Tutorial: OpenFlow in GENI

GENI Project Office

Design/Setup
Execute
Finish

“The current Internet is at an impasse because new architecture cannot be deployed or even adequately evaluated” [PST04]

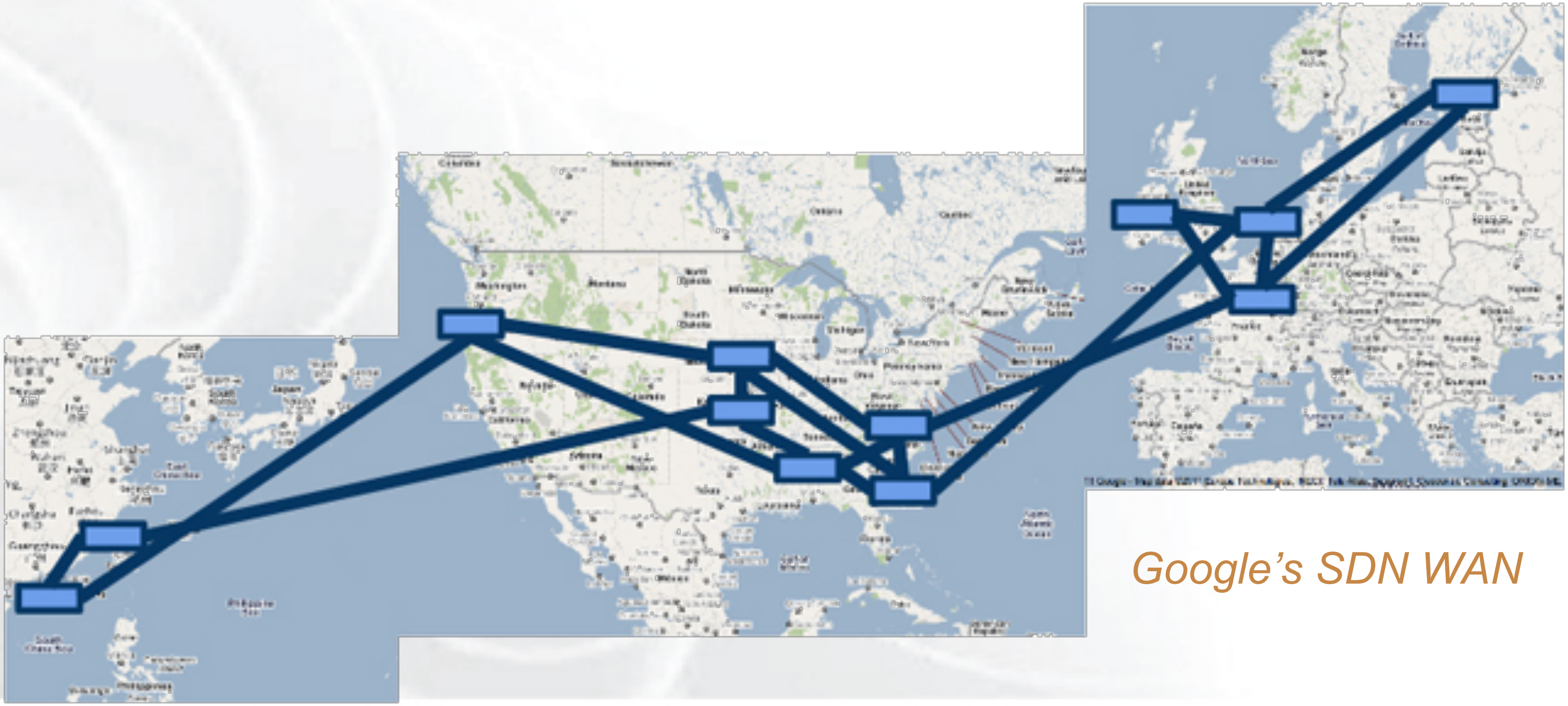
[PST04]: Overcoming the Internet Impasse through Virtualization, Larry Peterson, Scott Shenker, Jonothan Turner
Hotnets 2004

Modified slide from: http://cenic2012.cenic.org/program/slides/CenicOpenFlow-3-9-12-submit.pdf

OpenFlow…

- Enables innovation in networking

- Changes practice of networking



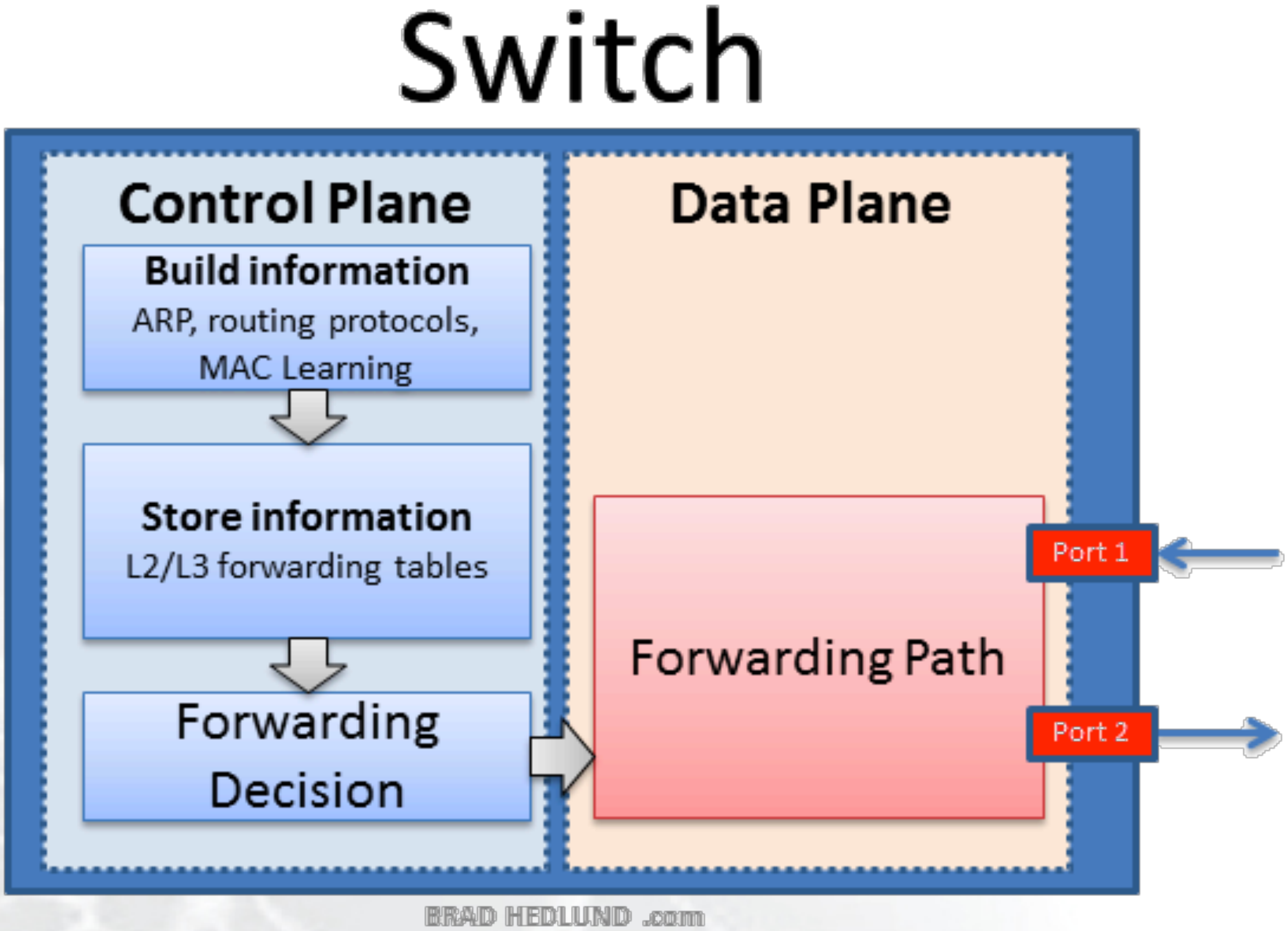
Google's SDN WAN

OpenFlow basics

How OpenFlow works … (1.0)

Hand’s on tutorial

OpenFlow’s basic idea



Switch

Control Plane

Build information

ARP, routing protocols, MAC Learning

Store information

L2/L3 forwarding tables

Forwarding Decision

Data Plane

Forwarding Path

Port 1

Port 2

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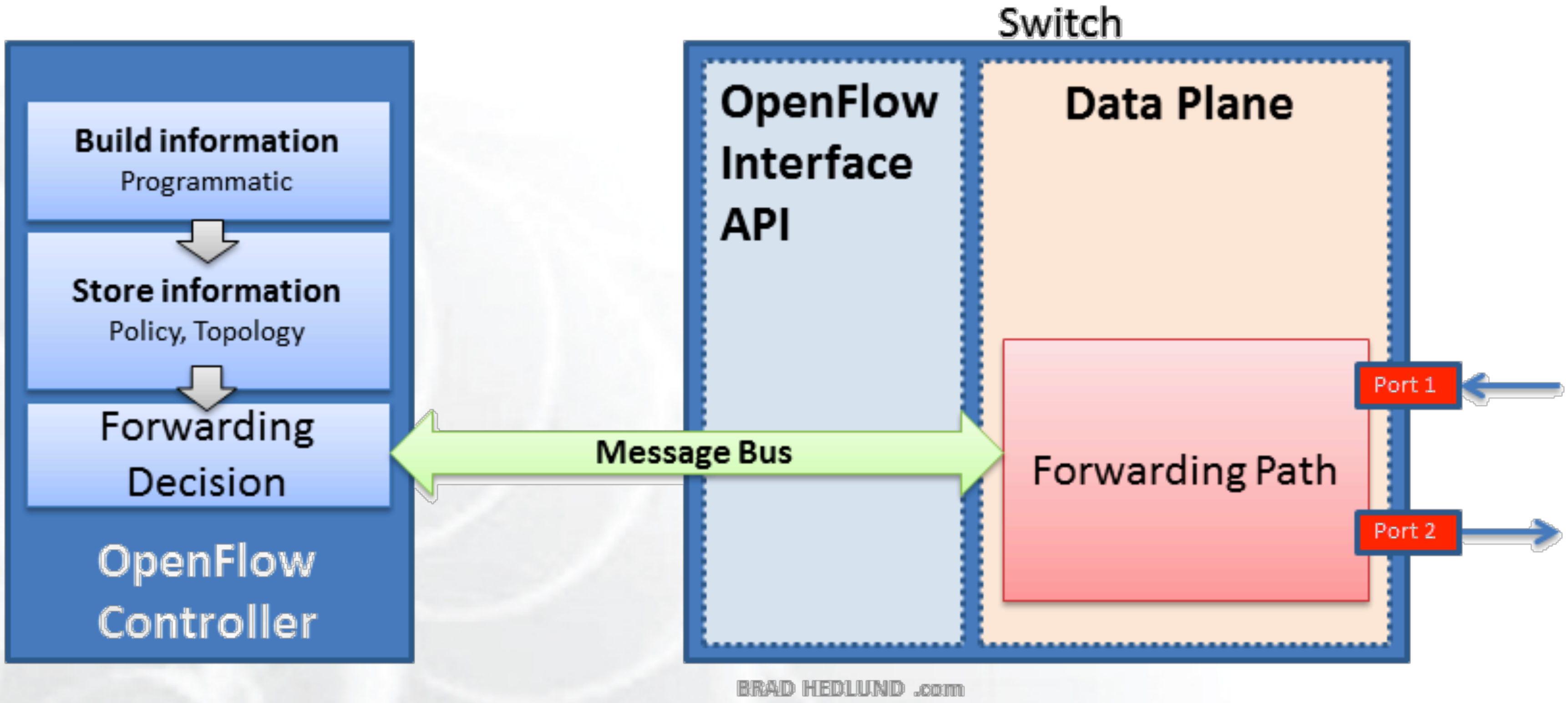
OpenFlow's basic idea

Externally controlled Switch



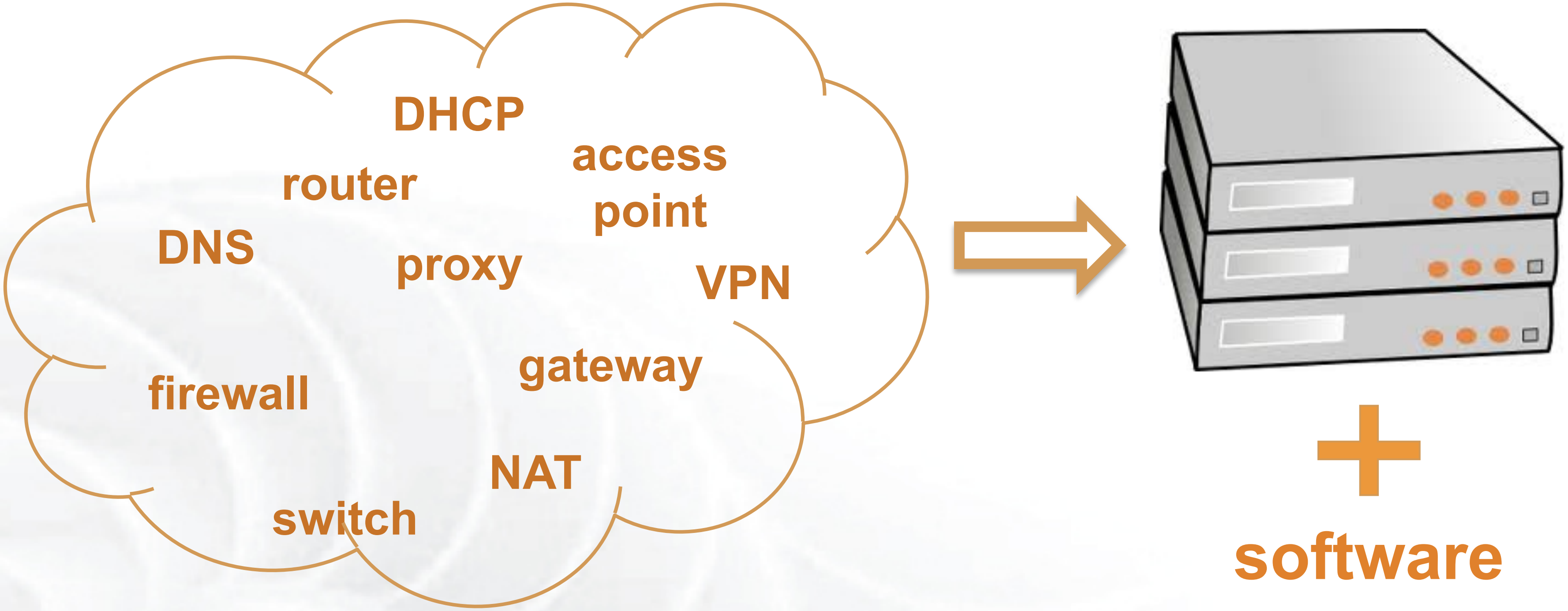
Sponsored by the National Science Foundation

OpenFlow is an API

- Control how packets are forwarded
- Implementable on COTS hardware
- Make deployed networks programmable
  - not just configurable
- Makes innovation easier

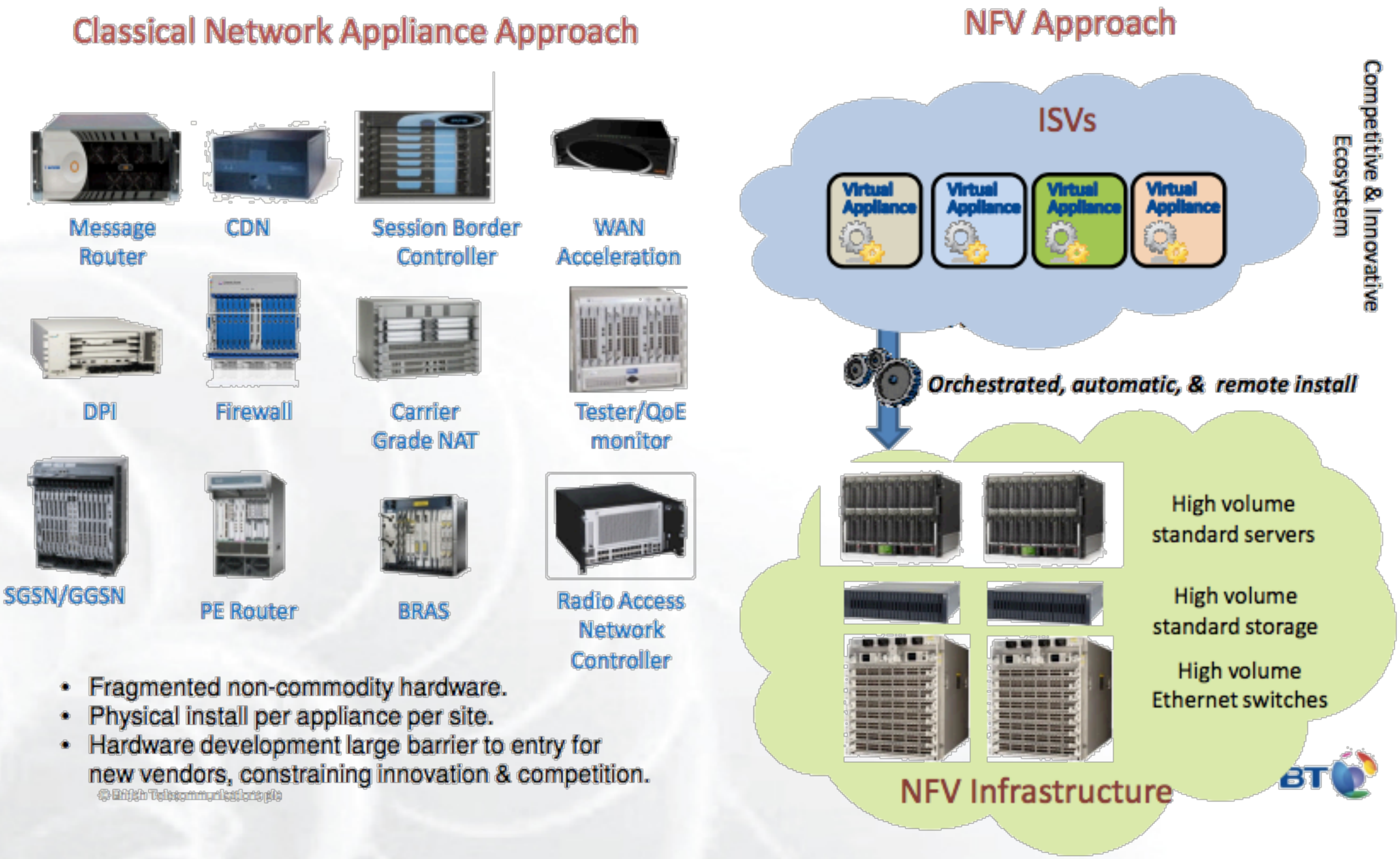
Modified slide from : http://www.deutsche-telekom-laboratories.de/~robert/GENI-Experimenters-Workshop.ppt

Network Devices



Any network device can be OpenFlow enabled

SDN and NFV



Classical Network Appliance Approach

Message Router
CDN
Session Border Controller
WAN Acceleration
DPI
Firewall
Carrier Grade NAT
Tester/QoE monitor
SGSN/GGSN
PE Router
BRAS
Radio Access Network Controller

- Fragmented non-commodity hardware.
- Physical install per appliance per site.
- Hardware development large barrier to entry for new vendors, constraining innovation & competition.

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NFV Approach

ISVs
Virtual Appliance
Virtual Appliance
Virtual Appliance
Virtual Appliance
Competitive & Innovative Ecosystem
Orchestrated, automatic, & remote install
High volume standard servers
High volume standard storage
High volume Ethernet switches
NFV Infrastructure
BT

Slide from: http://docbox.etsi.org/Workshop/2013/201304_FNTWORKSHOP/S07_NFV/BT_REID.pdf

OpenFlow benefits [1]

- **External control**
  - – Enables network Apps
  - – General-purpose computers (Moore's Law)
  - – Deeper integration
  - – Network hardware becomes a commodity
- **Centralized control**
  - – One place for apps to interact (authentication, auth, etc)
  - – Simplifies algorithms
  - – Global Optimization and planning

[1]: OpenFlow: A radical New idea in Networking, Thomas A. Limoncelli CACM 08/12 (Vol 55 No. 8)

Network Types

Campus

Multiple buildings, heterogeneous IT, groups of users, campus backbone

Enterprise Data Centers

Security, various sizes, storage, WAN optimizations

Data Centers – Clouds

Multi-tenant, virutalization, disaster recovery, VM mobility

WAN

Diversity, multiple domains/carriers/users

Deployment Stories

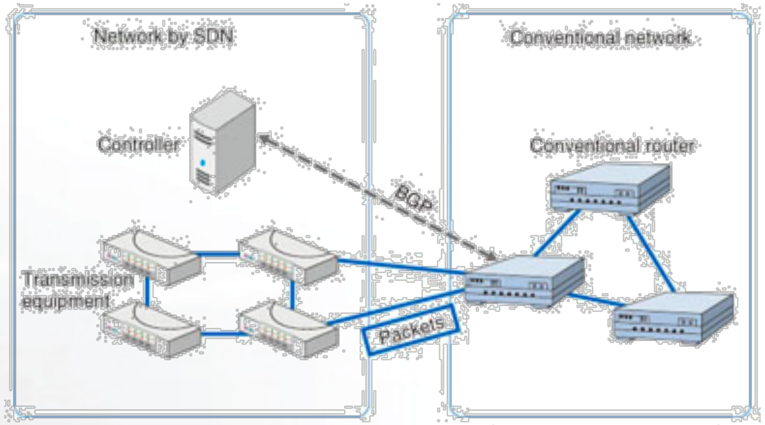
Google global private WAN [1]

Connects dozens of datacenters worldwide with a long-term average of 70% utilization over all links

Stanford Campus deployment

Part of Stanford campus migrated to OpenFlow

NTT's BGP Free Edge



https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201310fa3.html

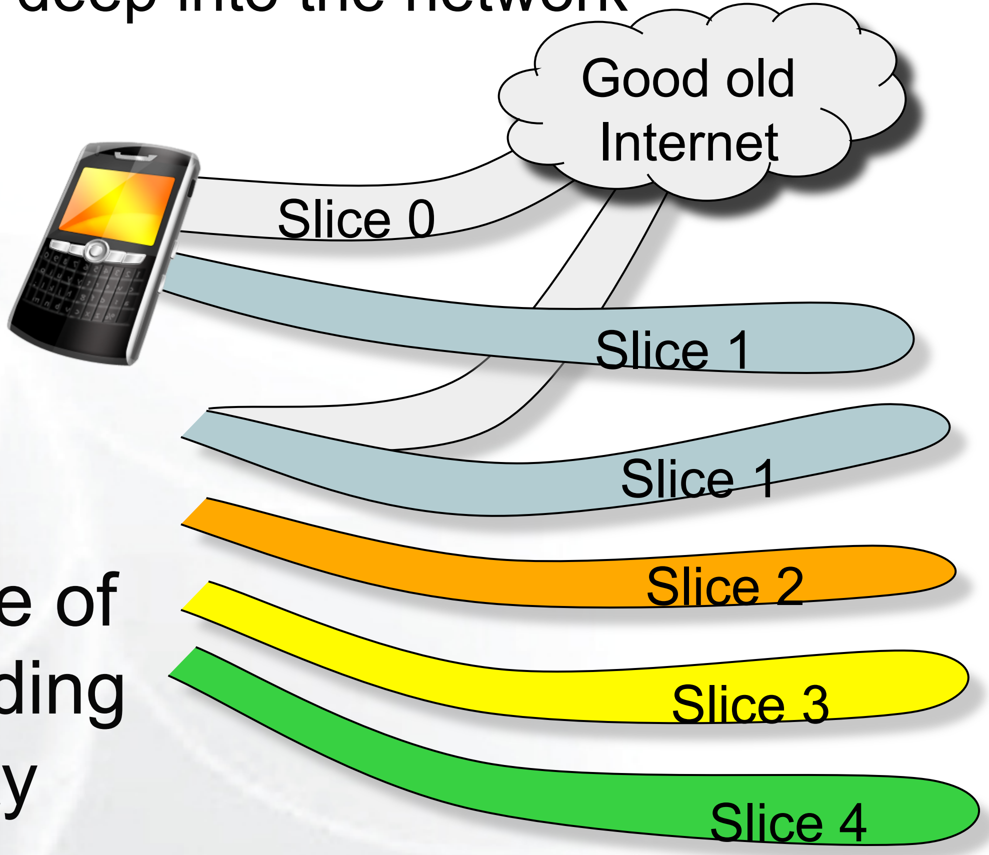
Internet 2 - AL2S

Can build Layer 2 circuits between any Internet 2 end-points

[1] *B4: Experience with a Globally-Deployed Software Defined WAN*, SIGCOMM'13, Jain et al.

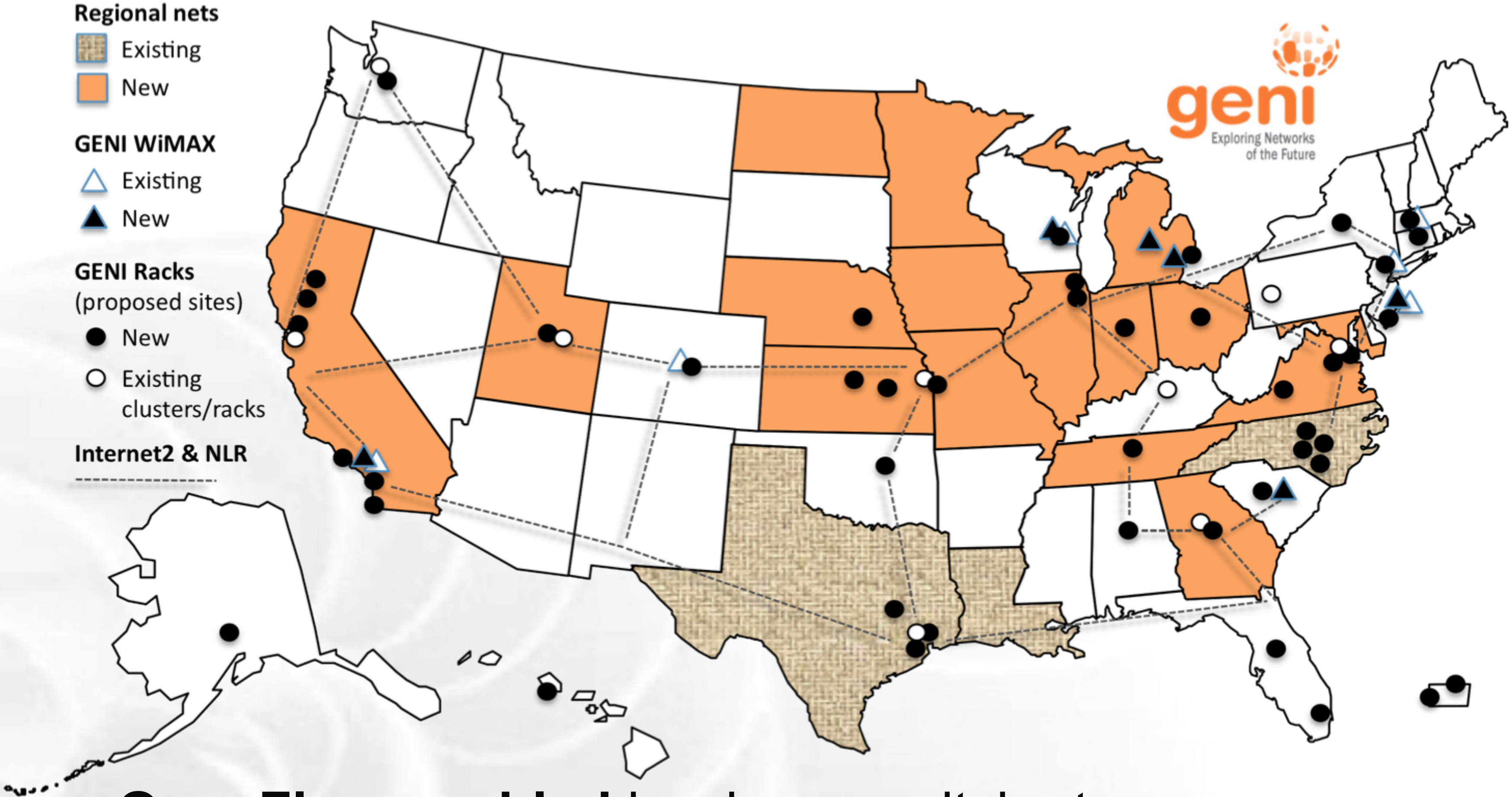
GENI and OpenFlow deployment

- Key GENI concept: slices & deep programmability
  - Internet: open innovation in application programs
  - GENI: open innovation deep into the network



OpenFlow switches one of the ways GENI is providing deep programmability

GENI OpenFlow Deployment

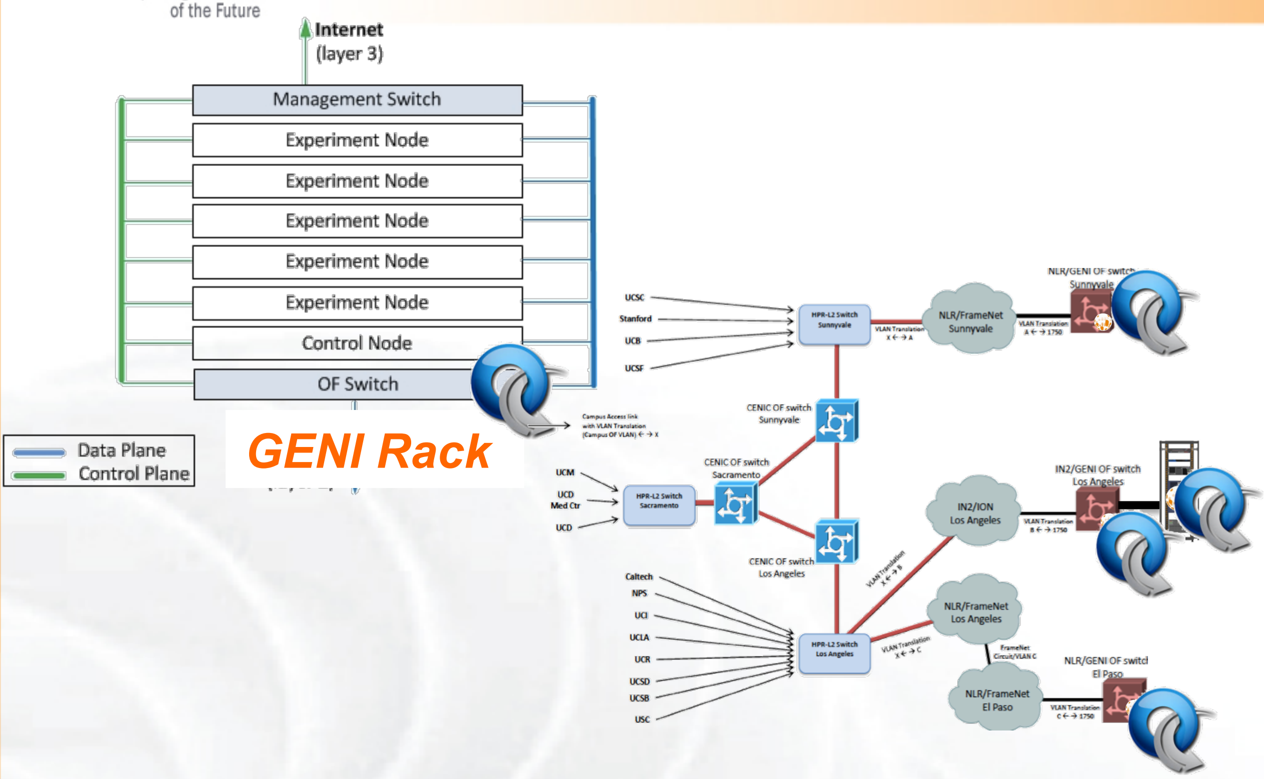


Regional nets
▨ Existing
🟧 New
GENI WiMAX
△ Existing
▲ New
GENI Racks (proposed sites)
● New
○ Existing clusters/racks
Internet2 & NLR
geni
Exploring Networks of the Future

OpenFlow-enabled hardware switch at:

- Each GENI Rack
- Backbone and regional networks

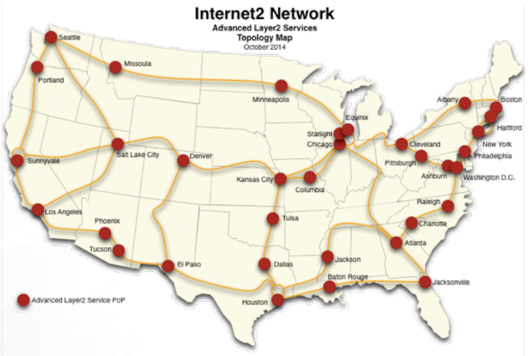
OpenFlow Switches



GENI Rack

GENI-enabled regionals

e.g. CENIC



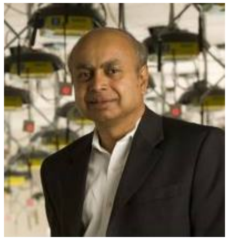
Internet2 AL2S and ION

GENI OpenFlow Experiments

Prasad Calyam, Missouri

VDC: real-time load-balancing functionality deep into the network to improve QoE

MobilityFirst: A new architecture for the Internet designed for emerging mobile/wireless service requirements at scale



Dipankar (Ray) Raychaudhuri, Rutgers, leads MobilityFirst

Jae Woo Lee, Columbia

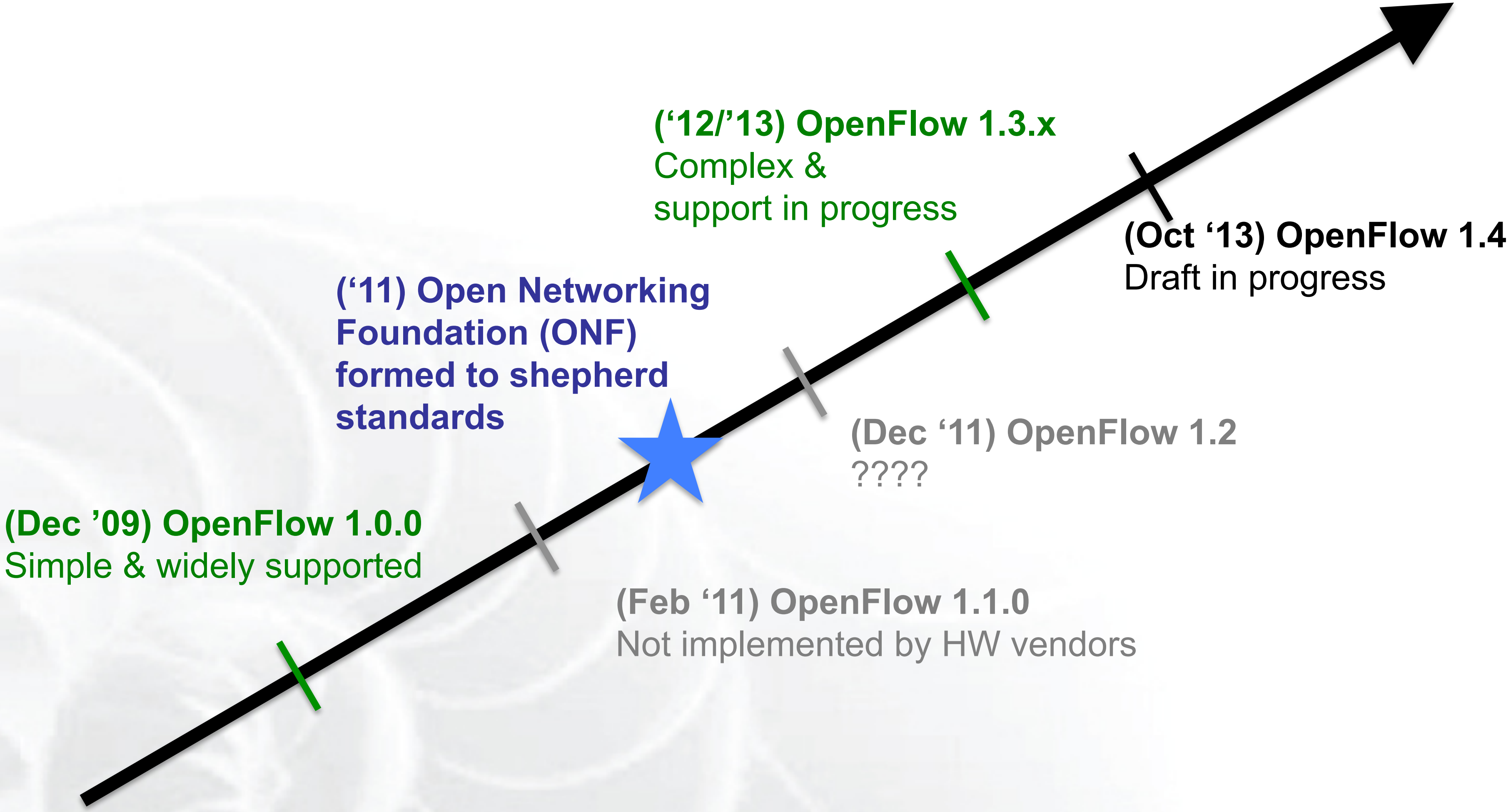
Active CDN: Program content distribution services deep into the network

OpenFlow basics

How OpenFlow works … (1.0)

Hands-On tutorial

OpenFlow versions



(Dec ’09) OpenFlow 1.0.0
Simple & widely supported

(Feb ‘11) OpenFlow 1.1.0
Not implemented by HW vendors

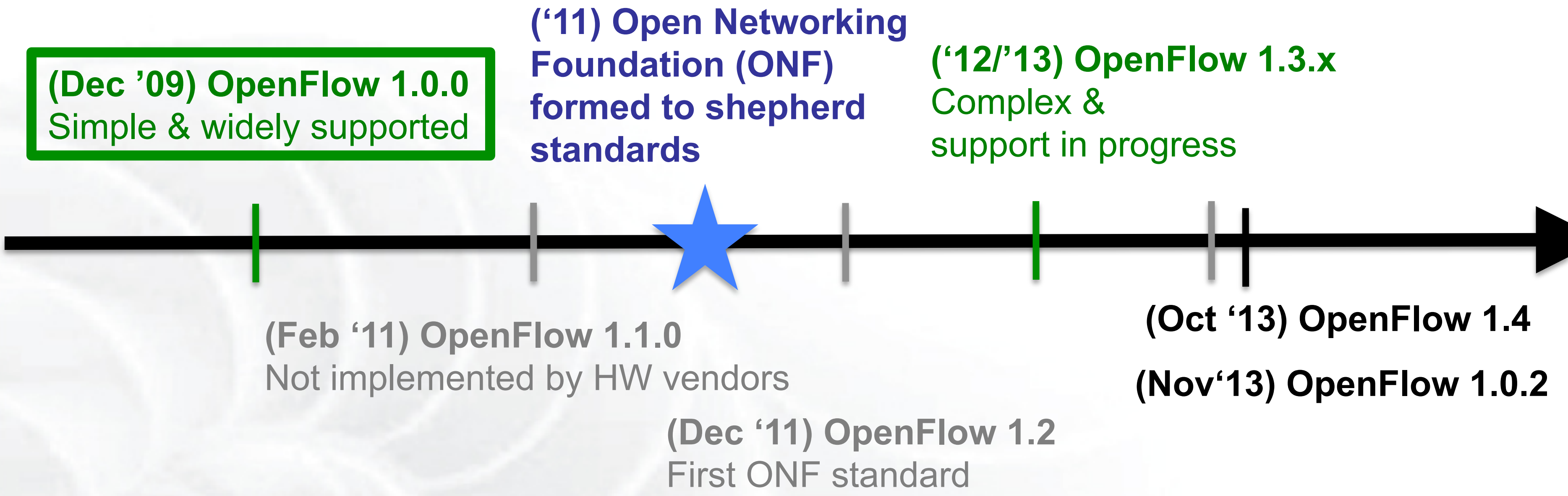
(‘11) Open Networking Foundation (ONF) formed to shepherd standards

(Dec ‘11) OpenFlow 1.2
????

(‘12/’13) OpenFlow 1.3.x
Complex &
support in progress

(Oct ‘13) OpenFlow 1.4
Draft in progress

OpenFlow versions



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First ONF standard

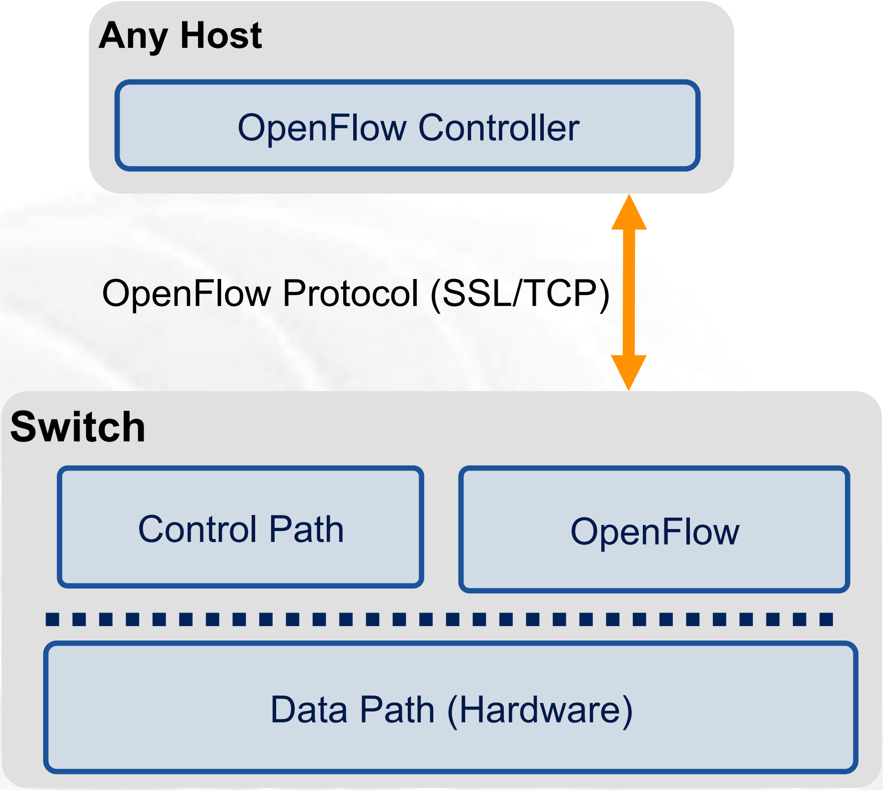
(Oct ‘13) OpenFlow 1.4

(Nov‘13) OpenFlow 1.0.2

OpenFlow controllers

- **Open source controller frameworks**
  - NoX – *C++*
  - PoX - *Python*
  - OpenDaylight - *Java*
  - FloodLight - *Java*
  - Trema – *C / Ruby*
  - Maestro - *Java*
  - Ryu - *Python*
- **Production controllers**
  - Mostly customized solutions based on Open Source frameworks
  - ProgrammableFlow - NEC

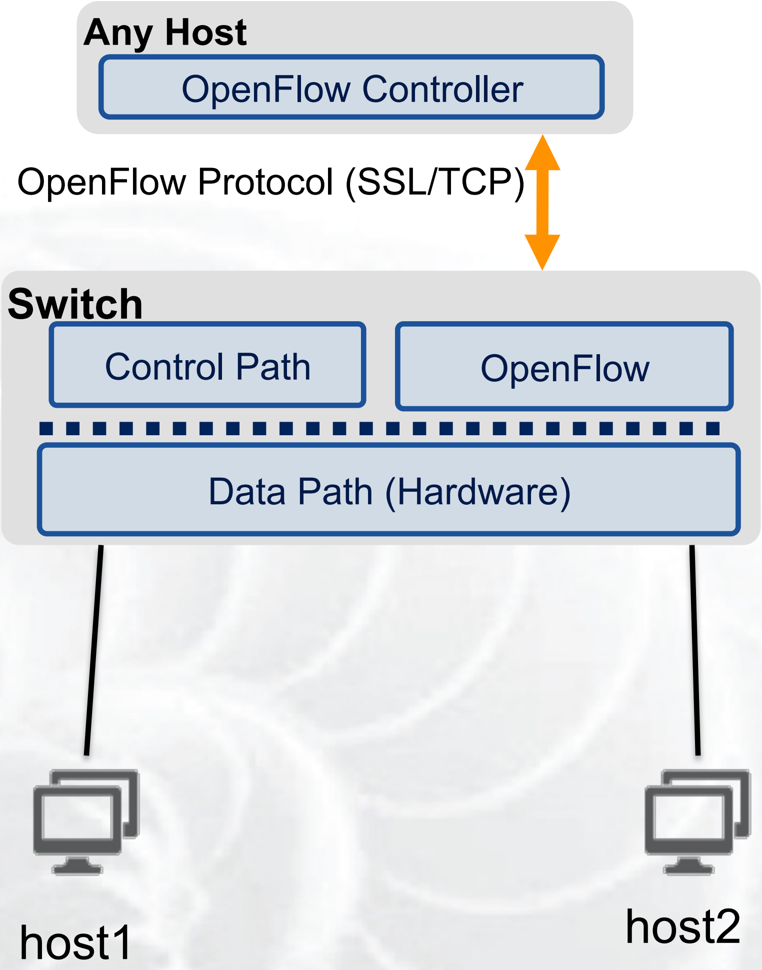
OpenFlow



- The controller is responsible for populating forwarding table of the switch
- In a table miss the switch asks the controller

Modified slide from : http://www.deutsche-telekom-laboratories.de/~robert/GENI-Experimenters-Workshop.ppt

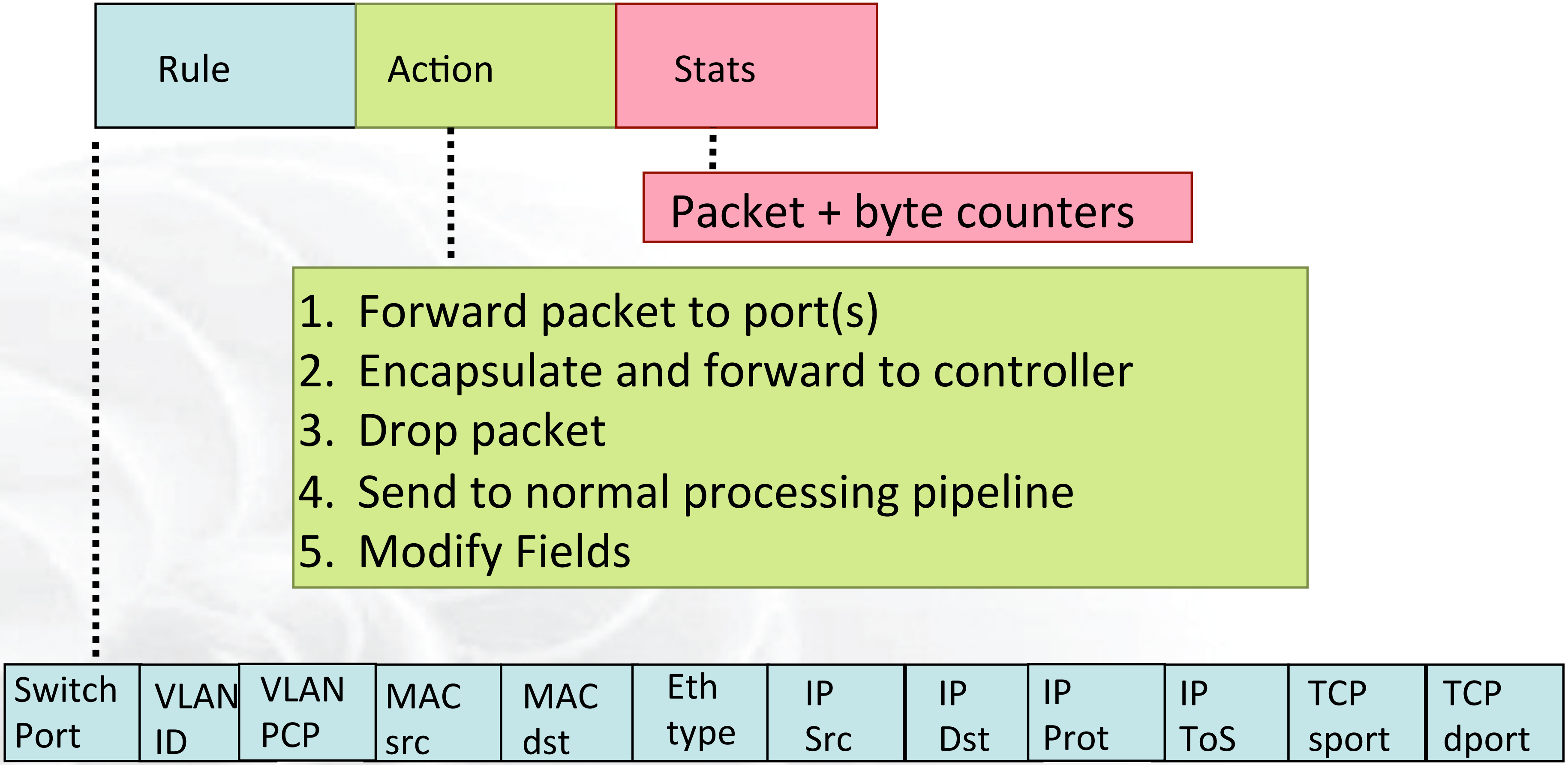
OpenFlow in action



- Host1 sends a packet
- If there are no rules about handling this packet
  - Forward packet to the controller
  - Controller installs a flow
- Subsequent packets do not go through the controller

Modified slide from : http://www.deutsche-telekom-laboratories.de/~robert/GENI-Experimenters-Workshop.ppt

OpenFlow Basics (1.0)



Rule | Action | Stats

Packet + byte counters

1. Forward packet to port(s)
2. Encapsulate and forward to controller
3. Drop packet
4. Send to normal processing pipeline
5. Modify Fields

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

+ mask what fields to match

slide from : http://www.deutsche-telekom-laboratories.de/~robert/GENI-Experimenters-Workshop.ppt

Use Flow Mods

- Going through the controller on every packet is inefficient
- Installing Flows either proactively or reactively is the right thing to do
- A Flow Mod consists of :
  - A **match** on any of the 12 supported fields
  - A **rule** about what to do matched packets
  - Timeouts about the rules:
    - Hard timeouts
    - Idle timeouts
  - The packet id in reactive controllers
  - Priority of the rule

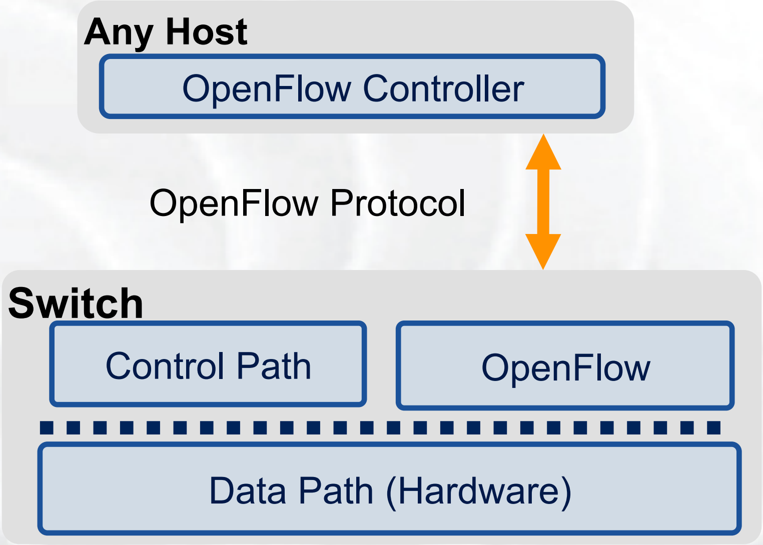
OpenFlow common PitFalls

- Controller is **responsible for all traffic**, not just your application!
  - ARPs, DHCP, LLDP
- Reactive controllers
  - Cause additional latency on some packets
  - UDP – many packets queued to your controller by time flow is set up
- Performance in hardware switches
  - Not all actions are supported in hardware
- No STP to prevent broadcast storms

OpenFlow datapaths

OpenFlow enabled devices are usually referred to as ***datapaths*** with a unique ***dpid***

It is not necessary that 1 physical device corresponds to 1 dpid



Different OpenFlow modes

- switches in **pure OF** mode are acting as one datapath
- **Hybrid VLAN switches** are one datapath per VLAN
- **Hybrid port switches** are two datapaths (one OF and one non-OF)

Each Datapath can point to only one controller at a time!

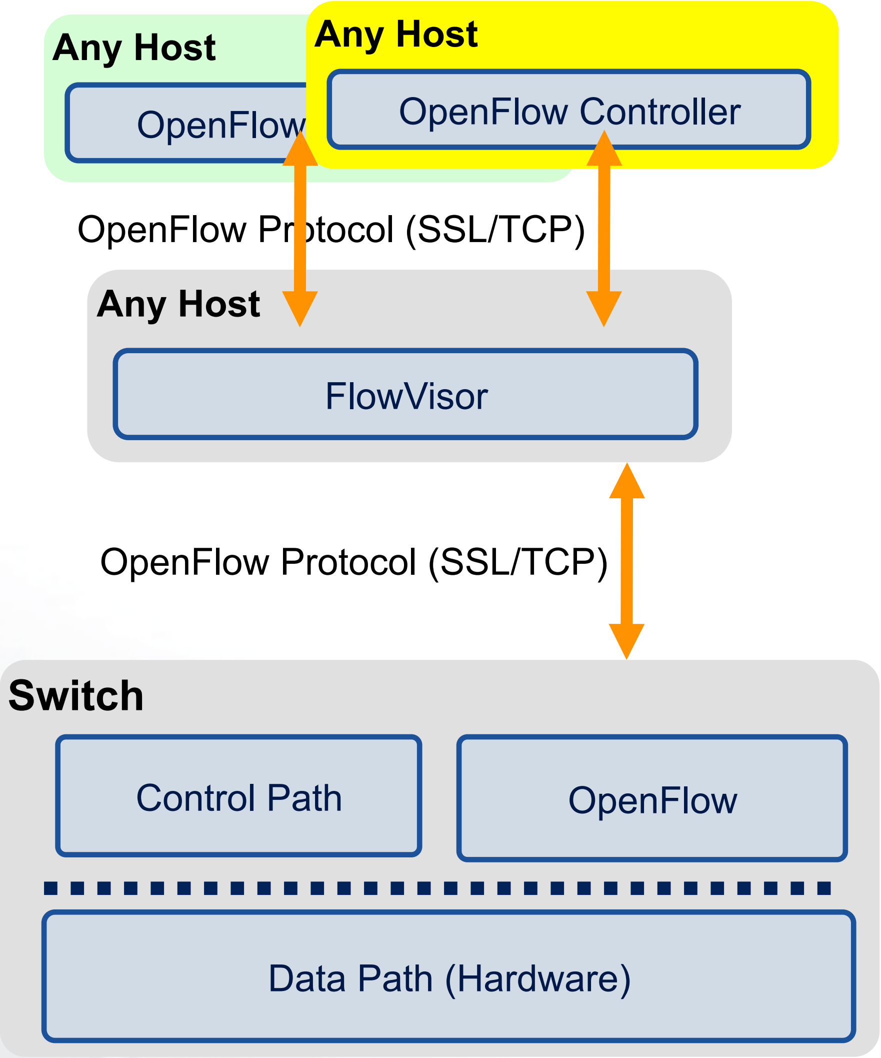
Multiplexing Controllers

FlowVisor

- Only one controller per datapath
- FlowVisor is a proxy controller that can support multiple controllers

FlowSpace describes packet flows :

- Layer 1: Incoming port on switch
- Layer 2: Ethernet src/dst addr, type, vlanid, vlanpcp
- Layer 3: IP src/dst addr, protocol, ToS
- Layer 4: TCP/UDP src/dst port



FOAM

- An OpenFlow Aggregate Manager
- It’s a GENI compliant reservation service
  - Helps experimenters reserve flowspace in the FlowVisor
- Speaks AM API v1 and AM API v2
- RSpecs GENI v3, OpenFlow v3 extension

Sharing of OpenFlow resources

In GENI:

- Slice by VLAN for exclusive VLANs
- Slice by IP subnet and/or eth_type for shared VLANs

In FIRE:

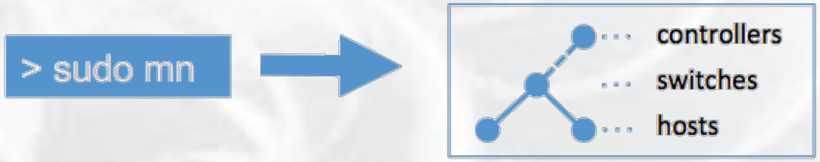
- On iMinds testbed
  - Slice by inport
- On OFELIA testbed
  - Slice by VLAN

OpenFlow Experiments

Debugging OpenFlow experiments is hard:

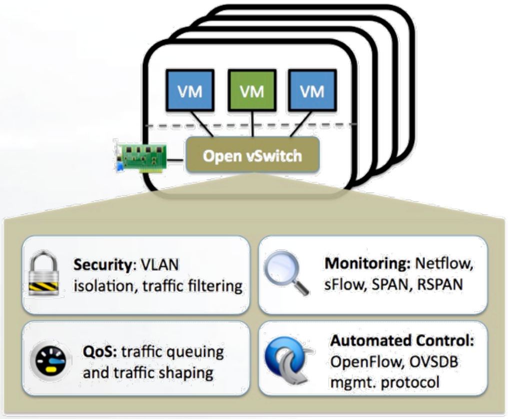
- Network configuration debugging requires coordination
- Many networking elements in play
- No console access to the switch

Before deploying your OpenFlow experiment test your controller.



```
> sudo mn
```

http://mininet.github.com/


VM
VM
VM
Open vSwitch
Security: VLAN isolation, traffic filtering
Monitoring: Netflow, sFlow, SPAN, RSPAN
QoS: traffic queuing and traffic shaping
Automated Control: OpenFlow, OVSDB mgmt. protocol

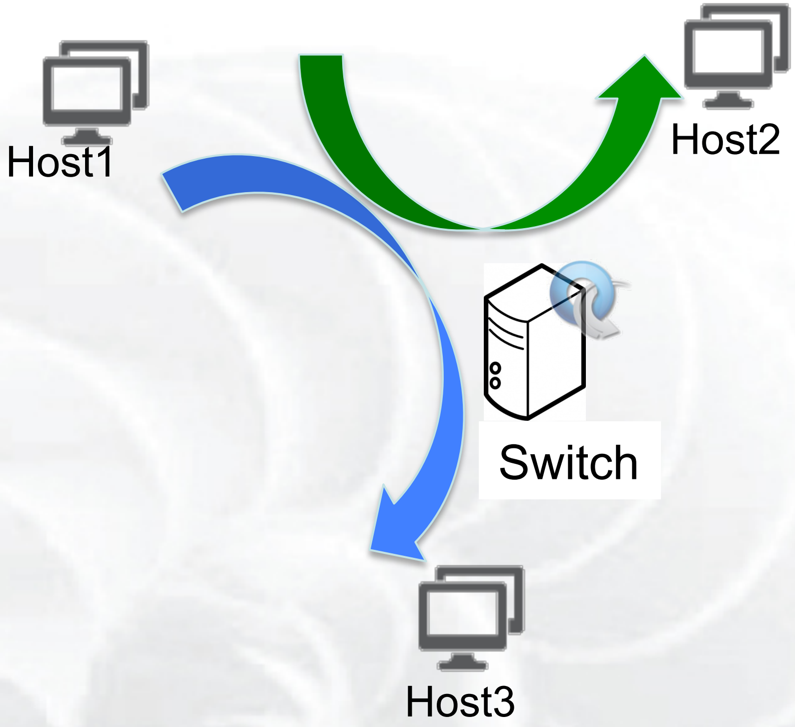
http://openvswitch.org/

OpenFlow basics

How OpenFlow works … (1.0)

Hands on tutorial

OpenFlow Tutorial Today



- Traffic forwarding
  - OVS switch-based exercise
  - Replace OVS switch with a hardware switch
  - Use OVS switch but move one of the hosts to another rack (stitched link)
- Network Function Virtualization
  - OpenFlow based NAT
  - OpenFlow based Firewall

QUESTIONS?