Welcome to GENI

Mark Berman
mberman@bbn.com
www.geni.net

May 23, 2016

Welcome!

Welcome to the GENI Regional Workshop

Please take this opportunity to …

- Learn about GENI and related testbeds and tools.
- Connect with workshop instructors and organizers to kickstart your planned research.

Thank you to our hosts

- Professor Ibrahim Matta and Boston University

geni
Exploring Networks of the Future

NSF

An Introduction to GENI
and
Thoughts on Changing Cyberinfrasttructure

Mark Berman
mberman@bbn.com
www.geni.net

May 23, 2016

Two Views of GENI

geni
Exploring Networks of the Future

May 23, 2016

NSF

View A:
GENI is a Distributed Laboratory

Experimentation Breaks the Innovation Logjam

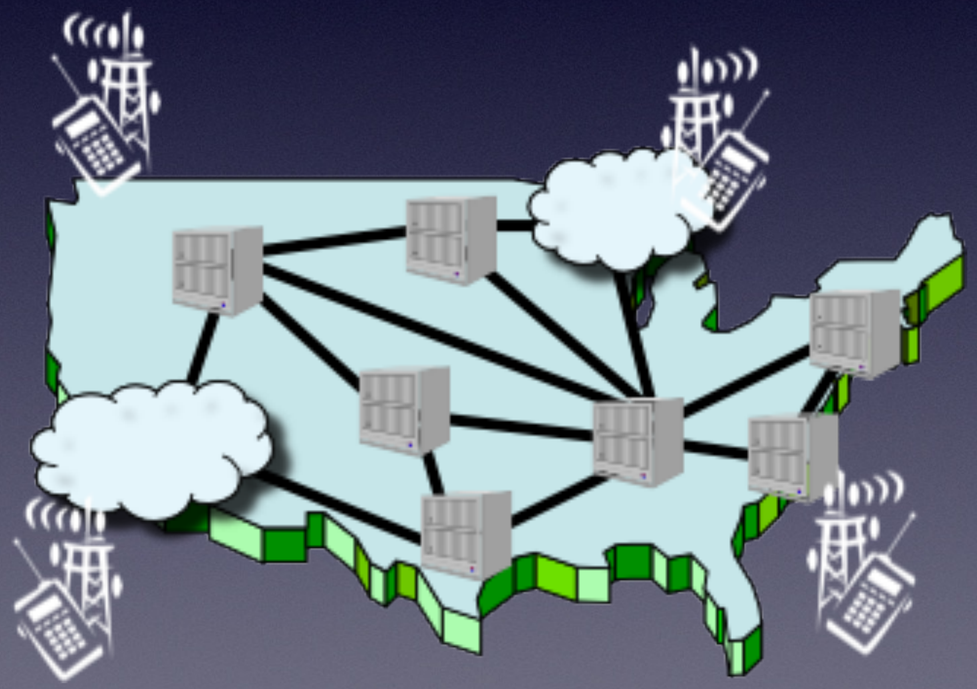
"I have a great idea."

"That will never work."

geni
Exploring Networks of the Future

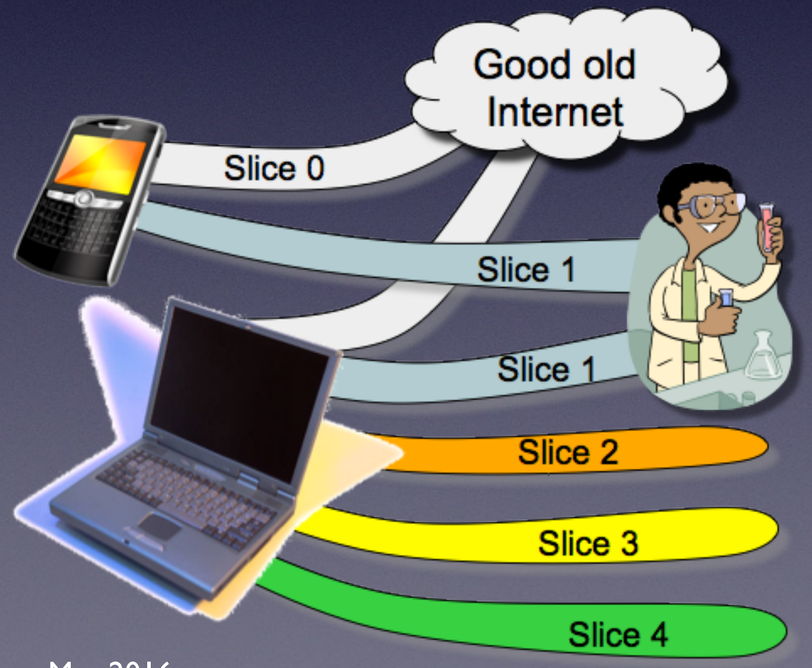
NSF

"Let's try it out."



"Looks like an app to me."

"It's my very own GENI slice."



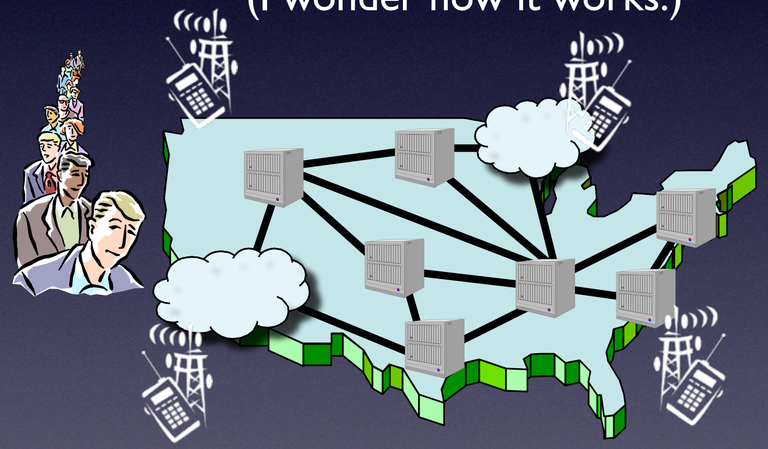
geni
Exploring Networks of the Future

NSF

“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.)

geni
Exploring Networks of the Future

NSF

View B:
GENI Revolutionizes Cyberinfrastructure

geni
Exploring Networks of the Future

May 2016

NSF

Cyberinfrastructure Lives to Serve

All applications and services rely on cyberinfrastructure.

High performance applications and services need precision cyberinfrastructure

- The right resources
- In the right place
- Running the right software

geni
Exploring Networks of the Future

NSF

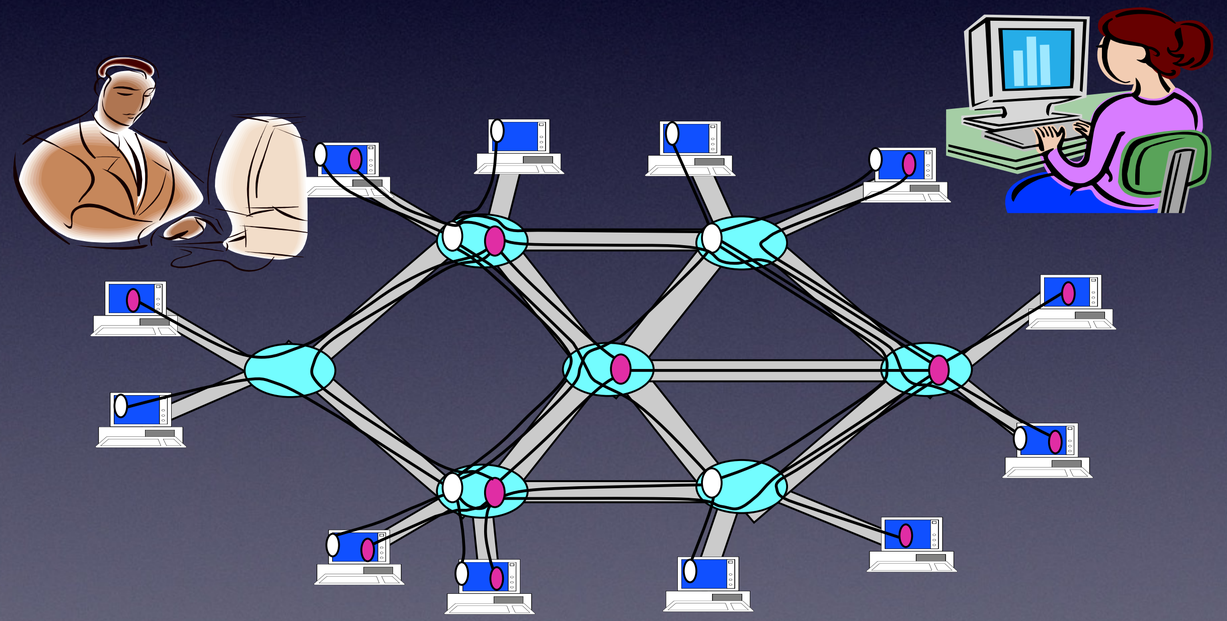
Two Key GENI Concepts

Slicing

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

Deep Programmability



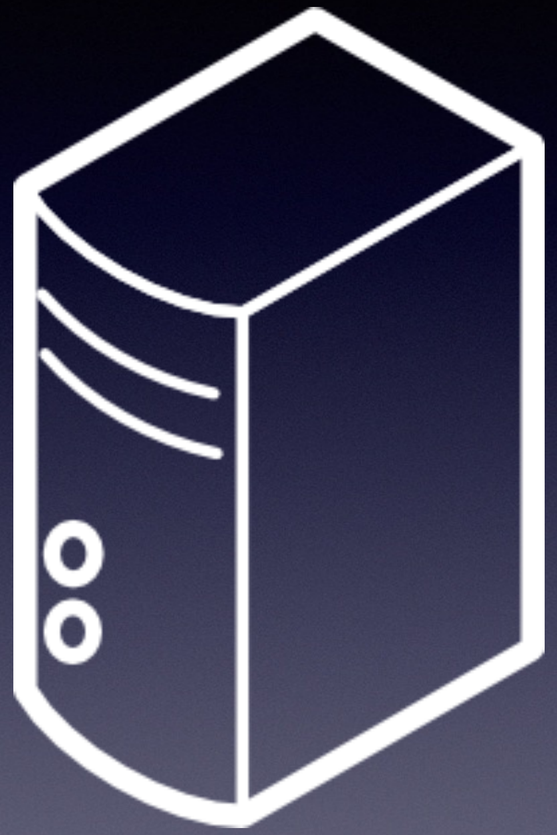
We can run many different "future Internets" in parallel.

geni
Exploring Networks of the Future

NSF

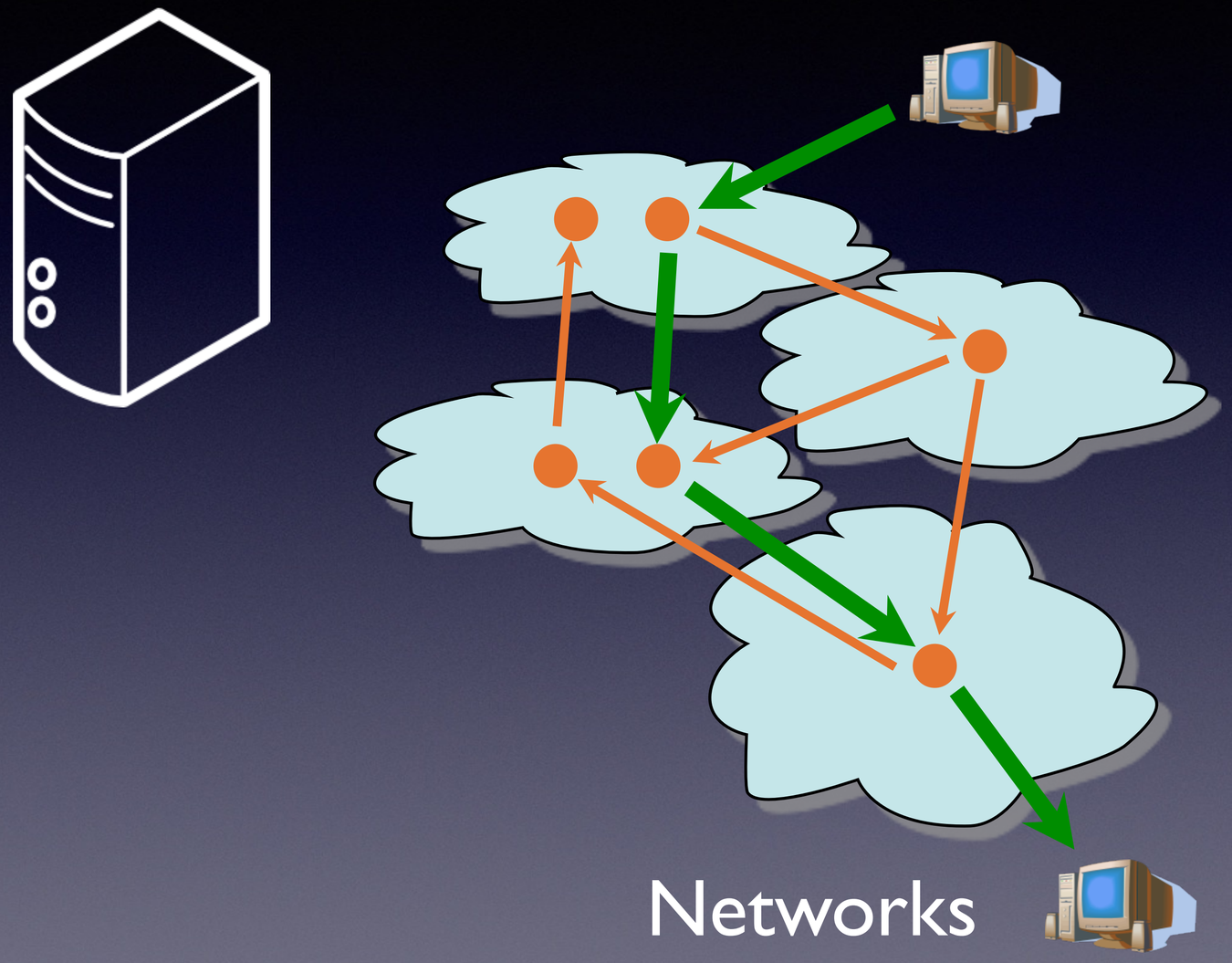
Program Everything

Program Everything

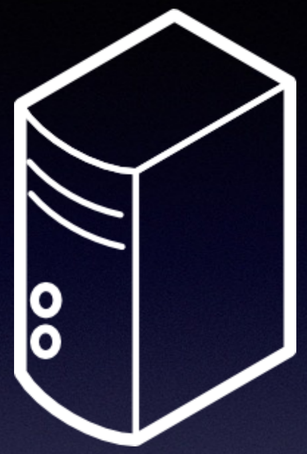


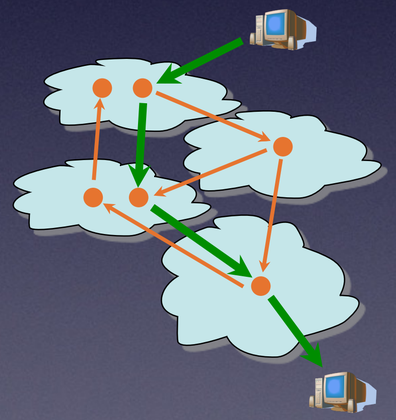
Computers

Program Everything



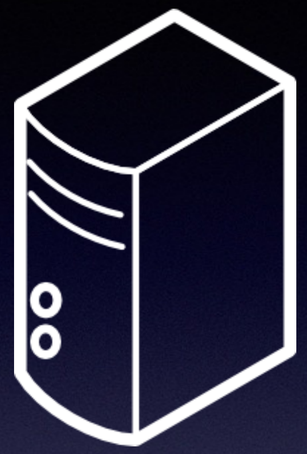
Program Everything

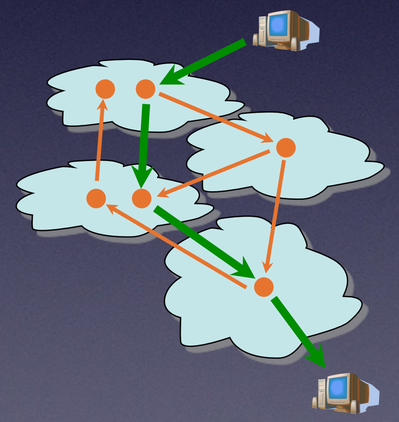




4G Cellular

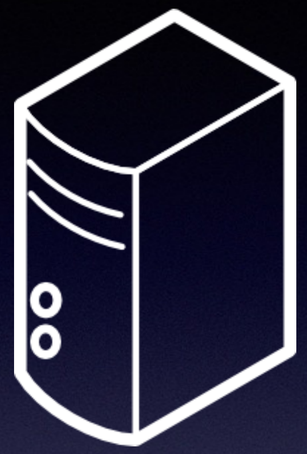
Program Everything

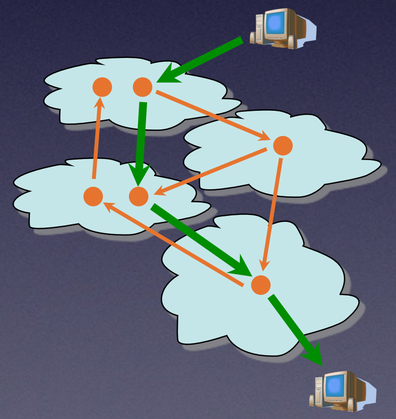


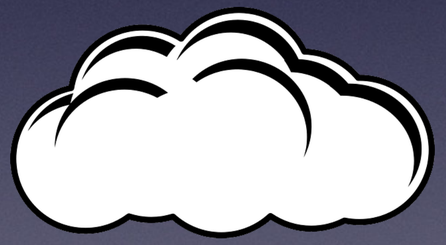


Clouds

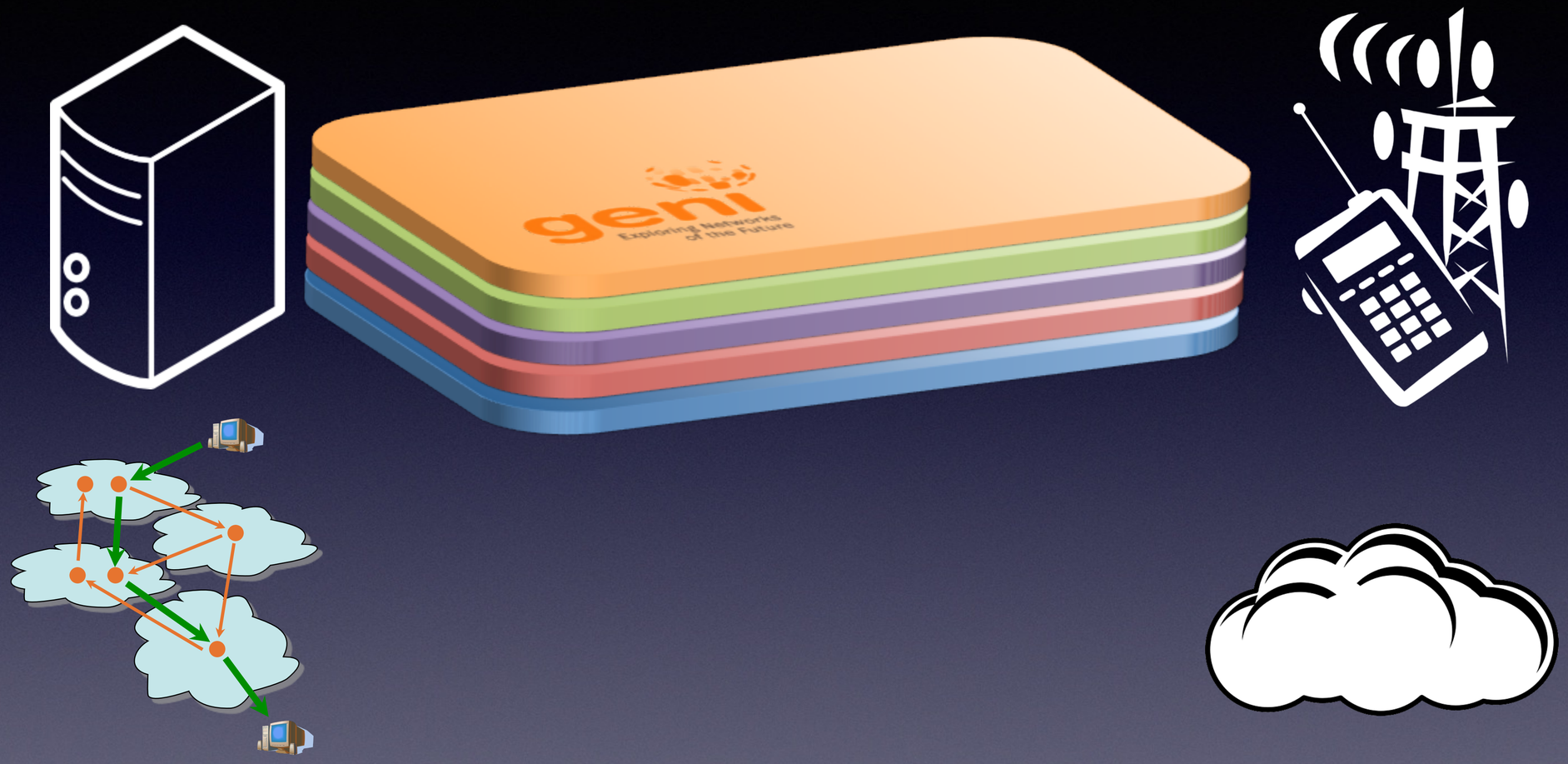
Program Everything





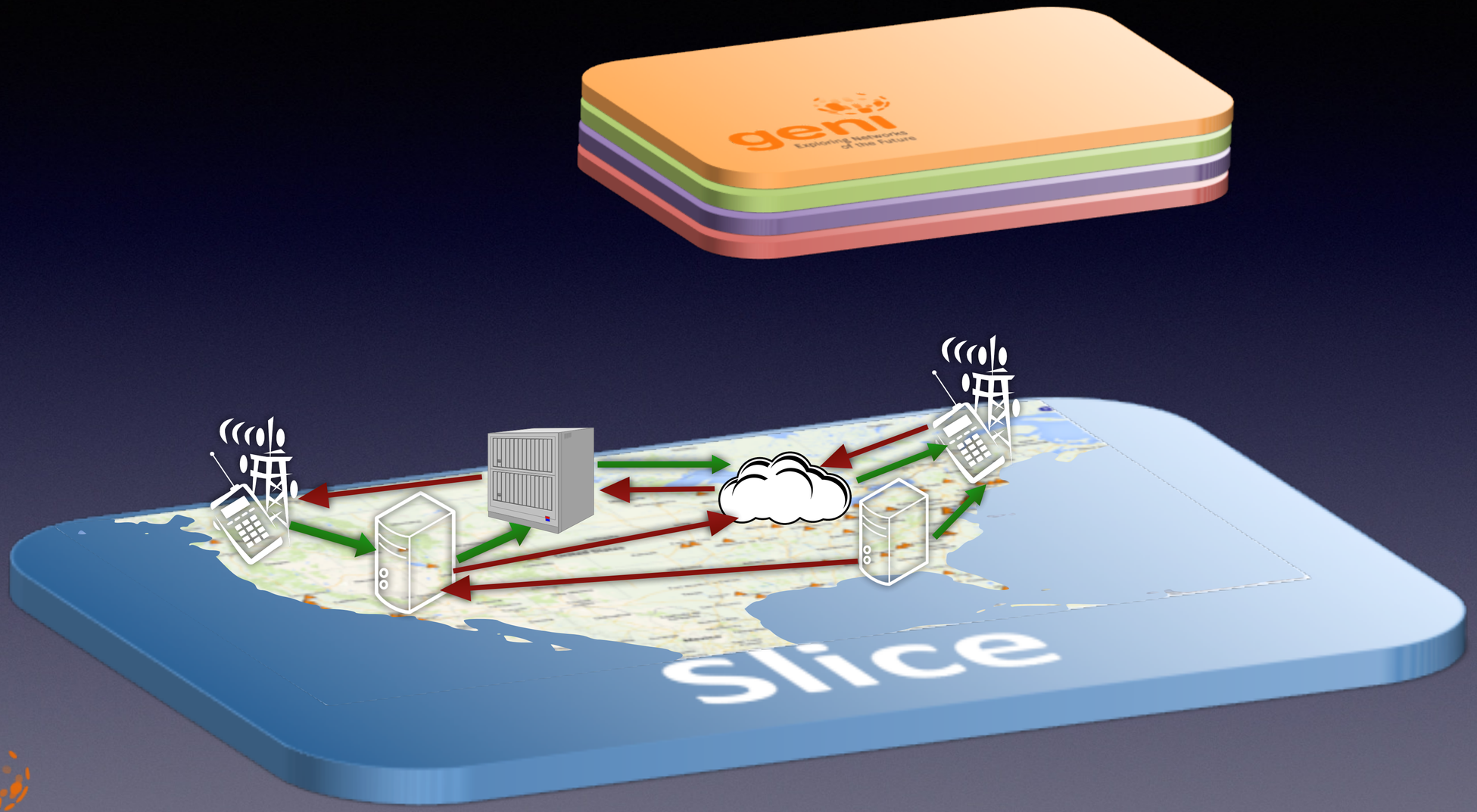


End-to-end Integrated Slices



End-to-end Integrated Slices

Precision Cyberinfrastructure



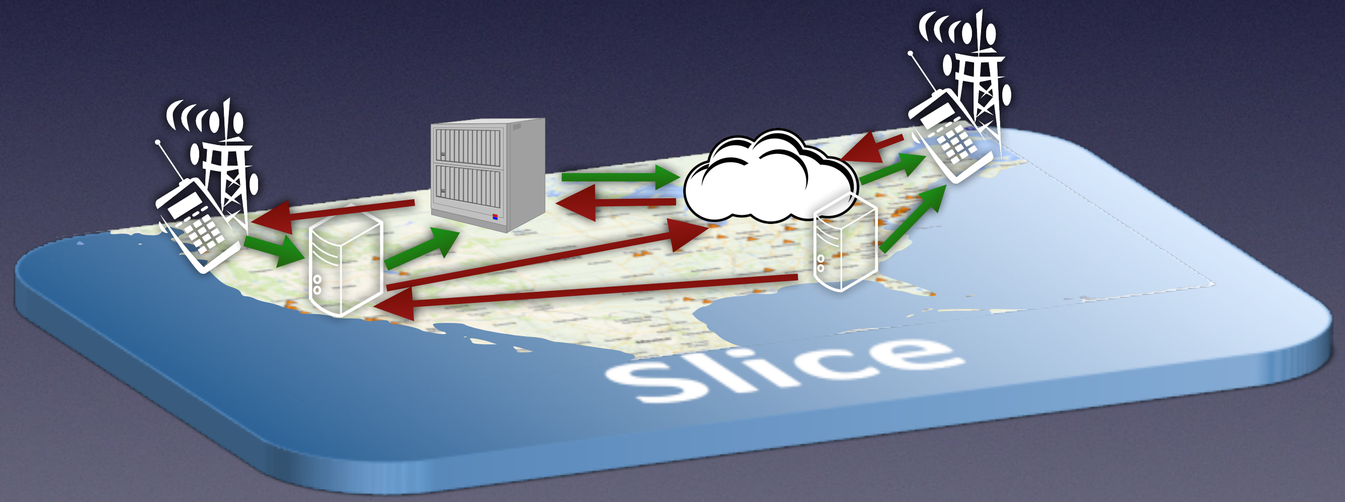
geni
Exploring Networks of the Future

NSF

May 23, 2016

Precision Matters

Precision Matters

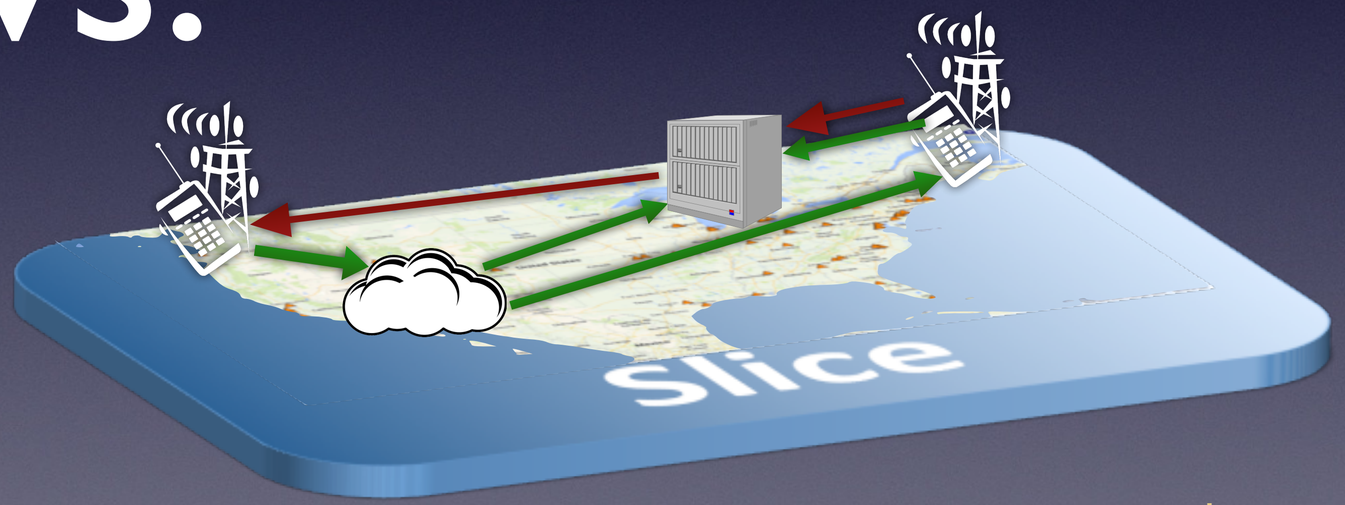


geni
Exploring Networks of the Future

NSF

Precision Matters

VS.



geni
Exploring Networks of the Future

NSF

Precision Matters

=

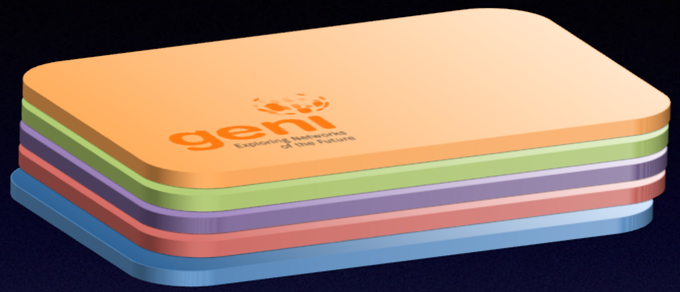
geni
Exploring Networks of the Future

NSF

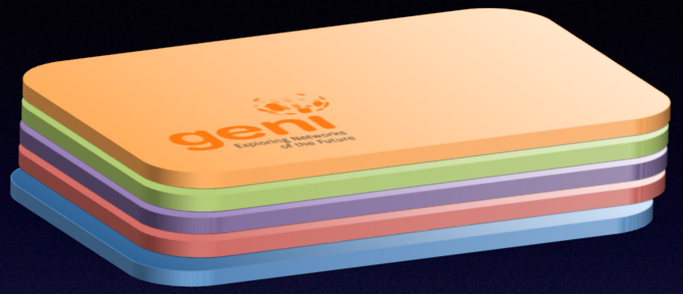
Slicing and Deep Programmability Implementation Mechanisms

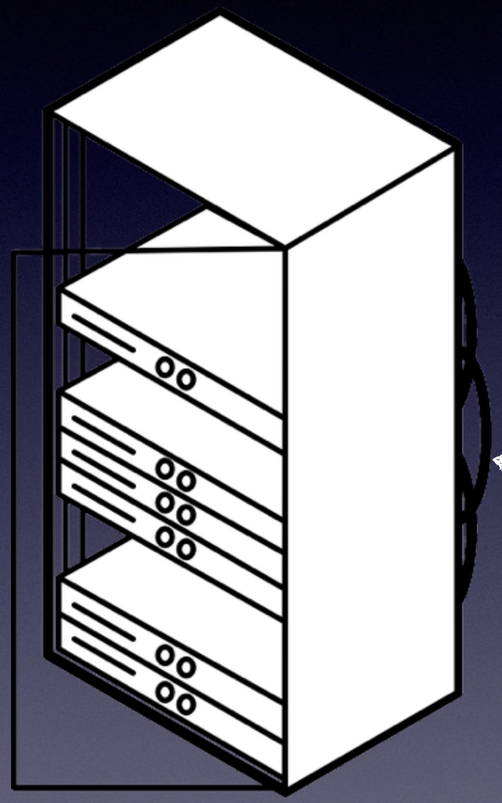
May 23, 2016

Slicing In a GENI Rack



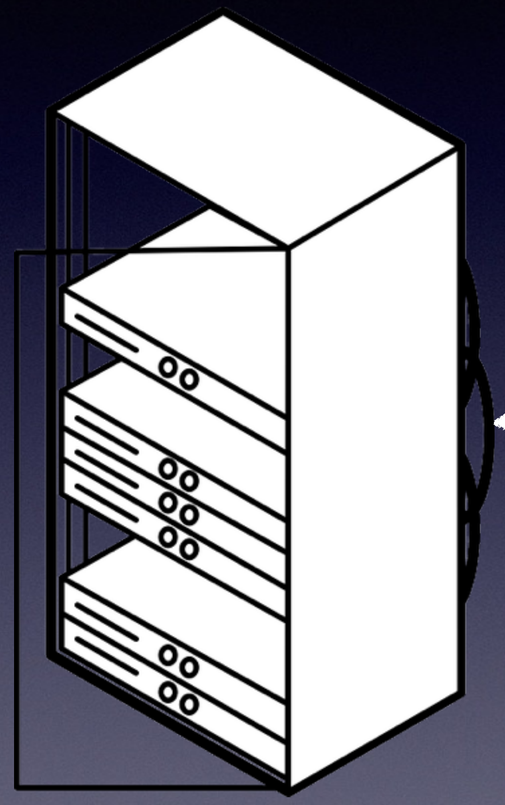
Slicing In a GENI Rack





GENI resources are grouped into aggregates, collections of resources under common management (usually at a single site).

Slicing In a GENI Rack



AM API

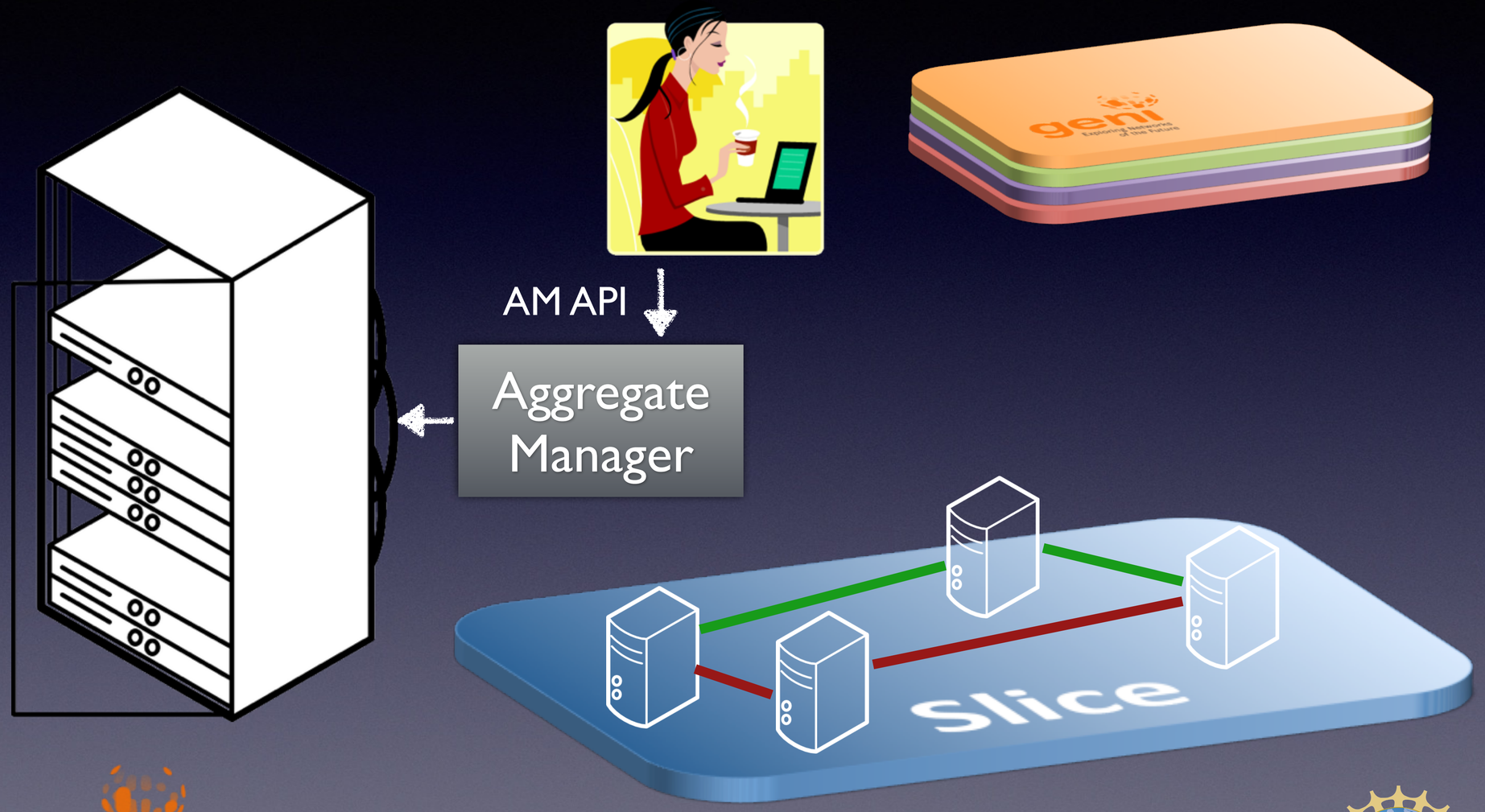
Aggregate Manager

Aggregate Managers (AM), one per aggregate, provision & configure all GENI resources

geni
Exploring Networks of the Future

NSF

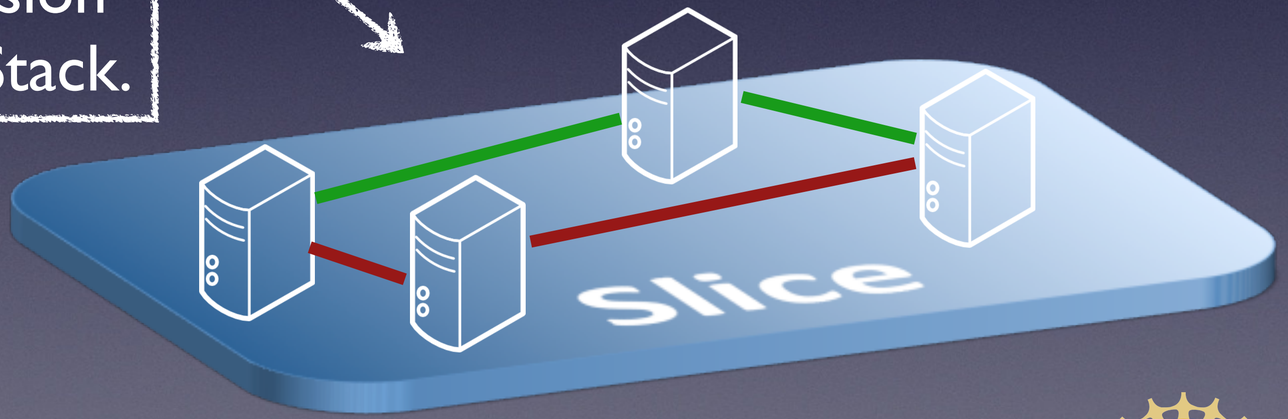
Slicing In a GENI Rack



Slicing In a GENI Rack

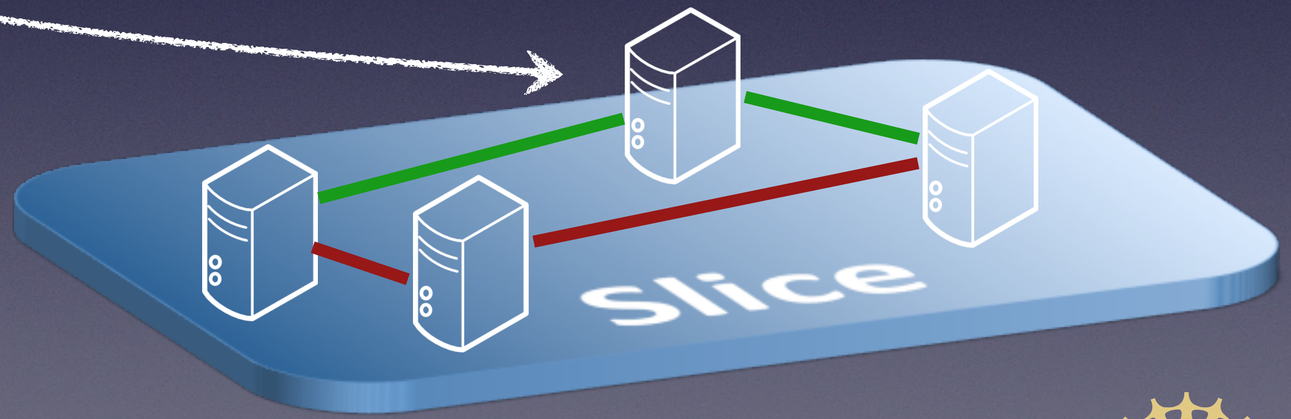
Compute resources may be "bare metal" or VMs.

Provisioning mechanism is an implementation choice. Current racks provision via Emulab or OpenStack.



Slicing In a GENI Rack

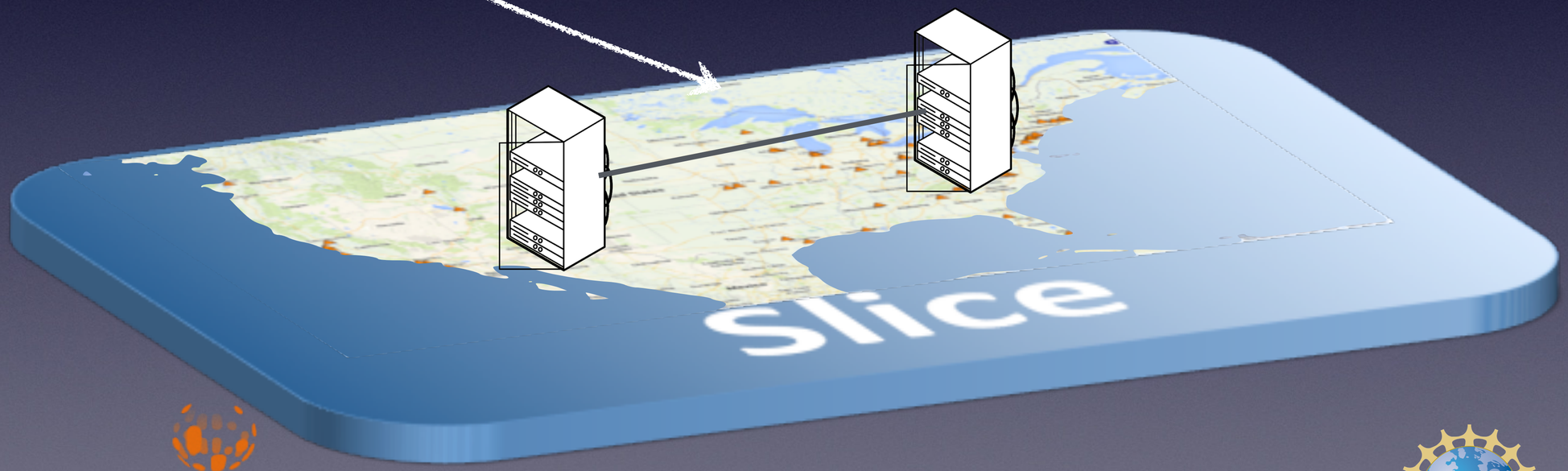
Within a rack, network is sliced by VLAN.



Slicing Across GENI

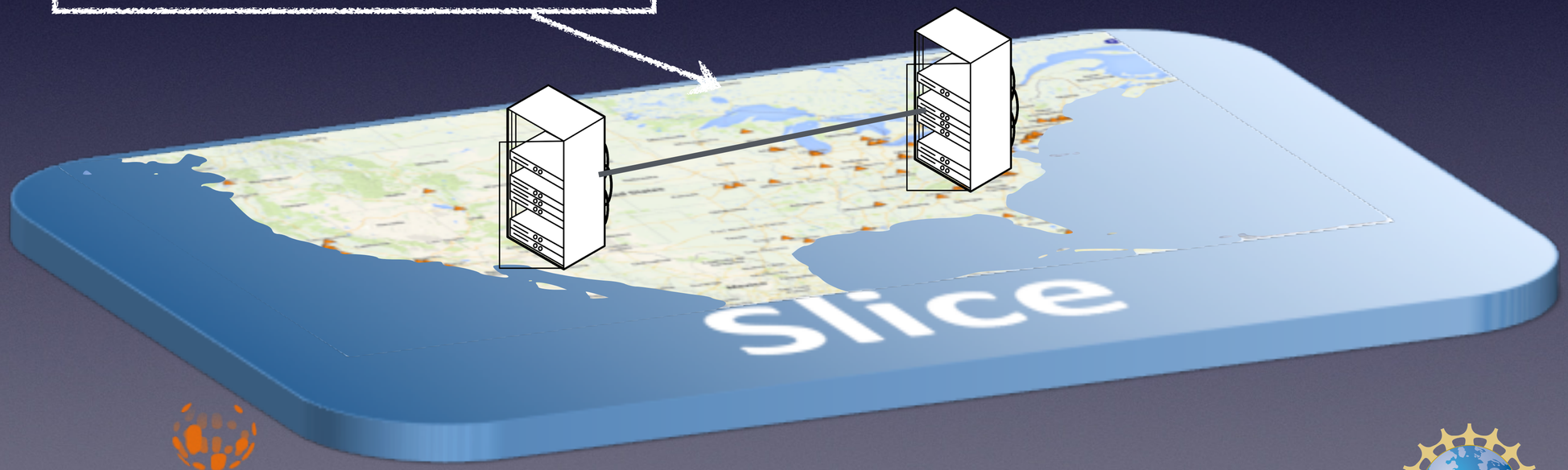
Between racks, network may be sliced by

- VLAN
- Dynamic circuit
- OpenFlow flowspace



Slicing Across GENI

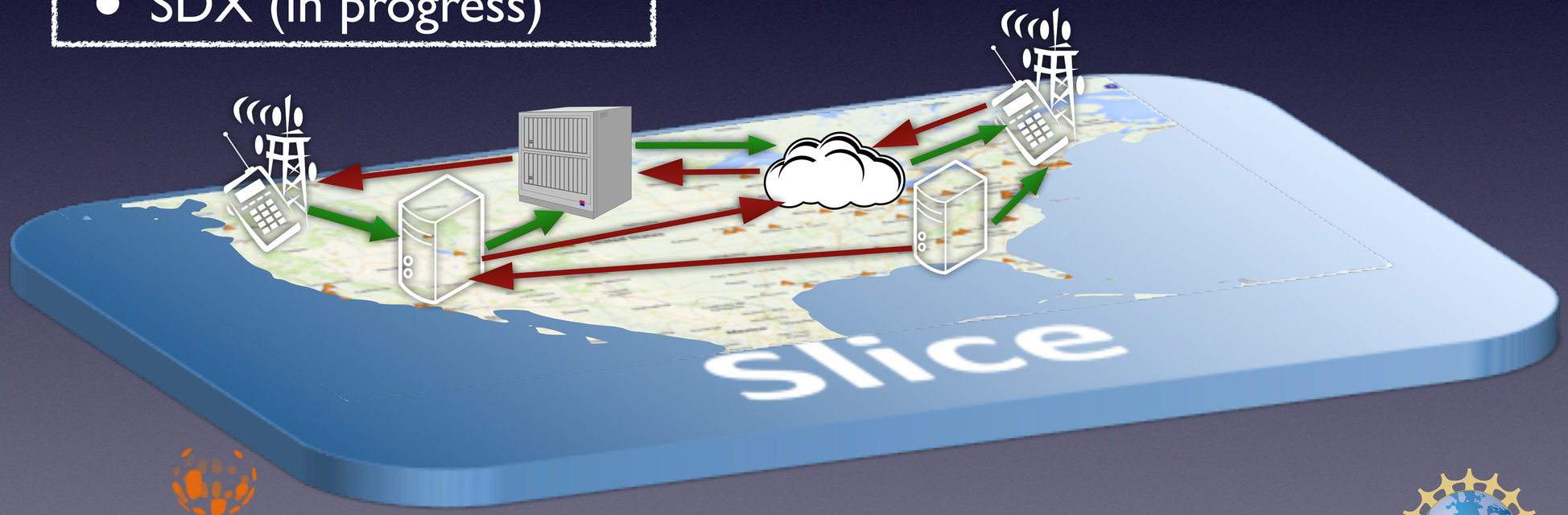
Initial flowspace slicing used FlowVisor, but simpler strategies meet experimenter needs, and are turning out to be more robust.



Slicing Across GENI

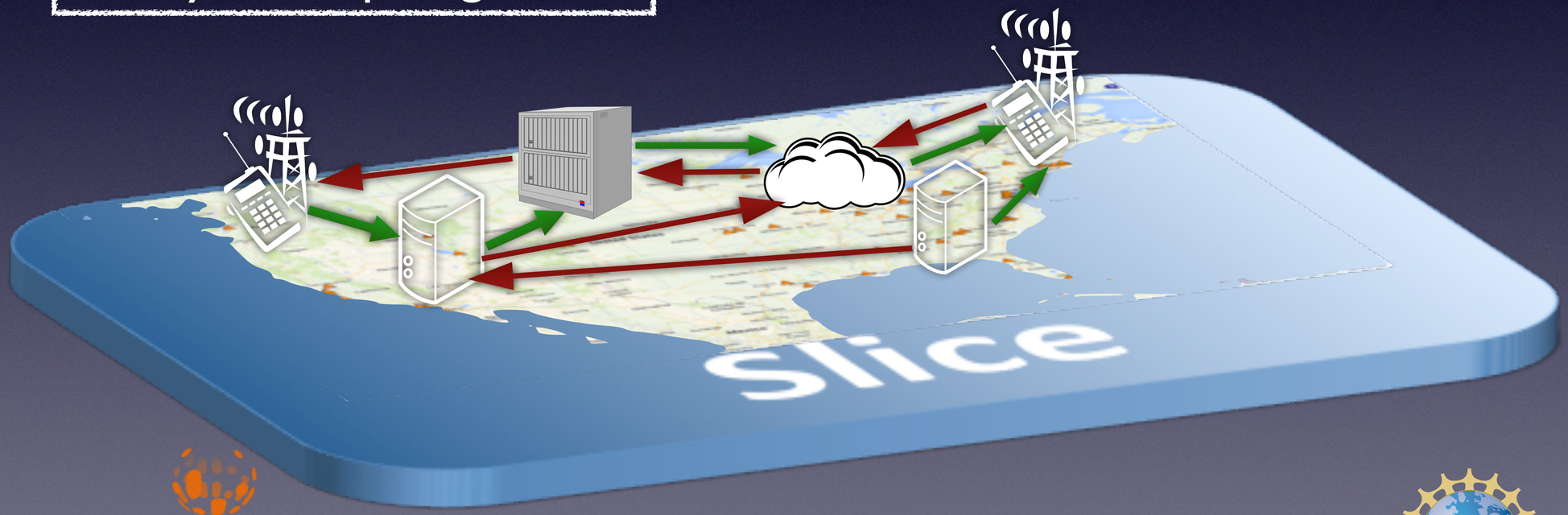
Slices are "stitched" across aggregates by

- VLAN translation
- SDN
- SDX (in progress)



Slicing Across GENI

GENI provides deeply programmable, wide-area, experimenter-specified layer 2 topologies.



geni
Exploring Networks of the Future

NSF

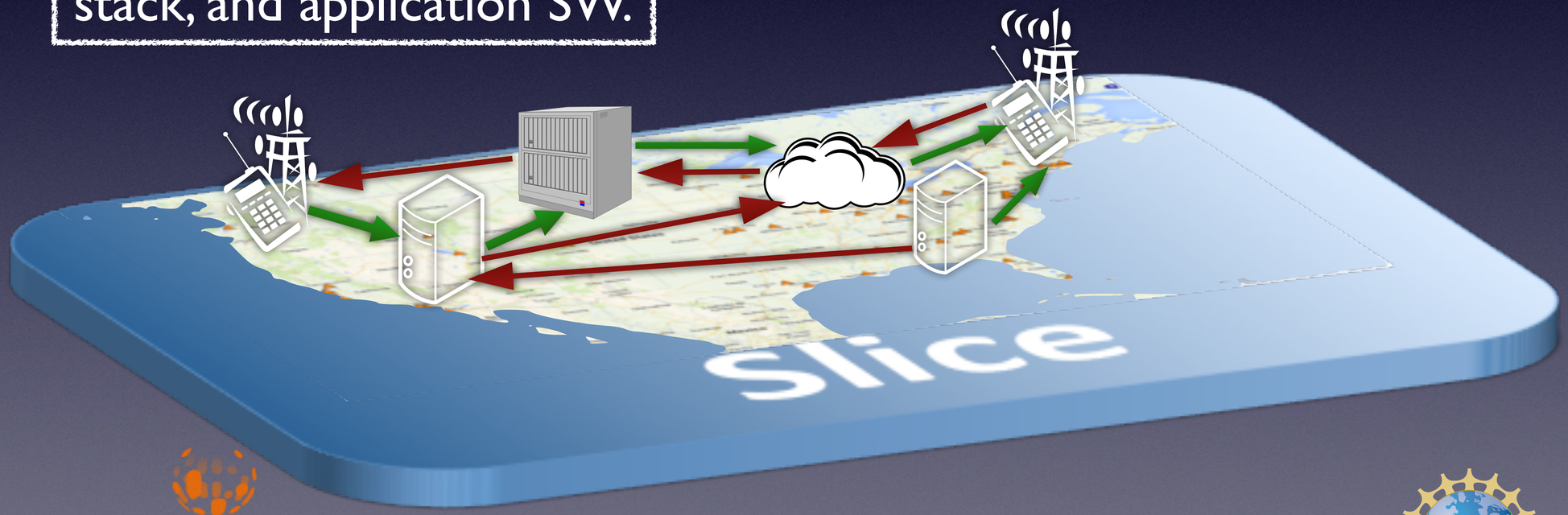
Key Capabilities in Core Network

Collaboration with Internet2 to include key slicing and deep programmability capabilities in AL2S (Advanced Layer 2 Service)

- AL2S OESS aggregate manager for dynamic virtual circuit provisioning to stitch slices
- Flow space firewall multiplexing OpenFlow controller proxy for deep programmability down to core network switches

Deep Programmability - Compute

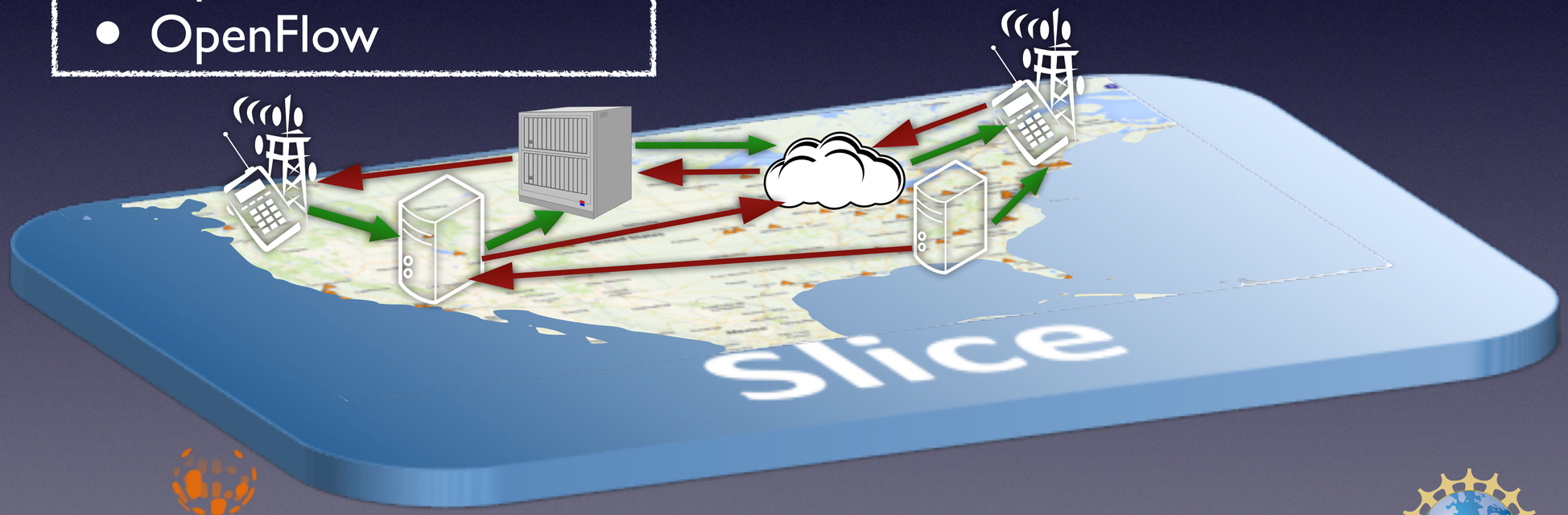
Experimenter has full access to program compute resources, including OS, network stack, and application SW.



Deep Programmability - Network

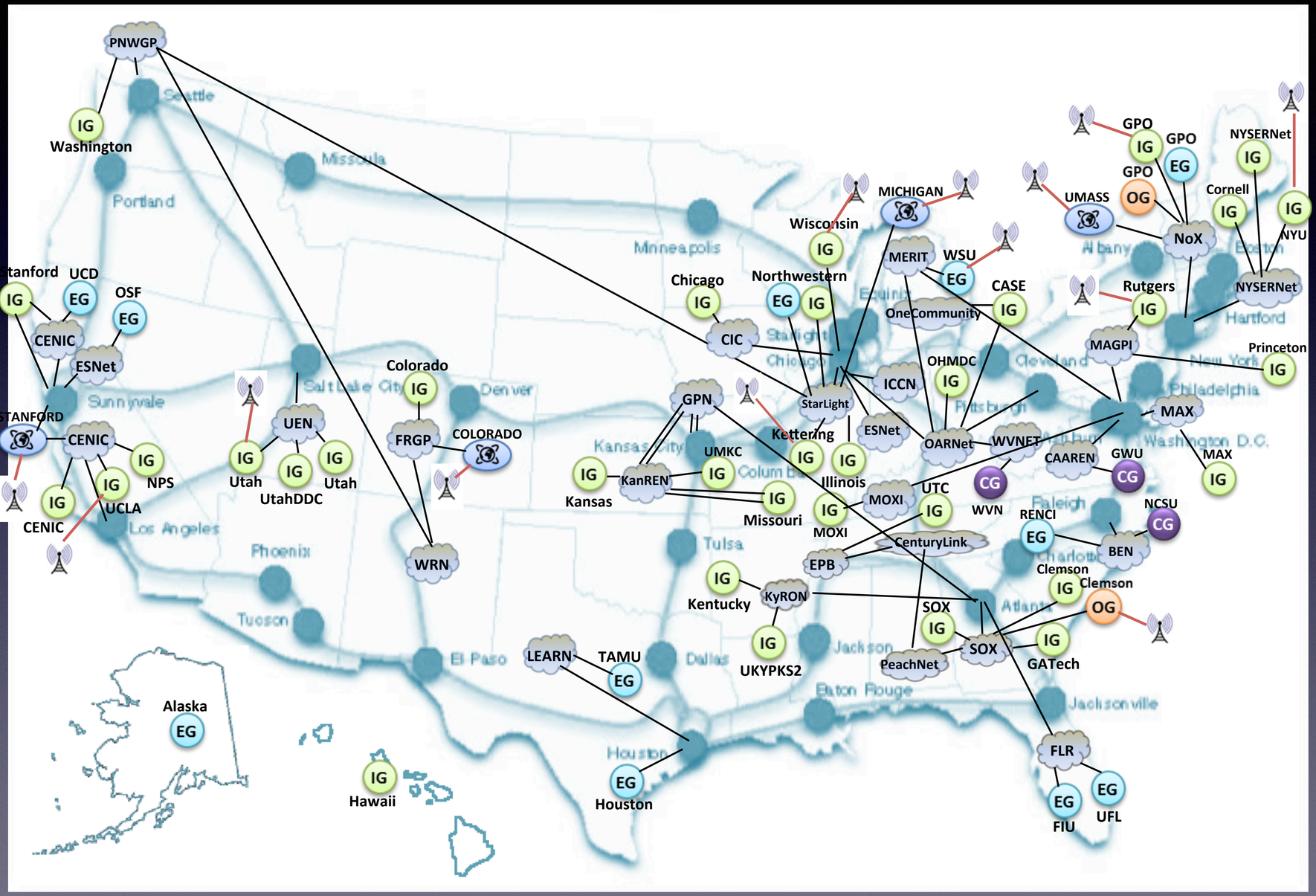
Network programming

- IP & non-IP protocols
- Software routers (e.g., Click)
- Open Virtual Switch
- OpenFlow



GENI's Sliced Infrastructure

GENI's Sliced Infrastructure



Nationwide Precision Cyberinfrastructure

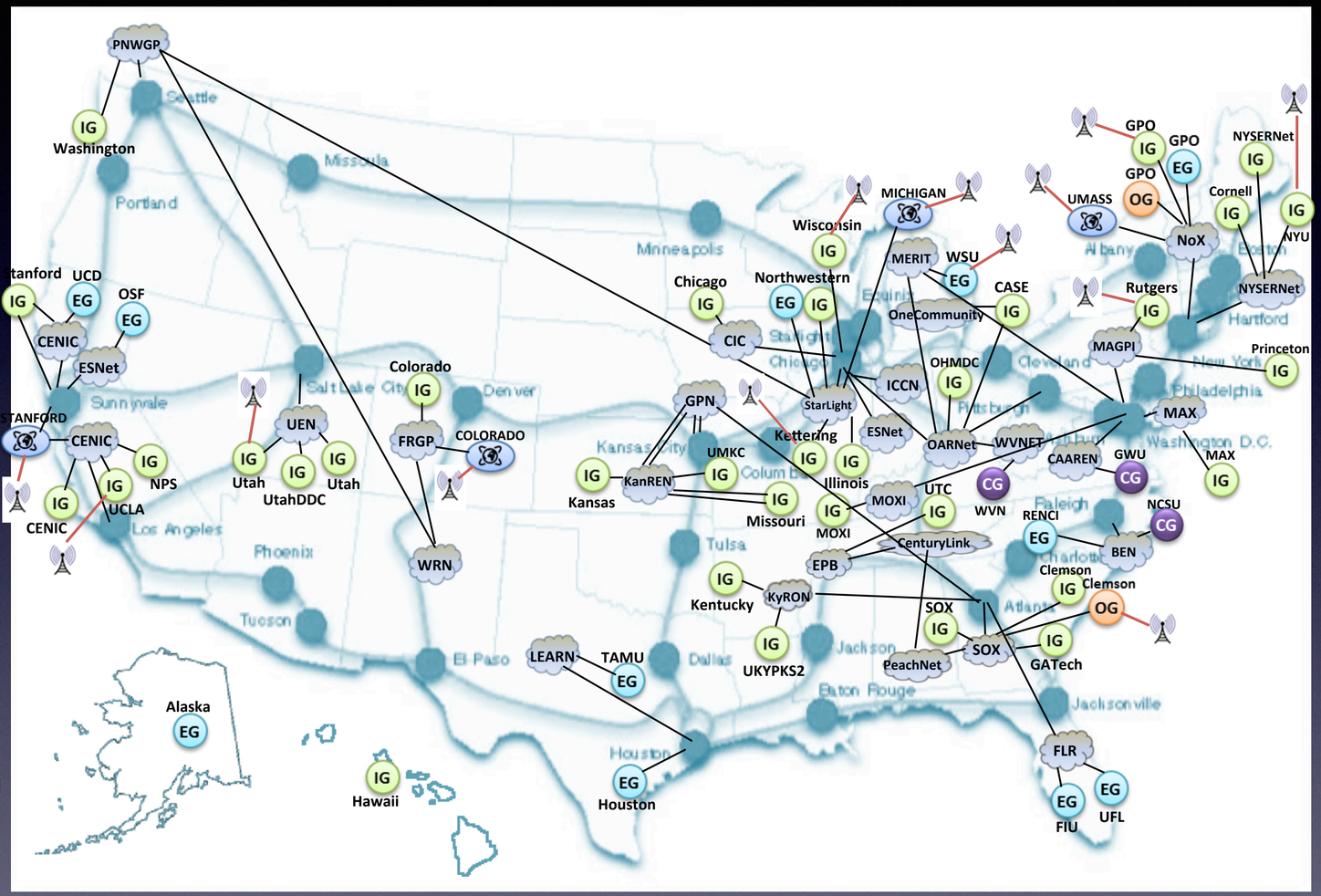
GENI-installed cyberinfrastructure

- GENI Racks - 58 racks in current deployment
- GENI Wireless - 26 base stations at 13 sites

All are <u>sliced</u> and <u>deeply programmable</u>

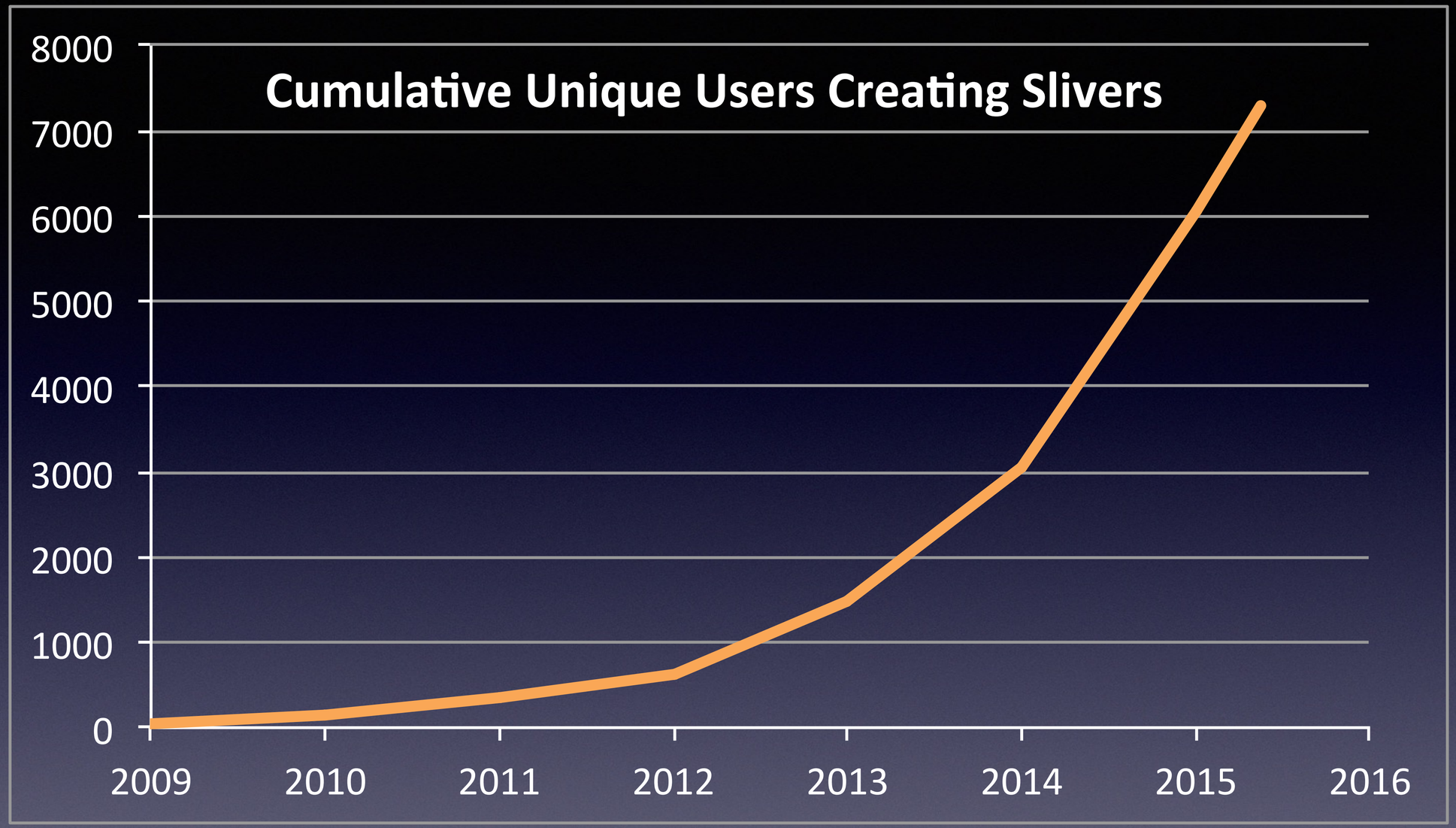
Interoperable US cyberinfrastructure includes

- NSF Cloud
- Campus Cyberinfrastructure (CC-*)
- US Ignite cities
- ACI-REF



Sliced R&E networks

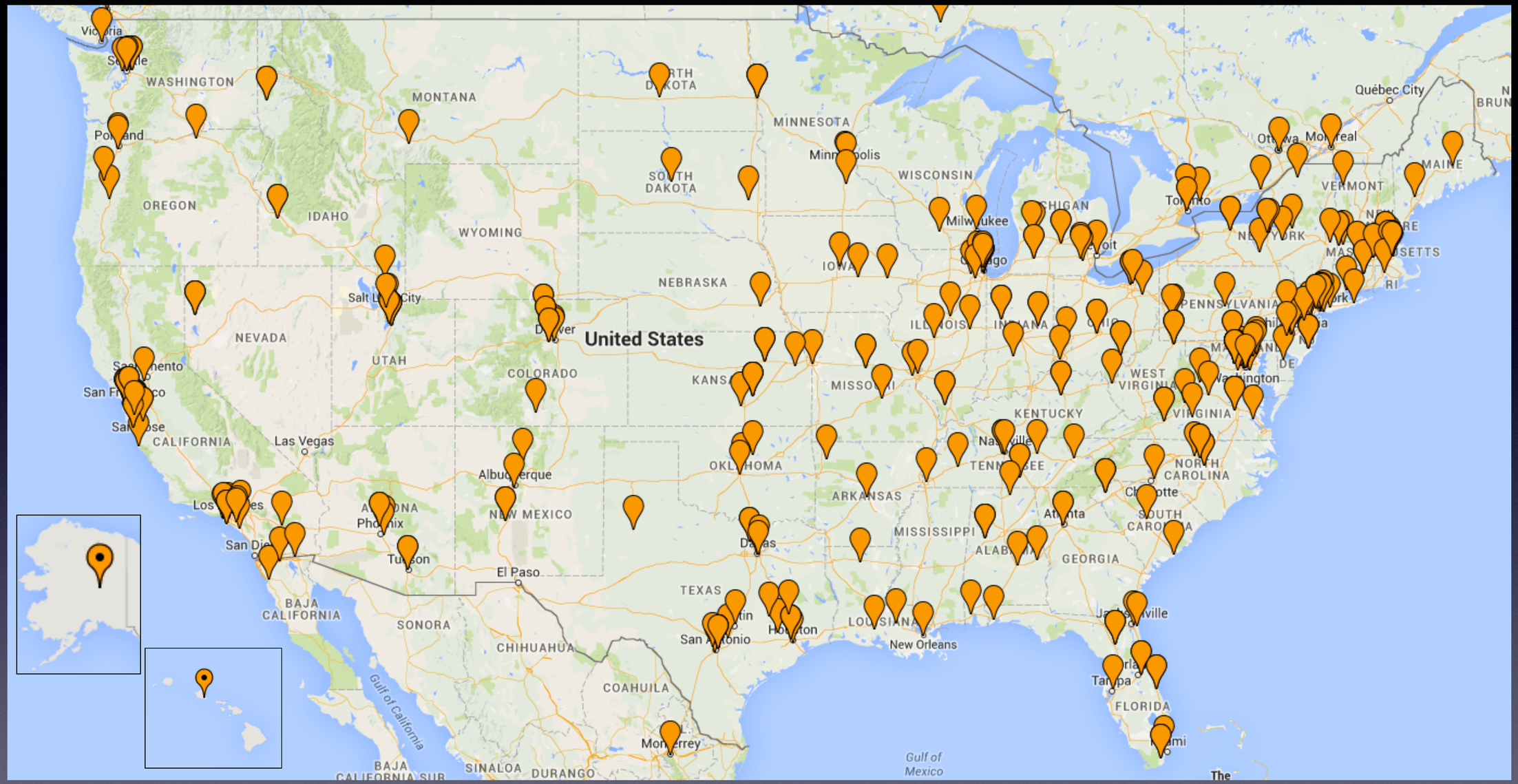
May 23, 2016



GENI is supporting thousands of researchers, educators, and students and their experiments.

geni
Exploring Networks of the Future

NSF



GENI Users Span the US

May 2016

geni
Exploring Networks of the Future

NSF

Supporting International Collaborations

May 2016

What are they all doing?

GENI Usage Patterns

Network research: future Internet architectures and protocols, clean-slate networking, IP-compatible and non-compatible experiments, cloud infrastructures, cellular wireless research

Computer science & STEM education: remote, distributed classroom laboratory, curriculum modules

Novel distributed app & service development: shared data applications, low-latency (locavore) and real-time interactions

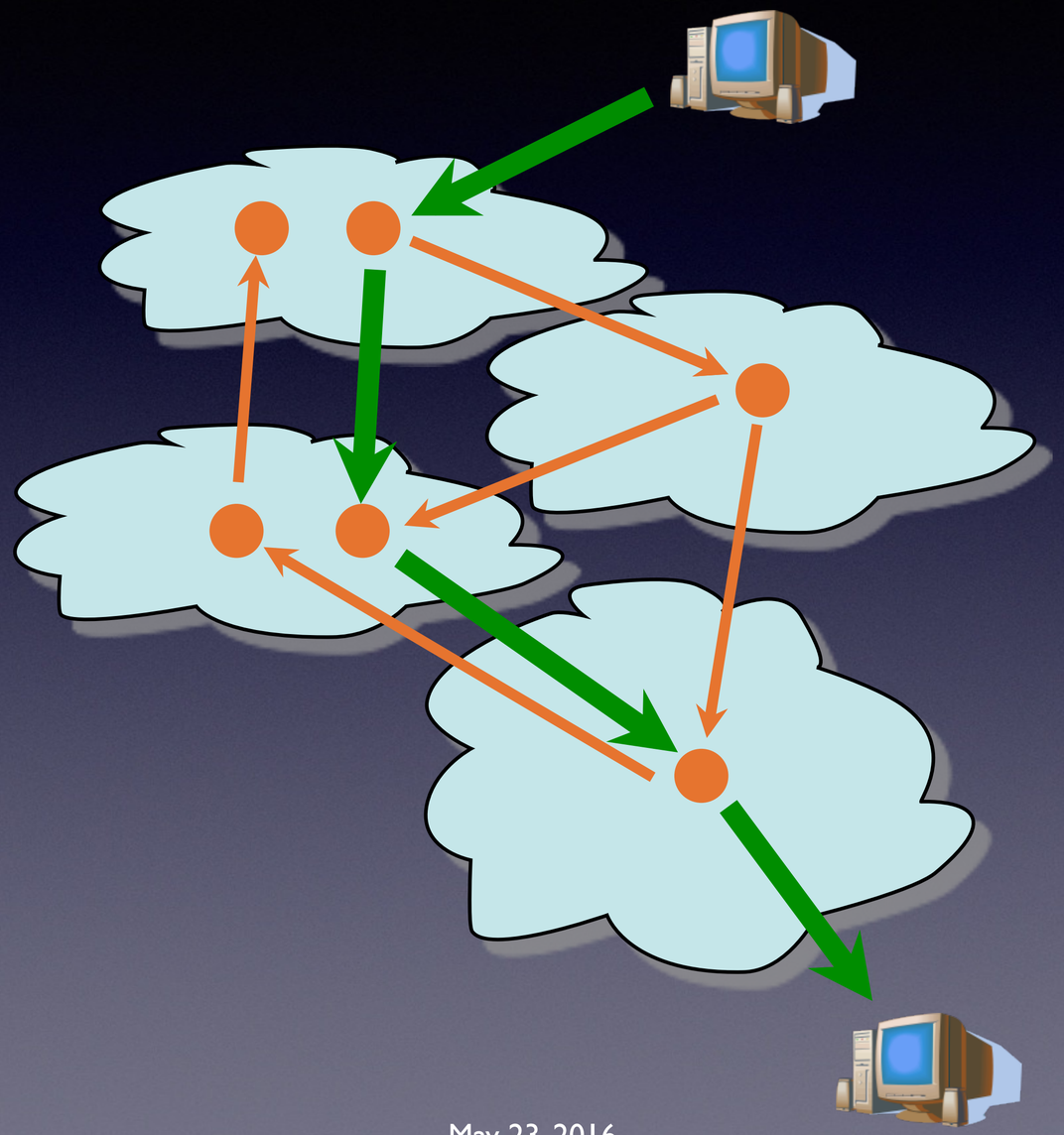
Dynamic infrastructure: software-defined exchanges & infrastructure (SDX/SDI), Science DMZ as a Service

Program Everything

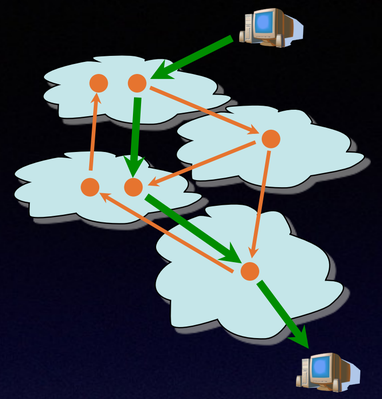
Research Examples

May 23, 2016

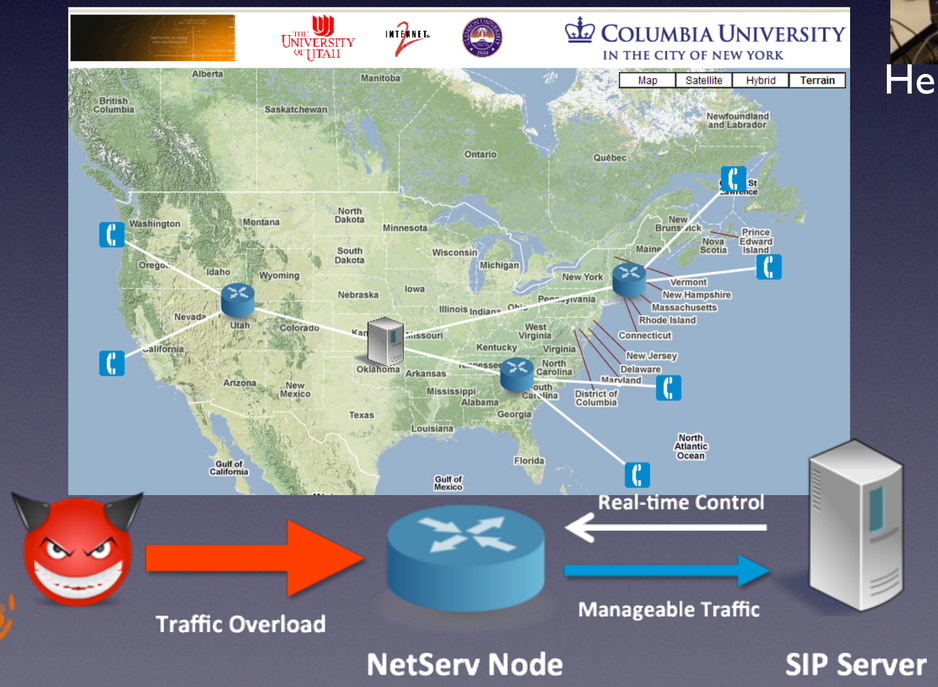
Program Everything



Program Everything



Henning Schulzrinne and NetServ Team, Columbia University



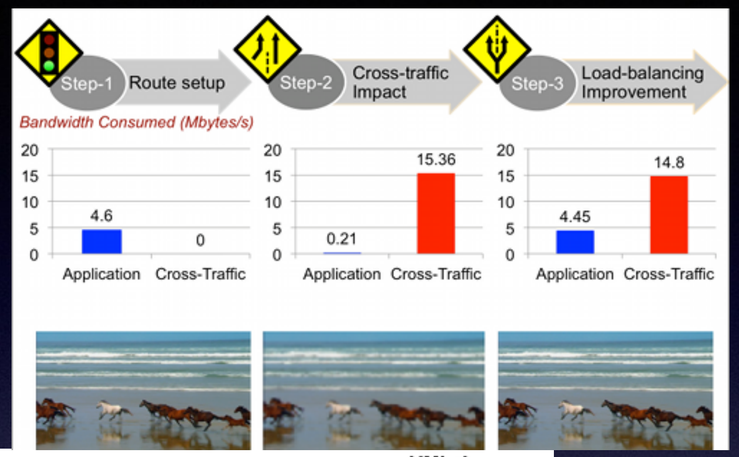
May 23, 2016

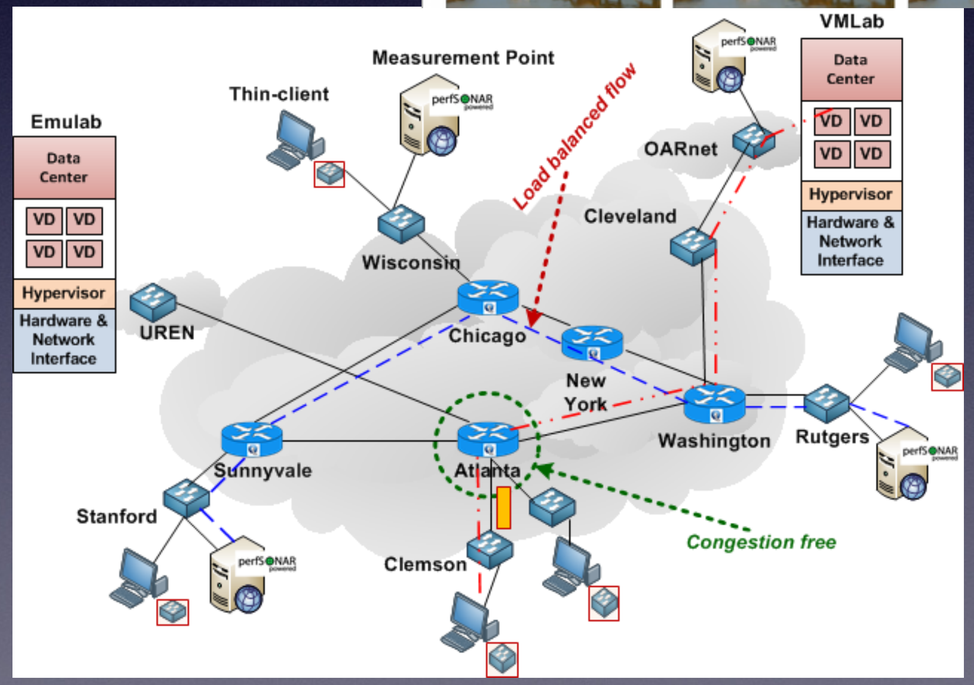
Program Everything

Program Everything

Virtual
Desktop
Clouds

Prasad Calyam, University of Missouri - Columbia



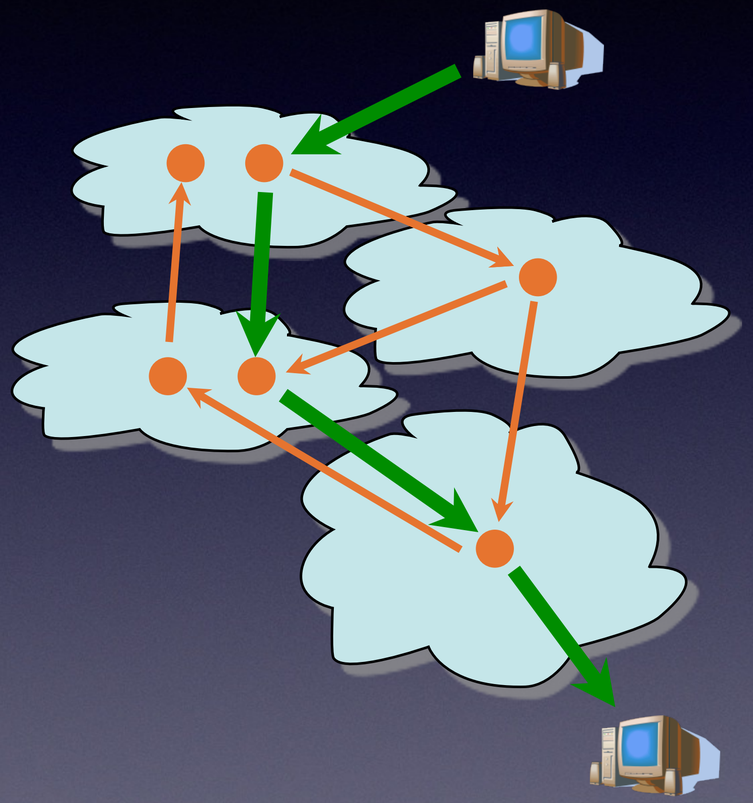


geni
Exploring Networks of the Future

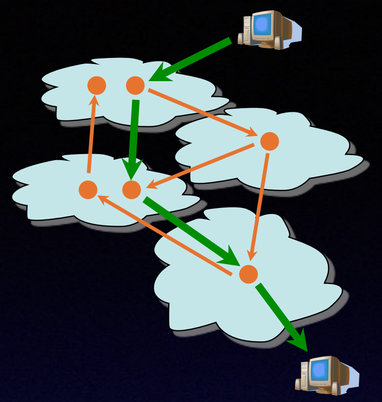
May 23, 2016

NSF

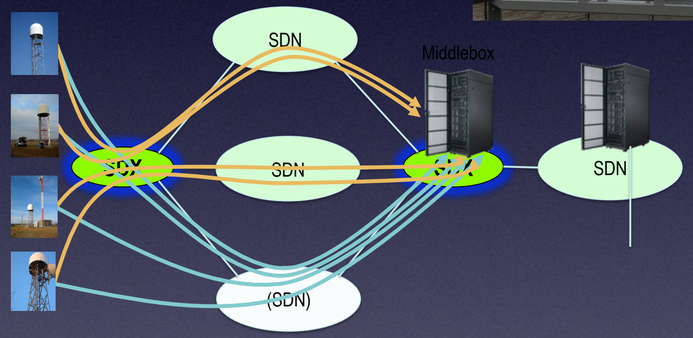
Program Everything

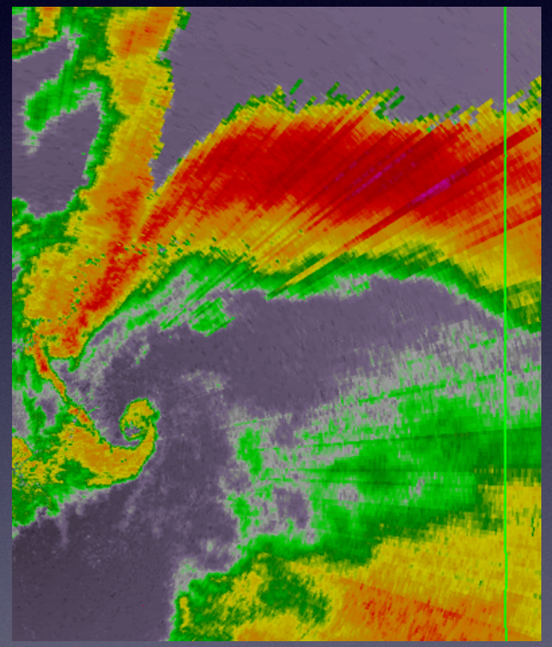


Program Everything



Michael Zink, University of Massachusetts - Amherst

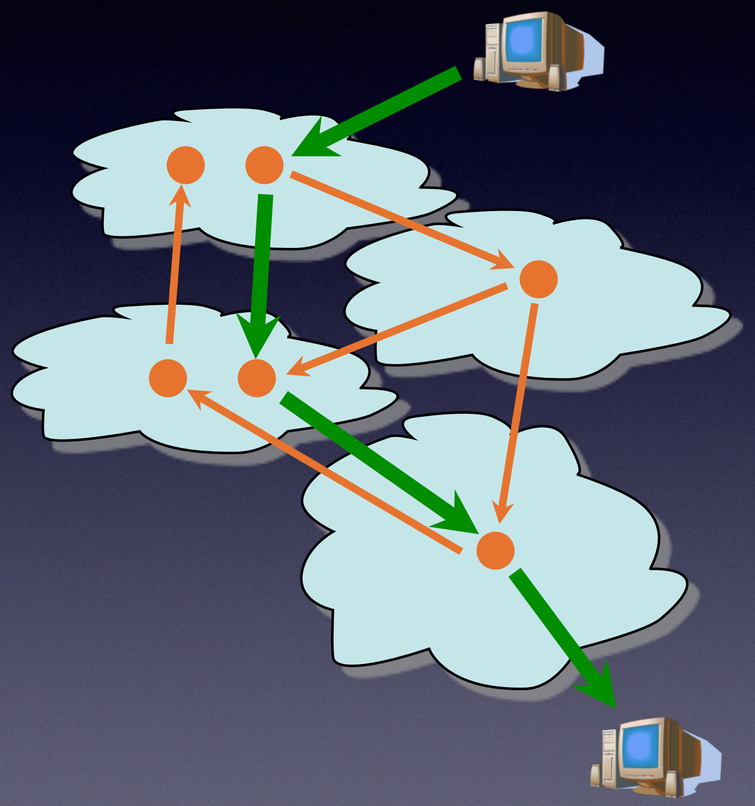




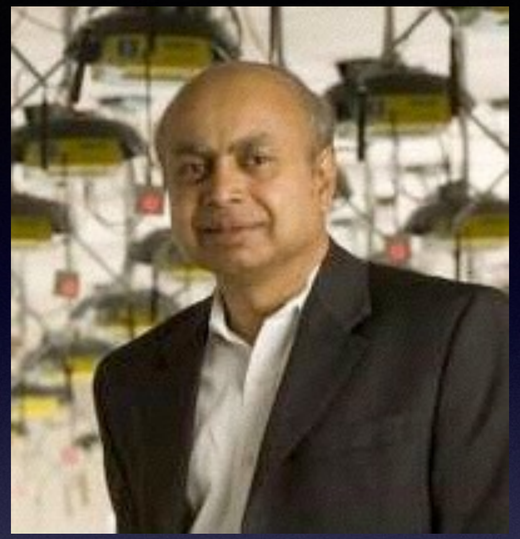
Using SDX to Enable Short-Term Severe Weather "Nowcast" Service

May 23, 2016

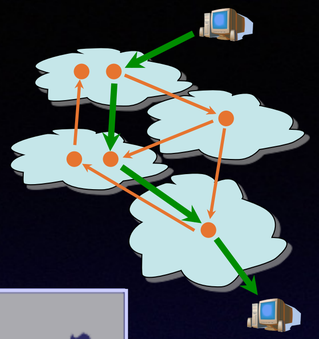
Program Everything

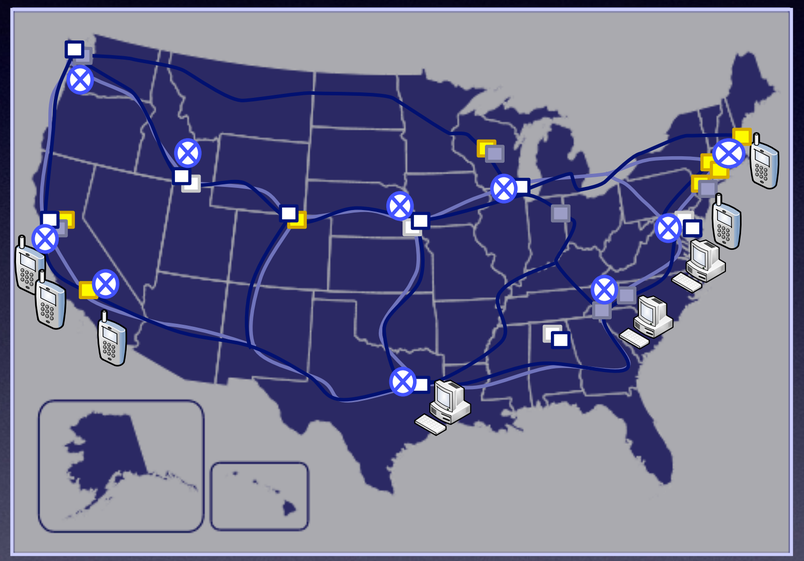


Program Everything



Dipankar (Ray) Raychaudhuri,
Rutgers University

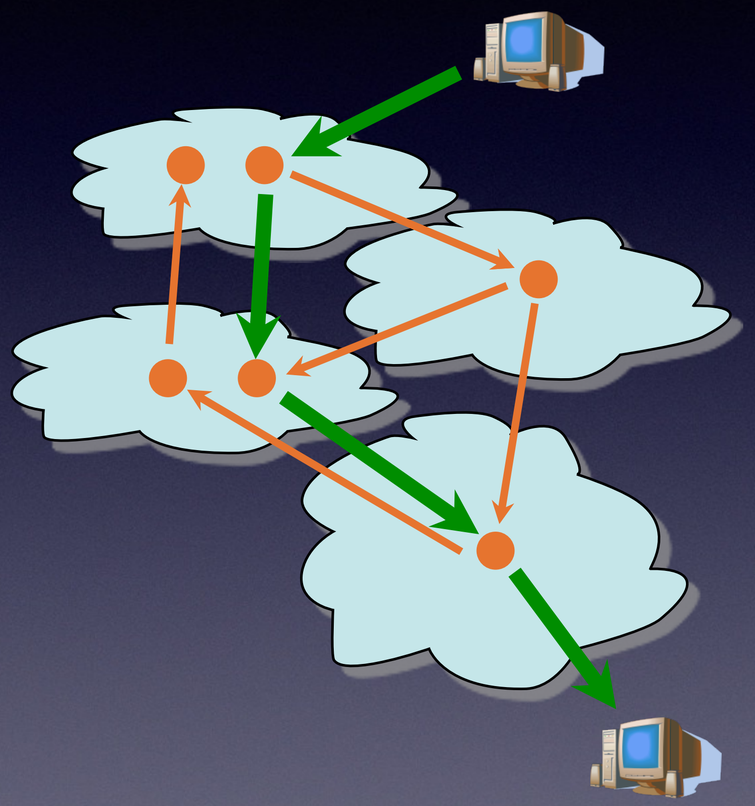




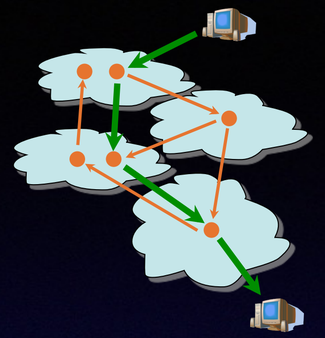
MobilityFirst scalable future Internet architecture for emerging mobility services

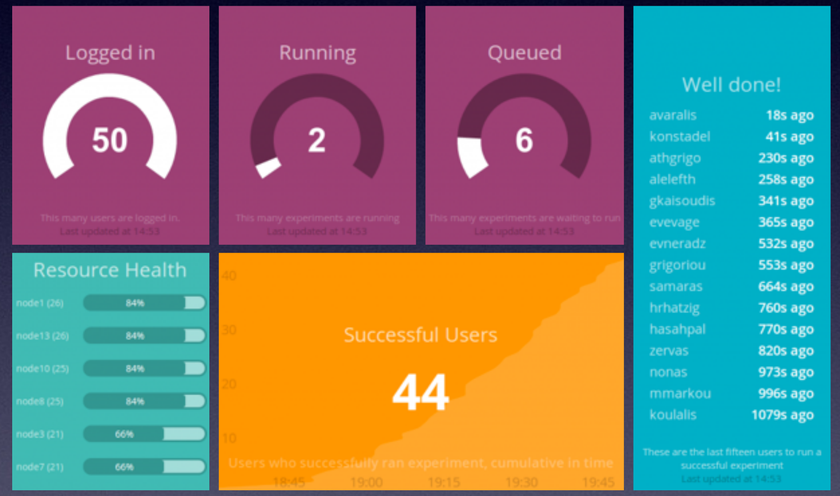
May 23, 2016

Program Everything



Program Everything



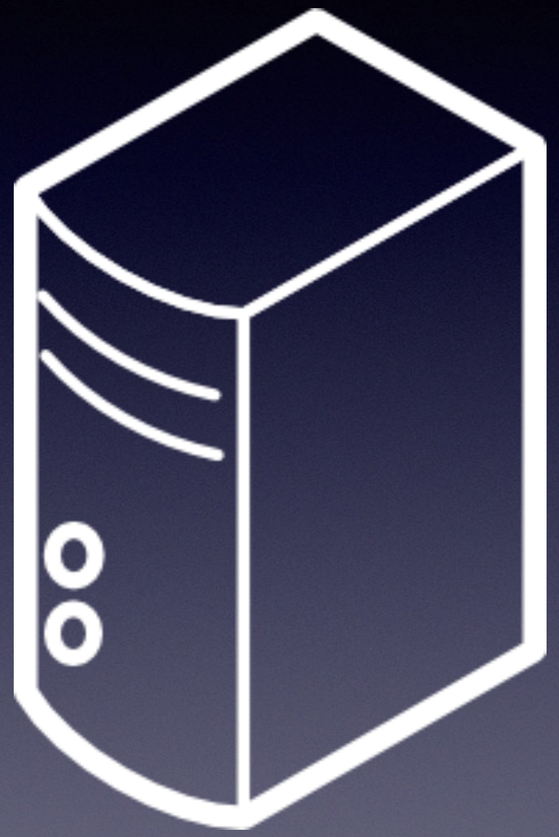


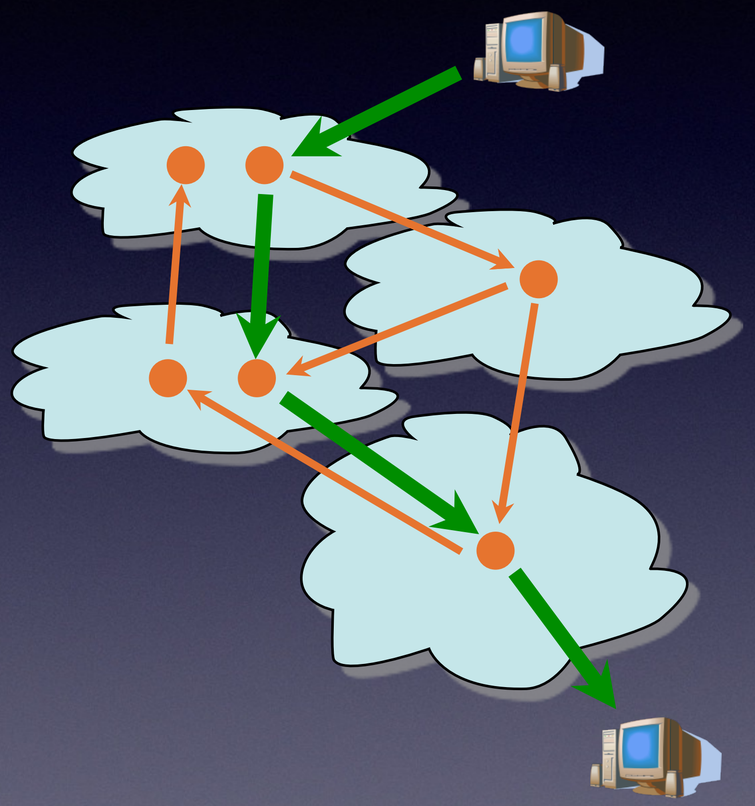
Thanasis Korakis and Fraida Fund,
NYU Polytechnic

"Classroom as a service" virtual wireless networking lab

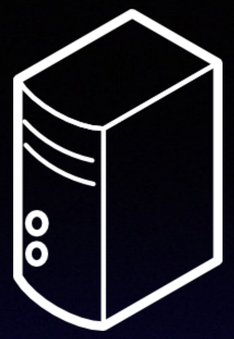
May 23, 2016

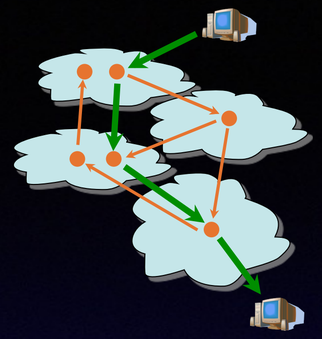
Program Everything



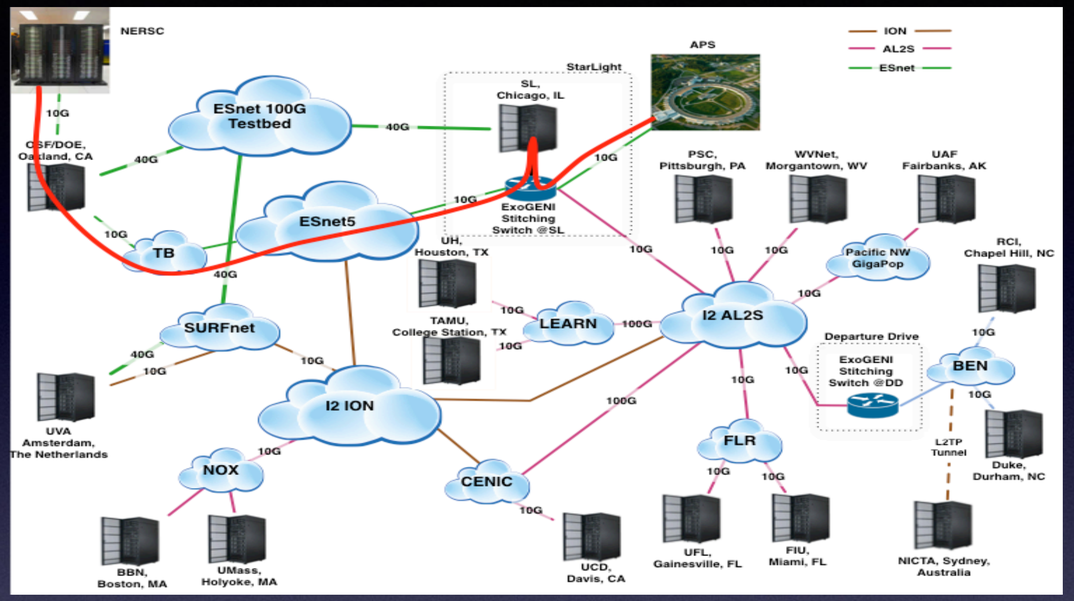


Program Everything





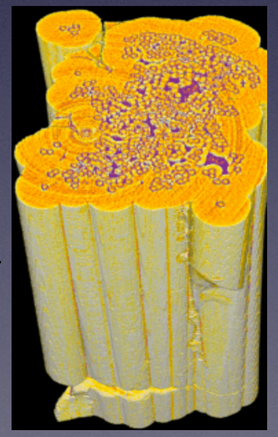
"Creating Science Super-Facilities with GENI"



Inder Monga
ESNet

Ilya Baldin
RENCI

Set collected by materials scientist Rob Ritchie, LBNL/ UCB



geni
Exploring Networks of the Future

NSF

May 23, 2016

What's next?

How Can We Accelerate Progress?

Pursue research and cyberinfrastructure development in tandem.

Deploy and federate more deeply programmable and sliceable cyberinfrastructure.

- Networks, HPC, clouds, cyberphysical systems, …
- Both new and existing cyberinfrastructure

Pursue research into flexible and dynamic control structures.

- More flexible and heterogeneous resource combinations
- Highly dynamic precision cyberinfrastructure configurations

Upcoming GENI Events - Get Involved!

Join us at the next Network Innovators Community Event (GENI NICE), at CoNEXT 2016, Irvine, CA, December 12, 2016

Watch for Spring 2017 GENI events

- GENI Engineering Conference (GEC25), Florida International University, Miami
- CNERT 2017 Workshop

geni
Exploring Networks of the Future

References

1. Final Report, NSF Workshop on the Development of a Next-Generation Cyberinfrastructure, December 2014.
2. NSF "Looking Beyond The Internet" steering group final report, March 2016.
3. Berman, M., Demeester, P., Lee, J. W., Nagaraja, K., Zink, M., Colle, D., Krishnappa, D. K., Raychaudhuri, D., Schulzrinne, H., Seskar, I. and Sharma, S. (2015), "Future Internets Escape the Simulator," Commun. ACM 58(6), 78– 89.
4. OpenMultinet: http://www.open-multinet.info/.

geni

Exploring Networks
of the Future

geni
Exploring Networks
of the Future

May 23, 2016