GENI

Exploring Networks of the Future

The start of GENI campus expansion

July 2012
GENI Project Office
www.geni.net

Sponsored by the National Science Foundation

Outline

- GENI – Exploring future internets at scale
- Introducing GENI: an example
- GENI's growing suite of infrastructure
- Experiments going live across the US!
- What's next for GENI?
- GENI and US Ignite
- Looking forward
- Experimentation with GENI

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

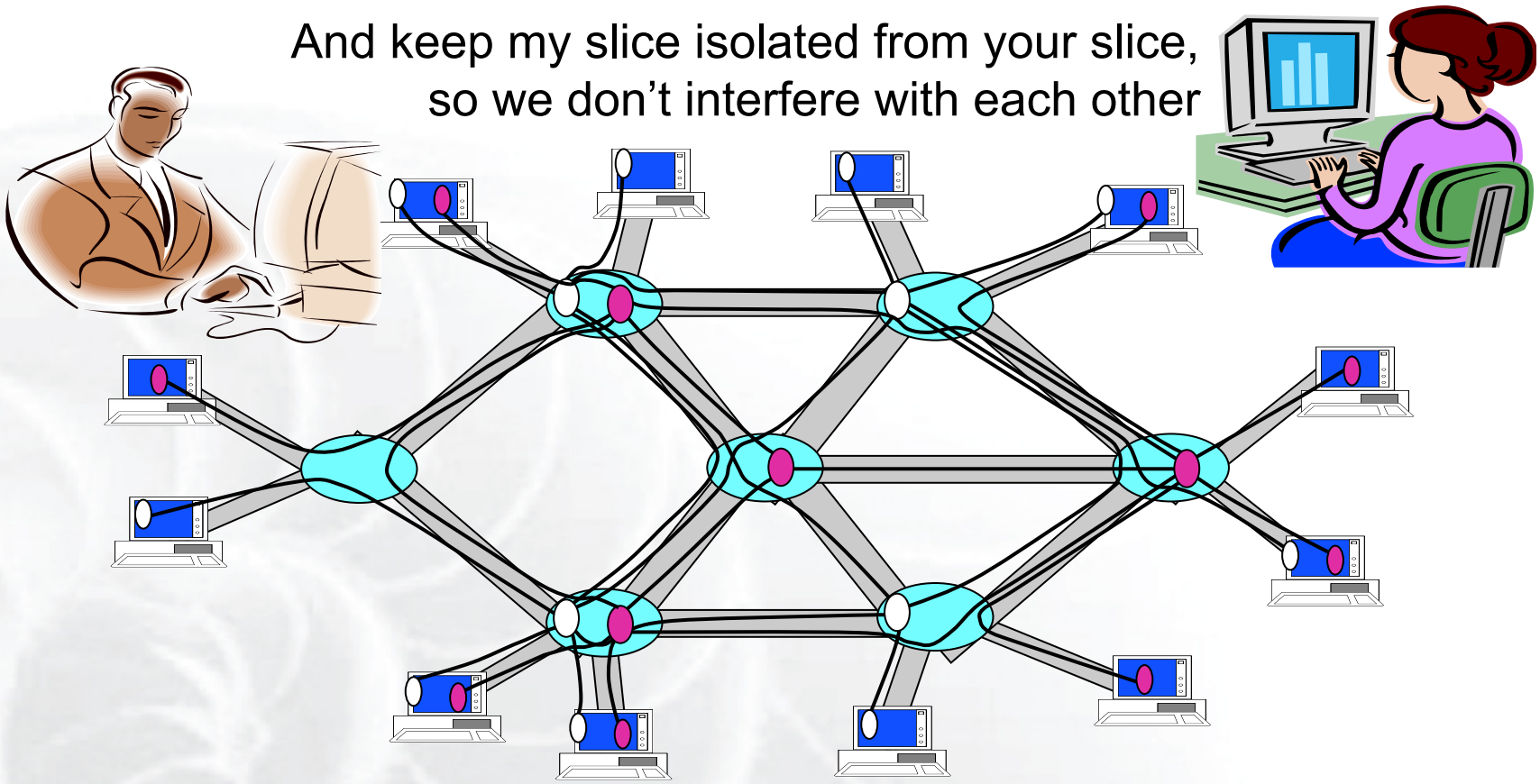
What is GENI?

- GENI is a virtual laboratory for **exploring future internets at scale**, now rapidly taking shape in prototype form across the United States
- GENI opens up huge new opportunities
  - **Leading-edge research** in next-generation internets
  - **Rapid innovation** in novel, large-scale applications
- Key GENI concept: slices & deep programmability
  - Internet: open innovation in application programs
  - GENI: open innovation deep into the network

Slices and Deep Programmability

Install the software I want *throughout* my network slice (into firewalls, routers, clouds, …)

And keep my slice isolated from your slice, so we don't interfere with each other



We can run many different "future internets" in parallel

GENI is now going live across the US

GENI-enabling testbeds, campuses, and backbones

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A bright idea

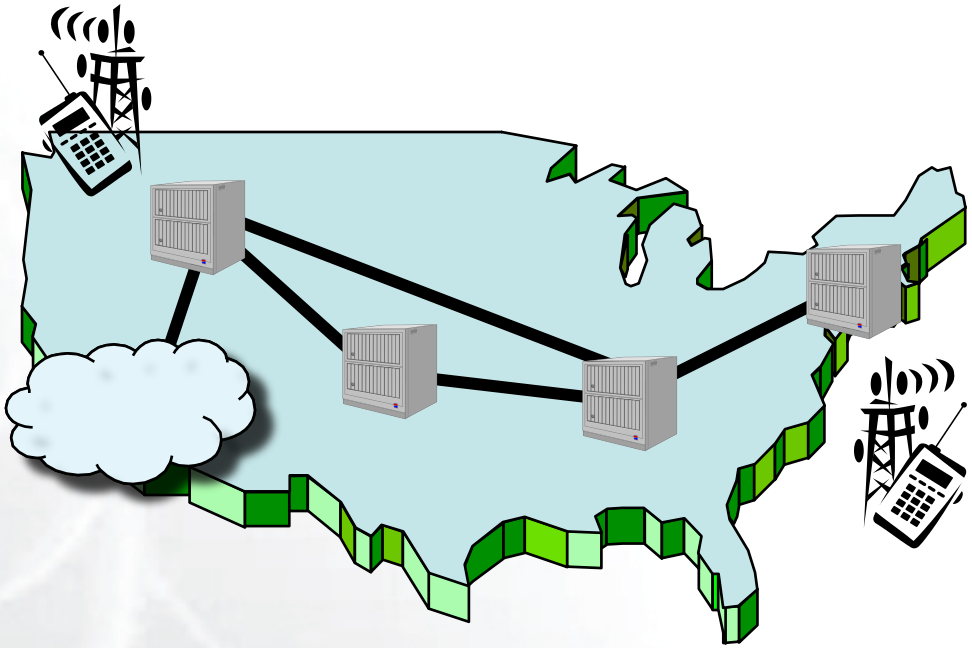
I have a great idea! The original Internet architecture was designed to connect one computer to another – but a better architecture would be fundamentally based on PEOPLE and CONTENT!

That will never work! It won't scale! What about security? It's impossible to implement or operate! Show me!

Trying it out

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

And so he poured his experimental software into clouds, distributed clusters, bulk data transfer devices ('routers'), and wireless access devices throughout the GENI suite, and started taking measurements . . .



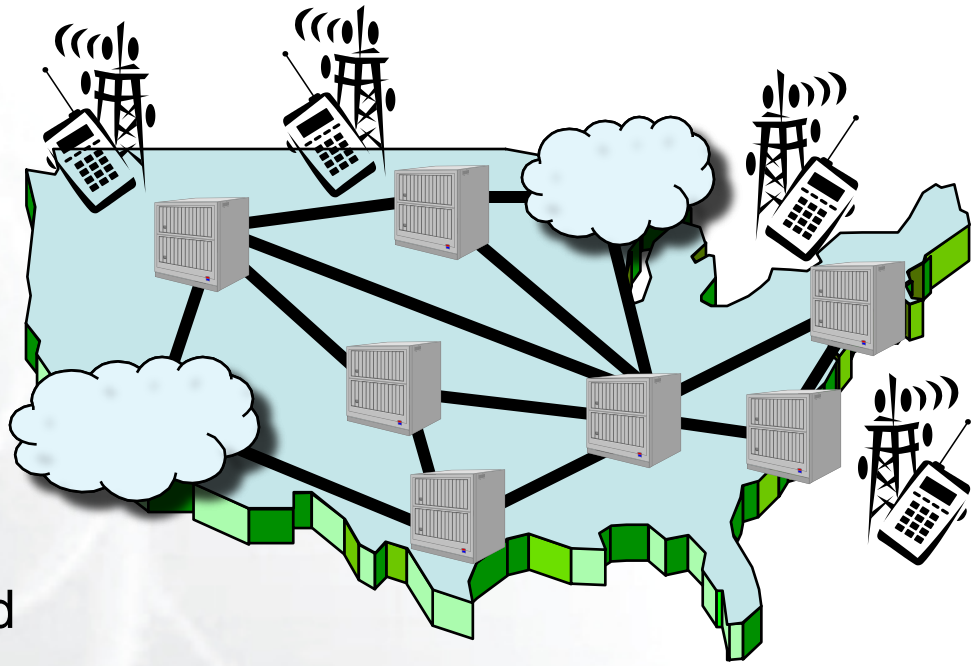
He uses a modest slice of GENI, sharing its infrastructure with many other concurrent experiments.

It turns into a really good idea

Boy did I learn a lot! I've published papers, the architecture has evolved in major ways, and I'm even attracting real users!

Location-based social networks are really cool!

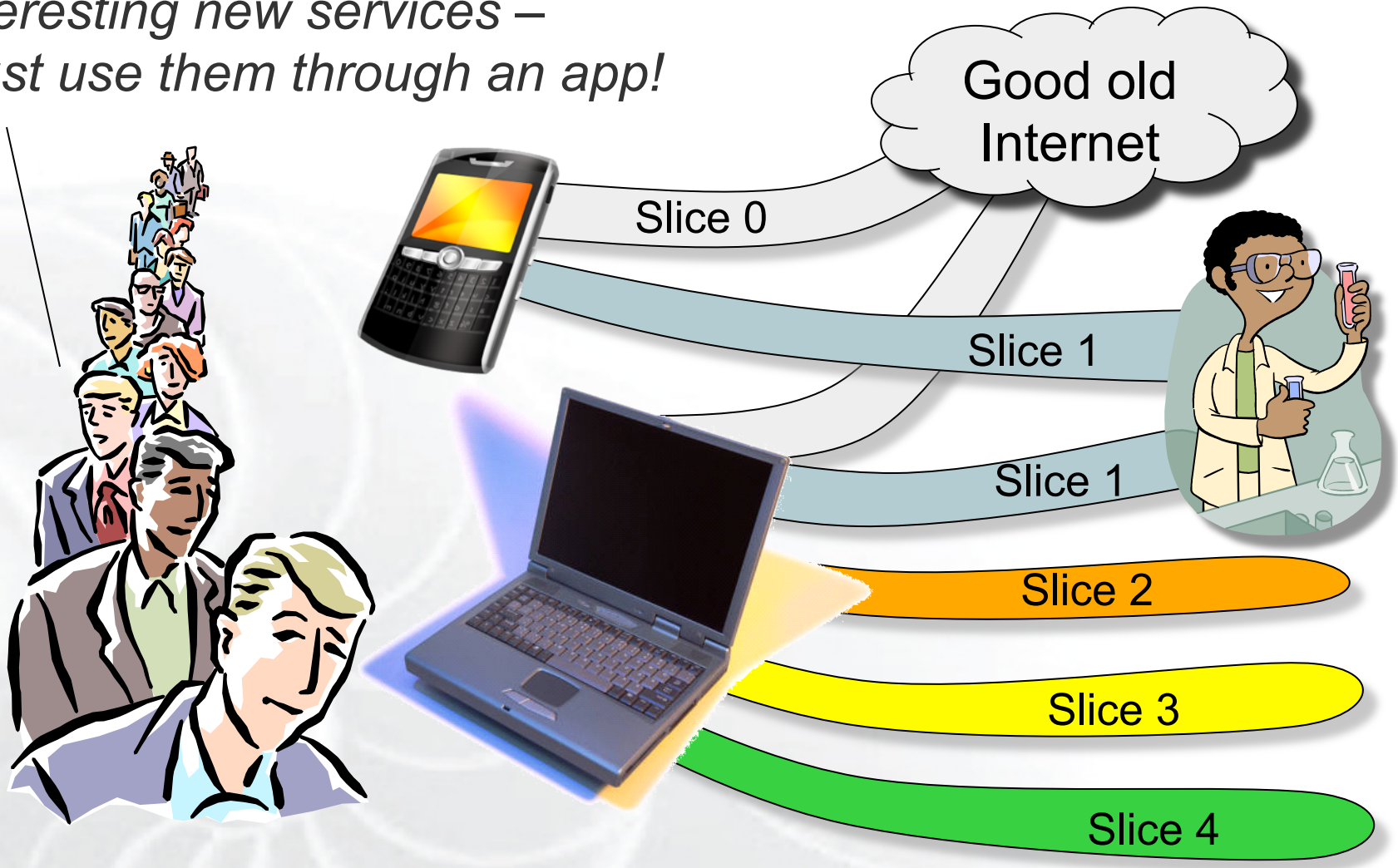
His experiment grew larger and continued to evolve as more and more real users opted in . . .



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

The (opt-in) user's view

Interesting new services –
I just use them through an app!



Experiment turns into reality

My experiment was a real success, and my architecture turned out to be mostly compatible with today's Internet after all – so I'm taking it off GENI and spinning it out as a real company.

I always said it was a good idea, but way too conservative.

Meanwhile . . .

I have a great idea! If the Internet were augmented with a scalable control plane and realtime measurement tools, it could be 100x as robust as it is today . . . !

And I have a great concept for incorporating live sensor feeds into our daily lives !

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**, which may or may not be compatible with today's Internet
  - **Both repeatable and "in the wild" experiments**
  - '**Opt in' for real users** into long-running experiments
  - Excellent **instrumentation and measurement** tools
  - **Large-scale growth for successful experiments**, so good ideas can be shaken down at scale

GENI creates a huge opportunity for ambitious research!

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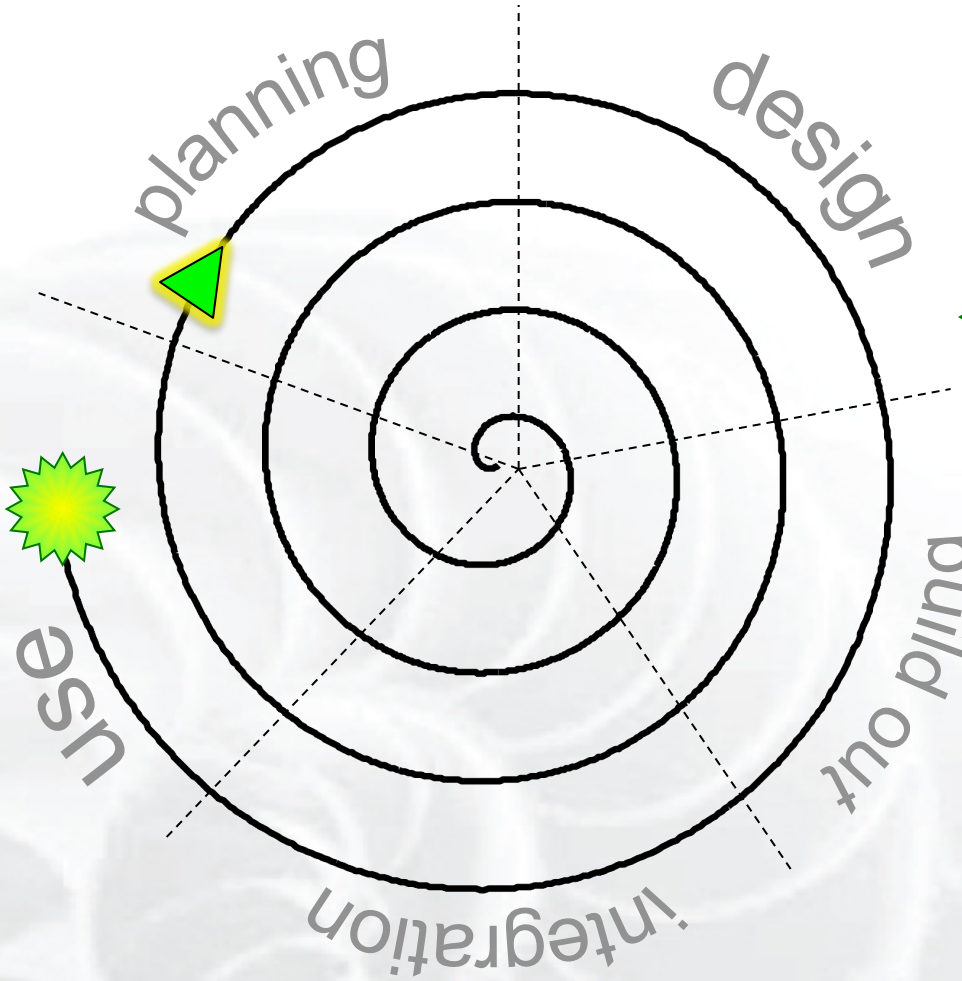
Start the transition to "real GENI"



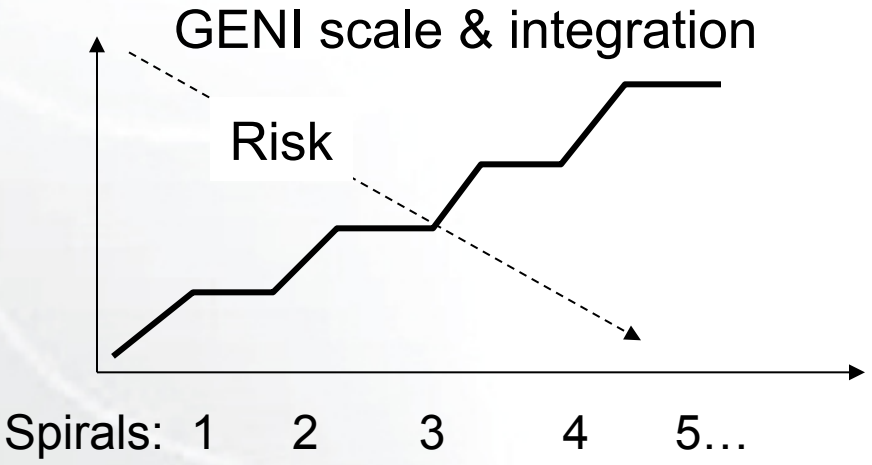
GENI Prototyping Plan

GENI Spiral 4

Ramp up experiments, 24 x 7 support (GMOC), formalize design, add GENI racks, deploy more OpenFlow and WiMAX, create first rev of GENI instrumentation system.

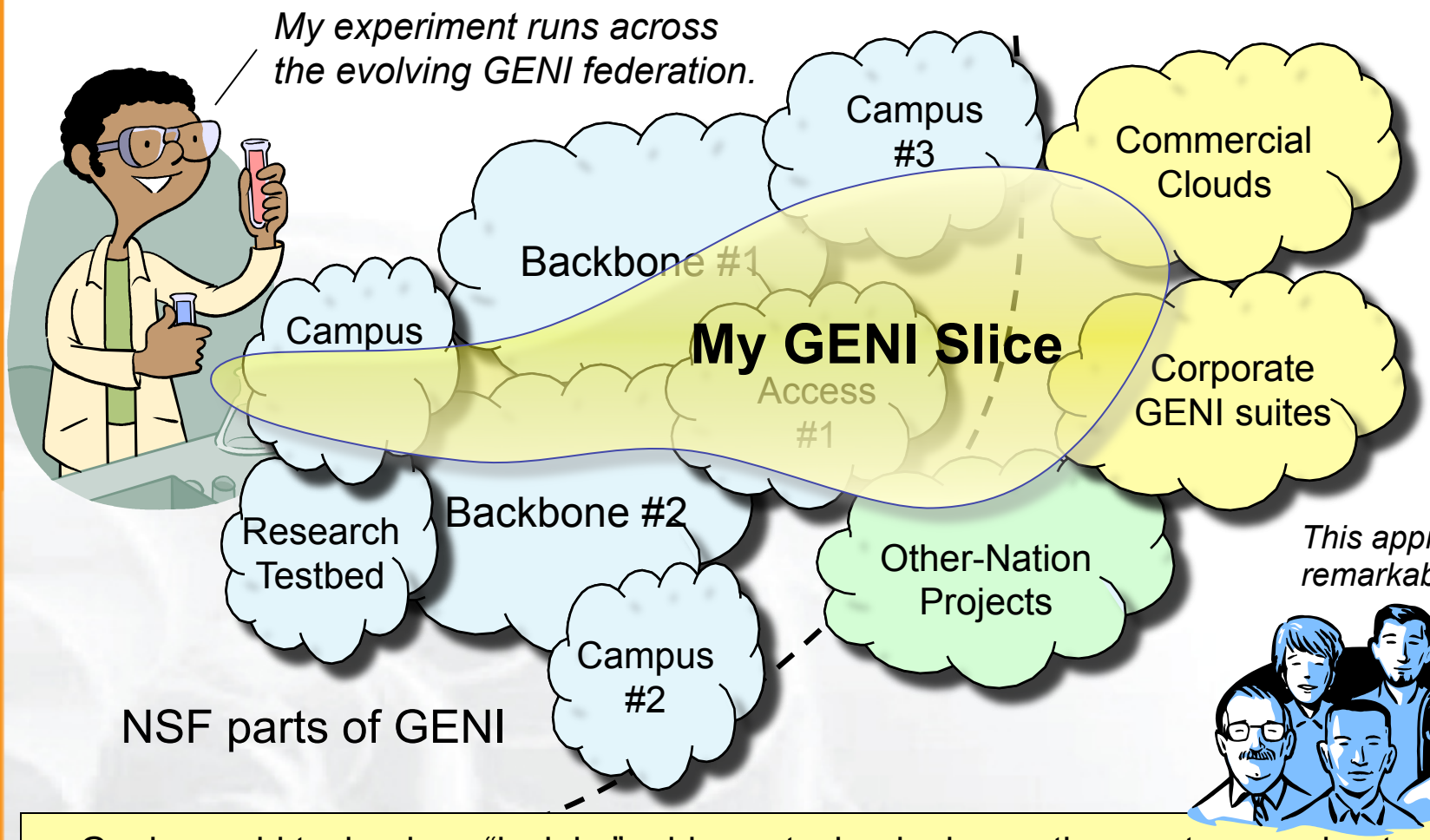
Envisioned **ultimate goal**

Large-scale distributed computing resources, high-speed backbone nodes, nationwide optical networks, wireless & sensor nets, etc.



Federation

GENI grows by "GENI-enabling" heterogeneous infrastructure

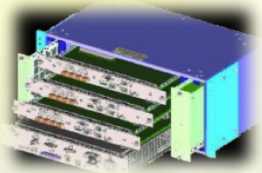


Goals: avoid technology "lock in," add new technologies as they mature, and potentially grow quickly by incorporating existing infrastructure into the overall "GENI ecosystem"

Enabling “at scale” experiments

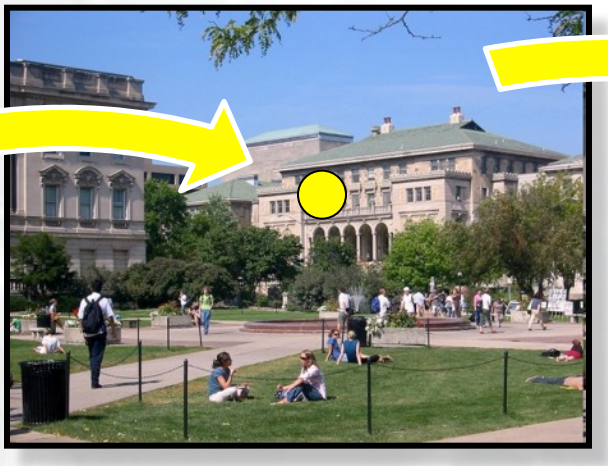
- **How can we afford / build GENI at sufficient scale?**
  - Clearly infeasible to build research testbed “as big as the Internet”
  - Therefore we are “GENI-enabling” testbeds, commercial equipment, campuses, regional and backbone networks
  - **Students are early adopters / participants in at-scale experiments**
  - Key strategy for building an at-scale suite of infrastructure

HP ProCurve 5400 Switch

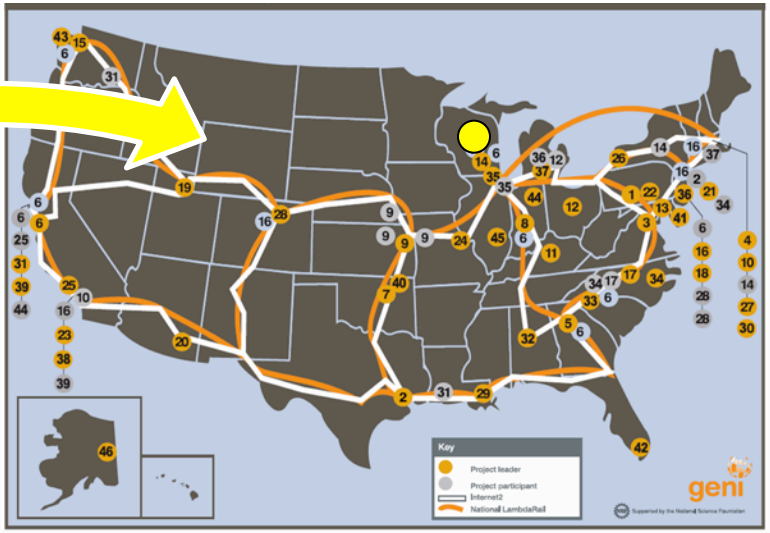


NEC WiMAX Base Station

GENI-enabled equipment



GENI-enabled campuses, students as early adopters



“At scale” GENI prototype

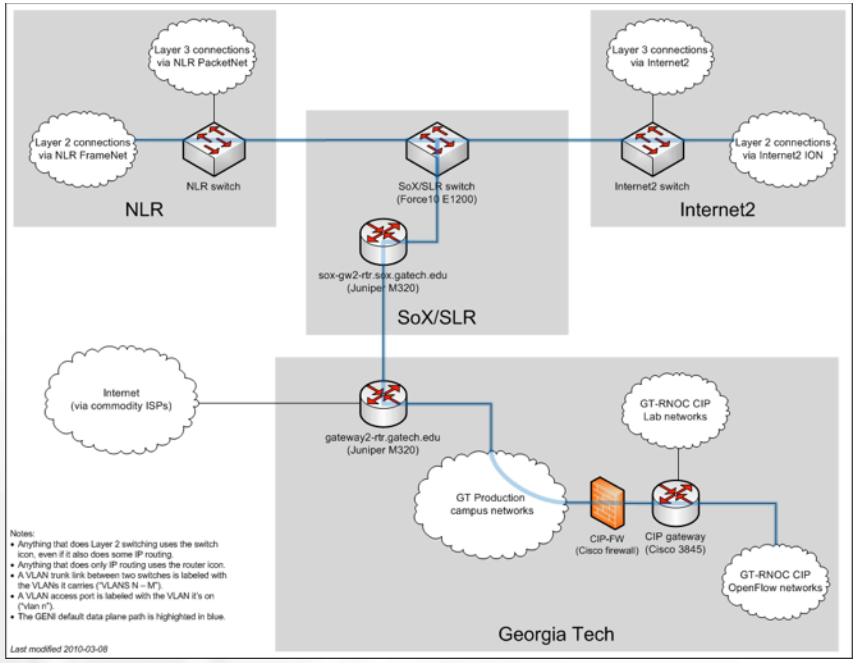
Georgia Tech: a great example
One of the first 14 GENI-enabled campuses

Nick Feamster
PI

Ellen Zegura

Russ Clark,
GT-RNOC

Ron
Hutchins,
OIT

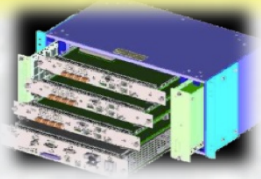


- OpenFlow in 4 GT lab buildings ***now***
- OpenFlow/BGPMux coursework ***now***
- Dormitory trial
- Students will "live in the future" – Internet in one slice, multiple future internets in additional slices

Trials of "GENI-enabled" commercial equipment

HP ProCurve 5400 Switch

Juniper MX240 Ethernet Services Router



NEC WiMAX Base Station

HTC Android smart phone

Toroki LightSwitch 4810

GENI racks

NEC IP8800 Ethernet Switch

Arista 7124S Switch

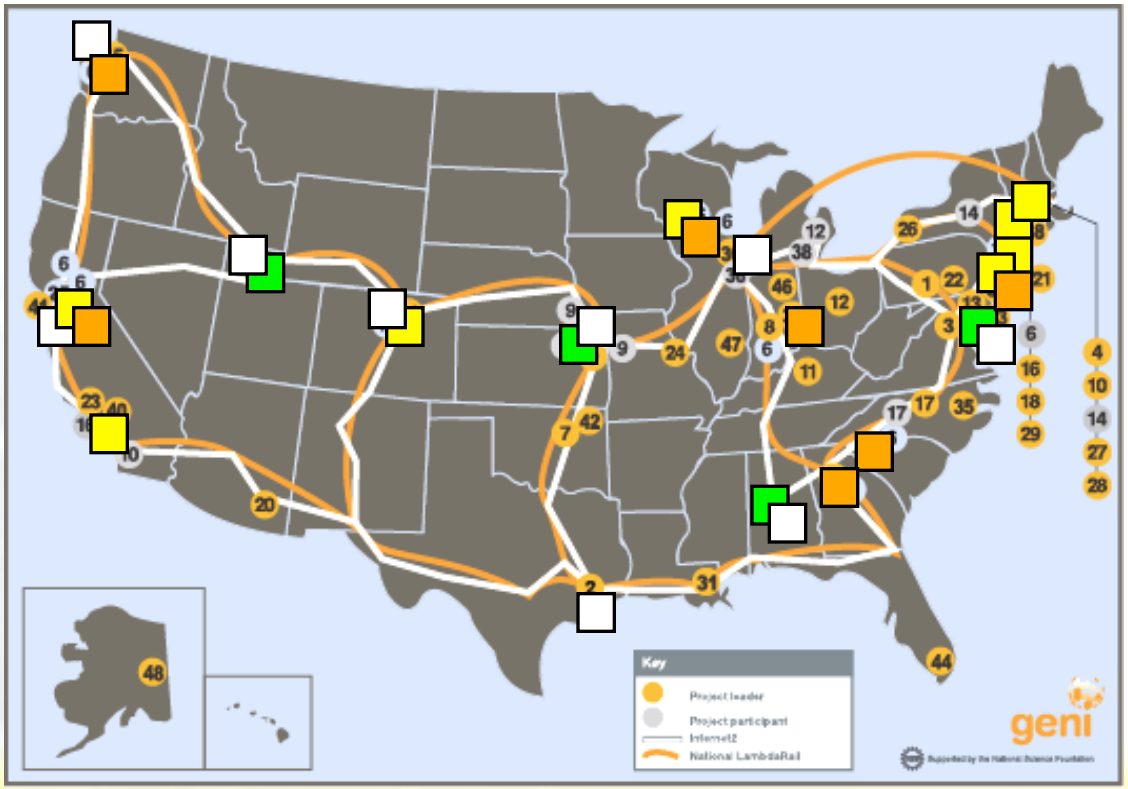
Building the GENI Meso-scale Prototype

OpenFlow

Stanford
U Washington
Wisconsin
Indiana
Rutgers
Princeton
Clemson
Georgia Tech

ShadowNet

Salt Lake City
Kansas City
DC
Atlanta



WiMAX

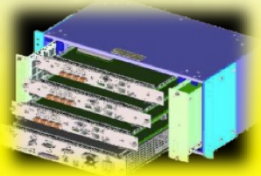
Stanford
UCLA
UC Boulder
Wisconsin
Rutgers
Polytech
UMass
Columbia

OpenFlow Backbones

Seattle
Salt Lake City
Sunnyvale
Denver
Kansas City
Houston
Chicago
DC
Atlanta


HP ProCurve 5400 Switch


Juniper MX240 Ethernet Services Router


NEC WiMAX Base Station

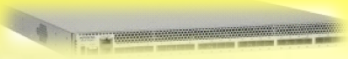

HTC Android smart phone


Toroki LightSwitch 4810

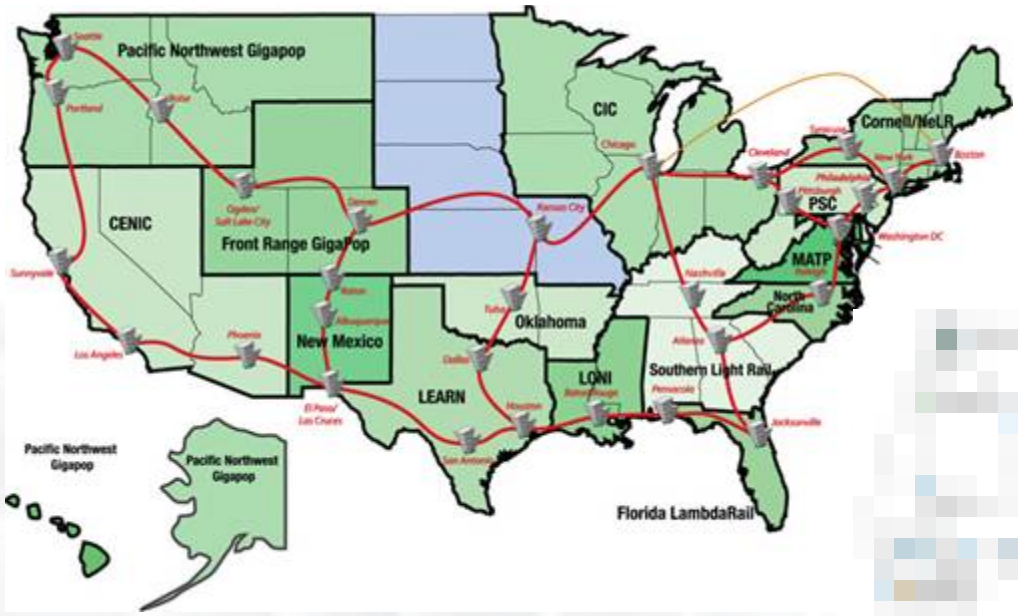

GENI racks


NEC IP8800 Ethernet Switch

OpenFlow


Arista 7124S Switch

National LambdaRail and Internet2



National LambdaRail

Up to 30 Gbps bandwidth

Internet2

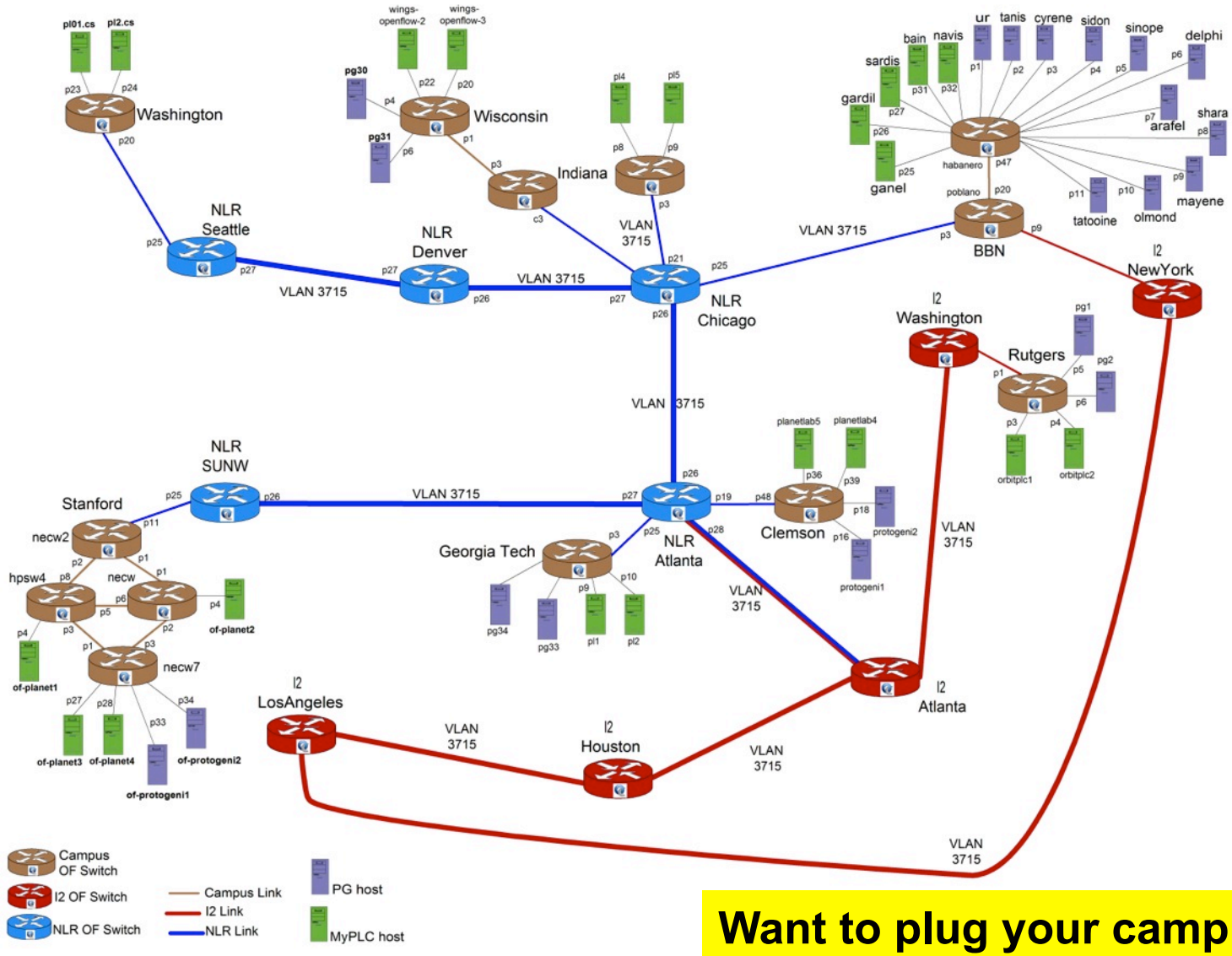
ProtoGENI & SPP

Buildout for GENI prototyping within two national footprints to provide end-to-end GENI slices (IP or non-IP)

Meso-scale GENI, August 2011

- Layer 2 slices span campuses, Internet2, and NLR
- Each VLAN contains ~ 25 OpenFlow switches and 40+ computers (PlanetLab & ProtoGENI)
- OpenFlow / FlowVisor manages slices within a VLAN
- Ongoing federated ops (8 campuses, 2 backbones, GMOC), each organization with its own operators, policies, etc.
- Now shaking down large-scale slices

PlanetLab, ProtoGENI, OpenFlow resources spanning multiple campuses, Internet2, & NLR



Want to plug your campus in?
Send email: help@geni.net


BEN
Breakable Experimental Network
of the Future
ORBIT
PLANETLAB
An open platform for developing, deploying, and accessing planetary-scale services
ProtoGENI
UIC
Many, many groups are already engaged in building GENI
THE QUILT
at&t
ARISTA
Battelle
ca
ciena
cisco
Corporation for National Research Initiatives
FUJITSU
hp invent
IBM
infinera
INTERNET2
JEFFREY HUNKER ASSOCIATES LLC
JUNIPER NETWORKS
Microsoft
NETRONOME
nicira
NLR light the future
NEC
Qwest
Radio Technology Systems
SPARTA
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Major research demos, Nov 2010

9 major experiments demo'd at GEC 9 (Nov 2010)

- **Some of the nation's best young researchers . . .**
  - Academic and industrial
  - Networking and distributed systems
  - Some helped build GENI, most have not
- **Demonstrating their earliest research experiments**
  - Many different ideas for "future internets"
  - Now being **tried out experimentally** for the first time
- On the nationwide, "meso-scale" GENI prototype

GENI supported 9 different future internet experiments, simultaneously, each in its own slice

Pathlet Architecture

GEC 9 experiment demonstration

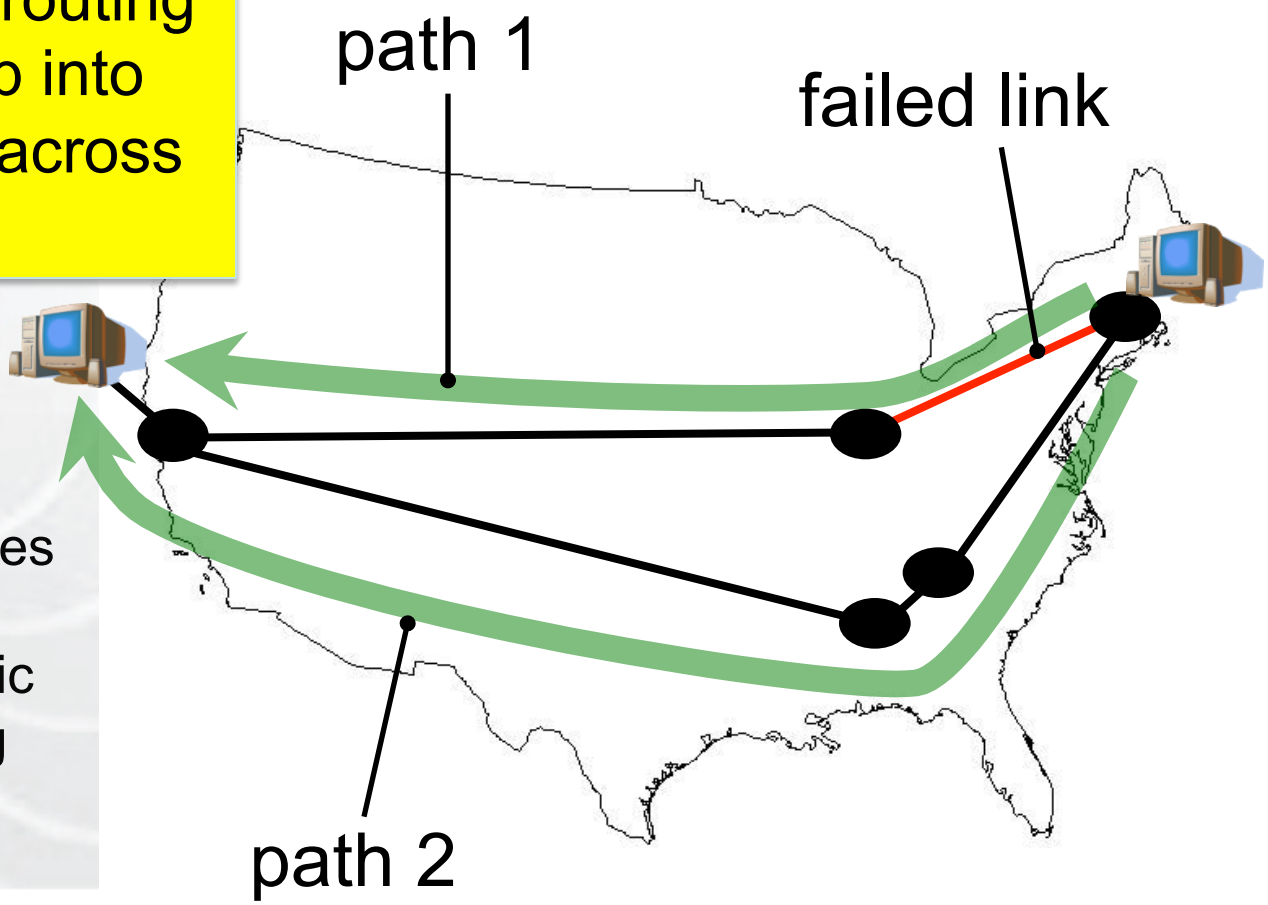
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Resilient Routing in the Pathlet Architecture

Ashish Vulimiri and Brighten Godfrey
University of Illinois at Urbana-Champaign

Deploy innovative routing architecture deep into network switches across the US

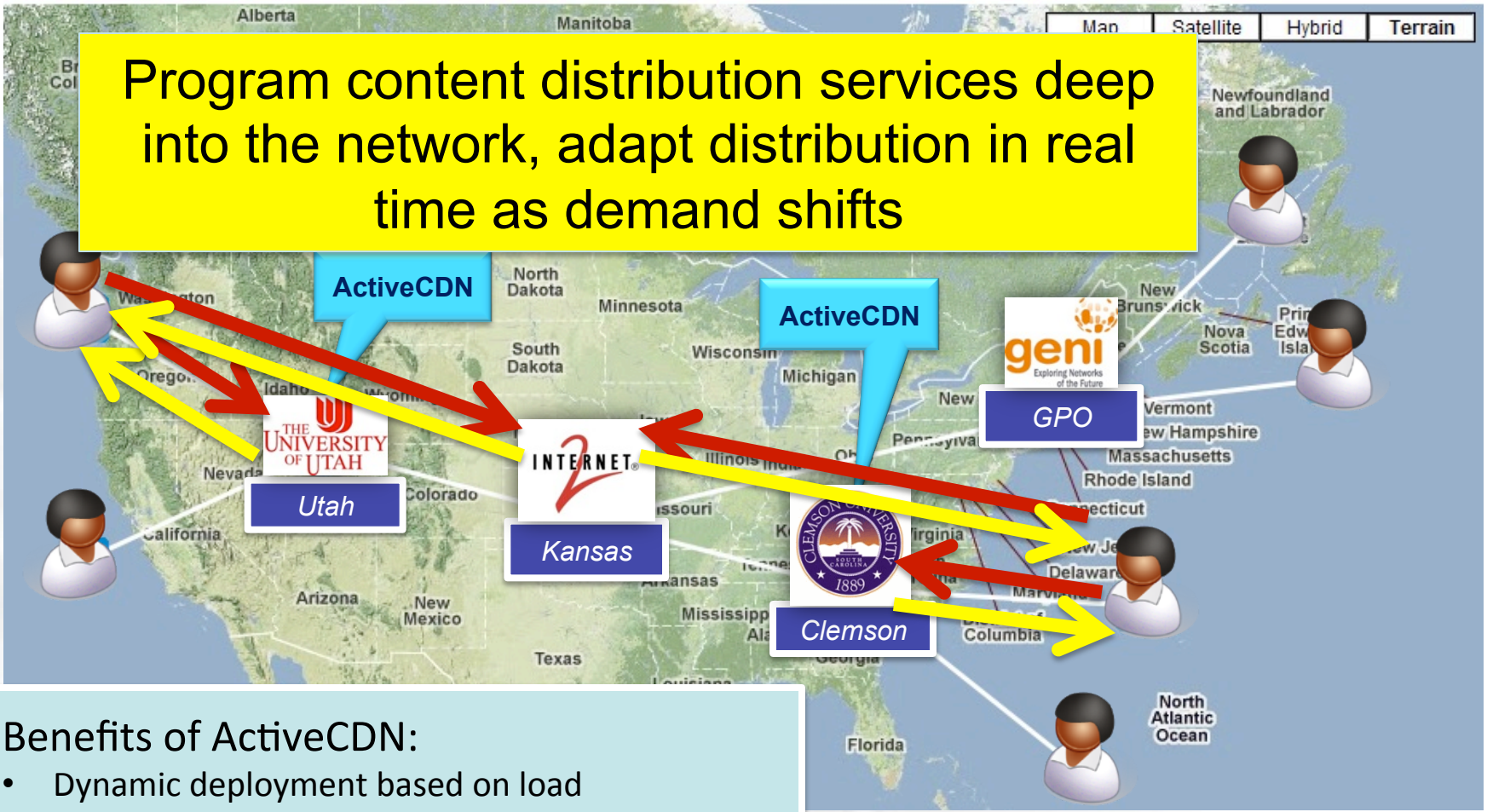
- Lets *users* monitor and select their own network paths to optimize their services
- Protects critical traffic even without waiting for adaptation time



Sponsored by the National Science Foundation

ActiveCDN

GEC 9 experiment demonstration



Benefits of ActiveCDN:

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

Jae Woo Lee, Jan Janak, Roberto Francescangeli, SumanSrinivasan, Eric Liu, Michael Kester, SalmanBaset, Wonsang Song, and Henning Schulzrinne
Internet Real-Time Lab, Columbia University

Weather NowCasting

GEC 9 experiment demonstration

ViSE views steerable radars as shared, virtualized resources
http://geni.cs.umass.edu/vise

David Irwin et al

UMASS AMHERST

casa Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere

Revolutionizing our ability to observe, understand, predict and respond to hazardous weather events

Generate "raw" live data ViSE/CASA radar nodes

http://stb.ece.uprm.edu/current.jsp

NLR

STARLIGHT

Create and run realtime "weather service on demand" as storms turn life-threatening

"raw" live data

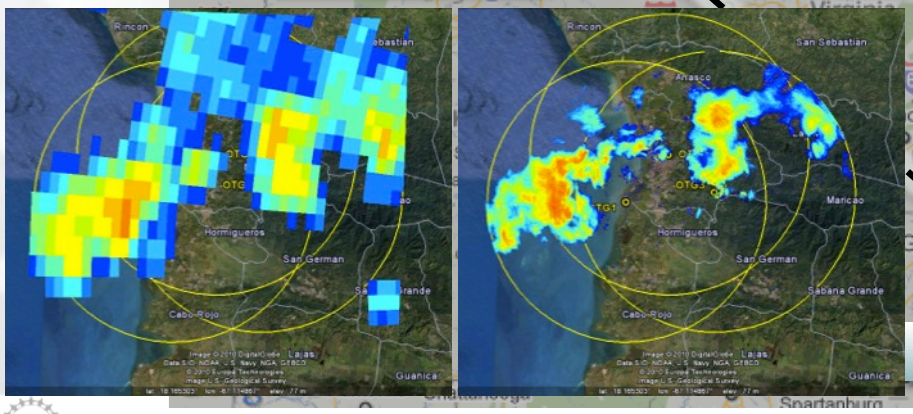
Nowcast images for display

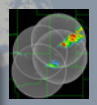
1. Spin up system in Amazon commercial EC2 and S3 services on demand

Multi-radar NetCDF Data

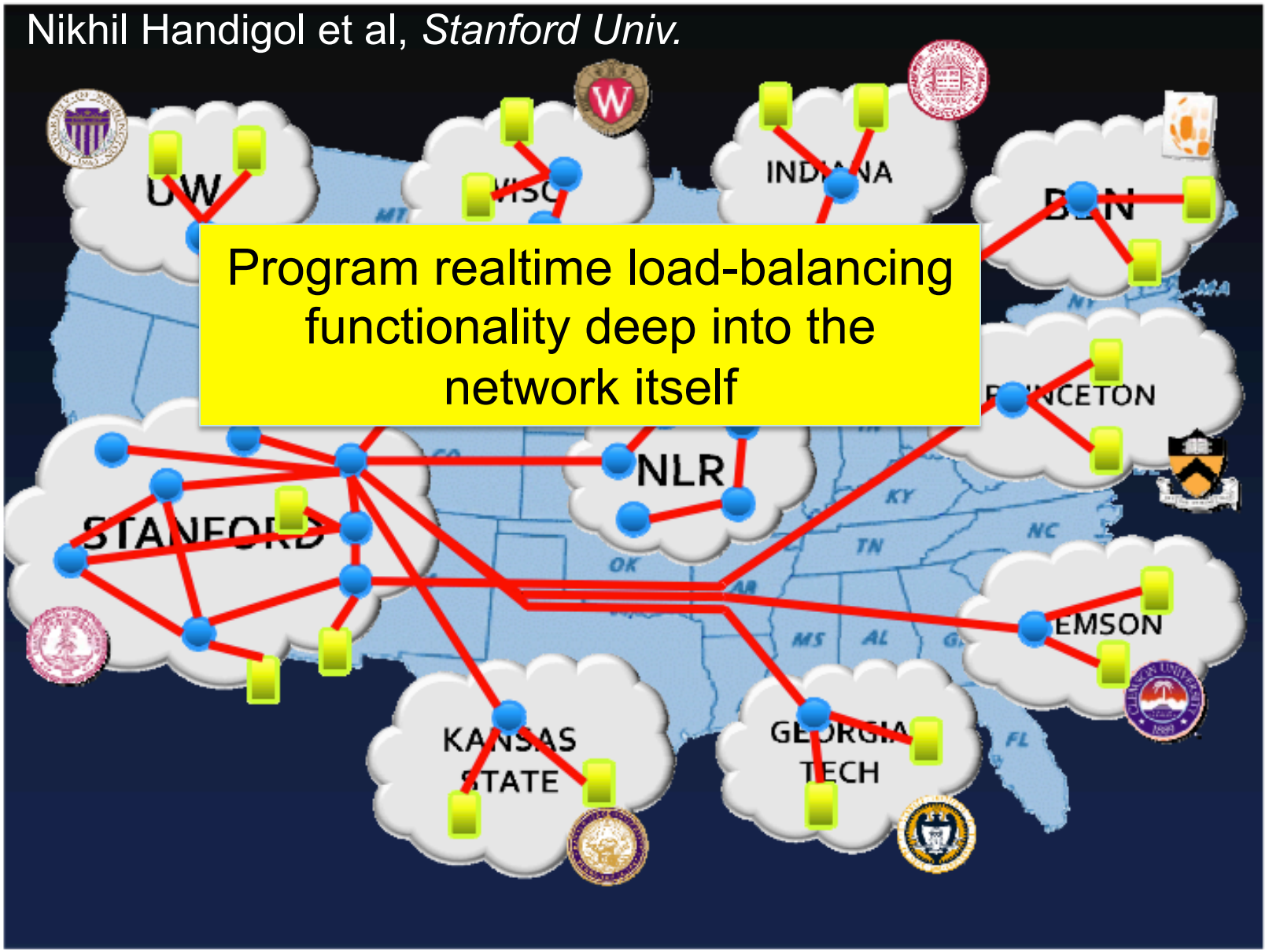
BEN Breakable Experimental Network

Nowcast Processing





Aster*x Load Balancing (via OpenFlow)



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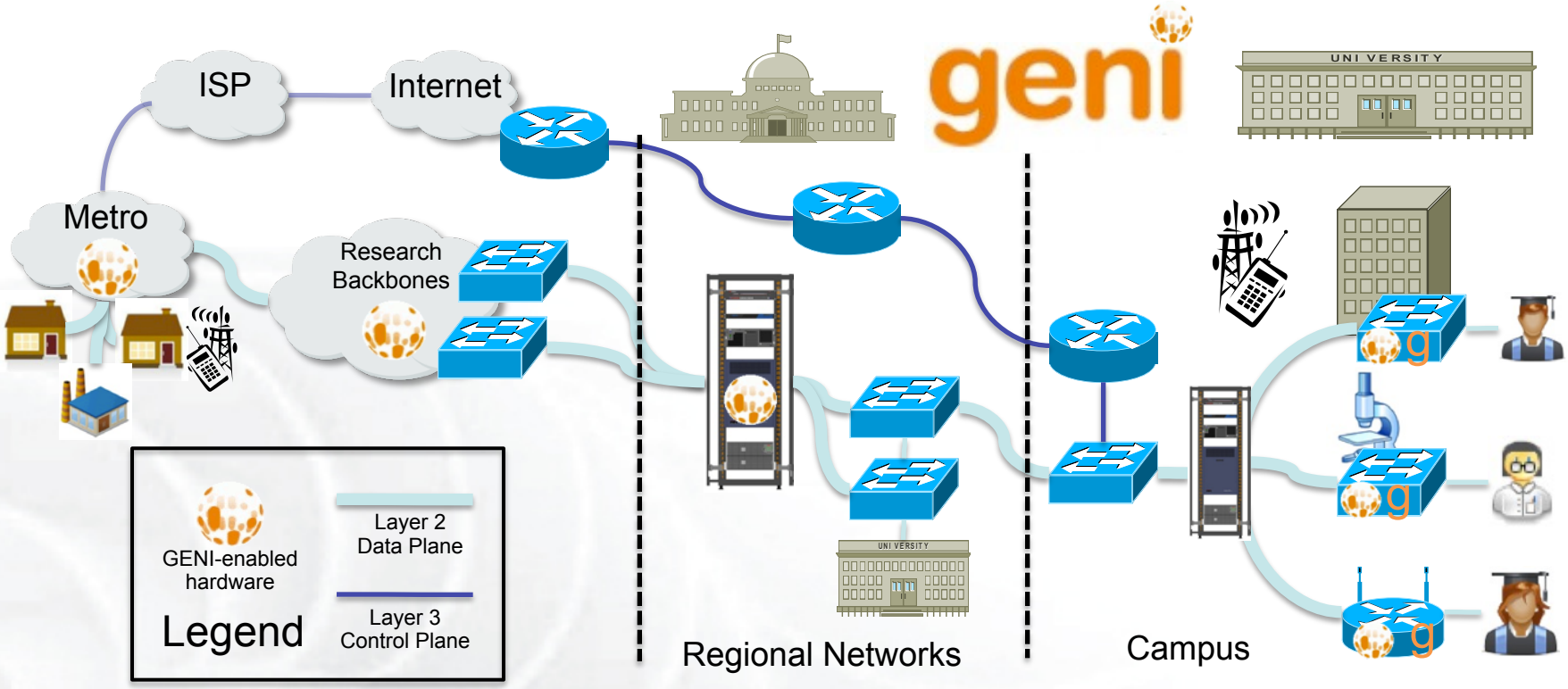
Looking forward
Growing to the "at scale" GENI

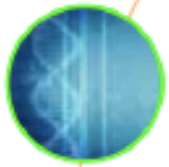
- Suggest 100-200 US campuses as target for "at scale"
  - Both academia and national labs
  - GENI-enable the campuses
  - Their students, faculty, staff can then "live in the future" using both today's Internet and many experiments
  - Build out backbones, regionals, and shared clouds to support the campuses
- Grow via ongoing spiral development
  - Identify, understand, and drive down risks
  - Learn what is useful and what is not
  - Early GENI campuses can help later ones
- Transition to community governance

Envisioned architecture



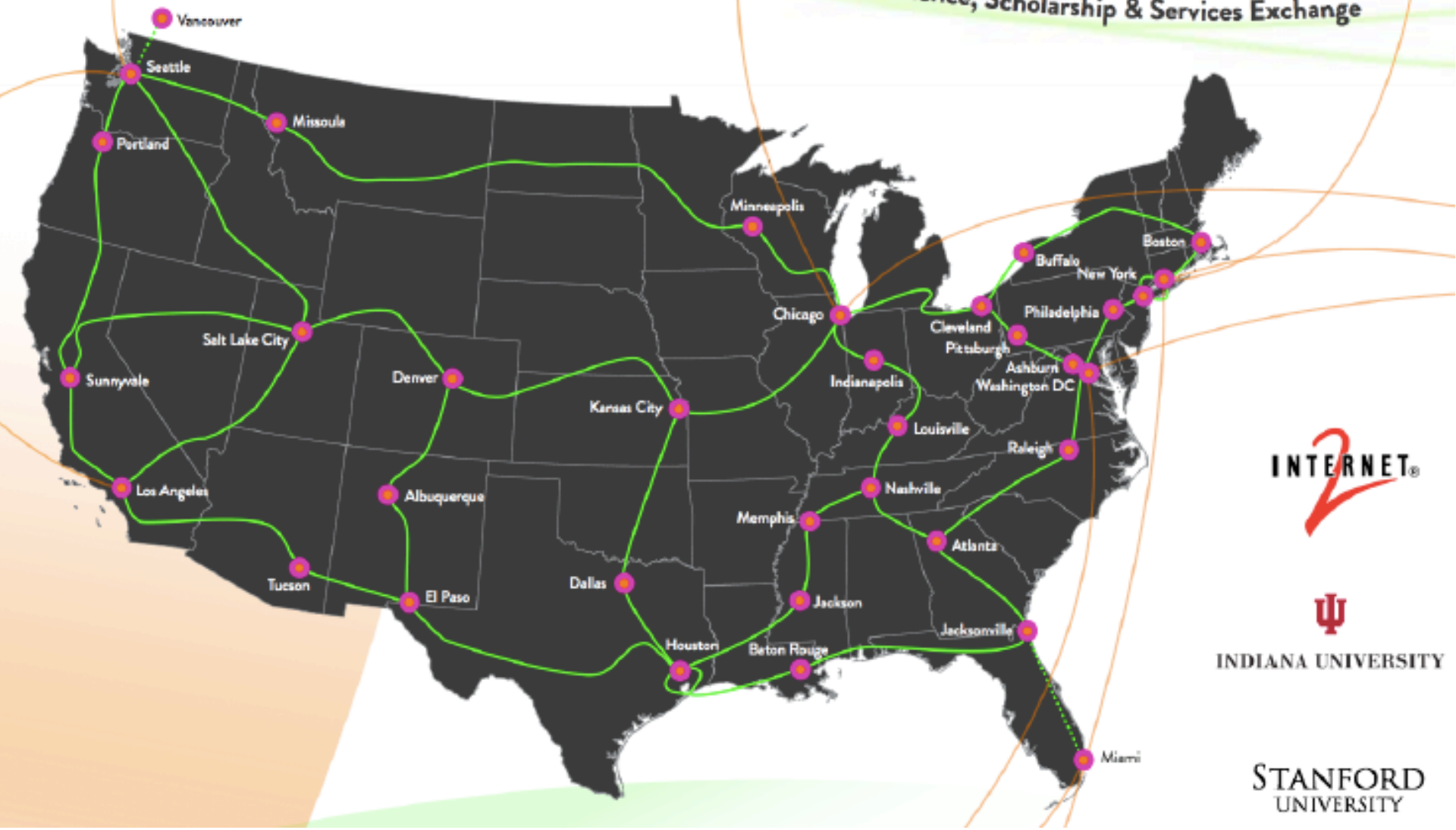
- Flexible network / cloud research infrastructure
- Also suitable for physics, genomics, other domain science
- Support “hybrid circuit” model plus much more (OpenFlow)
- Distributed cloud (racks) for content caching, acceleration, etc.



OS³E

The Open Science, Scholarship & Services Exchange



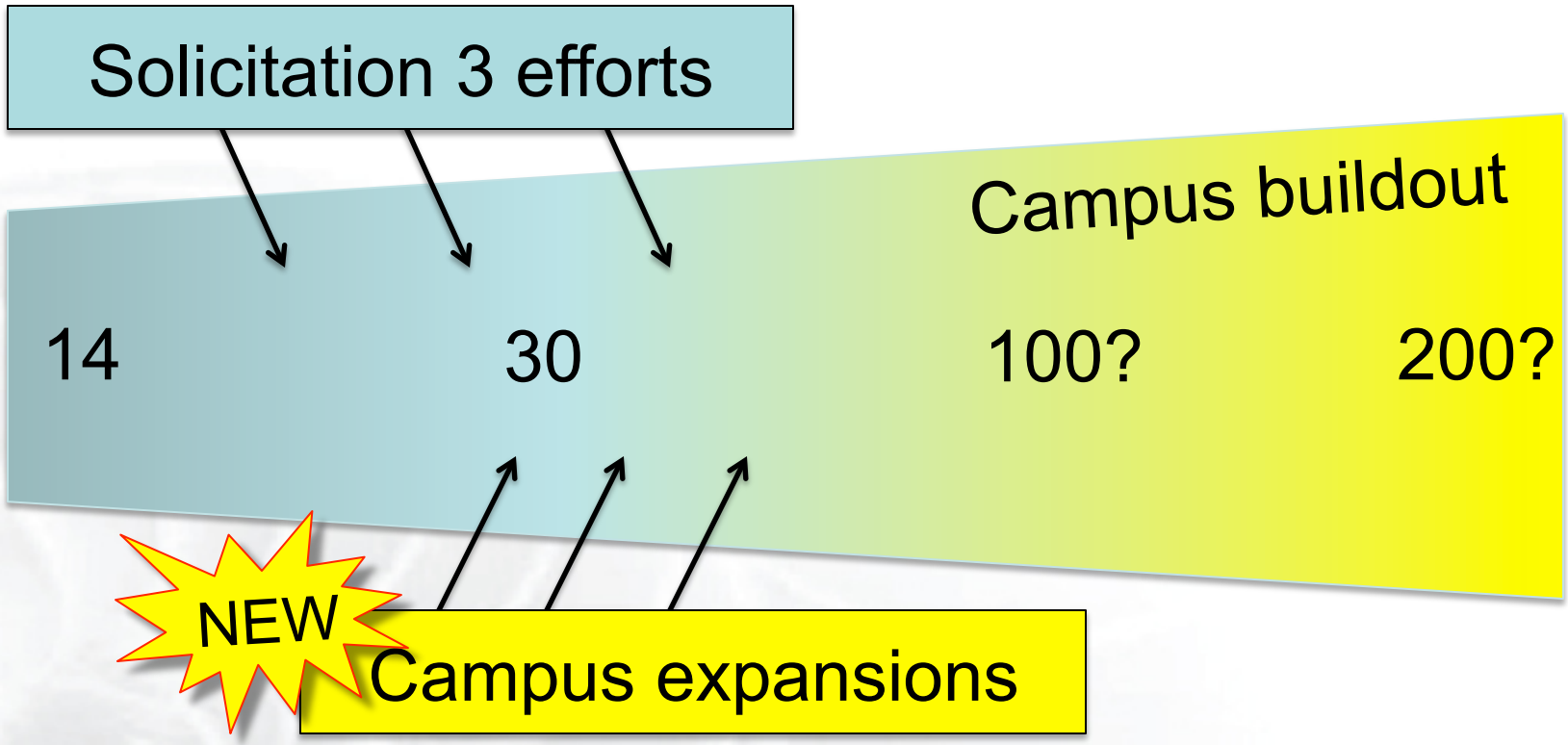
INTERNET2®

INDIANA UNIVERSITY

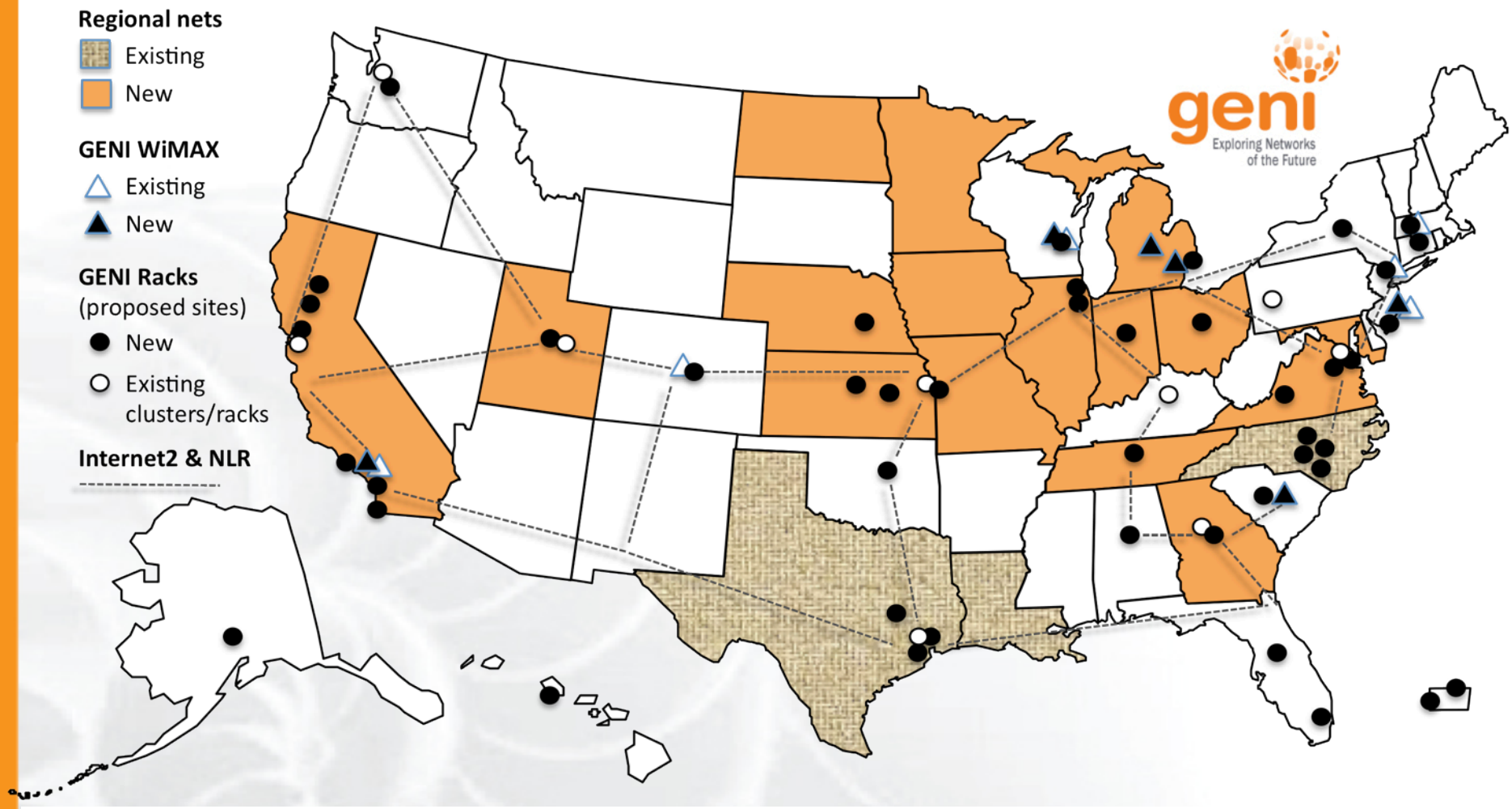
STANFORD UNIVERSITY

Growing GENI to 100-200 campuses

GENI racks, OpenFlow, WiMAX, training, ops



Spiral 4 build-outs well underway
Growing GENI's footprint



(as proposed; actual footprint to be engineered)

Solicitation 3's role in campus buildouts

- GENI Solicitation 3
  - More **WiMAX base stations** with Android handsets
  - GENI-enable 5-6 **regional networks**
  - Inject more **OpenFlow switches** into Internet2 and NLR
  - Add **GENI Racks** to 50-80 locations within campuses, regionals, and backbone networks

ExoGENI rack installation, 2/2012

GENI Racks serve as programmable routers, distributed clouds, content distribution nodes, caching or transcoding nodes, etc

GENI campus expansion

Dr. Larry Landweber, U. Wisconsin

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

- **Current GENI campuses** Clemson, Colorado, Columbia, Georgia Tech, Indiana, Princeton, Kansas State, NYU Poly, Rutgers, Stanford, UCLA,U MA Amherst, U Washington, U Wisconsin
- **CIO Initiative - 19 campuses** Case Western, Chicago, Colorado, Cornell, Duke, Florida International, U Kansas, Michigan, NYU, Purdue, Tennessee, U FLA, University of Houston, UIUC, U MA Lowell-Amherst, Utah, Washington, Wisconsin
- **Rapidly growing waitlist**

Ramping up experimenter workshops and training sessions for IT staff

Network Engineers “boot camp” on the day before this GEC, organized by Larry Landweber and given by Matt Davy and Steve Wallace, Indiana University

- GPO funding 3 workshops / year by Indiana University
- Goal: train IT staff on OpenFlow and (when available) GENI racks
- At GEC 12 in Kansas City:

Case Western Reserve	Cornell
Duke	Florida International
NYU	Purdue
Univ Chicago	Univ DC
Univ Florida	Univ Houston
UIUC	Univ Colorado
Univ Kansas (Lawrence)	Univ Massachusetts, Lowell
Univ Massachusetts, Amherst	Univ Michigan
Univ Tennessee, Chatanooga	Univ Utah
Univ Washington	Univ Wisconsin, Madison

- 35 additional schools have expressed interest and are on waitlist

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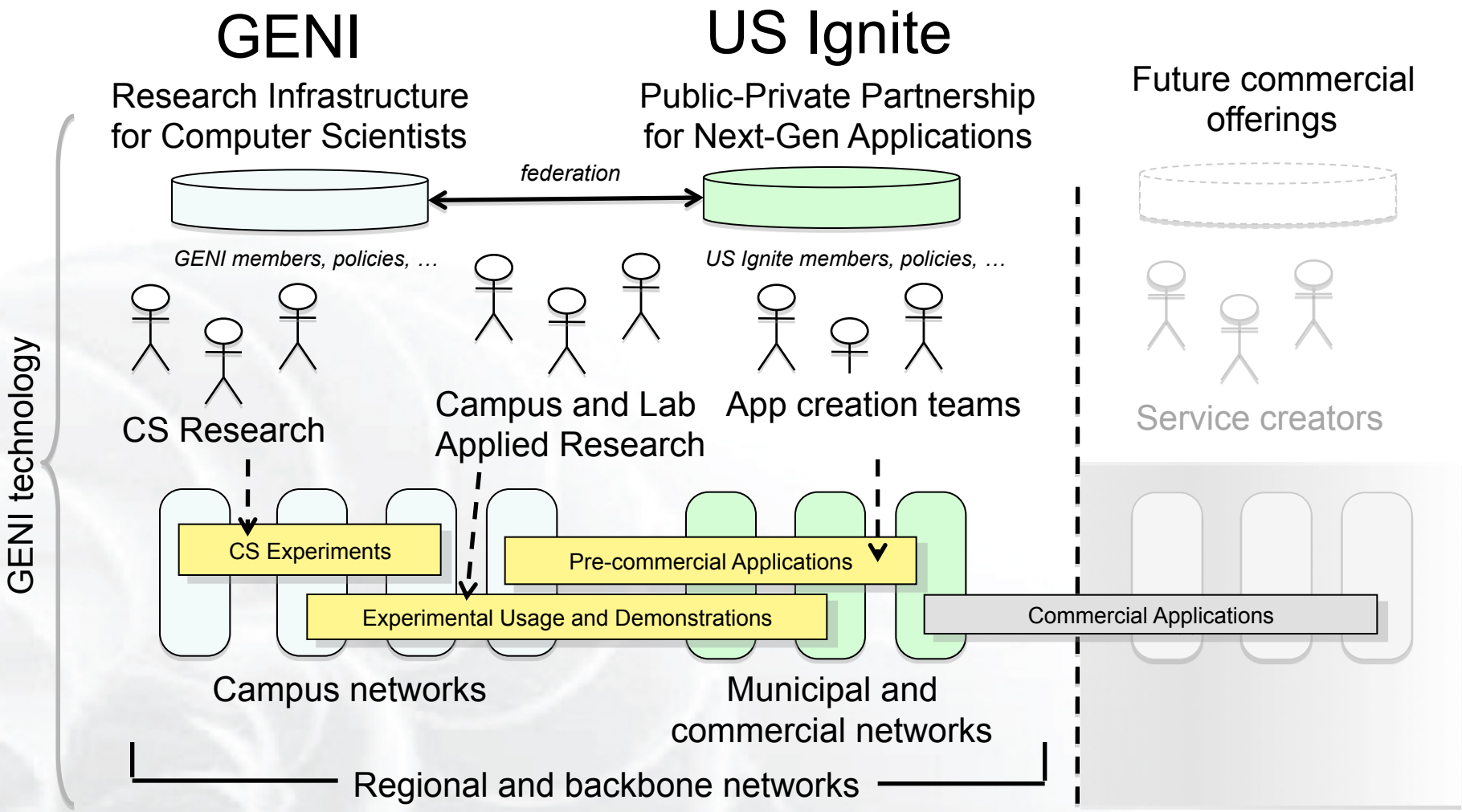
US Ignite

- US Ignite is an initiative to spark the development of **gigabit applications and services**
- **in areas of national priority**: advanced manufacturing, health, education, energy, economic development, transportation, and public safety/emergency preparedness
- **on an ultra high speed, deeply programmable, and sliceable network testbed**.

US Ignite is now taking shape

Bridging CS Experiments to Next-Gen Applications in Cities



US Ignite is a new organization that will promote advanced applications and infrastructure leveraging GENI research and technologies.

GENI-enabled cities
First concrete step in US Ignite activity

- Very strong interest from 6 US cities to date
  - Chattanooga, Cleveland, Lafayette LA, Philadelphia, Salt Lake City region, Washington DC
  - Their citizens will be able to “live in the future”
- Cities can be GENI-enabled very rapidly
  - We have visited all 6 cities for surveys, discussions
  - GENI rack, OpenFlow, and Layer 2 connectivity appear quite feasible
  - Can be federated into GENI very quickly
- Can support experimental, gigabit applications in GENI slices through cities
  - Creates **tremendous** new research opportunities

Draft of US Ignite City Technical Architecture

Early DRAFT CONCEPT – for discussion only!

Existing head-end

Most equipment not shown

Existing ISP connects

Layer 3 GENI control plane

Layer 2 connect to subscribers

OpenFlow switch(es)
Flowvisor
Remote management
Instrumentation
Aggregate manager
Measurement
Programmable PCs
Storage
Video switch (opt)

Layer 2 Ignite Connect (1 GE or 10GE)

New GENI / Ignite rack pair

Home

US Ignite in broadband cities
A huge opportunity for innovation & leap-ahead

- **Slicing** and **deep programmability** greatly expand the revolutionary potential of broadband
  - Citizens of the fortunate cities can “live in the future”
  - Today’s Internet on Channel 1
  - Many new next-generation applications on Channels 2, 3, . . .
  - Opens up leading-edge, high impact research fields
  - Creates huge opportunities for innovation and leap-ahead
- Appears fairly simple / low-cost technically
  - Depends on network equipment selected, etc.
- Social aspects are very important (city ≠ campus!)

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- GENI and US Ignite
- Looking forward

GENI moves to the next stage

- Ramp down of Solicitation 1 efforts. . .
  - Some prototyping efforts will sunset as Sol 1 funds run out
  - Many will continue under Sol 2 / 3 funding
  - Others have funds remaining, will receive extensions
- . . . and major growth in GENI infrastructure
  - Rise in experimentation and continuous operations
  - Growth across 20+ campuses, regionals, and backbones
  - US Ignite cities & next-gen applications coming online soon
- We're looking for 20+ campuses to take GENI to the next stage
  - It's really happening
  - About 30 campus CIOs are now actively engaged

Outline

- GENI – Exploring future internets at scale
- Introducing GENI: an example
- GENI's growing suite of infrastructure
- Experiments going live across the US!
- What's next for GENI?
- GENI and US Ignite
- Looking forward
- Experimentation with GENI

Experimentation with GENI: Workflow

Experiment Planning

- Find resources & tools
- Get account/ credentials
- Develop software

Experiment Deployment

- Present credentials
- Acquire resources
- Install software

Experiment Execution

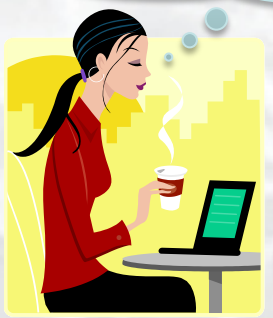
- Control experiment
- Instrument and measure
- Teardown experiment

A flourishing ecosystem of tools is emerging to support this workflow.

Finding Resources and Tools

- "Understanding GENI" page on GENI wiki lists available aggregates (resources) and tools
- Click on an aggregate name for more information on resources

http://groups.geni.net/geni/wiki/UnderstandingGENI



ExperimenterPortal – GENI: geni – Trac

http://groups.geni.net/geni/wiki/ExperimenterPortal

Google Calendar BBN Iweb Yahoo! Google Maps Wikipedia BBN GENI

8 GENI Aggregates Currently Available to Experimenters

8.1 Backbone Networks

Network	Description	Network Map
Internet2	Internet2 provides the U.S. research and education community a dynamic hybrid optical and packet network. GENI experimenters have access to 1Gbps of dedicated bandwidth from Internet2. Experimenters may create their own topologies using Layer 2 VLANS.	
National LambdaRail (NLR)	NLR provides the testbed for advanced research at over 280 universities and private and U.S. government laboratories. GENI experimenters have access to up to 30Gbps of non-dedicated bandwidth on NRL. Experimenters may create their own topologies using Layer 2 VLANS.	
GENI OpenFlow Core	GENI network core is a set of OpenFlow-capable switches in NLR and Internet2. There are currently two standing VLANs (3715 and 3716) carried on ten switches in the core. Experimenters may use these standing VLANs within the GENI core network without having to coordinate with NLR or Internet2. Experimenters will however have to coordinate with their campus and/or regional networks to connect to the GENI core. The two standing VLANS in the network core also bridge between the Internet2 and NLR networks.	

8.2 Programmable Hosts

Aggregate	Description	Compute Resources	Programmable Network	Accepts GENI Credentials	Network Connectivity	Experimenter Tools
PlanetLab	Testbed consisting of 1090 nodes at 513 sites around the world	Virtual machines on PlanetLab nodes	No	Yes	Internet	Gush, Omni, Raven, SFI
GPO Lab myPLC	PlanetLab installation consisting of 5 multi-homed nodes	Virtual machines on PlanetLab nodes	No	Yes	Internet2: IP; NLR: IP; Internet	Gush, Omni, SFI
Utah ProtoGENI	Over 500 co-located PCs that can be loaded with an experimenter specified OS image and connected in arbitrary topologies. Includes 60 nodes with 2 WiFi cards each, plus software-defined radio peripherals (USRP2)	Complete PCs or virtual machines on PCs	PCs can be set up as routers, plus experimenter-controllable switches (HP ProCurves)	Yes	Internet2: IP and Layer 2; Internet	ProtoGENI Tools, Gush
Kentucky ProtoGENI	Over 50 co-located PCs that can be loaded with an experimenter specified OS image and connected in arbitrary topologies. Strong instrumentation capabilities	Complete PCs or virtual machines on PCs	PCs can be set up as routers	Yes	Internet2: IP and Layer 2; Internet	ProtoGENI Tools, Instrumentation Tools
	co-located PCs that can be loaded with an experimenter specified image and connected in arbitrary topologies	Complete PCs	PCs can be set up as routers	Yes	Internet2: IP and Layer 2; NLR: IP and Layer 2; Internet	ProtoGENI Tools, Gush
Million Node GENI	Compute resources on thousands of platforms donated by individuals and institutions. Platforms may be mobile and/or behind firewalls and NATs.	Experimenter software, written in a subset of Python, runs in sandboxes on Million Node GENI platforms.	No	No	Internet	ProtoGENI Tools, Million Node GENI Tools

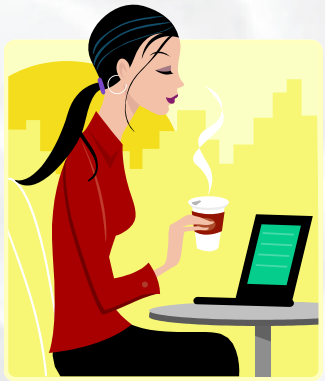
GENI Aggregate Providers: Please report errors and omissions in the table above to Vic Thomas

8.3 Programmable Networks

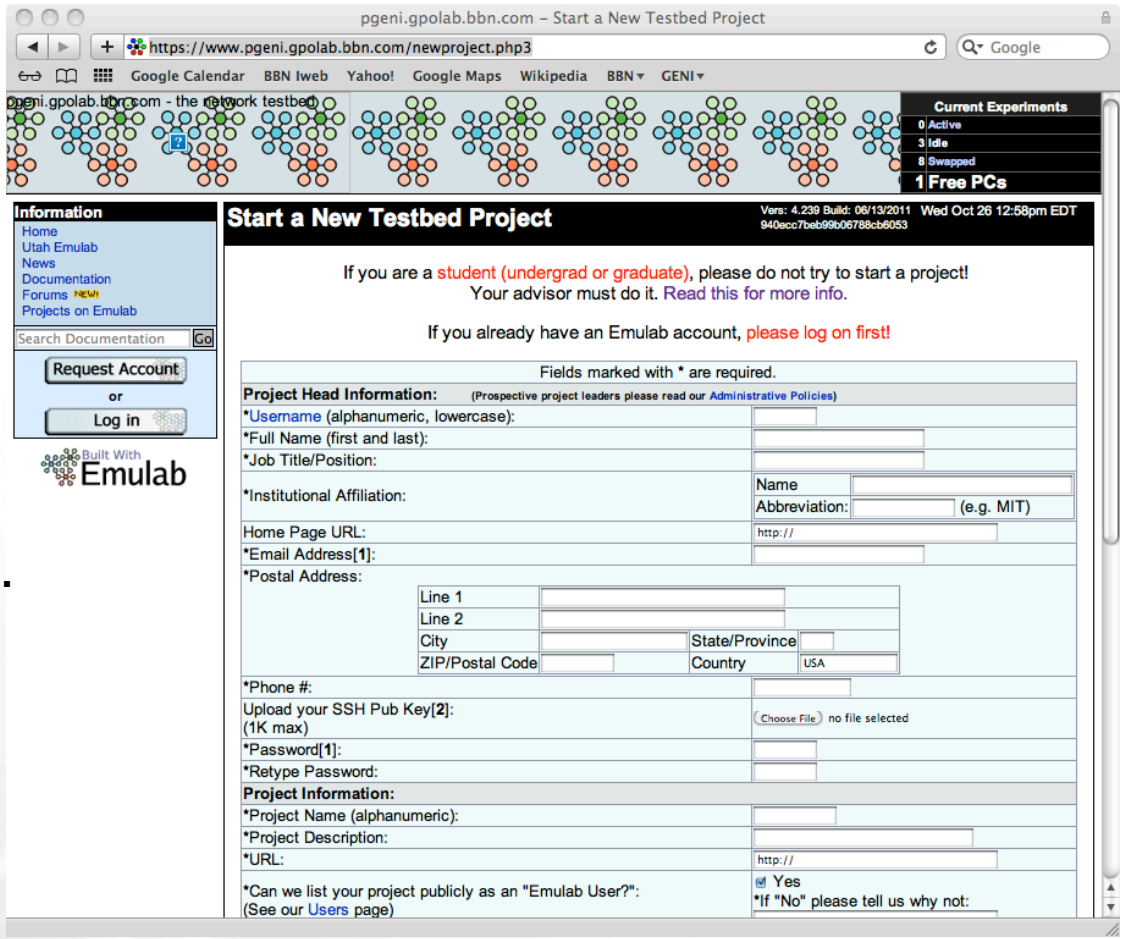
Aggregate	Description	Compute Resources	Accepts GENI Credentials	Network Connectivity	Experimenter Tools
Supercharged PlanetLab Platform (SPP) Nodes	Five high-performance PlanetLab nodes at Internet2 co-location sites. Nodes incorporate high-performance server and network processor blades to support service delivery over high speed overlay networks.	Experimenters program the General-Purpose Processing Engines (GPEs) and Network Processor Blades (NPE) of the SPP nodes.	No	Internet2	
ProtoGENI Backbone Nodes	Nodes at 5 Internet2 co-location sites. The ProtoGENI backbone runs Ethernet on a 1Gbps Internet2 wave, and slices it with VLANs. Researchers select the topology of VLANs on this infrastructure.	No	Yes	Internet2: Layer 2 and IP; Internet2 ION service (incl. many ProtoGENI sites); 1 Gbps to GpENI and Wisconsin ProtoGENI site, 10 GBps to Utah ProtoGENI site and Mid-Atlantic Crossroads; connected to SPP and ShadowNet nodes	ProtoGENI Tools
	BGP-session multiplexer that provides stable, on-demand access to global BGP route feeds. Arbitrary and even				

Obtaining a GENI Account

In person: - GPO GEC Help Desk
- GEC coding sprint on Wed.



Email: help@geni.net



Online: https://www.pgeni.gpolab.bbn.com/newproject.php3

Student accounts need to be approved by a professor.

Developing Software

- Software tools and languages used are typically aggregate specific
  - E.g. Compute resources may require software developed for a Linux environment
- For help on programming resources:
  - Guides and examples on aggregate provider web pages
    - Follow links from aggregate information pages in the Experimenter Portal

Tutorials on programming aggregates:
- ExoGENI Racks tutorial at 1.30pm today
- InstaGENI Racks tutorial at 1.30pm tomorrow
- WiMAX tutorial at 8am Wednesday

Experimenter Workflow in GENI

Experiment Planning

- Find resources & tools
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Experiment Deployment

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- Control experiment
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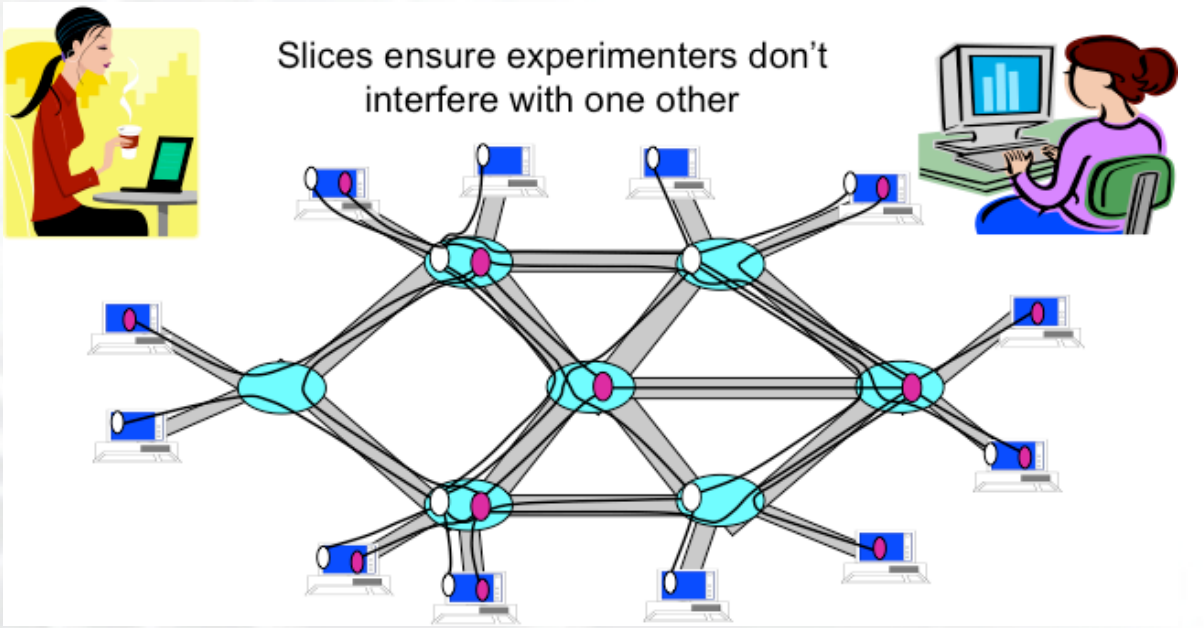
- Teardown experiment

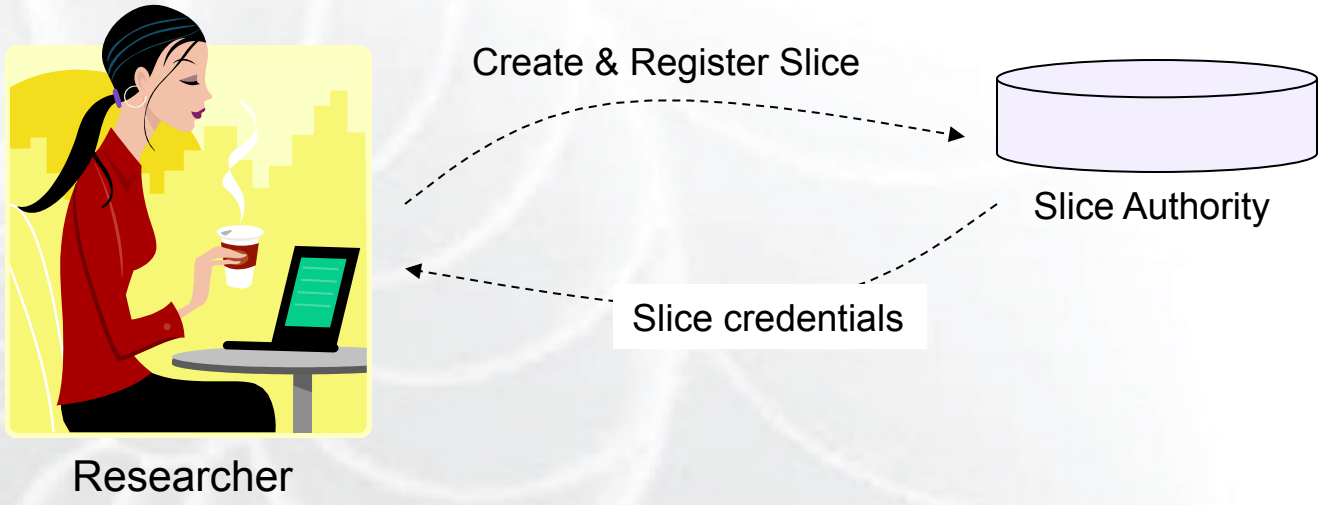
Deploying an Experiment: Slice Creation

- 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



Slice Creation

- Slice authority: GENI entity that creates and registers slices
- GENI currently has multiple slice authorities
  - PlanetLab, ProtoGENI, GPO Lab



Slivers

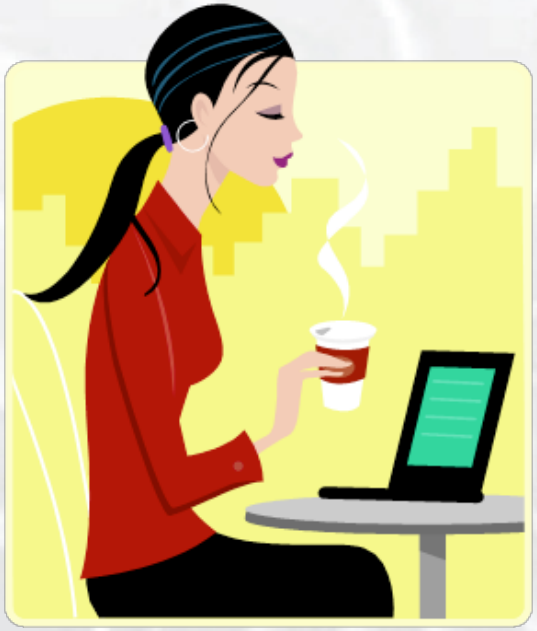
- Sliver: A resource unit assigned to a slice by an aggregate
  - A virtual machine on a compute node
  - A VLAN on a backbone network
- RSpecs: Lingua franca for describing and requesting resources
  - "Machine language" for negotiating resources
  - Experimenter tools eliminate the need for most experimenters to write or read RSpecs

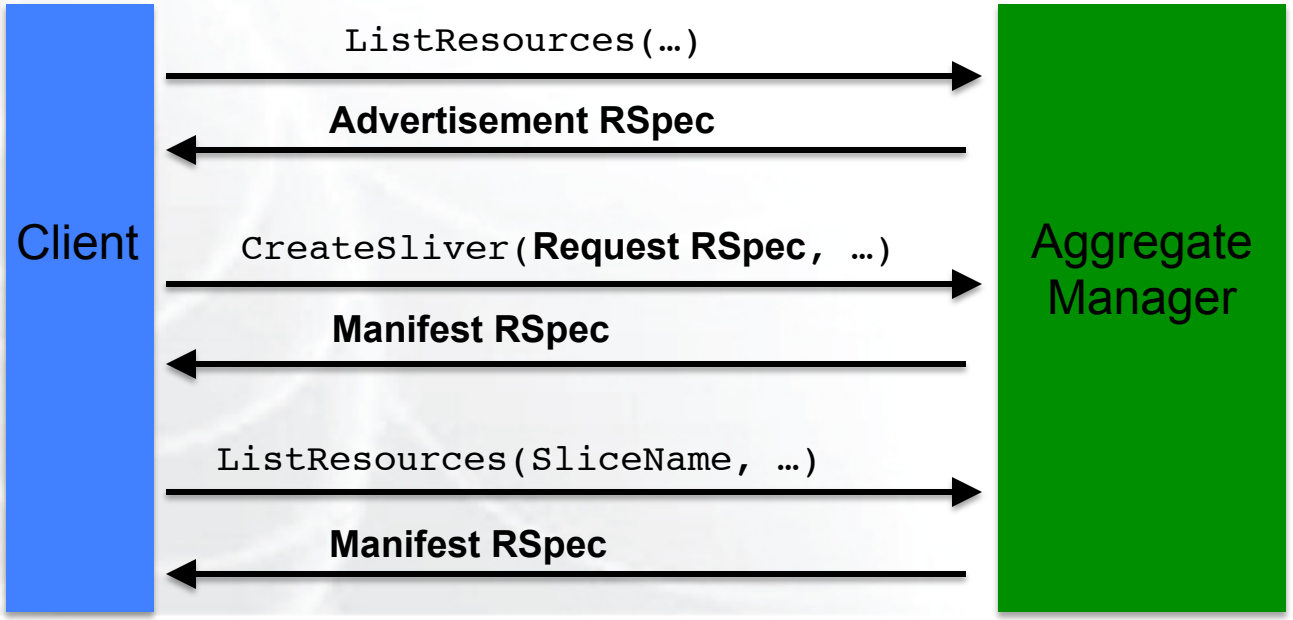
```
<?xml version="1.0" encoding="UTF-8"?>
<rspec xmlns="http://www.protogeni.net/resources/rspec/2"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="http://www.protogeni.net/resources/rspec/2
                           http://www.protogeni.net/resources/rspec/2/request.xsd"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

RSpec for requesting a single node

Using RSpecs to Add Slivers to a Slice

- Advertisement RSpec: What does an aggregate have?
- Request RSpec: What does the experimenter want?
- Manifest RSpec: What does the experimenter have?





Installing Experimenter Software

- Manifest RSpec has information about allocated resources
  - Hostnames, IP addrs, interface names, MAC addrs, …
  - Information used to install software
- Manual installation…
  - ssh into individual virtual machines/nodes and install software
- …and/or using experimenter tools
  - Gush, Raven and Flack tools automate installation
    - Useful for large experiments
  - Raven automatically updates slivers if new versions of software become available
    - Useful for long running experiments

Intro to Flack the InstaGENI tutorial at 1.30pm tomorrow

Floodlight (OpenFlow Controller Dev.) tutorial at 1.30pm today

Experimenter Workflow in GENI

Experiment Planning

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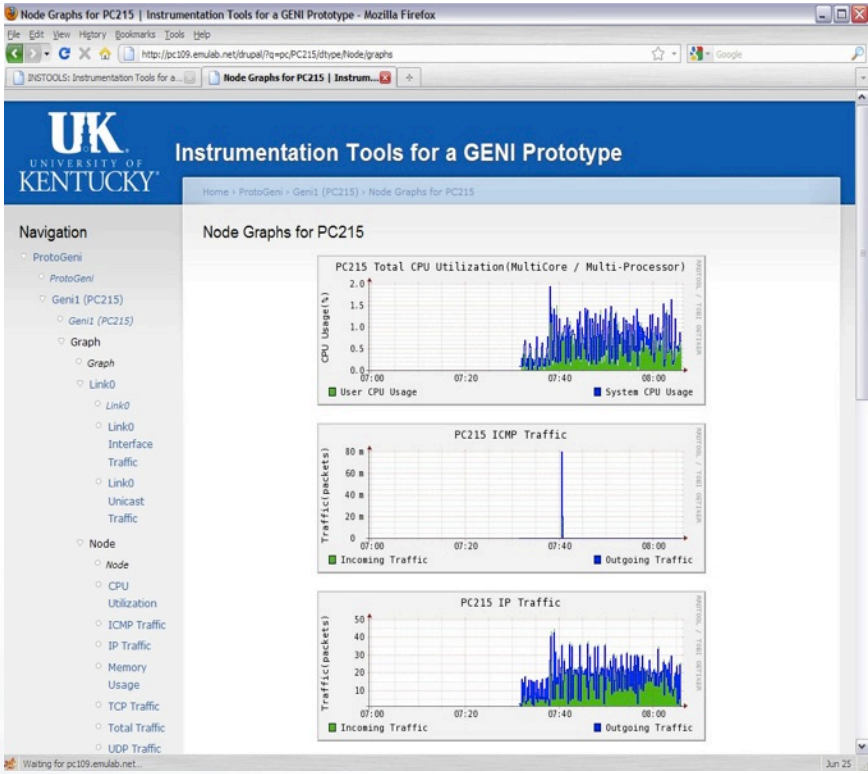
Controlling an Experiment

- Gush experiment control tool allows experimenters to
  - Start, pause, resume and stop experiments
  - Specify barriers for synchronizing a distributed experiment
  - Monitor experimenter software on slivers for failures and specify failure handlers
- The GENI AM API provides calls to
  - Inquire about the status of a sliver (`SliverStatus`)
  - Stop and deallocate a sliver (`DeleteSliver`)

Instrumentation and Measurement (I&M)

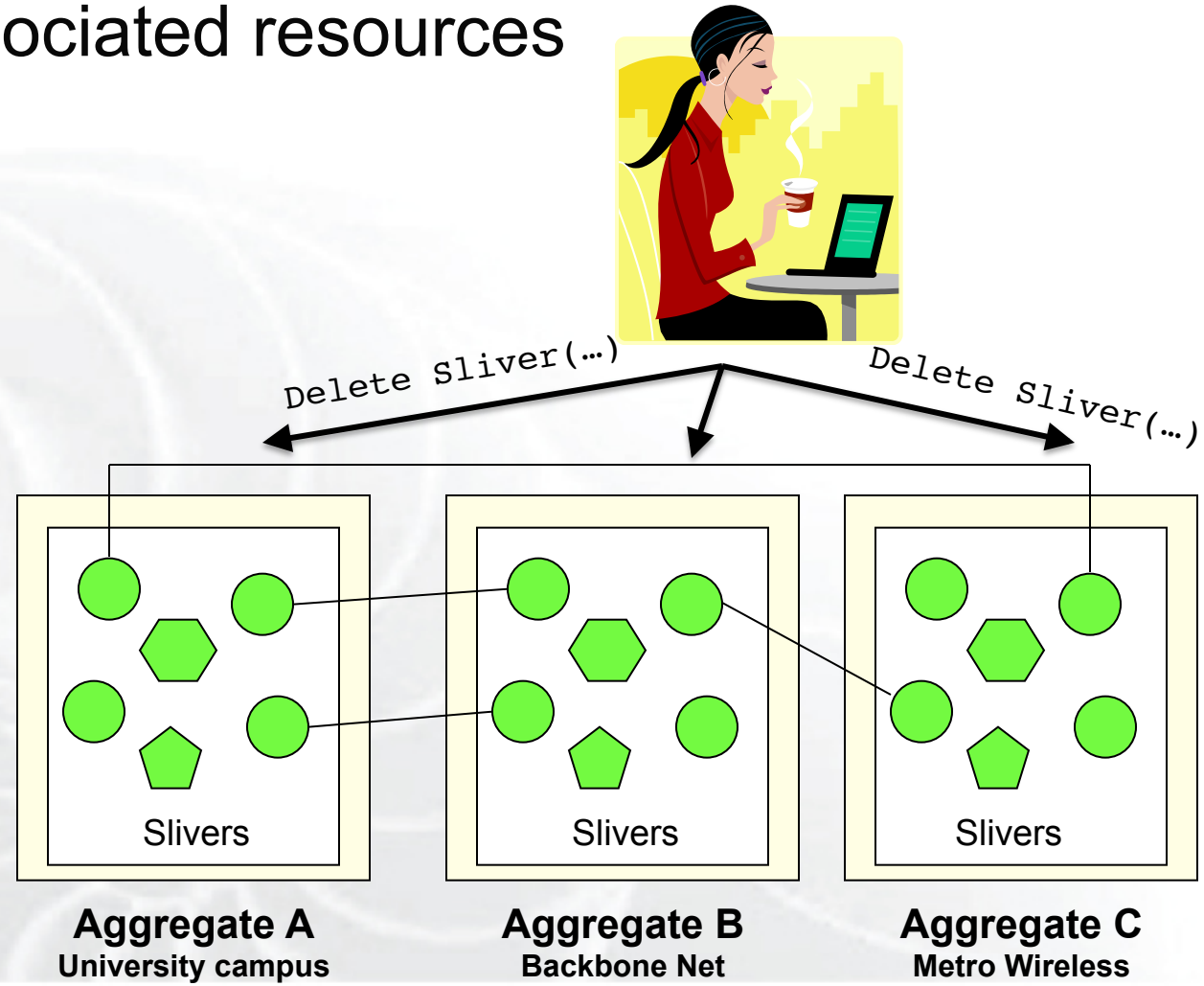
- GENI instrumentation tools
  - Instrumentation Tool: Integrated with ProtoGENI
  - OnTimeMeasure: Active measurement tool
  - MeasurementSystem: Packet capture based measurements
  - LAMP: Infrastructure measurement tool
- GENI Solicitation 3 is funding two large projects for unified I&M tools
  - GEMINI
  - GIMI



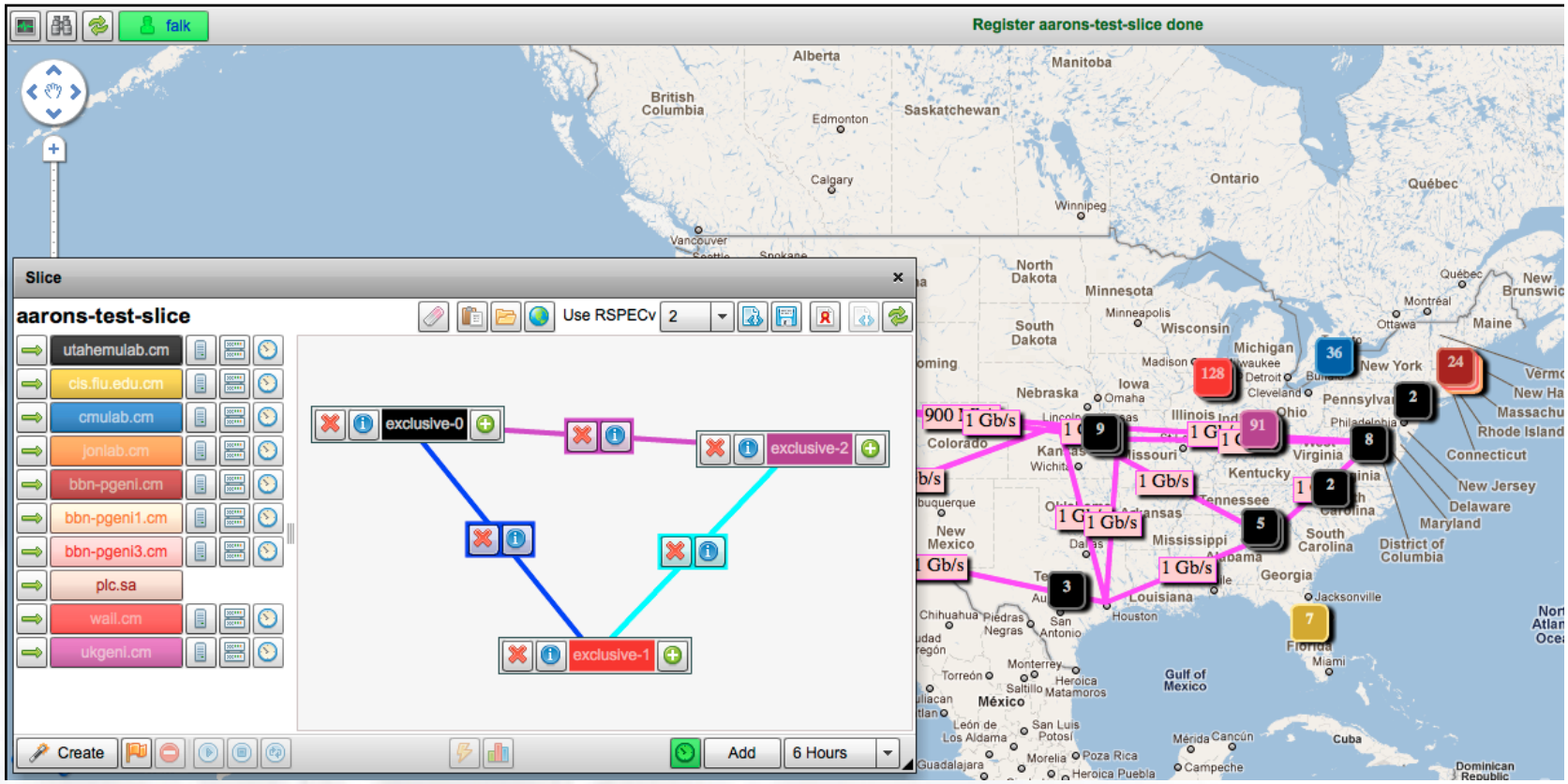
GIMI and GEMINI tutorials at 1.30pm today and tomorrow.

Experiment Teardown

- `DeleteSliver` stops sliver and deallocates associated resources



GENI Experimenter Tool: Flack



Graphical tool that hides the complexities of Rspecs and the GENI AM API

Brief intro to Flack at InstaGENI tutorial at 1.30pm tomorrow.

GENI Experimenter Tool: Omni

```
$ omni.py createsliver aliceslice myRSpec.xml
INFO:omni:Loading config file omni_config
INFO:omni:Using control framework pgeni
INFO:omni:Slice urn:publicid:IDN+pgeni.gpolab.
          expires within 1 day on 2011-07-07
INFO:omni:Creating sliver(s) from rspec file
INFO:omni:Writing result of createsliver for
INFO:omni:Writing to 'aliceslice-manifest-rspe
INFO:omni: ----------------------------------
INFO:omni: Completed createsliver:

  Options as run:
                aggregate: https://www.emulab.
                framework: pgeni
                native: True

  Args: createsliver aliceslice myRSpec.xml

  Result Summary: Slice urn:publicid:IDN+pgeni
Reserved resources on https://www.emulab.net/p
  Saved createsliver results to aliceslice-man
INFO:omni: ==================================
```

Command line tool that hides the complexities of the GENI AM API

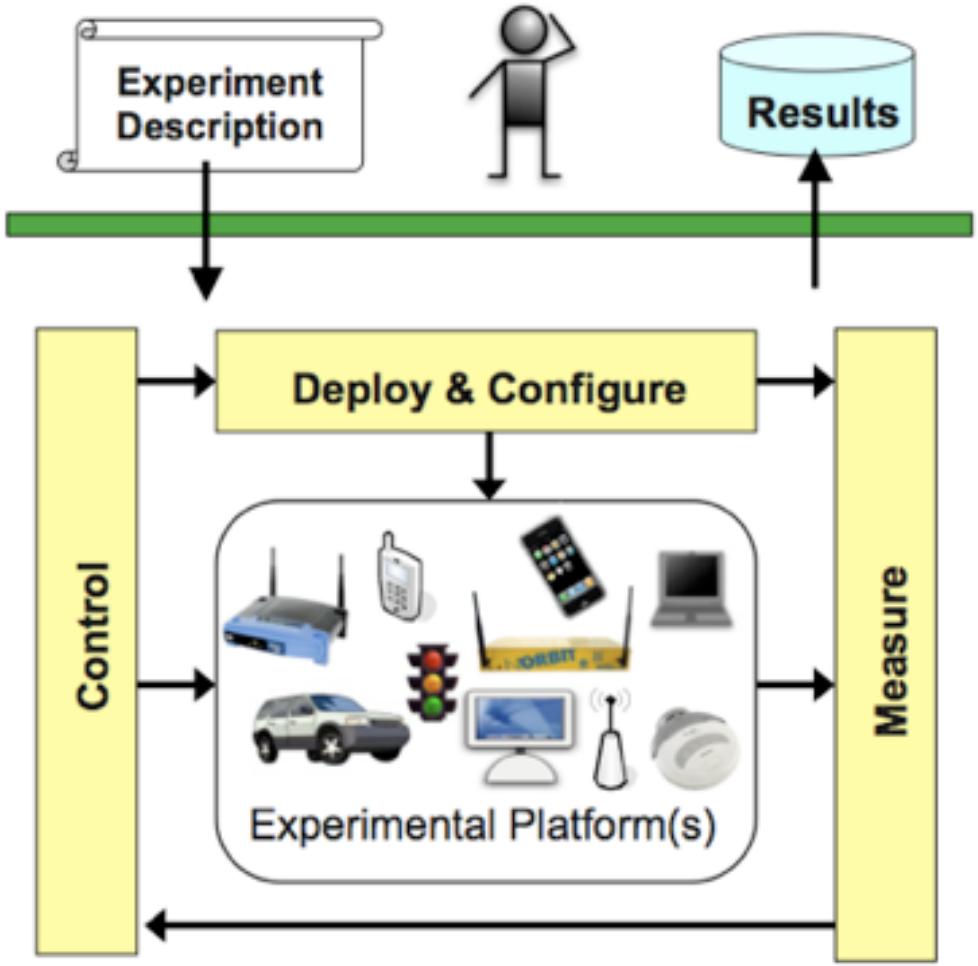
GENI Experimenter Tools: Gush & Nebula

Gush: Command line tool for greater control over experiments

```
jeannie@sysnet:~/gush/trunk$ ./gush -P 15000
gush> Gush has learned about the slice williams_gush.

gush>
gush> prefer williams
gush> prefer ucsd
gush> prefer planetlab1
gush>
gush>
gush> load tests/simple.xml
Project "simple" is selected.
Experiment "simple" is selected.
gush>
gush>
gush> run
Starting experiment run.
Running experiment simple...
gush> The configuration matcher has finished matching.
The resource allocator has finished successfully.
williams_gush@planetlab1.williams.edu:15413 has joined the mesh.
The file transfer of Package to planetlab1.williams.edu has been completed.
The software installation of Package on planetlab1.williams.edu was successful.
williams_gush@planetlab1.ucsd.edu:15413 has joined the mesh.
The file transfer of Package to planetlab1.ucsd.edu has been completed.
The software installation of Package on planetlab1.ucsd.edu was successful.
williams_gush@planetlab1.williams.edu:15413,7370: Hello World

williams_gush@planetlab1.ucsd.edu:15413,20638: Hello World

The experiment has ended.

gush>
gush> info mesh
Mesh:
williams_gush@planetlab1.ucsd.edu:15413: connected; (fds=7,7 last_heard=1299692920)
williams_gush@planetlab1.williams.edu:15413: connected; (fds=6,6 last_heard=1299692891)
Summary: 2 mesh members; 0 nodes connecting.
gush>
gush>
gush> info control
Experiment Controller State(0x8495dd8):
 * Experiment simple
Experiment: simple Controller: jeannie@sysnet:15000
Component: Cluster1 Controller: jeannie@sysnet:15000
Matching id 1299692167.1.default.jeannie@sysnet:15000
Component requests 2 hosts.
1 matchings known:
1299692167.1.default.jeannie@sysnet:15000,
 Node status (2):
   williams_gush@planetlab1.ucsd.edu:15413: running;
   williams_gush@planetlab1.williams.edu:15413: running;
Num not failed: 2
 Exceptions (0):
Process: cat
Controller. Status:
  williams_gush@planetlab1.ucsd.edu:15413 :  done;
  williams_gush@planetlab1.williams.edu:15413 :  done;

gush> disconnect
gush> williams_gush@planetlab1.williams.edu:15413 has decided to leave the mesh.
williams_gush@planetlab1.ucsd.edu:15413 has decided to leave the mesh.

gush>
```

Nebula: Graphical front-end to Gush

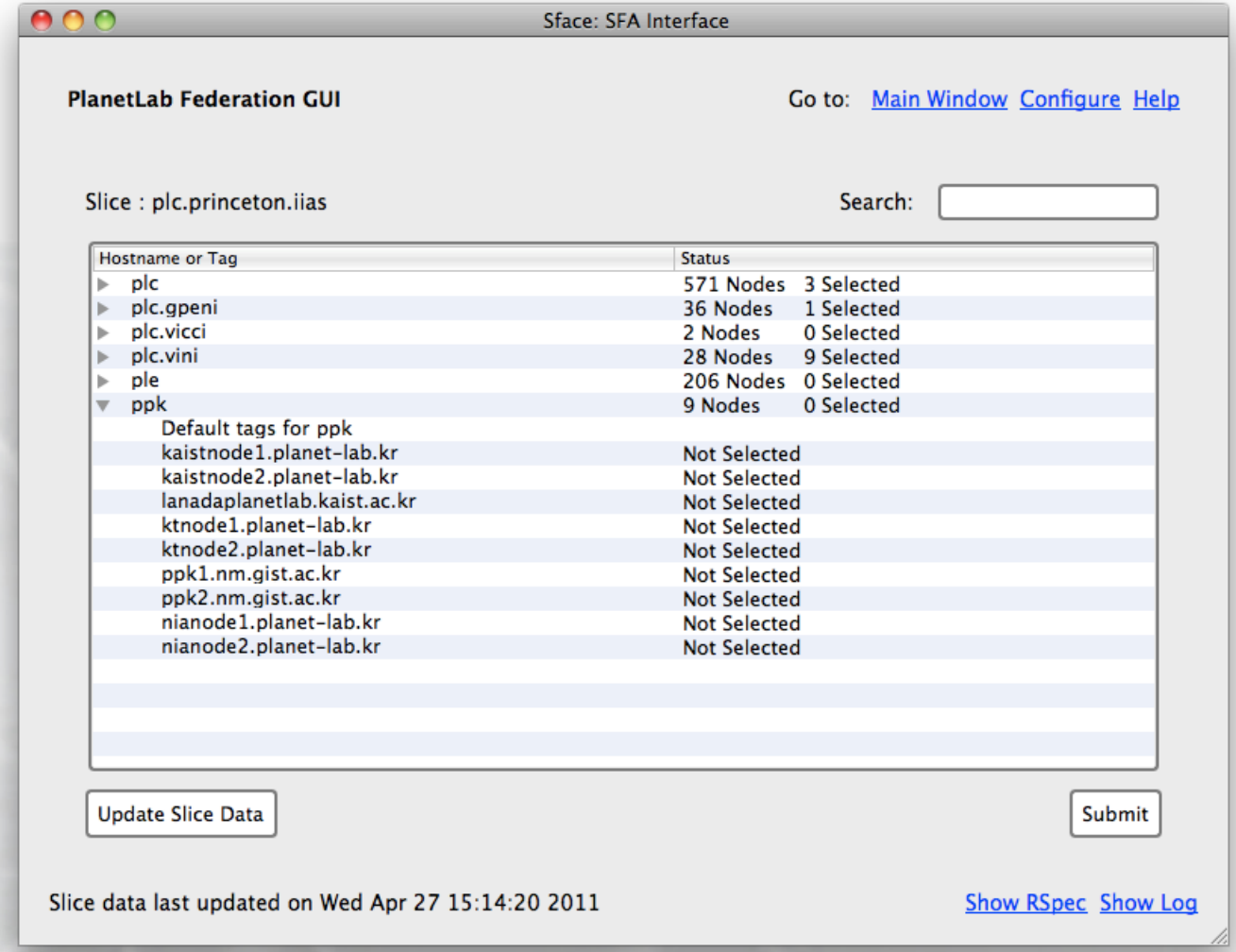
GENI Experimenter Tool Suite: OMF



A suite of tools for experiment deployment, control and measurement.

OMF tutorial at 10.30am today.

GENI Experimenter Tool: SFace



Graphical tool that hides the complexities of Rspecs and the GENI AM API

GEC14 Agenda

DRAFT AGENDA (6-25-12)

Start time	Mon, July 9	Tues, July 10	Wed. July 11
7:00	Newcomers breakfast (by invitation only)		
7:30			
8:00	I&M Design Topics	Plenary (part 1)	SDN in GENI
8:30			◆Experiment-er Roundtable
9:00	◆Tutorial: Intro to GENI		◆Tutorial: WiMAX
9:30			
10:00	Break (10:00 - 10:30)	Break (10:00 - 10:30)	Break (10:30 - 11:00)
10:30	Architects Meeting (Invite only)	Plenary (part 2)	Plenary (wrap-up) 11:00 - 11:45
11:00	Tutorial: NetKarma - A Provenance Tool for Experimenters		
11:30	◆Tutorial: OMF		
12:00	Lunch (on your own)	Lunch (on your own)	Lunch (on your own)
12:30			
1:00			
1:30	I&M and Monitoring	GENI Clearinghouse & Portal	◆Code Sprint
2:00	Tutorial: Floodlight	WiMax Deployments & Experiments	
2:30	◆Tutorial: ExoGENI / GIMI (1)	◆Tutorial: InstaGENI / GEMINI (1)	
3:00	Break (3:00 -3:30)	Break (3:30 -4:00)	Break (3:30 -4:00)
3:30	Opt-In Users	Racks & Campuses	◆Code Sprint (continue)
4:00	Curriculum	Int'l Federation	
4:30	◆Tutorial: ExoGENI / GIMI (2)* (Continue)	◆Tutorial: InstaGENI / GEMINI (2)* (Continue)	
5:00	Bus departing for MIT for the demos and posters (5:00 - 5:30)		
5:30	Evening Demo session & Networkig Event at MIT		
6:00			
6:30			
7:00			
7:30	Bus departing from MIT back to Westin Copley (7:30- 8:00)		
8:00			

* Must have attended session 1 before session 2.

◆ Recommended for newcomers

Many tutorials require a VirtualBox VM with tools and credentials pre-installed.
Stop by GPO Help Desk if you don't have one.

GENI Engineering Conferences
We welcome your participation in GENI

- **15th meeting, open to all:**
  October 23-25, 2012, Houston TX
  - Planning & discussion for experimenters, software, infrastructure
  - Tutorials and workshops
  - **Travel grants** to US academics for participant diversity