlow Switch: 00:10:00:00:00:00:00:01 - Port 2	

Openflow controller: tcp:10.216.32.15:6666

Actions:

Remove from slice:

Figure 1-4 i2CAT's OFELIA OpenFlow resources

Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



Experimental-driven research – Appendix III

• Alien Resources Aggregate: Create-Net Island ALIEN AM

Name: Create-Net Island ALIEN AM
 Status: ✔
 Physical location: Trento - Alien
 Slice Status: provisioned

Resources:

Device name
02:00:00:00:00:00:01
02:00:00:00:00:00:03
02:00:00:00:00:00:02
02:00:00:00:00:00:04

Time Slot
 Start Date: 2014-09-01 11:56:00
 End Date: 2014-10-31 11:56:00

Controller
 tcp:10.216.32.15:6667

VLAN ID
 20

Remove from slice:

Figure 1-5 CREATE-NET's ALIEN OpenFlow resources

Time Slot of Alien Slice

Resource Availability:

<<August 2014 October 2014>>

Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Start Date: 2014-10-17 11:58 The format should be YYYY-MM-DD HH:MM
 End Date: 2014-10-17 11:58 The format should be YYYY-MM-DD HH:MM

Figure 1-6 Time-slot configuration mask

• Virt. Aggregate: i2cat Virtualization AM

Name: i2cat Virtualization AM
 Status: ✔
 Physical location: Barcelona

Resources:

Server Name	Virt. Tech.	Operating System	CPU	Memory	Disc
Rodoreda	XEN	GNU/Linux Debian (6.0)	None	None	None
VM Name	State	Operating System	Memory	Mgmt IP	Actions
MulticastIPv4Server	running	GNU/Linux Debian (6.0)	512	10.216.12.103	<input type="button" value="Stop"/> <input type="button" value="Reboot"/>
<i>SSH common details: to access as root just type su inside (password: openflow)</i>					
Server Name	Virt. Tech.	Operating System	CPU	Memory	Disc
March	XEN	GNU/Linux Debian (6.0)	None	None	None
Server Name	Virt. Tech.	Operating System	CPU	Memory	Disc
Verdaguer	XEN	GNU/Linux Debian (6.0)	None	None	None

Actions: Create a new virtual machine in server:

Remove from slice:

Figure 1-7 i2CAT's virtualization resources

Project: ALIEN (Grant Agr. No. 317880)
 Deliverable Number: D5.3 - Appendix III
 Date of Issue: 12/11/2014

1.2.2 Multicast experiments

The two experiments consist of the following:

- Execution of the multicast IPv4 experiment with multimedia traffic crossing OFELIA and ALIEN switches. Sample video streaming will be used during the demonstration and the log of the controller will be shown to highlight the operations executed underneath.
- Execution of the multicast IPv6 experiment with multimedia traffic limited to the ALIEN switches. Also in this case the log of the controller will be shown to demonstrate to usage of an OpenFlow protocol version > 1.0.

Some details regarding the controllers' behaviour: when the server starts the multicast video streaming for a given group, the controller blocks the propagation of the flow in the network until at least one client joins the group. On the other side, the controller receives join messages of one or more clients for a specific group. The controller at this point knows which clients want to receive the data stream and is able to configure the flow entries in the network devices involved in the delivery of the stream to the clients. The configuration of the best paths from the server to the clients is possible thanks to centralized network view of the controller. In particular the controller can identify the best path between the server and clients that have joined the group. The best path in a multicast environment can exploit common links to serve the multicast group instead of provide different path for each client. The outcome is an optimization of the bandwidth usage.

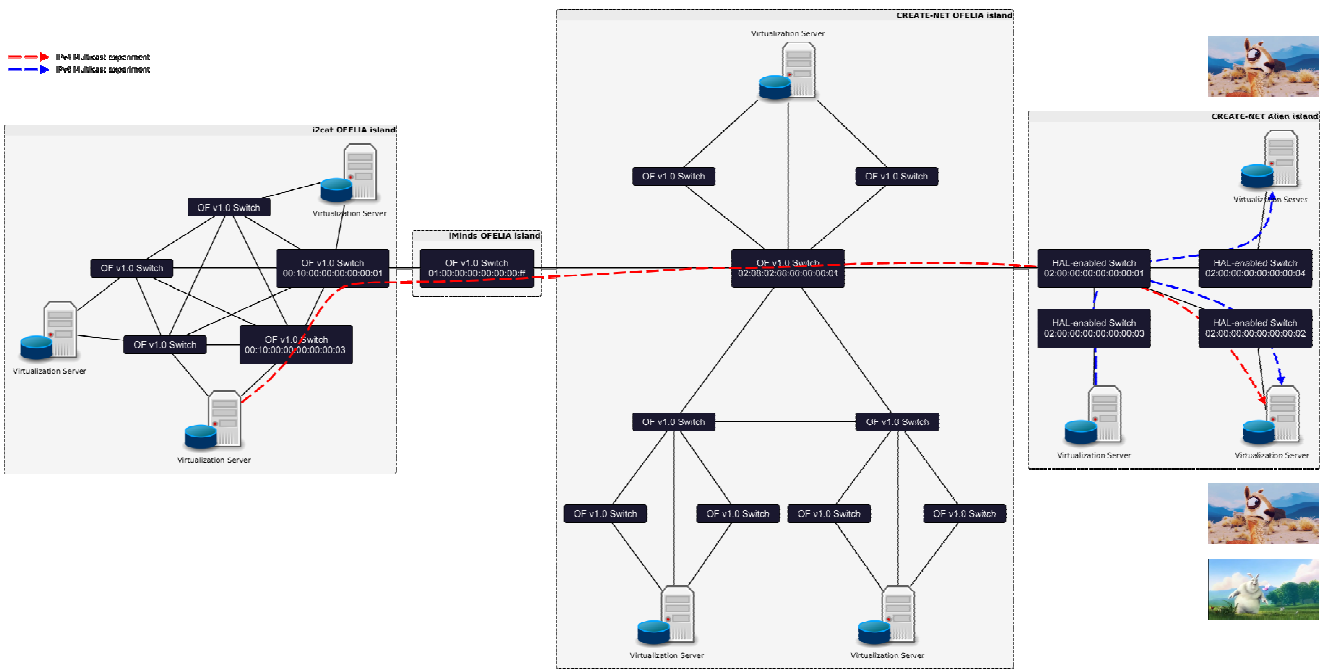


Figure 1-8 Experiments overview.

Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



1.2.3 Controller logs

This section reports on the log messages printed on the screen by the controllers. The goal of this section is to show and to better explain the sequence of operations performed by the controllers involved in the experiment. In short, the steps that are reported through the controllers logs are the following: (i) the multicast server start the transmission of the video stream, (ii) the controller receives the packet_in messages from the switch connected to the server and blocks the stream until at least one client tries to join the multicast group, (iii) the client sends a join message for the multicast group provided by the server, (iv) the controllers, which have the complete view of the part of the network under their control, compute a best path algorithm (Dijkstra) and proactively send the flow_mod messages to the switches included in the path between the server and the client, (v) the client receives the video stream through the path instantiated by the controller.

1) IPv4 multicast experiment

When the multicast server starts streaming the multimedia content, the FloodLight controller will receive a packet_in message from the first switch connected to the server (the i2CAT switch with dpid = 00:10:00:00:00:00:03):

```
Packet IN received switch 00:10:00:00:00:00:03 [ip src:192.168.10.4 ip
dst:224.0.0.1, vlan:623, in port:12]
```

As a consequence, the controller sends a drop rule to the switch with timeouts set to 0 (no expiration) which will be removed once at least one client will join the multicast group.

```
Sending drop flow-mod to the switch 00:10:00:00:00:00:03
```

When the client connected to an ALIEN device tries to join the multicast group advertised by the server, the Ryu controller send the flow_mods messages to the ALIEN switches in order to forward the join message towards the OFELIA facility through the OGW.

```
Packet IN received switch DPID:02:00:00:00:00:00:02 [ip src:192.168.10.2 ip
dst:224.0.0.1, vlan:20, in port:1]

New IPv4 flowmod to switch DPID: 02:00:00:00:00:00:02 [ip src:192.168.10.2
ip dst:224.0.0.1, vlan:20, in port:1, out_port:2]
o
Packet IN received switch DPID:02:00:00:00:00:00:01 [ip src:192.168.10.2 ip
dst:224.0.0.1, vlan:20, in port:2]
o
New IPv4 flowmod to switch DPID: 02:00:00:00:00:00:01 [ip src:192.168.10.2
ip dst:224.0.0.1, vlan:20, in port:2, out_port:1]
```

The join message is then received by switch 02:08:02:08:00:00:01 of the CREATE-NET OFELIA island. As we can notice, the OGW has re-tagged the packets with the VLAN ID 623 assigned to the experiment by the OCF (see the section above).



```
Packet IN received switch 02:08:02:08:00:00:00:01 [ip src:192.168.10.2 ip
dst:224.0.0.1, vlan:623, in port:8]
```

Afterwards, the FloodLight multicast application, which has detected the join message, installs the forwarding rules on the switches forming the best path between the multicast server and the ALIEN island where the client is located:

```
New IPv4 flowmod to switch DPID: 00:10:00:00:00:00:00:03 [ip src:192.168.10.4
ip dst:224.0.0.1, vlan:623, in port:12, out_port:1]
New IPv4 flowmod to switch DPID: 00:10:00:00:00:00:00:01 [ip src:192.168.10.4
ip dst:224.0.0.1, vlan:623, in port:3, out_port:11]
New IPv4 flowmod to switch DPID: 01:00:00:00:00:00:00:ff [ip src:192.168.10.4
ip dst:224.0.0.1, vlan:623, in port:3, out_port:8]
New IPv4 flowmod to switch DPID: 02:08:02:08:00:00:00:01 [ip src:192.168.10.4
ip dst:224.0.0.1, vlan:623, in port:1, out_port:8]
```

The same operation is done on the ALIEN switches by the Ryu controller. Therefore, now the video stream has a path from the server to the client:

```
Packet IN received switch DPID:02:00:00:00:00:00:00:01 [ip src:192.168.10.4 ip
dst:224.0.0.1, vlan:20, in port:1]
New IPv4 flowmod to switch DPID: 02:00:00:00:00:00:00:01 [ip src:192.168.10.4
ip dst:224.0.0.1, vlan:20, in port:1, out_port:2]
Packet IN received switch DPID:02:00:00:00:00:00:00:02 [ip src:192.168.10.4 ip
dst:224.0.0.1, vlan:20, in port:2]
New IPv4 flowmod to switch DPID: 02:00:00:00:00:00:00:02 [ip src:192.168.10.4
ip dst:224.0.0.1, vlan:20, in port:2, out_port:1]
```

2) IPv6 multicast experiment

The Ryu's logs related to the IPv6 multicast experiment are reported in this section. The process is the same shown above for the IPv4 experiment. In short, one of the two clients sends the request to join the multicast group through the switch 02:00:00:00:00:00:00:02:

```
Packet IN received switch DPID:02:00:00:00:00:00:00:02 [ip src:ff02::1 ip
dst:ff02::1, vlan:0, in port:2]
```

As can be noticed from the packet_in message above, for this experiment we used the VLAN ID = 0. In this way the IPv6 broadcast messages generated with this experiment are not forwarded to the OFELIA nodes (which are not able to manage them, being the IPv6 addresses supported only by OpenFlow version > v1.0). In fact, the OFGW is configured to forward and to re-tag only the messages coming from ALIEN with VLAN ID = 20. All the other messages are dropped.

Finally, below we have the flow_mod sent to the ALIEN switches in order to forward the video stream from the server to the client:

Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014



Experimental-driven research – Appendix III

```
Packet IN received switch DPID:02:00:00:00:00:00:00:03 [ip src:ff02::1 ip
dst:ff02::1, vlan:0, in port:1]
New IPv6 flowmod to switch DPID: 02:00:00:00:00:00:00:03 [ip src:ff02::1 ip
dst:ff02::1, vlan:0, in port:1, out_port:2]
Packet IN received switch DPID:02:00:00:00:00:00:00:01 [ip src:ff02::1 ip
dst:ff02::1, vlan:0, in port:3]
New IPv6 flowmod to switch DPID: 02:00:00:00:00:00:00:01 [ip src:ff02::1 ip
dst:ff02::1, vlan:0, in port:3, out_port:2]
Packet IN received switch DPID:02:00:00:00:00:00:00:02 [ip src:ff02::1 ip
dst:ff02::1, vlan:0, in port:2]
New IPv6 flowmod to switch DPID: 02:00:00:00:00:00:00:02 [ip src:ff02::1 ip
dst:ff02::1, vlan:0, in port:2, out_port:1]
```

The same process happens for the other client connected to the switch with datapath_id 02:00:00:00:00:00:00:04.

Project:	ALIEN (Grant Agr. No. 317880)
Deliverable Number:	D5.3 - Appendix III
Date of Issue:	12/11/2014