











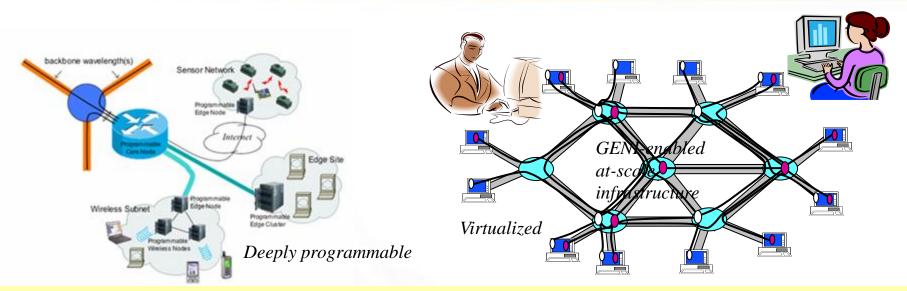
**Aaron Falk GENI Project Office** March 23, 2010 www.geni.net



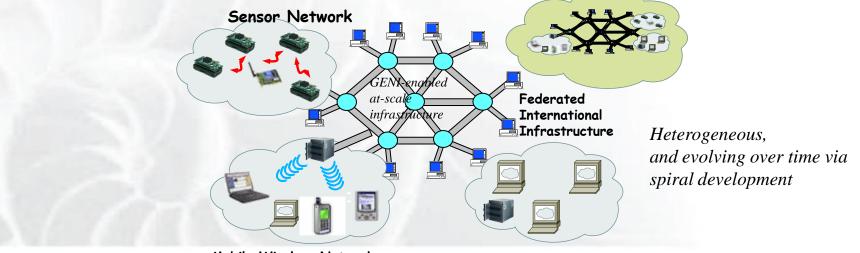
- GENI is a virtual laboratory for exploring future internets at scale.
- GENI creates major opportunities to *understand, innovate, and transform* global networks and their interactions with society.
- GENI opens up new areas of research at the frontiers of network science and engineering, and increases the opportunity for significant socio-economic impact.

### **GENI Conceptual Design** Infrastructure to support at-scale experimentation





#### **Programmable & federated, with end-to-end virtualized "slices"**



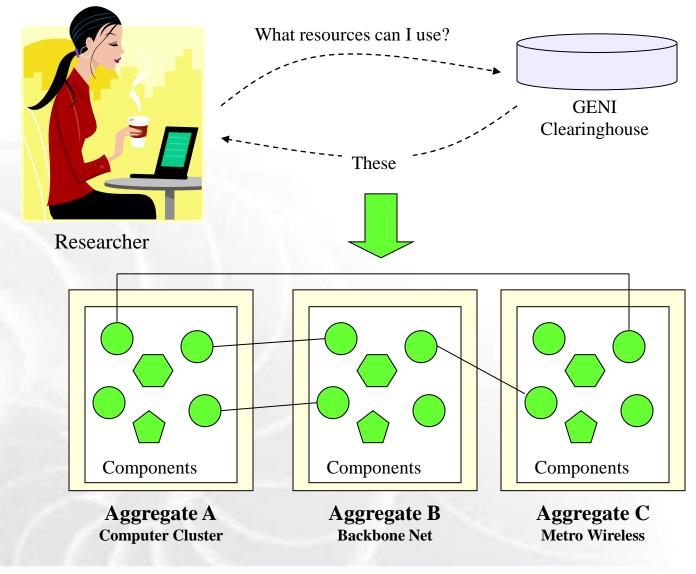
Sponsored by the National Science Poundation Wireless Network IETF-77 - NVRG Edge Site



## **GENI for the Short-Attention Span**

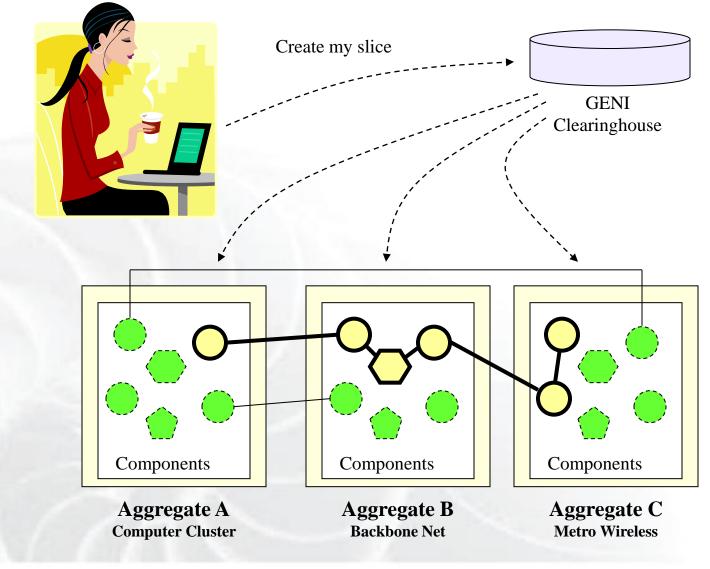


#### Resource discovery Aggregates publish resources, schedules, etc., via clearinghouses





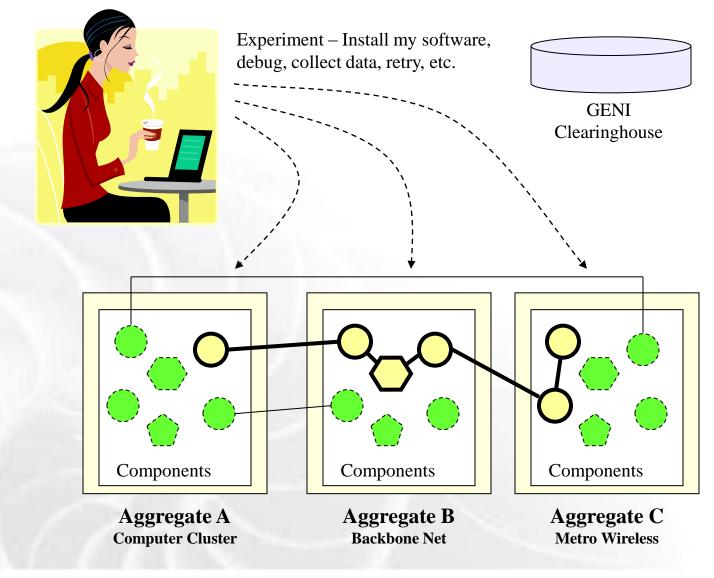
#### Slice creation Clearinghouse checks credentials & enforces policy Aggregates allocate resources & create topologies







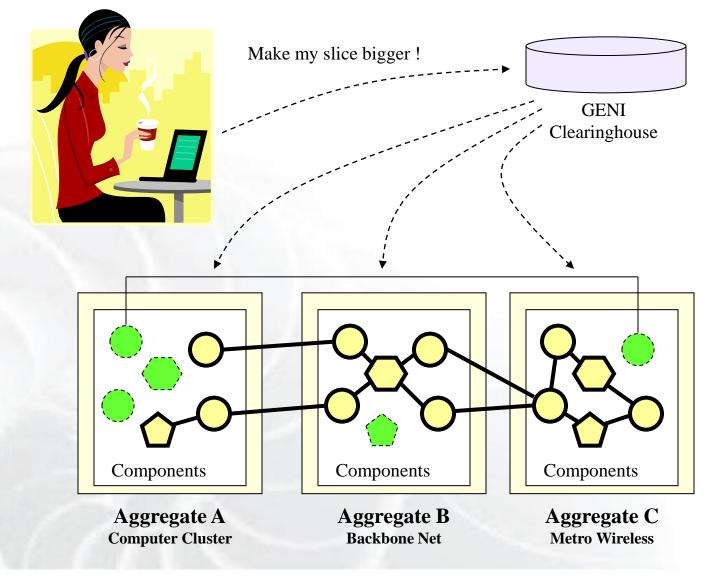
#### Researcher loads software, debugs, collects measurements





## **Slice growth & revision**

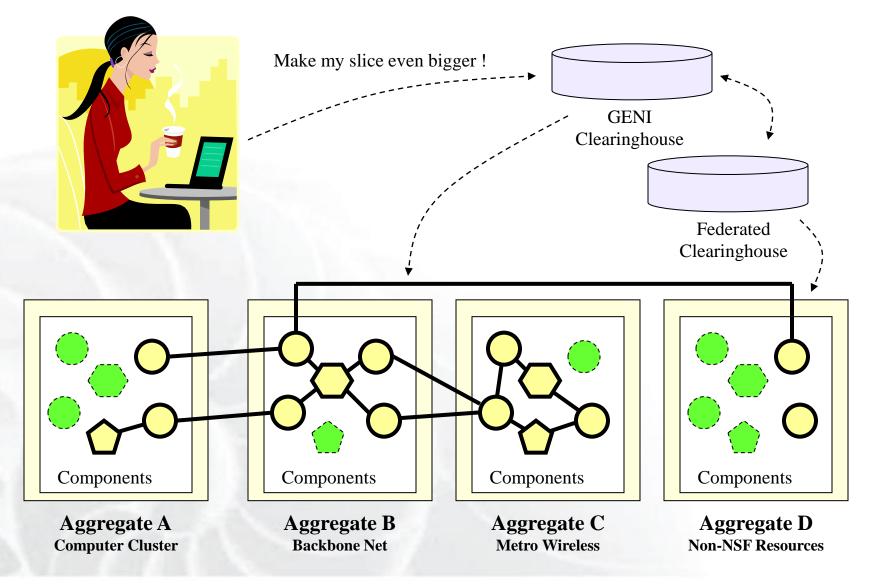
#### Allows successful, long-running experiments to grow larger

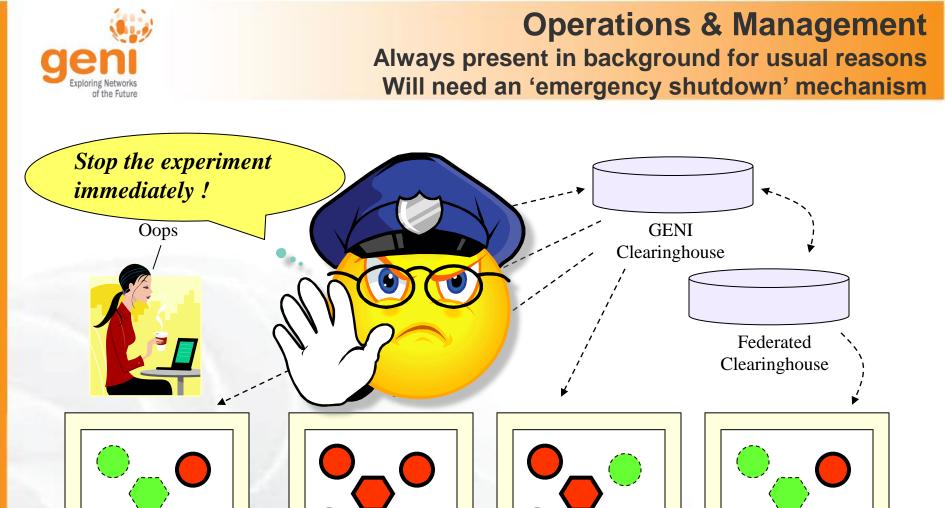




## **Federation of Clearinghouses**

Growth path to international, semi-private, and commercial GENIs





Sponsored by the National Science Foundation

Components

**Aggregate** A

**Computer Cluster** 

Components

**Aggregate C** 

**Metro Wireless** 

Components

**Aggregate B** 

**Backbone Net** 

Components

Aggregate D

Non-NSF Resources



## **Spiral 2 Academic-Industrial Teams**

Project Name	Project Lead	Project Participants	
1. CMUlab	Carnegie Mellon University		
2. D Meas, LEARN	<ul> <li>University of Houston</li> </ul>	-     Columbia University	
<ol><li>Digital Object Registry</li></ol>	<ul> <li>Corporation for National Research Initiatives (CNRI)</li> </ul>		
4. CLOUD-CTL, DOME, VISE	University of Massachusetts Amherst		
5. DTunnels	<ul> <li>The Georgia Institute of Technology</li> </ul>		😂 at&t 🛛 🥠
<ol><li>EnterpriseGENI, OpenFlow</li></ol>	<ul> <li>Stanford University</li> </ul>	- Princeton University	
		— University of California, Berkeley	- invent
	Georgia Institute of Technology		
	Indiana University		
	Princeton University		luniper <b>(11)</b>
	Rutgers University		
	University of Wisconsin -		NETWORKS
	University of Washington		NETWORKS CISCO
7. GENI4YR	Langston University		
8. GMOC, netKarma, K-GENI	<ul> <li>Indiana University</li> </ul>		ARISTA <i>infinera</i>
9. GpENI	<ul> <li>University of Kansas</li> </ul>	-  Kansas State University,	
	The University of Missouri-Kansas City	University of Nebraska-Lincoln	Innicia
10. GushProto		-  UC San Diego	
11. INSTOOLS, ISM Infrastructure	<ul> <li>University of Kentucky</li> </ul>		Microsoft ciena
12. KANSEL OTM		- Wayne State University	
13. MAX	University of Maryland		LUZI IC.
14. MeasurementSys	University of Wisconsin-Madison —	Boston University	
		Colgate University	
15. MillionNodeGENI, Security	University of Washington		
16. ORBIT, WIMAX	<ul> <li>Rutgers University ————————————————————————————————————</li></ul>	-  UCLA, Los Angeles, CA	
		— University of Colorado, Boulder, CO	
	Polytechnic University of NYU, Brooklyn, NY	University of Massachusetts, Amherst	
		<ul> <li>University of Wisconsin, Madison, WI</li> </ul>	IM I
17. ORCA/BEN	<ul> <li>The Renaissance Computing Institute (RENCI)</li> </ul>		NETRONOME
18. PlanetLab, Scaffold, Federation		-     Universite Pierre et Marie Curie (UPMC)	
19. ProtoGENI 20. PROVSERV	<ul> <li>University of Utah</li> <li>University of Arizona</li> </ul>		$\sim$
20. PROVSERV 21. ERM	Columbia		
22. REGOPT	<ul> <li>Pittsburgh Supercomputing Center (PSC)</li> </ul>		
23. SECARCH, Distributed Identity	<ul> <li>SPARTA, Inc.</li> </ul>		
24. SPP	<ul> <li>Washington University</li> </ul>		
25. TIED		University of California, Berkeley	SPARTA
26. UB OANets	SUNY Buffalo		VIANA
27. UMLPEN	University of Massachusetts Lowell		Dettelle
28. CR-GENI	<ul> <li>University of Colorado Boulder</li> </ul>	Radio Technology Systems LLC	Battelle
		Rutgers University	
29. CRON-T	<ul> <li>Louisiana State University</li> </ul>		CNRI
30. Design of Information Subs	• MIT		CIUR
31. DSL, HIVE	😐 UC Davis	-  Batelle  CA Labs	
32. EXP-SEC	<ul> <li>University of Alabama</li> </ul>	- CA Labs	
33. FPGA-RADIO	<ul> <li>Clemson University</li> </ul>		
34. GENI IMF	North Carolina State University	The Renaissance Computing Institute (RENCI)	Owest.
54. 0041 101		<ul> <li>Columbia University</li> </ul>	nicira
35. IGENI	Northwestern University ————————————————————————————————————	<ul> <li>University of Illinois Chicago</li> </ul>	
36. LAMP	<ul> <li>University of Delaware</li> </ul>	Internet2	
37. LEFA, Supercharged Planetlab	o Internet2	Brown University	
38. NLR	Cypress, CA		Radio Technology Systems
39. OpenCIRRUS	HP Labs, Palo Alto ————————————————————————————————————	-® UCSD	
40. OKGems	<ul> <li>Oklahoma State University</li> </ul>		
41. PIGEON-NET	<ul> <li>Howard University</li> </ul>		JEFFREY HUNKER ASSOCIATES LLC
42. PrimoGENI	<ul> <li>Florida International University</li> </ul>		Technology Government Global business Insight with impact
43. QUILT	<ul> <li>The Quilt</li> </ul>		
44. \$3-GENI		-  HP Labs	
45. SEC-POL	<ul> <li>University of Illinois (NCSA)</li> <li>University of Alaska Esideante</li> </ul>		11
46. VMI	<ul> <li>University of Alaska Fairbanks</li> </ul>		

# Service Servic



HP ProCurve 5400 Switch

Juniper MX240 Ethernet Services Router

NEC WiMAX Base Station

Cisco 6509 Switch

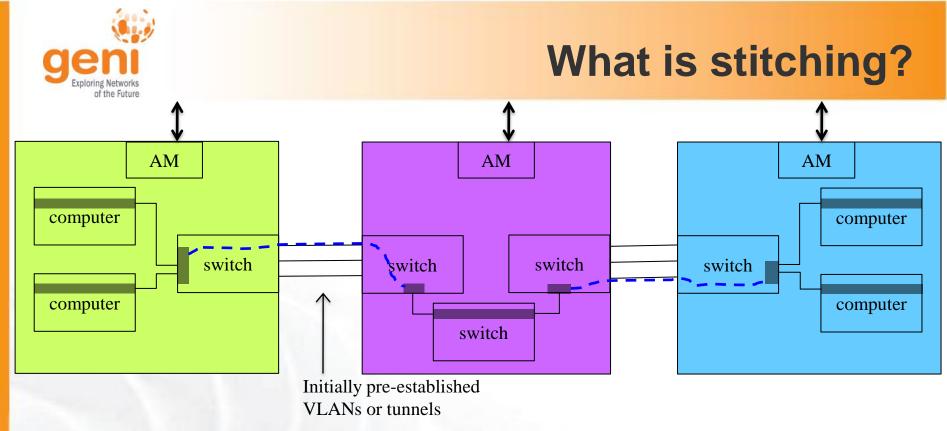
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NEC IP8800 Ethernet Switch



## **Network Virtualization in GENI**

- GENI uses multiple network virtualization strategies...
  - Tunnels over IP (GRE, OpenVPN)
  - Ethernet VLANs (incl QinQ Ethernet tunnels)
  - OpenFlow (switch forwarding rules based on any header field)
- ...to connect sliceable computation
  - Dedicated hosts (e.g., Emulab)
  - Virtual machines (e.g., PlanetLab, XEN, OpenVZ)
  - Clouds (e.g., Amazon EC2, Eucalyptus)
- ...and programmable network devices
  - Programmable switches (e.g., OpenFlow)
  - FPGA-based switches & routers (e.g., PEN, SPP, netFPGA)
  - Virtualizable routers (e.g., Juniper M7i)



- "Aggregate managers" orchestrate resource allocation locally
- "Stitching" is used to connect aggregates
- Establishes linkages among slivers or other entities created by different AMs
  - The near term emphasis is on Ethernet carriage, i.e., VLANS and tunnels that can carry Ethernet frames
  - Will want to extend this to other layers
- Several stitching approaches are under consideration