**GENI Project Progress Report Y1**

**ProjectTitle**: GENI Multi-Services Network Exchange (SDX)

**Principal Investigators**: Joe Mambretti, Jim Chen, International Center for Advanced Internet Research, Northwestern University

1. **Major Accomplishments**: October 1, 2013 (Initiation date) – September 30, 2014

Milestones achieved:

Task1: Undertake project planning for the GENI Multi Services Exchange (SDX) initiative (initiated Sept-Oct 2013) This project is designing and implementing key software and hardware components of a layer 2 SDN/OpenFlow exchange (SDX) between GENI layer 2 network resources and other research networks. The project is planning to provide tools for experimenters to request and receive resources from the exchange that are fully integrated with GENI standard interfaces such as the GENI clearinghouse, the GENI AM API, GENI stitching AMs, and the GENI Commercial Software Defined Exchange Point. The initiative is also integrating provided GENI tools with experimenter tools from other participating networks. Additional goals are to demonstrate one functioning exchange with at least two research network partners, two data-intensive science campuses, and multiple experimenters on multiple participating layer 2 networks. Another goal is to publish an API as an option for third party integration with the functioning exchange (taking into consideration that such entities may have their own methods for integration). In addition, this initiative is planning deploy two additional exchanges, based on the early experimental prototype experiences that will inform a revised initial implementation.

Task2. Design initial implementation, conduct discussions with project partners, including at the 18th GENI Engineering Conference, October 27-29, 2013, Polytechnic Institute of New York University Brooklyn, and at the SC13 supercomputing conference at Denver Colorado, begin initial equipment implementations, began to plan for GMSE activities including demonstrations at the GENI Engineering Conference (GEC 19) March 17-19, 2014 in Atlanta, Georgia (Oct 2013-Nov 2013) and at the GEC 20 at the University of California at Davis,

Task3. Plan for, design, implement and configure initial hardware and software for the prototype GENI Multi Services Exchange (SDX) at the StarLight International/National Communications Exchange Facility, continue planning for GMNE (SDN) activities including demonstrations GEC 19 in Atlanta, Georgia, March 17-19 (Dec 2013-Jan 2014).

Task4. Complete phase 1 of the initial hardware and software implementations and configurations for the GENI Multi Services Exchange – prototype SDX. With initiative partners, plan for, and stage interoperability demonstrations at GEC 19 Mar 17-19, 2014 with the GeorgiaTech and SOX prototype exchange in Atlanta, using the UMass Nowcast as an example applications, and using three optical networks to support dynamic L2 path provisioning (for a total of 5 domains). Begin design, development, and testing of experimenter tools (Feb 2014 - March 2014)

Task5. Continue the design, development and testing of experimenter tools (April 2014 – July 2014)

Task6. Plan for GENI Multi Services Exchange – prototype SDX activities at GEC20 at the University of California at Davis (June 22-24, 2014) and US Ignite (June 24-26, 2014)

Task7. Plan for staging pre-testing of GEC21 demonstration of the integrated exchange (GEC21 is planned for Bloomington Indiana Oct 21-23, 2014) (July 2014)

Task8. Develop plans to begin operating exchange with selected early integration partners in Q4 2014

Task9. Develop and stage SDX demonstrations for TERNIA Networking Conference in Dublin Ireland, May 2014.

Task10. Plan for SDX demonstrations for the Global LambdaGrid Workshop Sept 30-Oct 1 in Queenstown, New Zealand.

Task11. Plan for SDX demonstrations at the ACM SC14 supercomputing conference in November 2014 in New Orleans.

<u>Deliverables made:</u>

- D1. Completed initial GENI Multi Services Exchange (SDX) design
- D2. Completed and review design for layer 2 SDN/OpenFlow research exchange with GENI community  (March 31, 2014)
- D3. Developed prototype implementation and operations tools with working interfaces to GENI rack resources and APIs.  (March 31, 2014)

- D4. Began the design and development of experimenter tools (including controller) for prototype implementation (June 30, 2014)

- D5. Begin testing services, software and hardware implementations with other GENI AMs, GENI stitching and one prototype exchange research network (not a GENI network) – for example, as part of the GEC19 demonstrations (June 30, 2014)

- D6. Designed, implemented, and staged SDX demonstrations for GEC 20 at the University of California, Davis

- D7. Designed, implemented, and staged SDX demonstrations for GEC 21 at Indiana University in Bloomington, Indiana, including an integrated slice exchange with the University of Tokyo

- D8 With multiple international partners, planned, designed, implemented, and staged SDX demonstrations for the TERENA Networking Conference in Dublin Ireland, in May 2014

## 2.   Description of work performed

<u>Activities and Findings</u>

Ref: Above lists of tasks and milestones and descriptions below

<u>Project Participants:</u>
Joe Mambretti, Jim Chen, Fei Yeh, GENI Program Office, and
multiple project partners (ref collaborators section below)

<u>Publications:</u>

<u>Internal.Project Documents:</u>

Multiple presentations, descriptions, and posters, topology schematics, at GEC 19, Atlanta

Georgia and GEC 20, at the university of California, Davis, and related events

<u>External Publications:</u>
J. Mambretti, J. Chen, F. Yeh, "Software-Defined Network Exchanges (SDXs): Enabling Capabilities for Distributed Clouds With SDN Multi-Domain and Multi-Services Techniques," accepted paper, Future Internet and Distributed Clouds Workshop, Karlskrona, Sweden, Sept 12, 2014, co-located with ITC26, Sept 8-12, 2014.
J. Mambretti, J. Chen, F. Yeh, Software-Defined Network Exchanges (SDXs) and Infrastructure (SDI): Emerging Innovations In SDN and SDI Interdomain Multi-Layer Services and Capabilities," accepted paper, First International Science and Technology Conference «Modern Networking Technologies: SDN & NFV – The Next Generation of Computational Infrastructure», Moscow, Russia, Oct 28-29, 2014.
K-C Wang, M. Brinn, J. Mambretti, "From Federated Software Defined Infrastructure to Future Internet Architecture," accepted paper, First International Science and Technology Conference «Modern Networking Technologies: SDN & NFV – The Next Generation of Computational Infrastructure», Moscow, Russia, Oct 28-29, 2014.
Presentation: "Software-Defined Network Exchanges (SDXs) and Software-Defined Infrastructure (SDI)," J. Mambretti, Workshop on Prototyping and Deploying Experimental Software Defined Exchanges (SDXs), Washington DC, June 5-6, 2014.
Presentation: "Software-Defined Network Exchanges (SDXs): Emerging Innovations In SDN Interdomain Services and Capabilities" J. Mambretti 13th Annual ON*VECTOR International Photonics Workshop (ON*VECTOR - Optical Networked Virtual Environments for Collaborative Trans-Oceanic Research), University of California at San Diego, La

Jolla, California

Multiple Demonstrations of International SDX interoperability and Presentations: "Integrating NSI and SDN/OpenFlow For Implementation At Software-Defined Network Exchanges (SDXs)" J. Mambretti, TERENA Networking Conference, Dublin, Ireland, May 19-22, 2014

Presentation: "Integrating NSI and SDN/OpenFlow For Implementation At Software-Defined Network Exchanges (SDXs)", J. Mambretti, LHCONE/LHCOPN Workshop, Rome, Italy, April 28-29, 2014

Presentation: "International Optical SDN Across the Globe And Software-Defined Network Exchanges (SDXs)" J. Mambretti, Optical Software Defined Networking Workshop, Co-Located with GEC 20, Davis, California, June 22, 2014

Presentation: "Software-Defined Network Exchanges (SDXs) and Software-Defined Infrastructure (SDI)," J. Mambretti, SDX and SDI, VNode forum meeting, Tokyo, Japan, June 16, 2014

Presentation: "Software-Defined Network Exchanges (SDXs) and Software-Defined Infrastructure (SDI)," J. Mambretti, SDX and SDI, network planning meeting, Tokyo, Japan, June 17, 2014.

Presentation: "International Software Defined Networking Exchanges (SDXs) for Smart City Services and Applications," J. Mambretti, US/Korea Workshop on SDN/NFV for Smart Cities, Chicago, Illinois, August 16-17, 2014

Presentations: "Global Environment for Network Innovations (GENI)," "Integrating NSI and SDN/OpenFlow For Implementation At Software-Defined Network Exchanges (SDXs)," J. Mambretti, Software Defined Networking Exchange (SDX) and Software Defined Infrastructure Workshop (SDI), Posnan Supercomputing and Networking Center, Posnan, Poland, September 8-9, 2014

Presentation: "StarLight LHC P2P Status, NSI, SDN/OpenFlow and Software-Defined Network Exchanges (SDXs)," J. Mambretti, LHCONE/LHCOPN Joint Meeting, University of Michigan, Ann Arbor, September 15-16, 2014

Invitational Lecture, "Ultra Capacity and Deep Programmability in 21st Century Networks and Distributed Environments: Multi-100 Gbps Paths, Software Defined Networking (SDN), SDN Exchanges (SDXs) and Programmable Cloud - Services, Architecture, and Foundation Technologies," J. Mambretti, University of Auckland Auckland, New Zealand, September 26, 2014

Outreach.Activities:

Presentations at 13th Annual ON*VECTOR International Photonics Workshop (ON*VECTOR - Optical Networked Virtual Environments for Collaborative Trans-Oceanic Research), University of California at San Diego, La Jolla, California

Demonstrations and Presentations on multi days: Integrating NSI and SDN/OpenFlow For Implementation At Software-Defined Network Exchanges (SDXs), organized by iCAIR and SURFnet for the TERENA Networking Conference, Dublin, Ireland, May 19-22, 2014

Presentation: International Optical SDN Across the Globe And Software-Defined Network Exchanges (SDXs) At Optical Software Defined Networking Workshop, Co-Located with GEC 20, Davis, California, June 22, 2014

Workshop on Prototyping and Deploying Experimental Software Defined Exchanges (SDXs), Washington DC, June 5-6, 2014.

Demonstrations, Presentations, Tutorial at Workshop On Large Scale Experimental Research Environments for Network Science: Two day workshop focused on exploring topics related to large scale persistent experimental research environments (EREs) for network science, (April 9-10) 2014 in Tainan, Taiwan, co-located with the PRAGMA 26 (Pacific Rim Application and Grid Middleware Assembly) workshop held in Tainan April 9-10, 2014. The ERE Workshop provided a forum to enable advanced network research communities and organizations in Taiwan who are participating in the Future Internet initiative and related testbeds and GENI participants to explore means by which they can transition toward a closer international cooperative network research environment partnership. The workshop was organized as a partnership between the National Center for High Performance Computing (NCHC) in Taiwan, the Global Environment for Network Innovations (GENI) Program Office (GPO), and the International Center for Advanced Internet Research at Northwestern University.

SDX and SDI forum meeting, Organized by University of Tokyo and iCAIR, with Aki Nakao. Tokyo, Japan, June16, 2014

SDX and SDI planning meeting with AIST, Tomohiro Kudoh et al, Tokyo, Japan, June16, 2014

Presentation for GENI Regional Network participants conference call "Software-Defined Network Exchanges (SDXs) and Software-Defined Infrastructure (SDI)" June 11, 2014

GLIF Technical Workshop, co-located with GEC 19, Atlanta, Georgia

Presentation: "Integrating NSI and SDN/OpenFlow For Implementation At Software-Defined Network Exchanges (SDXs)," J Mambretti, LHCONE/LHCOPN Workshop, Rome, Italy, April 28-29, 2014.

US Ignite Application Summit in Silicon Valley, Sunnyvale, CA, June 24-27, participation
Ciena Vectors Summit, June 3, 2014, Ottawa, Canada, participation
Presentation: "International Software Defined Networking Exchanges (SDXs) for Smart City Services and Applications" J. Mambretti, US/Korea Workshop on SDN/NFV for Smart Cities, Chicago, Illinois, August 16-17, 2014
Presentations: "Global Environment for Network Innovations (GENI)," "Integrating NSI and SDN/OpenFlow For Implementation At Software-Defined Network Exchanges (SDXs)," J. Mambretti, Software Defined Networking Exchange (SDX) and Software Defined Infrastructure Workshop (SDI), Posnan Supercomputing and Networking Center, Posnan, Poland, September 8-9, 2014
Presentation: "StarLight LHC P2P Status, NSI, SDN/OpenFlow and Software-Defined Network Exchanges (SDXs)," J. Mambretti, LHCONE/LHCOPN Joint Meeting, University of Michigan, Ann Arbor, September 15-16, 2014
Invitational Lecture, "Ultra Capacity and Deep Programmability in 21st Century Networks and Distributed Environments: Multi-100 Gbps Paths, Software Defined Networking (SDN), SDN Exchanges (SDXs) and Programmable Cloud - Services, Architecture, and Foundation Technologies," J. Mambretti, University of Auckland Auckland, New Zealand, September 26, 2014
GLORIAD Annual Workshop, September 29, 2014, Queenstown, New Zealand, participation
Global Lambda Integrated Facility (GLIF) Americas (GLIF-Am) Community Meeting, September 29, 2014, Queenstown, New Zealand, organization and participation
Planning for SDX demonstrations at SC14, International Conference for High Performance Computing, Networking, Storage, and Analysis in New Orleans, La, Nov 16-21, 2014

Collaborations:
National Center for High Performance Computing (NCHC) and NARLabs in Taiwan, Grace Lee, WunYuan Huang, Te-Lung Liu and multiple other participants
University of Massachusetts Amhurst Nowcast project, Mike Zink, PI, Divyashri Bhat
SURFNet/NetherLight (Amsterdam, Netherlands), Ronald van der pol, PI
University of Tokyo, Aki Nakao, PI
AIST, Tomohiro Kudoh, PI
CANARIE, Canadian R&E network, Hervy Guy, PI, Thomas Tam
Communications Research Center, Bobby Ho, PI
ESnet, multiple participants
Smart Applications on Virtual Infrastructure (SAVI) Canadian research initiative, multiple participants
GENI Internet Exchange Georgia Tech, Russ Clark, PI
Mid-Atlantic Crossroads (MAX) exchange research initiative, Tom Lehman, PI
GLORIAD (Global Ring Network for Advanced Application Development), Greg Cole PI
Global Lambda Integrated Facility (GLIF), multiple participants
Open Grid Forum Network Service Interface Activities (NSI), multiple participants
KISTI, Republic of Korea, Dongkyun Kim, PI, Buseung Cho PI
University of Amsterdam, Caas de Laat, PI
InstaGENI Project, GENI, Jack Brassil, PI
Virtual Topology Service Project, Nick Bastin, PI
StarLight International/National Communications Exchange Facility consortium, multiple participants
Metropolitan Research and Education Network (MREN) consortium, multiple participants
Ciena Research Labs, multiple participants
REANNZ (New Zealand R&E network), SDX initiatives, Steve Cotter, PI, T. Charles Yun, Jamie Curtis, Andrej Ricnik
Cybera, Canadian regional R&E network, John Shillington, PI, Alex Valiushko
KDDI Labs, Tokyo, Japan, Michiaki Hayashi
Hitachi Research, Tokyo Japan, Toshiaki Tarui
Google, Josh Bailey
Poznan Supercomputing and Networking Center, Poland, Artur Binczewski Belter Bartosz Miłosz Przywecki Piotr Rydlichowski

Other Contributions:
  Multiple additional activities related to designing, developing, and
          implementing distributed environments for computer