

GENI and the Challenges of Network Science

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4 March 2008



GENI and Network Science

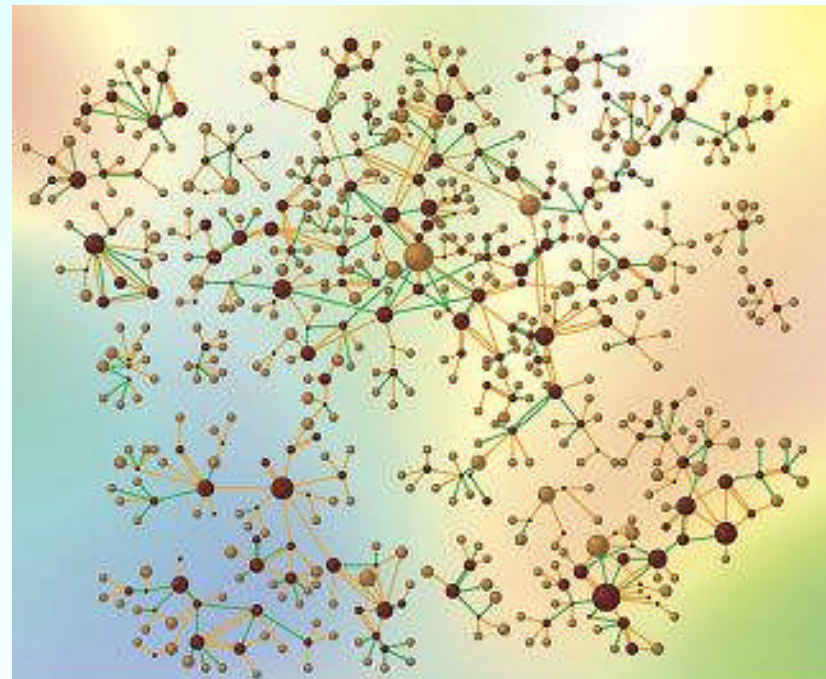
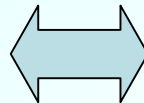
Propositions of This Talk

- Network science exists (*almost true*)
- GENI can contribute to Network Science
- Network Science can contribute to GENI
- Science and society can benefit from both

GENI and Network Science

Talk Outline

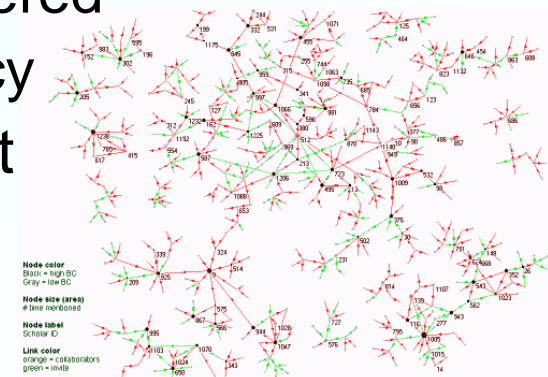
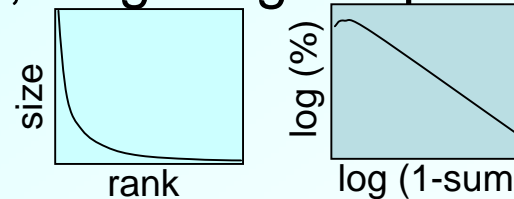
- “Network Science” and “Computer-Related Networks”
- Challenges for Network Science
- Opportunities for GENI
- Implications for GENI



“Network Science”

All Kinds of Networks

- The study of common properties and mechanisms that hold over all “networks”
 - There are robust empirical laws for networks
 - Heavy-tailed distributions, long-range dependence
 - Self-similarity
 - Small-world phenomena
 - Pareto distribution of applications, communities
 - Disparate *kinds* of networks have deep relations
 - Biological, physical, social, engineered
 - Layers of abstraction & dependency
 - Emerging discipline: not proven out



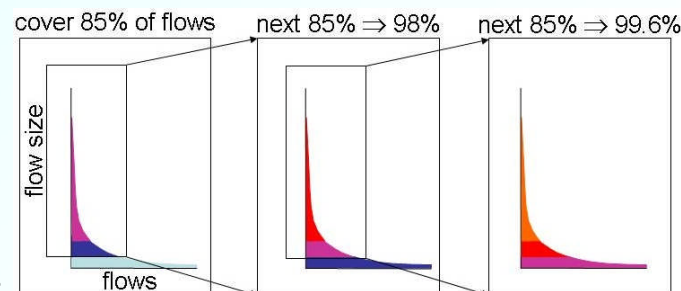
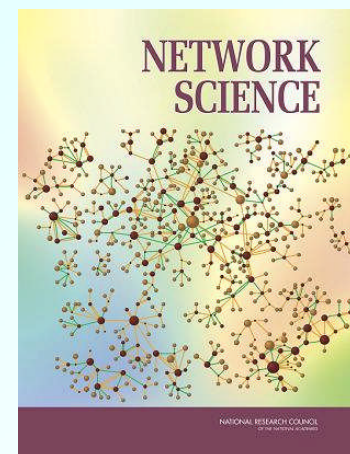
**Computer-related
networks are central**

“Computer-Related Networks” (CRNs)

- GENI is a testbed for more than “computer networks”
- I use “computer-related networks” (CRNs) to emphasize that GENI research includes
 - Communicating devices (varying intelligence)
 - Communicating applications and services
 - Communicating infrastructure
 - Naming, routing, discovery, authentication, security, robustness, maintenance, reconfiguration, policy, ...
 - Communicating *humans* using these device and services
 - Researchers [distinguished class of GENI users]
 - End users
 - Service & data creators and suppliers
 - Operators
 - Not assuming existing IP technology, WWW, or packets

A Broader Research Opportunity: Network Science & GENI

- What is a network? The 3 “CEL” attributes:
 - **Connectivity**: Nodes with finite links between them
 - **Exchange**: Exchanging resources takes time
 - **Locality**: Nodes only interact through links
- Common research themes:
 - Dynamics, resilience, evolution, analysis, synthesis, visualization
 - Network interactions, layers, abstraction, representation
- Enrich CRN research with NetSci perspective
 - Broad insights
 - Challenging hypotheses & examples
- Enrich network science with CRN perspective
 - Varied, well-instrumented, well-studied, multi-layer networks



Challenges For Network Science

- NetSci hypotheses claim **universality**: must be tested across ensembles of different networks
 - Topological properties (small-world, heavy-tails,...)
 - Evolutionary trajectories (emergent phenomena, ...)
 - Dynamic behavior (phase transitions, ...)
- NetSci hypotheses propose abstract **mechanisms**: must be mapped to real networks
 - Do these mechanisms really describe what happens in well-instrumented networks?
 - Do they have the effects predicted (transient, steady-state)?
- **Do we learn something new?**

GENI Can Be a Unique Facility

NetSci ↔ Computer Science

- Network Science needs a facility for research on
 - Ensembles of highly varied, well-instrumented, multi-scale, multi-layer networks
 - With known, controllable cross-network interactions
 - Including both emergent and engineered networks
- Such facilities do not now exist
- GENI is uniquely situated for
 - Testing the hypotheses of Network Science
 - Bringing Network Science to the benefit of research on computer-related networks
 - Bringing CRN research to the benefit of Network Science

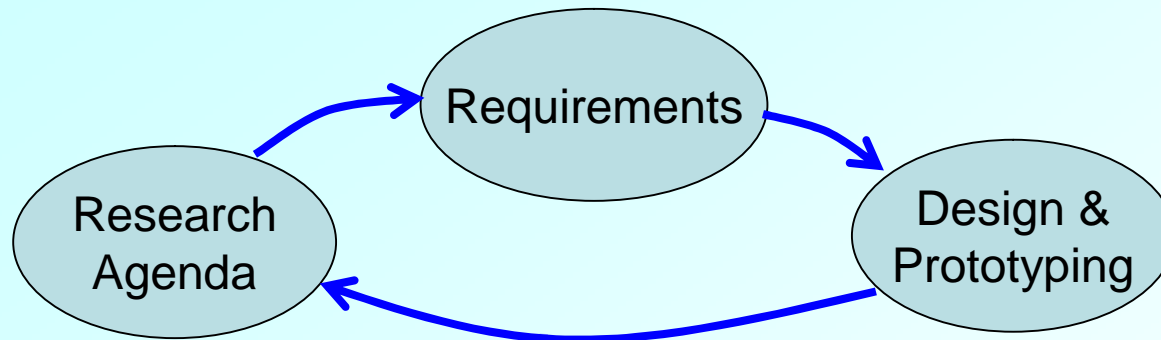
Opportunities For GENI Offered by Network Science (1)

- A source of strong scientific hypotheses to test
 - Proposed network evolution mechanisms
 - Drivers of evolution: percolation, attachment preferences, highly optimized tolerance, ...
 - Barriers to evolution: centrality, Nash equilibria, ...
 - Evolutionary consequences for structure and behavior
 - Scaling laws:
 - Locality of interaction, small-world networks, self-similarity for size distributions (node degrees, communities, frequency of use, ...)
 - Behavioral phenomena
 - Phase transitions, emergent behavior, resilience, ...

Opportunities For GENI Offered by Network Science (2)

- A source of ideas
 - Unfamiliar network structures and mechanisms
 - Economic networks based on potlatch, ecological networks driven by mimetic phenomena (warning, crypsis, Mullerian & Batesian mimicry), kinship networks based on fraternal polyandry,
 - Cross-network mechanisms
 - Resilience by social network instead of computer net?
 - Efficient support for economic or social networks?
 - Damping epidemics by improving remote interactions?
 - Insight into CRN structures and mechanisms
 - What would we change to speed or slow evolution?
 - Mutual evolution of overlay networks

Exploiting the Opportunities

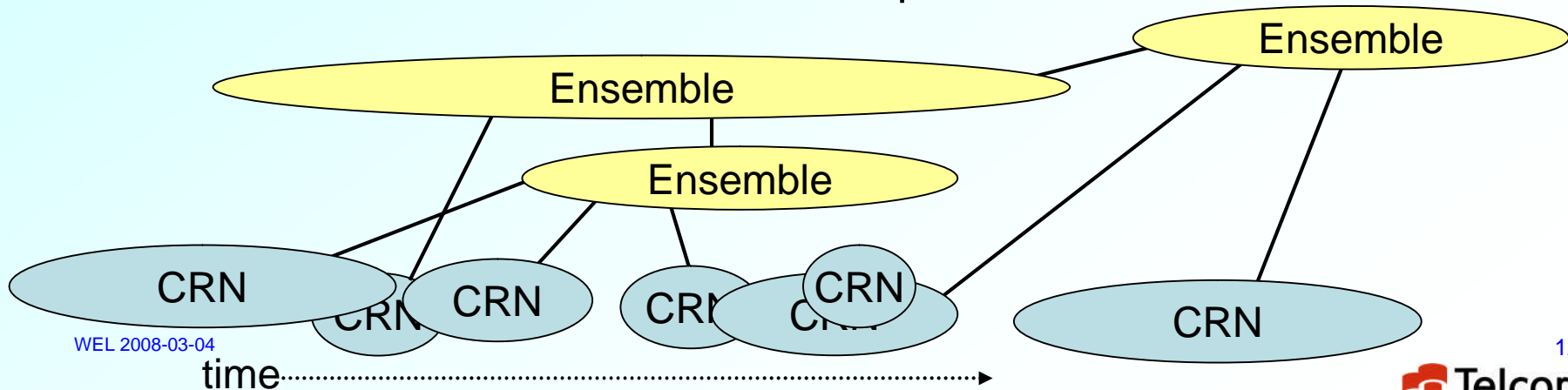


- Add this context to our research agenda
 - Our research community, NetSEC, other NetSci communities
- Develop requirements that support NetSci studies on ensembles of CRN experiments
- Design, prototype, experiment
 - Mechanisms, impacts, operations, measurements, legal, ...
- Inform and evolve the research agenda
 - New possibilities
 - Necessary trade-offs to be resolved in supporting the agenda

Network Science Studies on GENI

Spanning Multiple GENI CRN Experiments

- Possible NetSci studies: relation to experiments studied
 - Pure observation of CRN experiments
 - Mutual influence over time between study and CRN experiments
 - Embedded NetSci plug-ins in CRN experiments
 - (Partial) control of CRN experiment parameters or environment
- Ensembles: multi-experiment collections
 - Active and default opt-in of CRN experiments
 - Completed and current CRN experiments
 - Used in CRN and NetSci multi-experiment studies



Implications for GENI

Many Issues to Address (Affect All WGs)

- Policy, technical, operational, legal, ...
- What NetSci studies should GENI address?
- What measurements should GENI experiments take so (other) researchers could study NetSci issues? Defaults, plug-ins, scrubbing, timeliness, data ownership, retrospective studies, repeatability/replayability, specs & ontologies, ...
- How do experiments opt into or out of NetSci studies? What is the default? Experiment specs?
- How do NetSci studies recruit specific GENI CRN experiments & other NetSci ensembles?
- How do end-users opt in and out? Do they?

The Grand Challenge The Grand Opportunity

Understanding Complex Networks

Approaches:

- Theory
- Modeling and simulation
- Experimentation
- Real-world application

New Insights

Results:

- Prediction
 - Design & synthesis
 - Control
 - Directed evolution
- of all the networks that
matter to society

Thank you!