GENI

Global Environment for Network Innovations

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www.geni.net
Clearing house for all GENI news and documents
Thank you Matt! and Karl!

And also introducing . . .

- National Science Foundation
  - Dr. Suzi Iacono
  - Dr. Karl Levitt

- DARPA
  - Dr. Mike VanPutte

- GENI Project Office
  - Dr. Harry Mussman
  - Dr. Vic Thomas

There once was a Bishop from Davis . . .
GPO goals for this workshop

• Engage the security community to play an active, central role in GENI’s planning, prototyping, and early trial experiments (now rolling out as Spiral 1; first demos in March)

• Very concretely – encourage you to submit proposals for GPO Solicitation #2, due Feb. 20
Outline

• What is GENI?
• How we’ll build it, how we’ll use it (Two Comic Books)
• The GENI system concept
• GENI Spiral 1
• How can you participate?
GENI supports Fundamental Challenges
Network Science & Engineering (NetSE)

Science
Understand the complexity of large-scale networks
- 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
- 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
- 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

Network science and engineering researchers
Distributed systems and substrate researchers
Security, privacy, economics, AI, social science researchers

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Research Agenda to Experiments to Infrastructure

- **Research agenda**
  - Identifies fundamental questions
  - Drives a set of experiments to validate theories and models
- **Experiments & requirements**
  - Drives what infrastructure and facilities are needed
- **Infrastructure could range from**
  - Existing Internet, existing testbeds, federation of testbeds, something brand new (from small to large), federation of all of the above, to federation with international efforts
  - No pre-ordained outcome

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Existing Input

- Clark et al. planning document for Global Environment for Network Innovations
- Shenker et al. “I Dream of GENI” document
- Kearns and Forrest ISAT study
- Feigenbaum, Mitzenmacher, and others on Theory of Networked Computation
- Hendler and others in Web Science
- Ruzena Bajcsy, Fran Berman, and others on CS-plus-Social Sciences
- NSF/OECD Workshop “Social and Economic Factors Shaping the Future of the Internet”
- NSF “networking” programs
  - FIND, SING, NGNI
“Our founders”

The GENI Planning Group and Many, Many Working Group Volunteers

Larry Peterson, Princeton (Chair)        Nick McKeown, Stanford
Tom Anderson, Washington                Dipankar Raychaudhuri, Rutgers
Dan Blumenthal, UCSB                    Mike Reiter, CMU
Dean Casey, NGENET Research             Jennifer Rexford, Princeton
David Clark, MIT                        Scott Shenker, Berkeley
Deborah Estrin, UCLA                    Amin Vahdat, UCSD
Joe Evans, Kansas                       John Wroclawski, USC/ISI
Terry Benzel, USC/ISI                   CK Ong, Princeton

And Within NSF

Peter Freeman                          Guru Parulkar       Ty Znati
Debbie Crawford                        Darleen Fisher       Gracie Narcho
Larry Landweber                        Cheryl Albus         Paul Morton
Suzi Iacono                            Allison Mankin

Their hard work has created GENI’s Conceptual Design, the starting point for all our work going forward.
The GENI Vision
A national-scale suite of infrastructure for long-running, realistic experiments in Network Science and Engineering

Programmable & federated, with end-to-end virtualized “slices”

Heterogeneous, and evolving over time via spiral development
Outline

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How We’ll Use GENI

Note that this is the “classics illustrated” version – a comic book!

Please read the Network Science and Engineering Research Agenda to learn all about the community’s vision for the research it will enable.

Your suggestions are very much appreciated!
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 clusters of CPUs and disks, 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.

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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 reliable 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 Network Science and Engineering program.

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Moral of this story

• GENI is meant to enable . . .
  – Trials of new architectures, which may or may not be compatible with today’s Internet
  – Long-running, realistic experiments with enough instrumentation to provide real insights and data
  – ‘Opt in’ for real users into long-running experiments
  – Large-scale growth for successful experiments, so good ideas can be shaken down at scale

• A reminder . . .
  – GENI itself is not an experiment!
  – GENI is a suite of infrastructure on which experiments run

GENI creates a huge opportunity for ambitious research!
How We’ll Build GENI

Note that this is the “classics illustrated” version – a comic book!

Please read the GENI System Overview and GENI Spiral 1 Overview for detailed planning information.
Spiral Development
GENI grows through a well-structured, adaptive process

GENI Prototyping Plan

- An achievable **Spiral 1**
  Rev 1 control frameworks, federation of multiple substrates (clusters, wireless, regional / national optical net with early GENI ‘routers’, some existing testbeds), Rev 1 user interface and instrumentation.

- **Envisioned ultimate goal**
  Example: Planning Group’s desired GENI suite, probably trimmed some ways and expanded others. Incorporates large-scale distributed computing resources, high-speed backbone nodes, nationwide optical networks, wireless & sensor nets, etc.

- **Spiral Development Process**
  Re-evaluate goals and technologies yearly by a systematic process, decide what to prototype and build next.
Federation
GENI grows by “gluing together” heterogeneous infrastructure

My experiment runs across the evolving GENI federation.

Goals: avoid technology “lock in,” add new technologies as they mature, and potentially grow quickly by incorporating existing infrastructure into the overall “GENI ecosystem”
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GENI System Decomposition (simplified)
Engineering analysis drives Spiral 1 integration
Resource discovery
Aggregates publish resources, schedules, etc., via clearinghouses

What resources can I use?

GENI Clearinghouse

These

Researcher

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Components

Aggregate A
Computer Cluster

Components

Aggregate B
Backbone Net

Components

Aggregate C
Metro Wireless

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

Create my slice

GENI Clearinghouse

Components

Aggregate A
Computer Cluster

Components

Aggregate B
Backbone Net

Components

Aggregate C
Metro Wireless

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Experimentation
Researcher loads software, debugs, collects measurements

Experiment – Install my software, debug, collect data, retry, etc.

GENI Clearinghouse

Aggregate A
Computer Cluster

Aggregate B
Backbone Net

Aggregate C
Metro Wireless
Slice growth & revision
Allows successful, long-running experiments to grow larger

Components
Aggregate A
Computer Cluster

Components
Aggregate B
Backbone Net

Components
Aggregate C
Metro Wireless

Make my slice bigger!
GENI Clearinghouse

www.geni.net
Federation of Clearinghouses
Growth path to international, semi-private, and commercial GENIs

Aggregates:
- **Aggregate A**: Computer Cluster
- **Aggregate B**: Backbone Net
- **Aggregate C**: Metro Wireless
- **Aggregate D**: Non-NSF Resources

Make my slice even bigger!

GENI Clearinghouse

Federated Clearinghouse

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Operations & Management

Always present in background for usual reasons
Will need an ‘emergency shutdown’ mechanism

Stop the experiment immediately!

Oops

GENI Clearinghouse
Federated Clearinghouse

Aggregate A
Computer Cluster

Aggregate B
Backbone Net

Aggregate C
Metro Wireless

Aggregate D
Non-NSF Resources
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GENI Spiral 1 has now begun!
First results expected in 6-12 months

GENI Project Office Announces $12M for Community-Based GENI Prototype Development

July 22, 2008

The GENI Project Office, operated by BBN Technologies, an advanced technologies solutions firm, announced today that it has been awarded a three year grant worth approximately $4M a year from the US National Science Foundation to perform GENI design and risk-reduction prototyping.

The funds will be used to contract with 29 university-industrial teams selected through an open, peer-reviewed process. The first year funding will be used to construct GENI Spiral 1, a set of early, functional prototypes of key elements of the GENI system.
GENI’s Critical Technical Risks
These risks drive the Prototyping Goals for GENI Spiral 1

Critical Risk #1
Clearinghouse & control framework is central but never demonstrated

Critical Risk #2
End-to-end slices across multiple technologies have never been demonstrated

Aggregate A
Computer Cluster

Aggregate B
Backbone Net

Aggregate C
Metro Wireless

Create my slice
Key Goals for GENI Spiral 1
Drive down the critical technical risks in GENI’s concept

Goal #1
Fund multiple, competing teams to develop GENI Clearinghouse technology, encourage strong competition within the first few spirals

Goal #2
Demonstrate end-to-end slices across representative samples of the major substrates / technologies envisioned in GENI
1st GENI Solicitation – proposal areas

- Large deployment (national)
- Regional / access
- Wireless & sensor nodes
- Optical nodes
- Electronics / switch / router
- Control, workflow, manage, measure, etc
- Security-specific

Number of submitted and selected proposals.
Spiral 1 integration and trial operations
Five competing control frameworks, wide variety of substrates
Cluster A Integration
(uses TIED/DETER control framework)

- DETER Trial Integration
  - DETER security testbed
  - Emphasis on federation
  - Clearinghouse, CM
  - 100+ nodes at ISI, UC Berkley

- GMOC
  - Global Research NOC (Indiana)
Cluster B Integration
(uses PlanetLab control framework)

- PlanetLab
  - Clearinghouse, CM
  - 800+ nodes
  - VINI (virtual topologies)
- Enterprise GENI
  - GENI VLANs on enterprise nets
- SPP Overlay Nodes
  - Programmable routers
- GUSH Tools
  - Experiment design tools
- Provisioning Service
  - Slice & experiment management tools
- Mid-Atlantic Crossroads
  - Regional network with VLAN control plane
- GpENI
  - Regional network with sliceable optics & routers
- GMOC
Cluster C Integration (uses ProtoGENI/Emulab Control Framework)

- **ProtoGENI**
  - Clearinghouse, CM
  - Emulab resources
  - (370+ nodes)

- **CMULab**
  - Home Wireless APs
  - Emulab cluster
  - Wireless emulation testbed

- **Instrumentation Tools**
  - UK Edulab (compute/store)

- **Measurement System**
  - GIMS prototype

- **Virtual Tunnels**
  - Dynamic tunnel tools
  - BGP distribution tools

- **GMOC**
Cluster D Integration  
(uses ORCA Control Framework)

- ORCA/BEN
  - ORCA resource leasing software
  - Metro-Scale Optical Testbed (BEN)
- VISE
  - CASA (radar, video, weather sensors)
- Kansei Sensor Network
  - Wireless sensor network arrays
  - 3 federated sites each w/~100 sensor nodes
- Diverse Outdoor Mobile Environment (DOME)
  - Programmable nodes with radios on city busses
- GMOC
Cluster E Integration
(uses ORBIT control framework)

- **ORBIT**
  - Heterogeneous testbed control, management, & measurement software
  - WINLAB wireless testbeds resources (400+ sensor nodes)
  - NICTA (Australia) wireless outdoor traffic testbed

- **WiMAX**
  - Open, programmable WiMAX base station

- **GMOC**
Generous Donations to GENI Prototyping

Internet2 and National Lambda Rail

Internet2
10 Gbps dedicated bandwidth

National Lambda Rail
Up to 30 Gbps nondedicated bandwidth

40 Gbps capacity for GENI prototyping on two national footprints to provide Layer 2 Ethernet VLANs as slices (IP or non-IP)
Currently in the works
Prototyping GENI through campuses

- August Meeting at O’Hare
  - Thanks to EduCause (Mark Luker, Garret Sern)
  - Stimulated by Larry Landweber

- CIOs from 11 major research universities
  - Berkeley, Clemson, GA Tech, Indiana, MIT, Penn State, Rice, U. Alaska, UIUC, UT Austin, U. Wisconsin

- Discussions of representative GENI prototypes
  - Nick McKeown, Stanford (OpenFlow)
  - Arvind Krishnamurthy, UW (Million Node GENI)
  - GPO Staff

- Near-term GENI / CIO activities
  - How to “GENI-enable” campus IT infrastructure
  - Coordinated policy for handling side-effects of network research (Larry Peterson, Helen Nissenbaum)
GENI Spiral 1

- Provides the very first, national-scale prototype of an interoperable infrastructure suite for Network Science and Engineering experiments
- Creates an end-to-end GENI prototype in 6-12 months with broad academic and industrial participation, while encouraging strong competition in the design and implementation of GENI’s control framework and clearinghouse
- Includes multiple national backbones and regional optical networks, campuses, compute and storage clusters, metropolitan wireless and sensor networks, instrumentation and measurement, and user opt-in
- Because the GENI control framework software presents very high technical and programmatic risk, the GPO has funded multiple, competing teams to integrate and demonstrate competing versions of the control software in Spiral 1

Nothing like GENI has ever existed; the integrated, end-to-end, virtualized, and sliceable infrastructure suite created in Spiral 1 will be entirely novel.
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GENI in Context
Supports the Evolving NetSE Research Agenda

- NSF CISE
- Network Science & Engineering (NetSE) Council
  - "Voice of the Community"
    - Definitive source of "what we need in GENI"
    - Authors of GENI Research Agenda
    - Technical advisory to GPO
- GENI Project Office (GPO)
  - Project management
  - System engineering
  - Prototype selection, funding, guidance
  - Integration and early trials
  - Home for Working Groups

Evolving NetSE Research Agenda

Evolving GENI Prototype Infra. Suite

3 to 4 years

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NetSE Council

Ellen Zegura (Chair)  Tom Anderson (UW)  Joe Berthold (Ciena)  Charlie Catlett (Argonne)  Mike Dahlin (UT Austin)  Chip Elliott (GPO)

Joan Feigenbarum (Yale)  Stephanie Forrest (UNM)  Jim Hendler (RPI)  Michael Kearns (U.Penn)  Ed Lazowska (UW)  Peter Lee (CMU)

And not shown . . .

Roscoe Giles
Helen Nissenbaum

Larry Peterson (Princeton)  Jennifer Rexford (Princeton)  Alfred Spector (Google)
GENI is being Designed & Built by the Community
Via an Open, Transparent, & Fair GPO Process

- All design, prototyping, & construction will be performed by the research community (academia & industry)

- Openness is emphasized
  - Design process is open, transparent, and broadly inclusive
  - Open-source solutions are strongly preferred
  - Intellectual property is OK, under no-fee license for GENI use

- GPO will be fair and even-handed
  - BBN brings no technology to the table
  - BBN does not intend to write any GENI software, nor does it envision bidding on any prototyping or construction activities (but “never say never”)
  - If BBN does create any GENI technology, it will be made public at no cost
Working Groups drive GENI’s Technical Design
Meet every 4 Months to Review Progress Together

- **Working Groups**, open to all
  - The locus for all GENI technical design
  - Patterned on the early IETF
  - Discuss by email, create documents, meet 3x per year in person
  - Each led by Chair(s), plus a professional System Engineer

- **GENI Engineering Conferences**, open to all who fit in the room
  - Held at regular 4-month periods
  - Held on / near university campuses (volunteers?)
  - All GPO-funded teams required to participate
  - Systematic, open review of each Working Group status
    (all documents and prototypes / trials / etc.)
  - Also time for Working Groups to meet face-to-face
  - Results in prioritized list for next round of prototype funding areas
    (priorities decided by NetSE and GPO)
GENI Working Groups (WGs)
Open to all, participate via geni.net email lists

Shaded areas pose major security / privacy challenges

- **Substrates**
  All hardware, real-estate, facilities, etc., required for the GENI infrastructure suite (including optical networks, wireless, computers, etc.)

- **Control Framework with Federation**
  Written definitions of the core GENI mechanisms for providing experimental control of a node or collection of nodes. The very earliest version must incorporate federation.

- **Experiment Workflow**
  Tools and mechanisms by which a researcher designs and performs experiments using GENI. Includes all user interfaces for researchers, as well as data collection, archiving, etc.

- **User Opt-In**
  How do “real users” (not researchers) participate in GENI experiments. Includes both mechanisms and considerations such as privacy, etc.

- **Operations, Management, Integration, and Security**
  How do operators provision, operate, manage, and trouble-shoot GENI? Includes all mechanisms for integrating and securely operating the GENI infrastructure suite.
GENI Engineering Conferences
Meet every 4 months to review progress together

- **4th meeting March 31-April 2, 2009, Miami, open to all**
  - Team meetings, integrated demos, Working Group meetings
  - Also discuss GPO solicitation, how to submit a proposal, evaluation process & criteria, how much money, etc.
  - **Travel grants** to US academics for participant diversity

- **Subsequent Meetings, open to all who fit in the room**
  - Held at regular 4-month periods
  - Held on / near university campuses (volunteers?)
  - All GPO-funded teams required to participate
  - Systematic, open review of each Working Group status (all documents and prototypes / trials / etc.)
  - Also time for Working Groups to meet face-to-face
  - Discussion will provide input to subsequent spiral goals
GPO Solicitations
Academic-industrial teams favored but not required

• Second solicitation active – proposals due Feb. 20!

• What kinds of proposals do we solicit?
  – Analyses & idea papers
  – Prototypes of high-risk GENI technology
  – Integrations and trials of prototypes

• How are proposals judged?
  – Merit review
  – Joint academic / industrial teams are favored but not required
  – Open source will be favored but not required
    (IP licenses on www.geni.net)
GENI Solicitation 2 – Proposals due Feb. 20

• Overview
  – Solicitation issued December 2008
  – Proposals due February 20, 2009
  – Total funds ~ $3.5 M / yr for 3 years, as always subject to availability of funds
  – Existing / new GENI participants both welcome

• Strong preference given to . . .
  – Joint Academic / Industrial teams
  – Active participation of campus / regional infrastructure providers (e.g., letter from campus CIO)

• Main solicitation interests
  – Security design and analysis for GENI
  – Experimental workflow prototypes
  – Instrumentation and measurement prototypes
  – Early tries at international federation
  – Other good ideas

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Solicitation and background information
GENI is a Huge Opportunity

• **GENI is an unbelievably exciting project for the community**
  – Our research community has changed the world profoundly. GENI opens up a space to do it again.

• **We believe the whole community will build GENI together**
  – Our vision is for a very lean, fast-moving GPO, with substantially all design and prototyping performed by academic and industry research teams.

• **GENI Spiral 1 is now underway!**
  – within a GENI project framework that is open, transparent, and broadly inclusive.

**www.geni.net**
Clearing house for all GENI news and documents