

## **GENI Enabled Software Defined Exchange (GENI-SDX)**

### **Project Status Report**

#### **Project 2003**

**March 1, 2016 – February 28, 2017**

#### **Annual Report**

### **I. Major accomplishments**

#### **1) GENI Enabled Software Defined Exchange (GENI-SDX)**

This objective of this project is to develop and deploy GENI enabled Software Defined Exchanges (SDXs). This includes developing an operational SDX Aggregate Manager (AM) that can be deployed at existing and new exchange points. This activity builds on previous work which resulted in a prototype GRAM based MAX Aggregate Manager (GRAM/MAX-AM) deployment on the Washington International Exchange (WIX). The initial WIX SDX prototype focused on the network resources available in the WIX. The larger vision for SDX is one that includes network, storage, and compute resources. In pursuit of this objective, we are developing solutions that allow the following types of systems to be embedded, or attached, to an SDX:

- Network Service Interface (NSI) based Network Element Control
- Amazon Web Services (AWS) Connection as an SDX Resource
- OtherCloud Resources
- GENI Racks

During this reports time period the following activities and accomplishments are noted:

-Completed restructuring of the MAX Aggregate Manager (AM) to accommodate the switch from SFA to GRAM and to provide a proper framework for SDX resource and feature incorporation. This restructure facilitates flexible incorporation of a variety of SDX attached resources such as local compute, storage, and public cloud attachment points. This restructuring leveraged the UMD/MAX developed StackV is an open source model driven orchestration system: [github.com/MAX-UMD/stackV.community](https://github.com/MAX-UMD/stackV.community).

-Completed implementation of MAX AM with support for NSI, GRAM, and AWS. Two instances of this have been deployed. One is covering the MAX Regional Network dynamic circuit infrastructure. The other is covering the Washington International Exchange (WIX) where it interacts with the GRNOC run OSCARS system.

-Work is ongoing to utilize the same technology on the UMD/MAX Software Defined ScienceDMZ. The objective is to show that the same technology base (GRAM based MAX-AM with SDX resource management enhancements) can also be utilized for Software Defined ScienceDMZs. An initial deployment of a GENI Enabled Software Defined Science DMZ was deployed in October 2016.

#### **2) GENI Engineering Conference (GEC) 24, March 8-9, 2016, Arizona State University, Phoenix, Arizona**

Presented a demonstration of a GENI enabled Software Defined Exchange (SDX) which utilizes

Network Service Interface (NSI) for network element control, and included public cloud resources from Amazon Web Services (AWS) as part of GENI Stitched topologies. The work demonstrated is driven by a vision for future R&E cyberinfrastructure that consists of an ecosystem of ad hoc and dynamically federated Software Defined Exchanges (SDXs) and Software Defined ScienceDMZs services. GENI technologies are leveraged in the form of the MAX Aggregate Manager which utilizes the GENI Rack Aggregate Manager (GRAM) software for GENI Federation functions. This MAX/GRAM AM utilized the Open Grid Forum (OGF) NSI protocol to provision services across the network elements within the Washington International Exchange (WIX) located in McLean, Virginia and the MAX Regional Network. GENI Request RSpec extensions were defined to allow AWS resources to be included in GENI stitching topology requests. The demonstration poster is available here:

- <https://wiki.maxgigapop.net/twiki/pub/GENI/Publications/2016-03-8-geni-gec24-sdx-poster-umd-max.pdf>

3) Global Experimentation for Future Internet (GEFI) Workshop, April 18-21, 2016, Brussels, Belgium

-Organized and acted as co-chair for a session on "Federation, software defined infrastructure, testbeds and connectivity".

Presented on "Washington International Exchange (WIX) as a Software Defined Exchange (SDX)". This presentation provided an overview of the WIX SDX, the MAX GENI AM, and AWS integration. The presented slides are available here:

- <http://groups.geni.net/geni/attachment/wiki/MAX-GENI-SDX/2016-04-18-gefi-session2-tlehman-v3.pdf>

-Presented during the session "Cloud and big data" on "Hybrid Cloud Services Software Defined ScienceDMZ". This presentation provided an overview and a vision for Software Define ScienceDMZ architecture and services with GENI AM access. The presented slides are available here:

- <http://groups.geni.net/geni/attachment/wiki/MAX-GENI-SDX/2016-04-19-gefi-session3-tlehman.pdf>

-Presented at the co-located NetFutures 2016 Conference on "Software Defined Exchange (SDX): Vision, Development, Collaboration". This presentation discussed a vision for an ecosystem of distributed SDXs and Software Define ScienceDMZs to provide a service innovation marketplace. The presented slides are available here:

- <http://groups.geni.net/geni/attachment/wiki/MAX-GENI-SDX/2016-04-20-netfutures-gefi-tlehman.pdf>

4) GENI NICE Conference, December 12, 2016, Irvine California

Held as part of CoNEXT 2016, The 12th International Conference on emerging Networking EXperiments and Technologies

-Presented a demonstration on the GENI Enabled "Software Defined Exchange (SDX)" and a "Software Defined ScienceDMZ (SD-SDMZ)" deployed at the Washington International Exchange (WIX) and the University of Maryland/Mid-Atlantic Crossroads (UMD/MAX), respectively. The demonstration poster is available here:

- <http://groups.geni.net/geni/attachment/wiki/MAX-GENI-SDX/2016-12-12-geni-sdx-sd-sdmz-poster-v3.pdf>

-Presented and participated in a panel "What's next for SDX research?". The presented slides are available here:

- <http://groups.geni.net/geni/attachment/wiki/MAX-GENI-SDX/20161212-lehman-sdx-panel.pdf>

5) GENI Engineering Conference (GEC) 25, March 15-15, 2016, Florida International University, Miami, Florida.

Participated in a demonstration of a distributed SDX environment which included the WIX, Starlight, SOX, and Ampath SDXs. Paths across Internet2 AL2S and DOE ESnet were utilized to connect the SDXs. The WIX SDX slides presented as part of this demonstration are available here:

- <http://groups.geni.net/geni/attachment/wiki/MAX-GENI-SDX/20170314-wix-sdx-max-v1.pdf>

Presented at the GENI Transition session regarding plans for operational support and future SDX development. The slides presented at this session are available here:

- <http://groups.geni.net/geni/attachment/wiki/MAX-GENI-SDX/20170314-geni-transition-max-v1.pdf>

## **A. Milestones status**

Milestones/Deliverables

The milestones and deliverables for this project are as defined below.

### a) GRAM and SDX based MAX-AM System Restructure

This task will restructure and refactor the MAX-AM to accommodate the switch from SFA to GRAM and to provide a proper framework for SDX feature incorporation. This adjustment to the MAX-AM is also needed to facilitate future feature incorporation and to enhance supportability associated with deployments on other infrastructures, such as ScienceDMZs.

Status: Completed restructuring of the MAX Aggregate Manager (AM) to accommodate the switch from SFA to GRAM and to provide a proper framework for SDX resource and feature

incorporation. This restructure facilitates flexible incorporation of a variety of SDX attached resources such as local compute, storage, and public cloud attachment points. This restructuring leveraged the UMD/MAX developed StackV open source model driven orchestration system: [github.com/MAX-UMD/stackV.community](https://github.com/MAX-UMD/stackV.community).

#### b) GRAM based MAX-AM Release (AWS and NSI Support)

This release will include NSI support that will provide the ability to talk to NSI network controllers such as OSCARS. It is also expected that OESS will have an NSI API available in this time frame. This task will include testing and verification with the latest OSCARS and OESS. This release will also add AWS Connections as a resource to SDX and MAX-AM

Status: Completed implementation of MAX AM with support for NSI, GRAM, and AWS. This open source software has the GENI public license and is available on github at this location: [github.com/MAX-UMD/stackV.community](https://github.com/MAX-UMD/stackV.community).

#### c) SDX Deployments

This task will deploy the GRAM/MAX-AM to cover the WIX.

Status: Two instances of this have been deployed. One is covering the MAX Regional Network dynamic circuit infrastructure. The other is covering the Washington International Exchange (WIX) where it interacts with the GRNOC run OSCARS system.

#### d) GENI Racks as an SDX Resource

This task will add support for GENI Racks as a resource to MAX-AM. We expect that this will be based on InstaGENI or OpenGENI Racks.

Status: We included connections between the MAX InstaGENI rack and the WIX SDX as part of demonstration topologies. This demonstrated the basic concept of thinking of GENI Racks as being resources available as part of flow management at SDX locations. We have also completed a design for moving the MAX InstaGeni rack to a location at UMD/MAX where we can have multiple dataplane connections to WIX, AL2S, and the local ScienceDMZ. This will allow us to further demonstrate the use of GENI Racks as integrated components of SDX flow management. We plan to complete addition work in this area during the next years activities.

#### e) GRAM Policy Enhancements Addition

The GRAM policy features will likely need some enhancements to address the various SDX use cases. We will work with the GRAM developers to define and document the enhanced policy requirements. We will also modify the MAX-AM to support these new GRAM policy features. We anticipate that these will include adding more granularity to the policy decisions to allow resource control at the user and network element level. This task will include implementing the associated changes in the MAX-AM to support the GRAM enhancements added by the GRAM developers. We assume that the enhanced GRAM software will be available one month prior to the MAX-AM release deliverable due date below.

Status: We leveraged the GRAM ABAC like policy mechanism to control access to WIX SDX

resources based on Federation (Clearinghouse) level, Virtual Organization (Project) Level, Slice Level, and User Level. We plan to enhance the policy features as part of the next years activities. In particular we would like to add more granularity on the policy statements to allow the policy controls to be applied to specific vlans and resources (ports, links, etc). Based on work so far, we think the currently implemented GRAM Policy engine will allow us to do this. As a result we do not think we need any changes to the currently implemented GRAM policy engine. If we find that changes are needed to the GRAM implementation we may need to seek guidance or additional information from BBN implementation team.

#### f) Other Cloud as an SDX Resource

This task will add Other Cloud as a resource to MAX-AM. We expect that this will be based on Rackspace.

Status: We have begun looking at how to add other cloud resources in addition to the integrated AWS VPC and Direct Connect resources now supported. This activity is planned to be continued as part of next years work. One area we are investigating is integrating the Equinix Cloud Exchange resources into the set of WIX SDX available resources. This requires further study but the idea is that additional cloud infrastructures such as Microsoft Azure, Google Cloud, and others are available there.

#### g) GRAM Based MAX-AM System Update

This task will focus on updating the overall GRAM base MAX-AM system based on lessons learned during the previous deployment and testing. We anticipate that there will be many features and functionalities that we will want to reevaluate based on real use case testing. This task will consist of defining needed enhancements, implementation plan development, and implementation.

Status: We did not need any GRAM updates for the work completed so far. There may be some GRAM updates required as part of next years work. We will provide additional information on this once design work has been completed for the finer granularity policy features.

#### h) Application of GENI Enabled SDX Technologies

A key objective of this work is application of the GENI enabled Software Defined Exchange (SDX) technology to a variety of infrastructures and use cases. This task will focus on applying these technologies to other systems such as ScienceDMZs and other SDXs. The initial ScienceDMZ use case will be at MAX/University of Maryland. This ScienceDMZ deployment will be used to define an example use case for discussions with others who are deploying ScienceDMZs. The WIX SDX deployment will be used to define a reference SDX deployment for discussions with other exchange point operators. A key part of the SDX deployment vision will be that of a notion of distributed SDX ecosystem. The hope is that we will be able to deploy the GENI Enabled SDX technology at multiple SDXs and ScienceDMZs and demonstrate distributed policy based operations.

Status: Work is ongoing to utilize the same technology on the UMD/MAX Software Defined ScienceDMZ. The objective is to show that the same technology base (GRAM based MAX-AM

with SDX resource management enhancements) can also be utilized for Software Defined ScienceDMZs. An initial deployment of a GENI Enabled Software Defined Science DMZ was deployed in October 2016.

i) GENI Production Support

We will continue to support GENI Production operations including supporting stitching operations and Stitching Computation Service (SCS) support/bug fixes. This will also include supporting Internet2 if they change their Aggregate Manager to support multipoint stitching on OESS. This support will include requirements definition, design support, testing support, and any modifications needed to the SCS. This is an ongoing task and will be supported as needed during the time period.

Status: During this reporting period we continued supporting the operational MAX developed Stitching Computation Service (SCS) which is now run by the GENI NOC at Indiana University. The open source SCS software is available on a public GitHub repository: <https://github.com/xi-yang/MXTCE-GENI-SCS>.

During this time period we continued to support GENI Operational Stitching. This included supporting GENI NOC running, upgrading, and testing of the operational SCS. In addition, UMD/MAX also continued running multiple instances of the SCS for test and development. Information for SCS software deployment, maintenance, and upgrade is maintained here:

-<https://wiki.maxgigapop.net/twiki/bin/view/GENI/NetworkStitchingSoftware>

**B. Deliverables made**

The following is summary of the deliverables due for this reporting period:

- a) MAX AM restructure with GRAM and architecture to support SDZ and ScienceDMZs
- b) MAX AM with GRAM, AWS, and NSI support
- c) SDX Deployment on WIX
- d) GENI Racks as an SDX Resource
- e) GRAM Policy Enhancements
  - Specification Document
  - MAX-AM with support for Enhanced GRAM Policy Features
- f) OtherCloud as an SDX Resource
- g) GRAM Based MAX-AM System Update
  - Update Plan document
  - MAX AM Update Release
- h) Application of GENI Enabled SDX Technologies
  - ScienceDMZ Deployment Reference Document and deployment at UMD/MAX
  - SDX Deployment Reference Document
  - Outreach to and Coordination with other SDX and ScienceDMZ Operators
- i) GENI Production Support

All deliverables were completed as described in section A Milestone Status. The documentation deliverables were in the form of presentations as listed above and below. More formal GENI

Enabled SDX design, release, and operations documentation is planned as part of next year's activities.

## **II Description of work performed during last quarter**

### **A. Activities and findings**

A key finding as a result of these activities is that GENI federation and stitching technologies can be utilized for multiple use cases. We demonstrated the benefit of applying GENI technologies to use cases such as Software Define Exchanges (SDX). A prototype GENI Enabled SDX at the Washington International Exchange (WIX) was deployed and demonstrated. It appears that SDXs will likely be an important component of future R&E infrastructures. During this reporting period we continued working on the vision of a GENI powered SDX that includes compute and storage resources at the SDX along with dynamic network features. Work completed during this project demonstrated that GENI software and technologies can be readily utilized to power these types of infrastructures. In particular the GRAM based AM seems like a good starting point for developing GENI based SDXs.

Our work with other SDX deployments at Starlight SDX, SOX SDX, and Ampath SDX have provided an early indication of the power of distributed SDX topologies for specialized flow management processes.

### **B. Project participants**

Tom Lehman (MAX)

Xi Yang (MAX)

Alberto Jimenez (MAX)

### **C. Publications (individual and organizational)**

No formal publications were published during this time period.

### **D. Outreach activities**

The core of our outreach activities was in the form of collaboration with other SDX and aggregate operators and presentations at various community forums. This included presentations and/or demonstrations at GENI GEC24, Global Experimentation for Future Internet (GEFI) Workshop, GENI NICE, and GENI GEC25.

### **E. Collaborations**

This project included outreach across a broad spectrum of organizations and projects thru our work with other aggregate and SDX providers such as Starlight SDX, SOX SDX, Internet2 AL2S, Ampath SDX, and other GENI Rack deployment sites.

### **F. Other Contributions**

none.