Resilience Experiments in the GpENI Programmable Future Internet Testbed

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I. Introduction and Motivation

Testbeds play an important role in evaluating new protocols, and GpENI (Great Plains Environment for Network Innovation) [1] is a Future Internet research testbed that provides worldwide scalability to researchers to conduct their experiments. In this extended abstract, we describe experiments for which GpENI will be used, with emphasis on network infrastructure resilience [2]. GpENI is part of the GENI and FIRE programs.

II. GpENI Programmable Testbed

To be useful in performing future-Internet experiments, a number of features must be present in a testbed.

A. Multi-Layer Programmability

To perform experiments in which new network topologies, mechanisms, and protocols are proposed to enhance resilience and survivability, it is essential to have programmable control of each layer. At the lowest level, programmability is required to control the layer 2 topology, particularly with respect to redundancy and geographic diversity, in order to enable experimentation with network topologies that attempt to maintain connectivity even when network components fail or are destroyed. In GpENI this control of layer-2 connectivity is provided by DCN (Dynamic Circuit Network) [3]. At the next higher level, programmable routing functionality is enabled in GpENI using Quagga and XORP integrated into the GENIwrapper version of VINI running on dedicated nodes in each site cluster nodes [4]. At the highest levels, the ability to deploy novel transport protocols and applications on a significant number of end systems is necessary to experiment at large scale. This is partially enabled in GpENI itself with approximately 80 GeniWrapper PlanetLab nodes throughout 40 sites in the US, Europe, and Asia, and the ability to tie-in many more hosts from federated GENI aggregates and G-Lab [5] in Germany (which maintains a GpENI node cluster).

B. GpENI Deployment

The GpENI infrastructure [1] is in the process of expanding to 40 clusters with 200 nodes worldwide, federated with the larger GENI PlanetLab control framework and interconnected to several ProtoGENI facilities, as shown in Figure 1. This enables users to perform resilience and survivability experiments at scale, both in terms of node count and with the geographic scope needed to emulate area-based challenges such as large-scale disasters. In our own research efforts, we are using these facilities to enable experiments that cross-verify the analytical and simulation-based resilience research currently underway at The University of Kansas [6], [7], leveraging topology and challenge generation tools (KU-LoCGen [8] and KU-CSM [9], [10]) developed for this purpose, with emphasis on resilience metrics [11] and multi-path multi-realm diverse transport [12] developed as part of our NSF FIND research in the PostModern Internet Architecture project.

III. Future Internet Experimentation

This section gives some examples of the types of research questions we expect to be able to answer through experimentation on the GpENI testbed.

A. Resilience Research

Designing resilient networks is a multi-layer problem. Our approach is to examine the end-to-end layer, including mechanisms such as diverse multipath [12], error-correcting erasure codes, and retransmission algorithms. We compare the performance of these mechanisms both with and without cross-layer information passed between the end-to-end and lower layers. In order to perturb the network and observe the benefits of the end-to-end mechanisms being tested a sophisticated challenge model generator is required. The KU-CSM [9], [10] challenge model generator simulates various challenges in ns-3, including random software and hardware failures, malicious attacks, and geographically correlated failures that represent a large-scale natural or human-caused disaster. Figure 1 shows an example of how we apply area based challenges to the network. A set of polygons (circles in this case) of increasing size are used to simulate a cascading power failure or coronal mass ejection affecting Europe overlaid on the GpENI topology. As the challenge increases in size, the overall packet delivery ratio is affected, and we tune our end-to-end resilience mechanisms to reduce that effect as much as possible.

B. Methodology and Cross-Verification

The need for cross-verification brings up the question of *what with*? The ns-3 open-source simulator stands out. ns-3 is taking a more rigorous and modular approach than its predecessors, however it is much less established.

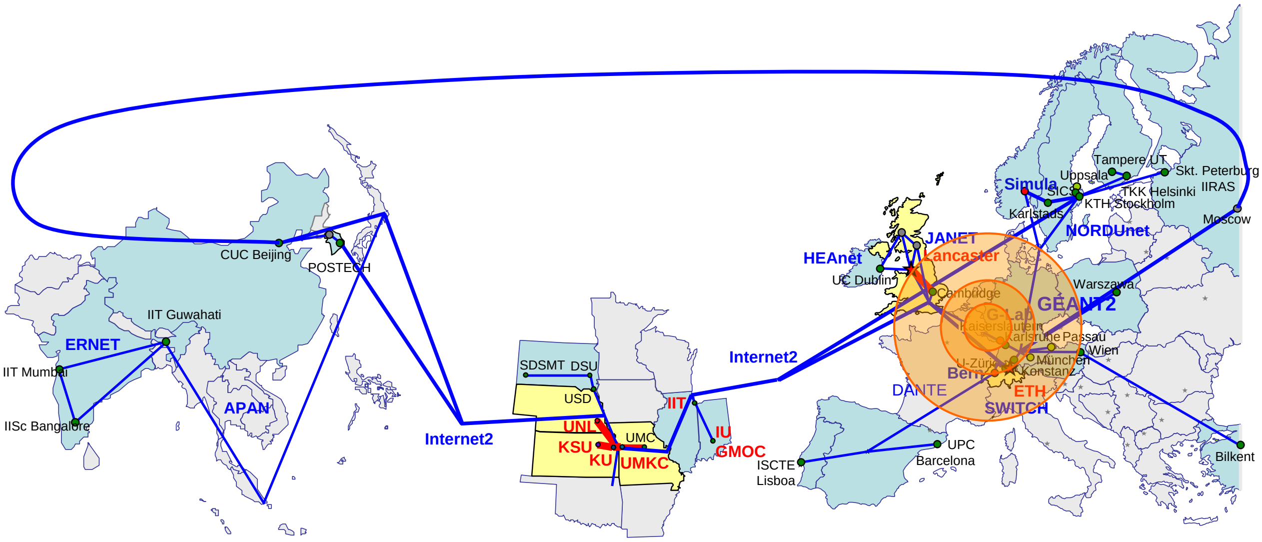

Fig. 1. GpENI map

Resilient topologies generated by KU-LoCGen and analyzed by KU-CSM are used to generate layer-2 topologies that configure the topology of GpENI experiments. We evaluate performance when slice topologies are challenged by correlated failures of nodes and links, measuring connectivity, packet delivery ratio, goodput, and delay, when subject to CBR, bulk data transfer, and transactional (HTTP) traffic. We also characterize the packet-loss probability of wireless links using federated GENI resources.

C. Large-Scale Experiments

Large scale resilience experiments are run over interconnected aggregates using DCN [3] (within GpENI) and OpenFlow configured paths, with VINI/Planetlab layer-3 topologies, to emulate both existing ISP and synthetic topologies. Over these topologies we run our multipath-aware transport protocol ResTP to evaluate its performance under varying application and traffic loads. Based on the output of our challenge generation simulations, we selectively disable node slivers and links to emulate correlated network failures and attacks. In the future we will also use the wireless emulator under the ProtoGENI framework to emulate jamming attacks to wireless access networks. Each challenge set is classified as a single scenario and each scenario is run multiple times to establish reasonable confidence in the results.

IV. Conclusions

Experiments which involve evaluating new protocols and the performance of Future Internet architectures require fully programmable testbeds. GpENI is a Future Internet programmable research testbed that provides worldwide scalability to researchers to conduct their experiments. We presented an overview of experimentation we are conducting on GpENI.

V. Acknowledgments

This extended abstract is adapted from a previously published paper [13]. This research was supported in part by NSF FIND (Future Internet Design) Program under grant CNS-0626918 (Postmodern Internet Architecture), by NSF grant CNS-1050226 (Multilayer Network Resilience Analysis and Experimentation on GENI), and by the EU FP7 FIRE programme ResumeNet project (grant agreement no. 224619).

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