Empowered by Innovation



## OpenFlow: From the Future Internet Research into your Network DENOG 3 meeting, October 20th 2011



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### It's ME between YOU and LUNCH

But if you watch this talk, you will see

A spaceship

- A car with a jet engine
- A powerful robot (twice!)

And a fully programmable network ©



### Abstract

**OpenFlow**, a child of Stanford's future internet research programme is on the way into productive networks. Separating control and user plane, OpenFlow allows to program network behaviour directly by the network operator, reducing time-tomarket for specific solutions and avoiding having to wait for all vendors to implement the desired functionality. With OpenFlow, a centralized controller instance communicates with the network nodes using the **standardized OpenFlow protocol**. Network applications reside on top of the controller. In the talk, we will present the main concept and functionality. Furthermore, we will present the applicability to data center and carrier networks and the newly available pan-European testbed provided by the EU **OFELIA** project.



# **NEC LABS IN HEIDELBERG**

## **NEC Laboratories Europe (NLE)**

- ~100 staff in Heidelberg(D) (UK, NEC E HQ)
- Leading researchers from all over Europe
- Collaboration with network operators, ICT vendors, users in Europe
- Close links with leading European research institutes & universities
- Research areas in NLE
  - Future Internet and B3G/4G
  - ITS (Vehicular Communications & ITS Services)
  - Network & Service Management
  - Security, Privacy & Performance
  - M2M/Internet of Things
  - Media Services
  - Cloud Computing
  - Green ICT

### NEC Laboratories Europe

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# WHY OPENFLOW?



# The internet is a great invention!

# But, ehem..



# Houston, we have a problem...



### Internet Technology ... somehow stuck ...

Internet Protocol (IP) forms the basis of current communication networks...





... the technology originates from the Sixties...

Workarounds have been applied so that it survived





It works ... but ... we're stuck. No innovation

(BTW, How long do we talk about introducing IPv6???)



### Current technology can't cope with business needs

Network innovation is impossible with closed/proprietary systems

- Need an open solution to implement new services with short time to market
  - Operators do not want to wait for all their vendors to implement before being able to launch a new service

### The Cloud Age is here!

- Dynamically store data and compute everywhere
- Move virtual machines or services around on the fly



- IP technology has not been designed for that!
- -> Business changes rapidly, the network cannot even follow (this used to be the other way round...)



### Something's wrong...

We still use old technology... "pimp It" to make it suitable for recent needs and spend our time in managing and deploying it...



### Let's get back control over our networks!





### A child of "Future Internet" research:





#### **OpenFlow: Enabling Innovation in Campus Networks**

March 14, 2008

Nick McKeown Stanford University

Guru Parulkar Stanford University Tom Anderson University of Washington

Larry Peterson Princeton University Hari Balakrishnan MIT

Jennifer Rexford Princeton University

Scott Shenker University of California, Berkeley Jonathan Turner Washington University in St. Louis

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# HOW OPENFLOW WORKS



## **OpenFlow: full control over flow routing**



Back to the roots: communication between endpoints create a flow

- New way of thinking in flows, not in packets / protocols
- OpenFlow allows to control flow path routing end-to-end
- OpenFlow allows to implement service inside the network



NEC

## **OpenFlow: centralized intelligence**



We put the intelligence out of the network into a controller and configure the flow centrally



Re-gain full control of the network to network operator.

 Open parts of network to third parties without impacting other services on the network -> Network as a Service NaaS



### How it works on a switch level

- A plain OpenFlow switch only forwards frames in case it has a flow entry
- In case it does not have one, *it can ask somebody who knows* ③
  - Asks the controller for an according flow entry



### Flow-based matching & actions





## **OpenFlow: flow switching definition**



#### Flow Switching with any combinations of tuples as a key

- Exact Matching
- Wild Card Matching
  - Aggregated MAC-subnet: MAC-src: A.\*, MAC-dst: B.\*
  - Aggregated IP-subnet: IP-src: 205.16.\*/24, IP-dst: 206.12.\*/24

No worries, extensions for MPLS, IPv6, ... available / on the way

Standard is being expanded these days at ONF



#### In Openflow, the world is flat. Headers only serve as criteria for flow matching

And to talk to the outside world ③

### Simple examples

Ingress Port	Ether src	Ether dst	Ether type	IP ToS	VLAN id	IP src	IP dst	IP proto	TCP/ UDP src port	TCP/ UDP dst port	
*	*	*	*	*	*	*	*	*	*	22	drop
*	*	*	*	*	*	*	1.2.3.4	<b> </b> *	*	*	port 4
*	*	*	*	*	*	1.2.3.4	. *	*	*	80	port 2 port 3



### **OpenFlow: Programmable Network**

- OpenFlow defines a standard interface between network element and controller
- Users can add modular applications and and develop their own network functionality
- No changes needed on network element!

#### "Software Defined Networking"



### Advantages...

- Faster: you can do it all on your own
- Cheaper: no hardware upgrades needed
- Less risk since you can scale it up
- Feeds innovation: gets small enterprises, small and virtual network operators back into the game

### This is not a future vision. It's here

PFC Controller	VOR TOPHOLOG No Von VVTR.5121     VOR VVTR.5121     VOR TOPHOLOG No Von VVTR.5121     VOR TOPHOLOG No VOR VVTR.5121     VOR TOPHOLOG No VOR VVTR.5121     VOR VVTR.512     VOR VVTR.512	New industry forum ass	sures 🎢 🏹 🔐		
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# **USE CASE EXAMPLES**



### **OpenFlow in the data center**





### **OpenFlow for broadband networks (xDSL, LTE, ...)**

#### Ethernet + MPLS rule here

- How about CAPEX / OPEX here? How about flexibility?
- Network sees QoS tags, VLANs, but that's it. **No service / subscriber awareness**



OpenFlow allows to control your network's traffic on a fine granularity

- (Green) Path routing, QoS, Accounting, …
- As in data center, how about placing your applications where you want them to be?





### **EU Project: OpenFlow in Europe** Linking Infrastructure and Applications

- Create a unique experimental facility
  - That allows researchers to not only experiment on a test network
  - But to control the network itself precisely and dynamically
  - Islands publicly available for experiments
- The OFELIA facility is based on OpenFlow
  - NEC OpenFlow switches to be used
  - Experimentation on multi-layer and multi-technology networks
  - Islands up and running!
    - Next step: interconnection
- Eight OpenFlow-enabed islands at academic institutions:
  - Berlin (TUB) partial replacement of existing campus network with OFswitches
  - Ghent (IBBT) central hub, large-scale emulation wall
  - Zürich (ETH) connection to OneLab and GpENI
  - Barcelona (i2CAT) experience with facility projects (laaS, FEDERICA)
  - Essex (UEssex) national hub for UK optical community; L2 (Extreme) switches, FPGA testbed
  - Rome and Catania (CNIT) two islands with focus on Information Centric Networking
  - Trento (CREATE-NET) a city-wide distributed island based on L2 switches and NetFPGA; opt-in users via heterogeneous access technologies (AdVisor in addition to FlowVisor)
- Open Call in Spring 2012:
  - To invite experimenters that bring their use cases and scenarios to the facility
  - Feedback loop to extend the OFELIA facility according to the needs of the user community

Duration: Oct. 2010 - Sept. 2013, OFELIA Website: http://www.fp7-ofelia.eu/



#### Eight Interconnected OpenFlow Islands



Basic OFELIA Facility Island Building Blocks



# **SUMMARY** (AND THE ROBOT AGAIN)



### **Our Vision**



### **ProgrammableFlow**



Impact on all parts of society by enabling mobile services on-demand, Machine to machine communication, eHealth, Internet of things ... Re-enable innovation on networks everywhere to stimulate cutting-edge service development

Create a new community developing innovative services without being hindered by existing limitations



### Some links

OpenFlow - Enabling Innovation in Your Network

http://www.openflow.org/

Open Networking Foundation

https://www.opennetworking.org/

### NEC's P-Flow Video

- http://www.youtube.com/watch?v=4kno-X49QoM
- ... or search for "NEC OpenFlow" on Youtube

### **OFELIA** Testbed

- http://www.fp7-ofelia.eu/
- NEC Labs Europe OpenFlow site
  - http://www.openflow.eu/





### **Empowered by Innovation**

