

GENI Stitching: Networks On-Demand

GEC17 July 22, 2013 Heidi Picher Dempsey Luisa Nevers

Sponsored by the National Science Foundation



GENI and Stitching

•



- GENI infrastructure is built on shared resources
- Providers only own part of an end-to-end data path
 - GENI participants provide resource managers and tools to ease collaboration
- Easier experiment setup
- Less custom
 engineering





- Stitching long supported in many commercial and R&E networks (e.g. OSCARS, GLIF)
- GENI rack teams both supported native stitching between like racks since earliest deployments and still do (ProtoGENI Flack and ORCA Flukes)
- GENI mesoscale supported custom-engineered
 VLAN connections for specific experiments
- GENI adopted interoperable stitching framework 2011



- Today we can stitch between unlike components (IG and EG racks, core, regional networks)
- Operations trials underway with I2 ION stitching aggregate, early racks, and brave regionals.
- Expect to expand to wherever GENI racks are deployed (note: international will require federation)
- Can easily go beyond GENI (open source, standards-based)

Stitching Collaborators Today





- GENI rack teams (RENCI/IBM, University of Utah/HP/ Northwestern)
 - Support GENI AM API and RSpec for stitching
 - Develop code to configure rack switches and assign slices



Stitching Collaborators (cont.)



Chad Kotil

Xi Yang

Tom Lehman

 Stitching Computation Service and ION Aggregate Teams (MAX/University of Maryland and Internet2)

- Compute paths and dependencies
- Request/Translate connections
- Set up dynamic layer 2 data plane connections



- Resource Owner/Operators (COTN/CENIC, KyRON, NOX, Stanford, UEN, University of Kentucky, University of Maryland, University of Utah)
 - Delegate VLANs and manage infrastructure







Kentucky Regional Optical Network





- Stitching client (using OMNI in the demo, other tools work too)
 - Request connections
 - Report results to experimenter
- GENI Clearinghouse (credentials only)
- Operations (GPO for initial trials)
 - Monitoring, reporting tools coming
 - Service desk help after that

Initial Operations Trials





During operations trials, network engineers and brave experimenters exercise stitching "in the wild." Developers collaborate and improve the tools and procedures.

Planned by Next GEC





GENI Network Stitching Testing

- Functional, operator, resource, measurement and topology tests
- Exercise stitching tools in real operational environments
- Real experimenters and operators
- Find scaling issues and needed improvements
- Prepare for larger GENI rollout

(○ ○ ○ GeniNetworkStitchingTestPlan – GENI: geni – 7	Гrac 😰
	● Mttp://groups.geni.net/geni/wiki/GeniNetworkStitchingTestPlan) 🕃 🗸 Google 🔍 🗣 🍙 💽 🗸
l	GeniNetworkStitchingTestPlan +	

GENI Network Stitching Test Plan

This page provides an outline of the testing for the GENI Network Stitching that is currently planned in the ⇒ Network Stitching Architecture discussion page. For testing described in this plan, it is assumed that the GCF tool stitcher, can be used to execute tests using credentials from the \Rightarrow GPO PG Clearinghouse. Upon completion of this test plan, some tests will be re-executed using ⇒ GENI Clearinghouse credentials via the GENI Clearinghouse Portal. If support for stitching is available, Flack may also be used to execute some tests in this plan. Overall goals of this plan are:

- Verify that experimenters can get the resources they request.
- GENI Network Stitching Test Plan Stitching Functional Tests **GENI AM API Functions** GENI RSpec Support Negative and Boundary tests Operator Functions VLAN Delegation Configuration Bandwidth allocation Monitoring Experimenter Functions Experiment Resources Scenarios Experiment Measurements GNS-T1 - Topology 1 - Utah InstaGENI to GPO InstaGENI GNS-T2 - Topology 2 - InstaGENI Utah to GPO ExoGENI GNS-T3 - Topology 3 - InstaGENI Utah to GPO ExoGENI to LONI and MAX GNS-T4 - Topology 4 - InstaGENI Utah to GPO ExoGENI to CENIC GNS-T5 - Topology 5 - InstaGENI Utah to GPO ExoGENI to NYSERNet GNS-T6 - Topology 6 - Utah PG to GPO InstaGENI Post GEC17 testing OpenFlow Over Stitched VLAN Paths Multi-point support Topology Service Negotiation Support References
- Verify that operators can tell what resources are in use, and determine who is using the resources.
- Verify that the aggregates present an accurate picture of stitching resources available.
- Validate representative network stitching topologies and collect sample measurements for stitching those topologies

See the \Rightarrow GENI Network Stitching Test Status page for details about test execution.

http://groups.geni.net/geni/wiki/GeniNetworkStitchingTestPlan

Sponsored by the National Science Foundation

Stitching Testing Status

- Overall test status on GENI wiki (link below).
- Detailed test case captures linked to each test type (includes RSpecs).

GeniNetworkStite	hingTest	Status/Resource	ces – GENI: geni – Trac	
🛞 http://groups.geni.net/geni/wiki/GeniNetworkStitchingTestStat	tus/Resou	ces	☆ マ C 🛛 🚺 🕶 Google	۹ 🕹 🍙
GeniNetworkStitchingTestStatu +				
periment Resources Scenarios				in I mainmannin I minin
	512 32	S. 1982.0		5 5.0° 5.003
This page captures status and execution details for	the Ex	periment Re	esources Scenarios. For overall sta	tus see the \Rightarrow GEN
Network Stitching Test Status page and for test de	tails see	e the \ominus GE	NI Network Stitching Test Plan page	e.
Last update: 07/16/13				
Scenario	State	Ticket	Comments	
Scenario 1 (Utah IG to Utah PG)	Pass		Single slice with 1 stitched VLA	N
Scenario 1 (Utah IG to GPO IG)	Pass	#1045	Single slice with 1 stitched VLA	N
Scenario 2 (Utah IG to Utah PG)	Fail	#1044	Single slice with multiple stitch	ed VLANs
Scenario 3 (Utah IG to GPO IG)	Pass		Multiple slices with 1 stitched V	LAN each
Scenario 3 (Utah IG to Utah PG)	Pass		Multiple slices with 1 stitched V	/LAN each
Scenario 4 (Utah IG to GPO IG)			Multiple slices with multiple stit	ched VLANs each
Scenario 4 (Utah IG to Utah PG)			Multiple slices with multiple stit	ched VLANs each
Scenario 5 (IG Utah to PG Utah to IG GPO)	Fail	#1047	Single 3 nodes linear slice with VLAN hops	multiple stitched
Scenario 6 (IG Utah to PG Utah to IG GPO to MAX MyPLC)	Fail	#1047 #1056	Single 4 nodes linear slice with VLAN hops	multiple stitched

State Legend	Description
Pass	Test completed and met all criteria
Pass: most criteria	Test completed and met most criteria. Exceptions documented
Fail	Test completed and failed to meet criteria.
Complete	Test completed but will require re-execution due to expected changes
Blocked	Blocked by ticketed issue(s).
In Progress	Currently under test.

http://groups.geni.net/geni/wiki/GeniNetworkStitchingTestStatus

Sponsored by the National Science Foundation

Stitching Variations

GENI Network Stitching combinations supported and tested:

	GPO InstaGENI	Utah InstaGENI	Utah PG	UKY PG	MAX
GPO InstaGENI	N/A	~	>	•	•
GPO ExoGENI	Not Supported	~	Not tested	Not tested	Not tested
Utah InstaGENI	~	N/A	~	~	~
Utah PG	✓	✓	N/A	✓	~
UKY PG	v	✓	✓	N/A	 ✓
MAX	v	v	✓	v	~
Stanford Non-GENI	~	Not tested	Not tested	Not tested	Not tested

- Select infrastructure for stitching.
 - VLANs, LANs, racks, other aggregates
 - ION core stitching only for GENI trials
- Select local endpoints and available bandwidths
- Delegate VLANs for GENI stitching.
- Set up additional local VLANs (optional).
- Run a GENI stitching service (optional).
- Contact <u>help@geni.net</u> to integrate, test, and announce.

- Internet 2 ION can allocate any VLAN ID dynamically in core network and provide VLAN translation.
- Most network providers and campuses delegate smaller VLAN ID ranges for GENI.
- VLAN Stitching Computation Service combines ION and delegated VLAN segments to find paths endpoints.
- Operations trials public wiki page records who delegated what:

https://hpn.dragon.maxgigapop.net/twiki/bin/view/GENI/StaticNetworksView

Delegated VLANs Page

○ ○ ○ StaticNetworksView < GENI < TWiki					
A https://hpn.drago	n. maxgigapop.net /twiki/bin/view/GENI/StaticNetworksView		☆ ▽ (C Google	۹ 🝙
	MANFRED MID-Atlantic Network Facility for Research, Experimentation, an	DEVELOPMENT TWikLorg		Jump Search	C Edit Attach
ome ubstrate equest Access	Tags: create new tag, view all tags				
cessing Slices	Delegated GENI Stitching VLANs				
oftware	COTN(CENIC)				
— Aggregate Manager — PlanetLab MyPLC		A			
ublications	Description Componentid	AggregateManagerURL	Description Componentid	Aggi	egateManagerURL
Posters Demonstrations letwork Stitching	to Stanford GENI Rack	ntp://gen-an.net.internetz.eou.12346	GENI Rack to I2 ION (place holder)	tenace-duminySwitch.duminyPortgec17	igeni-am.stanioro.eou. 12346
lilestones and Deliverables	VlanProvider(s)				
failing Lists Cey Contributors	um:publicid:IDN+cenic.org				
Related Sites	Capacity MaximumReservableCapacity	MinimumReservableCapacity	Granularity AvailableVlanRange	Com	ments
National Science Foundation	1000Mbps 10000Mbps	1Mbps	n/a 3721	n/a	
ndex	InterfaceA		InterfaceZ		
Changes	Description Componentid	AggregateManagerURL	Description Componentid	Aggi	regateManagerURL
search	BBN GPO-IG urn:publicid:IDN+instageni.gpolab.bbn.com+interface+procurve2:5.2	4 https://www.instageni.gpolab.bbn.com:12369	Internet2 ION urn:publicid:IDN+ion.internet	2.edu+interface+rtr.newy:ae0:bbn http://	/geni-
6LOGON_OR_WELCOME% Private Intranet	to Internet2 ION via NOX	/protogeni/xmlrpc/am/2.0	to BBN GPO-IG via NOX	am.n	et.internet2.edu:12346
	VianProvider(s)				
	urn:publicid:IDN+nox.org				
	Capacity MaximumReservableCapacity	MinimumReservableCapacity	Granularity AvailableVlanRange	Com	ments
	1000Mbps 1000Mbps	1Mbps	n/a 3747-3749	n/a	
	10010				
			Interface7		
	Description ComponentId	AggregateManagerURL	Description Componentid	Aga	regateManagerURL
	ProtoGENI urn:publicid:IDN+emulab.net+interface+procurve-pgeni-salt:3.21	https://www.emulab.net:12369/protogeni	Internet2 ION urn:publicid:IDN+ion.internet	2.edu+interface+rtr.salt:ge- http://	/geni-
	Utah to	/xmlrpc/am	to ProtoGENI 10/2/7:protogeni	am.n	et.internet2.edu:12346
	Internet2 ION		Utah via UEN		
	via LIEN				

1. Get Omni Client

- GENI network stitching support introduced in gcf 2.3.1
- New version under test -- check GCF wiki page for availability and features:

http://trac.gpolab.bbn.com/gcf/wiki/WikiStart

- GENI network stitching support also in progress for Flack
- GENI stitching via GENI Portal in development, not yet available

2. Find sites that support GENI Stitching

- Test sites available now, more coming after GEC17.
- Current sites that have successfully passed stitching tests:
 - GPO (InstaGENI and ExoGENI)
 - University of Utah (InstaGENI and ProtoGENI)
 - University of Kentucky (ProtoGENI)
 - MAX (MyPLC)
 - CENIC (with Stanford non-GENI Compute Resource)

How to Stich: Experimenters

3. Get request RSpecs for your endpoints

 GENI Network Stitching only requires a component manager id in the <link> definition for each of the end-point aggregates:

<link client_id="link">

<component_manager name="urn:publicid:IDN+instageni.gpolab.bbn.com+authority+cm"/> <component_manager name="urn:publicid:IDN+emulab.net+authority+cm"/>

</link>

• Example Rspecs in experiment on GENI wiki:

http://groups.geni.net/geni/wiki/GENIExperimenter/ExperimentExamplestitching

How to Stich: Experimenters

4. Execute Experiment

- Simple experiment set-up commands. Code in stitcher.py creates slivers at all needed aggregates, including network stitching path.
- Stitcher.py parses your RSpec to determine <u>all</u> compute resource aggregates. No longer need to specify "-a aggregateName".
- Stitcher.py uses the MAX Stitching Computation Service (SCS) to determine VLAN path needed for your experiment

How to Stich: Experimenters

Finish

5. Finish Experiment

- Simple experiment tear-down commands.
- Stitcher.py deletes your slivers at all known slice aggregates, including your network stitching path.
- Stitcher.py deletes slivers at all known aggregates on the GENI Portal, if it does not know which aggregates are part of your slice.

Demo GENI Network Stitching

The GENI Network Stitching live demo shows an experiment that creates a network stitching path between the GPO InstaGENI and the Utah InstaGENI. Shown below is the end-to-end network path:

Demo GENI Network Stitching (cont.)

Get Request RSpec

• RSpec used for this demo is available at:

http://groups.geni.net/geni/browser/trunk/stitch-examples

Remember the portion of the RSpec that matters to stitching:

<link client id="link">

<component_manager name="urn:publicid:IDN+instageni.gpolab.bbn.com +authority+cm"/>

<component_manager name="urn:publicid:IDN+utah.geniracks.net+authority +cm"/>

</link>

Demo GENI Network Stitching (cont.)

Stitcher Workflow:

1. Stitcher gets your slice credential and verifies that it is a valid slice in which to create your circuit and runs rspeclint on your RSpec file, if rspeclint is found in search path.

- **2. Stitcher.py contacts SCS** to get the list of AMs needed to establish the stitching path, including, if needed, the Internet2 ION aggregate.
- **3. Stitcher generates request RSpec** for each of the aggregates in the network path requesting both network and compute resources. Slivers are created at each aggregate.
- **4. Stitcher.py requests ION DCN circuits** and checks for circuit readiness. It may try up to 10 times, pausing 30 seconds between each try. Usually needs only one try.

5. Stitcher.py assembles a combined manifest RSpec which shows all aggregates and VLANs used in the slice.

• What does it look like?

\$ omni.py createslice sliceName
\$ stitcher.py createsliver sliceName rspec.xml -o
\$ readyToLogin.py sliceName -a AM

.... the experiment

\$ stitcher.py deletesliver sliceName

Execute

Stitching Variations

Multiple stitched connections share the infrastructure. Running alongside this live demo are several other live slices using stitched topologies:

- GPO ExoGENI to Utah InstaGENI
 - A previously set up slice named *Indemo1* is running between GPO EG and Utah IG using a network stitching path.
 - Traffic exchange between GPO ExoGENI (192.1.242.20) to Utah InstaGENI (pc1.utah.geniracks.net port 32058) via stitched path.
 - Let's see the live results
- GPO InstaGENI to Stanford via CENIC's COTN
 - A previously set up slice named *Instan* is running between GPO InstaGENI and a non-GENI Stanford compute resource using a stitching path via COTN.
 - Traffic exchange between GPO VM (pc5.utah.geniracks.net port 31290) to Stanford host (netw-cenic01.stanford.edu)

- Max MyPLC to University of Kentucky PG
 - A previously set up slice named *max-pg-ky* is running between MAX MyPLC and University of Kentucky PG using a network stitching path.
 - Traffic exchange between MAX MyPLC host (planetlab2.dragon.maxgigapop.net) to UKY PG (pc63.uky.emulab.net port 33338) via stitched path.

Stitching Test Status

Testing started May 22, 2013:

- Survey of AM API support, RSpecs support, Negative and Boundary testing completed.
- Network topology tests ran successfully for current aggregates. More interesting scenarios coming as we add more aggregates and VLANs.
- Reliability has progressed noticeably since testing started.
- Some known issues remain, but workarounds are available.
- Features not yet available: OpenFlow over stitched VLAN paths and multipoint VLAN topologies

Stitching Test Findings

Issues found for all aggregates; most addressed.

- ION/I2 issues
 - ION DCN Circuits allocation/creation
 - SCS configuration
 - Advertisement/Manifest RSpecs content
 - Some scaling/speed issues
- InstaGENI/PG issues
 - Utah InstaGENI endpoint requires capacity be for link
 - Duplicate IP addresses with multiple links
 - Requesting invalid capacity does not generate error
 - Stitching slivers /etc/hosts incorrect remote entries
 - Default MTU failures with VLAN tags

Stitching Going Forward

- Operations trials continuing
- If you are getting a GENI rack, you'll be in the trials automatically
- Open to all interested providers, experimenters, and developers
- Join us! <u>help@geni.net</u>

Apologies to Disney and Sony

Backup

Stitching Between Different Rack Types

GPO ExoGENI to Utah InstaGENI Stitching

000	☆ Inevers — Inevers@ig-utah:~ — ssh — 109×19	Le al
lnevers@sendaria;	A '¥	
lnevers@sendaria:	ssh -p 33082 -i /home/lnevers/.ssh/geni_cert_portal_key lnevers@pc5.utah.geniracks.net	
Last login: Tue J	at to 11:20:20 2015 From Senuaria.gpolab.bon.com	
[lnevers@ig-utah ^	~]\$ ping -c 5 192.168.1.2	
PING 192.168.1.2	(192.168.1.2) 56(84) bytes of data.	
64 bytes from 192.	.168.1.2: icmp_req=1 ttl=64 time=0.024 ms	
64 bytes from 192.	.168.1.2: icmp_req=2 ttl=64 time=0.020 ms	
64 bytes from 192.	.168.1.2: icmp_req=3 ttl=64 time=0.020 ms	
64 bytes from 192.	.168.1.2: icmp_req=4 ttl=64 time=0.021 ms	
64 bytes from 192.	.168.1.2: icmp_req=5 ttl=64 time=0.014 ms	
102 100 1 2 -	000	
192.168.1.2 p	<pre>lnevers@sendaria: \$ ssh -i /home/lnevers/.ssh/geni_cert_portal_key root@192.1.242.10</pre>	
5 packets transmi	Linux debian 2.6.52 5 amager wi orn non oan io iorzereg ord zoie zoie zoo_or	
[]novorc@ig_utab	The programs included with the Debian GNU/Linux system are free software:	
[thever sorg-utan	the exact distribution terms for each program are described in the	
	individual files in /usr/share/doc/*/copyright.	
	Depian GNU/Linux comes with ABSULUIELY NU WARKANIY, to the extent	
	last login: Wed Jul 17 17:41:05 2013 from sendaria.goolab.bbn.com	
	root@eq-qpo:~# ping -c 5 192.168.1.1	
	PING 192.168.1.1 (192.168.1.1) 56(84) bytes of data.	
	64 bytes from 192.168.1.1: icmp_req=1 ttl=64 time=0.018 ms	
	64 bytes from 192.168.1.1: icmp_req=2 ttl=64 time=0.032 ms	
	64 bytes from 192.168.1.1: icmp_req=3 ttl=64 time=0.024 ms	
	64 bytes from 192.168.1.1: 1cmp_req=4 ttt=64 time=0.027 ms	
	04 bytes 110m 192.100.111. 10mp_red=5 ttt=04 time=0.021 ms	
	192.168.1.1 ping statistics	
	5 packets transmitted, 5 received, 0% packet loss, time 3999ms	
Jets.	rtt min/avg/max/mdev = 0.018/0.024/0.032/0.006 ms	
Sponsored by the N	lational Science Foundation	32

Stitching to Endpoints Outside GENI

GPO InstaGENI to Stanford via CENIC's COTN Stitching

000 <u>A Inevers – Inevers@ig-gno1:~ – sch – 116×16</u>	271
lnevers@sendaria: 🖇 ssh -p 36154 –i /home/lnevers/.ssh/geni_cert_portal_key lnevers@pc2.instageni.gpolab.bbn.com	
Last login: Tue Jul 10 10.02.20 2010 from senderia.gpolab.bbn.com	
[lnevers@1g-gpo1 ~]\$ ping -C 5 192.108.1.1 PING 192 168 1 1 (192 168 1 1) 56(84) bytes of data	
64 bytes from 192.168.1.1: icmp reg=1 ttl=64 time=80.3 ms	
64 bytes from 192.168.1.1: icmp_req=2 ttl=64 time=80.3 ms	
64 bytes from 192.168.1.1: icmp_req=3 ttl=64 time=80.3 ms	
64 bytes from 192.168.1.1: icmp_req=4 ttl=64 time=80.3 ms	
64 bytes from 192.100.1.1: $100p_req=5$ ($tt=64$ ($ttme=60.5$ ms	
192.168.1.1 ping statistics	
5 packets transmitted, 5 received, 0% packet loss, time 4005ms	
rtt min/avg/max/mdev = 80.322/80.367/80.399/0.255 ms	
	8
lnevers@sendaria: \$ ssh netw-cenic01.stanford.edu -i /home/lnevers/.ssh/id_rsa	
Last login: Tue Jul 10 10:18:34 2013 Trom 128.89.91.19	
[(1000 - cenicol ~]\$ ping 192.108.1.2 - c 5 PINC 102 169 1 2 (102 169 1 2) 56(94) bytes of data	
64 bytes from 192,168,1,2 (192,100,1,2) 50(64) bytes of data.	
$64 \text{ bytes from } 192.168.1.2; \text{ icmp_seq=1 ttt=64 time=80.4 ms}$	
64 bytes from 192.168.1.2: icmp_seq=3 ttl=64 time=80.3 ms	
64 bytes from 192.168.1.2: icmp seg=4 ttl=64 time=80.3 ms	
64 bytes from 192.168.1.2: icmp_seq=5 ttl=64 time=80.3 ms	
192.168.1.2 ping statistics	
5 packets transmitted, 5 received, 0% packet loss, time 4084ms	
rtt min/avg/max/mdev = 80.326/80.358/80.418/0.360 ms	
[lnevers@netw-cenic01 ~]\$	
Sponsored by the National Science Foundation 3	33

Stitching PlanetLab and Emulab Nodes

MAX MyPLC to UKY PG Stitching

○ ○ ○ ☆ Inevers — Inprj_maxpgky@planetlab2:~ — ssh — 113×17	IJ
Connection to planetlab2.d.agon.maxgigapop.net closed.	a
lnevers@sendaria: /\$ ssh -i /home/lnevers/.ssh/geni_cert_portal_key lnprj_maxpgky@planetlab2.dragon.maxgigapop.net	
Last login: Tue Jul 10 10:34:23 2013 from sendaria.gpolab.bbn.com	
[lnprj_maxpgky@planetlab2 ~]\$ ping 10.33.4.1 -c 5	
PING 10.33.4.1 (10.33.4.1) 56(84) bytes of data.	
64 bytes from 10.33.4.1: 1 cmp_seq=1 ttl=64 time=38.0 ms	
$64 \text{ bytes from 10.33.4.1: icmp_seq=2 ttt=64 time=38.0 ms}$	
64 bytes from 10.33.4.1: icmp_seq=4 ttl=64 time=38.0 ms	
64 bytes from 10.33.4.1: icmp_seq=5 ttl=64 time=38.0 ms	
10.33.4.1 ping statistics	
5 packe 0 0 0 1 Inevers — Inevers@pgky:~ — ssh — 107×16	20
rtt mir Dennei []pevers@paky_~]\$	E
[[npr]] [nevers@pgky ~]\$ Mrite feiled: Breken pipe	Ĩ
<pre>lnevers@sendaria: \$ ssh -p 33338 -i /home/lnevers/.ssh/geni_cert_portal_key lnevers@pc63.uky.emulab.net</pre>	
Last login: Tue Jul 10 10:44:00 2010 from sendaria.gpolab.bbn.com	
[lnevers@pgky ~]\$ ping 10.33.4.2 -c 5	
PING 10.33.4.2 (10.33.4.2) 56(84) bytes of data.	
64 bytes from 10.33.4.2: icmp_req=1 ttl=64 time=80.1 ms	
64 bytes from 10.33.4.2; $1 \text{ cmp}_{reg=2}$ ttl=64 time=38.0 ms	
$64 \text{ bytes from 10.33.4.2: icmp_reg=4 tt]=64 time=38.0 \text{ ms}$	
64 bytes from 10.33.4.2: icmp_req=5 ttl=64 time=38.0 ms	
10.33.4.2 ping statistics	
5 packets transmitted, 5 received, 0% packet loss, time 4004ms	
rtt min/avg/max/mdev = 38.003/46.456/80.158/16.851 ms	
[lnevers@pgky ~]\$ [1