CLEMSON UNIVERSITY

Software Defined Networking, OpenFlow, What Does It Do for Us

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Electrical & Computer Engineering
Clemson University

A Quick Internet History (1970's-2010's)

'69- '85 ARPANET ('81 IPv4) 50 kb/s → 230.4 kb/s
'85- '95 NSFNET 56 kb/s → T3:45 Mb/s
'93-now commercial ('98 IPv6) … → 100 Gb/s
plenty of protocols, apps, contents created

World IPv6 Day 06-08-2011

- Wireless technologies also has been evolving
  - Faster, more ubiquitous, lower power, lower cost


WiFi


Bluetooth


Zigbee


MIMO

DSRC

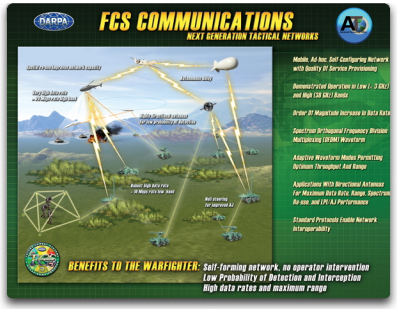
WiMAX

LTE

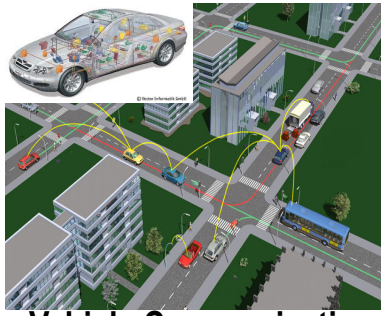
Wireless USB

WiGig

  - A number of new network settings surfaced as well



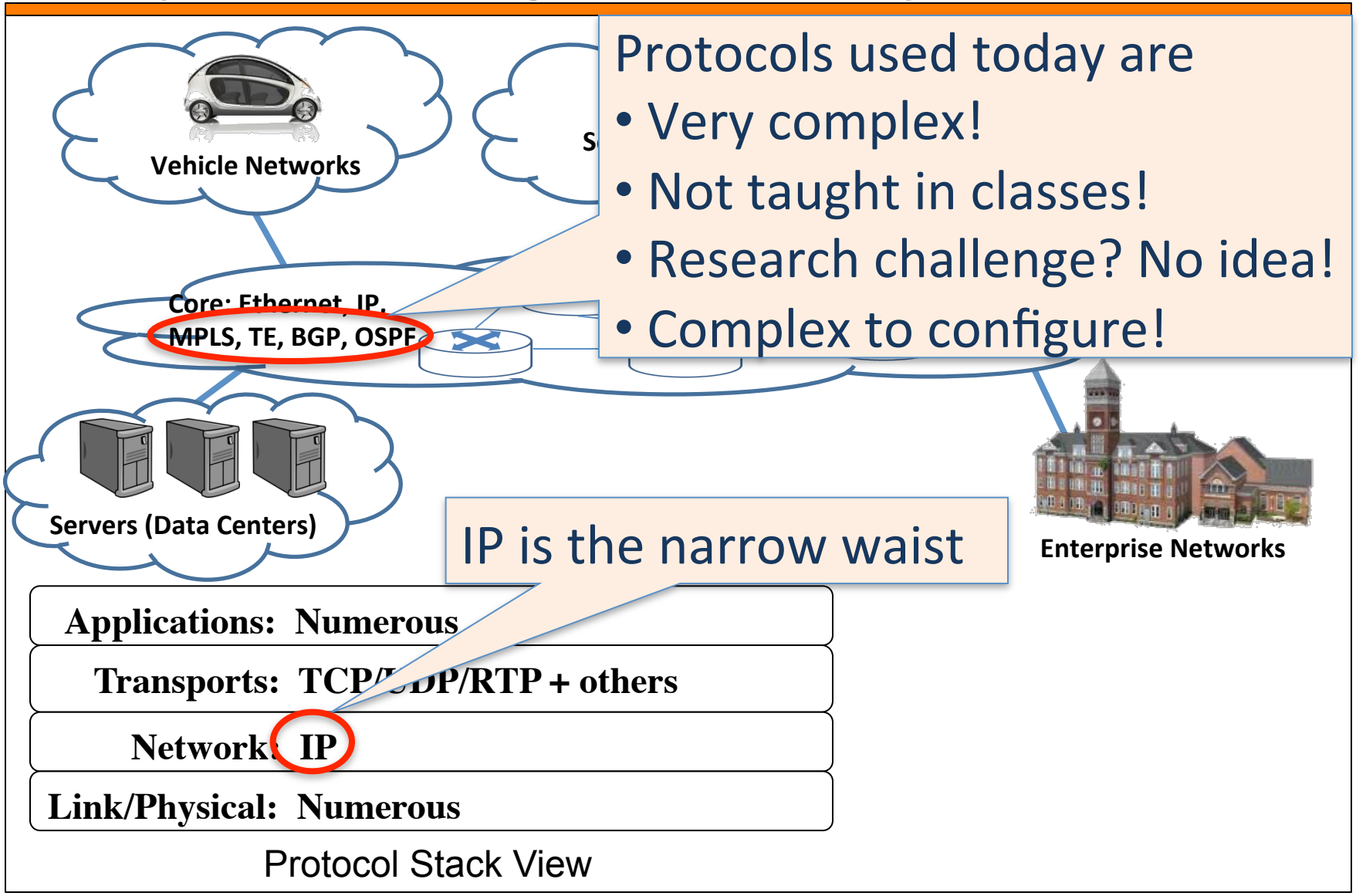
Military Communication
MANET


Vehicle Communication
V2V/V2I, Smart Grid

e-Manufacturing
sensor actuator network

e-Health
body and environment sensors

Open Challenges for Today's Internet



In the mean time …

GENI

Global Environment for Network Innovations

A NSF Testbed for Future Internet Research with Deep Programmability, Virtualized Components, and Real Users

Chip Elliott
BBN Technologies
GENI Project Director
www.geni.net

Sponsored by the National Science Foundation

Community Sees Three Internet Challenges

Science Issues

We cannot currently understand or predict the behavior of complex, large-scale networks

Innovation Issues

Substantial barriers to at-scale experimentation with new architectures, services, and technologies

Society Issues

We increasingly rely on the Internet but are unsure we can trust its security, privacy or resilience

NSF Future Internet Architecture (FIA) Projects

Press Release 10-156

NSF Announces Future Internet Architecture Awards

Awards will help develop new ideas and innovations towards the development of a more robust, secure and reliable Internet

Children using the Internet for a school project.
Credit and Larger Version

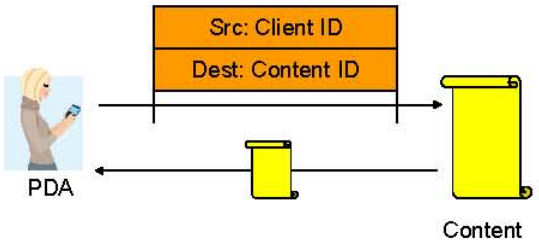
August 27, 2010

The Directorate for Computer and Information Science and Engineering (CISE) at the National Science Foundation (NSF) announced today awards for four new projects, each worth up to $8 million over three years, as part of the Future Internet Architecture (FIA) program.

These awards will enable researchers at dozens of institutions across the country to pursue new ways to build a more trustworthy and robust Internet.

XIA: eXpressive Internet Architecture

eXpressive Internet Architecture



- Client expresses communication intent for content explicitly
  - Network uses content identifier to retrieve content from appropriate location
- How does client know the content is correct?
  - Intrinsic security! Verify content using self-certifying id: hash(content) = content id
- How does source know it is talking to the right client?
  - Intrinsic security! Self-certifying host identifiers

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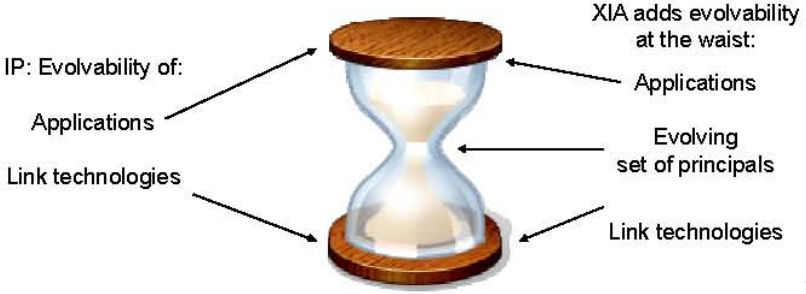
XIA: An Architecture for a Trustworthy and Evolvable Future Internet

Peter Steenkiste, Dave Andersen, David Eckhardt, Sara Kiesler, Jon Peha, Adrian Perrig, Srini Seshan, Marvin Sirbu, Hui Zhang, Carnegie Mellon University
Aditya Akella, University of Wisconsin
John Byers, Boston University

What Do We Mean by Evolvability?

- Narrow waist of the Internet has allowed the network to evolve significantly
- But need to evolve the waist as well!
  - Can make the waist smarter



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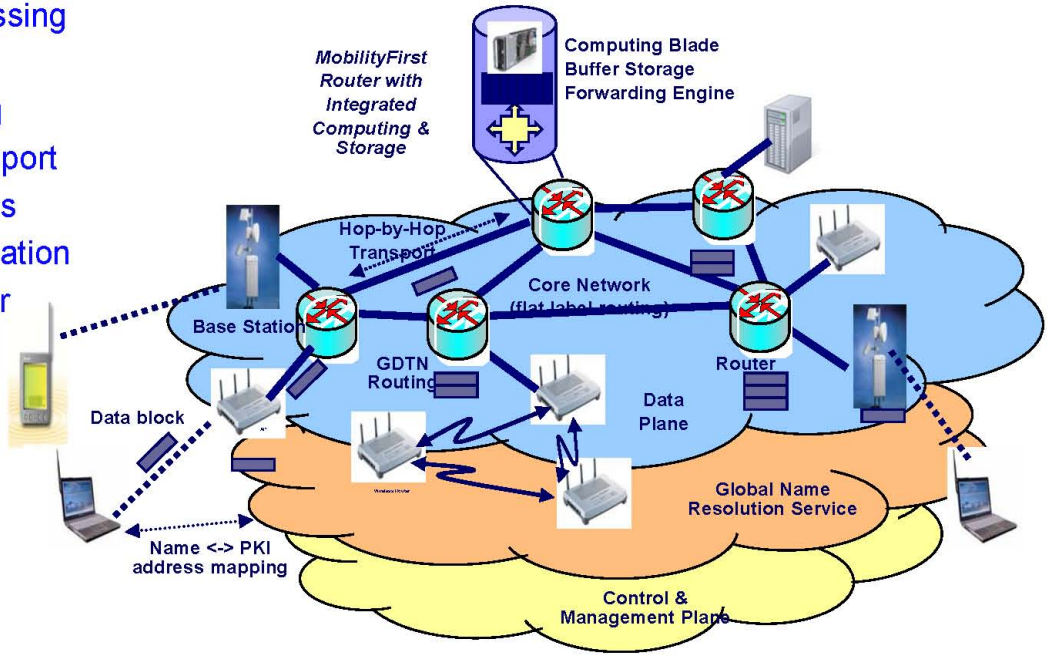
MobilityFirst

- Separation of naming & addressing
- Fast global naming service
- Storage-aware (GDTN) routing
- Hop-by-hop (segmented) transport
- Self-certifying public key names
- Support for content/context/location
- Programmable computing layer
- Separate network mgmt plane



New components, very distinct from IP, intended to achieve key mobile Internet design goals

RUTGERS (LEAD)
D. Raychaudhuri, M. Gruteser, W. Trappe, R, Martin, Y. Zhang, I. Seskar, K. Nagaraja, S. Nelson

A. Venkataramani, J. Kurose, D. Towsley

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL
M. Reiter

Duke UNIVERSITY
X. Yang, R. RoyChowdhury

UMASS LOWELL
G. Chen

University of Nebraska Lincoln
B. Ramamurthy

THE UNIVERSITY of WISCONSIN MADISON
S. Bannerjee

Massachusetts Institute of Technology
W. Lehr

MICHIGAN
Z. Morley Mao

The GENI Testbed

- GENI has a diverse, rapidly growing set of resources – mostly prototypes – available for experimenter use
  - Compute resources: VM, hosts, cloud
  - Network resources: programmable switches, routers, & wireless

A GENI ‘slice’ can interconnect any of them using a range of connectivity options

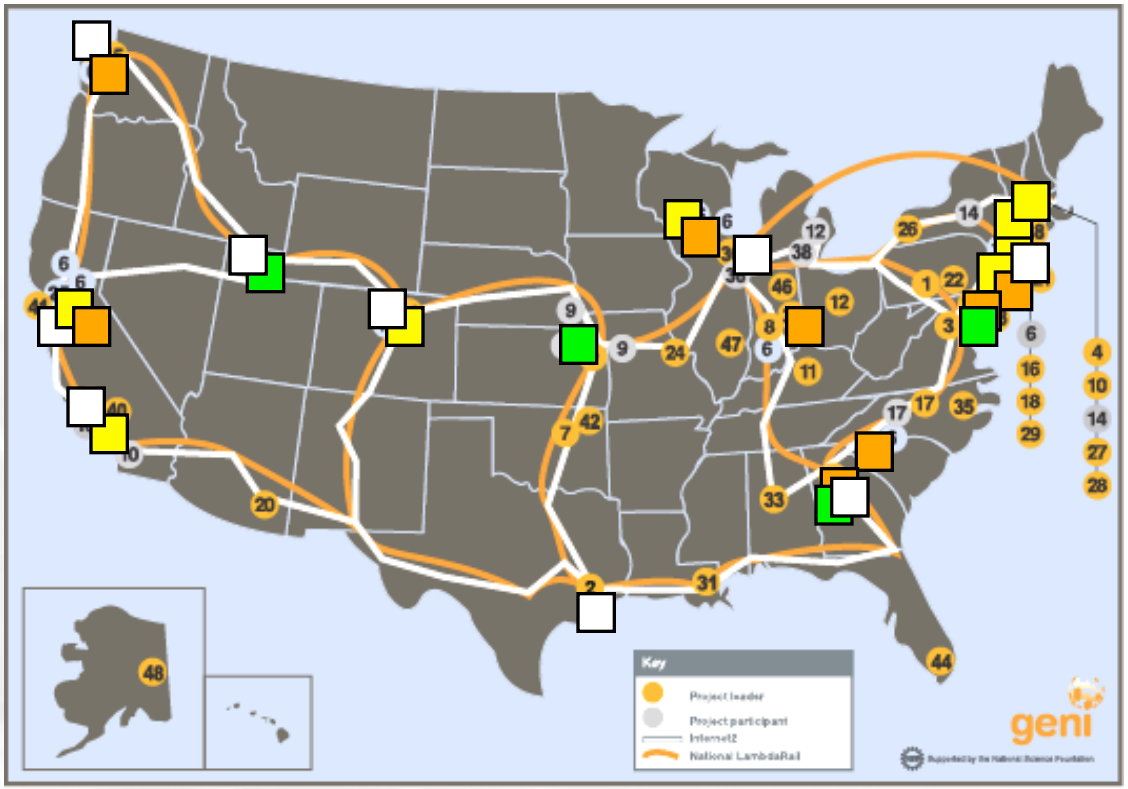
Nationwide Meso-scale OpenFlow Network

OpenFlow

Stanford
U Washington
Wisconsin U
Indiana U
Rutgers
Princeton
Clemson
Georgia Tech

ShadowNet

Salt Lake City
Kansas City
Washington, DC
Atlanta



WiMAX

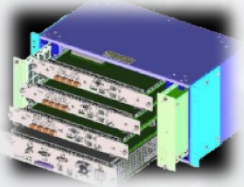
Stanford
UCLA
UC Boulder
Wisconsin
Rutgers
NYU Polytech
UMass
Columbia

OpenFlow Backbones

Seattle
Salt Lake City
Sunnyvale
Denver
New York City
Houston
Chicago
Los Angeles
Atlanta

HP ProCurve 5400 Switch

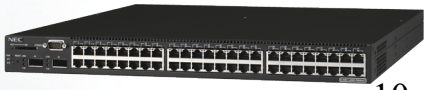
Juniper MX240 Ethernet Services Router



NEC WiMAX Base Station

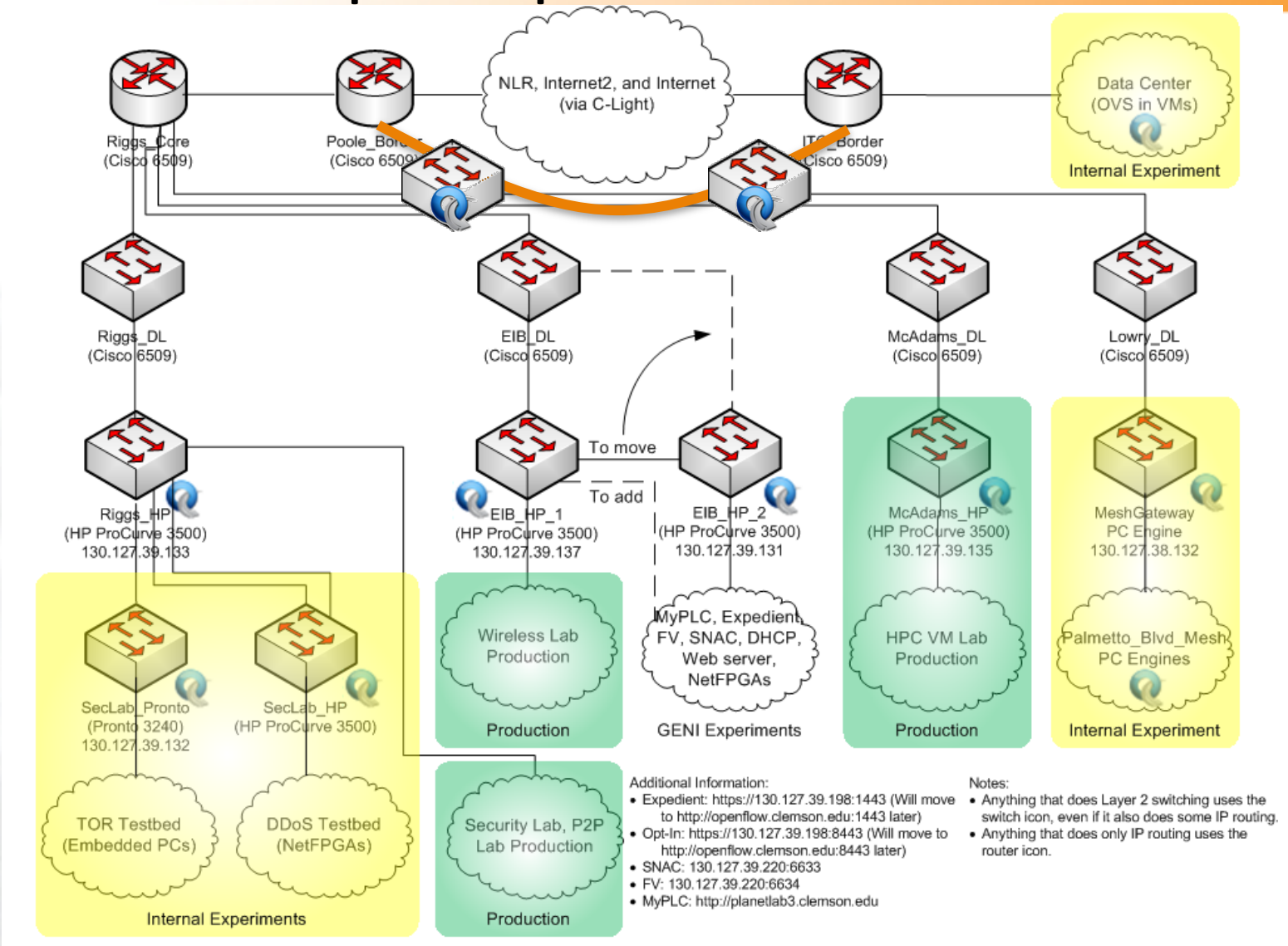
Toroki LightSwitch 4810

Arista 7124S Switch



NEC IP8800 Ethernet Switch

Campus OpenFlow Network



Looking ahead…

- GENI Racks
  - Notionally: rack of ~40 computers & programmable switch, connected to a GENI backbone
  - Next 2-3 years: 20-40 racks in campuses, industrial research labs, topologically significant locations

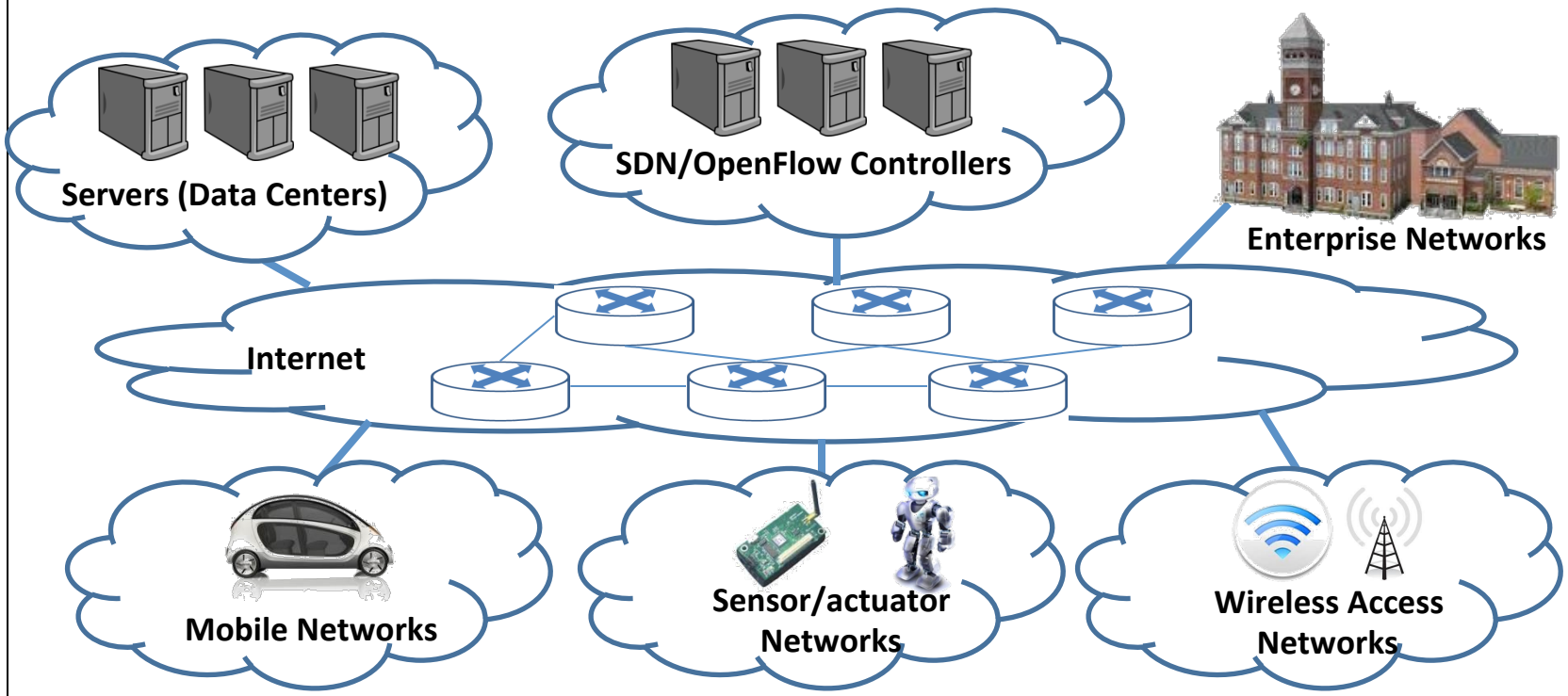
GENI Racks

- Real users
  - Notionally: Enable campus networks to allow students , faculty, & staff to directly join (opt-in) in GENI experiments
  - Next 2-3 years: OpenFlow and WiMax deployments on 10-20 campuses enable direct-to-end-system experiments

Opt-In Users

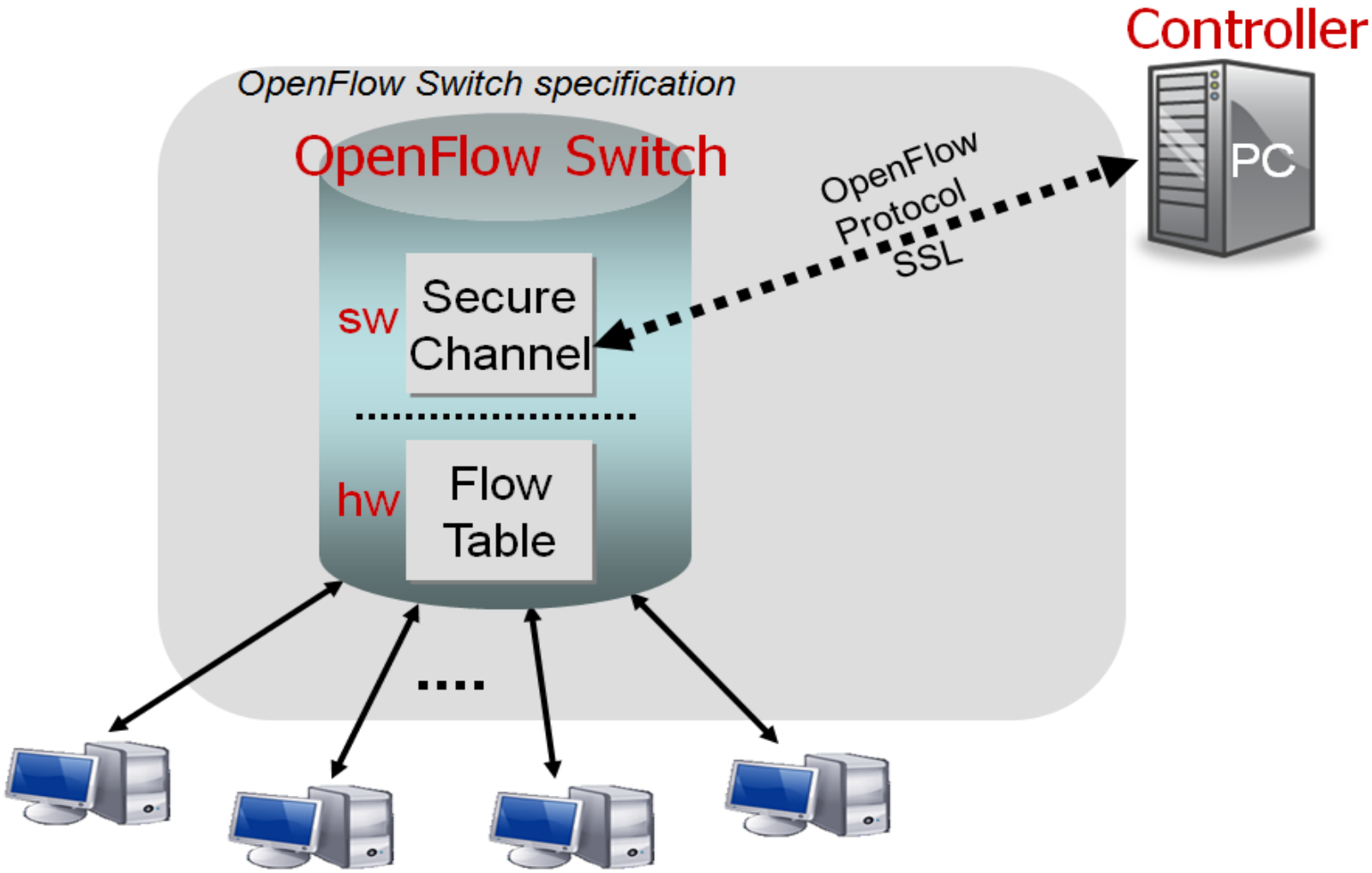
GENI's vision: expand reach to 100-200 campuses

OpenFlow: A Software Defined Networking Paradigm



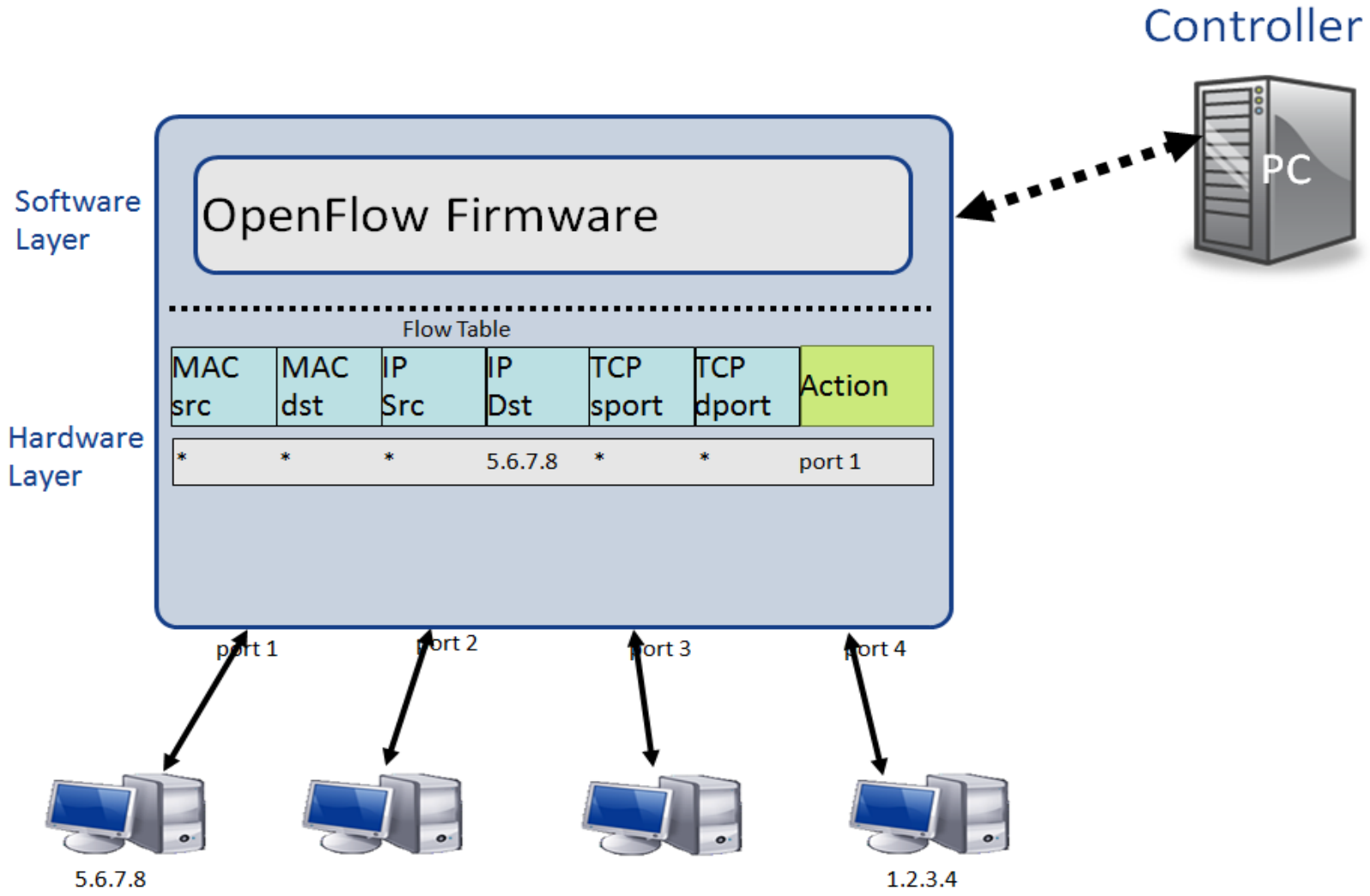
- Software Defined Networking (SDN)
  - OpenFlow as one first commercial SDN solution
  - Network switching by software controllers – automated operation
  - Single-view control plane – unified management
  - Virtualized infrastructure – seamless, secured/isolated sharing

OpenFlow Approach



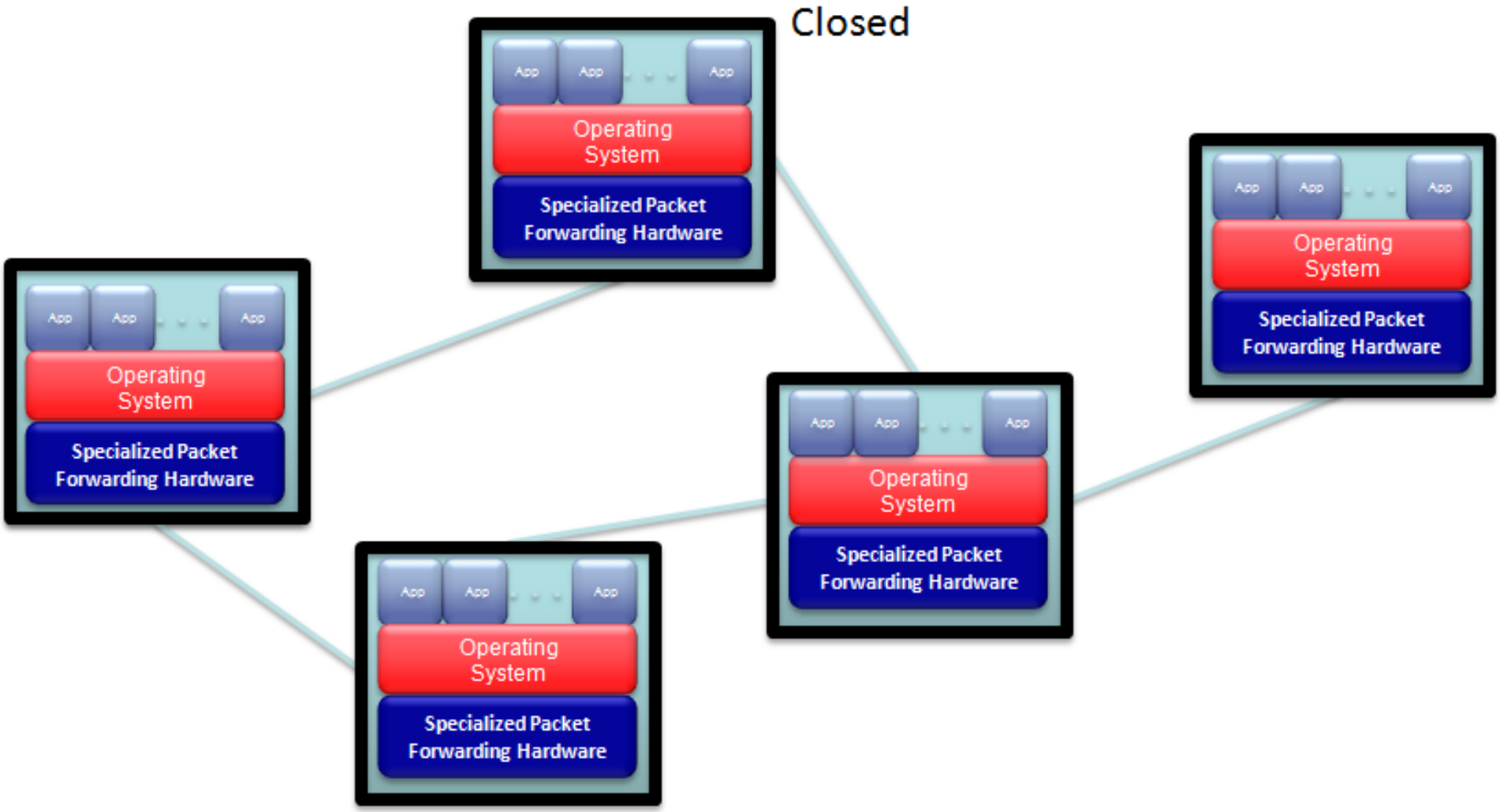
Graphics Courtesy of Stanford Clean-Slate Program

OpenFlow Flow Table: Matching + Action



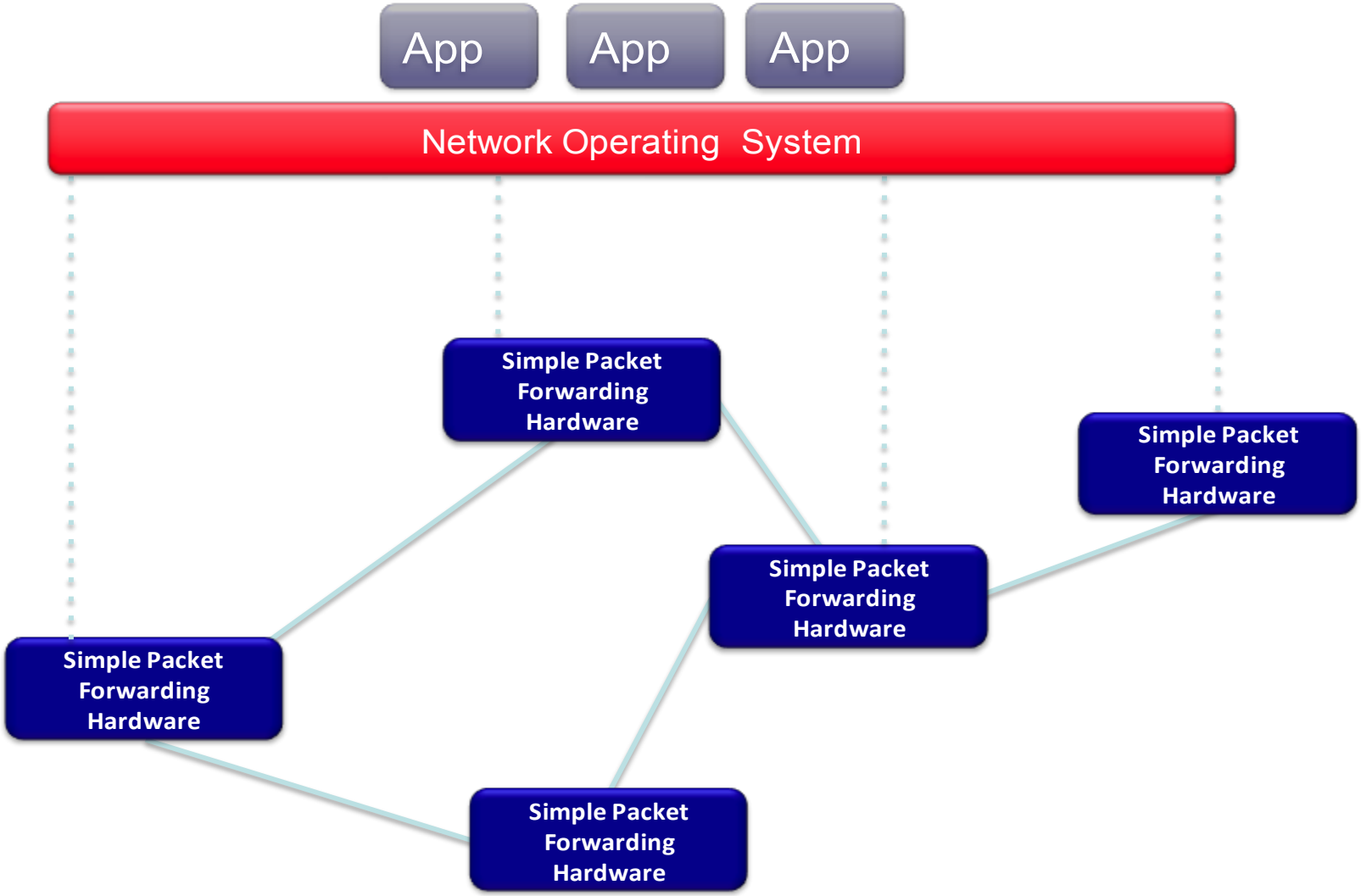
Graphics Courtesy of Stanford Clean-Slate Program

Today: Distributed Network Control Plane



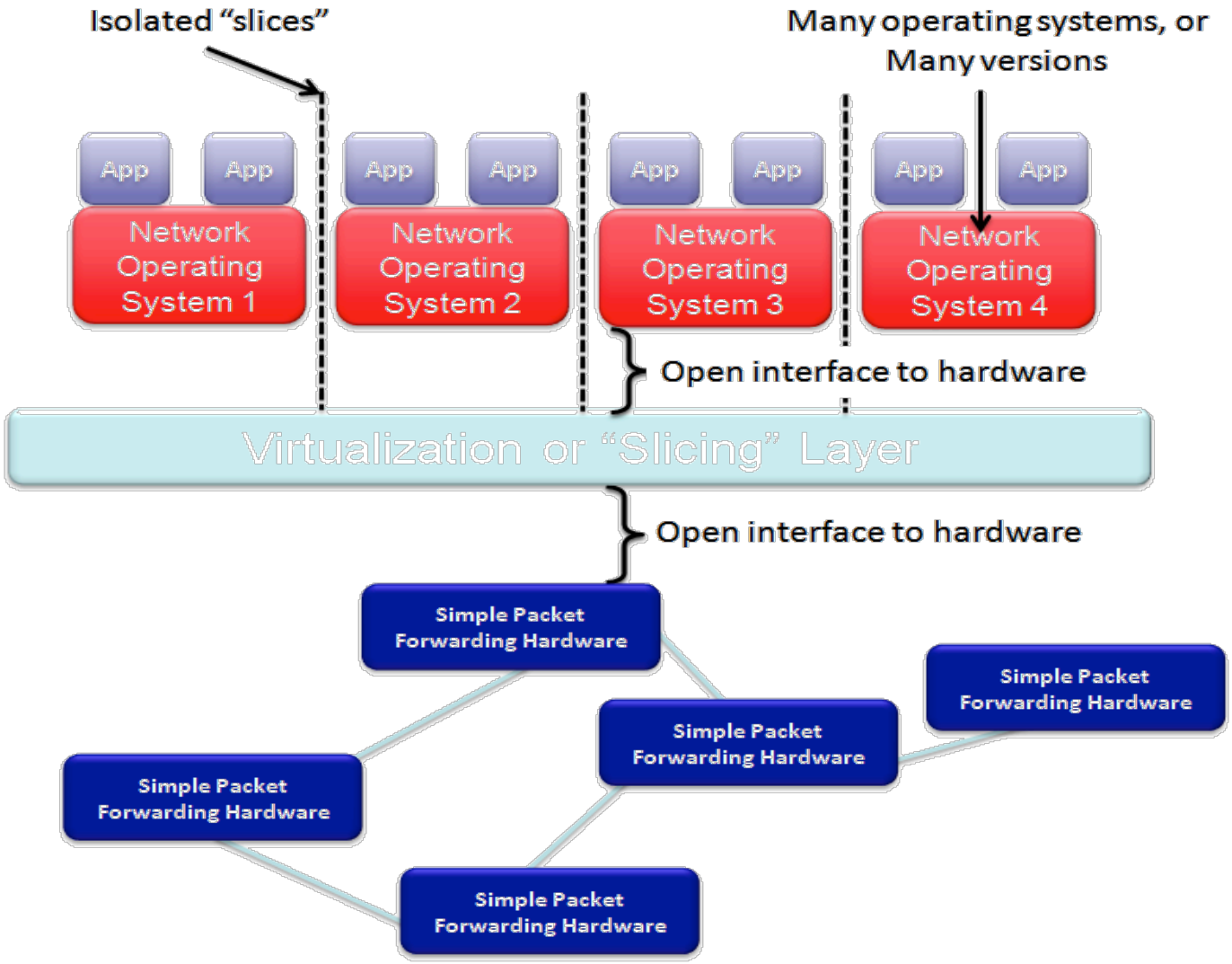
Graphics Courtesy of Stanford Clean-Slate Program

SDN: Centralized Network Control Plane



Graphics Courtesy of Stanford Clean-Slate Program

SDN: Control Plane Virtualization



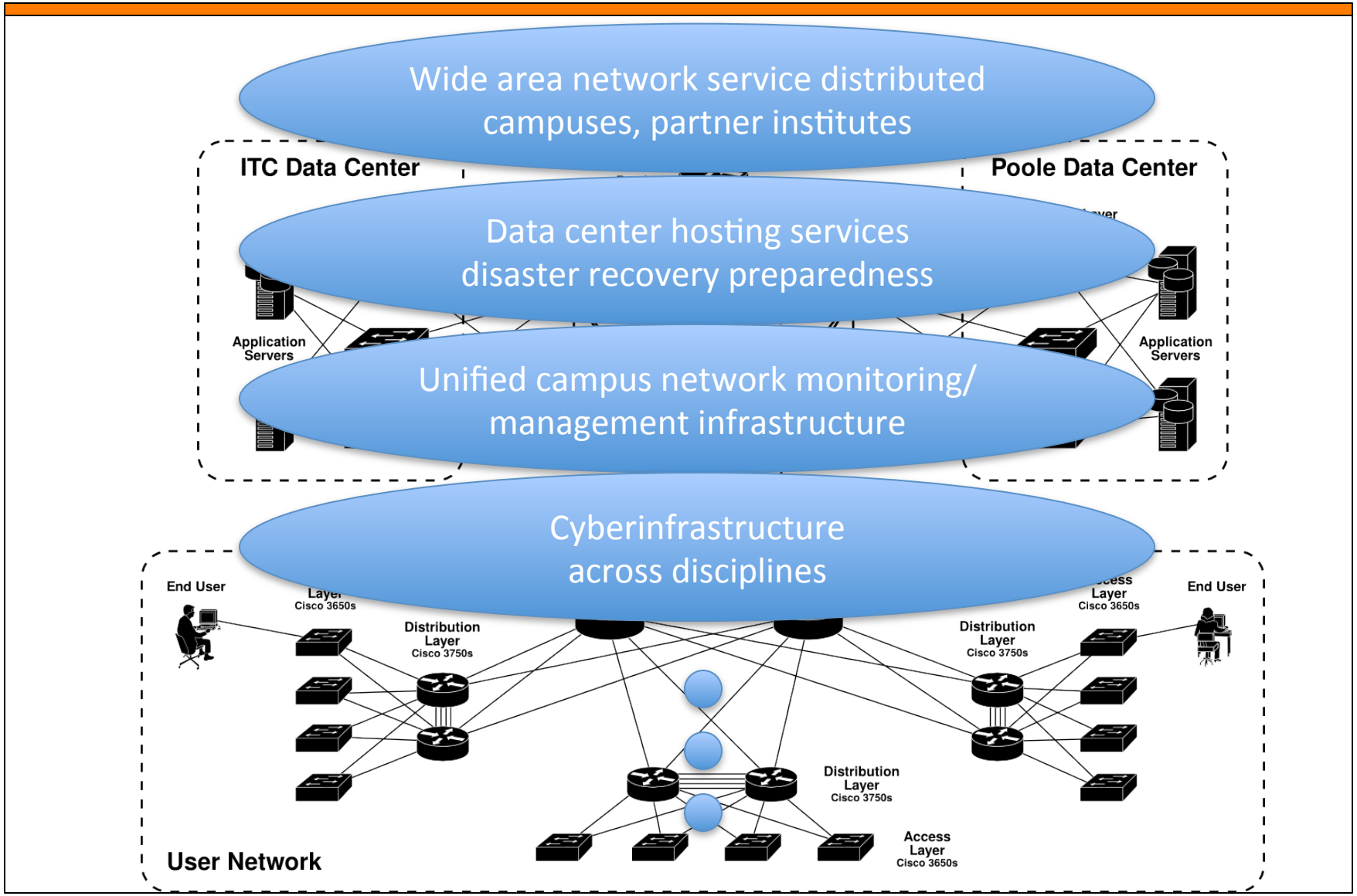
Graphics Courtesy of Stanford Clean-Slate Program

What Will SDN Change?

- It changes many things
  - L2: topology discovery instead of spanning tree protocols
  - L3: centralized routing on global network view
  - Routing need not be based only on IP
  - Routes between computers can differ for different apps
  - Do path engineering instead of routing
- It does not change everything
  - Network remains a distributed system
  - Network still needs distributed consistency
  - Network still needs to handle racing conditions
  - Centralized control still lacks fast adaptation, resiliency, scalability – need distributed actions, too

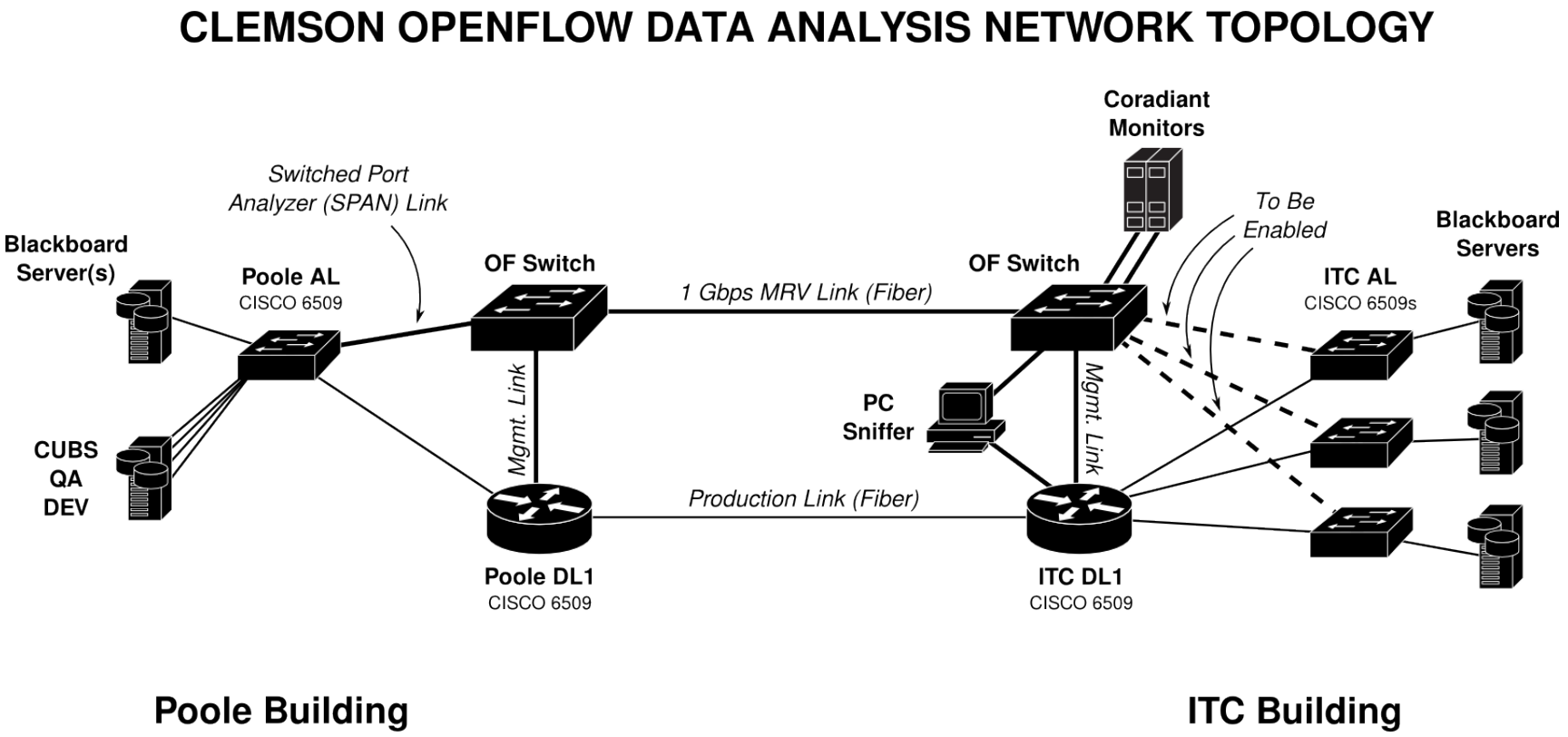
WHAT DOES SDN DO FOR US?

Manage Complex Networks More Easily, Automated

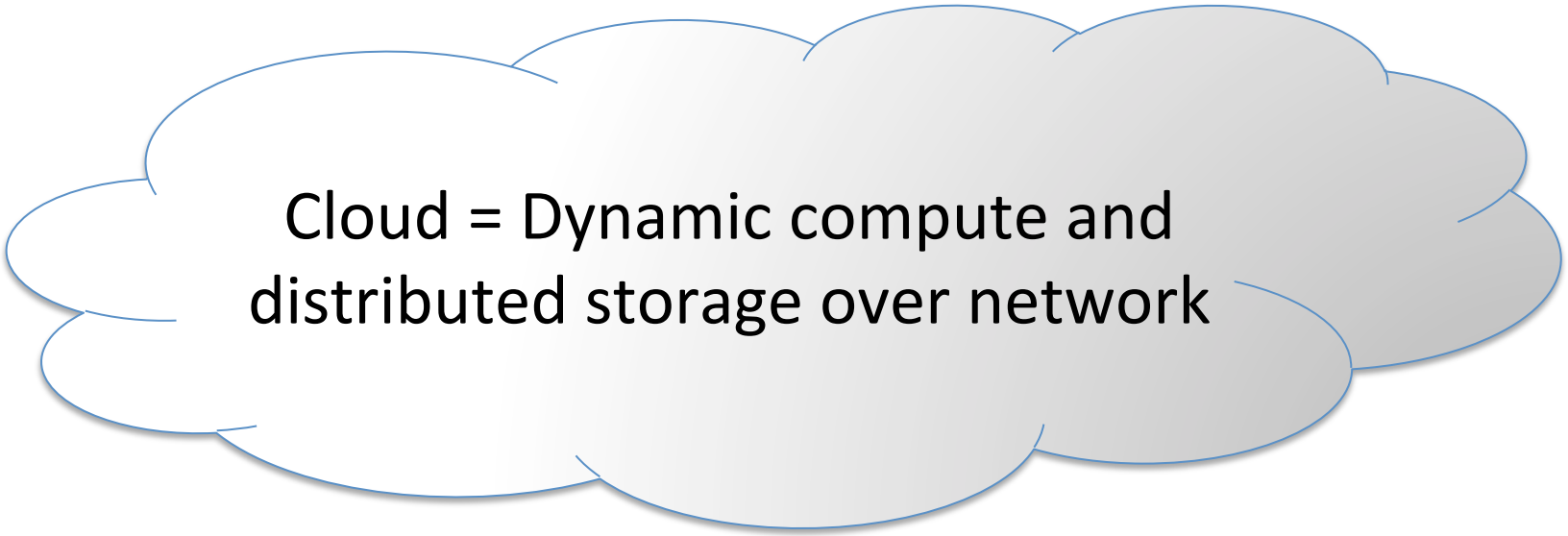


Data Analysis Networks

- Security group has been asking for distributed analysis solution
- Server group has been asking for application tracking solution

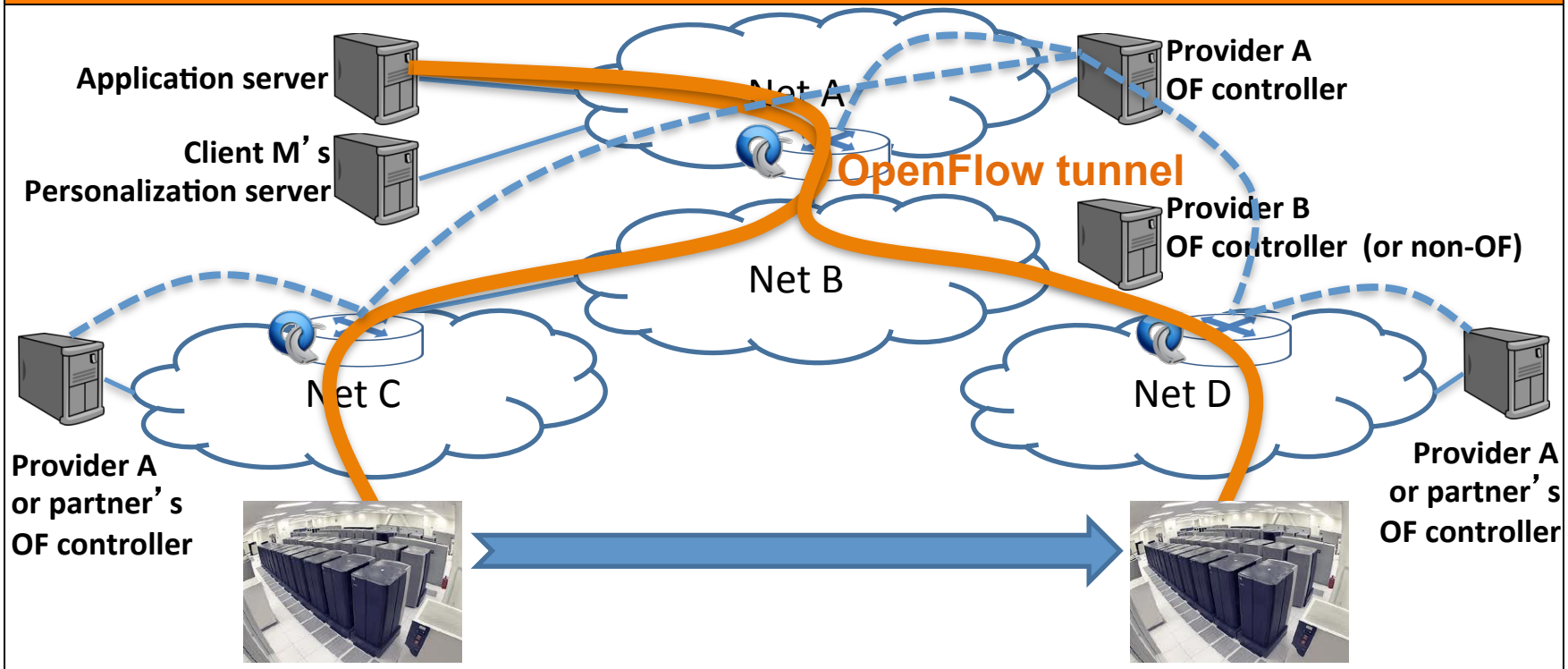


"Cloud" vs. SDN?



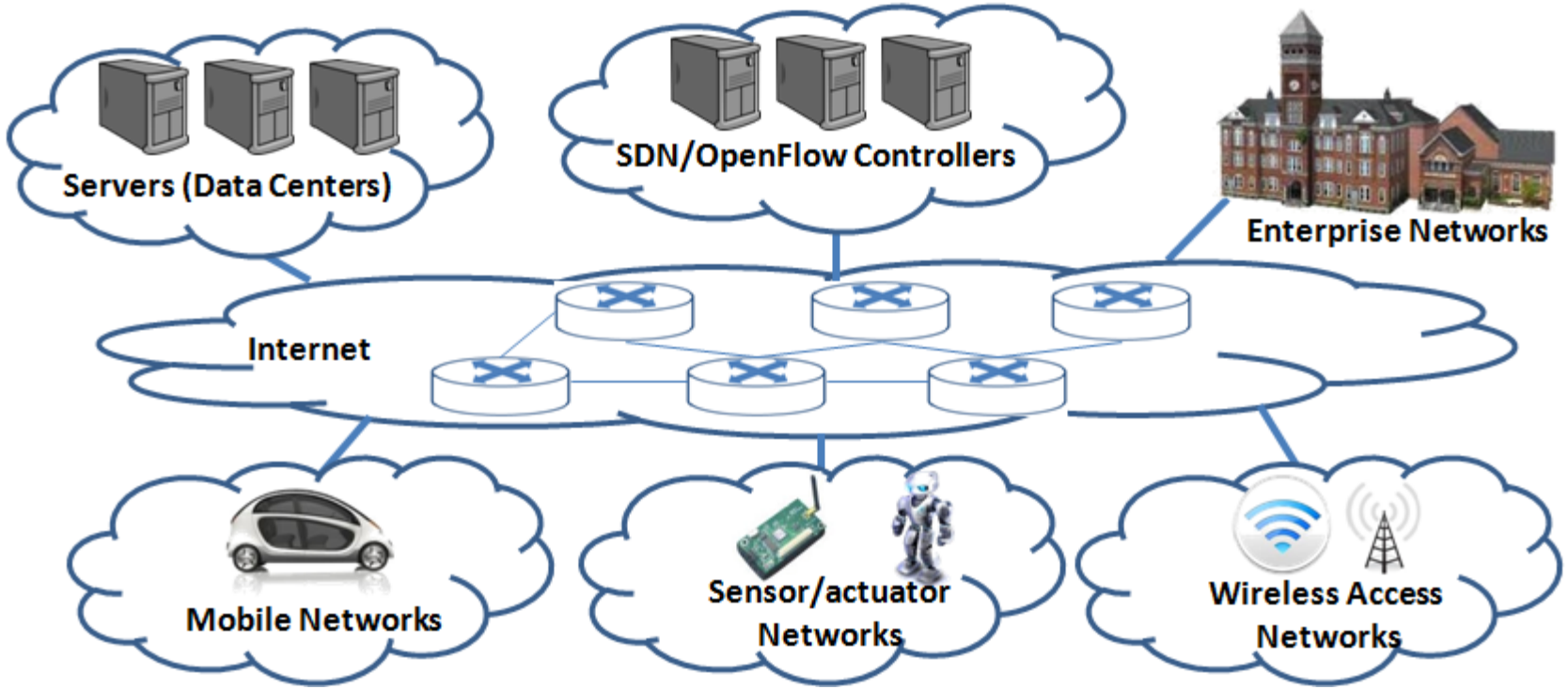
- Data centers, many of them
  - Configured on demand (e.g., Amazon, Rackspace)
- Cloud computing: data → servers, servers→data
  - Dynamic servers, dynamic storage → dynamic network
  - Disaster recovery: data center migration

Data Center Disaster Recovery



- From **reactive** to **proactive** networking
  - Mobile IP: Distributed, **reactive** (long latency), requires compatible agents everywhere, **provider-dictated**
  - OpenFlow: Centralized, **proactive**, solutions for diverse network scenarios, opportunities for both **provider and client customization**

SDN: Seamless Adaptation vs. Explicit Control?

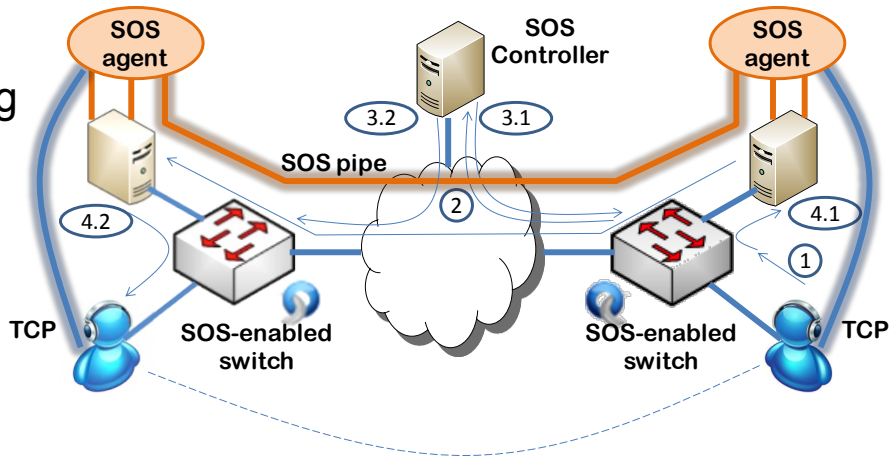


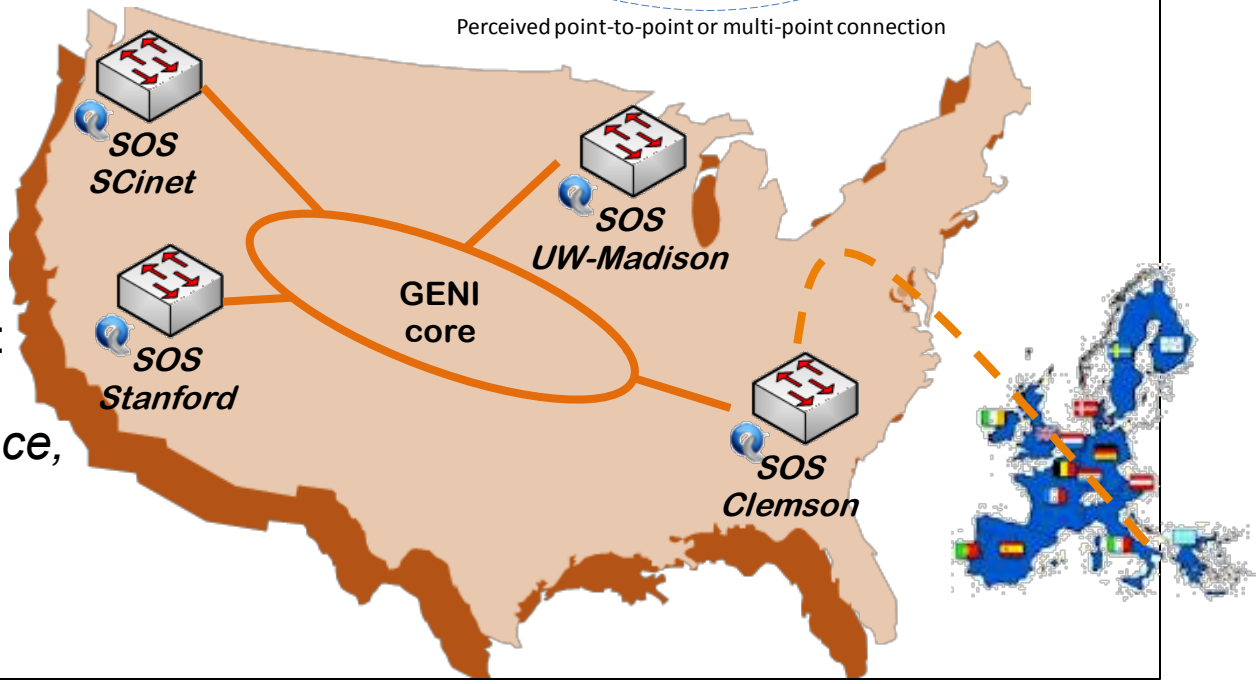
- With SDN, controller may be used for:
  - Seamless adaptation – a network provider perspective
  - Explicit control – end user expresses preference to controller
    - Imagine bandwidth on demand

Large Data Transport Enhancement

Steroid OpenFlow Service (SOS)
by Aaron Rosen and KC Wang

- *Seamless TCP throughput upgrade, e.g., 2.5 Mbps → 120 Mbps*
- *Multipath support*
- *Automatic site agent detection*





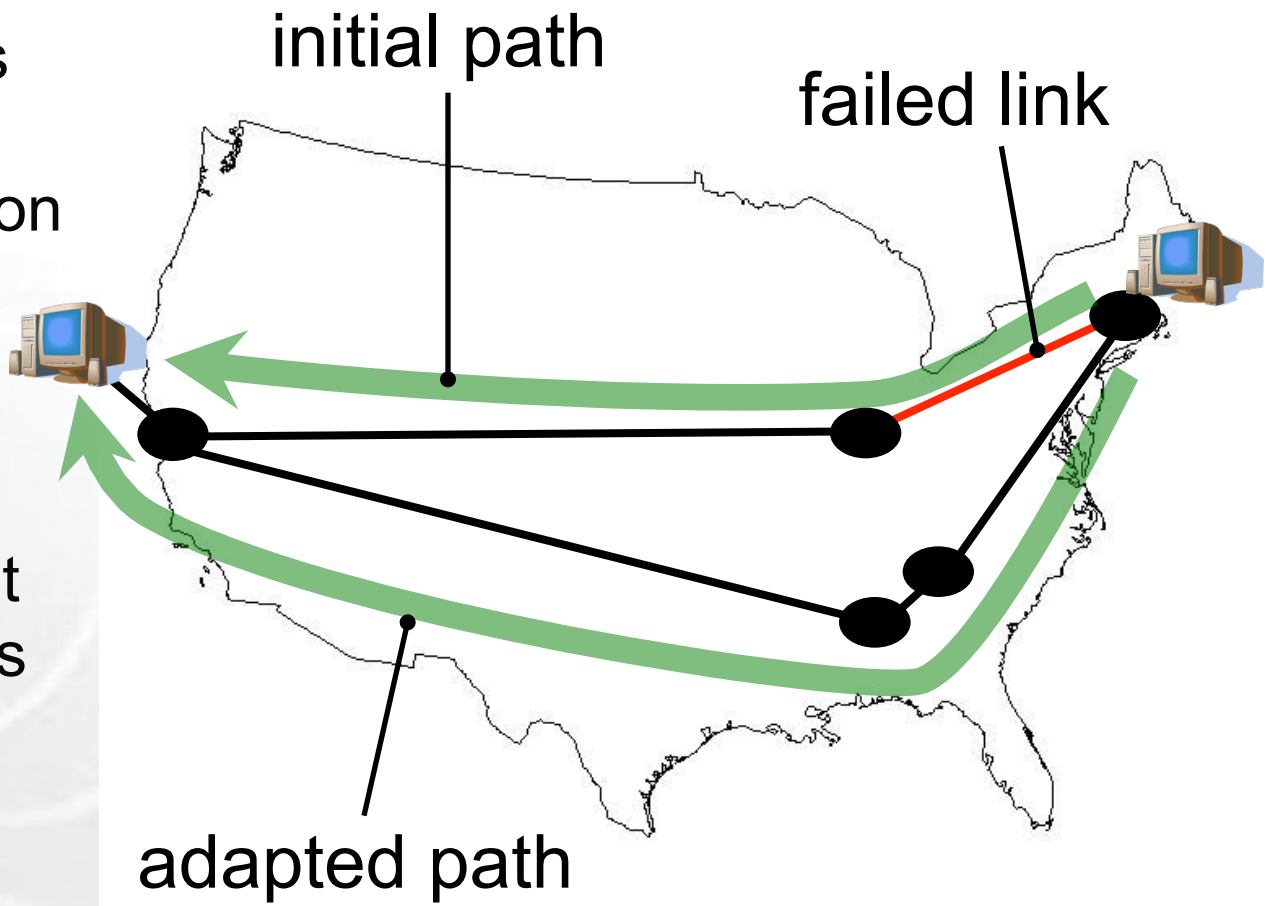
Upcoming demos of SOS:

- *NSF 12th GENI conference, Kansas City, MO.*
- *Supercomputing 2011, Seattle, WA.*

SOS Combining Multiple Paths on GENI

Pathlet

- Source switches paths within seconds based on end-to-end observations
- Today's Internet can take minutes or longer, and may not adapt automatically

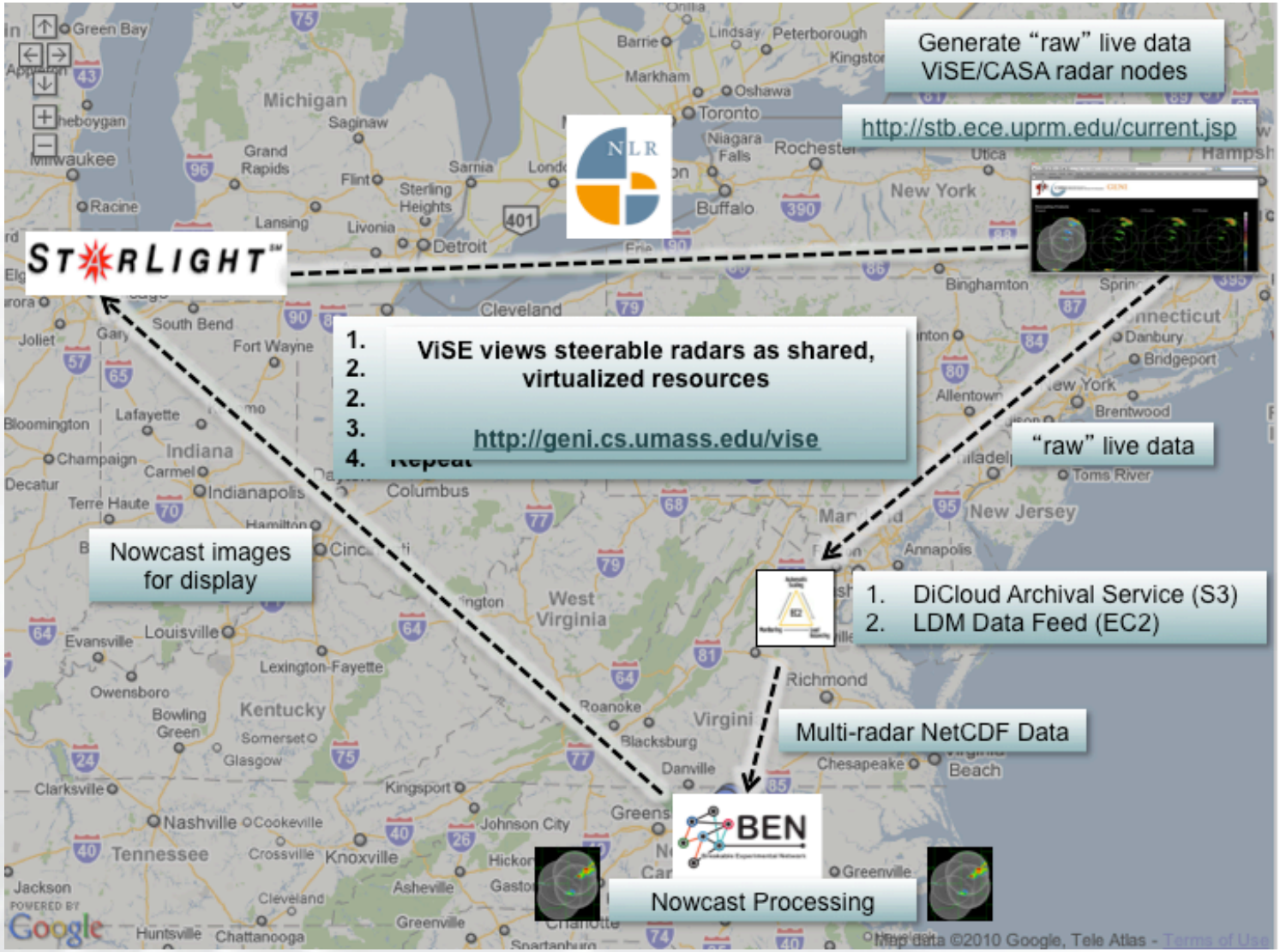


NetServ

Benefits of ActiveCDN:

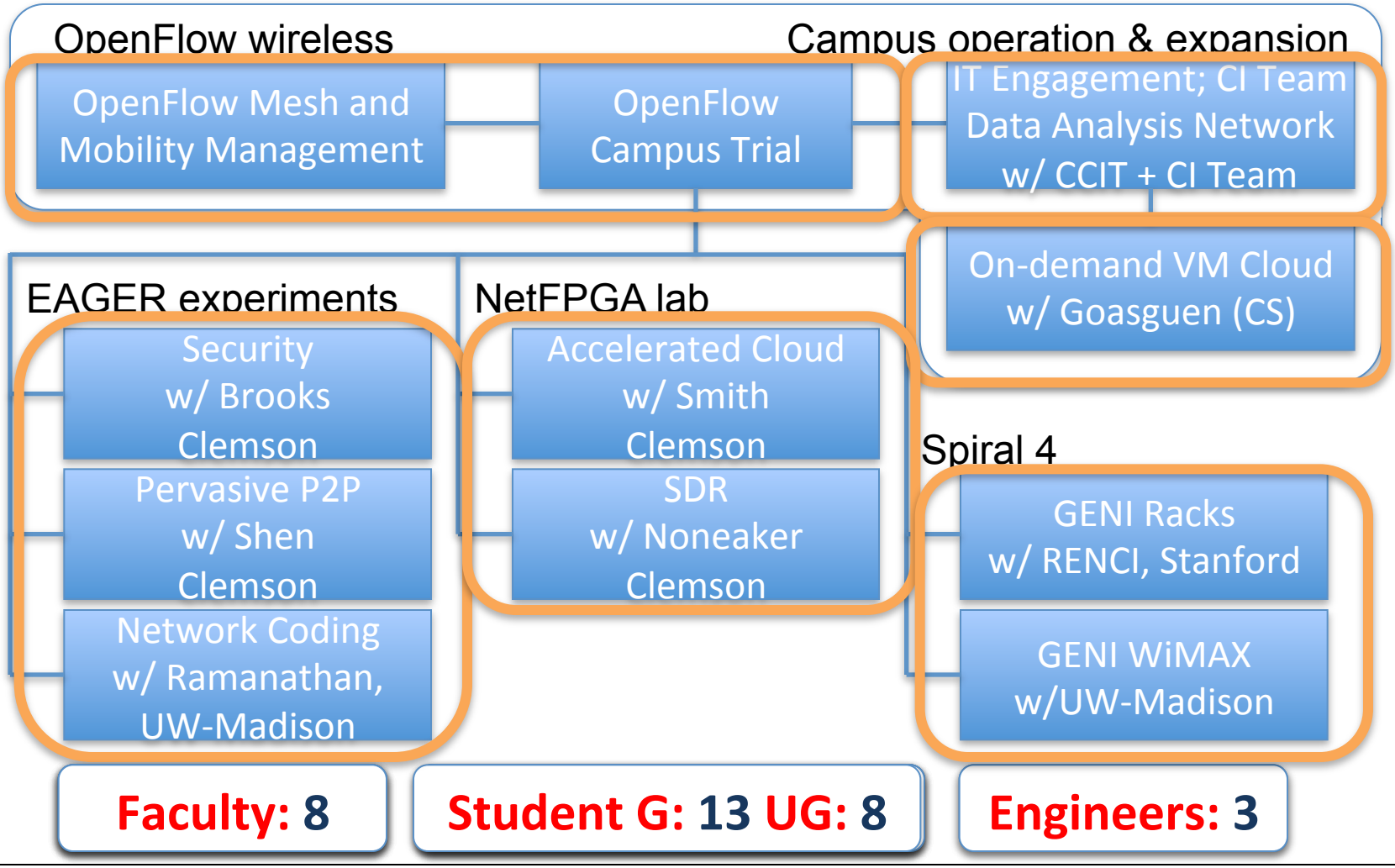
- Dynamic deployment based on load
- Localized services such as weather, ads and news

NowCast

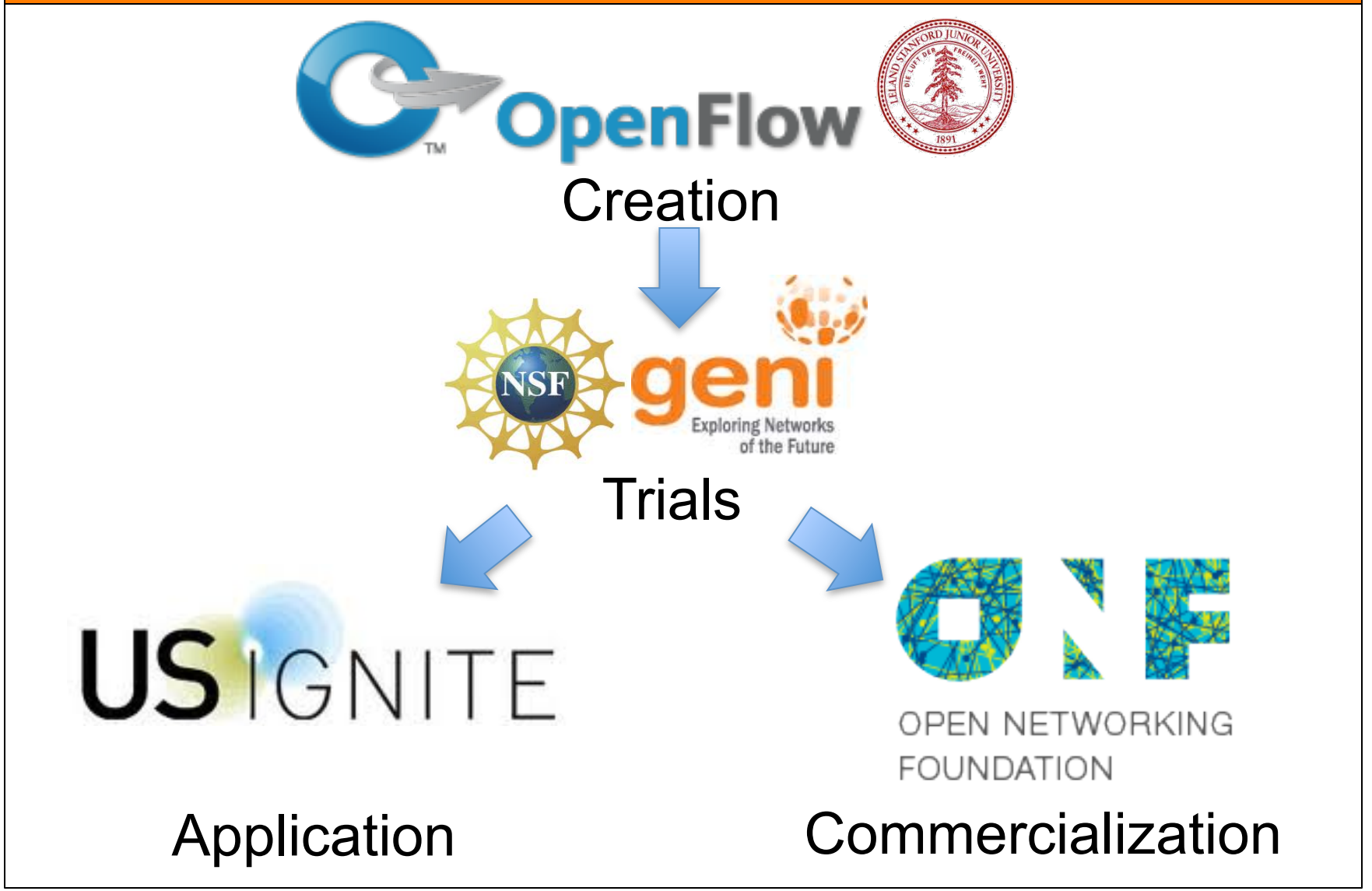

Generate "raw" live data
ViSE/CASA radar nodes
http://stb.ece.uprm.edu/current.jsp
STARLIGHT
1. ViSE views steerable radars as shared, virtualized resources
2.
2.
3.
4. Repeat
http://geni.cs.umass.edu/vise
"raw" live data
Nowcast images for display
1. DiCloud Archival Service (S3)
2. LDM Data Feed (EC2)
Multi-radar NetCDF Data
BEN
Nowcast Processing
Google
Map data ©2010 Google, Tele Atlas - Terms of Use

OpenFlow "Inspired" Research at Clemson

- They may not know it's good for them yet!



Recent Development in SDN/OpenFlow



Standard, Software, Hardware

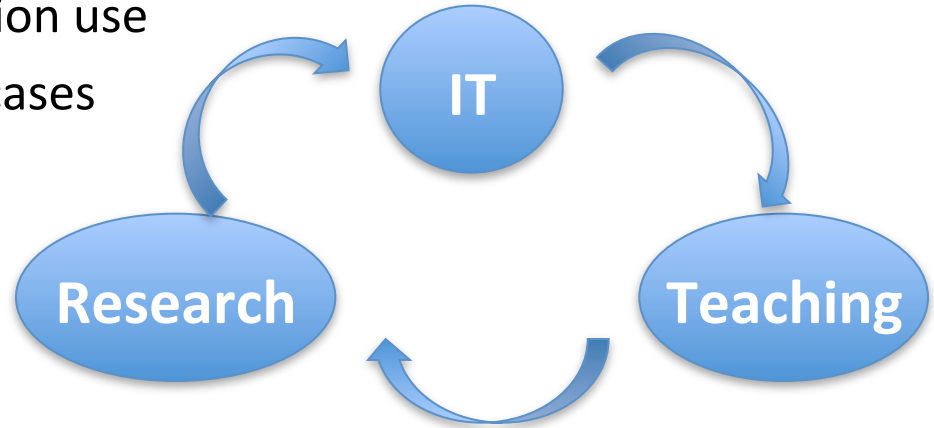
- OpenFlow standard by ONF
  - OpenFlow 1.0 support
  - OpenFlow 1.1.0 draft
- OpenFlow software
  - Firmware:
    - Open Source: indigo 1.0 (on Pronto/Broadcom switches), Sep 2010
    - HP ProCurve 2.02v, NEC/IBM ProgrammableFlow, Dell
    - more …
  - Controller software
    - Open source: NOX (noxrepo.org), beacon (openflowhub.org)
    - Big Switch, Nicira, HP, NEC/IBM …
- Switch hardware
  - Pronto, HP, NEC/IBM, Dell/Force10 switches on the market, more to come …

Streamlined Development Tools and Process

- Phase 1: Prototyping with Mininet
  - Use single PC to virtualize network
  - Allows one to easily define topology
- Phase 2: Running on nation-wide GENI testbed
  - Real network delay and bandwidth characteristics
  - Configure GENI OpenFlow network + computing hosts
- Phase 3: Production deployment

Work with Your Campus IT

- To facilitate sustained growth and leverage the power of all parties in University to stay creative, we need a new model.
  - Students
    - Graduate research assistants
    - Undergraduate "Creative Inquiry" program
    - Undergraduate IT internship program + curriculum
  - Network engineers
    - Support researchers deploy and operate GENI
    - Operate GENI in production use
    - Innovative institute use cases
  - Faculty
    - Research
    - Teaching



What's Your Idea?

- You can use it NOW!
- You can start programming TODAY!
- You can be the next

- Check out these resources:
  - Openflow.org
  - Geni.net

FURTHER QUESTIONS

CONTACT: KWANG@CLEMSON.EDU