Transforming Scientific Collaboration via Software-Defined Infrastructure

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November 2015

Abstract

Software-defined infrastrucure (SDI) has tremendous potential to transform the nature of scientific collaborations by facilitating *a*d hoc instantiation of wide-area, heterogeneous infrastructure configurations that traverse institutional boundaries. Building on groundwork laid by GENI and other future Internet and distributed cloud (FIDC) testbeds, several software-defined exchange (SDX) implementations are making great strides exploring this potential. At the same time, NSF's series of campus cyberinfrastructure programs (CC-NIE, CC-IIE, CC*DNI) has accelerated deployment of campus-based cyberinfrastructure backed by high-performance networking. Significant challenges remain in several key areas, including heterogeneous cyberinfrastructure description and discovery, as well as multi-domain policy description and enforcement.

1 The Advent of Software-Defined Infrastructure

SDXs have captured the imagination of the research cyberinfrastructure community, even as this same community is actively working to fully define and explore the SDX concept. One area of active exploration is SDI, in which an exchange extends its capabilities beyond managing the exchange of IP and/or SDN traffic among multiple administrative domains. Advanced SDXs may provide SDI capabilities, including visibility into and policy-mediated access and control of diverse cyberinfrastructure resources that are owned and operated by multiple institutions. Increasingly, these cyberinfrastructure resources offer the two key capabilities of *deep programmatility* and *slicing*, enabling researchers to configure divers cyberinfrastructure resources to meet the specific functional and perofrmance demands of collaborative projects. A number of SDXs, offering varying degrees of SDI capability, are currently in prototype development and preliminary use in the US. Some examples include the following:

- "AtlanticWave-SDX aims to ... [create] an environment in which researchers and practitioners can collaborate on at-scale experimentation and prototyping of SDN applications and services, enabling domain scientists to instantiate instruments on demand, or application-specific infrastructure on demand, across multi-domain networks, on a global scale." [1]
- The Washington International Exchange (WIX) at the University of Maryland is developing a SDI-capable exchange, based on a GENI-style aggregate manager, with a goal of not only hosting services on its own organic infrastructure, but also bridging to services at collaborating in-

[1] AtlanticWave-SDX: A Distributed Intercontinental Experimental Software Defined Exchange for Research and Education Networking. [Online] `http://amlight.net/?page_id=1283`

stitutions and commercial providers, including Amazon Web Services (AWS). [2]

- "The StarLight SDX ... will serve as an innovation platform on which to introduce next-generation services, architectures, policies, processes, and technologies." [3]

2 Research Challenges

A number of trends in the development and deployment of research cyberinfrastructure favor the emergence of a growing web of interconnected resources that can be called upon as needed to stand up precise resource configurations that are not limited by traditional boundaries of institutions or pre-engineered scientific facilities.

Under NSF leadership, the campus cyberinfrastructure series of programs, including CC-NIE, CC-IIE, and CC*DNI, have served to connect a growing base of both generic and special-purpose cyberinfrastructure to high-performance and low-friction networks, using strategies such as ScienceDMZ. [4] Building on these developments, the Advanced Cyber-Infrastructure Research and Education Facilitators (ACI-REF) project is "forging a nationwide alliance of educators to empower local campus researchers to be more effective users of advanced cyberinfrastructure (ACI)." [5]

Taken in combination with SDX and SDI research, these efforts are already beginning to demonstrate both the research potential of on demand precision cyberinfrastructure and its feasability. While there has never been a more promising time to advance this promising agenda, a number of research challenges remain. [6] These challenges include:

- Resource description and discovery for heterogeneous cyberinfrastructure
- Rich policy definition and enforcement that transcend administrative boundaries and capture implicit policy assumptions
- Control plane capabilities that enable agile and adaptive federated configurations
- Strategies for securing data in federated cyberinfrastructure across domains

[2] Washington International Exchange (WIX) as a Software-Defined Exchange (SDX). [Online] `http://groups.geni.net/geni/raw-attachment/wiki/GENIFireCollaborationWorkshopSeptember2015/Session5/2015-09-18-geni-sdx-lehman.pdf`

[3] The Global StarLight Software Defined Networking Exchange (SDX): A Novel Advanced International Communications Facility. [Online] `https://www.evl.uic.edu/entry.php?id=2081`

[4] Science DMZ: A Scalable Network Design Model for Optimizing Science Data Transfers. [Online] `https://fasterdata.es.net/science-dmz/`

[5] ACI-REF: Advanced CyberInfrastructure Research and Education Facilitators [Online] `http://wwww.condo-of-condos.org`

[6] Final Report, NSF Workshop on the Development of a Next-Generation Cyberinfrastructure [Online] `http://www.nics.utk.edu/~victor/nextgencipapers/NextGenCIWorkshop-Report-Final.pdf`