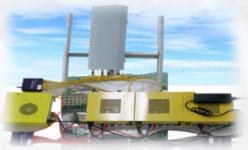
geni
Exploring Networks of the Future



GENI

Exploring Networks of the Future

Niky Riga

www.geni.net

Sponsored by the National Science Foundation

Outline

GENI – Exploring future internets at scale

The GENI Concept

Building GENI

Experimental and Classroom use of GENI

What's next for GENI?

GENI: An experimenter's view

Global networks are creating extremely important new challenges

Science Issues

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

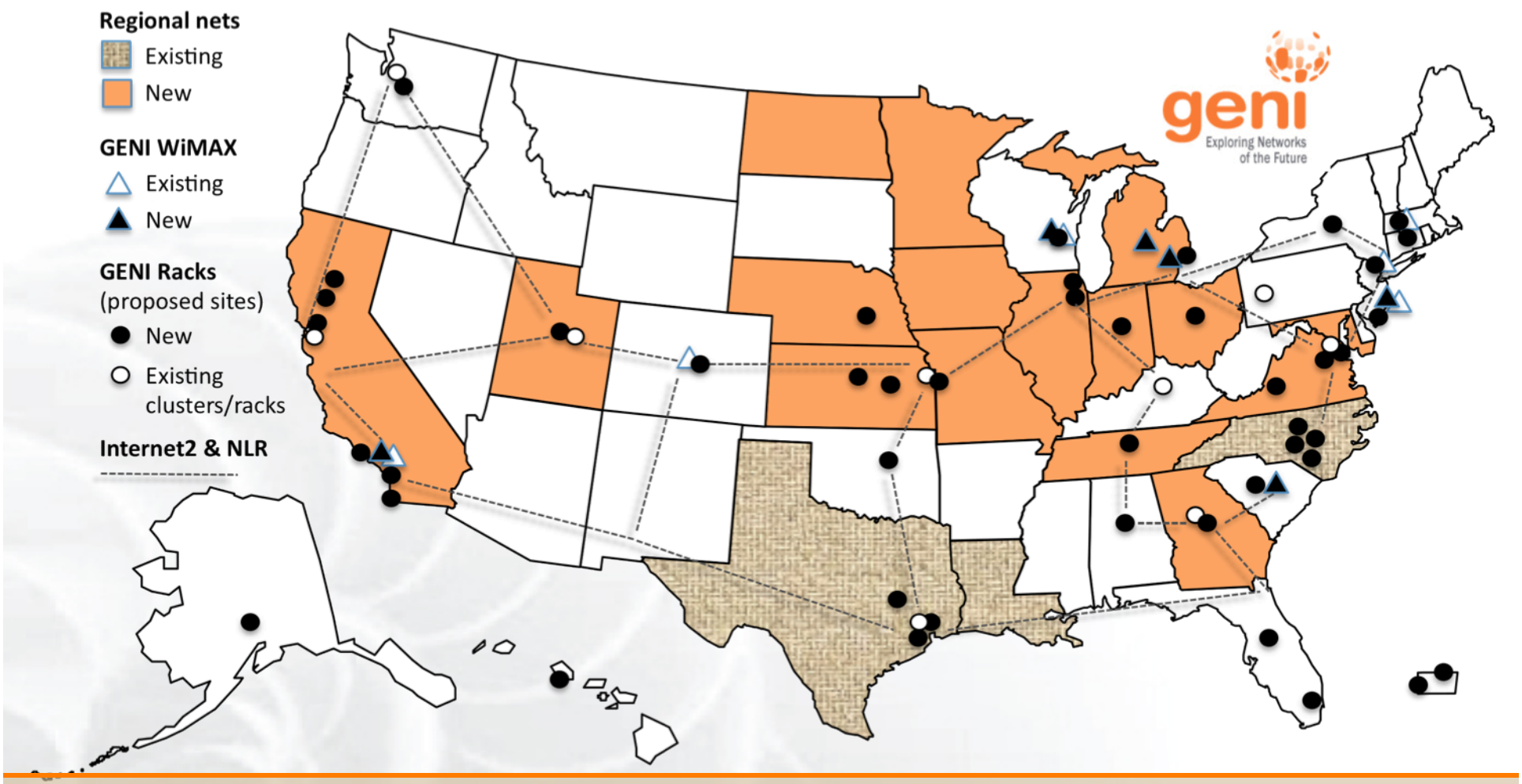
Innovation Issues

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

Society Issues

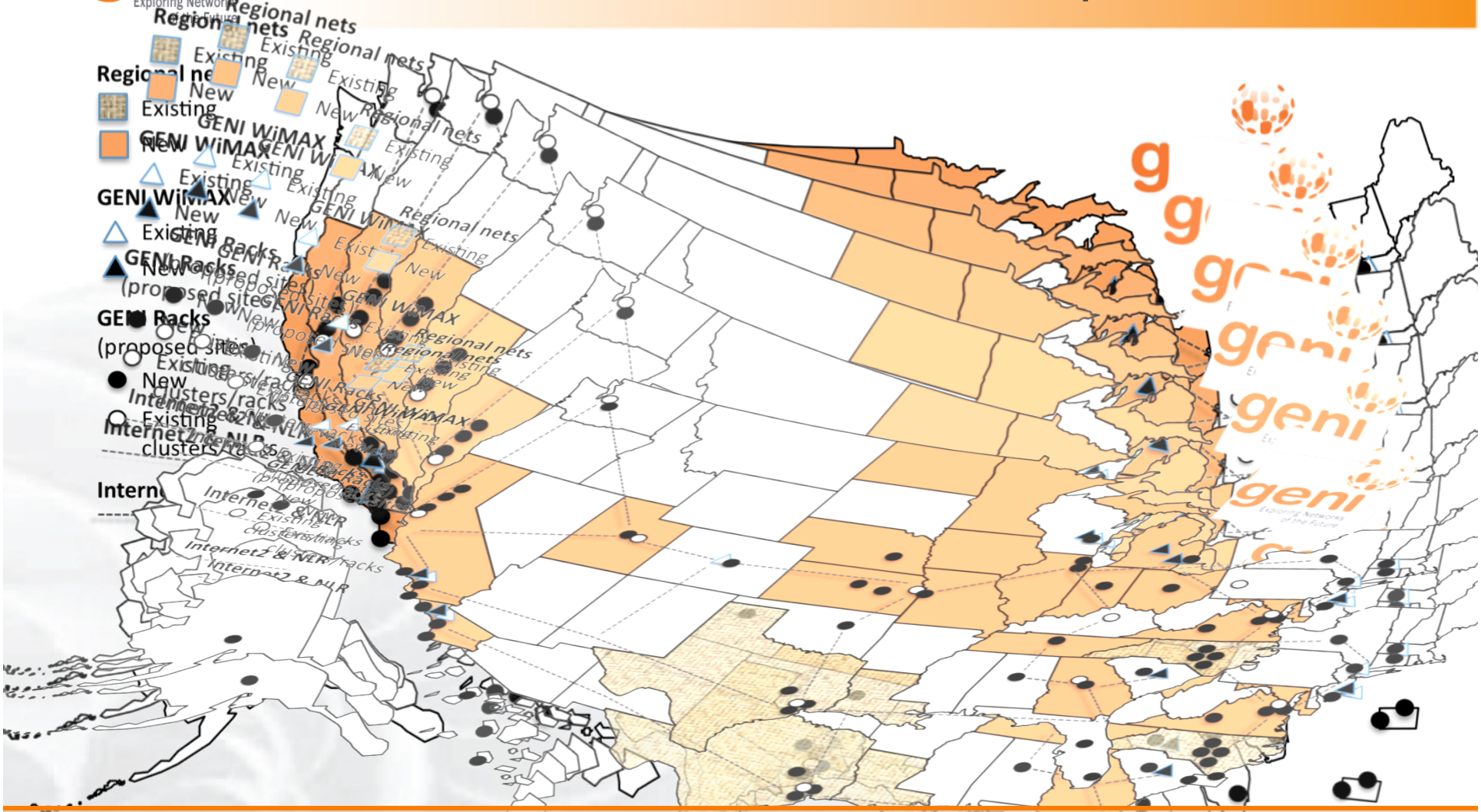
We increasingly rely on the Internet but are unsure we can trust its security, privacy or resilience

GENI: Infrastructure for Experimentation



GENI provides compute resources that can be connected in experimenter specified Layer 2 topologies.

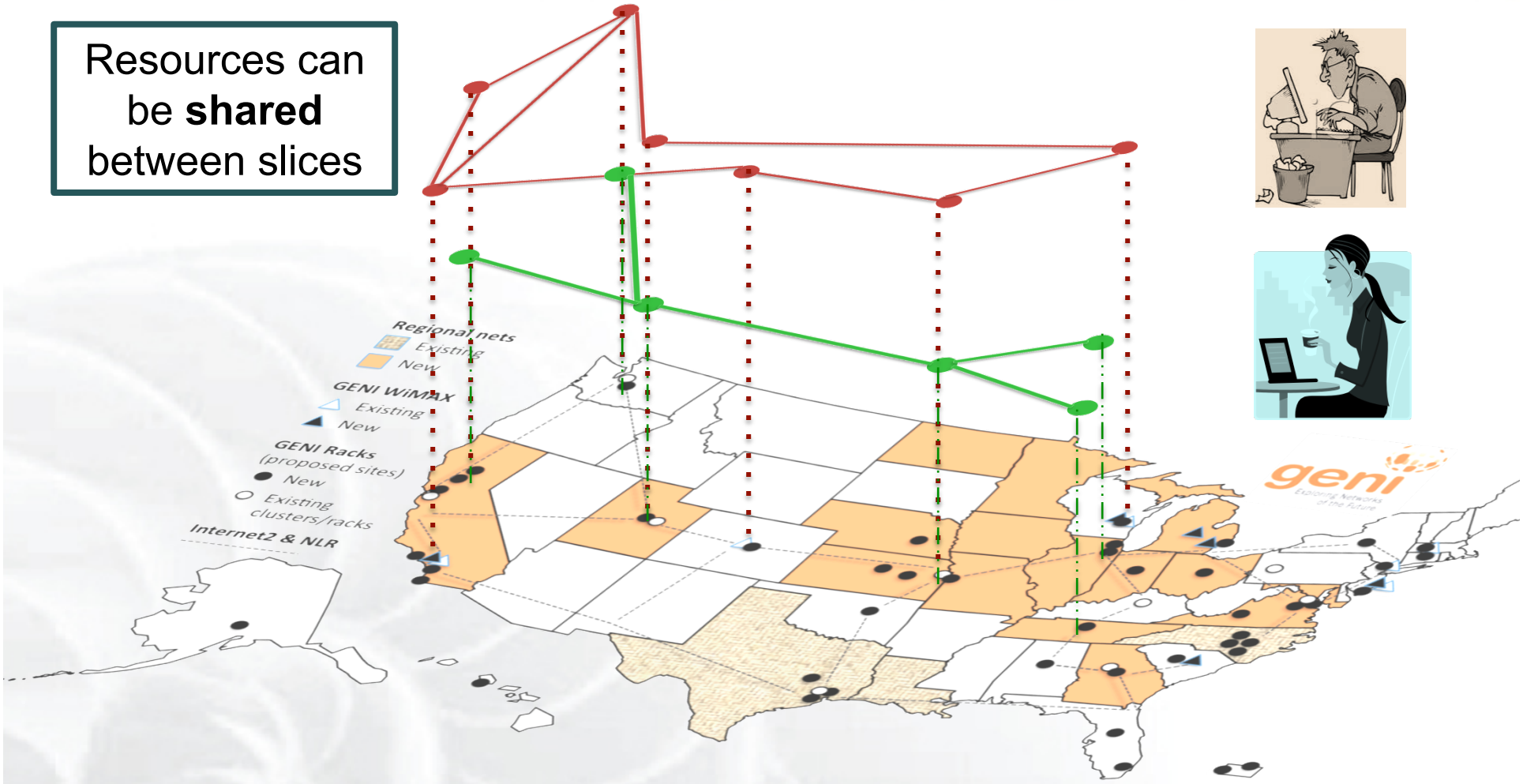
GENI: Infrastructure for Experimentation



GENI provides compute resources that can be connected in experimenter specified Layer 2 topologies.

Multiple GENI Experiments run Concurrently

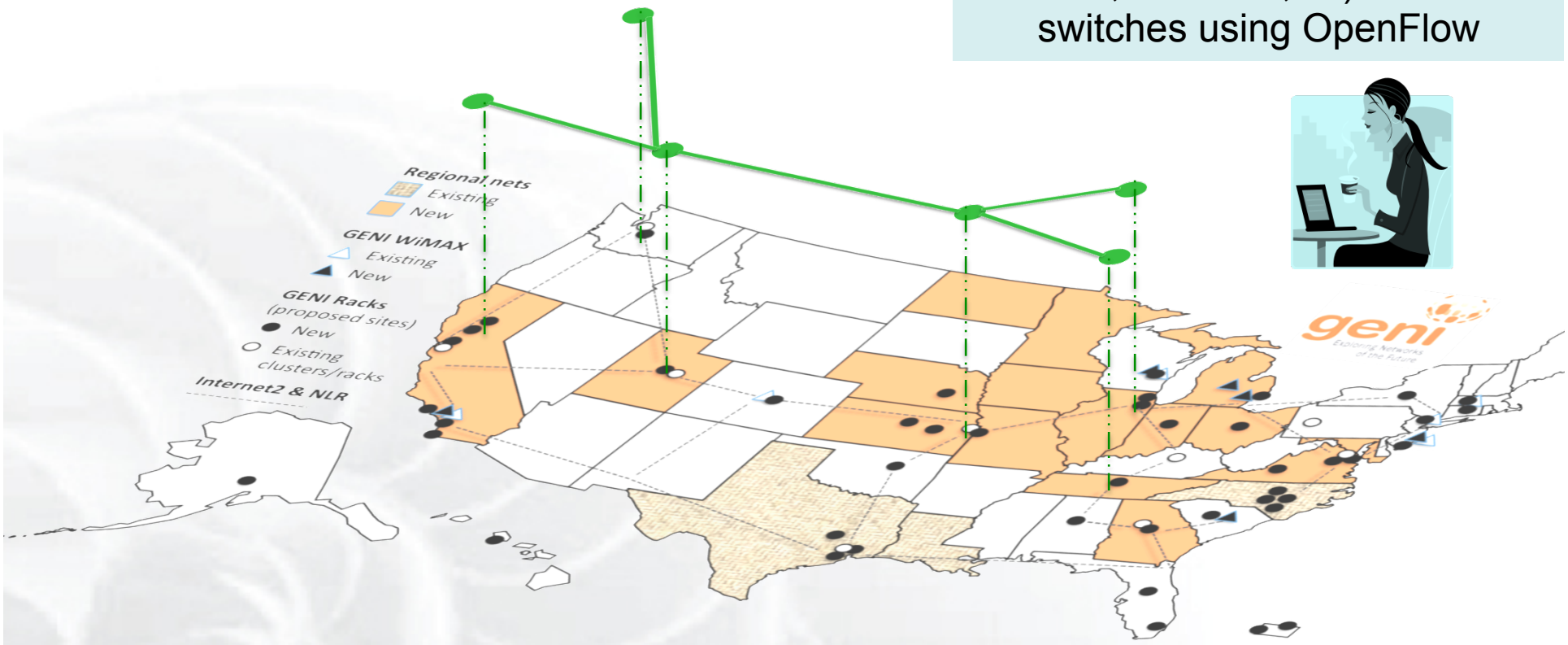
Resources can be **shared** between slices



Experiments live in **isolated** "slices"

GENI is “Deeply Programmable”

I install software I want throughout my network slice (into routers, switches, …) or control switches using OpenFlow



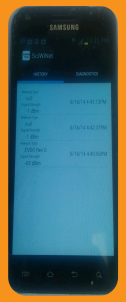
Experimenters can set up custom topologies, protocols and switching of flows

Compute Resources

GENI Racks: small clouds

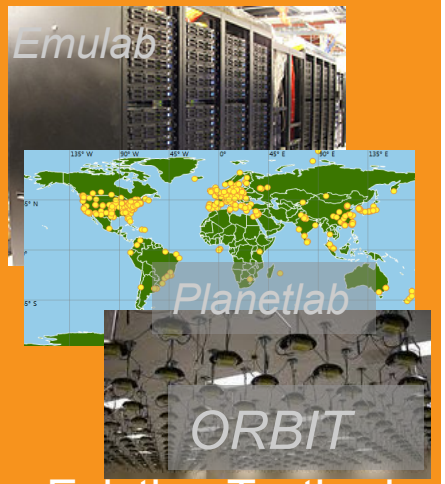
Virtual Machines

Bare metal Machines



Android Phones

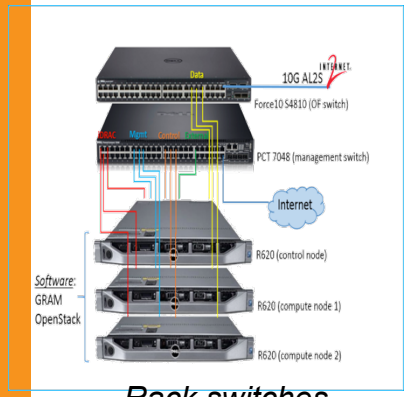
Wireless nodes



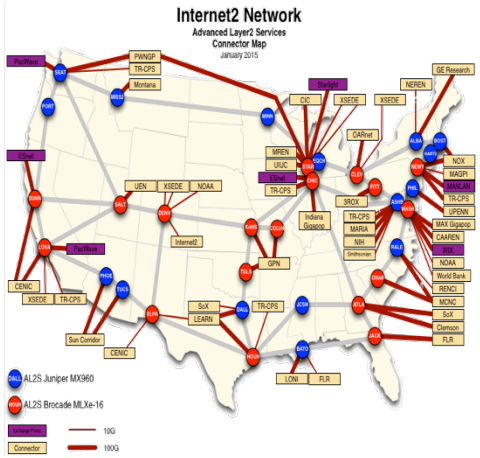
Existing Testbeds

Network Resources

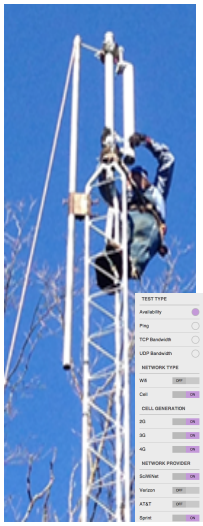
Layer 2 VLANS and Access to Programmable Switches



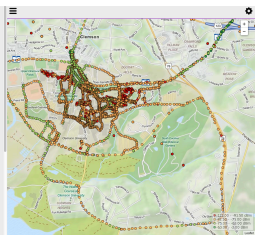
Rack switches

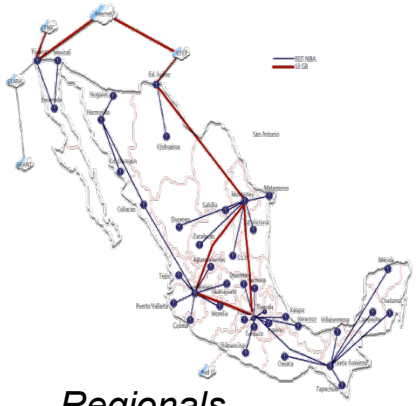


Internet2: US Research Backbone



WiMAX/LTE base stations, 4G/3G Network





Regionals

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GENI: An experimenter's view

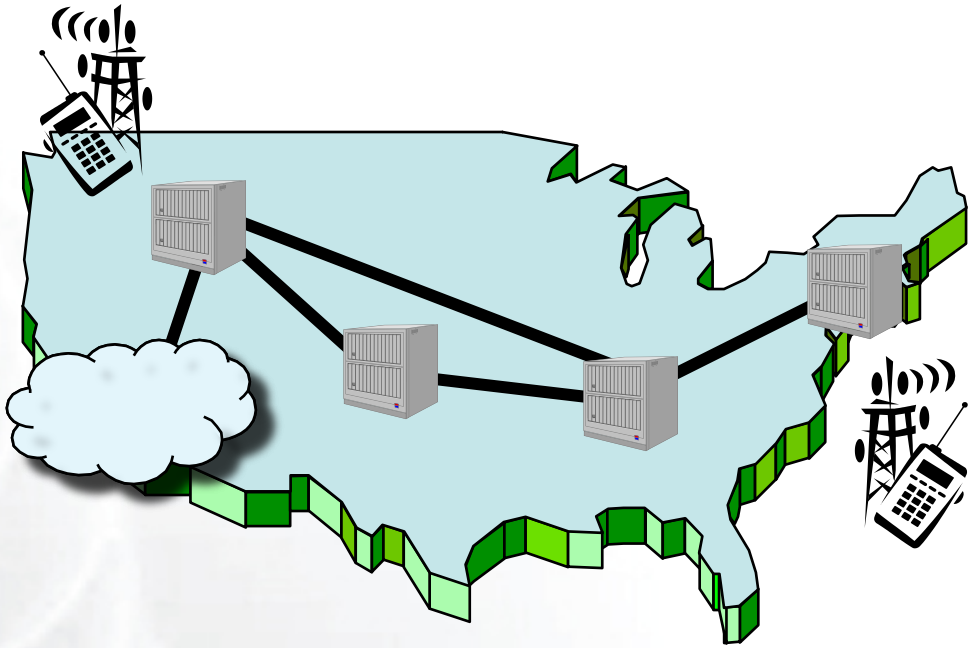
A bright idea

"I have a great idea."

"That will never work."

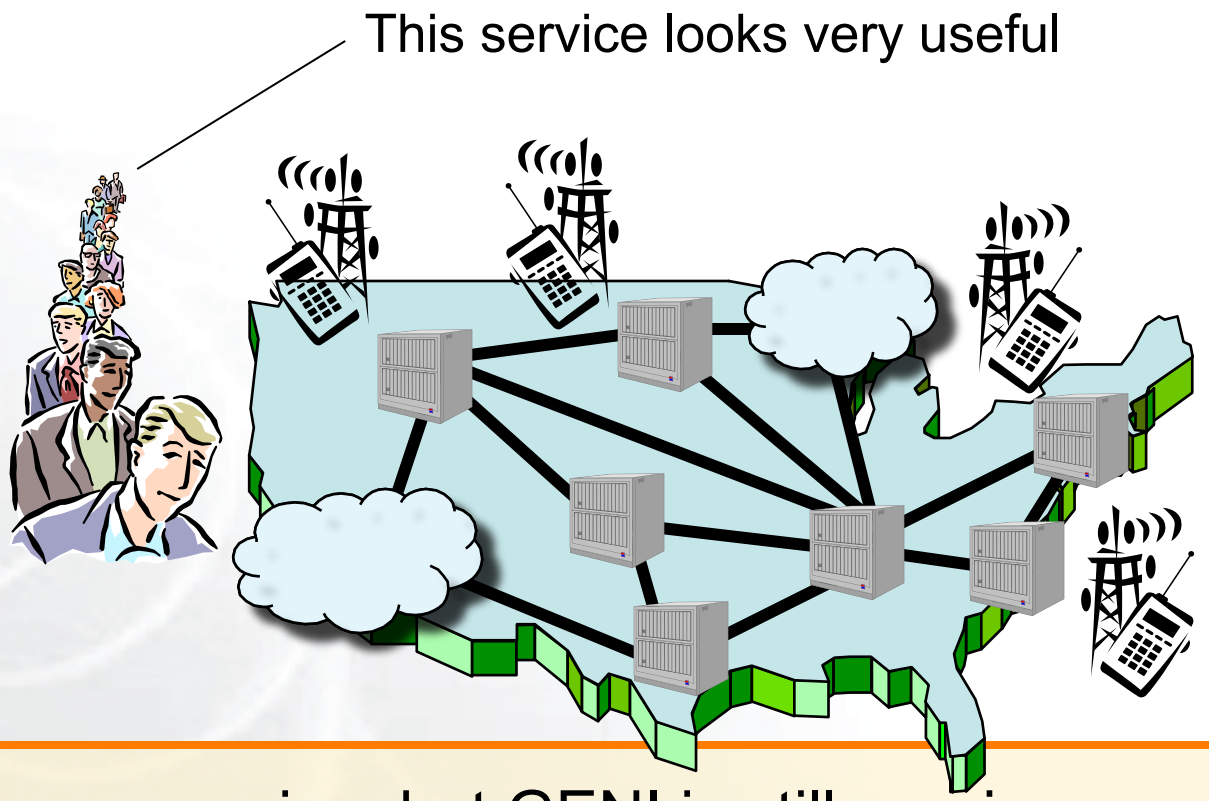
Let's try it out!

My new architecture worked great in the lab, so now I'm going to try a larger experiment for a few months.



He uses a modest slice of GENI, sharing its infrastructure with many other concurrent experiments.

It turns into a really good idea

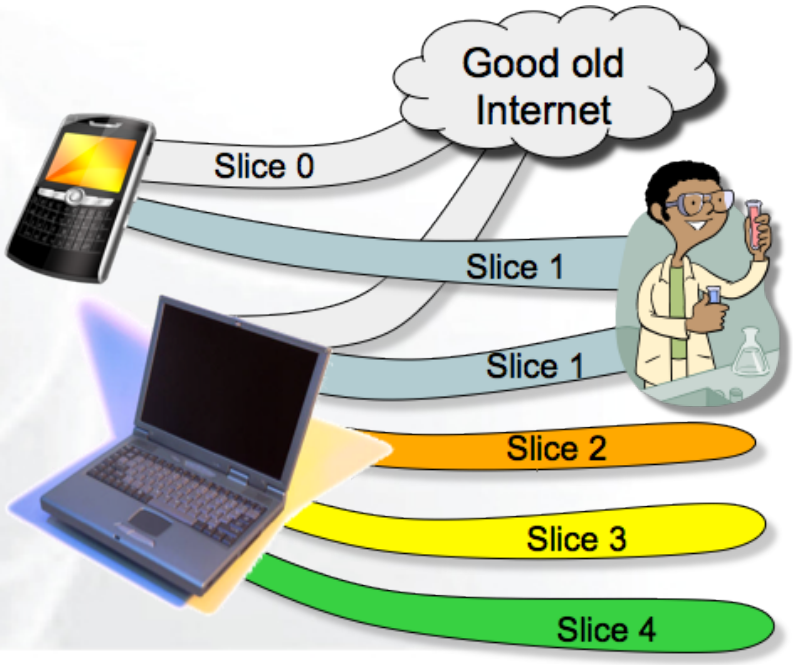


His slice of GENI keeps growing, but GENI is still running many other concurrent experiments.

Attracts real users

"Looks like an app to me."

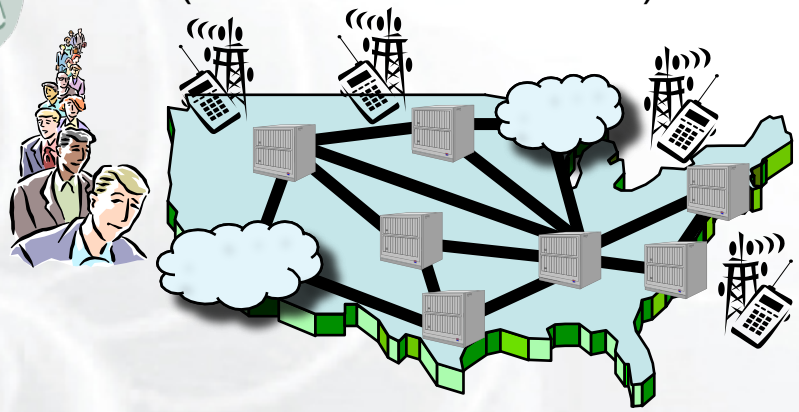
"It's my very own GENI slice."



“Boy did I learn a lot!”

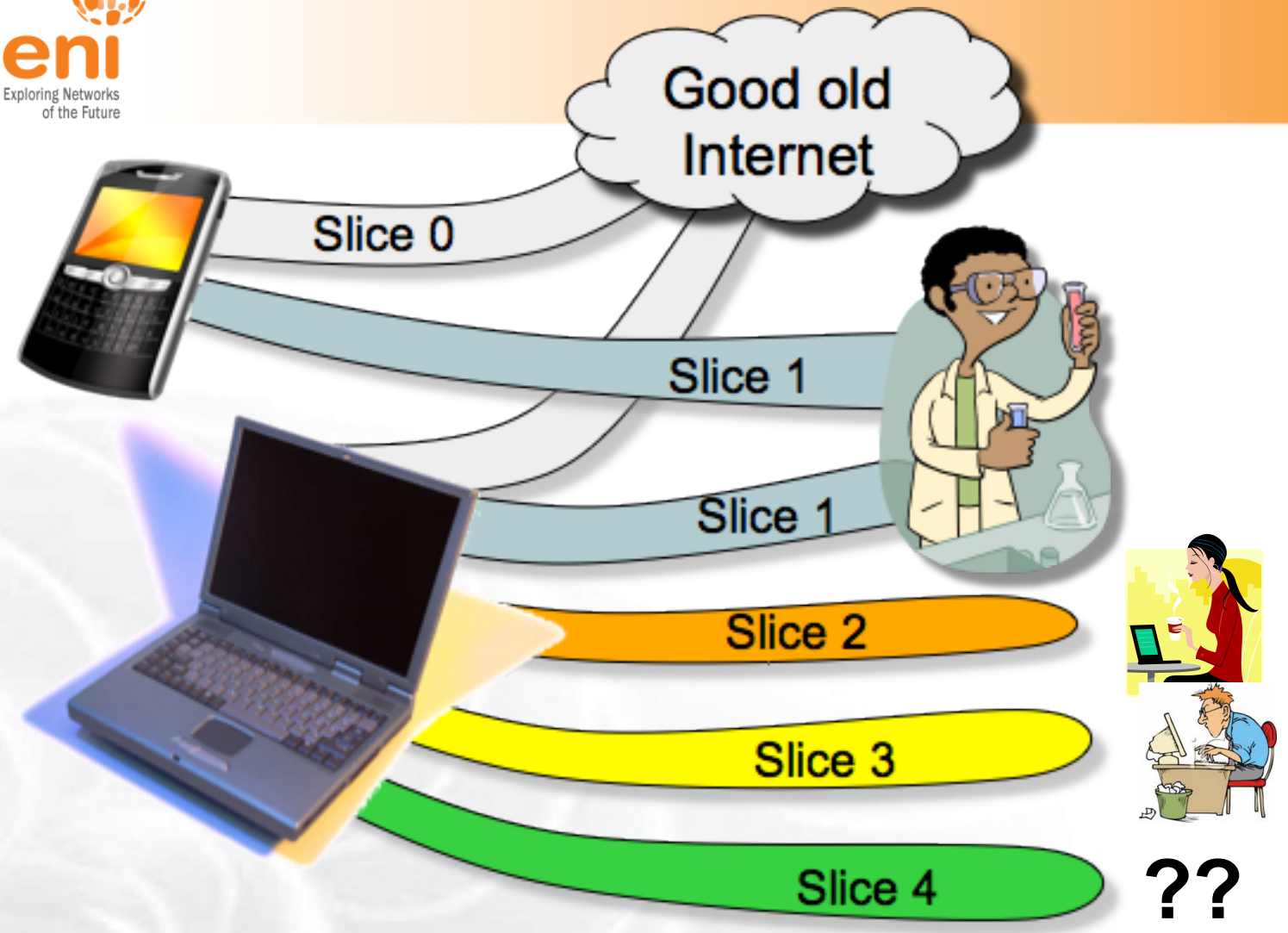
“What a cool service.”

(I wonder how it works.)



“I always said it was a great idea.”

(But way too conservative.)

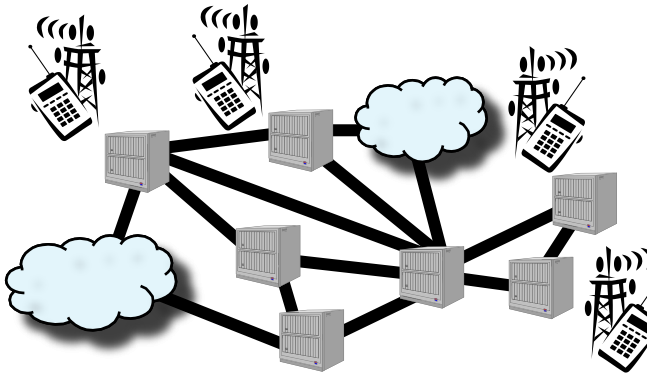


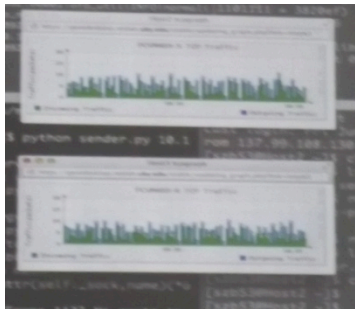
If **you** have a great idea, check out the
NSF CISE research programs for current opportunities.

Moral of this story

GENI is meant to enable . . .

- At-scale experiments
- Internet-incompatible experiments
- Both repeatable and “in the wild” experiments
- ‘Opt in’ for real users
- Instrumentation and measurement tools





GENI creates a huge opportunity for ambitious research!

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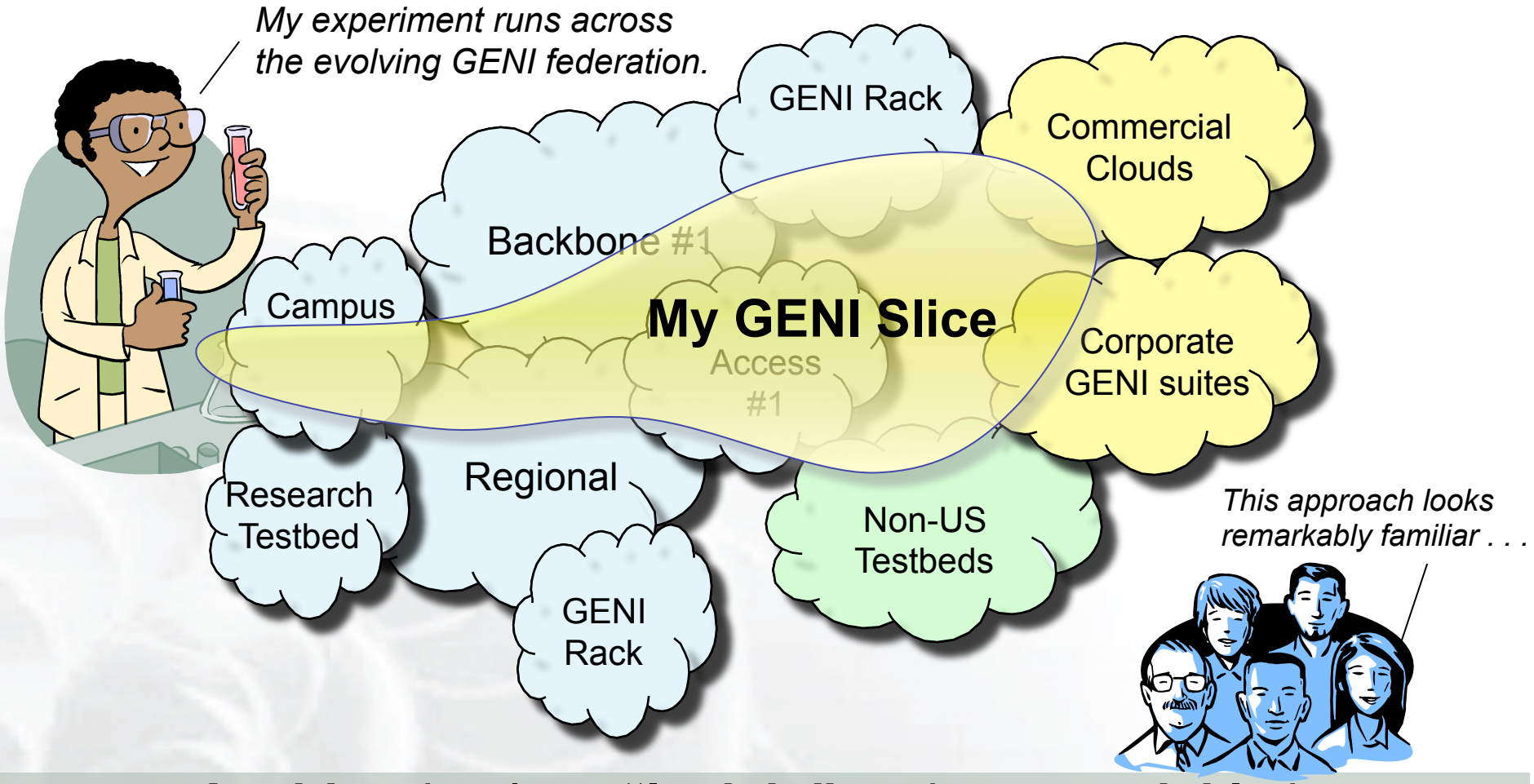
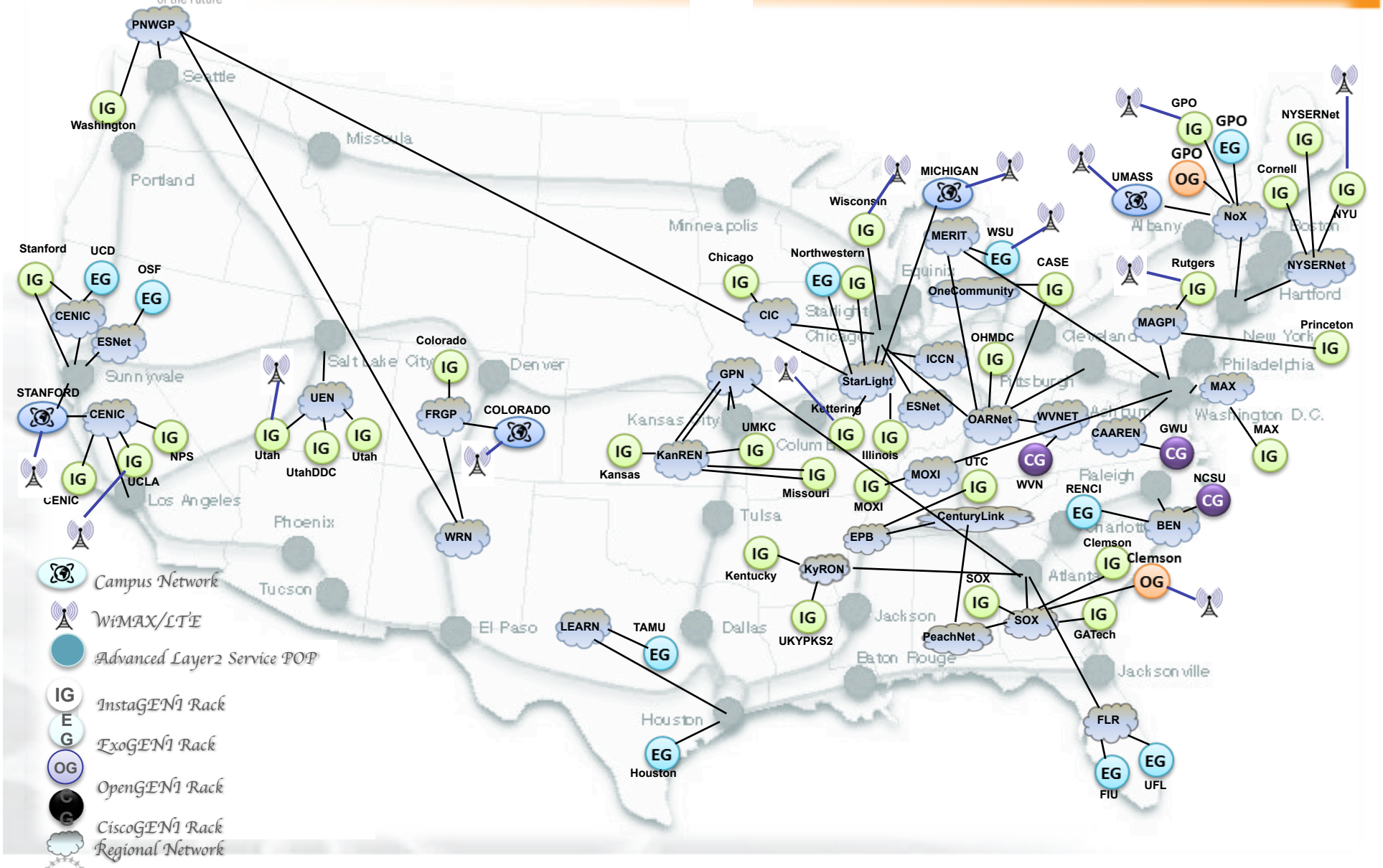
Federation

GENI grows by GENI-enabling heterogeneous infrastructure



Avoid technology **"lock in"** and **grow quickly** by incorporating existing infrastructure

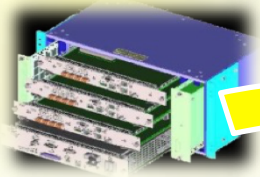
GENI's footprint



Build GENI at sufficient scale

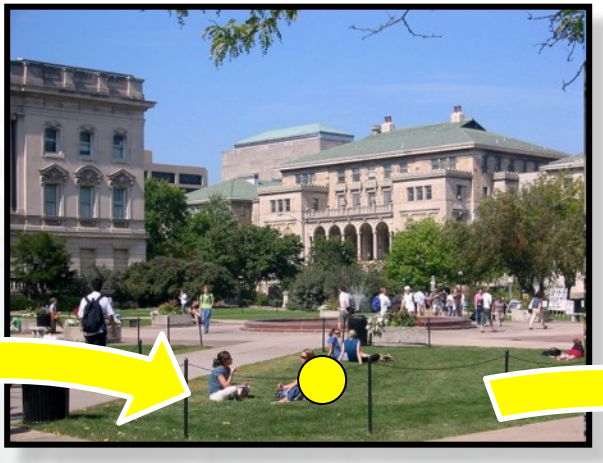
Infeasible to build a testbed as big as the Internet

HP ProCurve 5400 Switch

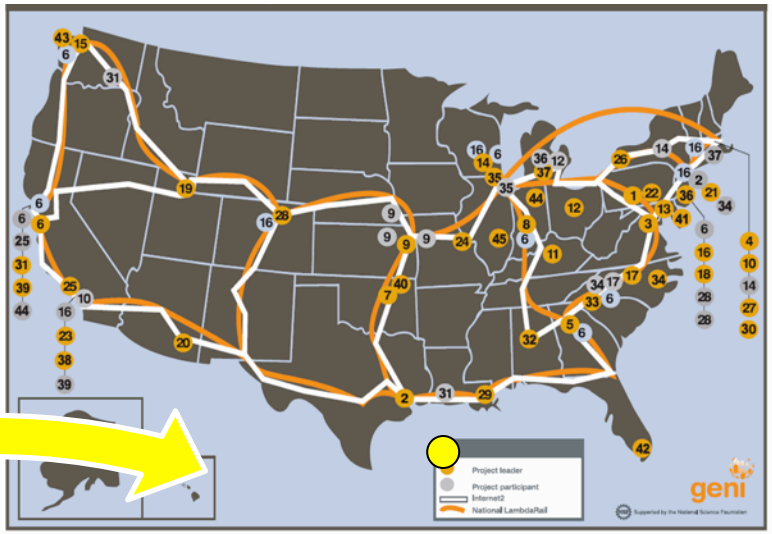


NEC WiMAX Base Station

GENI-enabled equipment



GENI-enabled campuses, students as early adopters

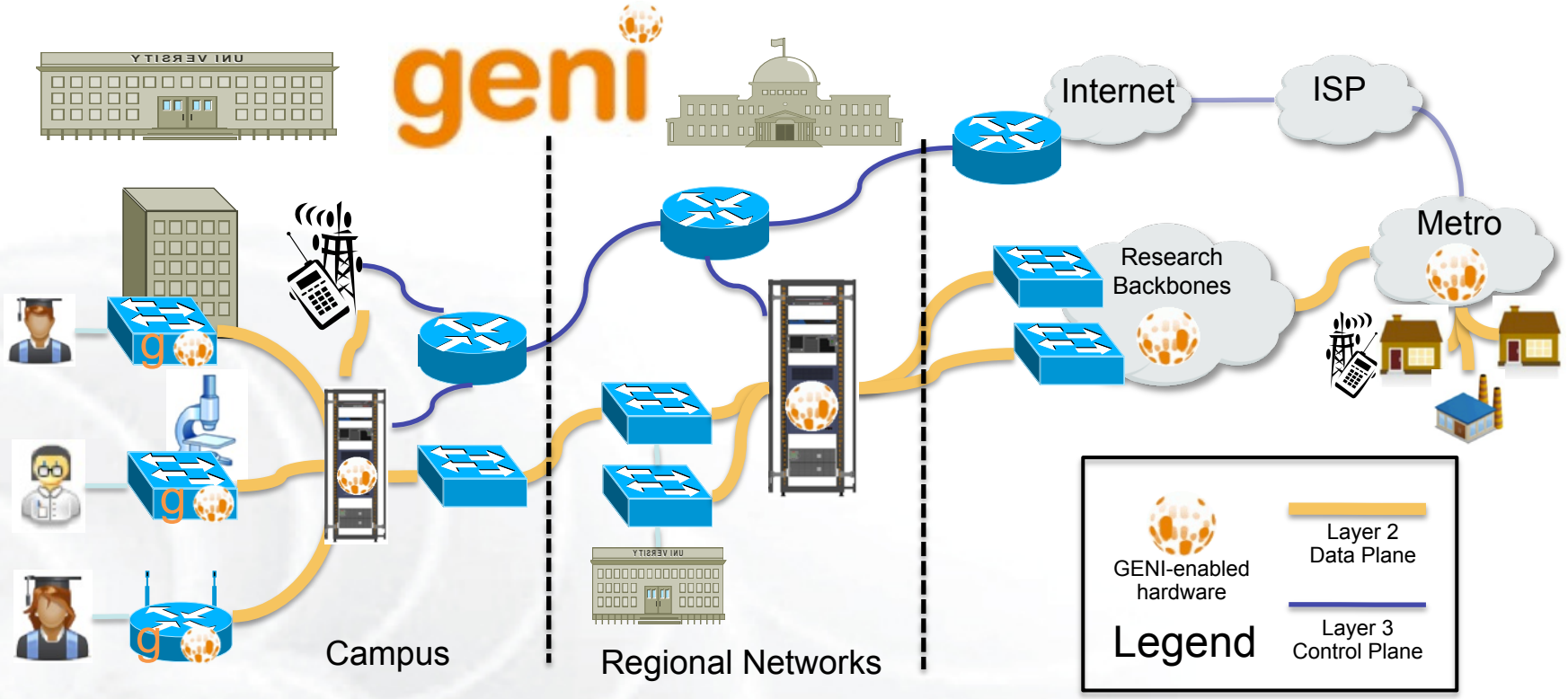


"At scale" GENI prototype

GENI-enable testbeds, commercial equipment, campuses, regional and backbone networks

Campus photo by Vonbloompasha

GENI Network Architecture



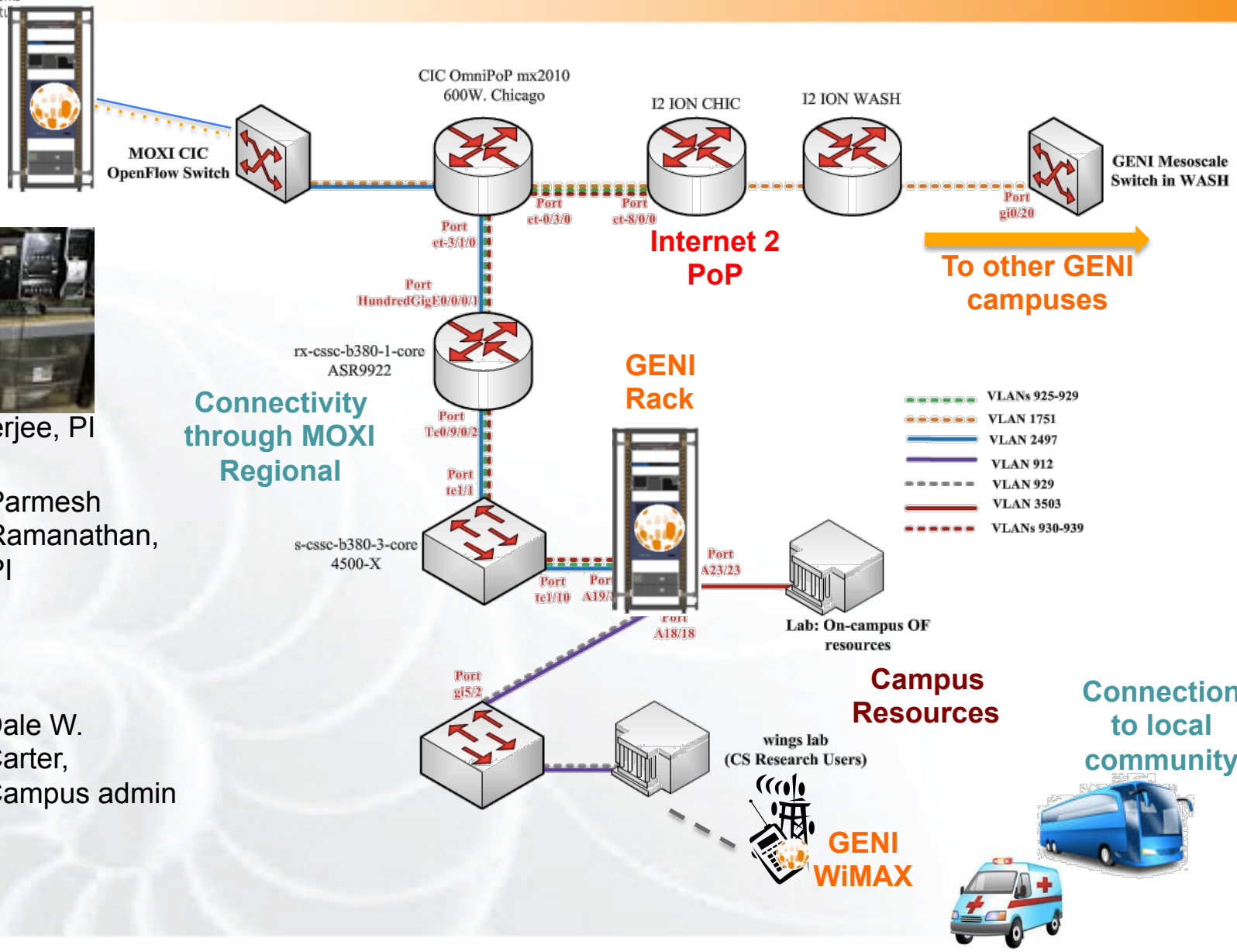
- Flexible network / cloud research infrastructure
- Also suitable for physics, genomics, other domain science
- Distributed cloud (racks) for content caching, acceleration, etc.

Wisconsin: a Great Example

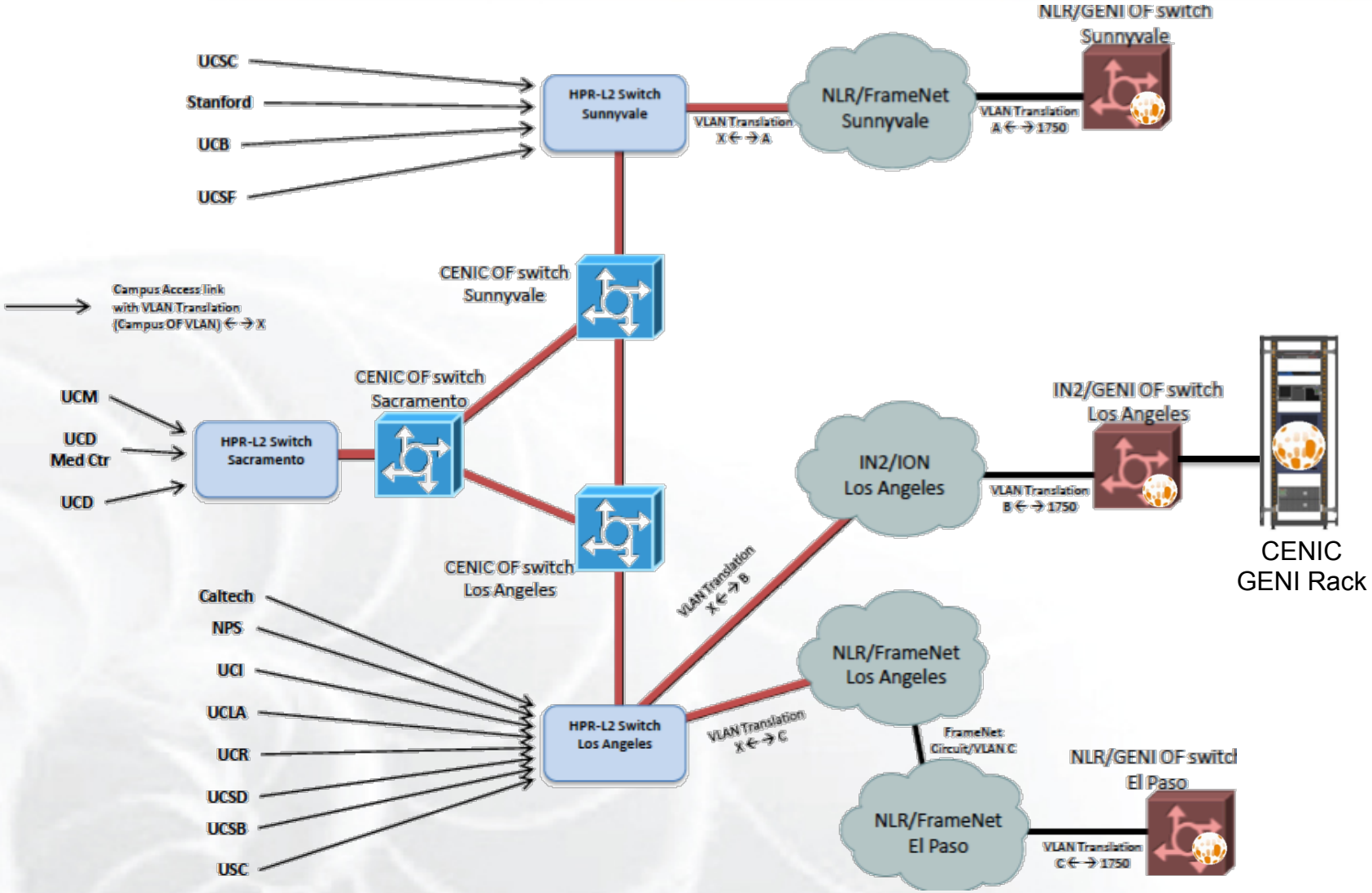
Suman Banerjee, PI

Parmesh Ramanathan, PI

Dale W. Carter, Campus admin



Example regional network
CENIC OpenFlow buildout



Creating and deploying GENI racks

Ilia Baldine
RENCI
More resources / rack, fewer racks

IBM

Rajesh Narayanan
DELL

KC Wang Clemson

Latest addition

DELL

Rick McGeer
Fewer resources / rack, more racks

hp invent

GENI on Internet2

- Collaboration to **implement national-scale infrastructure**
  - sliced and deeply-programmable
  - incorporating OpenFlow/SDN switches, GENI Racks, etc.
  - high-speed (10-100 Gbps)
- Internet2 provides dynamic link provisioning to GENI experimenters
  - Uses AL2S (Advanced Layer 2 Services)
- Experimenters can run OpenFlow controllers in AL2S
  - Experimenter roundtable session: 1.30am

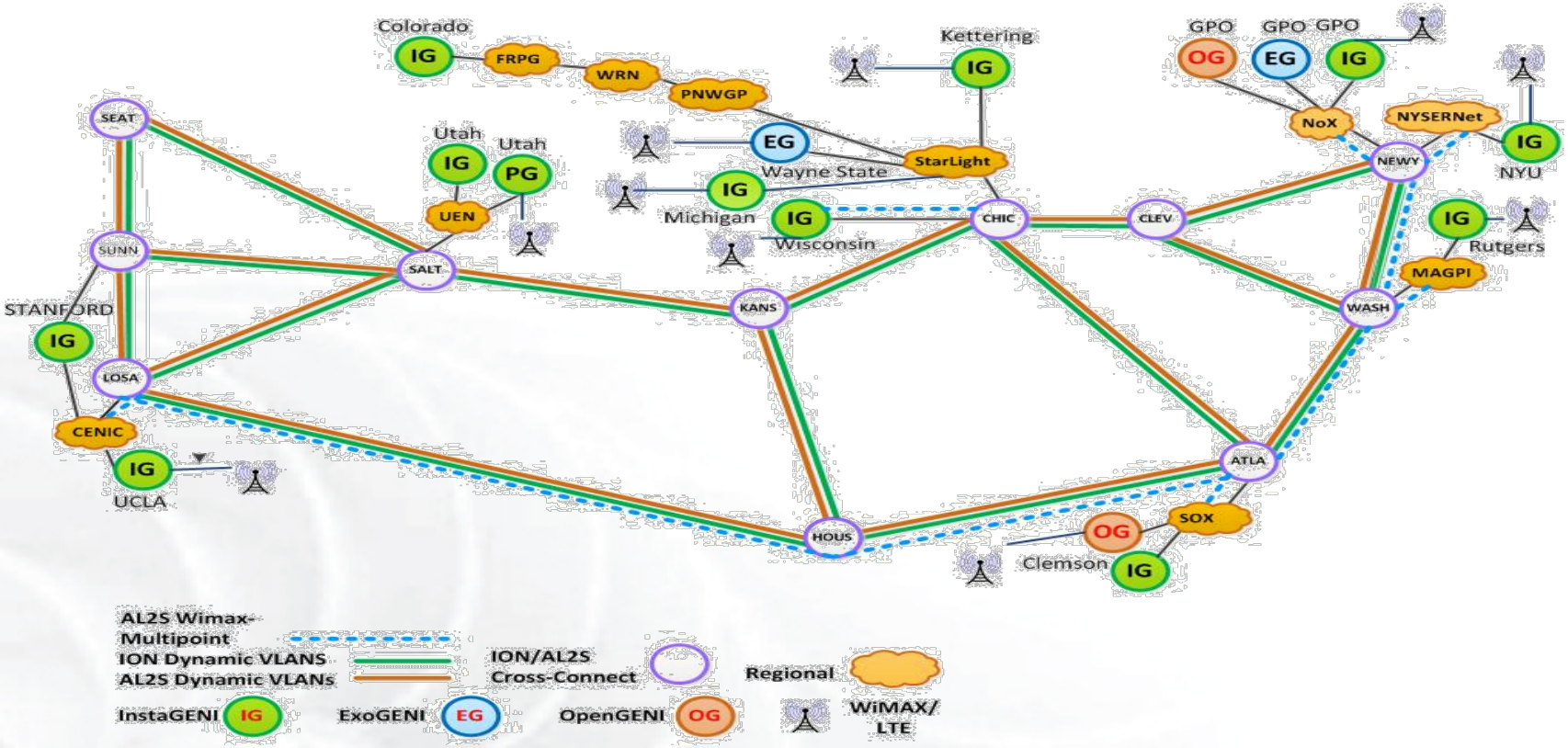
GENI Wireless

- **Agreement with Sprint**
  - Sprint and Rutgers University have signed a **master spectrum agreement**
  - encompassing all Wireless sites, to ensure **operation in the EBS Band**.
  - An **emergency stop procedure**, in case of interference with Sprint service, has been agreed upon.

- **Prototyping and Deploying LTE in GENI**
  - NSF Funded effort led by Ivan Seskar
  - 2 year projects
  - 10 proposed sites

LTE Developers session
Wed: 4pm – 5:30pm

GENI Wireless 2015



- 26 Wimax Base Stations in 13 Sites
- 90 android handsets available to experimenters
- Sliced, virtualized and interconnected through AL2S
- Prototype LTE Deployment at Rutgers and Kettering

GENI Operations

GMOC: GENI Meta-operation Center

- Keeps track of outages
- Notification system for resource reservation
- Monitors most GENI Aggregates
- Coordinates LLR Requests
  - **L**egal **L**aw Enforcement & **R**egulatory
- Handles Emergency Stop

GENI Monitoring Portal developed by UKY

Monitoring hands-on Demo
Operations Session **-** *Wed 4pm-5:30pm*

https://mail1.grnoc.iu.edu/mailman/listinfo/experimenter-ops

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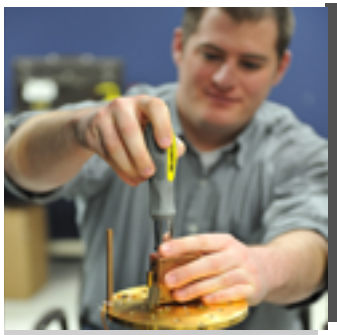
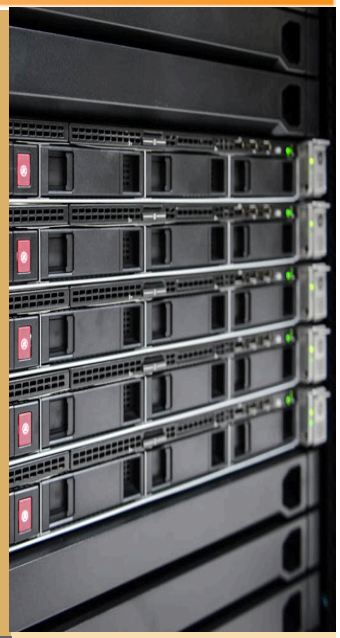
GENI Use By Numbers



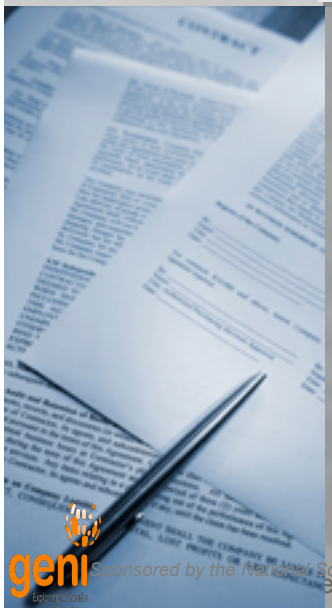
4300
Users

2600
Students trained on GENI by

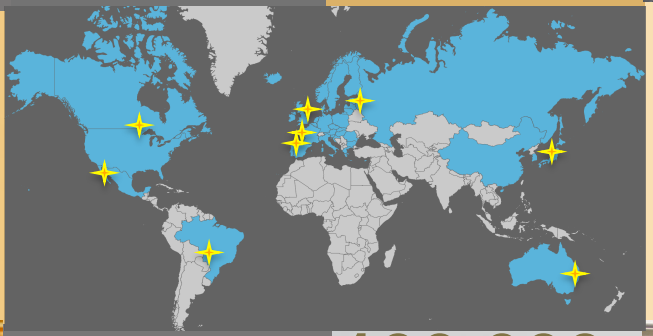
45
Different instructors



200+
publications



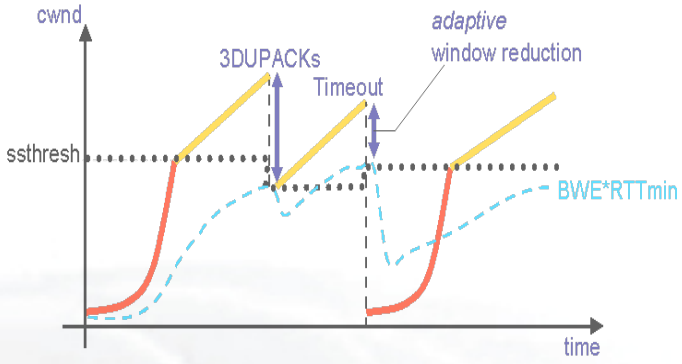
180
Universities



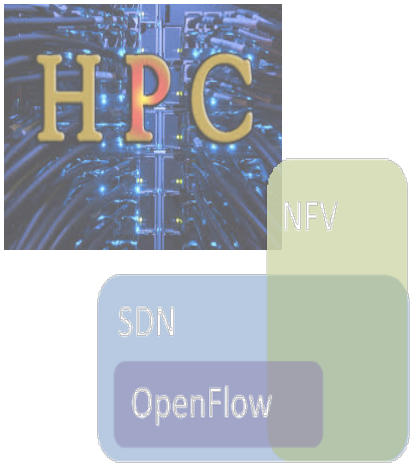
30
Countries

100,000+
Experiments instantiated

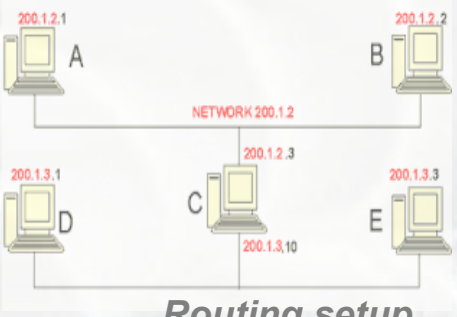
Use of GENI in Education



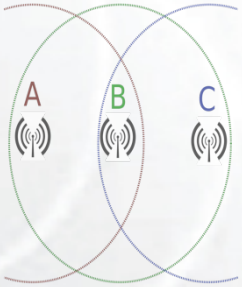
Protocol Behavior



New technologies

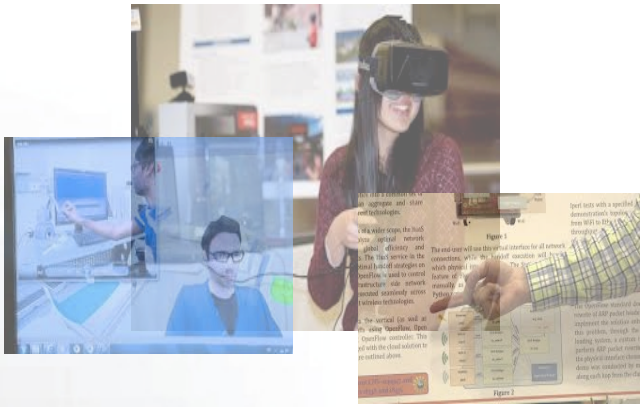


Routing setup



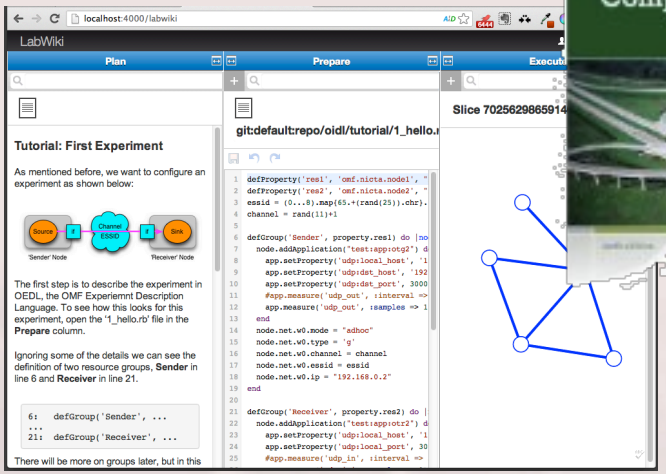
Wireless Communication

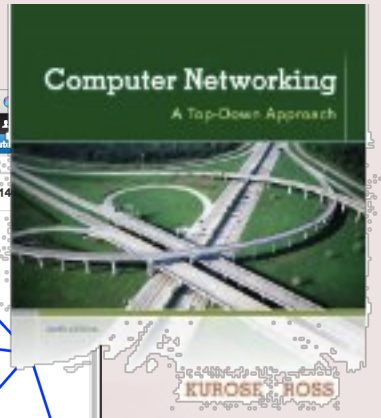
Teach Basic Concepts



Semester Projects

GENI in the Classroom

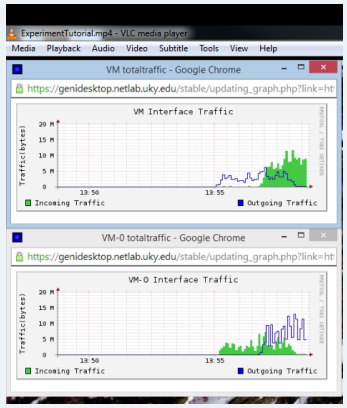




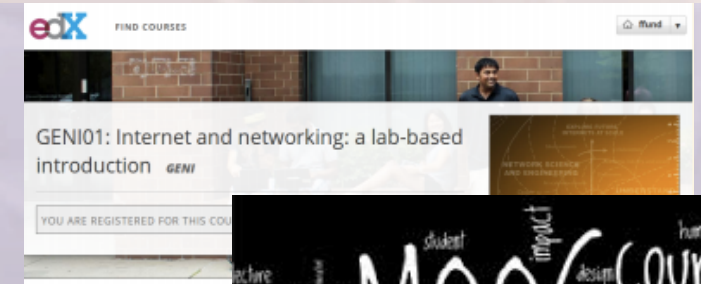
Labs on GENI for networking textbook

Mike Zink
UMass Amherst

GENI Modules to teach networking concepts



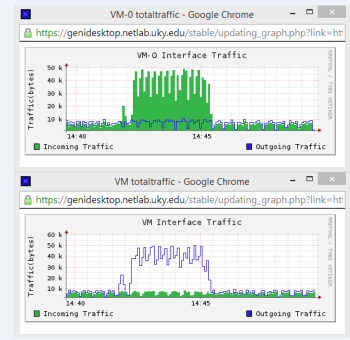
Example Demo Module



Massive Online Open Courses on GENI

Shivendra Panwar, Thanasis Korakis
NYU Poly

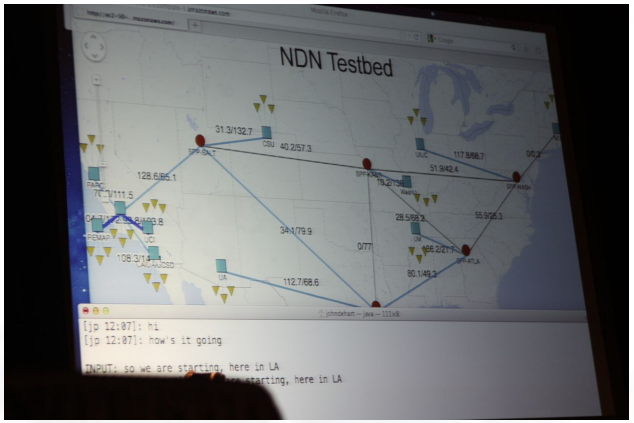
Use GENI to educate the Internet users, not the Internet creators.

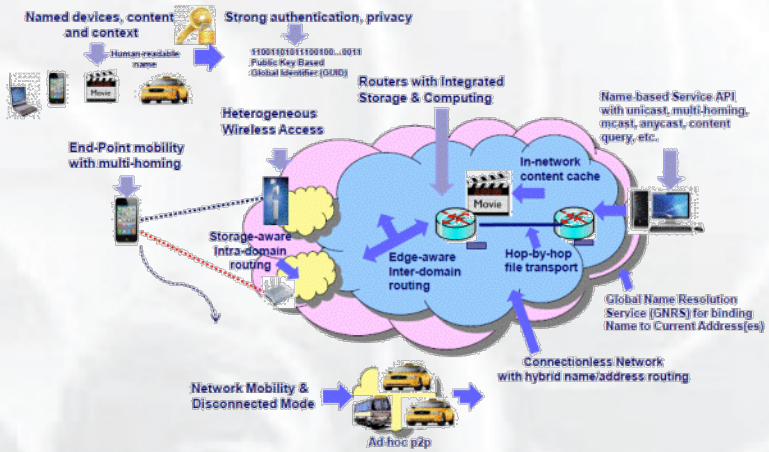


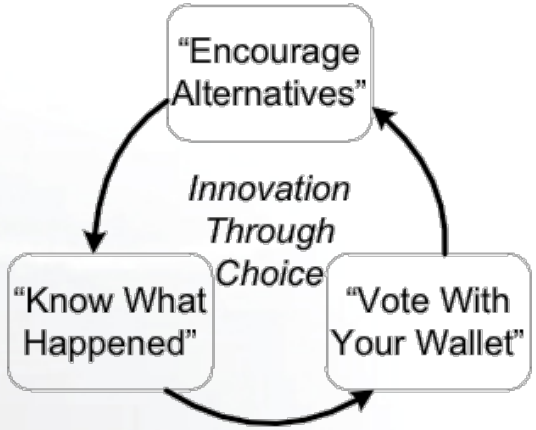
Example Assignment

Kevin Jaffay, Jay Aikat
UNC-Chapel Hill

FIA Teams have Slices on GENI





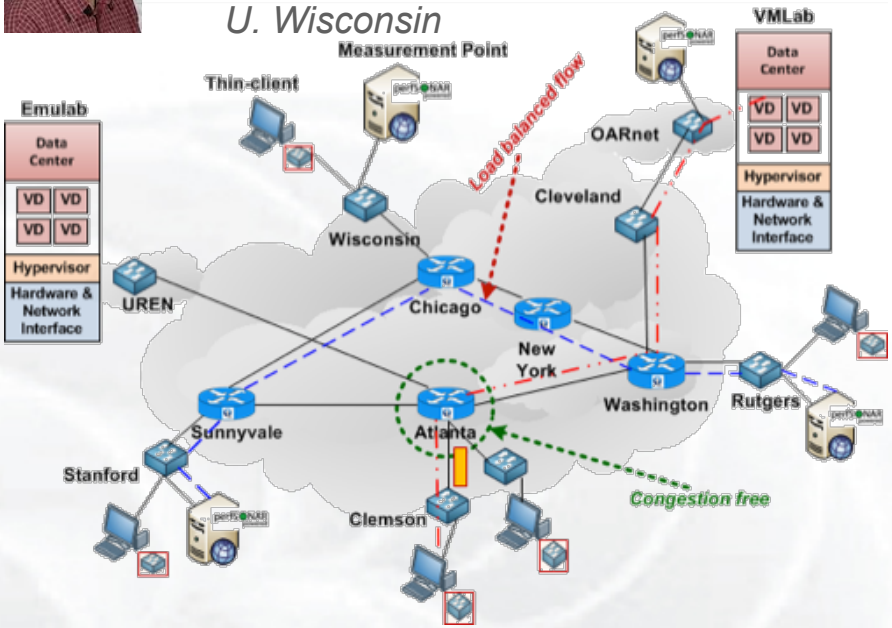


GENI is a unique testbed that can support these teams.

Software Defined Networking Research

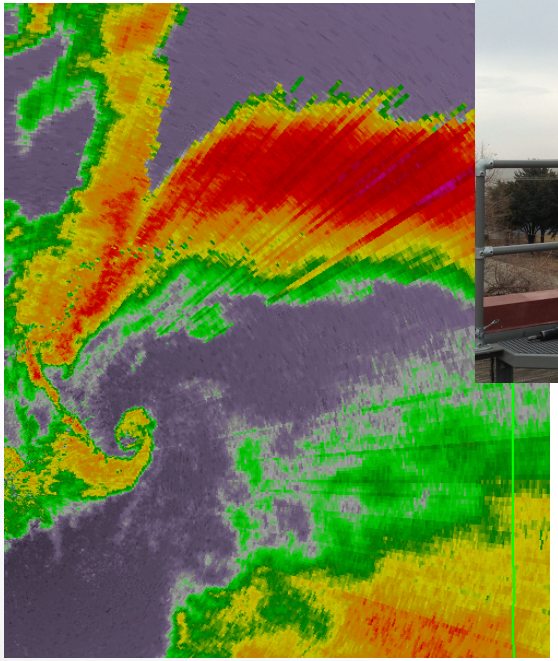
KC Wang
Clemson U.

Parmesh Ramanathan
U. Wisconsin



GENI Cinema

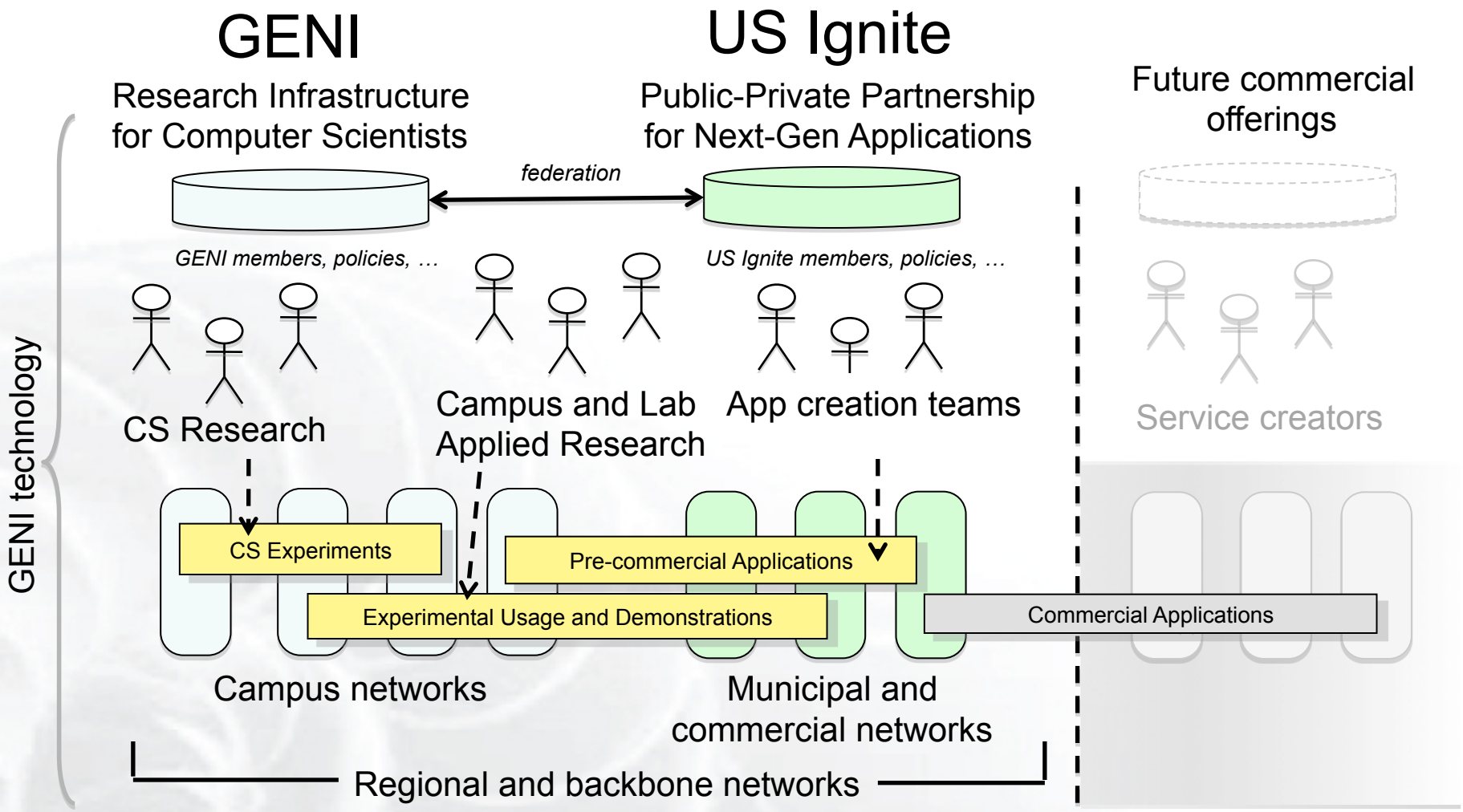
Improve in-time weather forecasting using **S**oftware **D**efined e**X**changes



Mike Zink
Umass Amherst

GENI is the largest multi-domain SDN testbed

US Ignite: Builds application of the future



US Ignite promotes advanced applications and infrastructure leveraging GENI research and technologies.

Outline

GENI – Exploring future internets at scale

The GENI Concept

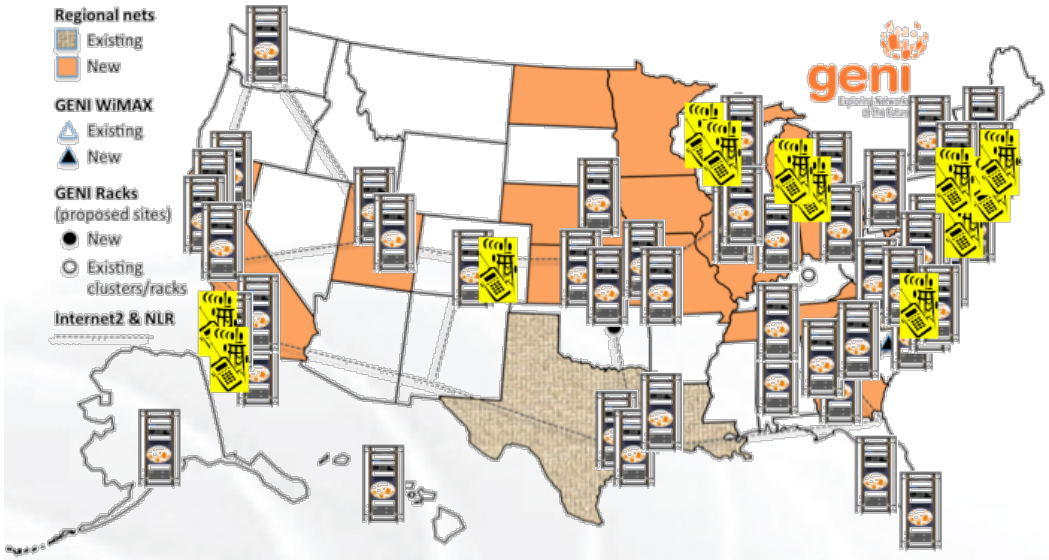
Building GENI

Experimental and Classroom use of GENI

What's next for GENI?

GENI: An experimenter's view

Interested in GENI Enabling your Campus?



"GENI-enabled" means . . .
OpenFlow + GENI racks, plus
WiMAX on some campuses

OpenGENI vendor

InstaGENI vendor

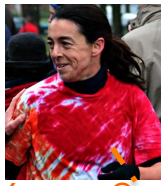
ExoGENI vendor

To buy a GENI Rack talk to rack vendors or GPO

GENI's International Collaborations

GENI is working actively with peer efforts on five continents to define and adopt common concepts and APIs.

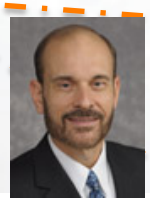
TransGeo Distributed Clouds:
Think Globally, Compute Locally



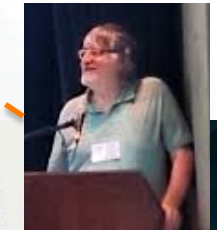
Yvonne Coady
U. Victoria
Canada

Rob Ricci
U. Utah
US

Joe Mambertti
Northwestern
US



Julio Ibarra
FIU, **US**



Michael Stanton
USP, **Brazil**

Piet Demeester
Ughent
Belgium

Rick McGeer
HP, **US**

Compute *"green index"* for cities worldwide

Paul Mueller
U. Kaiserslautern
Germany

Aki Nakao
U. Tokyo
Japan

Federation fosters International Collaborations

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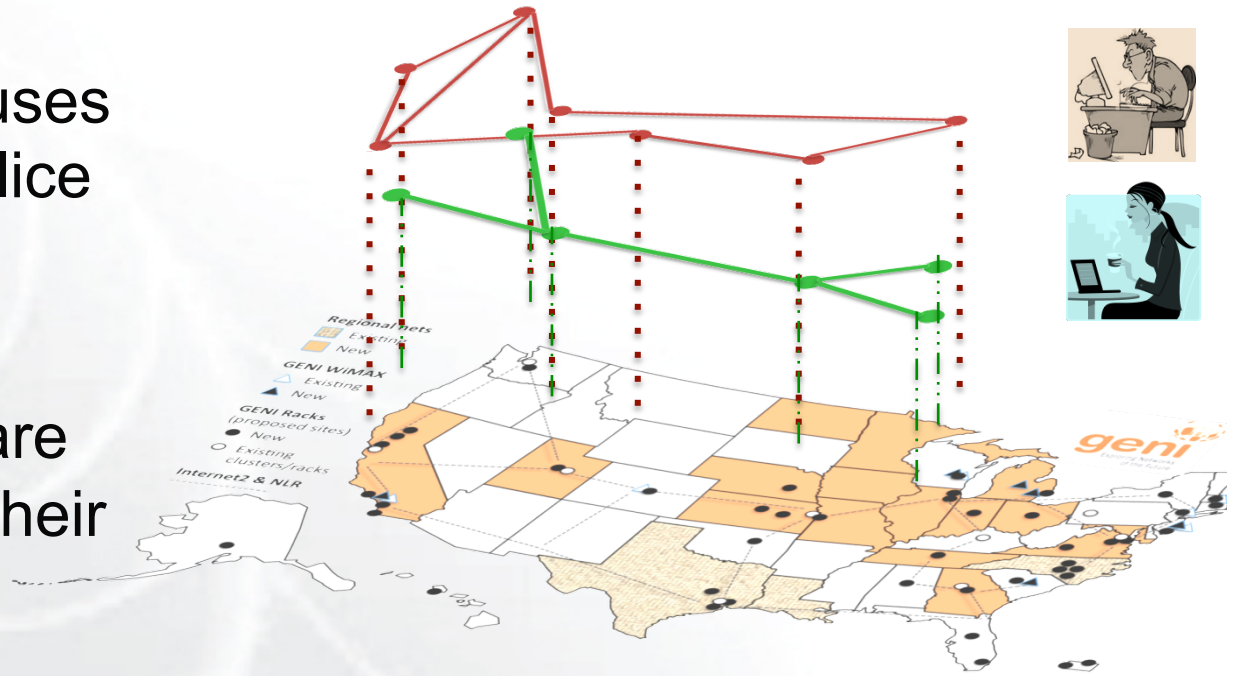
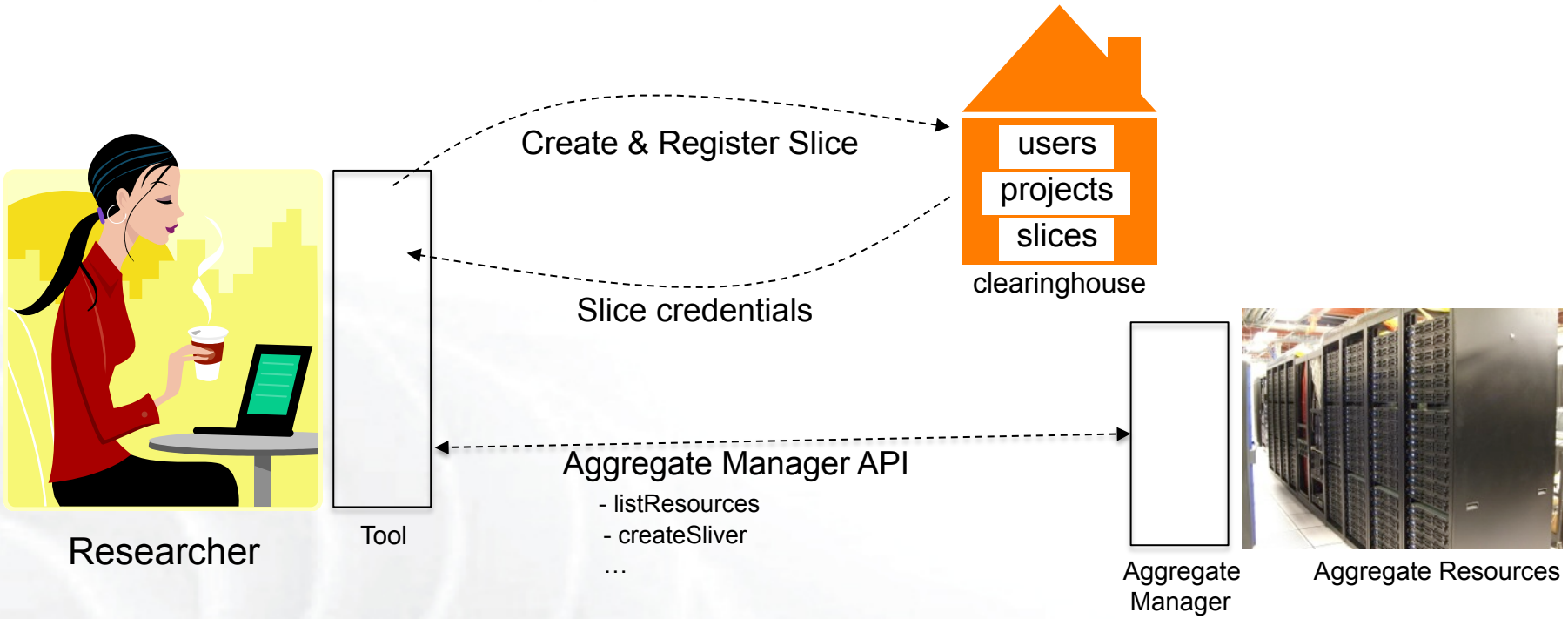
Slice

Abstraction for a collection of resources capable of running experiments

- An experiment uses resources in a slice
- Slices isolate experiments
- Experimenters are responsible for their slices



Clearinghouse and Aggregates



- Clearinghouse: Manages users, projects and slices
  - Standard credentials shared via custom API or new Common CH API
  - GENI supported accounts: GENI Portal/CH, PlanetLab CH, ProtoGENI CH
- Aggregate: Provides resources to GENI experimenters
  - Typically owned and managed by an organization
  - Speaks the GENI AM API
  - Examples: PlanetLab, Emulab, GENI Racks on various campuses

GENI User Authentication

The GENI Portal leverages InCommon for single sign-on authentication

InCommon®

Experimenters from 304 educational and research institutions have InCommon accounts

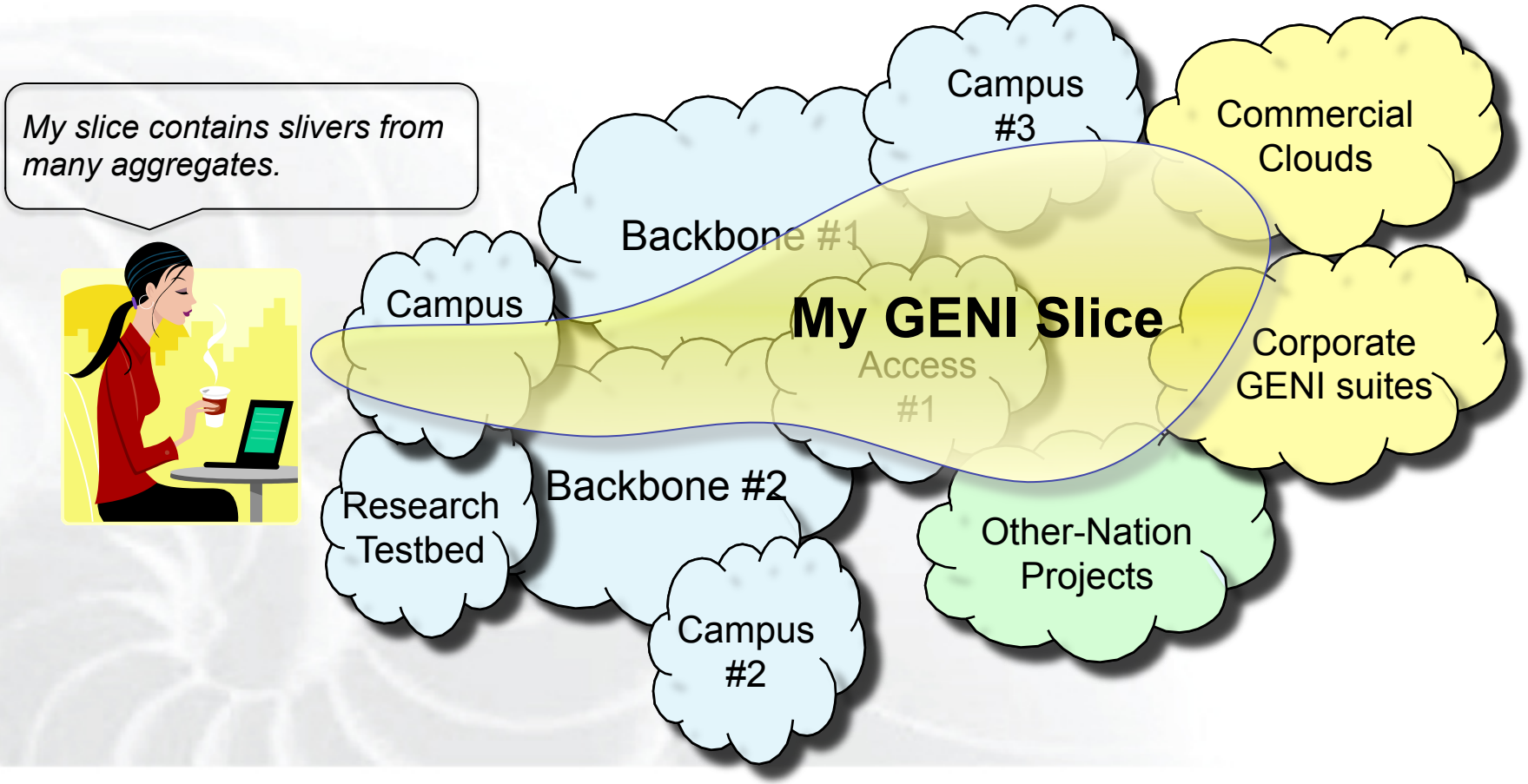
For many experimenters:

- no new passwords
- familiar login screens

GENI Project Office runs a federated IdP to **provide accounts** for non-federated organizations.

GENI: Terms and Definitions

- Sliver: One or more resources provided by an aggregate
  - E.g. Bare machines, virtual machines, VLANs



RSpecs

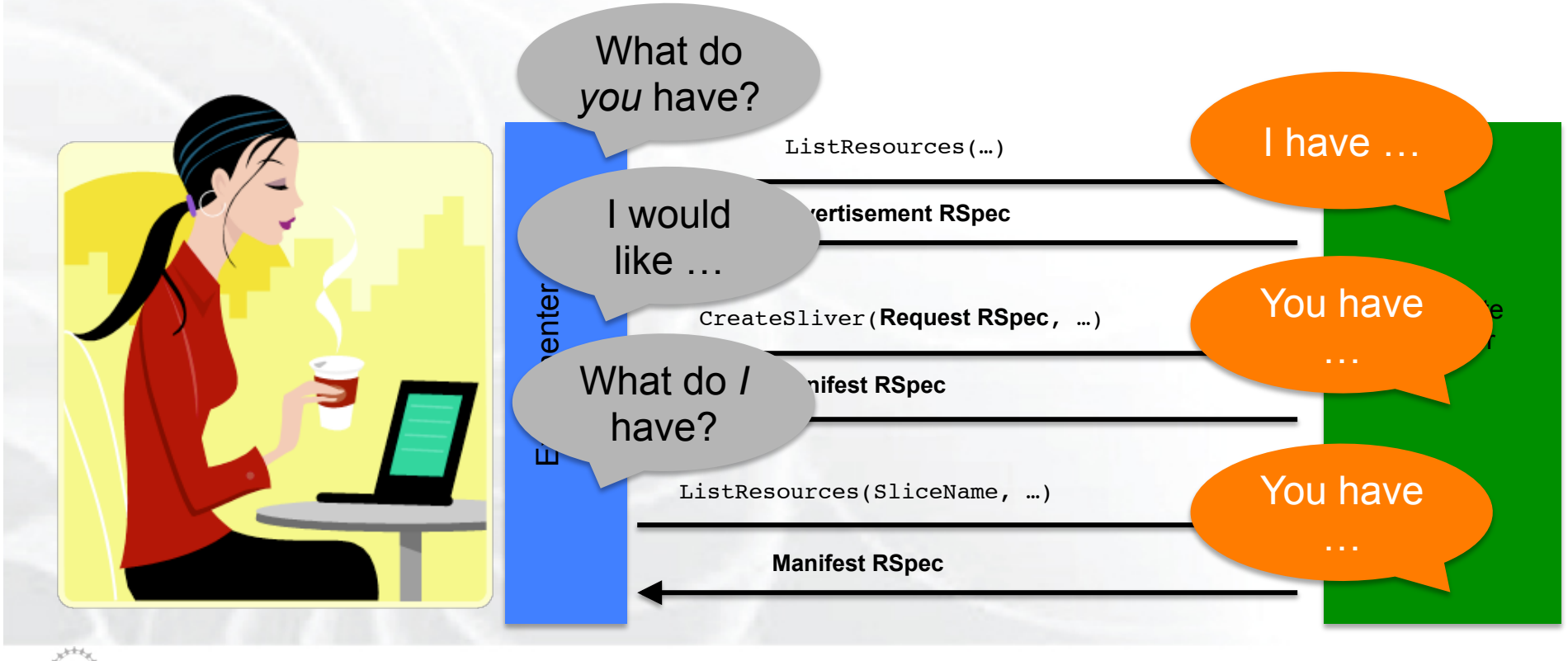
- RSpecs: Lingua franca for describing and requesting resources
  - "Machine language" for negotiating resources between experiment and aggregate
  - Experimenter tools eliminate the need for most experimenters to write or read RSpec

```
<?xml version="1.0" encoding="UTF-8"?>
<rspec xmlns="http://www.protogeni.net/resources/rspec/2"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://www.protogeni.net/resources/rspec/2
                           http://www.protogeni.net/resources/rspec/2/request.xsd"
       type="request" >
  <node client_id="my-node"
        exclusive="true">
    <sliver_type name="raw-pc" />
  </node>
</rspec>
```

RSpec for requesting a single node

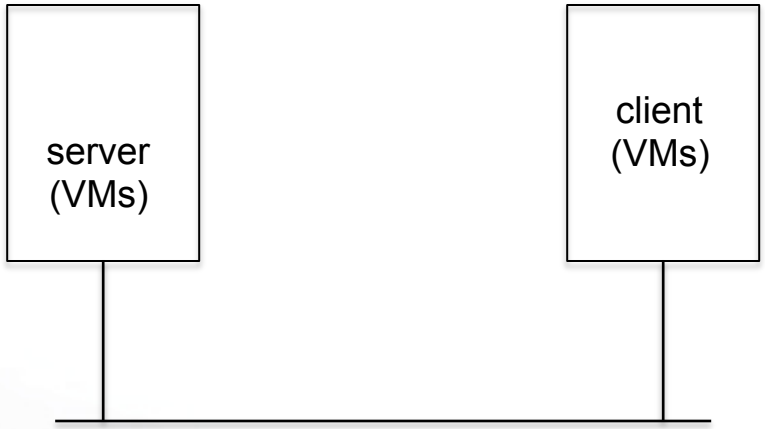
Reserving Resources using RSpecs and the AM API

- Experimenter tools and aggregates talk to each other using resource specifications (RSpecs) and the GENI Aggregate Manager API (GENI AM API)
- Advertisement RSpec: What does an aggregate have?
- Request RSpec: What does the experimenter want?
- Manifest RSpec: What does the experimenter have?



Putting it all Together: Demo

- Demo
  - Login to the GENI Portal
  - Create a slice
  - Create a sliver at one aggregate
    - Two computers (VMs), connected by a LAN
  - Install and run software on the machines
  - View output of software
  - Delete sliver
- Experimenter tool: Jacks



Do Try This at Home!

- Tutorials on the GENI wiki
  - Look for the 

icon on the GENI wiki and then click on 

for tutorials
- Participate in the hands-on tutorials at the GEC
- Get a GENI account today!

Get a GENI Account Today!

At the GEC:

- **Registration Desk**
- **Experimenter drop-in**

Email: help@geni.net

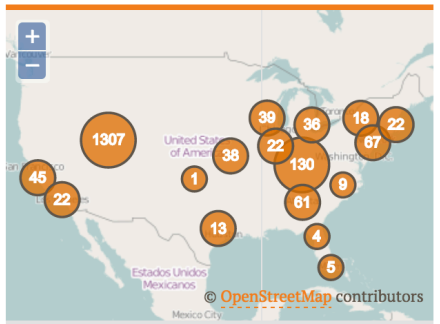
Welcome to GENI

GENI is a new, nationwide suite of infrastructure supporting "at scale" research in networking, distributed systems, security, and novel applications. It is supported by the National Science Foundation, and available without charge for research and classroom use.

Use GENI

Find out more about using GENI

- New to GENI?
- Information for GENI experimenters
- Published research that used GENI resources
- Get help using GENI

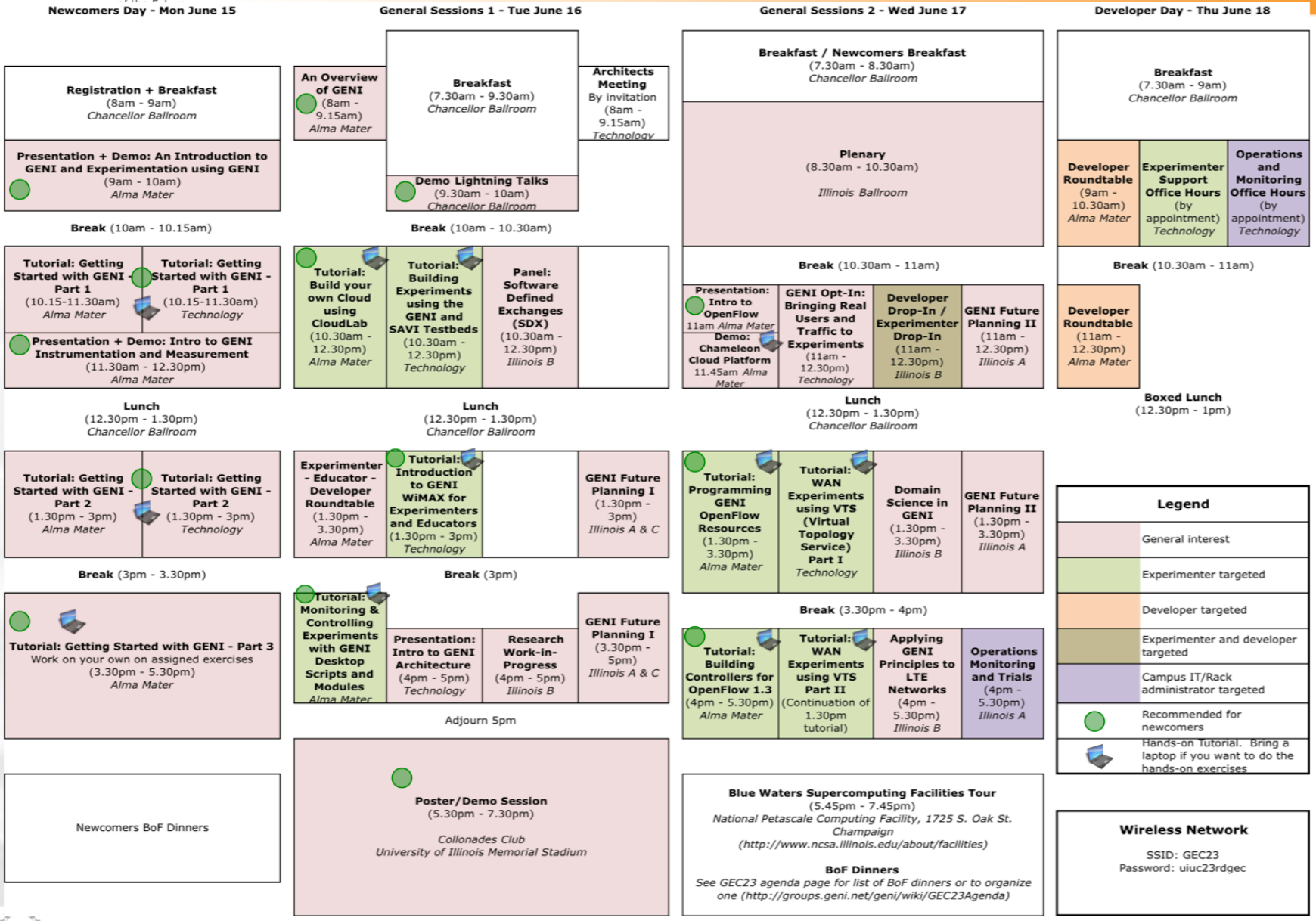


These are some of the many resources being used in GENI experiments across the country.

Online: https://portal.geni.net

Students need a professor to create a GENI project

GEC23 Agenda Overview



GENI at Conferences and Workshops

TRIDENTCOM
Testbeds and Research Infrastructures for the Development of Networks and Communities

Tutorial: Building Experiments Using the GENI and SAVI Testbeds
24 June 2014
Vancouver, Canada

Computer and Networking Experimental Research using Testbeds
29 June 2014
With ICDCS in Columbus, OH

Papers and demos on research validated using testbeds

Project Silver
Rethinking Security in the Era of Cloud Computing

Cloud Security Curriculum Development Workshop

Tutorial on Network Function Virtualization using GENI
Organized by Jay Aikat, U. of North Carolina

QUESTIONS?