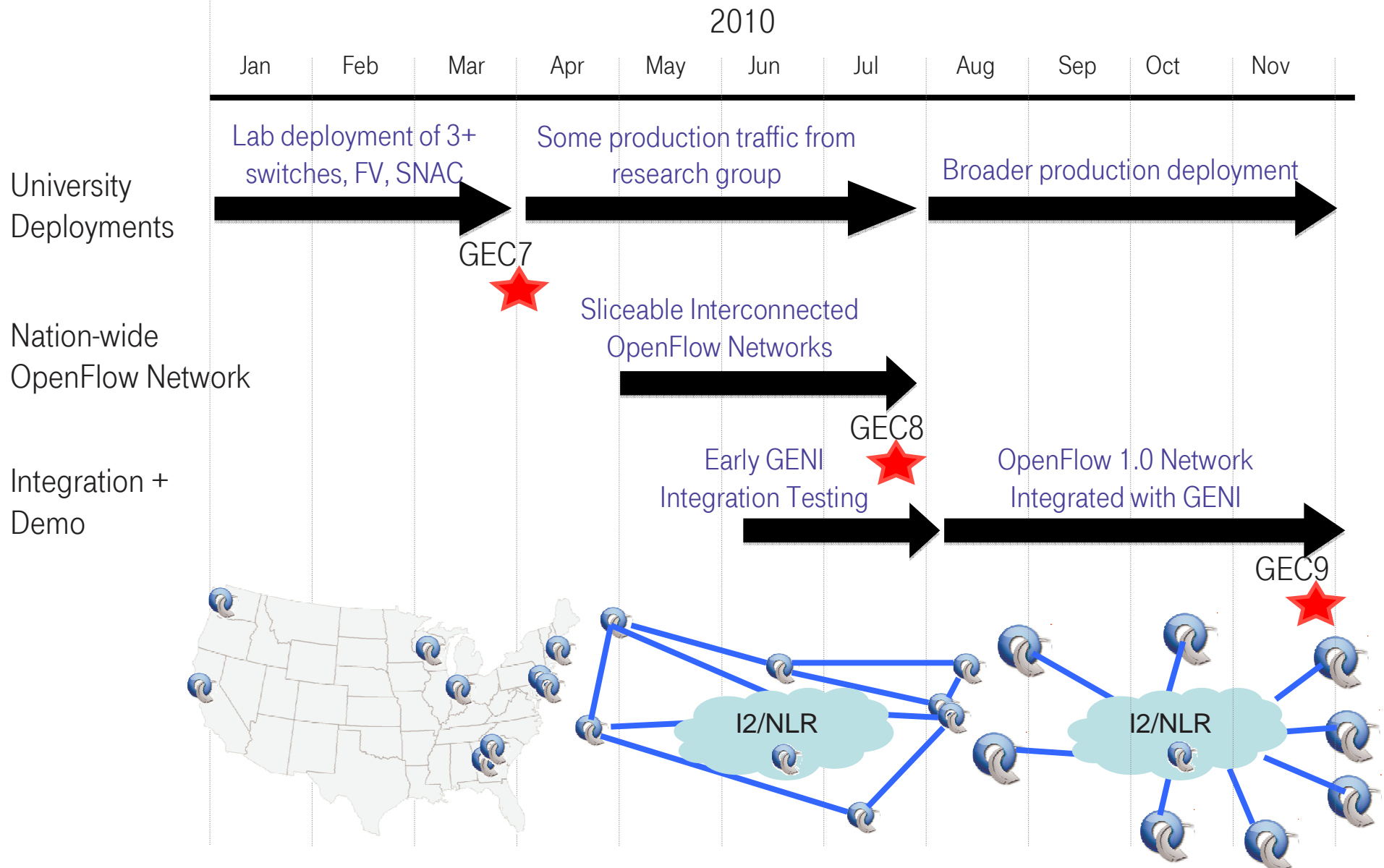# OpenFlow Campus Trials

GEC7

Stanford University

Continued progress

- **OpenFlow 1.0**
  - Spec released in Dec 2009
  - Reference implementations and early vendor implementations available

- **Increasing vendor interest**
  - HP support
  - NEC moving aggressively
  - Toroki
  - Quanta + Stanford software
  - Extreme networks (?)
  - More vendors in the pipeline

- **Increasing provider interest and engagement**
  - Google, Amazon, Yahoo, Microsoft, …
  - DT, Verizon, Level3,

- **EU**
  - Funded three large projects

- **China**
  - CERNET, CSTNET, and others interested

OpenFlow GENI roadmap

2010

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov

University Deployments

Lab deployment of 3+ switches, FV, SNAC

Some production traffic from research group

Broader production deployment

GEC7

Nation-wide OpenFlow Network

Sliceable Interconnected OpenFlow Networks

GEC8

Integration + Demo

Early GENI Integration Testing

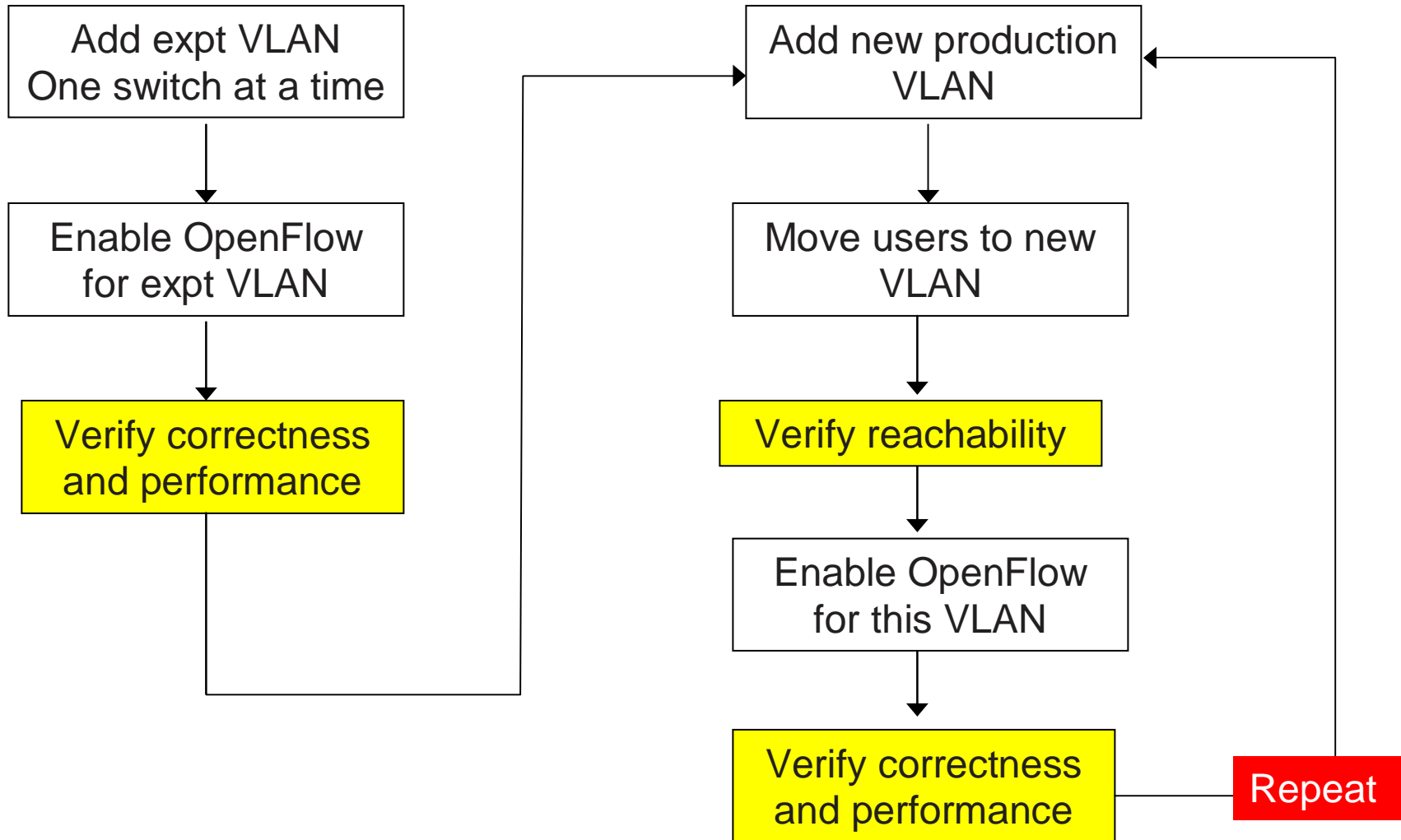OpenFlow 1.0 Network Integrated with GENI

GEC9

I2/NLR

I2/NLR

GEC8: Nation-wide OpenFlow network

- 6+ OpenFlow switches, operated by campuses

- OpenFlow VLAN A:
  - Handles all research group traffic
  - Controlled by FlowVisor + SNAC

- OpenFlow VLAN B is sliced by FV into 3 or more slices:
  - For research and experimentation

- Early integration testing with GENI control plane

- Demo: Show expt spanning 2 or more campuses at GEC8 meeting, along with FV GUI for local aggregate.

Key challenges

- Scale OpenFlow deployment
  - Add more switches and WiFi APs
  - Add slicing for production & experimentation

- Achieve network stability with experimentation
  - Keep users and experimenters happy

- Connect campus OpenFlow network to I2/NLR OpenFlow backbone

- Start integration with GENI control plane

- GEC8 not that far off and during summer

Solution: Staged deployment

Add expt VLAN
One switch at a time

↓

Enable OpenFlow
for expt VLAN

↓

Verify correctness
and performance

Add new production
VLAN

↓

Move users to new
VLAN

↓

Verify reachability

↓

Enable OpenFlow
for this VLAN

↓

Verify correctness
and performance

Repeat

Resources

- **Support system**
  - People, online resources, and more

- **Stanford deployment experience**
  - OpenFlow becoming production ready, but expect issues and plan well

- **Goals within our reach if we plan well**
  - Specific deployment plan for each campus
  - Customize support plan accordingly

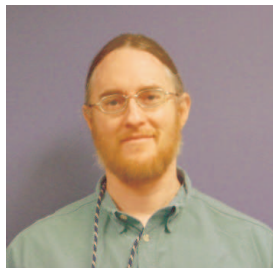# Support System

Support team

Stanford

Masa Srini Paul Johan

GPO/BBN

Josh Heidi

Support system

- Bi-weekly calls:
    - Help debug deployment issues
    - Help prepare a customized deployment / demo plan

- Website:
  www.openflowswitch.org/foswiki/bin/view/OpenFlow/Deployment/

- Mailing lists:
    openflow-discuss, openflow-spec, openflow-dev,
    nox-dev, egeni-trials, deployment-help

- Bug tracking system:
    - http://www.openflowswitch.org/bugs/snac,
      /bugs/toroki, /bugs/flowvisor, /bugs/openflow
    - For bugs with HP, please mail jean.tourrilhes@hp.com
    - For bugs with NEC, please mail ofs-support@spf.jp.nec.com

Support system (contd.)

- BBN/GPO information wiki:
  - http://groups.geni.net/geni/wiki/OFCLEM, wiki/OFGT, wiki/OFIU, wiki/OFPR wiki/OFRG, wiki/OFUWA, wiki/OFUWI, wiki/OFNOX, wiki/OFBBN, wiki/EnterpriseGeni, wiki/CampusConnectivity

- BBN/GPO mailing lists:
  - openflow@geni.net, backbone-integration@geni.net, geni-node-ops@geni.net, response-team@geni.net

- One-on-one support from Josh Smift for
  - Wide-area network GENI connection
  - GENI API and integration

Status of Components

Different components in the Network

SNAC Controller

Custom Controller

Running on same machine and different TCP ports

Production Flows of VLAN 120

John Doe's exptl flows

FLOWVISOR

OpenFlow Protocol

NEC IP8800

Toroki LS4810

WiFi

HP Procurve 5400

Legacy Enterprise Network
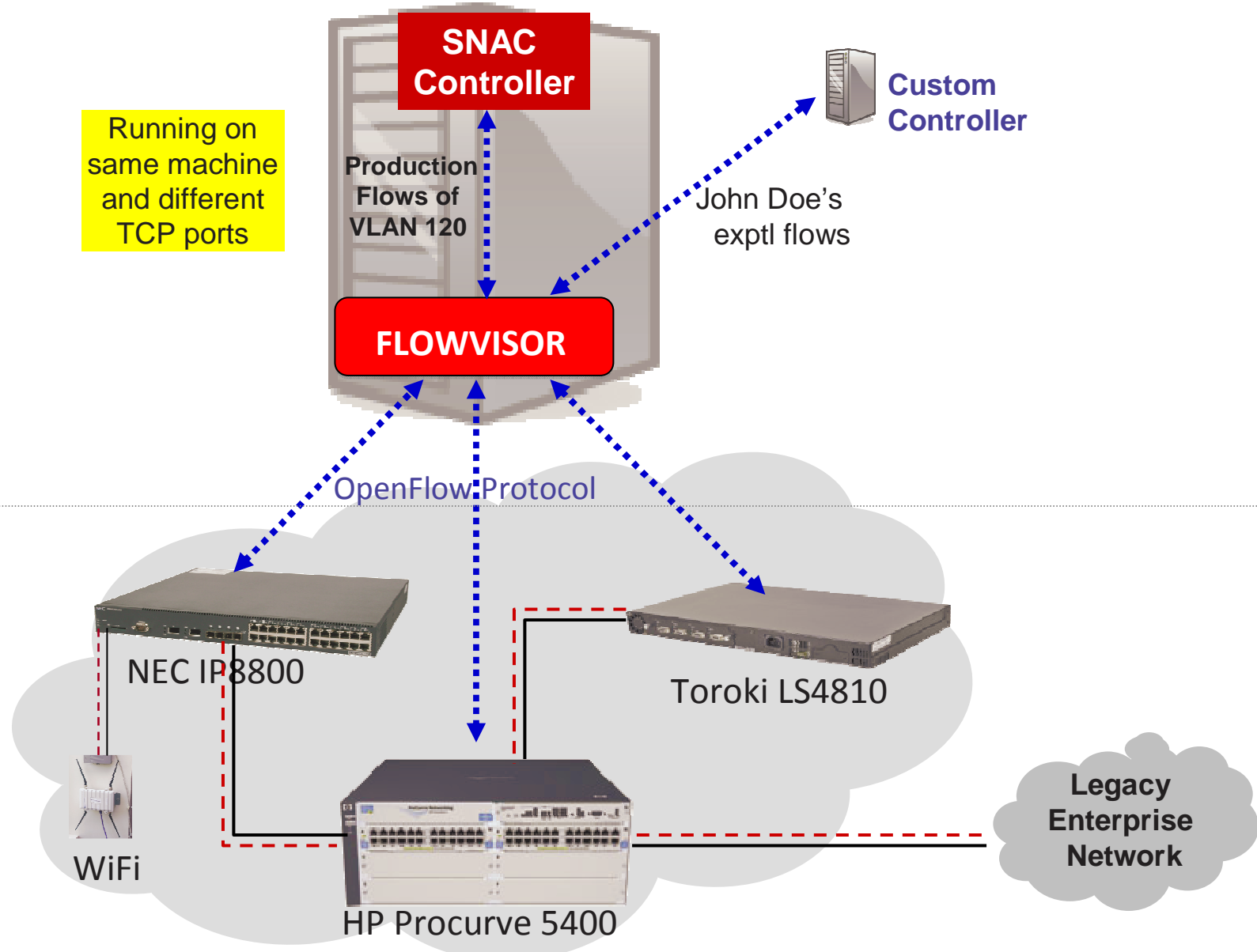
Availability of OpenFlow components

Modules	Currently Available Version	Version used for GEC8	Version used for GEC9	When GEC9 demo version becomes available?
OpenFlow Switch	0.8.9 (1.0 for s/w ref design)	1.0(Stanford + ?), 0.8.9 (others)	1.0*	•HP & NEC: April 2010 (Alpha version available for HP)
NOX	0.6	0.6	1.0	Aug 2010
SNAC	0.4	0.4	1.0	TBD
FlowVisor	0.4	0.5	1.0	Aug 2010
FlowVisor console	-	0.5	1.0	
Aggregate Manager	SFA_0.9.5	0.5	1.0	
ENVI	Available online in the production deployment page			
LAVI				
Monitoring & Debugging Tools				

(*) Ensures compatibility across campuses

Summary of resolved issues

- Frequent stats request causing HP CPU spikes
  - Well understood issue that we pay attention to
  - Workaround: Reduce frequency of stats request or block it at FV

- HP switch dropping LLDP packets:
  - HP dropping LLDP packets with multicast source address
  - Resolved by fixing *discovery* module of SNAC

- Switches not allowing hot swap of ports
  - The controller ignores port status change during runtime
  - Resolved by fixing *discovery* module of SNAC

- Link timeout incorrect causing frequent churn
  - Resolved by increasing link timeout in SNAC module

Summary of resolved issues (contd.)

- Packet_out action of TABLE did not work for NEC switch
  - Caused first packet to be dropped
  - Resolved by firmware fix from NEC

- HP switch issues:
  - Poor browsing performance
  - Resolved by firmware fix from HP

- Wireless DHCP
  - Invalid packet forwarding
  - Resolved by erasing stale bindings in *authenticator* of SNAC

- Duplicate packets sent to OFPP_LOCAL
  - For WiFi APs having of0 port, invalid action is sent by *FlowVisor*
  - Resolved by performing additional check in *FlowVisor*

Summary of existing issues

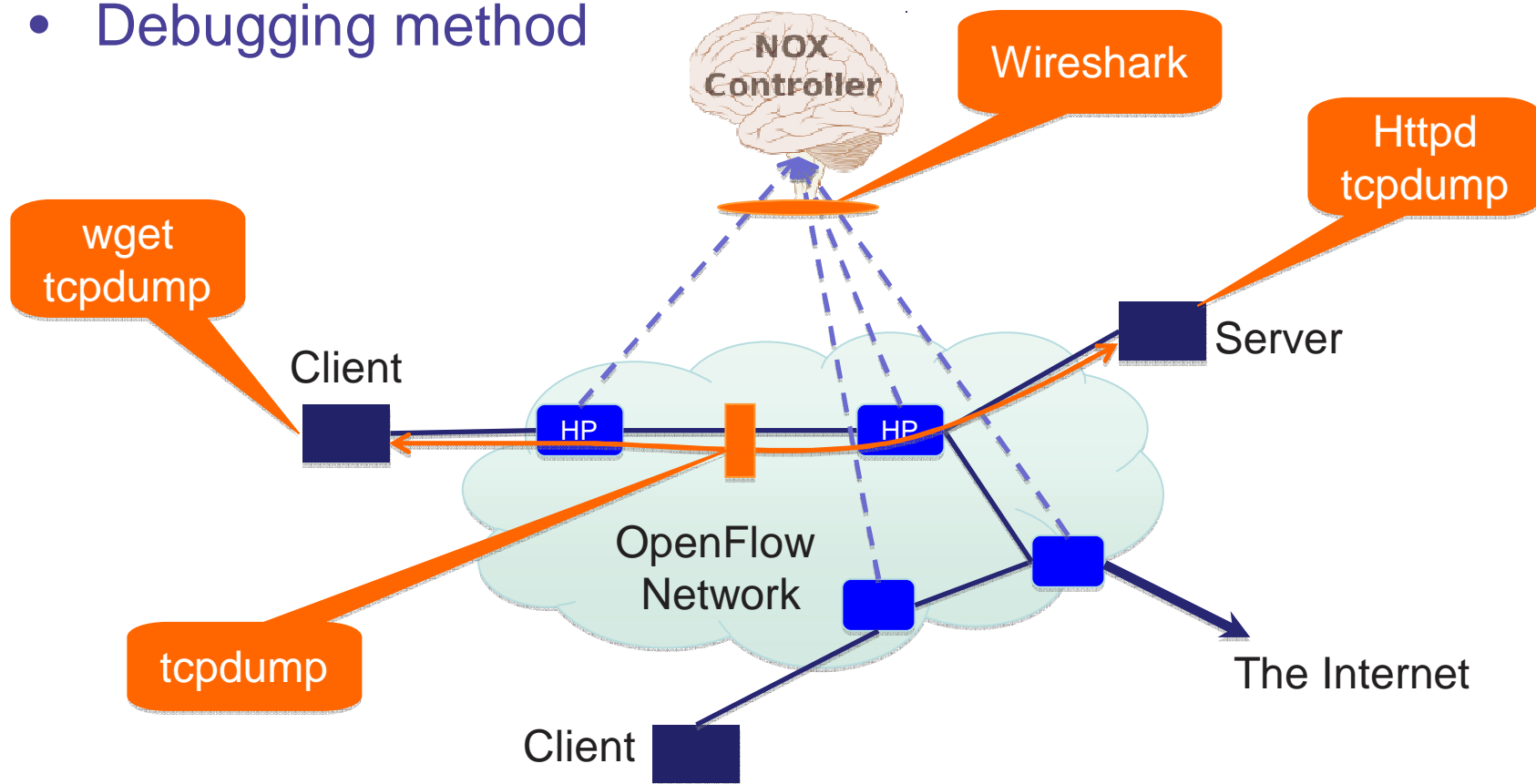Most issues are non-blockers in our deployment

- Toroki switch issues:
  - Open issues:
    - MAC rewriting not working
    - Instability during power cycle
    - Flows not expiring when controller is stopped while traffic is running
  - Status: Vendor is working on a fix

- Invalid state storage in SNAC
  - Removing port during run time of SNAC is not supported
  - Status: Need to investigate performance impact

- Invalid bindings in SNAC following topology change
  - Status: Being discussed on nox-dev list

Summary of existing issues (contd.)

- ## No spanning tree support in controller
  - Caused an outage in CIS/CISX, when operator installed a loop
  - Status: Developing a NOX/SNAC module

- ## No link bundling (LACP) support in OpenFlow switch
  - Status: Vendors are looking at fix
  - Workaround: Use dedicated OpenFlow links

- ## No redundancy or failover with ver0.8.9

- ## No IPv6, Multicast, or 802.1X support in controller

Resolved #1: HP wget performance issue

- ## Symptom
  - Web browsing performance was poor if HP switch is on the path

- ## Debugging method

NOX Controller

Wireshark

Httpd tcpdump

wget tcpdump

Client

Server

HP

HP

OpenFlow Network

tcpdump

The Internet

Client

Resolved #1: HP wget performance issue

1266568067.414724 IP 172.24.74.121.44544 > 171.67.216.18.80: S 288018868:288018868(0) win 5840
1266568070.412083 IP 172.24.74.121.44544 > 171.67.216.18.80: S 288018868:288018868(0) win 5840
1266568070.412554 IP 171.67.216.18.80 > 172.24.74.121.44544: S 2119182178:2119182178(0) ack 288018869

We recommend using the *wireshark dissector* for debugging purposes

No. ↓	Time	Source	Destination	Protocol	Info
4	0.348571	171.67.75.2	128.208.4.156	TCP	8833 > 38309 [ACK] Seq=13 Ack=429 Win=1002 Len=0 TSV=1180389900 TSER=97037950
5	0.603936	Supermic_b0:54:ab	Broadcast	OFP+ARP	Packet Out (CSM) (108B) => Who has 0.0.0.0? Tell 49.48.46.55
6	0.604148	128.208.4.156	171.67.75.2	OFP	Error (SM) (12B)
7	0.623652	171.67.75.2	128.208.4.156	TCP	8833 > 38309 [ACK] Seq=121 Ack=441 Win=1002 Len=0 TSV=1180389969 TSER=97038019
8	0.632078	10.79.1.41	10.79.1.29	OFP+TCP	Packet In (AM) (BufID=397822) (92B) => 42620 > http [SYN] Seq=0 Win=5840 Len=0 MSS=1460 TSV=51494144 TSER=0
9	0.651661	171.67.75.2	128.208.4.156	TCP	8833 > 38309 [ACK] Seq=121 Ack=533 Win=1002 Len=0 TSV=1180389976 TSER=97038026
10	0.666384	IntelCor_b0:04:b1	Broadcast	OFP+ARP	Packet Out (CSM) (108B) => Who has 0.0.0.0? Tell 49.48.46.55 (duplicate use of 49.48.46.55 detected!)
11	0.666541	128.208.4.156	171.67.75.2	OFP	Error (SM) (12B)
12	0.724099	171.67.75.2	128.208.4.156	TCP	8833 > 38309 [ACK] Seq=229 Ack=545 Win=1002 Len=0 TSV=1180389994 TSER=97038035
13	0.726943	Supermic_b1:35:cf	Broadcast	OFP+ARP	Packet Out (CSM) (108B) => Who has 0.0.0.0? Tell 49.48.46.55 (duplicate use of 49.48.46.55 detected!)

▷ Frame 8 (158 bytes on wire, 158 bytes captured)
▷ Ethernet II, Src: Intel_4c:ce:68 (00:0e:0c:4c:ce:68), Dst: Cisco_15:44:80 (00:18:74:15:44:80)
▷ Internet Protocol, Src: 128.208.4.156 (128.208.4.156), Dst: 171.67.75.2 (171.67.75.2)
▷ Transmission Control Protocol, Src Port: 38309 (38309), Dst Port: 8833 (8833), Seq: 441, Ack: 121, Len: 92
▽ OpenFlow Protocol
  ▷ Header
  ▽ Packet In
     Buffer ID: 397822
     Frame Total Length: 74
     Frame Recv Port: 63
     Reason Sent: No matching flow (0)
   ▽ Frame Data: 003048B054AB080027A1081B08004500003C2D3840004006...
    ▷ Ethernet II, Src: CadmusCo_a1:08:1b (08:00:27:a1:08:1b), Dst: Supermic_b0:54:ab (00:30:48:b0:54:ab)
   ▷ Internet Protocol, Src: 10.79.1.41 (10.79.1.41), Dst: 10.79.1.29 (10.79.1.29)
    ▷ Transmission Control Protocol, Src Port: 42620 (42620), Dst Port: http (80), Seq: 0, Len: 0

Resolved #1: HP wget performance issue

CONTROL TRAFFIC INDICATED PROPER OPENFLOW HANDSHAKE FOR FLOW
(MAC 0db916ef50->0d055d240, IPV4, 172.24.74.121 -> 171.67.216.18, TCP, 44544 -> 80, HTTP)

1266568066.254337, **PACKET_IN**, necsw port 35, Buf id 30158480
1266568066.254483, **FLOW_MOD**, necsw port 35
1266568066.254559, **PACKET_OUT**, necsw port 35, Buf id 30158480
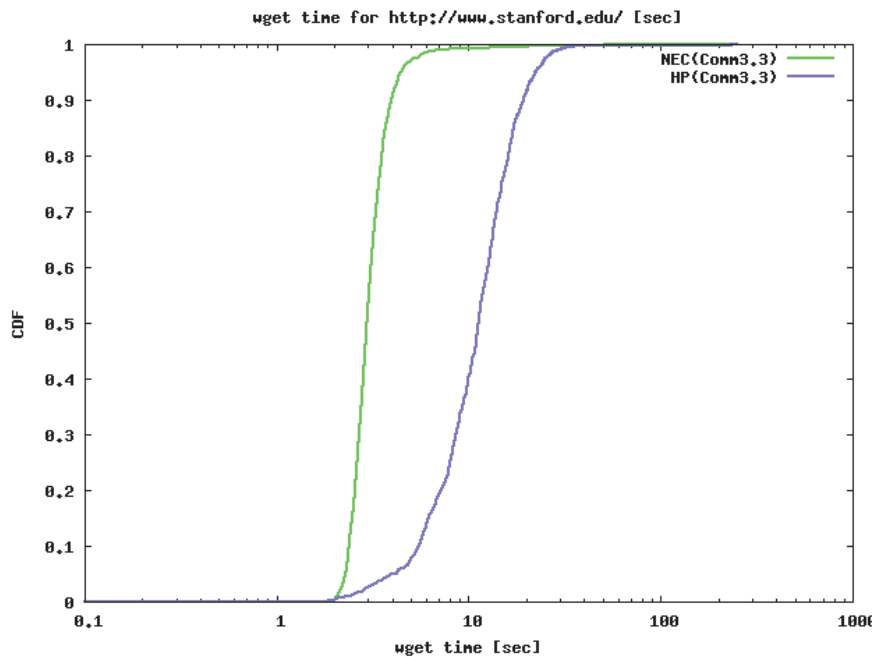1266568066.273144, **FLOW_MOD**, hpsw1 port 47
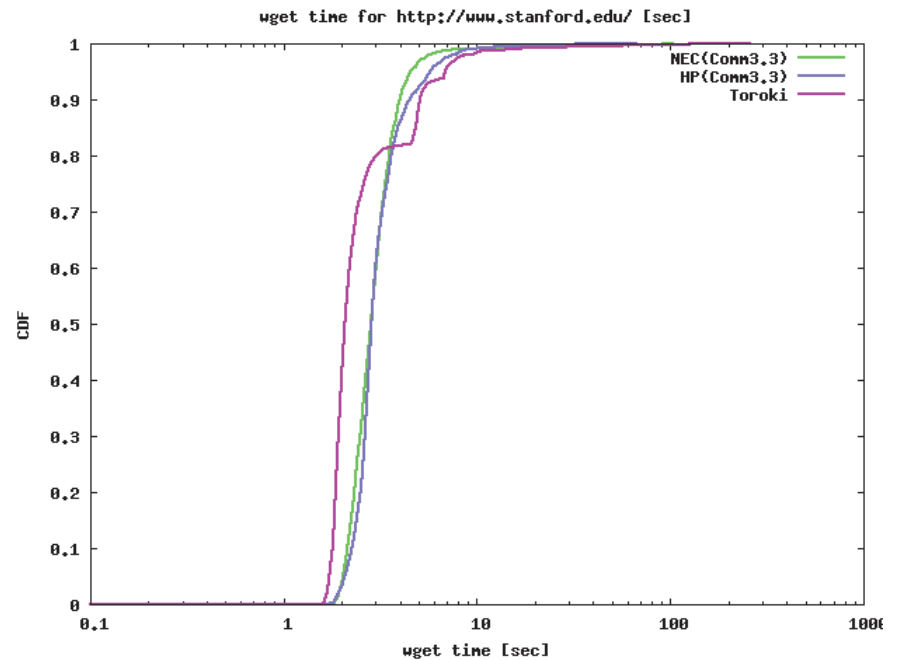
- Behavior at microscopic level
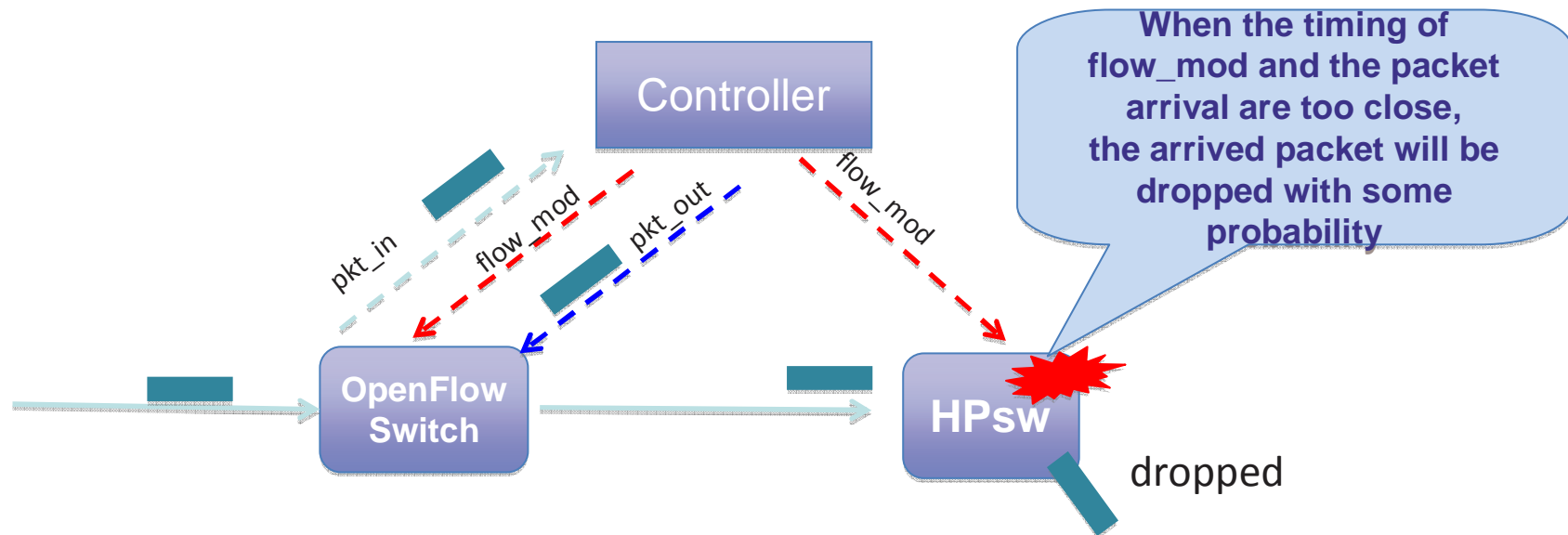
Resolved #1: HP wget performance issue
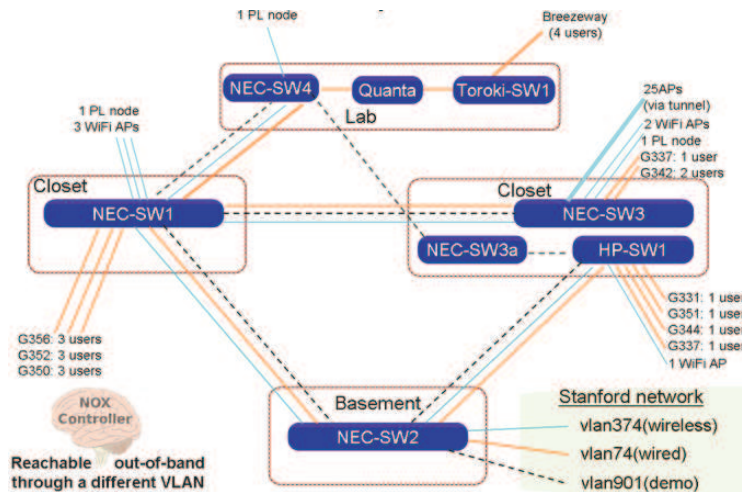
- Status: fixed (firmware fix)
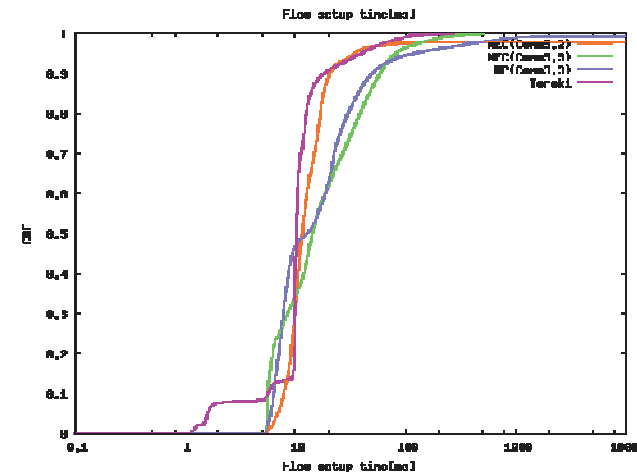
Before (Week 38)

After (Week 41)

Stanford OpenFlow deployment
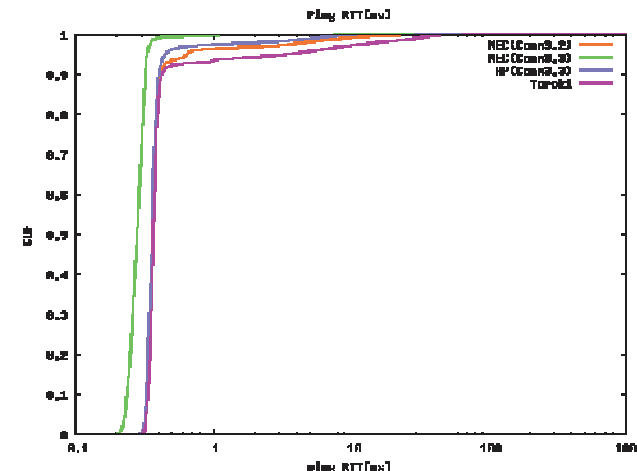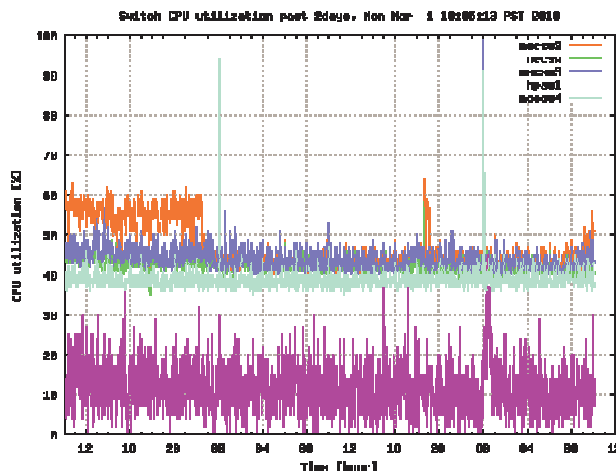
Status of Stanford deployment

- ## Network is getting more stable

VLAN 74 in Last week of Feb

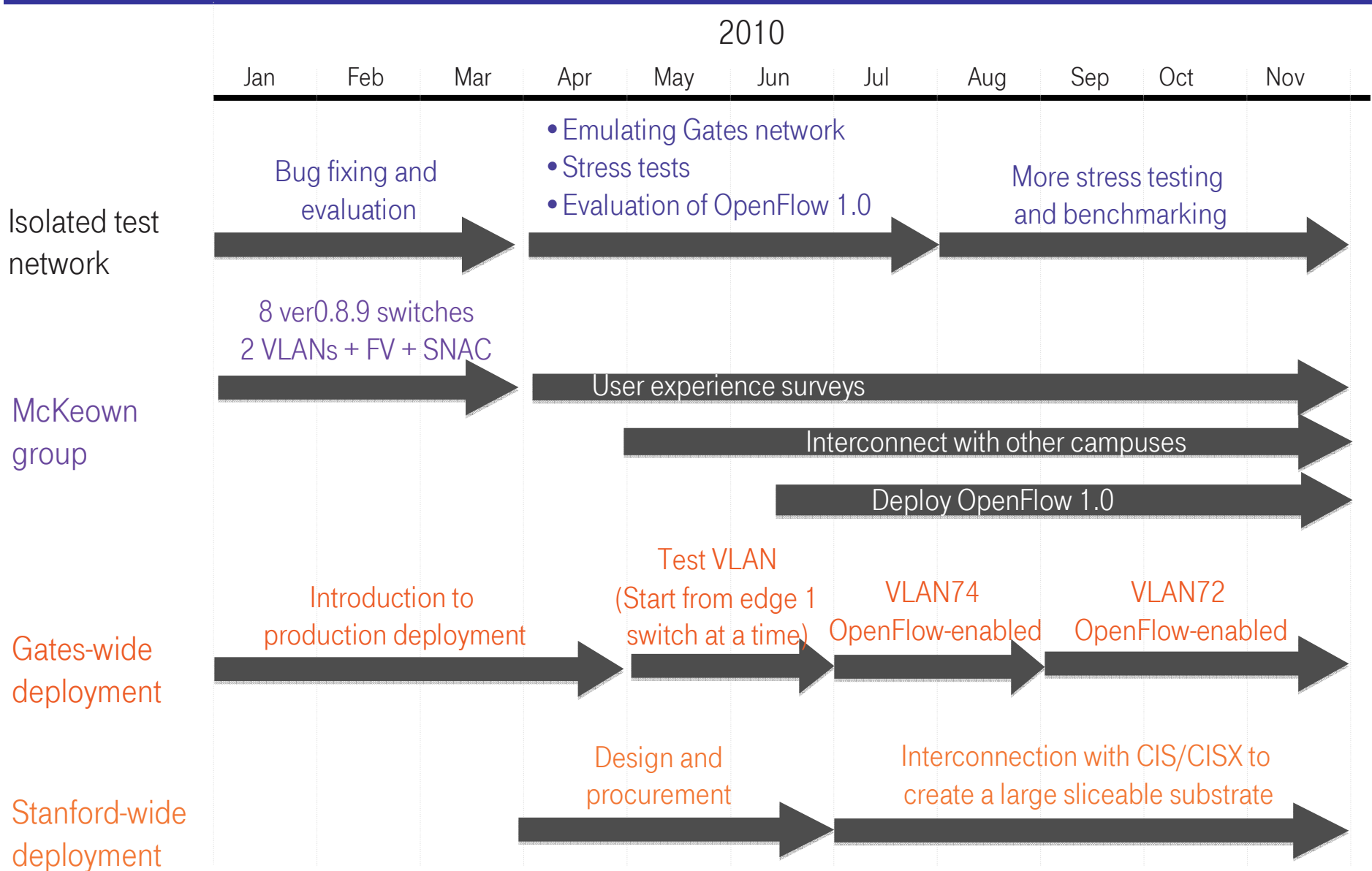CPU early this month

Next steps for Stanford deployment

2010

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov

Isolated test network

Bug fixing and evaluation

- Emulating Gates network
- Stress tests
- Evaluation of OpenFlow 1.0

More stress testing and benchmarking

McKeown group

8 ver0.8.9 switches
2 VLANs + FV + SNAC

User experience surveys

Interconnect with other campuses

Deploy OpenFlow 1.0

Gates-wide deployment

Introduction to production deployment

Test VLAN (Start from edge 1 switch at a time)

VLAN74 OpenFlow-enabled

VLAN72 OpenFlow-enabled

Stanford-wide deployment

Design and procurement

Interconnection with CIS/CISX to create a large sliceable substrate

Summary

- OpenFlow is getting closer to production quality

- Carefully plan "production deployment" to ensure we don't lose trust of our users and campus networking folks

- How may we help you?
  - Are you ready to help other newcomers?