

Workshop Report  
GENI / FIRE Collaboration Workshop  
September 17-18, 2015  
Washington, DC

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## Background

The fourth GENI/FIRE collaboration workshop was held in Washington, DC on September 17-18, 2015. A total of forty invited participants were present, with roughly equal representation of US- and EU-based researchers. A list of participants is provided as an appendix.

This series of workshops grows out of an agreement between the Global Environment for Network Innovations (GENI) and Future Internet Research and Experimentation (FIRE) projects to advance the following statement of joint interests.

“The EU and US research communities wish to perform collaborative research, on the basis of equality and reciprocity, in areas of mutual interest, which may be characterized as (a) investigations of the research infrastructures suitable for hosting at-scale experimentation in future internet architectures, services, and applications, and (b) use of such infrastructures for experimental research. We envision that our collaboration will encompass joint specification of system interfaces, development of interoperable systems, adoption of each other’s tools, experimental linkages of our testbeds, and experimentation that spans our infrastructures. We further envision that students and young professors from the US and EU will visit each other and collaborate deeply in these activities, in hopes of sparking friendships and life-long research collaborations between the communities.”

Workshops in this series alternate between EU and US locations. The workshops are jointly organized by the GENI and Fed4FIRE (Federation for FIRE) teams, along with their sponsors at the US National Science Foundation (NSF) and the European Commission Directorate General for Communications Networks, Content & Technology (DG Connect). Previous workshops include:

- Leuven, Belgium: October 14-15, 2013
- Cambridge, MA, USA: May 5-6, 2014
- Paris, France: November 20-21, 2014

## Summary and actions

The workshop was characterized by lively discussions and interchange, which involved not only groups of collaborators with previous, ongoing research collaborations, but also researchers with potential future collaborations. Specific discussions are summarized in the session descriptions below and detailed on the workshop web page. During the course of the workshop, a number of specific actions were identified.

1. Participants generally agreed that the workshops and associated collaborations have been tremendously successful. In particular, they

- applauded the opportunity for face-to-face collaborations via travel support to students and junior faculty. The group agreed to work to continue and expand such collaborations.
2. Participants and organizers identified other countries with active future internet and distributed cloud (FIDC) testbed activities that are well-suited to a similar style of collaboration. Organizers agreed to investigate and pursue approaches to expanding the existing workshop series and associated research collaborations to include researchers in these countries. Specific candidates identified include, but are not limited to: Brazil, Japan, South Korea, and Canada.
  3. Discussion during the federation session identified some discrepancies in approaches to identity management and accounting for layer two virtual circuit provisioning between US and EU testbeds. A group of interested participants agreed to work together to propose and implement mutually agreeable solutions.

Shortly after the completion of the workshop, at the invitation of DG Connect, organizers tentatively agreed to hold the next workshop in the series in conjunction with Net Futures 2016, during the week of April 18-22, 2016, in Brussels, Belgium.

## **Additional information**

A list of participants and the workshop agenda are provided as appendices to this report. The full content of the workshop, including session details and all presentations, is publically available from the workshop web page.

<http://groups.geni.net/geni/wiki/GENIFireCollaborationWorkshopSeptember2015>

## **Session Details**

The workshop was organized into five sessions, each co-chaired by one EU and one US participant. The first session was devoted to reports on progress and plans for specific funded research collaborations. Remaining sessions were organized around areas of shared technical interest, with individual presentations addressing recent work, research challenges, and potential collaborations.

Each session was designed to provide both an opportunity for individual presentations, as well as open discussion among the participants.

Brief summaries of each session are provided below. Interested readers are invited to download and review the presentation details, which are available from the workshop web page.

# Session 1: Reports and discussions of funded collaborations

## Session chairs

- Per Blixt
- Jack Brassil

## Session Summary

This opening session focused its attention on a series of specific research collaborations between US and EU researchers, funded under a GENI SAVI grant and FIRE projects, respectively. Six teams reported results and discussed future plans. During the session, a recurring theme of federation came to the fore. Researchers from FIRE projects and GENI are pursuing federation through multiple mechanisms. Specific presentations discussed the following.

Shared, open-source software components for key capabilities (e.g., as described in David Margery and Marshall Brinn's report on collaboration via the *geni-tools* open source project and Robert Ricci and Brecht Vermeulen's report on *federated monitoring*.)

Architectural measures that facilitate federation. Examples addressed both the control plane (e.g., Ilya Baldin & Chrysa Pappagiani's discussion of brokers) and the data plans (e.g., KC Wang and Jerry Sobieski's presentations on implementation of OpenFlow proxies and GTS).

Note that Bartek Belter's presentation on FELIX (an EU/Japan testbed collaboration), presented later in the **federation session**, showed a federation strategy that is very much in the same spirit and drew on several of the same elements.

Discussion during the presentations identified potential opportunities for opportunistic collaborations. For example, two GENI components, GENI Desktop and the GENI portal, are investigating incorporating simplified status information using a similar or identical approach to that described by Robert Ricci and Brecht Vermeulen.

Two additional presentations covered different topics. Ingrid Moerman presented joint work with Violet Syrotiuk, which applies locating arrays to reduce by many orders of magnitude the search space for wireless parameter optimization. Brecht Vermeulen presented a report on the recent FGRE summer school, which cross-trained researchers on GENI and Fed4FIRE.

The session concluded with a question from chairs Per Blixt and Jack Brassil, who asked participants to identify characteristics leading to successful trans-Atlantic research collaborations. There was wide agreement that face-to-face interactions are very important, and several people commented on the benefits of spending

several days or weeks at a collaborator's institution in order to jump start joint research projects.

## **Session 2: Cloud**

### **Session chairs**

- David Margery
- KC Wang

### **Session Summary**

The Cloud session was seeded with eight short talks to US and EU cloud research projects, capturing a range of cloud system research issues. The projects involved six cloud research platforms - NSF Clouds (Chameleon and CloudLab), Multi-Clouds, the UW-Madison city-scale heterogeneous wireless cloud, GEANT GTS, and Grid5000. The topics spanned cloud programmability, scheduling, federation, applications, and the emerging wired and wireless edge clouds. A clear common theme of the discussion was about the reality of multiple co-existing clouds, the approach to harness and expose a new paradigm across diverse and potentially federated clouds, and the new needs of addressing software design, execution, and management of complex applications for Internet users as well as Internet of Things devices.

Discussions amidst these presentation conveyed a converging consensus of the future cloud paradigm, with deeply programmable computing, networking, and storage elements across Internet in both data centers and near the edge. It is agreed that getting the multiple cloud platforms to interface is readily feasible at the data plane; at the same time, multiple avenues exist to enable control plane federation via software and automation. The eight projects alone have already involved federated infrastructure across US, EU, South America, and Asia. Federation based on commonly agreed API as well as third-party connectors (mapping resource requests from one API to another) have been explored. The community involved in these efforts sees a lot of opportunity for further orchestrated efforts to enable a global environment to facilitate production as well as research use of it.

## **Session 3: Wireless**

### **Session chairs**

- Ingrid Moerman
- Doug Sicker

### **Session Summary**

Presentation Highlights

- Ingrid Moerman (iMinds): Experimental facilities should not only offer hardware infrastructure, but also software platforms with unified programming interfaces for flexible and intelligent control of radio and network settings, together with technical support to experimenters. There is an evolution of wireless experiments, moving from academia to industry (mainly SME) and in some (limited) cases also the end-users.
- Luiz DaSilva (Trinity College Dublin): Wireless networks of the future will be virtualised: virtual wireless access network will feel to the user like a traditional network operated by a single entity, but is in fact orchestrated out of a diverse pool of resources with different ownership models. Main challenges are: How to select physical resources to meet the needs of a virtual operator? How to dynamically manage these virtual networks? How to ensure security, and privacy? What economic and public policy models will support this new model?
- Raymond Knopp (Eurecom): Today the cellular world is closed, impeding real impact from Academia to 3GPP. The future wireless world will be characterized by software radio, flexibility, commoditization of real-time RF and open source; a world where the open-source community will have impact and can introduce disruptive technologies.
- Ivan Seskar (Rutgers University): In order to deal with 5G technical challenges (mixed environment, CRAM with NFV and SDN, massive/cooperative MIMO, real-time issues, etc.), FPGA programming skills are required, while today there is no expertise with programming of large FPGA in academic world.
- Suman Banerjee (University of Wisconsin-Madison): Paradoop offers a virtualization framework that moves the cloud to the home router and drops 3rd part apps & services on demand. Paradoop avoids the typical problems associated to cloud-based networking, like disruptions and network viability.
- Kobus van der Merve (University of Utah): PhantomNet is an open programmable end-to-end mobile testbed that integrated OpenEPC with Emulab to enable research at the intersection of mobile networking, cloud computing and software defined networking.
- Yahya Al-Hamzi (Fraunhofer Fokus): 5G Playground answers industry experimentation requirements addressing multiple uses cases: Interoperability (providing a common ground for product development), Product prototyping (using parts of the 5G Playground software for developing PoC prototypes for new products), Remote experimentation (using the Fraunhofer FOKUS Facilities), calibration and benchmarking (customizing prototypes and products for the specific market).

The following issues were raised during discussion:

- Real-time requirements of software radios are particularly challenging for WiFi technologies (order 10  $\mu$ s inter frame spacing versus latency requirements of order ms for LTE)

- There is an increasing interest in SR (Software Radio) platforms. However, today software radio ends at the base station (at the LTE eNode B), while there is an increasing demand for smaller, low-power SR platforms for UE (user equipment) developments (e.g., LTE-unlicensed)
- Main challenges for experimentation with SR platforms are: dealing with many (500+) GPP cores, clock distribution, high-performance computing, finding researchers with FPGA programming skills

## Session 4: Ontologies

### Session chairs

- Ilya Baldin
- Paola Grosso

### Session Summary

The OMN/ontology topic attracted some attention and probably the most discussion of any session that day. In particular the presentation from Marshall Brinn and his prototype implementation of a SPARQL endpoint as part of AM API triggered a lot of attention. There were some concerns about the scalability and/or effect on the aggregates for having to run RDF stores and SPARQL engine implementations (possibility of a DDoS-like attack was brought up by users placing unbounded expensive queries).

In general there was resistance to the idea of building this capability into existing non-RDF-enabled aggregates, however the idea of enabling the clearinghouse with the capability to respond to SPARQL queries (presumably based on information collected from the aggregates and converted to OMN) was received positively. Idea of multiple 'resource search engines' was brought up as something that can be implemented.

The idea of a searchable clearinghouse is linked to the idea of brokers (because broker matching capability is similar to this idea except it offers more power due to the ability to offer promises of resources, which a clearinghouse wouldn't), however at this time these ideas are decoupled and will be pursued separately.

## Session 5: Federation

### Session chairs

- Rob Ricci
- Brecht Vermeulen



## Session Summary

The session started out with reports from a number of successful federations: GENI, CloudLab, Fed4FIRE, and PlanetLab. Of these GENI and CloudLab are primarily in the US, Fed4FIRE in the EU, and PlanetLab is spread throughout the world, with its two major centers of operation being in the US and Europe. All talks emphasized the strong relationships between the participants as a major contributing factor to the success of the federation. There was particular interest from participants to understand the system that PlanetLab has used for accountability: PlanetFlow logs all packets and the slice (container) that send them, so that after the fact, any traffic can be traced to the appropriate user for the appropriate action to be taken.

The session also included talks on two efforts to standardize and update APIs that are used for these federations. A "Common Federation API", based on those that have been developed by the GENI project, but with wider participation from other parties, has been in progress for some time now, and there are several working implementations. There are also multiple implementations that place these APIs on top of circuit reservation services, using Internet2's AL2S in the United States and NSI internationally.

One of the major themes that came up several times in the final set of talks in the session was how international Layer-2 connectivity should be handled. While the technical capacity for making circuits between domains is available, the policies governing them is less clear. One major question is whether requests for international Layer-2 circuits should be made using the credentials of the user who will use them, or with the credentials of the federated facility or network. In the US, GENI users are using their own credentials with Internet2 - internationally, the requests seem to be made by the facility that is federating. This topic will be the subject of a follow-up conversation by some members of the group.

## Appendix 1: Workshop Participants

- Yahya Al-Hazmi
- Ilya Baldin
- Suman Bannerjee
- Bartek Belter
- Mark Berman \*
- Per Blixt \*
- Jack Brassil \*
- Marshall Brinn \*
- Mauro Campanella
- Russ Clark
- Luiz Da Silva
- Piet Demeester \*
- Chip Elliott \*
- Michael Enrico
- Serge Fdida \*
- Timur Friedman
- Ada Gavrilovska
- Jim Griffieon
- Paola Grosso
- Zhenya Henderson \*
- Scott Kirkpatrick
- Raymond Knopp
- Larry Landweber \*
- Tom Lehman
- Yan Luo
- Joe Mambretti
- David Margery
- Ingrid Moerman
- Lucas Nussbaum
- Chrysa Pappagiani
- Dana Petcu
- Rob Ricci
- Ivan Seskar
- Doug Sicker
- Jerry Sobieski
- Kobus van der Merwe
- Nalini Venkatasubramanian
- Brecht Vermeulen \*
- KC Wang
- Mike Zink

(\*) Workshop Organizers

## Appendix 2: Workshop Agenda

### GENI-FIRE WORKSHOP, WASHINGTON DC SEPT. 17-18

Workshop location: Grand Hyatt, 1000 H St NW, Washington, DC

## Thursday September 17th

### 9h-9h15: Welcome

- Chip Elliott, GENI Project Office
- Erwin Gianchandani, CISE Acting Deputy Assistant Director
- Jim Kurose, CISE Assistant Director

### 9h15-10h30: Session 1

Chairs: Jack Brassil (US) and Per Blixt (EU)

Report, demonstrations and discussion on funded collaborations and possible future work from there

- Ilya Baldin – Chrysa Pappagiani: Resource management and topology embedding in distributed networked infrastructure environments
- Rob Ricci – Brecht Vermeulen: Health and availability service for user tools
- David Margery – Marshall Brinn: collaboration on Geni Control Framework (aggregate manager)
- Brecht Vermeulen – Kaiqi Xiong: FGRE summerschool 2015
- Violet Syrotiuk - Ingrid Moerman
- KC Wang – Jerry Sobieski – Paul Muller: From GTS to CloudLab: on OpenFlow, NSI, and GTS-GENI federation

### 11h00 – 13h: Session 2: Cloud

Chairs: KC Wang (US) and David Margery (EU)

- Introduction to the session
- Joe Mambretti, Northwestern - Federating the Chameleon Cloud testbed with multiple other research cloud testbeds around the world
- Rob Ricci, Utah – CloudLab
- Yan Luo, U Mass Lowell - How we plan to use NSFCloud to save the world
- Dana Petcu, West University of Timisoara, Romania - Multi-Clouds -- challenges, achievements and opportunities
- Ada Gavrilovska, G Tech - AppFlux: Taming App Delivery: a project on development of infrastructure for more scalable and timely distribution and delivery of apps for client and IoT devices
- Suman Banerjee, U Wisc - Designing and deploying a city-wide wireless infrastructure with edge programmability
- KC Wang, Clemson - From federated SDI to future Internet architecture
- Lucas Nussbaum - Thought after using Grid'5000, Cloudlab and Chameleon

### 14h00 – 15h30: Session 3: Wireless

Chairs: Doug Sicker (US) and Ingrid Moerman (EU)

- Ingrid Moerman: intelligent control in wireless networks
- Luiz DaSilva: virtualisation of wireless networks
- Raymond Knopp: flexibility of software radio architectures
- Ivan Seskar: wireless cloud
- Suman Bannerjee: wireless testbeds
- Kobus van der Merwe: wireless monitoring
- Yahya Al-Hazmi: The FUSECO 5G Playground - For Growing Together the 5G Technology

### 16h00 – 18h: Session 4: Ontologies

Chairs: Ilya Baldin (US) and Paola Grosso (EU)

- Paola Grosso and Ilya Baldin: Introduction to the session
- Paola Grosso: General overview of the OMN ontology motivation and progress
- Yahya Al-Hazmi: On the OMN ontologies, their hierarchy and tooling
- Chrysa Papagianni: Concrete usecases: on lifecycle ontology and on wireless ontology (to be presented on her behalf by P. Grosso)
- Ilya Baldin: Building efficient support for semantics in networked infrastructure systems
- Ivan Seskar
- Marshall Brinn: First experiences when implementing and discussion questions

Open discussion based on questions. Focus on next steps. (moderated by Paola and Ilya)

## Friday September 18<sup>th</sup>

### 9h-10h30, 11h-12h30: Session 5: Federation (Global federation, policies, SDX, connectivity, common federation APIs)

Chairs: Rob Ricci (US) and Brecht Vermeulen (EU)

- Federation success stories: (mention Problems that have arisen and were solved, problems that need to be solved)
  - Rob Ricci: Strategy of federation + GENI + Cloudlab + emulab
  - Brecht Vermeulen: Fed4FIRE
  - Timur Friedman: Planetlabs over the world
- APIs: short presentations on use and standardisation of the APIs around the world and what the future should bring
  - Brecht Vermeulen: AM api + federation api
  - Bartek Belter: EU-Japan, NSI (Felix project)
- Future of federations: Clear proposals of how we could solve particular problems on this, or what is foreseen in the specific work by the speakers
  - Rob Ricci on behalf of Marshall Brinn: Geni policy work
  - Tom Lehman: prototype of SDX with policies at WIX
  - Rob Ricci: Cloudlab federation

- Joe Mambretti: Chameleon federation
- Brecht Vermeulen: Fed4FIRE
- Michael Enrico: vision Geant on external use and end-to-end multi-domain bandwidth-on-demand
- Jerry Sobieski: Geant testbed as a service and federation
- Mauro Campanella: multi-domain federation

### **13h30 – 15h, 15h30-16h45 Session 6: Monitoring**

Chairs: Jim Griffioen (US) and Scott Kirkpatrick (EU)

- 14:00 – 14:10: Jim Griffioen and Scott Kirkpatrick: Introduction
- 14:10 - 15:20 Monitoring testbed networks, clouds, clusters, and slices (Discussion Leader: Jim Griffioen)
  - Mike Zink - Power and Temperature Measurement Infrastructure for CloudLab
  - Yahya Al-Hazmi -- monitoring ontologies -- demo
  - Brecht Vermeulen - Facility Monitoring for Federations
  - Chrysa Papagianni - Measuring reputation in testbeds
  - Dana Petcu - Monitoring in Multi-Clouds
  - Bartok Belter - Monitoring of Multi-domain Slices in FELIX
- 15:20 - 15:40 Break
- 15:40 - 16:10 Monitoring Wireless Infrastructure (Discussion Leader: Ivan Seskar)
  - Ingrid Moerman - ????
  - ???? - Measuring Broadband to the Sidewalk
- 16:10 - 17:00 Monitoring the Internet as a Whole (Discussion Leader: Scott Kirkpatrick)
  - Yan Luo - Privacy preserving network measurement
  - Timur Friedman - Smart Cities
  - Colin Anderson - Internet Misbehavior as seen from M-Lab
  - Scott Kirkpatrick - Crowd-sourced Data Demo

### **16h45 – 17h Conclusion**

Jack Brassil, Per Blixt