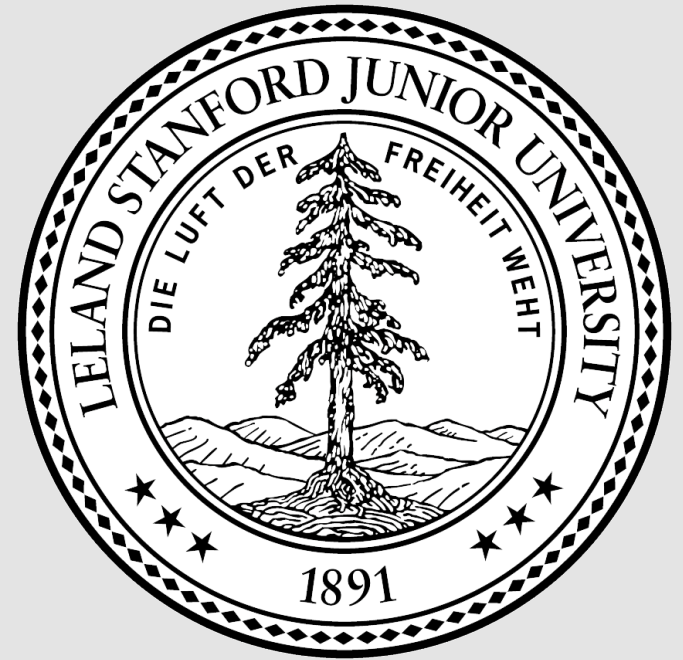


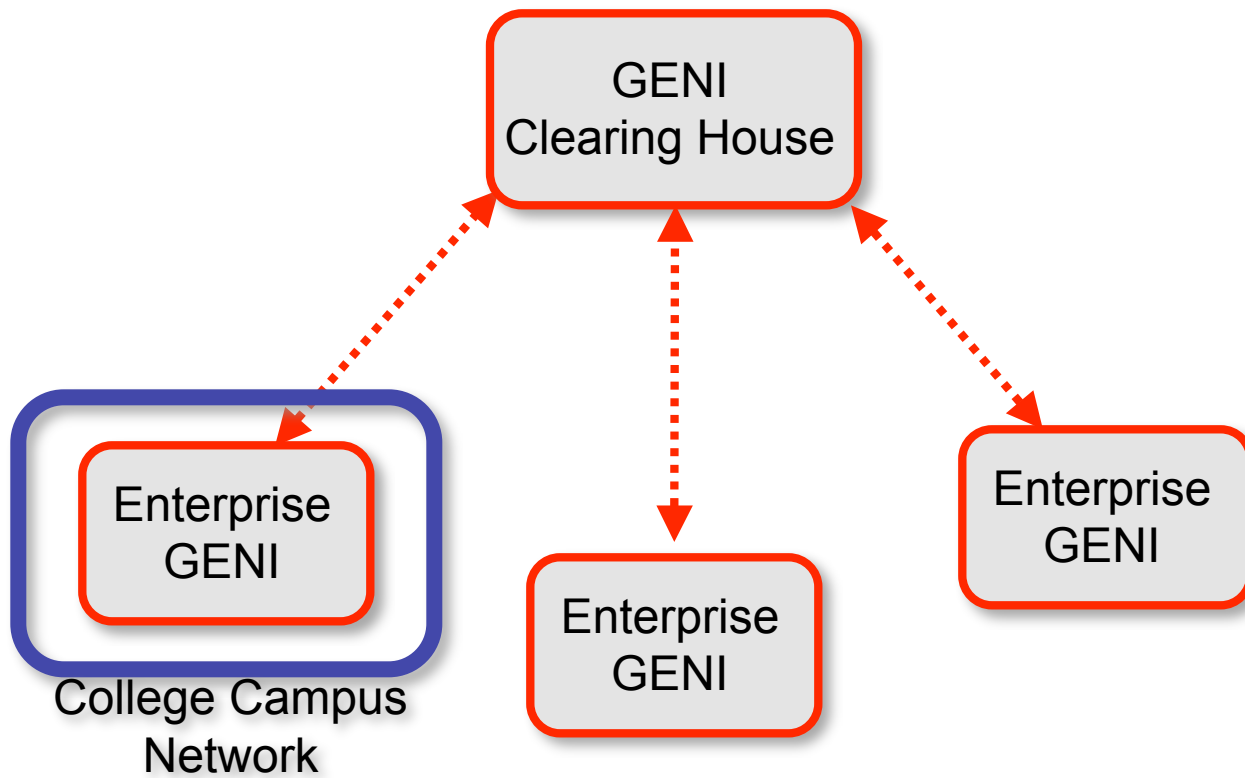


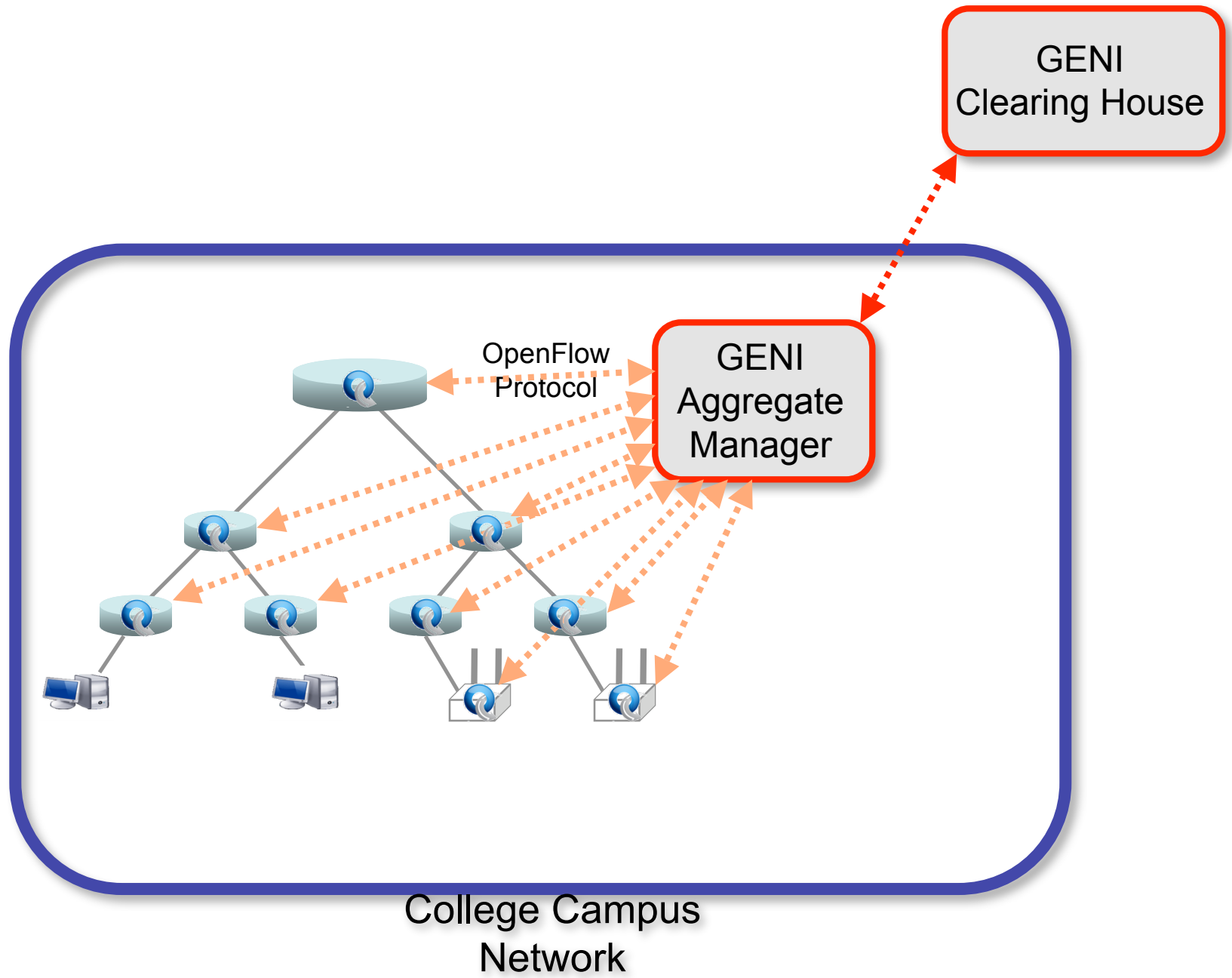
# Enterprise GENI

Nick McKeown  
[nickm@stanford.edu](mailto:nickm@stanford.edu)

**Stanford OpenFlow team:** Guido Appenzeller, Glen Gibb, David Underhill,  
David Erickson, Adam Covington, Brandon Heller, Rob Sherwood,  
Masayoshi Kobayashi, Guru Parulkar, Srinivasan Seetharaman, Yiannis Yiakoumis







# Staged Approach

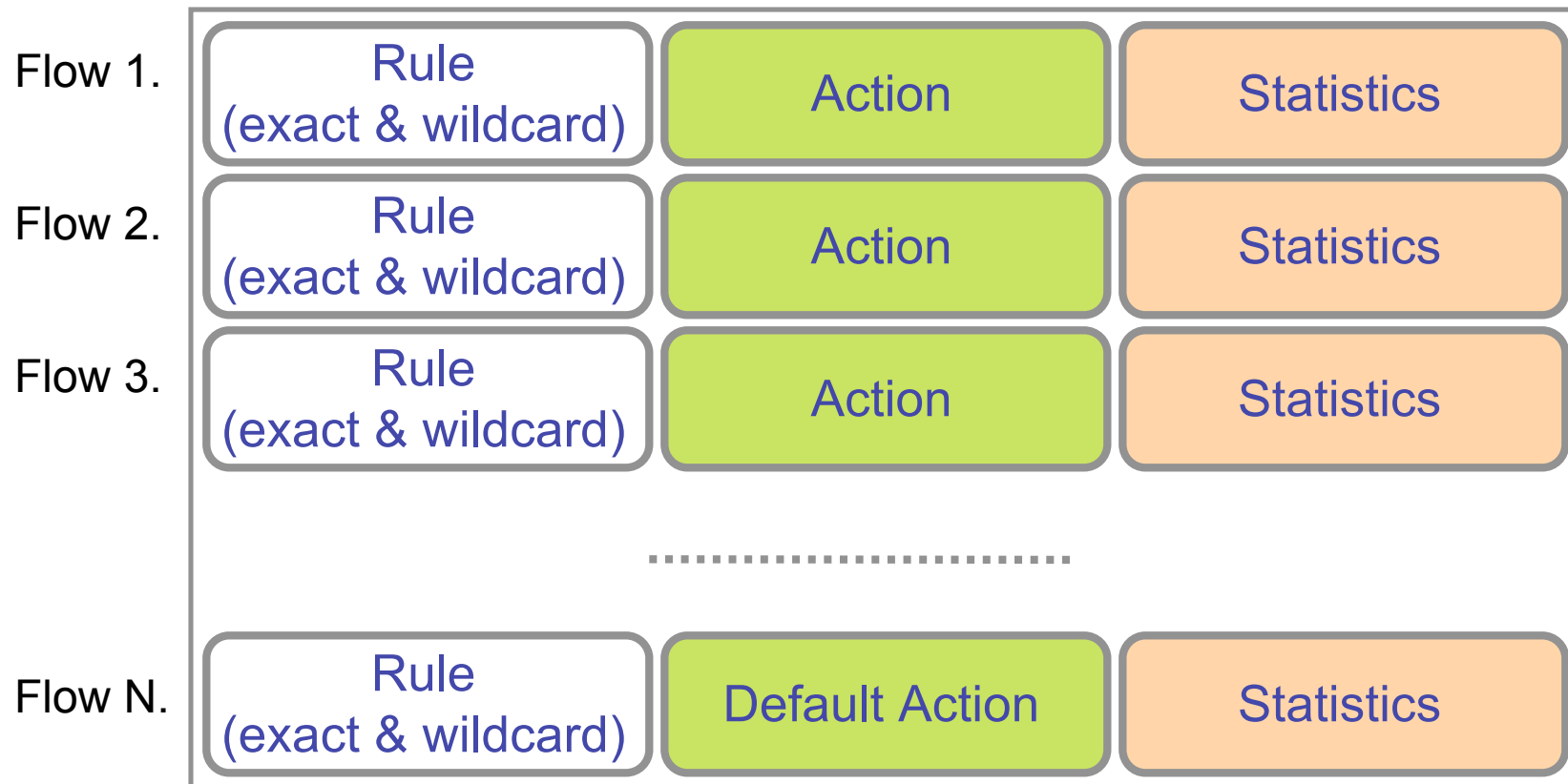
1. Define OpenFlow feature
2. Add OpenFlow to commercial switches and APs
3. Deploy at Stanford
4. Integrate with GENI Clearing House
5. Deploy on many college campus networks
6. We all create lots of open-source software so researchers can build on each other's work

(We're part-way into Stage 2)

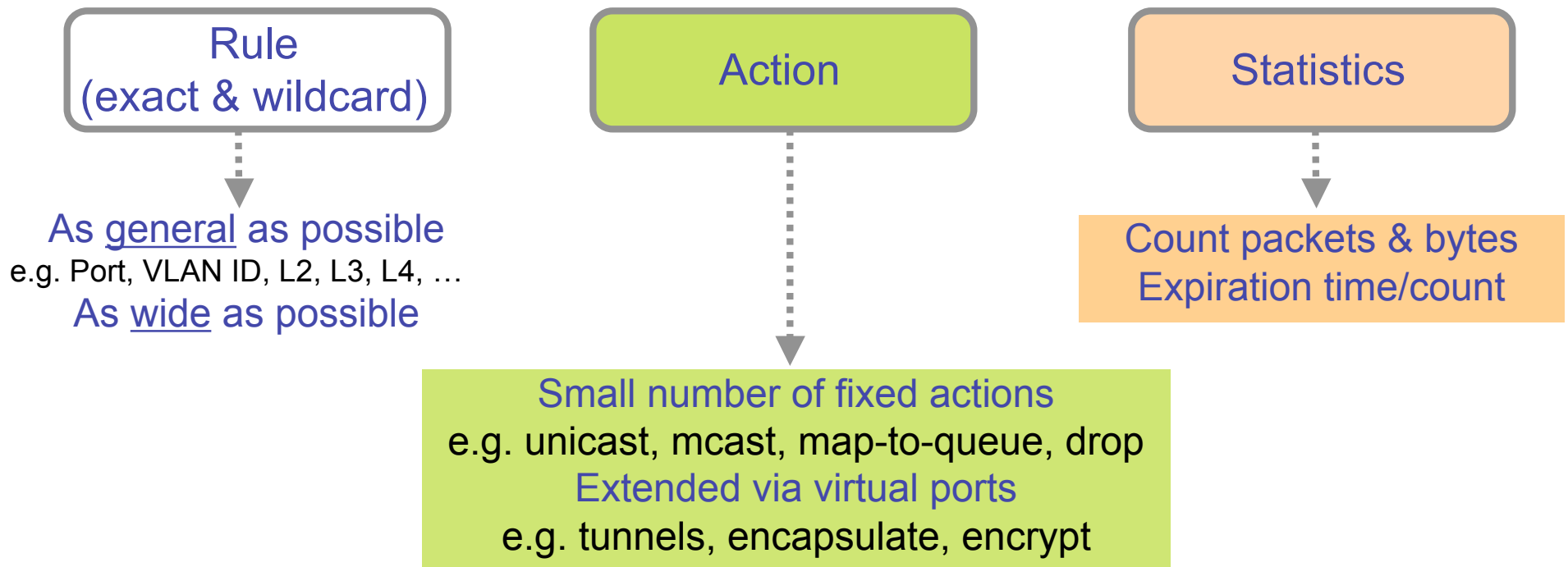
# OpenFlow Basics

# OpenFlow Basics (1)

Exploit the flow table in switches, routers, and chipsets

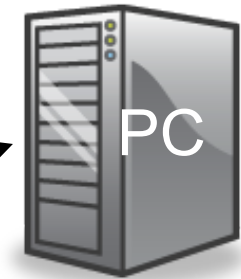


# OpenFlow Basics (2)



# OpenFlow Basics (3)

Controller



*OpenFlow Switch specification*



sw

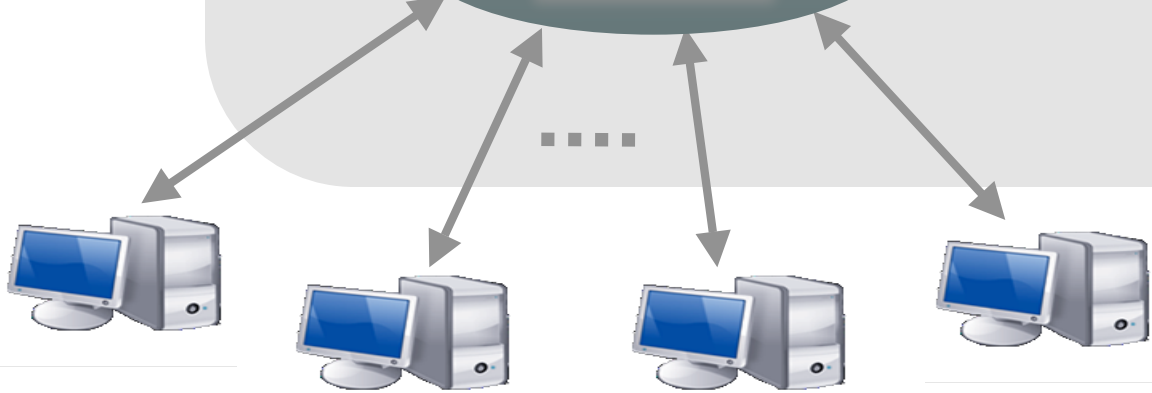
Secure Channel

hw

Flow Table

OpenFlow Protocol  
SSL

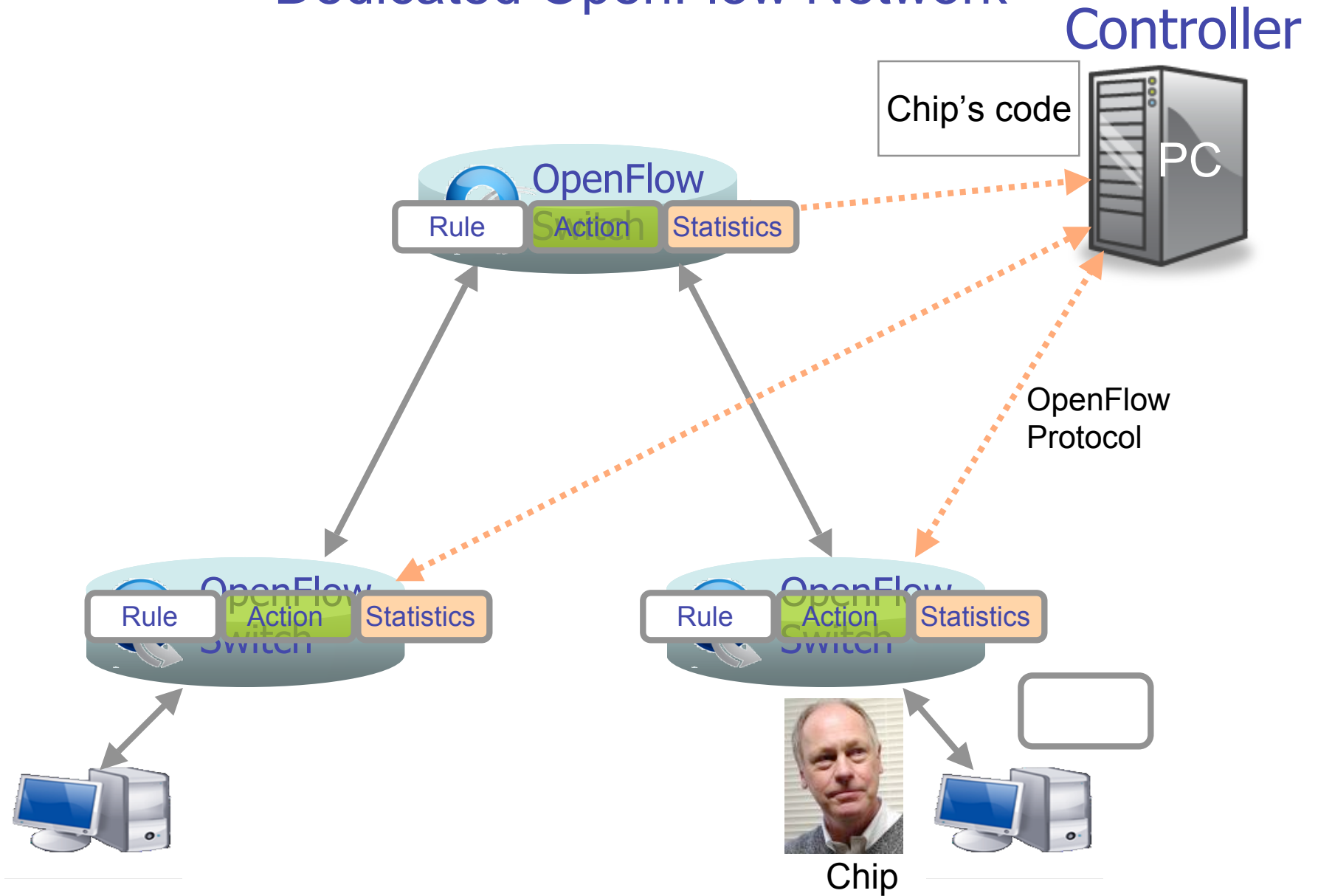
Add/delete flow entries  
Encapsulated packets  
Controller discovery





# OpenFlow Usage

## Dedicated OpenFlow Network



# Usage examples

## Chip's code:

- Static "VLANs"
- His own new routing protocol: unicast, multicast, multipath, load-balancing
- Network access control
- Home network manager
- Mobility manager
- Energy manager
- Packet processor (in controller)
- IPvChip
- Network measurement and visualization
- ...

<http://OpenFlowSwitch.org>



[Documents](#) [Downloads](#) [Wiki](#) [Community](#) [Blog](#) [About](#)



Enable Innovation in your Network.

OpenFlow is an open standard that allows you to run experimental protocols in production networks. It is in the process of being implemented by major switch vendors and used today by universities to deploy innovative networking technology in their campus networks.



**Learn More**

white paper, video,  
sample deployments



**Get Started**

downloads, tutorial  
quickstart guide



**Develop**

reference implementations  
specs and test suites

Let's see an example...

# HP



- Experimental feature on ProCurve 5400-series
- 144-ports of 1GE, hardware forwarding
- OpenFlow added by HP Labs and ProCurve group
- In 23 wiring closets in CS Building at Stanford



Praveen  
Yalagandula



Jean  
Tourrilhes



Sujata  
Banerjee



Rick  
McGeer



Charles  
Clark

# NEC



- Experimental feature on IP8800 series router
- 24-ports of 1GE, 2-ports of 10GE, hardware forwarding
- OpenFlow added by NEC team in Japan
- NEC announced plans for OpenFlow products
- Deployed at Stanford and in JGN2plus in Tokyo



Atsushi  
Iwata



Hideyuki  
Shimonishi



Jun  
Suzuki



Masanori  
Takashima



Nobuyuki  
Enomoto



Philavong  
Minaxay



Shuichi  
Saito  
NEC/NICT



Tatsuya  
Yabe



Yoshihiko  
Kanaumi  
NEC/NICT

# Juniper



- OpenFlow added to Junos SDK
- First platform: MX-480 carrier class Ethernet
- 24-ports 10GE or 240-ports 1GE
- Hardware forwarding
- Deployed in Internet2 in NY and at Stanford



Umesh  
Krishnaswamy



Michaela  
Mezo



Parag  
Bajaria



James  
Kelly



Bobby  
Vandalore



Shamit  
Kapadia

# Cisco



- Experimental feature on Catalyst 6509
- Software forwarding
- Deployed at Stanford



Pere  
Monclus



Sailesh  
Kumar



Flavio  
Bonomi

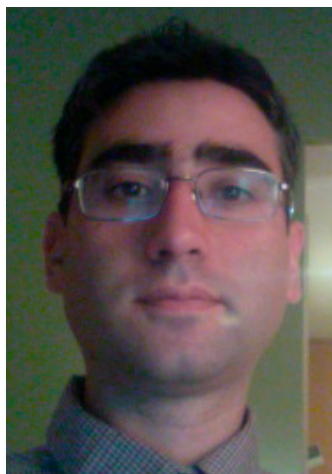


# Nicira

Controller



- Created NOX controller
- Available at <http://NOXrepo.org> (GPL)
- Deployed at Stanford



Martin  
Casado



Scott  
Shenker



Teemu  
Koponen



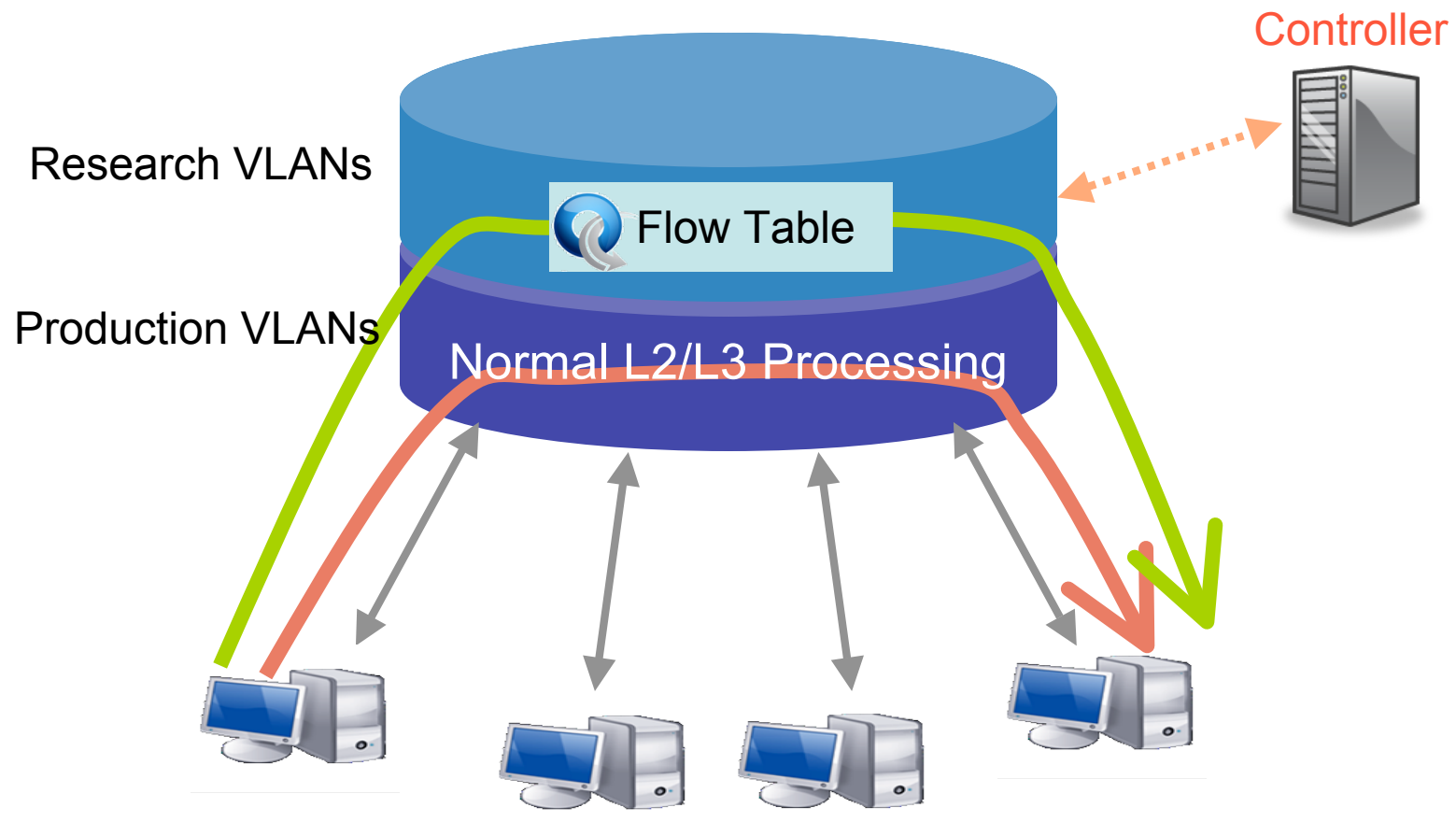
Natasha  
Gude



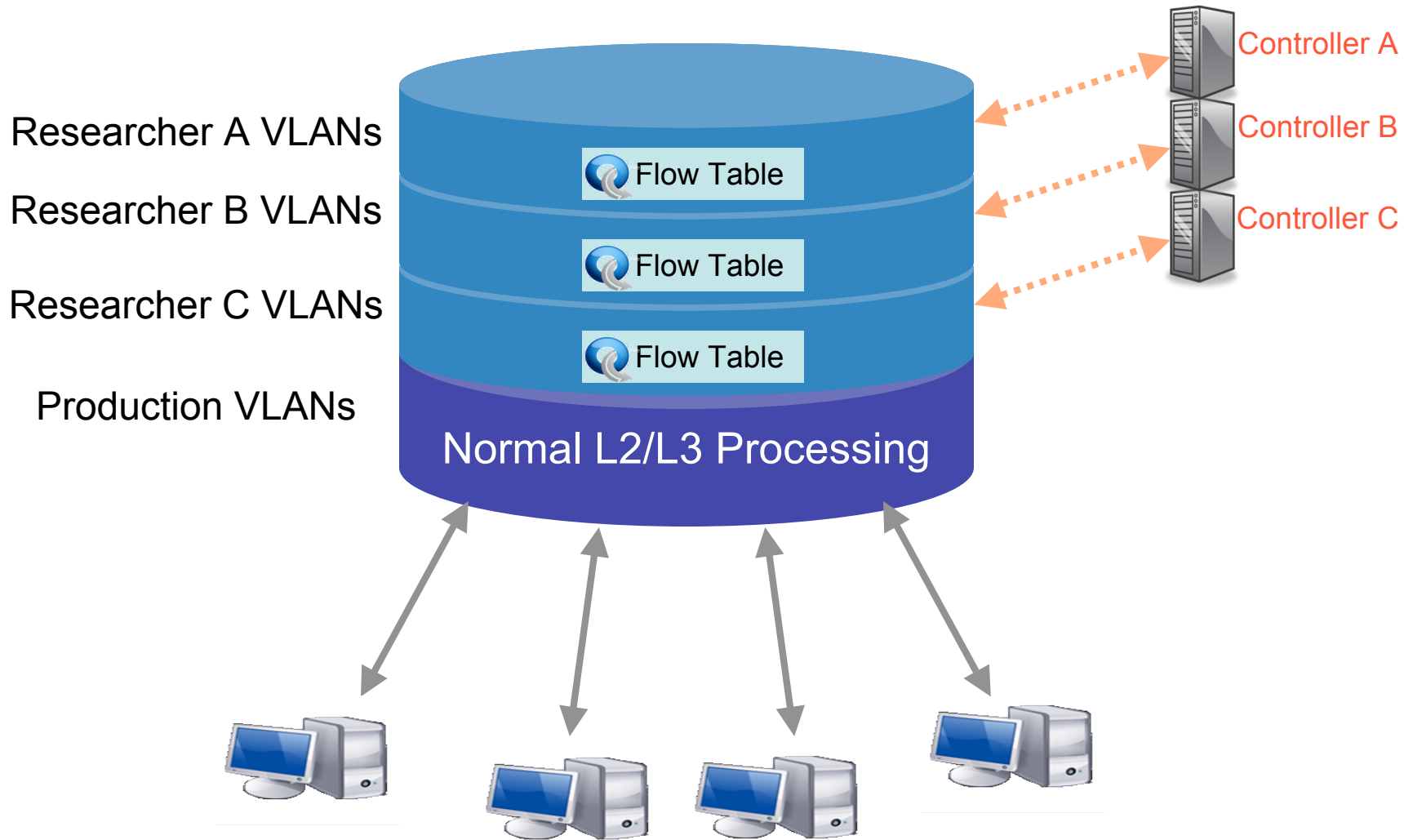
Justin  
Pettit

# Using Enterprise GENI for research

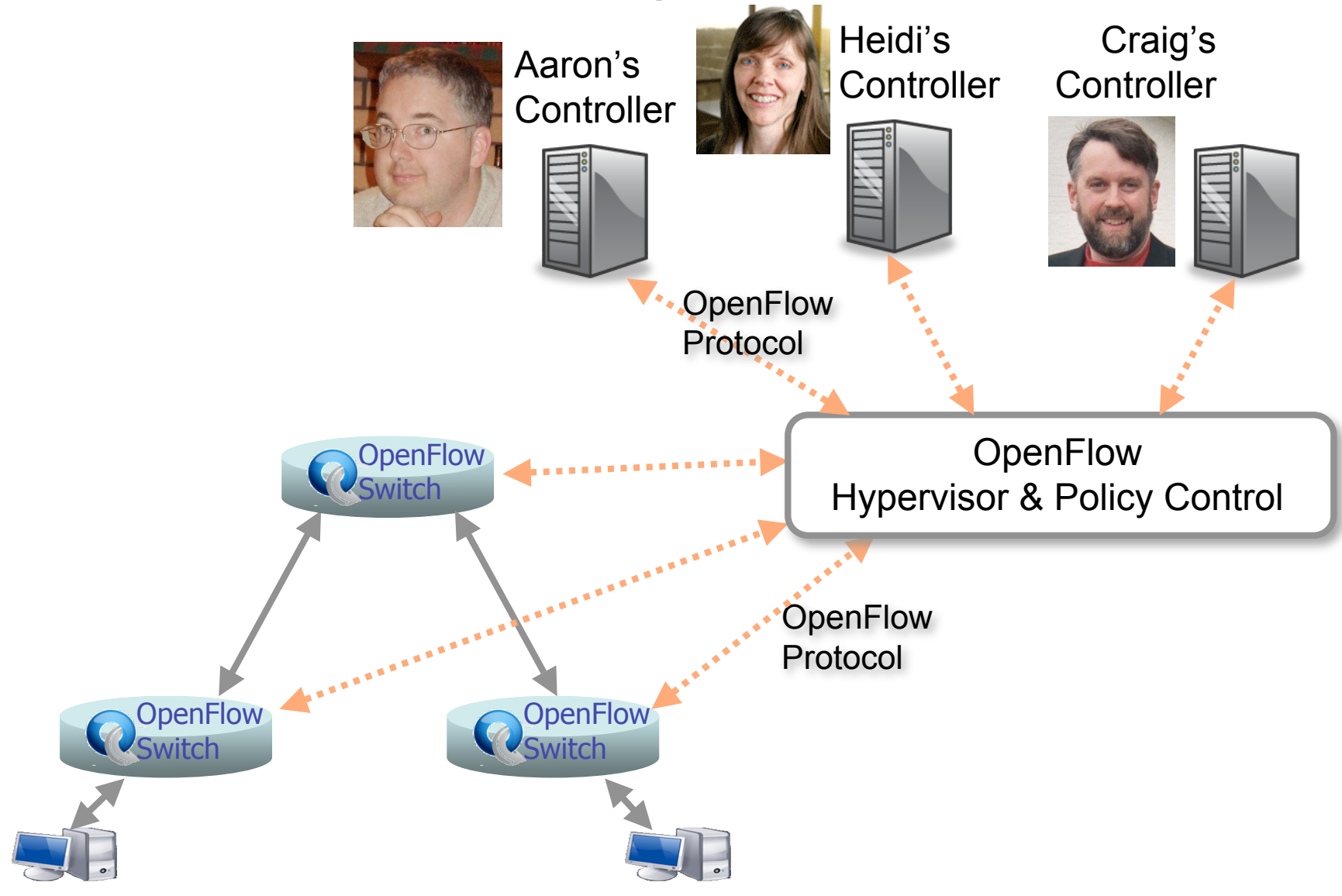
# Step 1: Separate VLANs for Production and Research Traffic



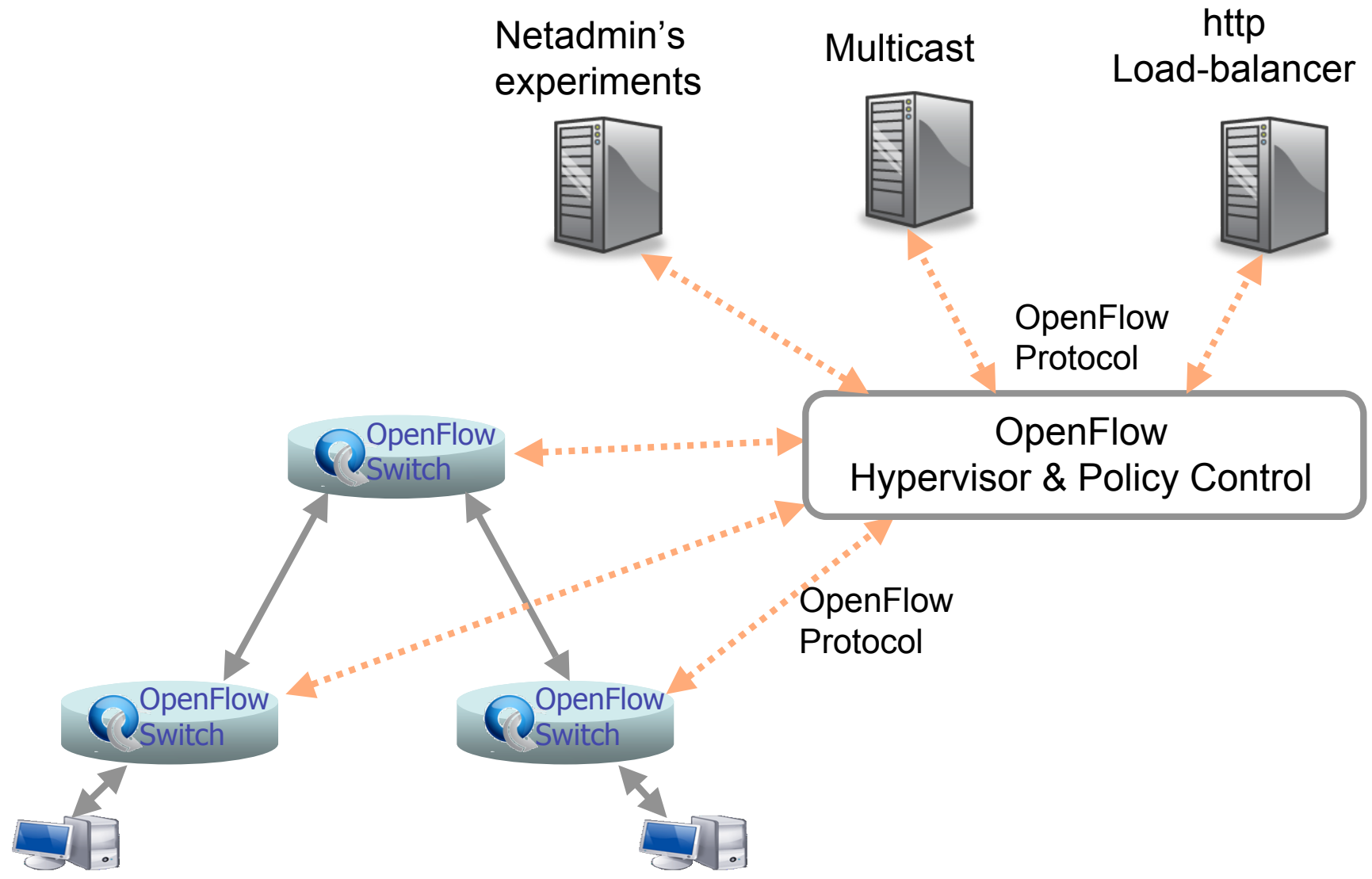
# Step 2: Virtualize OpenFlow Switch



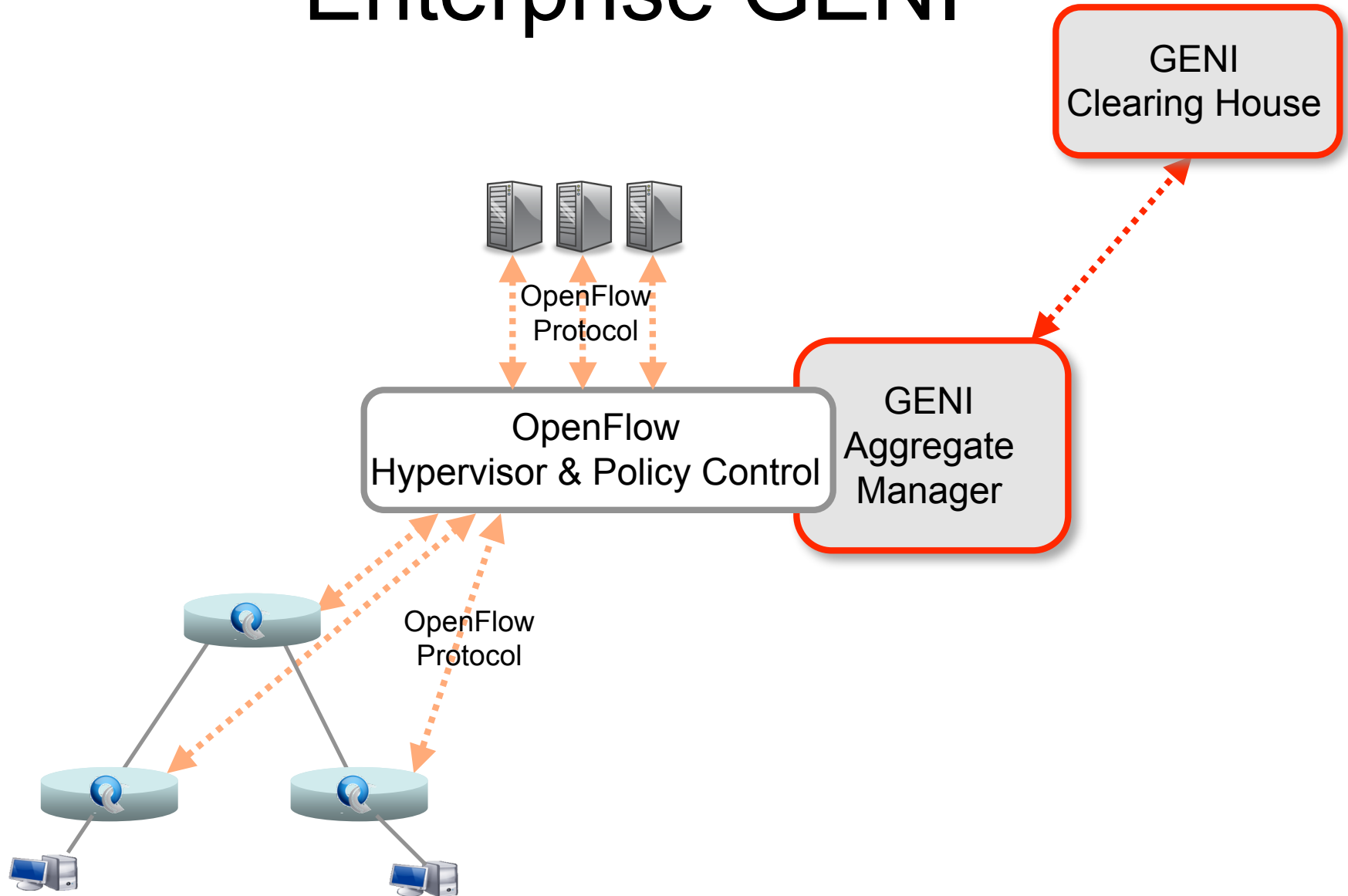
# Virtualizing Control



# Virtualizing Control



# Enterprise GENI



# Many Open Questions!

- ❖ Scalability of a controller
- ❖ Load-balancing over redundant controllers
- ❖ Federation, hierarchy and aggregation
- ❖ Protecting the controller against DDOS

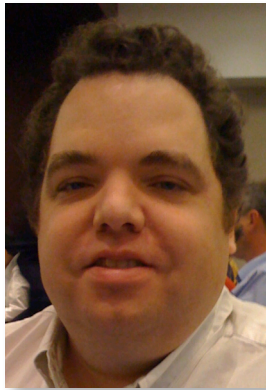
Our goal is to enable the research community to explore all these questions



# Thanks...

(It takes a village)

# Internet2 Team



Chris Small



Matt Zekauskas

Installing Juniper MX-480 in NY



Stanford Team

We plan trials in early 2009  
5-6 college campuses

Contact us if you would like to take part  
[nickm@stanford.edu](mailto:nickm@stanford.edu)