Building the At-Scale GENI Testbed

Mark Berman
GENI Project Office
Raytheon BBN Technologies
Cambridge, MA USA
mberman@bbn.com

I. Introduction

GENI, the Global Environment for Networking Innovation, is a distributed virtual laboratory for transformative, at-scale experiments in network science, services, and security. GENI is funded by the U.S. National Science Foundation.[1]

Since the autumn of 2010, experimenters have been using GENI in its emerging prototype implementation. Results from these two years of early experiments indicate that a broad variety of researchers are able to conduct investigations in a range of areas, including clean-slate networking, protocol design and evaluation, distributed service offerings, social network integration, content management, and in-network service deployment. Other likely beneficiaries include domain scientists and computer science education.

GENI is now progressing beyond its initial prototyping stage and into a period of wider deployment of increasingly standard components. The increased availability of key GENI capabilities in a new, "at-scale" GENI deployment promises a dramatic increase in the size and flexibility of configurations available to the research community.

II. Steps Toward At-Scale GENI

A. *Identify Vital Capabilities that Support Experiments*

Reports from the GENI experimenter community show that two key GENI capabilities are proving effective in supporting a wide variety of investigations. The first of these capabilities is *sliceability*, the ability to support virtualization (simultaneous shared access to shared physical resources), while maintaining some degree of isolation for simultaneous experiments. Because the selection of virtualization approach implies a tradeoff among performance, isolation, and cost, GENI supports multiple models of virtualization, even for a single resource type. GENI slicing includes both compute and network resources.

The second key capability is *deep programmability*, which refers to an experimenter's ability to influence the behavior of computing, storage, routing, and forwarding components deep inside the network, not just at or near the network edge. Traditional Internet development has not emphasized deep programmability as a desirable trait. In fact, many concerns, including equipment cost, performance, simplicity, interoperability, security, and others have often pushed in the opposite direction. By employing hardware and software technologies that virtualize the network (e.g. software routers, software defined networks [SDN]), GENI introduces new opportunities for innovation.

B. *Partner with Universities to "GENI-Enable" Campuses*

The GENI project is partnering with universities across the United States to create *GENI-enabled campuses*. To become GENI-enabled, a campus takes both technical and administrative steps. On the technical side, it designs and implements a deployment of GENI technologies. The campus also agrees to certain administrative steps, including making resources available to local and remote researchers on an ongoing basis. These actions require active participation on campus from both research faculty and the office of the chief information officer (CIO).

The current deployment phase will take GENI from its current size of fourteen sites to more than forty over the upcoming two years. (See Figure 1.)

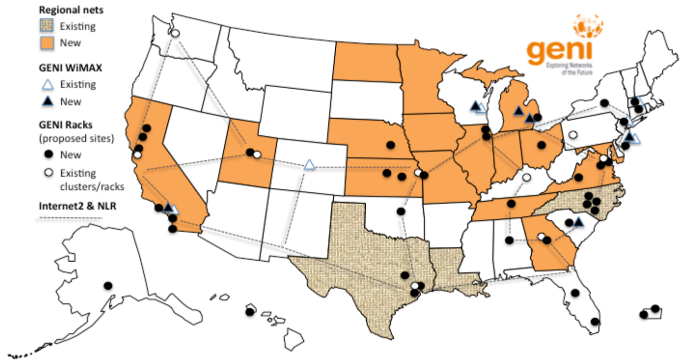

Figure 1: Current Phase Candidate GENI Expansion[2]

The next phase of GENI expansion is still in the planning stage, but it is tentatively anticipated to overlap the current phase and increase the overall scale to 100-200 campuses.

The research and administrative leadership of a university choose to GENI-enable a campus not only because they wish

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[1] GENI is funded by the National Science Foundation. Any opinions, findings, conclusions or recommendations expressed in this material are the author's and do not necessarily reflect the views of the National Science Foundation.

[2] Figure 1 shows the initial set of current phase GENI expansion sites proposed by rack development teams. Final site selection is subject to ongoing discussions.

to participate in GENI, but also largely because of the potential benefits to their campuses of the GENI underlying technologies. In an effort led by Dr. Larry Landweber and volunteers from existing GENI-enabled campuses, the GENI Project Office works actively with university IT leadership to identify and exploit these benefits, which include the possibility of supporting enhanced campus network management capabilities as well as enabling more effective and cost-effective approaches to network security.

C. Expand Deployment of Standardized Components

Three components form the core of the expanded deployment of at-scale GENI: GENI racks, OpenFlow/SDN, and GENI WiMAX base stations.

A *GENI rack* is the basic deployment unit of GENI computation and storage resources. From a hardware standpoint, a rack comprises multiple compute nodes, disk-based persistent storage, and OpenFlow switches. Over this hardware substrate, the rack runs a software stack that presents a standard GENI application programmer interface, supporting a common experimenter tool suite.

In addition to the SDN (software defined network) capability found in GENI racks, GENI-enabled campuses also deploy within the campus network a number of switches supporting SDNs. The size and specifics of the SDN-capable network on campus varies to meet site-specific goals. This campus SDN-capable network bridges the gap between experimenters and other end-users on campus and research backbone networks, while supporting both deep programmability for experimenters and the campus benefits discussed above.

Some GENI-enabled campuses deploy WiMAX (Worldwide Interoperability for Microwave Access) base stations and sector antennae. WiMAX base stations introduce researcher-owned and operated cellular systems into GENI. These base stations are sliceable, and they have proven suitable for a range of experiments. These include wireless-specific research, network research with a focus on mobility, and experiments in which wireless just happens to be an available connectivity option.

III. Looking Forward

Recent work by a growing community of GENI experimenters has already demonstrated the potential of the basic notion of a distributed, virtual laboratory supporting the key concepts of sliceability and deep programmability. As the number of deeply programmable sites grows dramatically through expansion to 100-200 GENI-enabled campuses, the options for available network topologies will grow combinatorially.