Outline

• SDN to OpenFlow

• OpenFlow a valid technology 😊
  – Basic Concept
  – How it works

• GÉANT OpenFlow Facility (GN3-JRA2T5)
Software Defined Networking (SDN) is transforming networking architecture.

In the **SDN architecture**:
- Control and data planes are decoupled.
- Network intelligence and state are logically centralized.
- The underlying network infrastructure is abstracted from the applications.
- …
- and OpenFlow, is the first standardized interface designed specifically for SDN


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**OpenFlow**  
**Basic Concept and how it works**

Source: OpenFlow tutorial, ONS, Santa Clara Marriot, April 16, 2012

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OpenFlow in a Nutshell

“OpenFlow is created and hosted at the University of Stanford in 2008 for evangelizing and supporting the OpenFlow Community”

What it is:
- An open standardized interface approaching SDN architectures
- L2 communication protocol - gives access to the forwarding plan of a network switch, router. (www.openflow.org)

Motivation:
- The improvement of research and innovation in networking,
- To encourage networking vendors to implement OpenFlow to their switching products.

Basic Idea:
- OpenFlow, is based on an Ethernet switch with an internal-flow table and a standardized interface to add and remove flow entries.
- Delivering a shared data & forwarding plane and a sliced, user-managed control plane at L2.

Regulation of the SDN (OpenFlow) Standards:
- Open Network Forum (ONF) (www.opennetworking.org)

The Network Industry today

Routing, management, mobility management, access control, VPNs, ...

Operating System

Specialized Packet Forwarding Hardware

- Million of lines of source code
- 5400 RFCs
- Barrier to entry
- Billions of gates
- Complex
- Power Hungry
OpenFlow Basics: Entities / Functionalities

Externally controlled Switch
OpenFlow Basics
Flow Table Entries OF v1.1

<table>
<thead>
<tr>
<th>Rule</th>
<th>Action</th>
<th>Stats</th>
</tr>
</thead>
</table>

Packet + byte counters

1. Forward packet to ports
2. Encapsulate and forward to controller
3. Drop packet
4. Send to normal processing pipeline
5. Any extensions you add!

Switch Port VLAN ID VLAN pcp MAC src MAC dst Eth type IP Src IP Dst IP ToS IP Prot L4 sport L4 dport

+ mask what fields to match

Packet Flow

Packet IN
Start at Table 0

Match in table n?

Update Counters, Executive Instructions:
- Update action set
- Update packet/ match set fields

Based on table configuration, do one:
- Send to the controller
- Drop it
- Continue to the next table

Go table n?

Execute action set.

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OpenFlow – Rule Examples (1)

Switching

<table>
<thead>
<tr>
<th>Switch Port</th>
<th>MAC src</th>
<th>MAC dst</th>
<th>Eth type</th>
<th>VLAN ID</th>
<th>IP Src</th>
<th>IP Dst</th>
<th>IP Prot</th>
<th>TCP sport</th>
<th>TCP dport</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*</td>
<td>*</td>
<td>00:1f...</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>port6</td>
</tr>
</tbody>
</table>

Flow Switching

<table>
<thead>
<tr>
<th>Switch Port</th>
<th>MAC src</th>
<th>MAC dst</th>
<th>Eth type</th>
<th>VLAN ID</th>
<th>IP Src</th>
<th>IP Dst</th>
<th>IP Prot</th>
<th>TCP sport</th>
<th>TCP dport</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>port3</td>
<td>00:20..</td>
<td>00:1f..</td>
<td>0800</td>
<td>vlan1</td>
<td>1.2.3.4</td>
<td>5.6.7.8</td>
<td>4</td>
<td>17264</td>
<td>80</td>
<td>port6</td>
</tr>
</tbody>
</table>

Firewall

<table>
<thead>
<tr>
<th>Switch Port</th>
<th>MAC src</th>
<th>MAC dst</th>
<th>Eth type</th>
<th>VLAN ID</th>
<th>IP Src</th>
<th>IP Dst</th>
<th>IP Prot</th>
<th>TCP sport</th>
<th>TCP dport</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>22</td>
</tr>
</tbody>
</table>

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OpenFlow – Rule Examples (2)

Routing

<table>
<thead>
<tr>
<th>Switch Port</th>
<th>MAC src</th>
<th>MAC dst</th>
<th>Eth type</th>
<th>VLAN ID</th>
<th>IP Src</th>
<th>IP Dst</th>
<th>IP Prot</th>
<th>TCP sport</th>
<th>TCP dport</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>5.6.7.8</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>port6</td>
</tr>
</tbody>
</table>

VLAN Switching

<table>
<thead>
<tr>
<th>Switch Port</th>
<th>MAC src</th>
<th>MAC dst</th>
<th>Eth type</th>
<th>VLAN ID</th>
<th>IP Src</th>
<th>IP Dst</th>
<th>IP Prot</th>
<th>TCP sport</th>
<th>TCP dport</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*</td>
<td>*</td>
<td>00:1f...</td>
<td>*</td>
<td>vlan1</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>port6, port7, port9</td>
</tr>
</tbody>
</table>

Details see: OF Switching Specification
http://www.openflow.org/documents/openflow-spec-v1.1.0.pdf

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OpenFlow Implementations

• Hardware Vendors
  – Commercial -> NEC, HP, Pronto, Toroki, IBM, Pica8
  – Experimental -> Juniper, Cisco

• Software
  – OF switches
    • Stanford's software reference design (user-space implementation)
    • Open vSwitch (user-space and kernel module implementation)
    • NetFPGA-based switch (hybrid solution based on Stanford's ref. sw)
  – OF controllers
    • NOX
    • Beacon
    • Trema (modular framework for developing OF controllers)
    • Other NOX-based implementations
    • NEC Programmable Flow
    • FlowVisor (Proxy Controller for slicing)

Source: OpenFlow tutorial, ONS, Santa Clara Marriott, April 16, 2012
Today we have
Closed Boxes, Fully Distributed Protocols

“Software Defined Networking” approach to open it
The “Software-defined Network”

1. Open interface to hardware

2. At least one good operating system
   Extensible, possibly open-source

3. Well-defined open API

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Global Control Plan or Network Operating System

Simple Packet Forwarding Hardware

Virtualization or “Slicing” Layer

Many versions of OS/Controller

Isolated “slices”

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FlowVisor Creates Virtual Networks

Conclusion in Graphics


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The SDN Stack – in practice

Controller

- NOX
- Beacon
- Trema
- Maestro
- ...

Slicing Software

- FlowVisor

Applications

- ENVI (GUI)
- LAVI
- n-Casting
- ...

Monitoring/debugging tools

- oftrace
- oflops
- openseer

Commercial Switches

- HP, NEC, Pronto, Juniper.. and many more

OpenFlow Switches

- Software Ref. Switch
- NetFPGA
- Broadcom Ref. Switch
- PCEngine WiFi AP
- Open vSwitch
- OpenWRT

The Case of GÉANT – TaaS

Source: – GÉANT JRA2T5 – GÉANT OpenFlow Facility Design, GN3-09-331/ Joint Research Workshop JRA1/JRA2T5 in Utrecht NL, and Vienna AT.

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Implementation over GÉANT (1)

Implementation over GÉANT (2)
Design Principles

- **5 OpenFlow PoPs** interconnected with a full mesh of L2VPNs over GÉANT
  - Co-located with GÉANT PoPs
- **2 general purpose servers** per PoP for:
  - 1x Open vSwitch providing OpenFlow functionality
  - 1x XEN hypervisor delivering user VMs and hosting services
- Using OpenFlow v1.0 -> **VLAN-based slicing**
  - Limited capabilities for non-VLAN slicing for VLAN-based experimentation
- Orchestration software: FP7 **OFELIA Control Framework (OCF)**
  - Resource allocation and instantiation (per slice)
  - Authentication/Authorization (AA) and policy framework
  - Web-based user interface for slice access and management
  - Robustness, stability and scalability in terms of number of users, support for concurrent experiments and number of managed resources.
  - Monitoring of slices and the OCF components themselves

Operations

<table>
<thead>
<tr>
<th>Virtualization</th>
<th>Monitoring</th>
<th>Resiliency</th>
<th>AAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servers</td>
<td>Data plane</td>
<td>OVS</td>
<td>Authorization schema</td>
</tr>
<tr>
<td>Proxy Controller</td>
<td>Management &amp; Control Plane</td>
<td>Controllers</td>
<td>Integration with Directory</td>
</tr>
<tr>
<td>OCF</td>
<td>Controllers</td>
<td>User VMs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OCF Services</td>
<td>OCF</td>
<td></td>
</tr>
</tbody>
</table>

Use Cases – Categories / Activities

• Using OpenFlow as a traffic engineering mechanism, managing backbone capacity and paths, for instance MPTCP and

• Using OpenFlow to deliver ‘vanilla’ layer 2 slices researching on layer 2 (and above) and experimentation on the actual data and control plane network technologies, for instance research on new protocols or capabilities

• Current activities on the OF Facility:
  • Contest Winner
    • “Improving resiliency and throughput of transport networks with OpenFlow and Multipath TCP” – Budapest University of Technology and Economics, MTA- BME Future Internet Research Group, 22.03.2013

OpenFlow and Performance

Performance Tests:

On Mockup@grnet

Results:

- 1st Test – OVS mac forwarding without OpenFlow
- 2nd Test – MAC forwarding functionality provided by OpenFlow controller
- 3rd Test – OFV mac forwarding OF enabled & VLAN tagged frames.
References

- OpenFlow – www.openflow.org
- OpenFlow – White paper:

- SDN(OpenFlow) activities Internet 2
  - http://www.internet2.edu/network/ose/
  - OFELIA: http://www.fp7-ofelia.eu/

- GÉANT – GN3, JRA2 Multidomain Network Service Research, T5
  - https://intranet.geant.net/sites/Research/JRA2/pages/home.aspx

- Standards of OpenFlow: Open Network Forum (ONF)
  - http://www.opennetworking.org
  - SDNRG (IRTF) - http://irtf.org/sdrg

- Deployment and Operation of Wide-area Hybrid OpenFlow Networks

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Thank you for your attention!

Questions?

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