

GENI

Exploring Networks of the Future

Niky Riga

www.geni.net

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



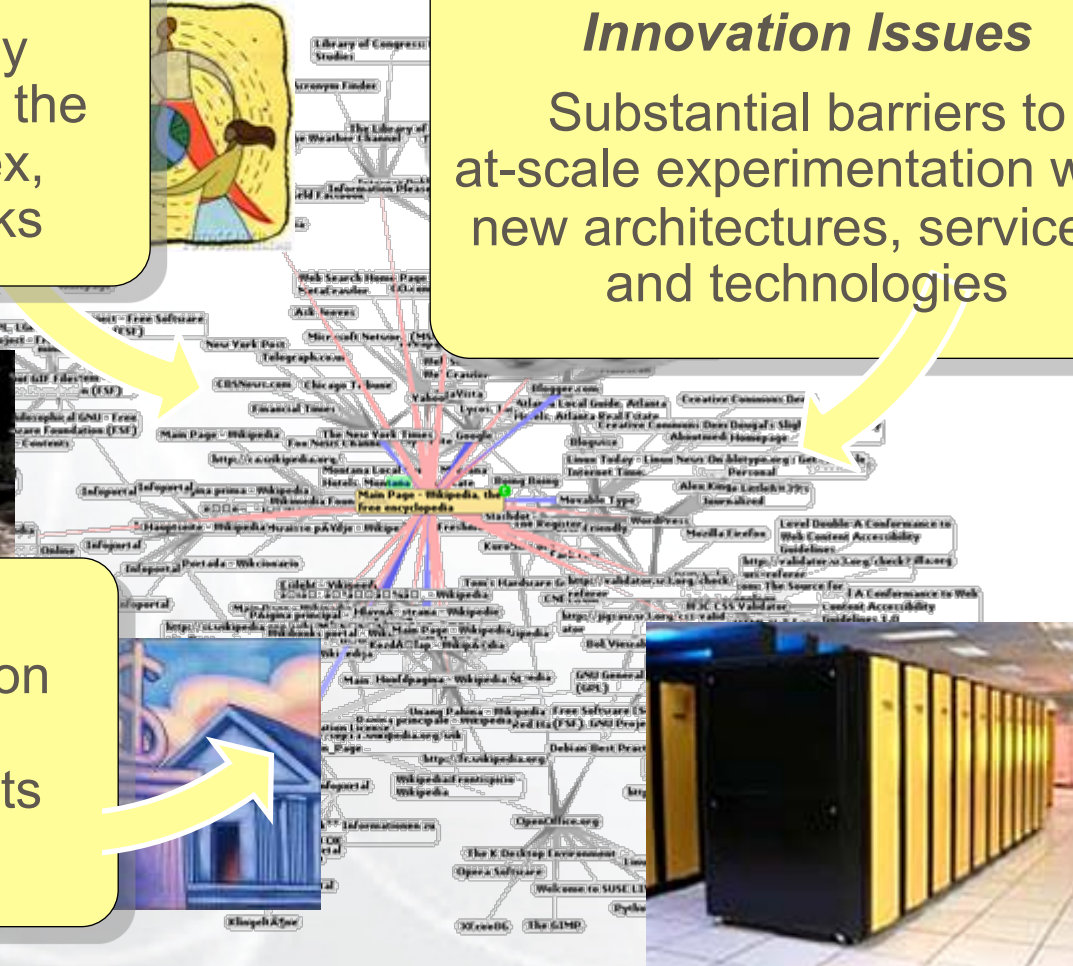
Innovation Issues

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

Regional nets



-  Existing
-  New

GENI WiMAX

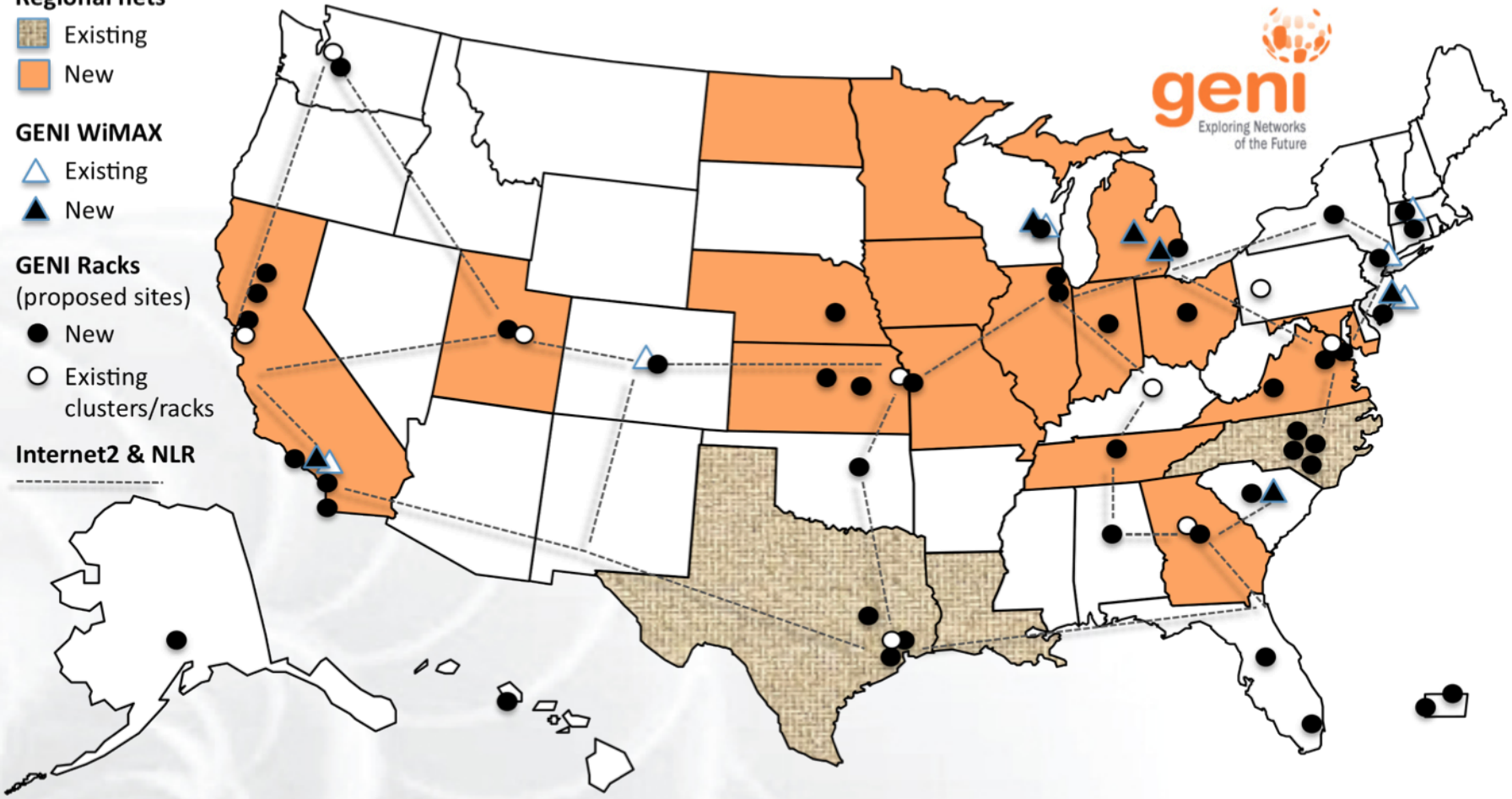
-  Existing
-  New

GENI Racks

(proposed sites)

-  New
-  Existing clusters/racks

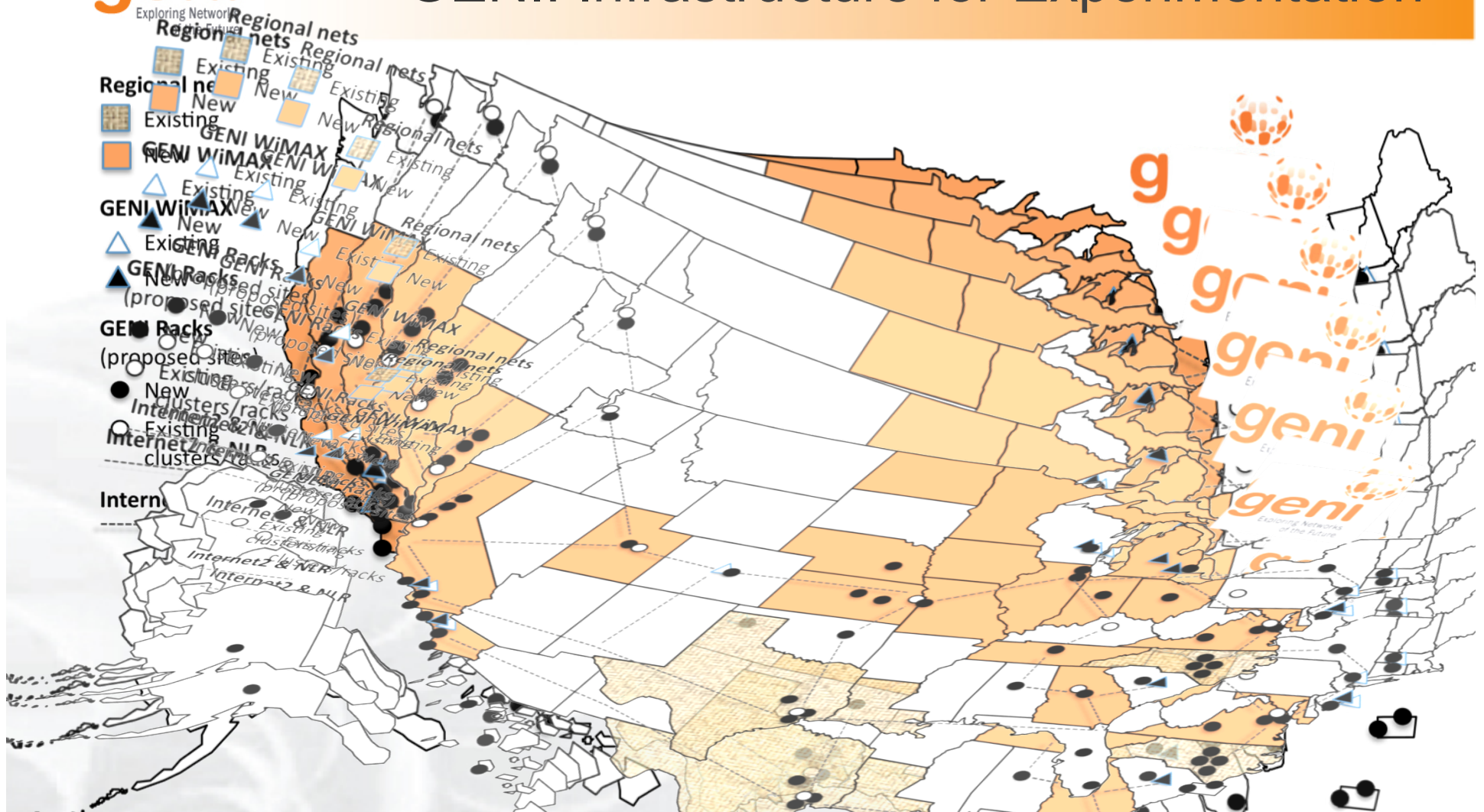
Internet2 & NLR



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



GENI: Infrastructure for Experimentation

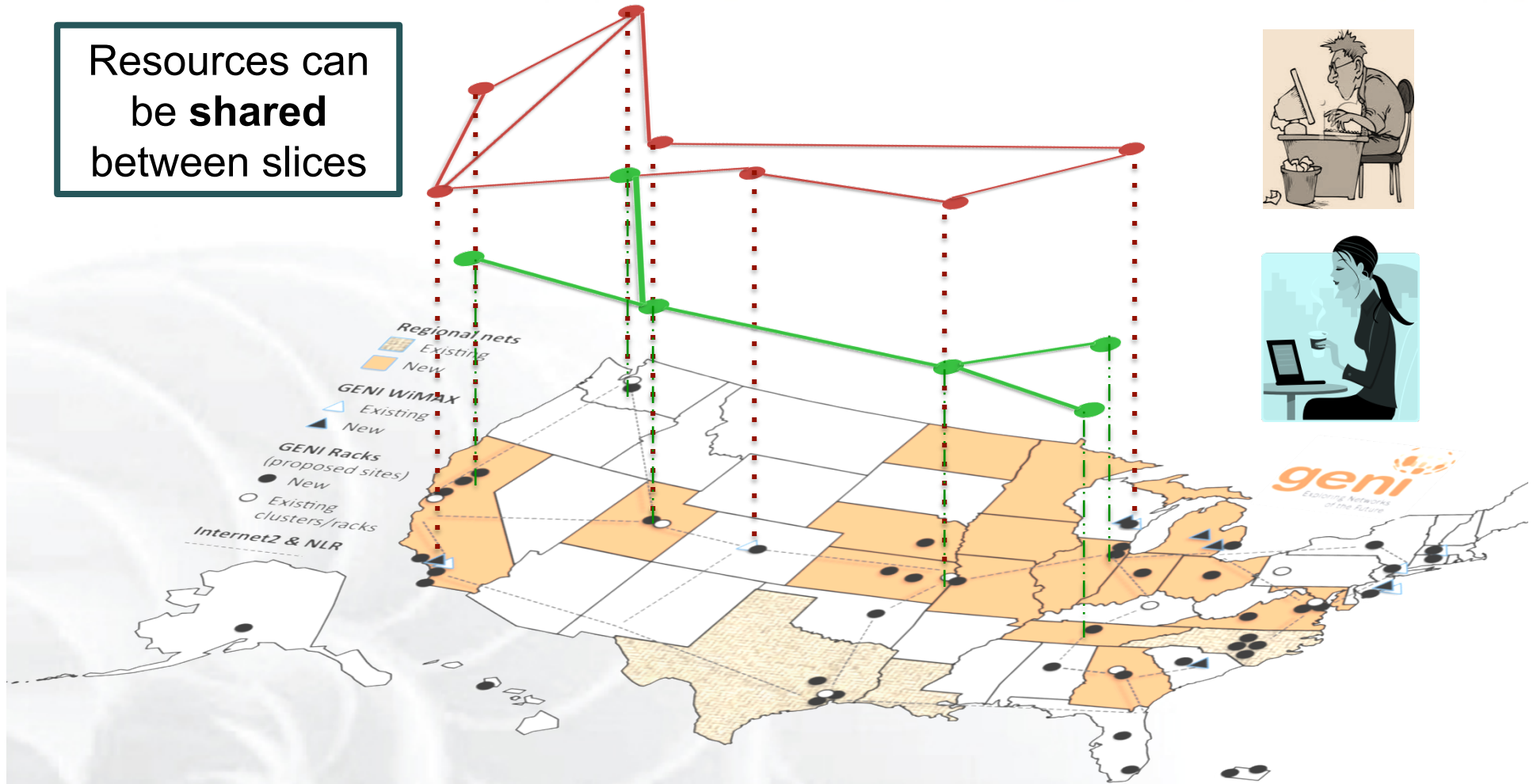


GENI provides compute resources that can be connected in experimenter specified Layer 2 topologies.



Multiple GENI Experiments run Concurrently

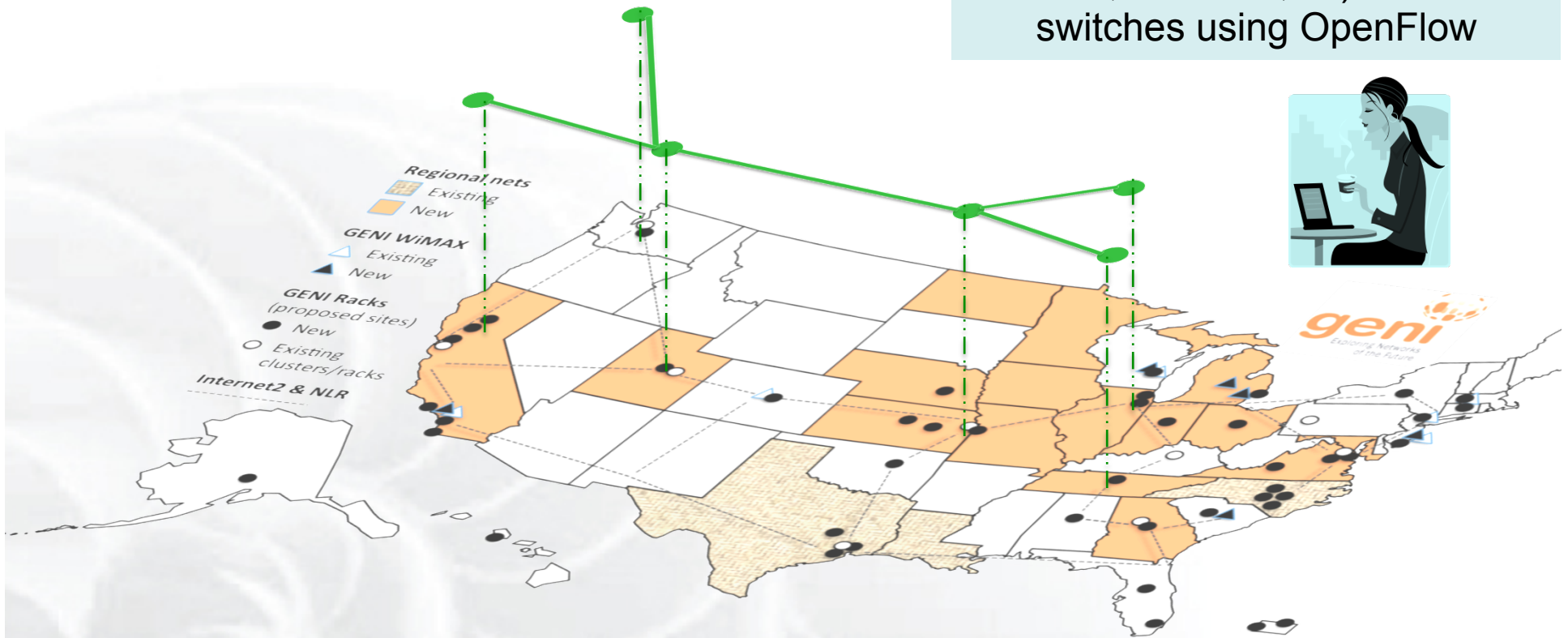
Resources can be shared between slices



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

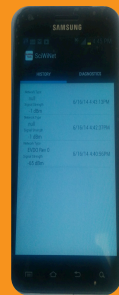


Experimenters can set up custom topologies, protocols and switching of flows

Compute Resources



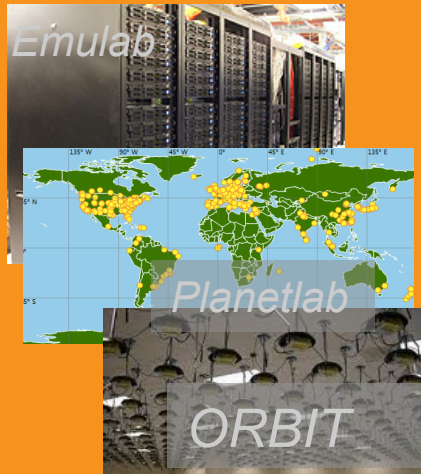
GENI Racks: small clouds
Virtual Machines
Bare metal Machines



Android
Phones



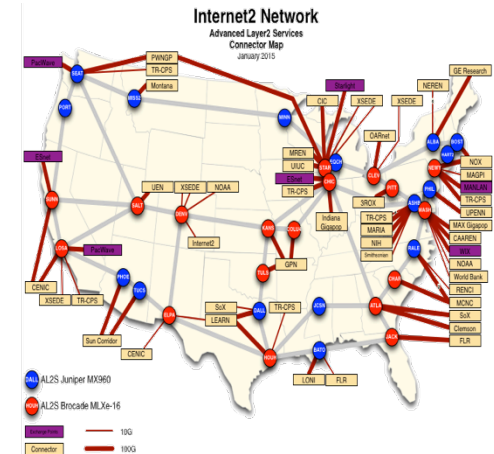
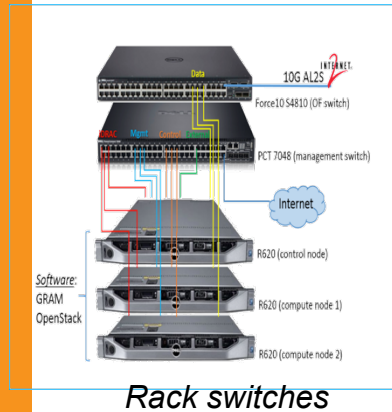
Wireless
nodes



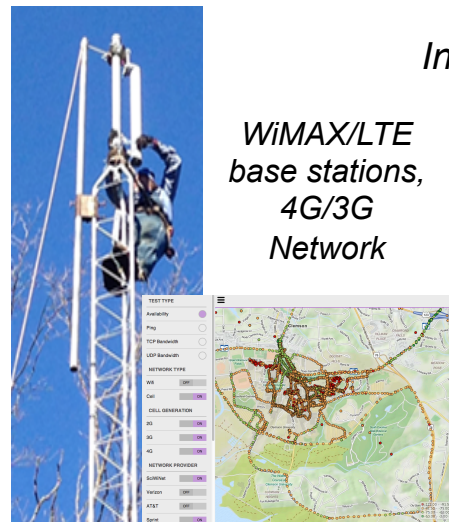
Existing Testbeds

Network Resources

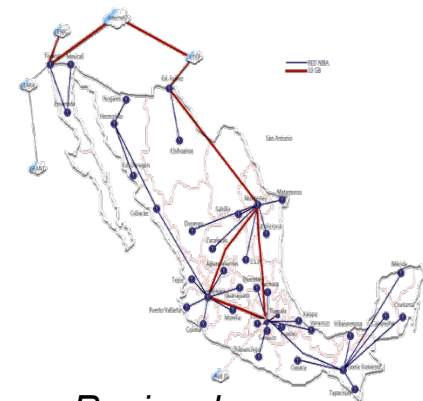
Layer 2 VLANs and Access to Programmable Switches



Internet2: US Research Backbone



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



Regionals

GENI – Exploring future internets at scale

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What's next for GENI?

GENI: An experimenter's view

“I have a great idea.”

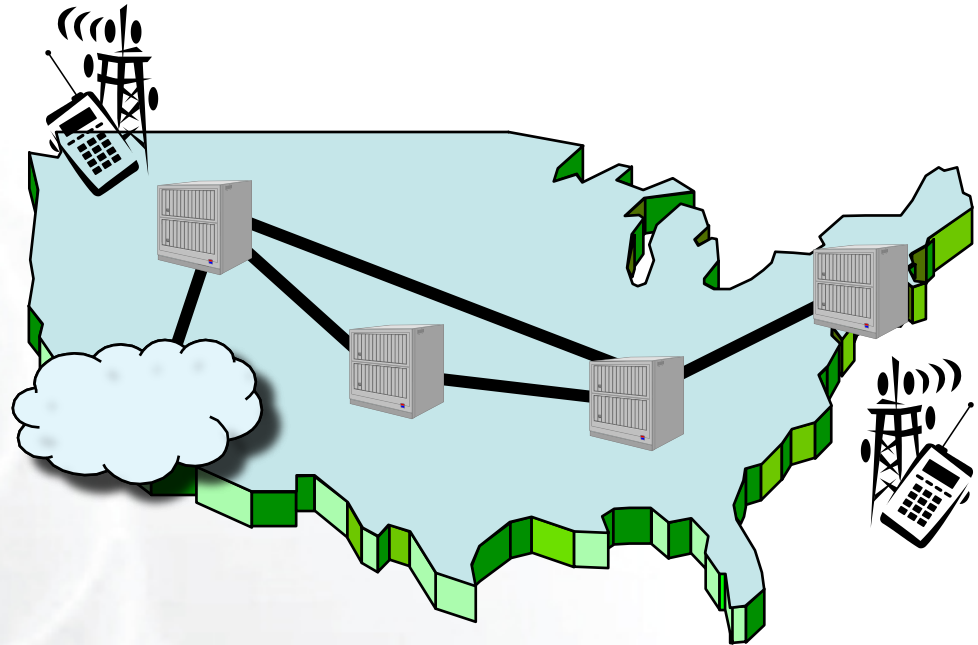


“That will never work.”



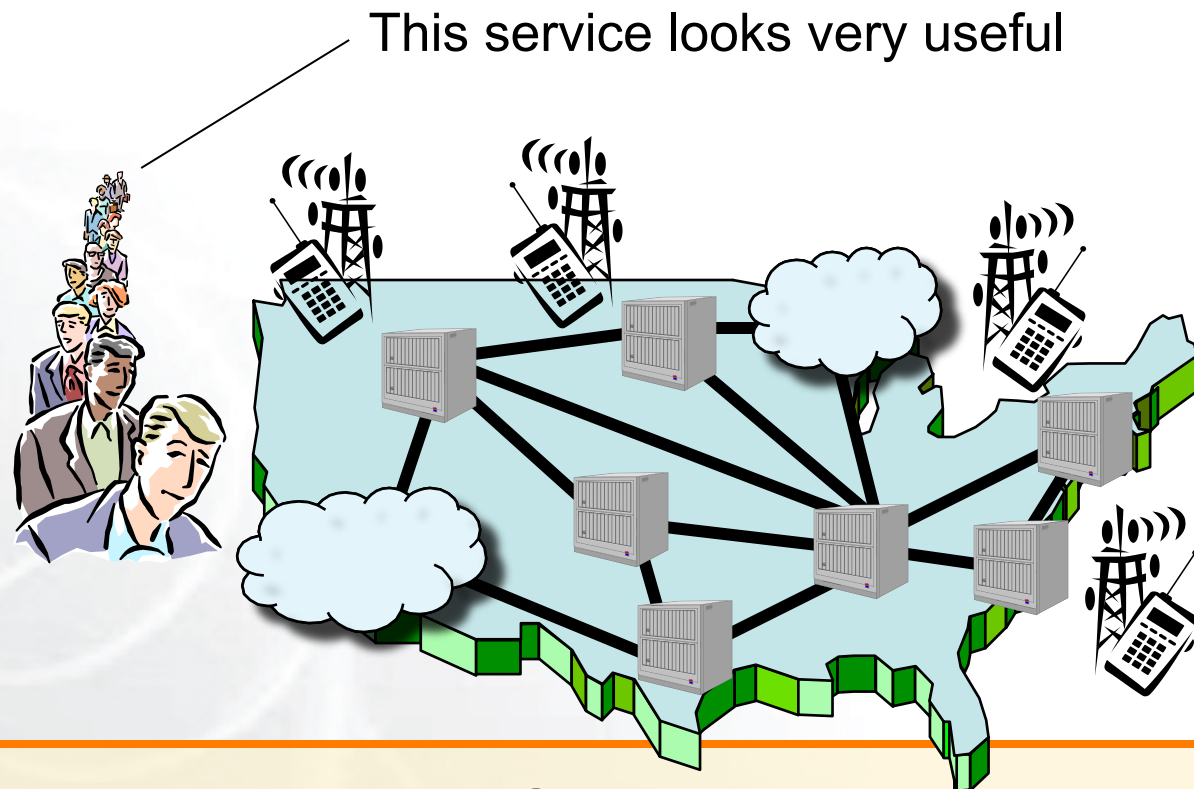
Let's try it out!

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



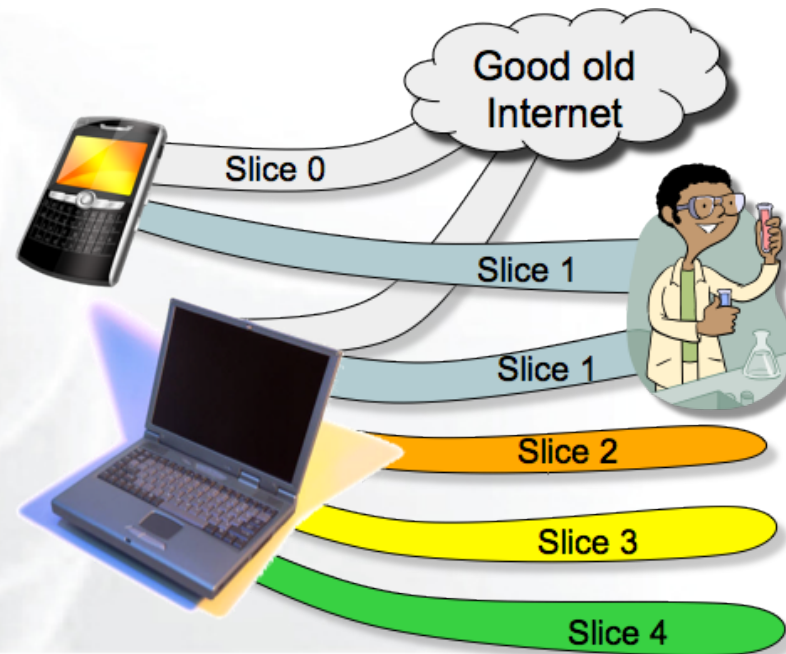
His slice of GENI keeps growing, but GENI is still running many other concurrent experiments.

Attracts real users

“Looks like an app to me.”



“It’s my very own GENI slice.”

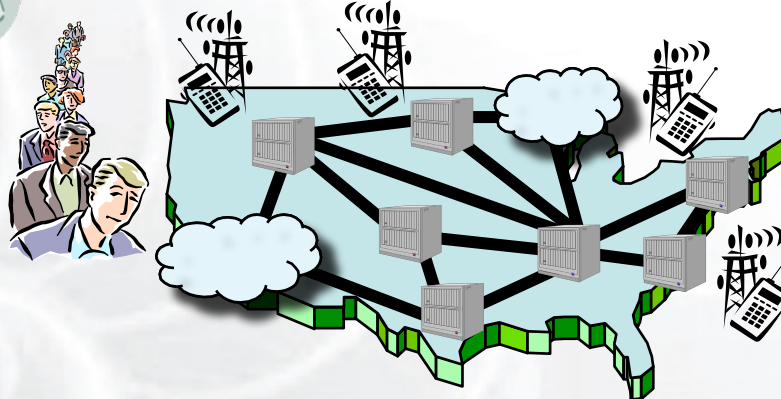


“Boy did I learn a lot!”



“What a cool service.”

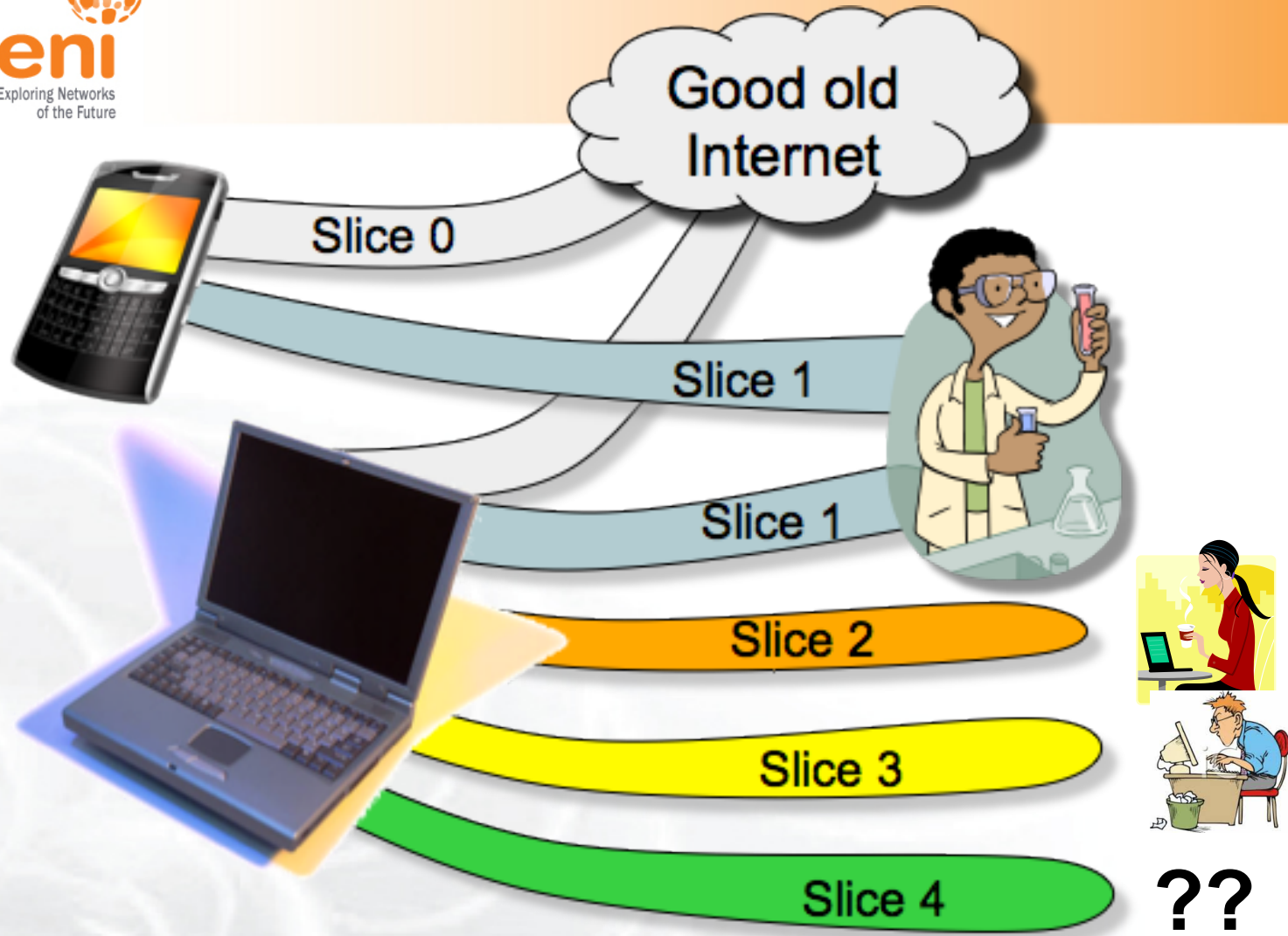
(I wonder how it works.)



“I always said it was
a great idea.”

(But way too conservative.)

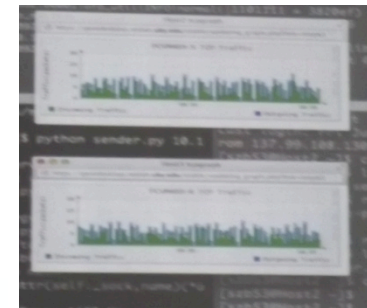
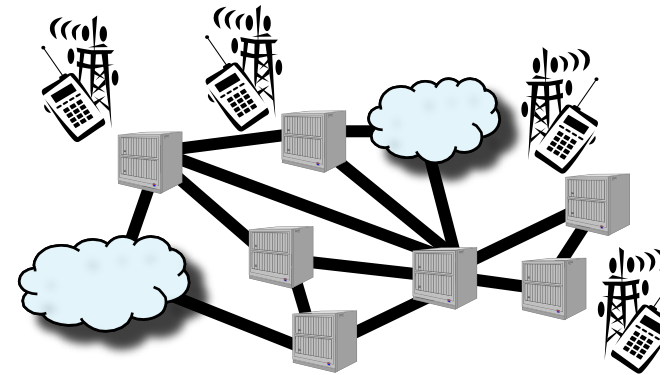




If you have a great idea, check out the NSF CISE research programs for current opportunities.

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!

GENI – Exploring future internets at scale

The GENI Concept

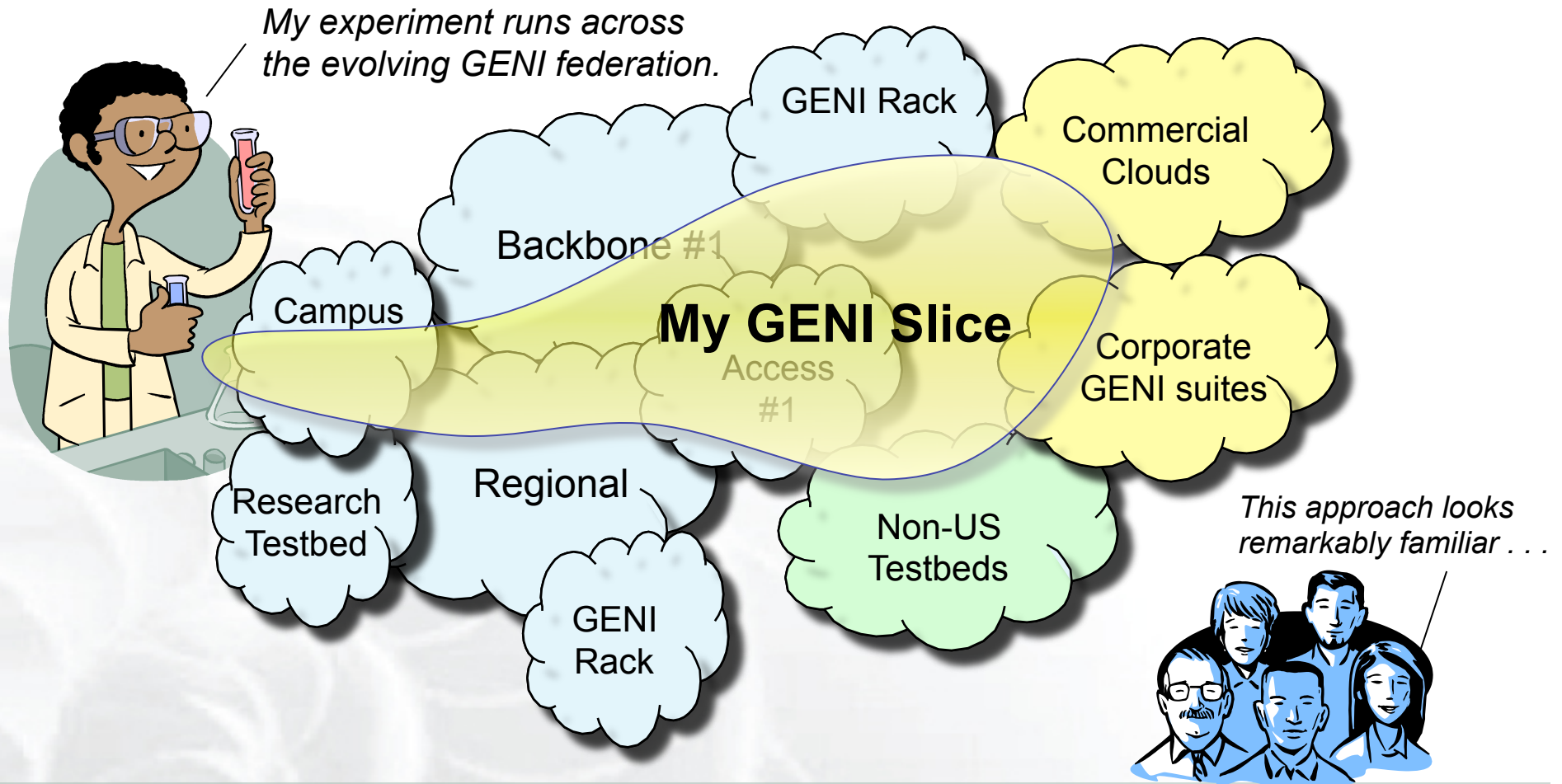
Building GENI

Experimental and Classroom use of GENI

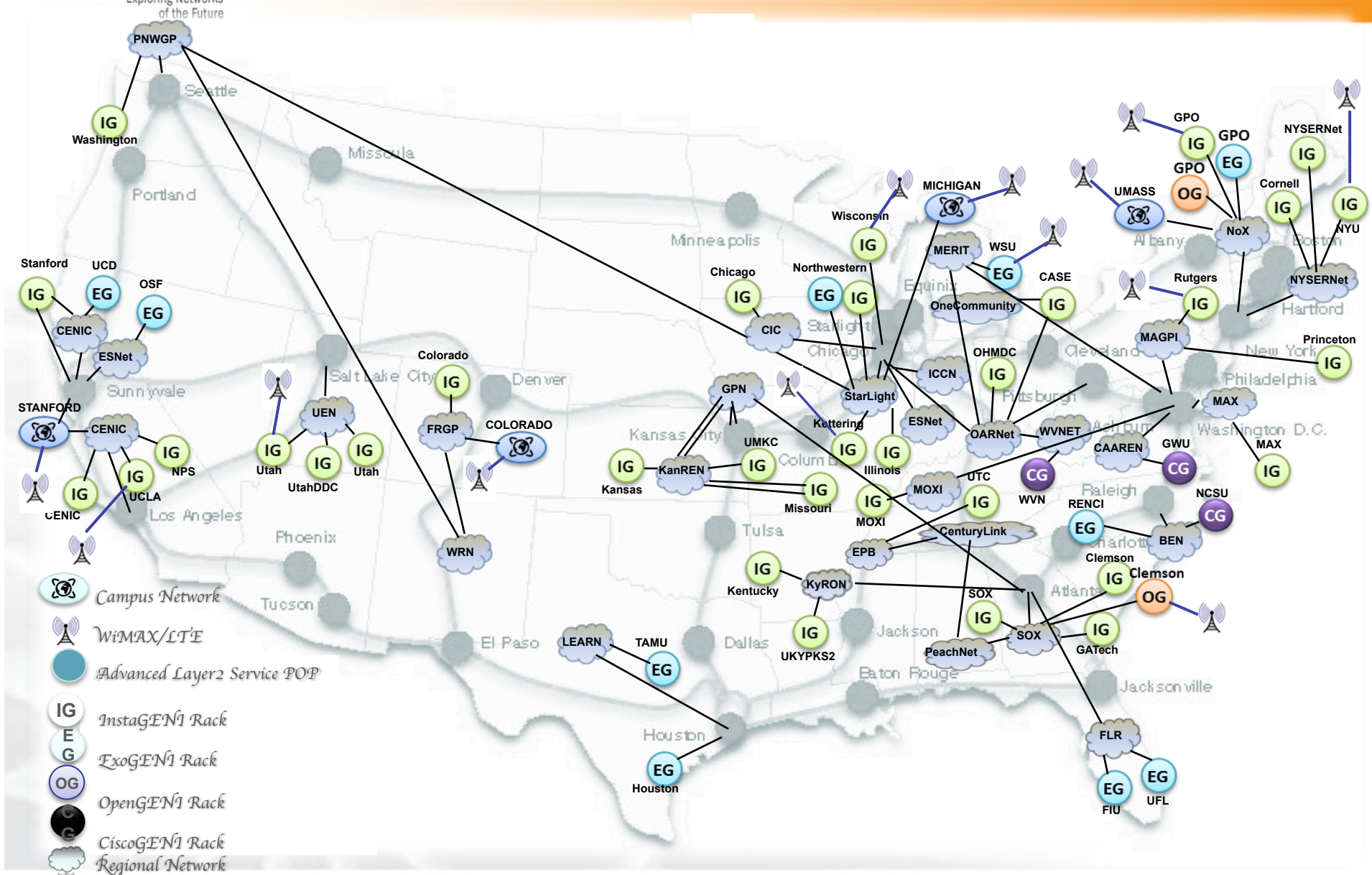
What's next for GENI?

GENI: An experimenter's view

GENI grows by GENI-enabling heterogeneous infrastructure

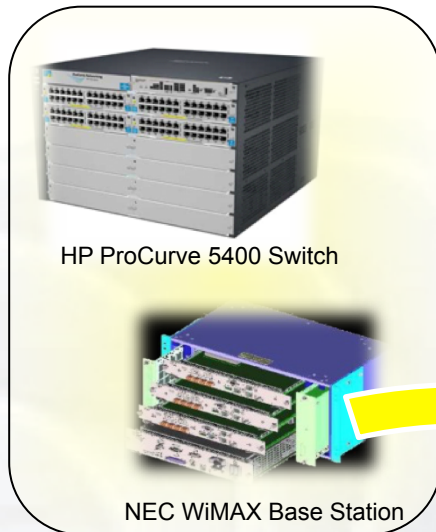


Avoid technology “lock in” and grow quickly by incorporating existing infrastructure

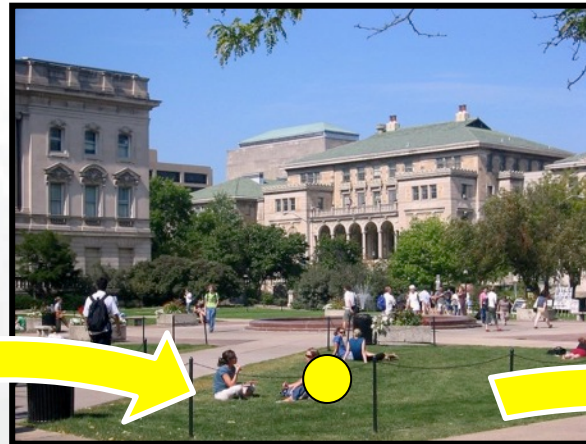


Build GENI at sufficient scale

Infeasible to build a testbed as big as the Internet



GENI-enabled equipment



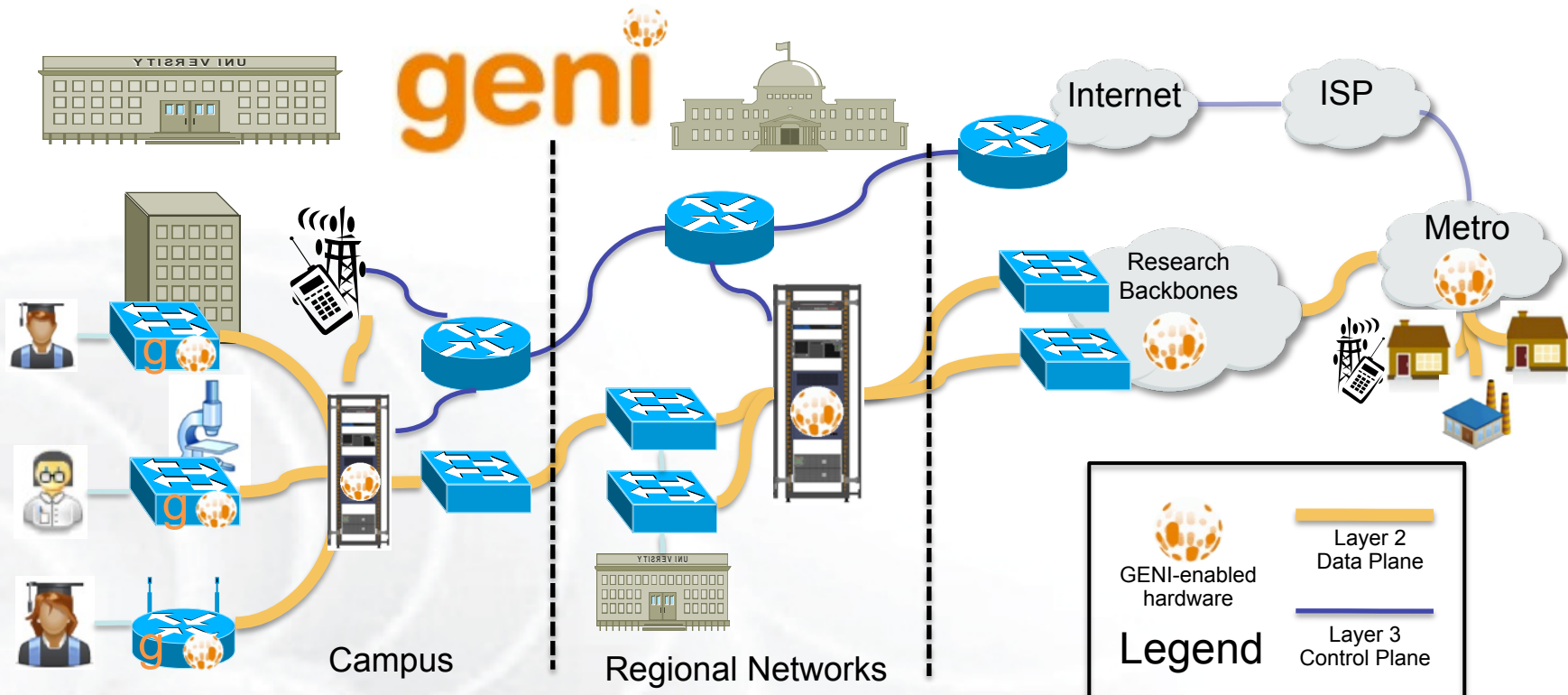
GENI-enabled campuses, students as early adopters



“At scale” GENI prototype

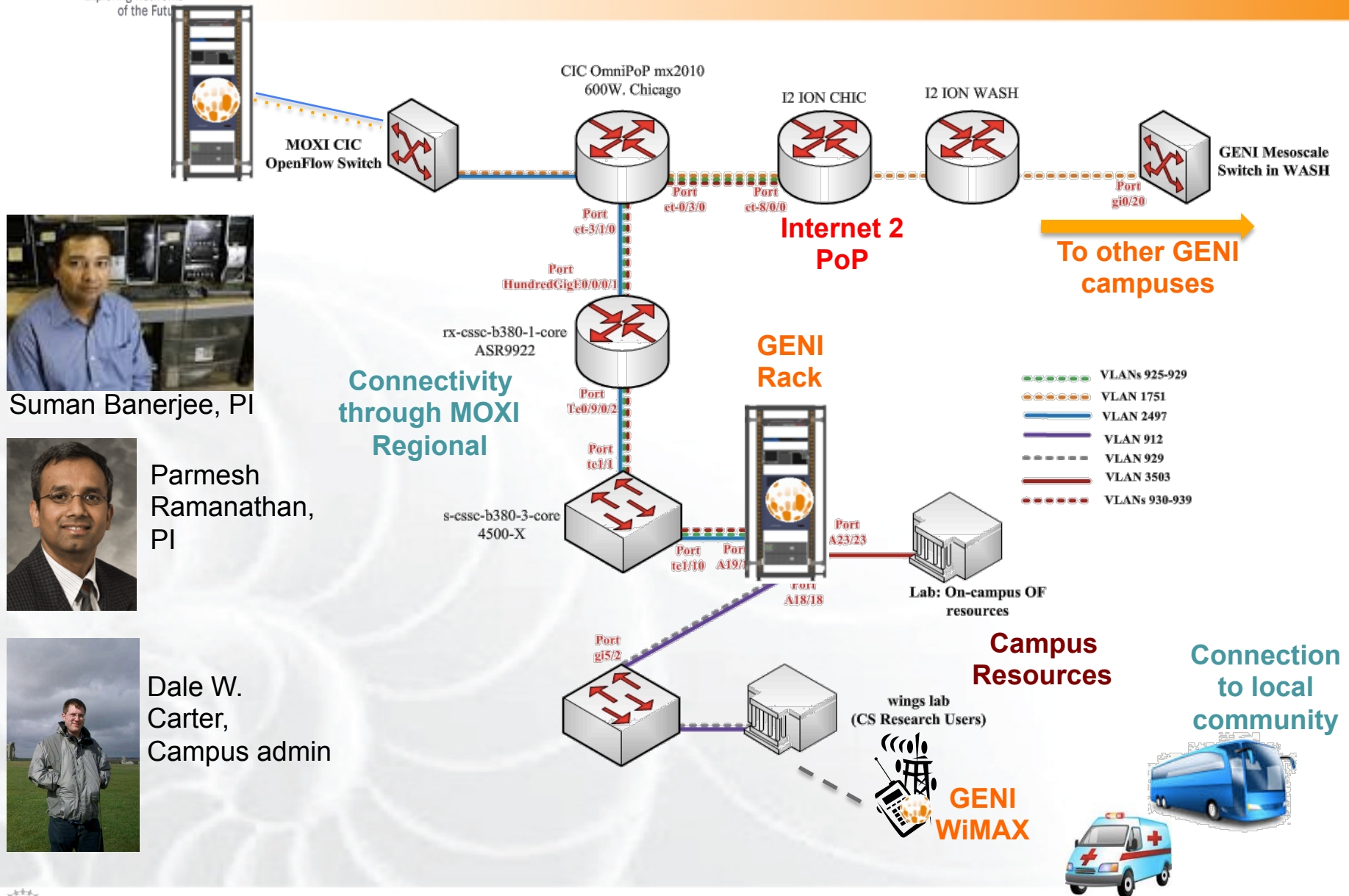
GENI-enable testbeds, commercial equipment, campuses, regional and backbone networks

Campus photo by Vonbloompasha



- 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

Creating and deploying GENI racks



Ilia Baldine
RENCI
More resources / rack,
fewer racks



Rajesh Narayanan
DELL



KC Wang Clemson



Rick McGeer
Fewer resources / rack,
more racks

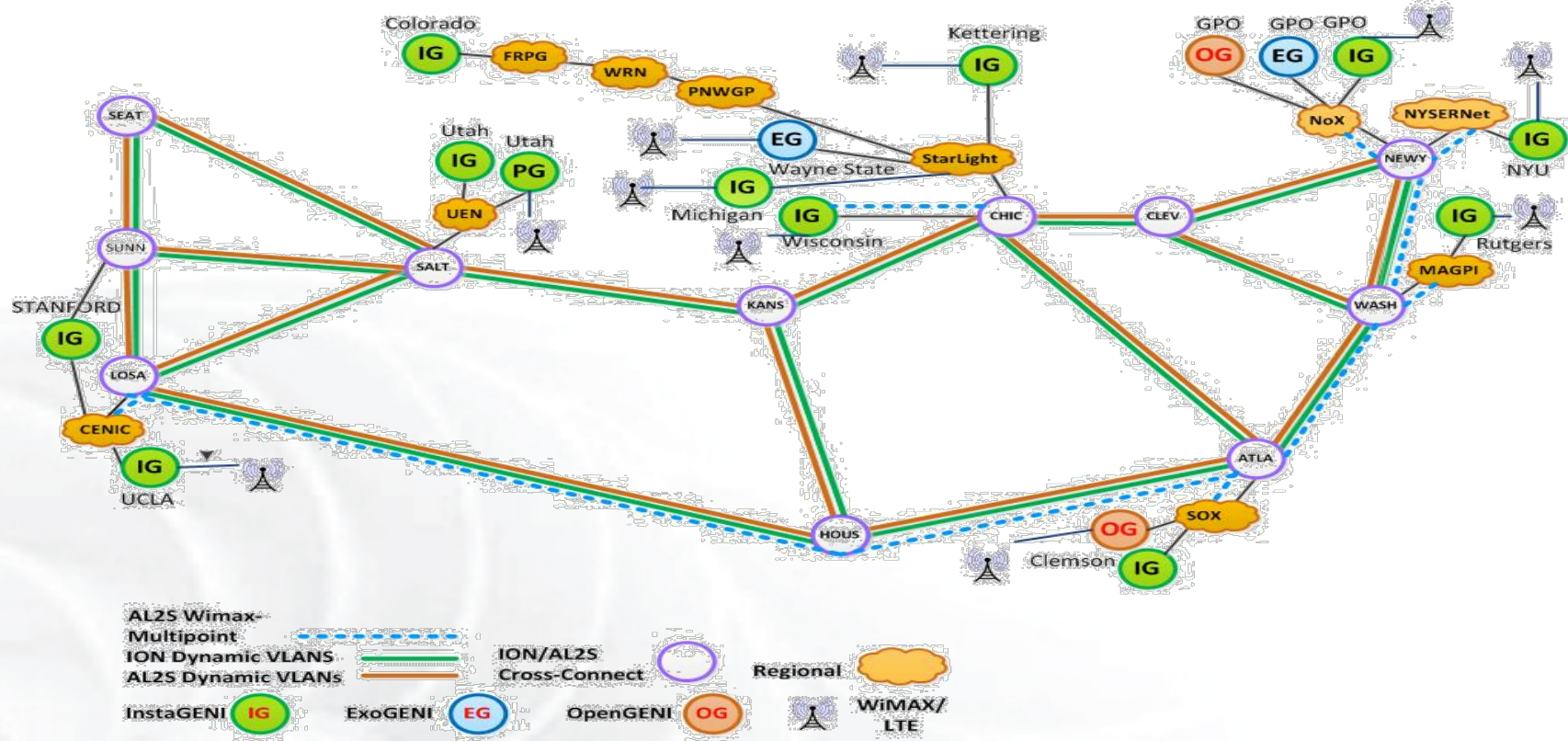


- Collaboration to **implement national-scale infrastructure**
 - sliced and deeply-programmable
 - incorporating OpenFlow/SDN switches, GENI Racks, etc.
 - high-speed (10-100 Gbps)
- Internet2 provides dynamic link provisioning to GENI experimenters
 - Uses AL2S (Advanced Layer 2 Services)
- Experimenters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

- **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



- 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

GMOC: GENI Meta-operation Center

- Keeps track of outages
- Notification system for resource reservation
- Monitors most GENI Aggregates
- Coordinates LLR Requests
 - Legal Law Enforcement & Regulatory
- Handles Emergency Stop



GENI Monitoring Portal developed by UKY

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

<https://mail1.gnoc.iu.edu/mailman/listinfo/experimenter-ops>

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The GENI Concept

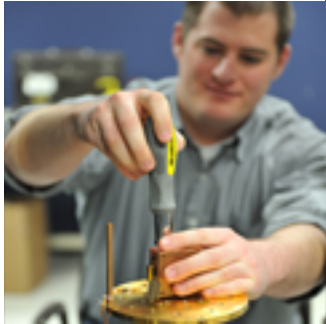
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GENI Use By Numbers



4300
Users



2600
Students
trained on
GENI by



200+
publications

45
Different
instructors



180
Universities

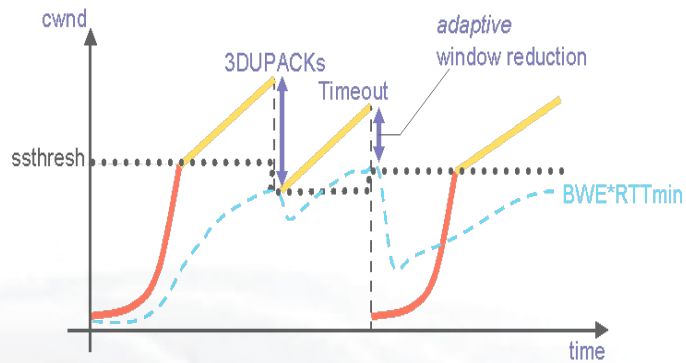


30
Countries



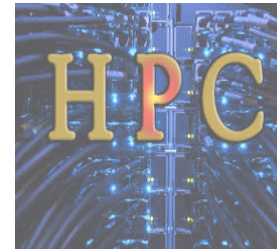
100,000+
Experiments
instantiated



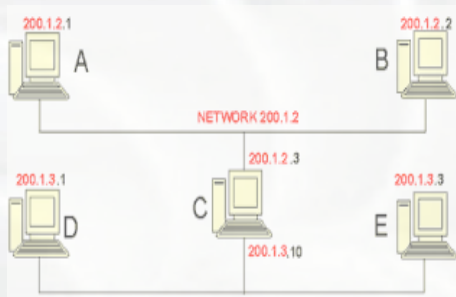


Congestion Avoidance (CA)
Slow-start (SS)

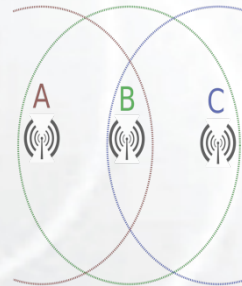
Protocol Behavior



New technologies

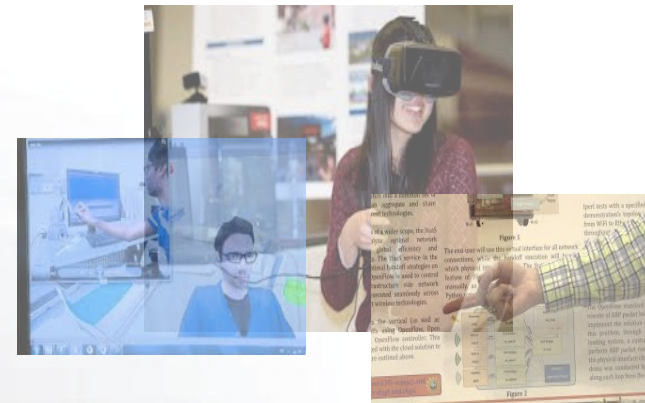


Routing setup



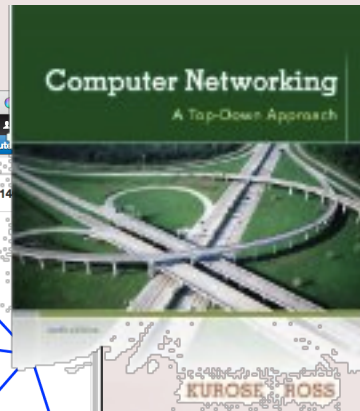
Wireless Communication

Teach Basic Concepts



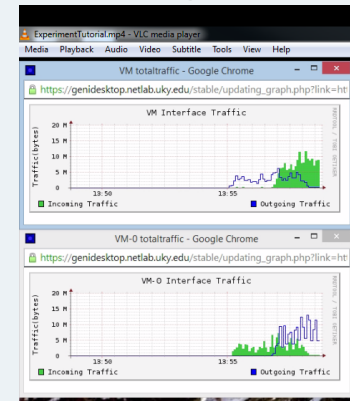
Semester Projects

Labs on GENI for networking textbook

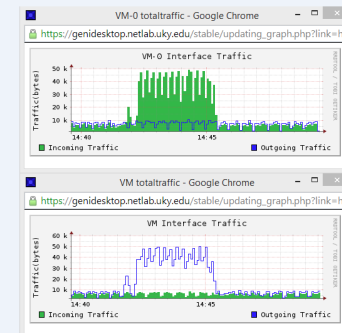


Mike Zink
UMass Amherst

GENI Modules to teach networking concepts



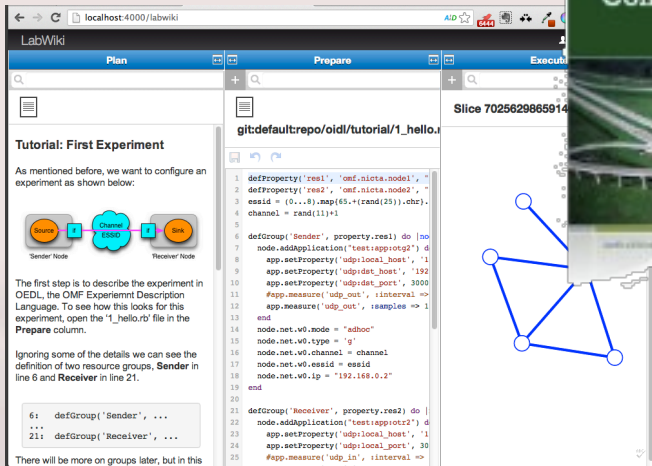

Example Demo Module



Example Assignment
Kevin Jaffay, Jay Aikat
UNC-Chapel Hill

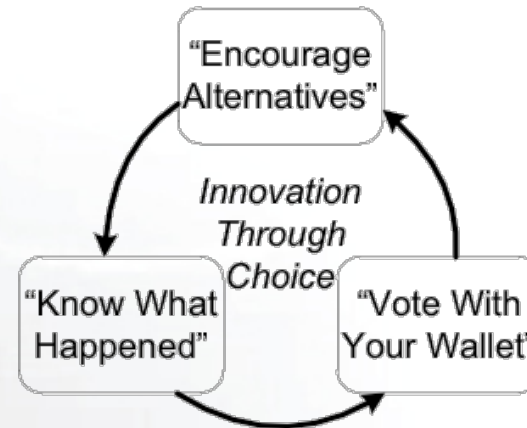
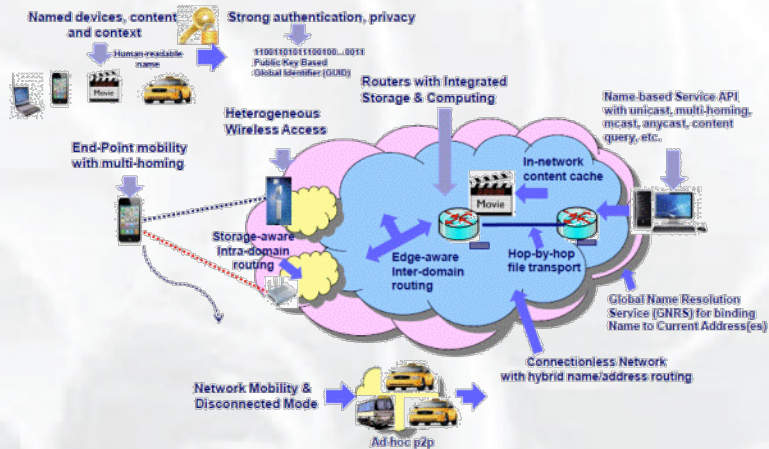
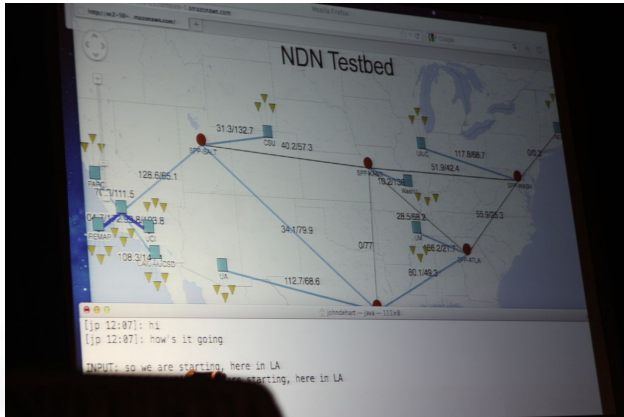
Massive Online Open Courses on GENI

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

Shivendra Panwar,
Thanasis Korakis
NYU Poly





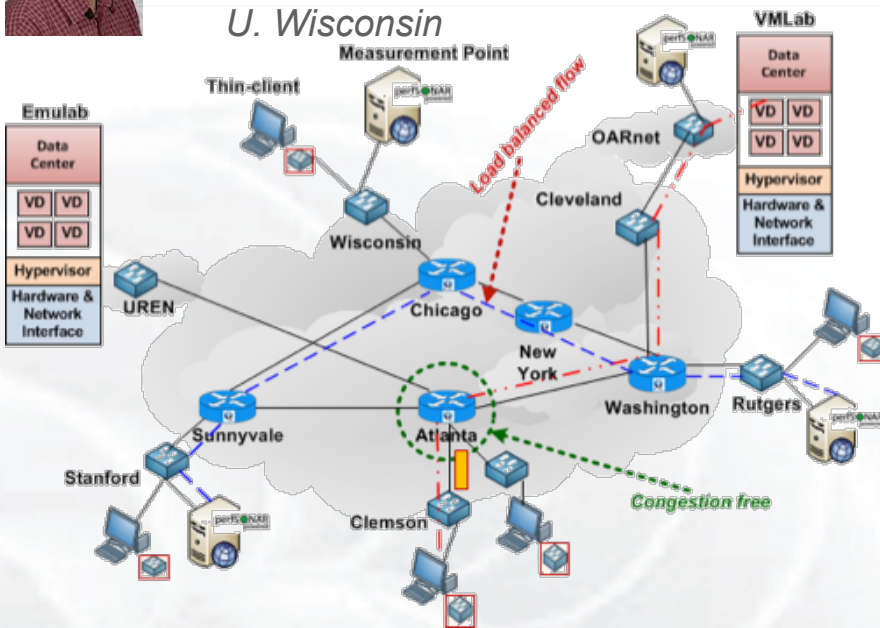
GENI is a unique testbed that can support these teams.



Parmesh Ramanathan
U. Wisconsin

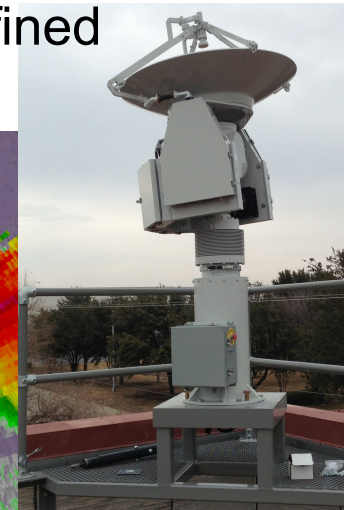
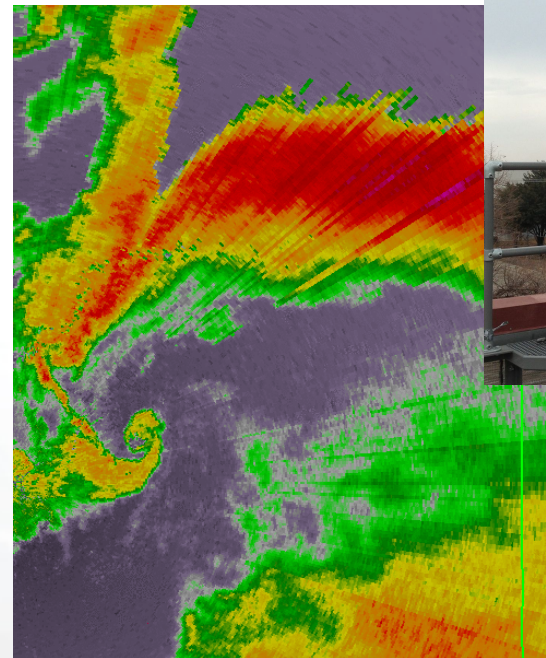


KC Wang
Clemson U.



GENI Cinema

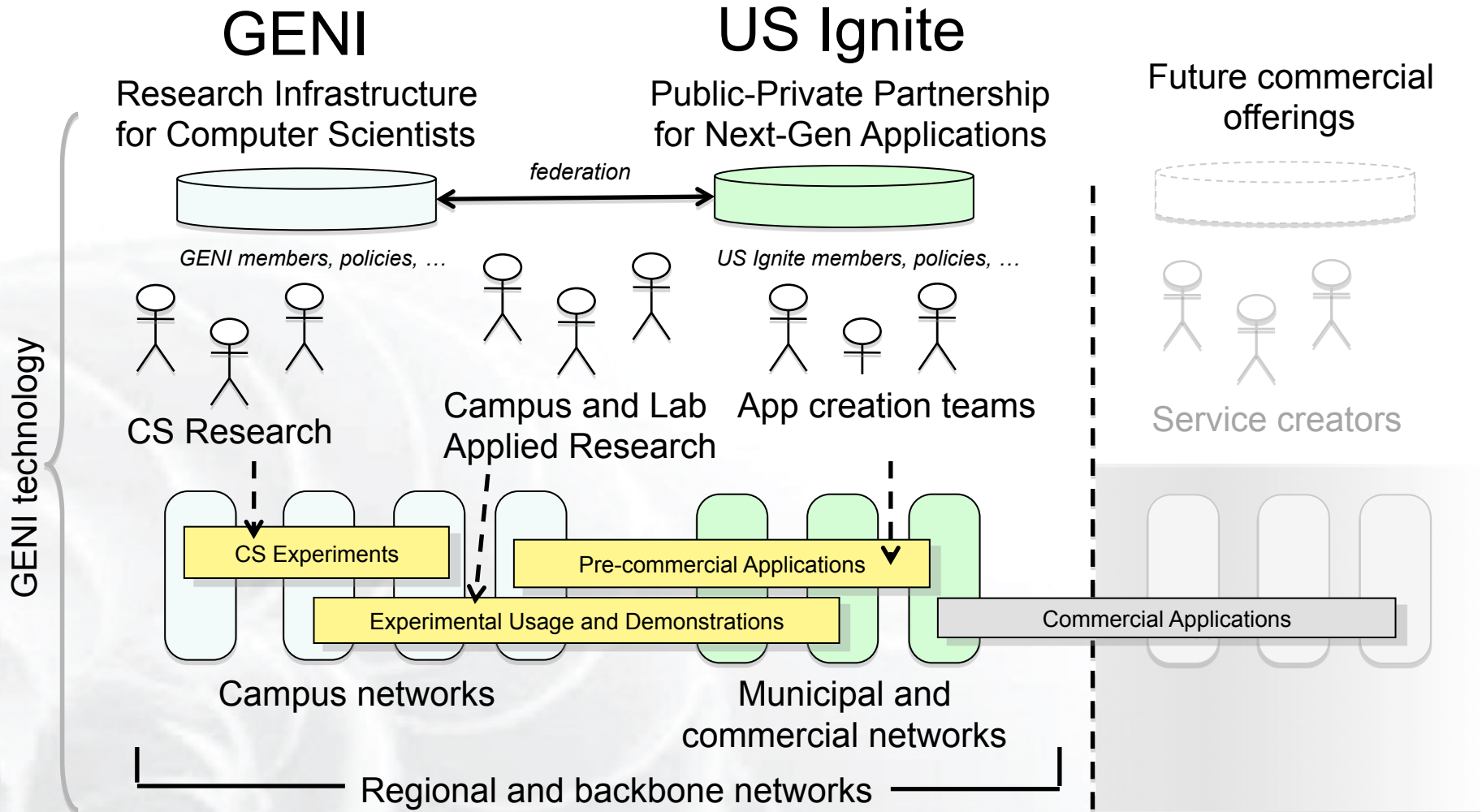
Improve in-time weather forecasting using **Software Defined eXchanges**



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.

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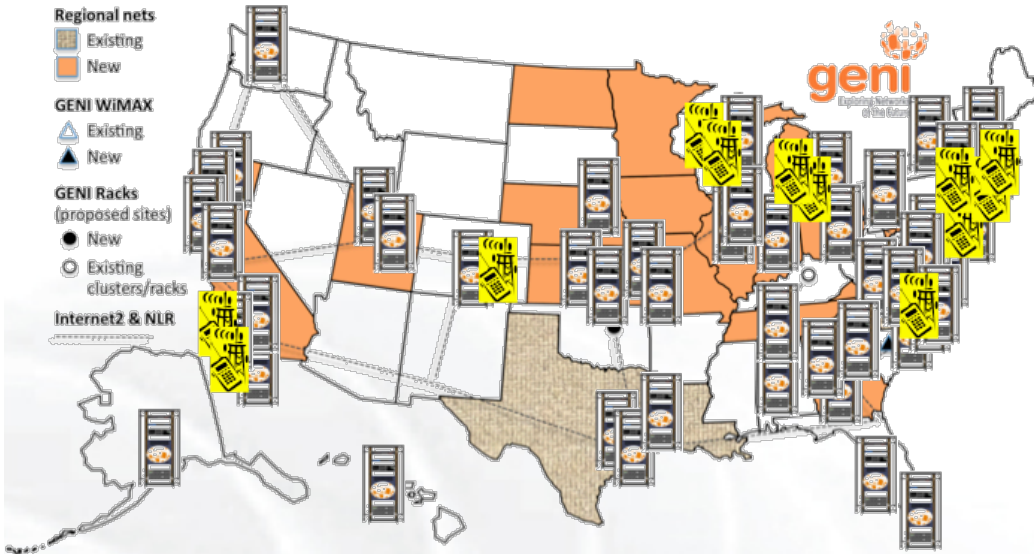
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What's next for GENI?

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

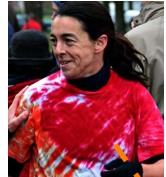
GENI's International Collaborations



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

Compute “green
index” for cities
worldwide



Yvonne Coady
U. Victoria
Canada



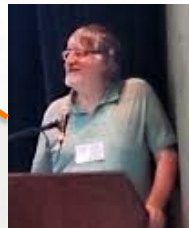
Rob Ricci
U. Utah
US



Joe Mamberti
Northwestern
US



Julio Ibarra
FIU, US



Michael Stanton
USP, Brazil



Piet Demeester
Ughent
Belgium



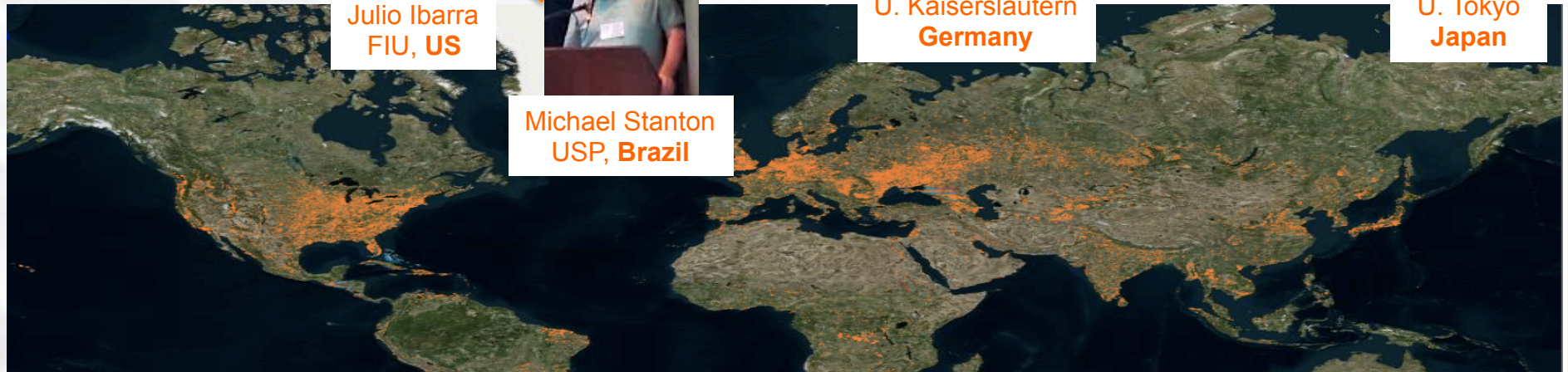
Rick McGeer
HP, US



Paul Mueller
U. Kaiserslautern
Germany



Aki Nakao
U. Tokyo
Japan



Federation fosters International Collaborations

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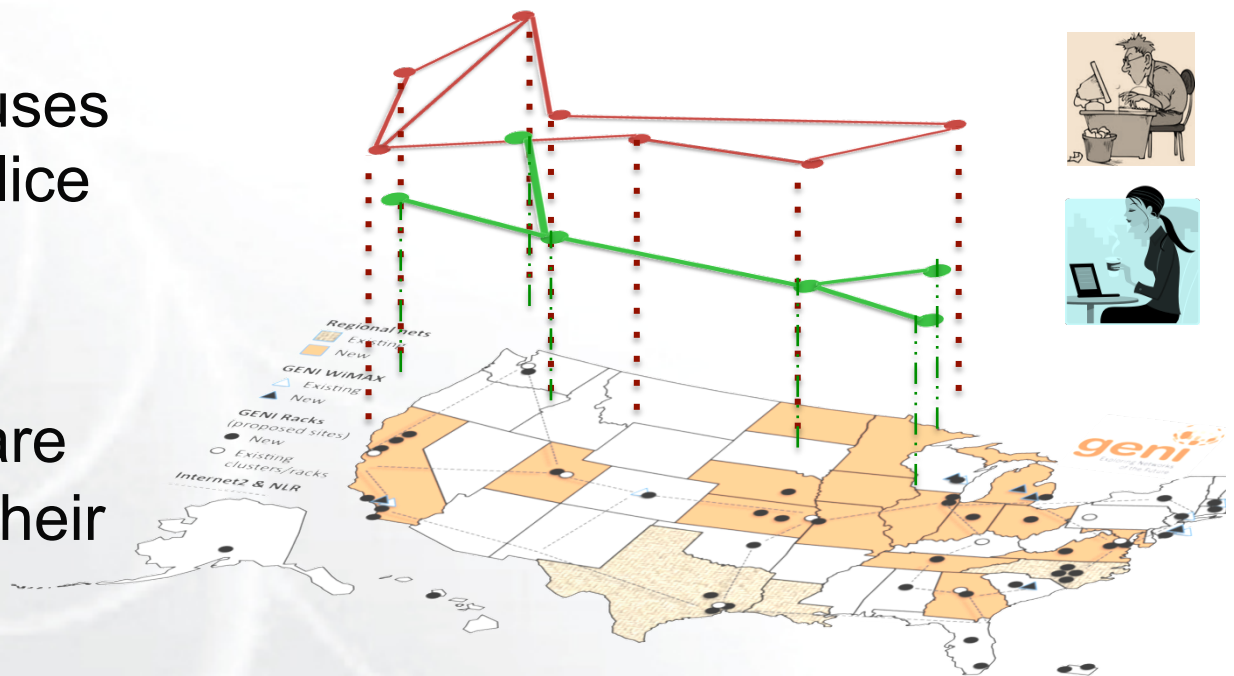
What's next for GENI?

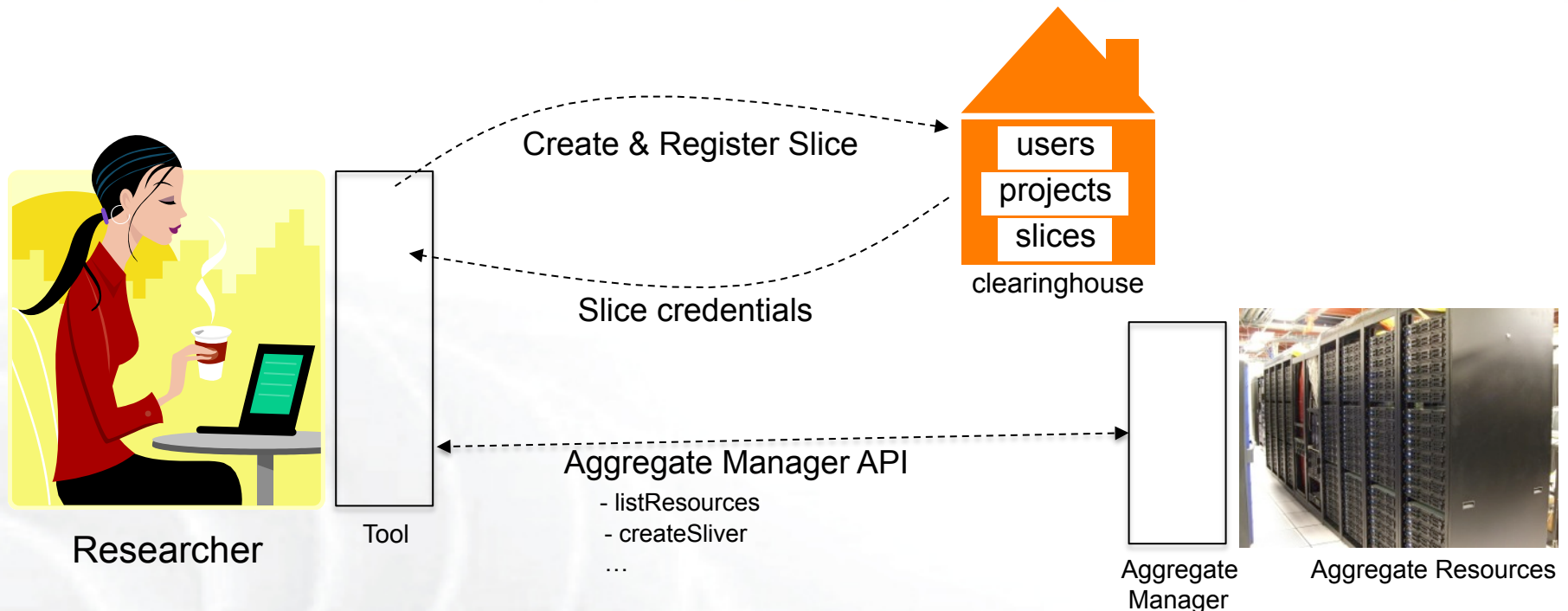
GENI: An experimenter's view

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: 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:

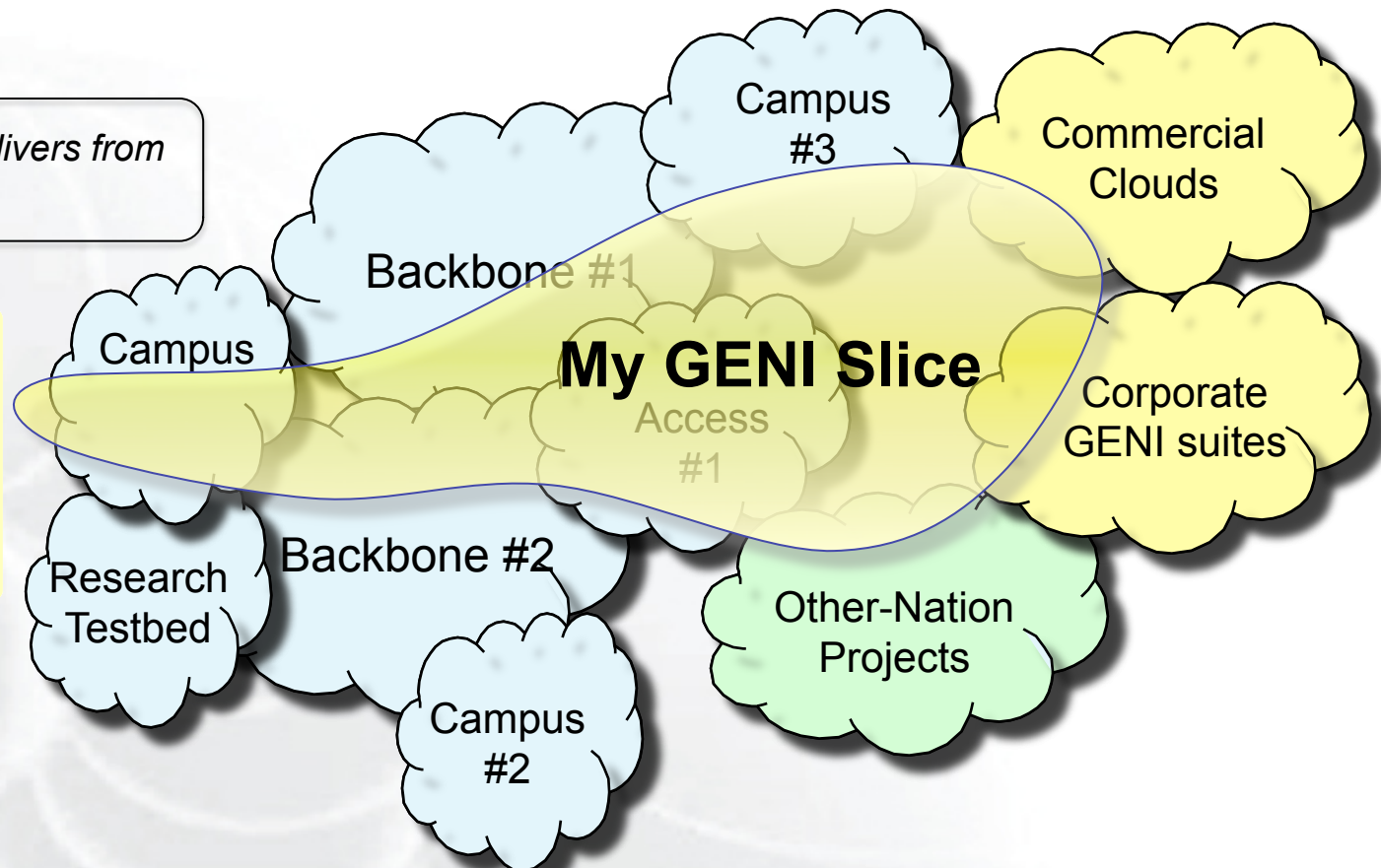
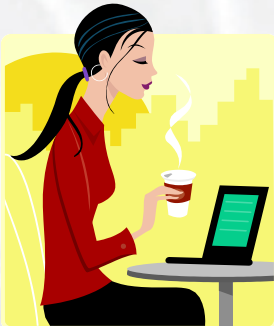
- no new passwords
- familiar login screens



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

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

My slice contains slivers from many aggregates.



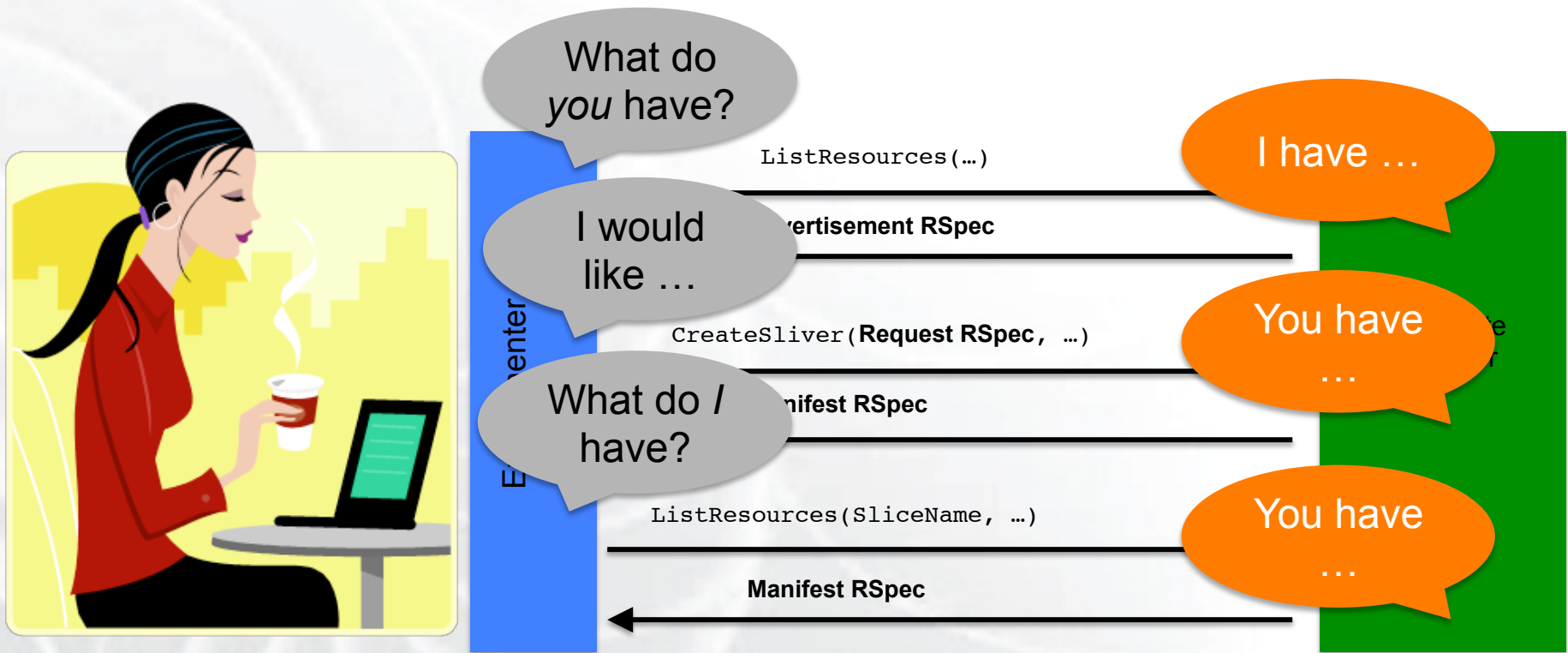
- RSpecs: Lingua franca for describing and requesting resources
 - “Machine language” for negotiating resources between experiment and aggregate
 - Experimenter tools eliminate the need for most experimenters to write or read RSpec

```
<?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>
```

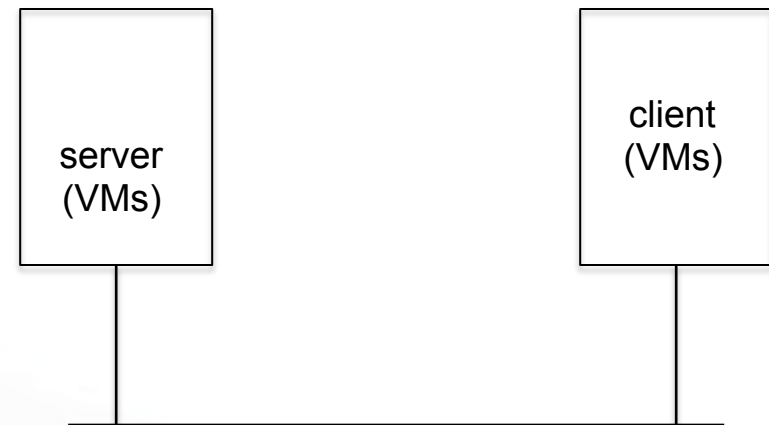
RSpec for requesting a single node



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?



- 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



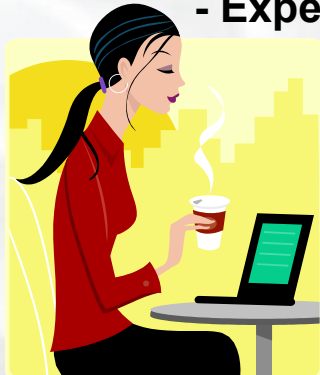
- Tutorials on the GENI wiki
 - Look for the  icon on the GENI wiki and then click on  for tutorials
- Participate in the hands-on tutorials at the GEC
- Get a GENI account today!

Get a GENI Account Today!



At the GEC:

- Registration Desk
- Experimenter drop-in



Email: help@geni.net



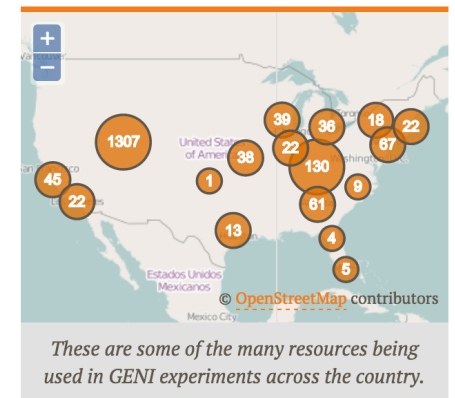
Welcome to GENI

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



Online: <https://portal.geni.net>

Students need a professor to create a GENI project

Newcomers Day - Mon June 15

General Sessions 1 - Tue June 16

General Sessions 2 - Wed June 17

Developer Day - Thu June 18

Registration + Breakfast
(8am - 9am)
Chancellor Ballroom

Presentation + Demo: An Introduction to GENI and Experimentation using GENI
(9am - 10am)
Alma Mater

An Overview of GENI
(8am - 9.15am)
Alma Mater

Breakfast
(7.30am - 9.30am)
Chancellor Ballroom

Demo Lightning Talks
(9.30am - 10am)
Chancellor Ballroom

Architects Meeting
By invitation
(8am - 9.15am)
Technology

Break (10am - 10.15am)

Tutorial: Getting Started with GENI - Part 1 (10.15-11.30am) Alma Mater	Tutorial: Getting Started with GENI - Part 1 (10.15-11.30am) Technology
Presentation + Demo: Intro to GENI Instrumentation and Measurement (11.30am - 12.30pm) Alma Mater	

Break (10am - 10.30am)

Tutorial: Build your own Cloud using CloudLab (10.30am - 12.30pm) Alma Mater	Tutorial: Building Experiments using the GENI and SAVI Testbeds (10.30am - 12.30pm) Technology	Panel: Software Defined Exchanges (SDX) (10.30am - 12.30pm) Illinois B
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Lunch
(12.30pm - 1.30pm)
Chancellor Ballroom

Lunch
(12.30pm - 1.30pm)
Chancellor Ballroom

Tutorial: Getting Started with GENI - Part 2 (1.30pm - 3pm) Alma Mater	Tutorial: Getting Started with GENI - Part 2 (1.30pm - 3pm) Technology
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Experimenter - Educator - Developer Roundtable (1.30pm - 3.30pm) Alma Mater	Tutorial: Introduction to GENI WiMAX for Experimenters and Educators (1.30pm - 3pm) Technology	GENI Future Planning I (1.30pm - 3pm) Illinois A & C
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Break (3pm - 3.30pm)

Break (3pm)

Tutorial: Getting Started with GENI - Part 3
Work on your own on assigned exercises
(3.30pm - 5.30pm)
Alma Mater

Tutorial: Monitoring & Controlling Experiments with GENI Desktop Scripts and Modules Alma Mater	Presentation: Intro to GENI Architecture (4pm - 5pm) Technology	Research Work-in-Progress (4pm - 5pm) Illinois B	GENI Future Planning I (3.30pm - 5pm) Illinois A & C
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Adjourn 5pm

Newcomers BoF Dinners

Poster/Demo Session
(5.30pm - 7.30pm)

Collonades Club
University of Illinois Memorial Stadium

Breakfast / Newcomers Breakfast
(7.30am - 8.30am)
Chancellor Ballroom

Plenary
(8.30am - 10.30am)
Illinois Ballroom

Break (10.30am - 11am)

Presentation: Intro to OpenFlow 11am Alma Mater	GENI Opt-In: Bringing Real Users and Traffic to Experiments (11am - 12.30pm) Technology	Developer Drop-In / Experimenter Drop-In (11am - 12.30pm) Illinois B	GENI Future Planning II (11am - 12.30pm) Illinois A
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Lunch
(12.30pm - 1.30pm)
Chancellor Ballroom

Tutorial: Programming GENI OpenFlow Resources (1.30pm - 3.30pm) Alma Mater	Tutorial: WAN Experiments using VTS (Virtual Topology Service) Part I Technology	Domain Science in GENI (1.30pm - 3.30pm) Illinois B	GENI Future Planning II (1.30pm - 3.30pm) Illinois A
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Break (3.30pm - 4pm)

Tutorial: Building Controllers for OpenFlow 1.3 (4pm - 5.30pm) Alma Mater	Tutorial: WAN Experiments using VTS Part II (Continuation of 1.30pm tutorial) Technology	Applying GENI Principles to LTE Networks (4pm - 5.30pm) Illinois B	Operations Monitoring and Trials (4pm - 5.30pm) Illinois A
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Blue Waters Supercomputing Facilities Tour
(5.45pm - 7.45pm)
National Petascale Computing Facility, 1725 S. Oak St.
Champaign
(<http://www.ncsa.illinois.edu/about/facilities>)

BoF Dinners
See GEC23 agenda page for list of BoF dinners or to organize one (<http://groups.geni.net/geni/wiki/GEC23Agenda>)

Breakfast
(7.30am - 9am)
Chancellor Ballroom

Developer Roundtable (9am - 10.30am) Alma Mater	Experimenter Support Office Hours (by appointment) Technology	Operations and Monitoring Office Hours (by appointment) Technology
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Break (10.30am - 11am)

Developer Roundtable (11am - 12.30pm) Alma Mater

Boxed Lunch
(12.30pm - 1pm)

Legend

	General interest
	Experimenter targeted
	Developer targeted
	Experimenter and developer targeted
	Campus IT/Rack administrator targeted
	Recommended for newcomers
	Hands-on Tutorial. Bring a laptop if you want to do the hands-on exercises

Wireless Network

SSID: GEC23
Password: uiuc23rdgce



**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



The International Workshop on Computer and Networking Experimental Research Using Testbeds

CNERT
Computer and Networking
Experimental Research
using Testbeds

The 35th IEEE International Conference
on Distributed Computing Systems
(ICDCS 2015)

In Hilton Downtown, Columbus, Ohio, USA
June 29th - July 2nd, 2015

June 29, 2015 Columbus, Ohio, USA

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?