Workshop on Research Recommendations for the Broadband Task Force

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Outline

- GENI Background:
  Infrastructure for “Future Internet” Research

- Broadband Research Recommendation (infrastructure)

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

Network Science & Engineering (NetSE)

Science → Understand the complexity of large-scale networks → Network science and engineering researchers

- Understand emergent behaviors, local-global interactions, system failures and/or degradations
- Develop models that accurately predict and control network behaviors

Technology → Develop new architectures, exploiting new substrates → Distributed systems and substrate researchers

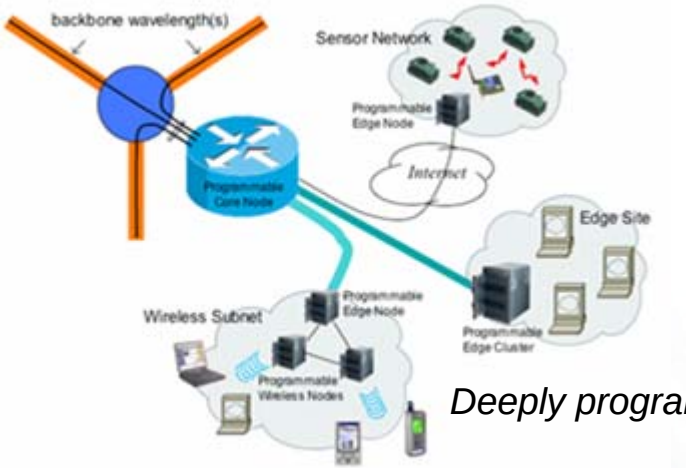
- Develop architectures for self-evolving, robust, manageable future networks
- Develop design principles for seamless mobility support
- Leverage optical and wireless substrates for reliability and performance
- Understand the fundamental potential and limitations of technology

Society → Enable new applications and new economies, while ensuring security and privacy → Security, privacy, economics, AI, social science researchers

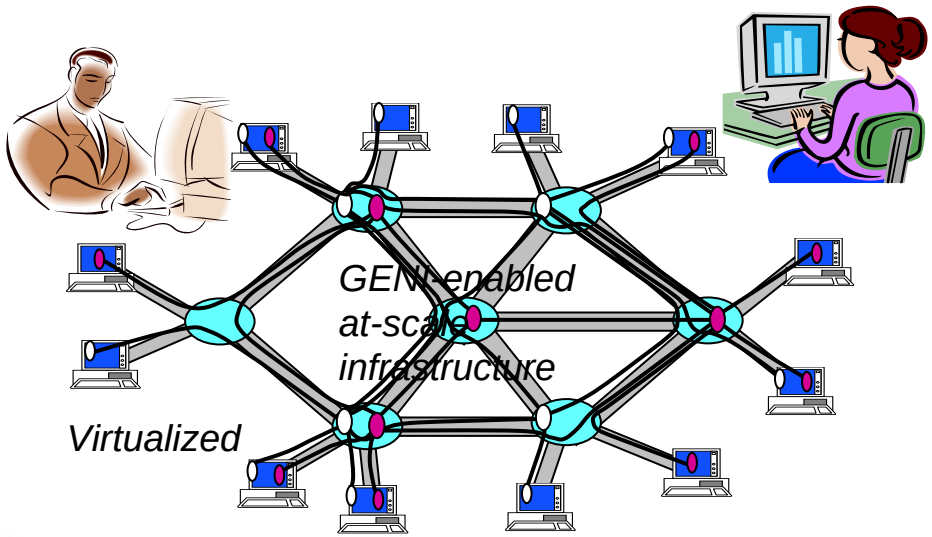
- Design secure, survivable, persistent systems, especially when under attack
- Understand technical, economic and legal design trade-offs, enable privacy protection
- Explore AI-inspired and game-theoretic paradigms for resource and performance optimization

GENI Conceptual Design

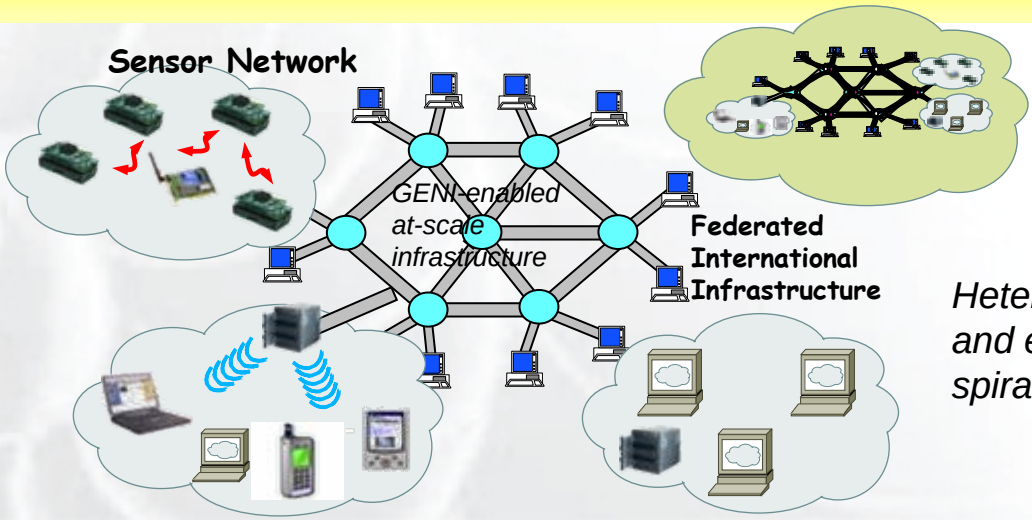
Infrastructure to support at-scale experimentation



Deeply programmable



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



Heterogeneous, and evolving over time via spiral development

Basic strategy for prototyping GENI

- Large numbers of real users, participating in experiments, are critical for “future internet” research
- It is clearly infeasible to build research infrastructure “as big as the Internet”
- Therefore we are now “GENI-enabling” commercial equipment . . .
- . . . and then want to use it in production infrastructure that can also carry research experiments (in ways that don’t interfere with production traffic)

GENI Academic-Industrial Teams

Project Name	Project Lead	Project Participants
1. CMUlab	Carnegie Mellon University	
2. D Meas, LEARN	University of Houston	Columbia University
3. Digital Object Registry	Corporation for National Research Initiatives (CNRI)	
4. CLOUD-CTL, DOME, ViSE	University of Massachusetts Amherst	
5. DTunnels	The Georgia Institute of Technology	
6. EnterpriseGENI, OpenFlow	Stanford University	Princeton University, University of California, Berkeley
	Clemson University	
	Georgia Institute of Technology	
	Indiana University	
	Nicira Networks	
	Princeton University	
	Rutgers University	
	University of Wisconsin	
	University of Washington	
7. GENI4YR	Langston University	
8. GMOC, netKarma, K-GENI	Indiana University	
9. GpENI	University of Kansas	Kansas State University, University of Nebraska-Lincoln
	The University of Missouri-Kansas City	
10. GushProto	Williams College	UC San Diego
11. INSTOOLS, ISM Infrastructure	University of Kentucky	
12. KANSEI, OTM	Ohio State University	Wayne State University
13. MAX	University of Maryland	
14. MeasurementSys	University of Wisconsin-Madison	Boston University, Colgate University
15. MillionNodeGENI, Security	University of Washington	
16. ORBIT, WiMAX	Rutgers University	UCLA, Los Angeles, CA
	Columbia University, NY, NY	University of Colorado, Boulder, CO
	Polytechnic University of NYU, Brooklyn, NY	University of Massachusetts, Amherst
		University of Wisconsin, Madison, WI
17. ORCA/BEN	The Renaissance Computing Institute (RENCI)	Duke University
18. PlanetLab, Scaffold, Federation	Princeton University	Universite Pierre et Marie Curie (UPMC)
19. ProtoGENI	University of Utah	
20. PROVSERV	University of Arizona	
21. ERM	Columbia	
22. REGOPT	Pittsburgh Supercomputing Center (PSC)	
23. SECARCH, Distributed Identity	SPARTA, Inc.	
24. SPP	Washington University	
25. TIED	USC Information Sciences Institute	University of California, Berkeley
26. UB_OANets	SUNY Buffalo	
27. UMLPEN	University of Massachusetts Lowell	
28. CR-GENI	University of Colorado Boulder	Radio Technology Systems LLC, Rutgers University
29. CRON-T	Louisiana State University	
30. Design of Information Subs	MIT	
31. DSL, HIVE	UC Davis	Batelle, CA Labs
32. EXP-SEC	University of Alabama	
33. FPGA-RADIO	Clemson University	
34. GENI IMF	North Carolina State University	The Renaissance Computing Institute (RENCI), Columbia University
35. iGENI	Northwestern University	University of Illinois Chicago
36. LAMP	University of Delaware	Internet2
37. LEFA, Supercharged Planetlab	Internet2	Brown University
38. NLR	Cypress, CA	
39. Open--CIRRUS	HP Labs, Palo Alto	UCSD
40. OKGems	Oklahoma State University	
41. PIGEON-NET	Howard University	
42. PrimoGENI	Florida International University	
43. QUILT	The Quilt	
44. S3-GENI	Purdue University	HP Labs
45. SEC-POL	University of Illinois (NCSA)	
46. VMI	University of Alaska Fairbanks	

Building the GENI Meso-scale Prototype

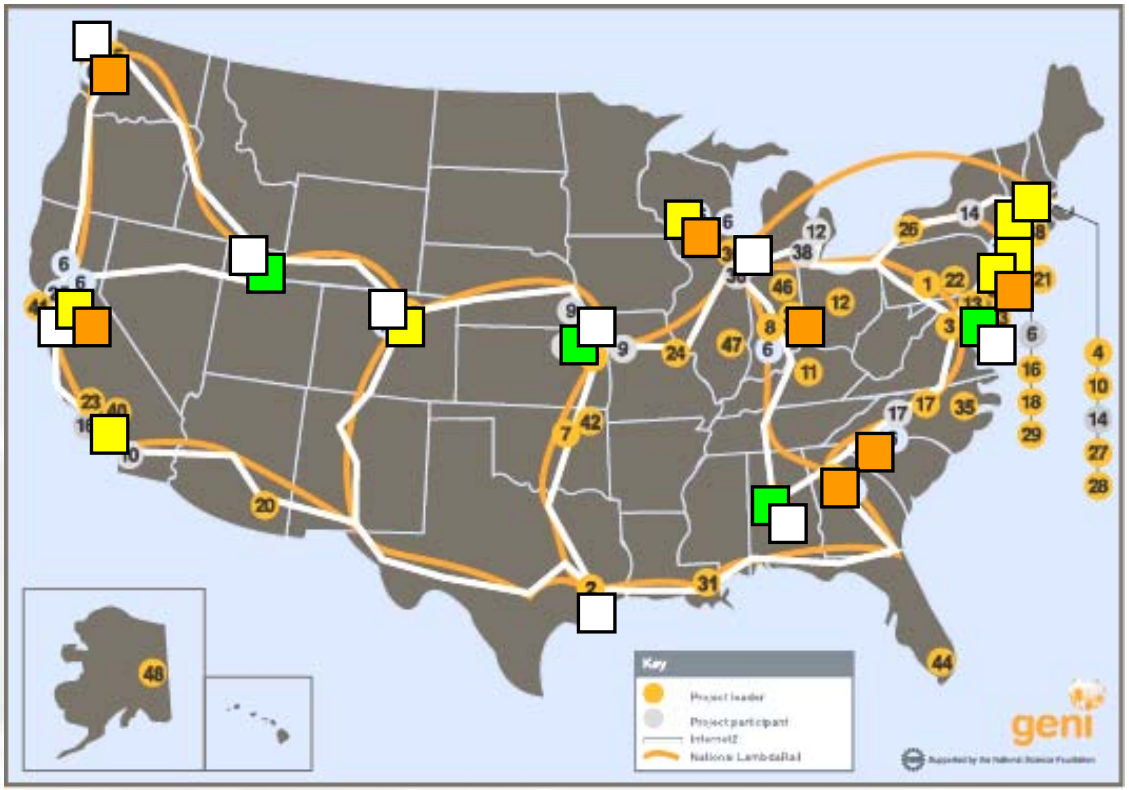
by "GENI-Enabling" Commercial Equipment and Infrastructure

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

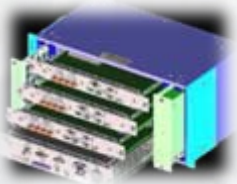
OpenFlow Backbones

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

HP ProCurve 5400 Switch

Juniper MX240 Ethernet Services Router

Arista 7124S Switch



NEC WiMAX Base Station

Cisco 6509 Switch

NEC IP8800 Ethernet Switch

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  (infrastructure)

Specific recommendation

- Require that all broadband infrastructure receiving federal subsidy must be “research enabled”

- What does this mean?
  - Data plane: The infrastructure must be capable of carrying both research and production traffic at the same time, in different slices
  - Control plane: must be compatible with control software that permits “on demand” allocation of infrastructure resources, e.g., for running research experiments
  - Both wireline and wireless broadband should be covered, in order to maximize the number of real users who can join experiments
  - In some technologies, good isolation (QOS) will be easy; in others, it may not be worth the trouble
  - We note that many, many different kinds of today’s commercial technologies are compatible with this mandate

Examples

- Broadband optical networks
  - Can satisfy such a mandate with wavelengths, packet level traffic engineering, etc.
- Campus networks
  - Can satisfy such a mandate with Ethernet VLANs, WiFi SSIDs, etc.
- Radio and cellular systems
  - Can satisfy such a mandate by spectrum allocations or more flexible techniques (eg via a non-profit Mobile Virtual Network Operator for research experiments)

Few downsides

- Adds little or no cost to broadband build
  - Most readily available technology is already compatible with this approach
  - Does not require additional infrastructure be built
- Neutral
  - Does not favor any vendor over any other
  - Does not favor any type of operator over any other
  - Does not favor any research use over any other
- If a bad idea, can easily be undone
  - Just turn off the research allocations, devote everything to production traffic

Widespread benefits

- Opens up broadband infrastructure for research experimentation and innovation
- Gives many people ready access to experimental services
- Removes barrier between “successful experiment” and “real service”
- Useful for a very broad range of research
  - GENI example
  - Also: physics (LHC etc), astronomy, cyber experiments in many domains (medical, biology, environment), . . .
- **Specific research projects will no longer need to “build their own” infrastructure, which will save considerable time and expense**