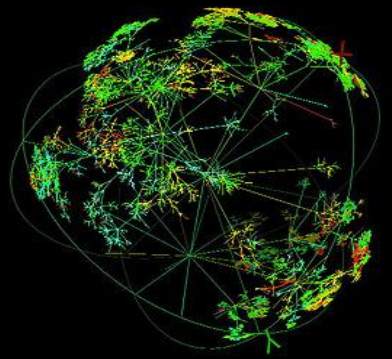
The International Global Environment for Network Innovations (iGENI), The International OpenFlow Testbed, and Related Experimental Research Facilities

Joe Mambretti, Director, (j-mambretti@northwestern.edu)
International Center for Advanced Internet Research (www.icair.org)
Northwestern University
Director, Metropolitan Research and Education Network (www.mren.org)
Co-Director, StarLight, PI-iGENI, PI-OMNINet (www.startap.net/starlight)

GLIF/OGF Techs Meeting
Maastricht, Netherlands
June 6, 2013



iCAIR

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Topics

- Mega Trends In Advanced Networking
- National Science Foundation's Global Environment for Network Innovations (GENI)
- NSF's International GENI (iGENI)
- Related International Projects
- GENI, iGENI, and Related International Projects As A Potential Model for Next Generation Communications Services, Network Architecture, and Capabilities

GriPhyN
Data Intensive Science

NEPTUNE
A Fiber-Optic Telescope to Inner Space

NEES

GENOMES to LIFE
BIOLOGICAL SOLUTIONS FOR ENERGY CHALLENGES
U.S. DEPARTMENT OF ENERGY

NG Digital Sky Survey

NEON
National Ecological Observatory Network

ATLAS

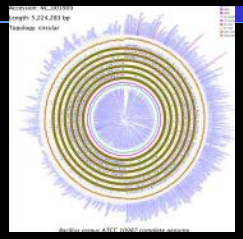
ALMA

ALMA: Atacama Large Millimeter Array

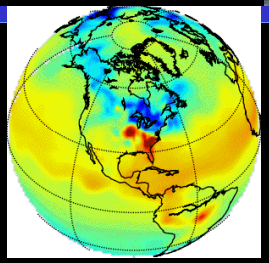
ANDRILL: Antarctic Geological Drilling
www.andrill.org

BIRN

BIRN: Biomedical Informatics Research Network
www.nbirn.net



CAMERA metagenomics
camera.calit2.net



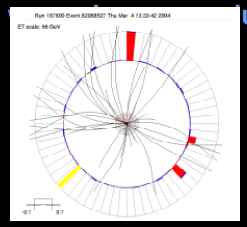
Carbon Tracker
www.esrl.noaa.gov/gmd/ccgg/carbontracker

CineGrid™

CineGrid
www.cinegrid.org

LHC ONE

LHCONE
www.lhcone.net



DØ (DZero)
www-d0.fnal.gov

GEON

GEON: Geosciences Network
www.geongrid.org

GLEON: Global Lake Ecological Observatory Network

OOI
OCEAN OBSERVATORIES INITIATIVE
CYBERINFRASTRUCTURE
Providing a link between ocean research and discovery

OOI-CI
ci.oceanobservatories.org

ISS: International Space Station
www.nasa.gov/station

CLASS

Comprehensive Large-Array Stewardship System
www.class.noaa.gov

LIGO
www.ligo.org

PRAGMA

Pacific Rim Applications and Grid Middleware Assembly
www.pragma-grid.net

WLCG
Worldwide LHC Computing Grid

WLCG
lcg.web.cern.ch/LCG/public/

TeraGrid™

TeraGrid
www.teragrid.org

IVOA

IVOA: International Virtual Observatory
www.ivoa.net

Open Science Grid

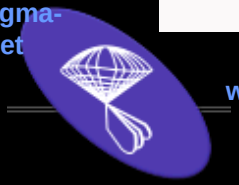
OSG
www.opensciencegrid.org

the globus alliance

Globus Alliance
www.globus.org

SKA
SQUARE KILOMETRE ARRAY

SKA
www.skatelescope.org



Sloan Digital Sky Survey
www.sdss.org

XSEDE

XSEDE
www.xsede.org

iCAIR

Compilation By Maxine Brown

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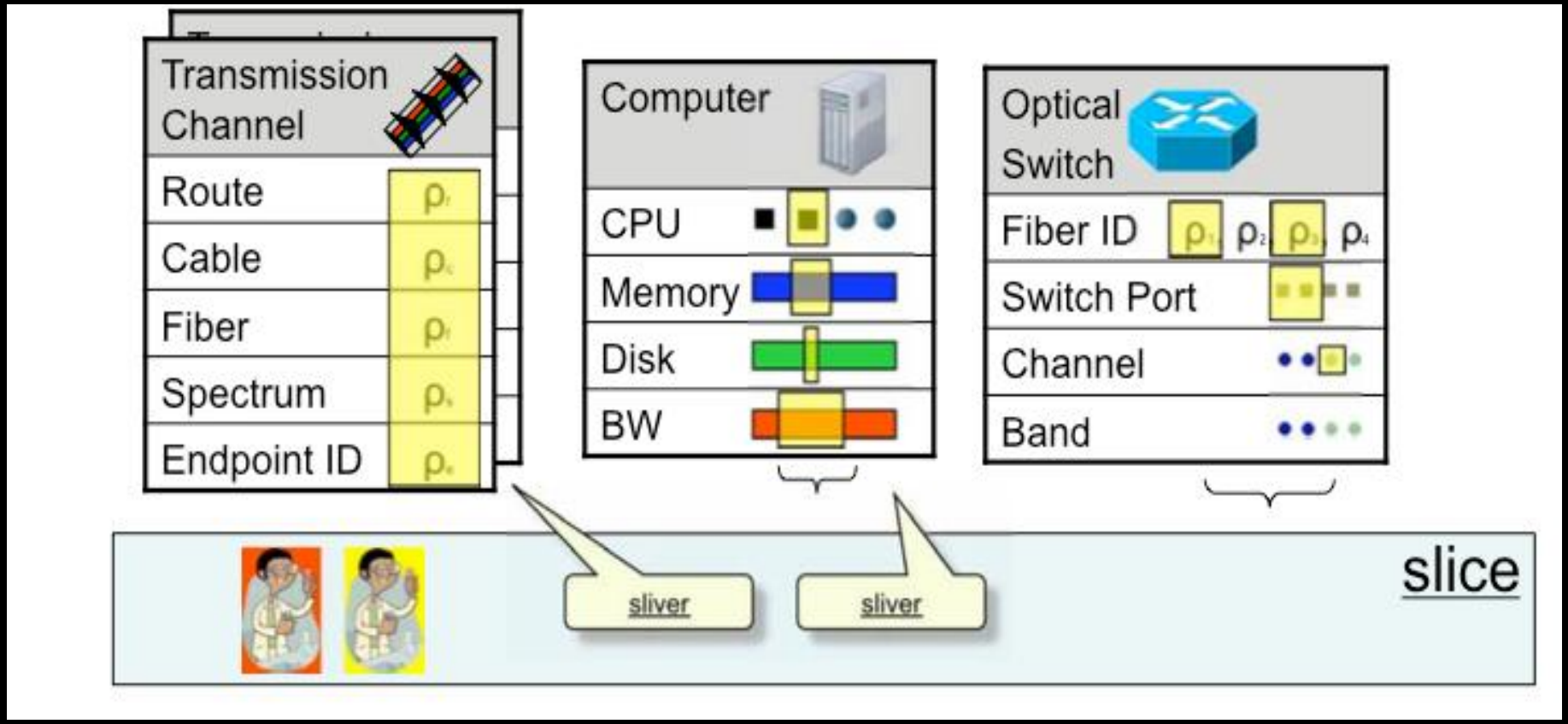
National Science Foundation's Global Environment for Network Innovations (GENI)

- GENI Is Funded By The National Science Foundation's Directorate for Computer and Information Science and Engineering (CISE)
- GENI Is a Virtual Laboratory For Exploring Future Internets At Scale.
- GENI Is Similar To Instruments Used By Other Science Disciplines, e.g., Astronomers – Telescopes, HEP - Synchrotrons
- GENI Creates Major Opportunities To Understand, Innovate and Transform Global Networks and Their Interactions with Society.
- GENI Is Dynamic and Adaptive.
- GENI Opens Up New Areas of Research at the Frontiers of Network Science and Engineering, and Increases the Opportunity for Significant Socio-Economic Impact.

GENI Slicers and Slivers



Source: BBN GENI Program Office

GENI Control Frameworks

- Four Primary Control Frameworks
  - Open Resource Control Architecture (ORCA)
  - ProtoGENI
  - PlanetLab
  - ORBIT
- Integrated Through The GENI Aggregate Manager API, Which
  - Specifies A Set Of Functions For Reserving Resources
  - Describes Common Format for Certificates And Credentials to Enable Compatibility Across All Aggregates

Related Projects

- **Multiple Innovative Network Research Initiatives Have Been Established Around the World**
  - **The National Science Foundation Funded Global Environment for Network Innovations (GENI)**
  - **The European Union Future Internet Research Environment (FIRE)**
  - **The Japanese New Generation Network (NGN)**
  - **The Korean Future Internet Initiatives**
  - **G-Lab At Kaiserslautern**
  - **And Many Others.**

iGENI: The International GENI

- The iGENI Initiative Has Been Designing, Developing, Implementing, and Operating a Major New National and International Distributed Infrastructure.
- iGENI Underscored the "G" in GENI Making GENI Truly Global.
- iGENI Is a Unique Distributed Infrastructure Supporting Research and Development for Next-Generation Network Communication Services and Technologies.
- This Infrastructure Has Been Integrated With Current and Planned GENI Resources, and Is Operated for Use by GENI Researchers Conducting Experiments that Involve Multiple Aggregates At Multiple Sites.
- iGENI Infrastructure Has Been Connected With Current GENI National Backbone Transport Network, With GENI Regional Transport Extensions, and With International Research Networks and Experimental Sites
-

International Federated Network Testbeds

- An International Consortium Has Created And Is Currently Continuing To Develop A Large Scale Distributed Environment (Platform) for Basic Network Science Research, Experiments, and Demonstrations.
- This Initiative Is Designing, Implementing, and Demonstrating An International Highly Distributed Environment (at Global Scale) That Can Be Used for Advanced Next Generation Communications and Networking.
- The Environment Is Much More Than "A Network" – Other Resources Include Programmable Clouds, Sensors, Instruments, Specialized Devices, and Other Resources.
- This Environment Is Based On Interconnections Among Major Network Research Centers Around the World

StarLight – "By Researchers For Researchers"

StarLight is an advanced national and international communication exchange facility optimized for high-performance data intensive applications

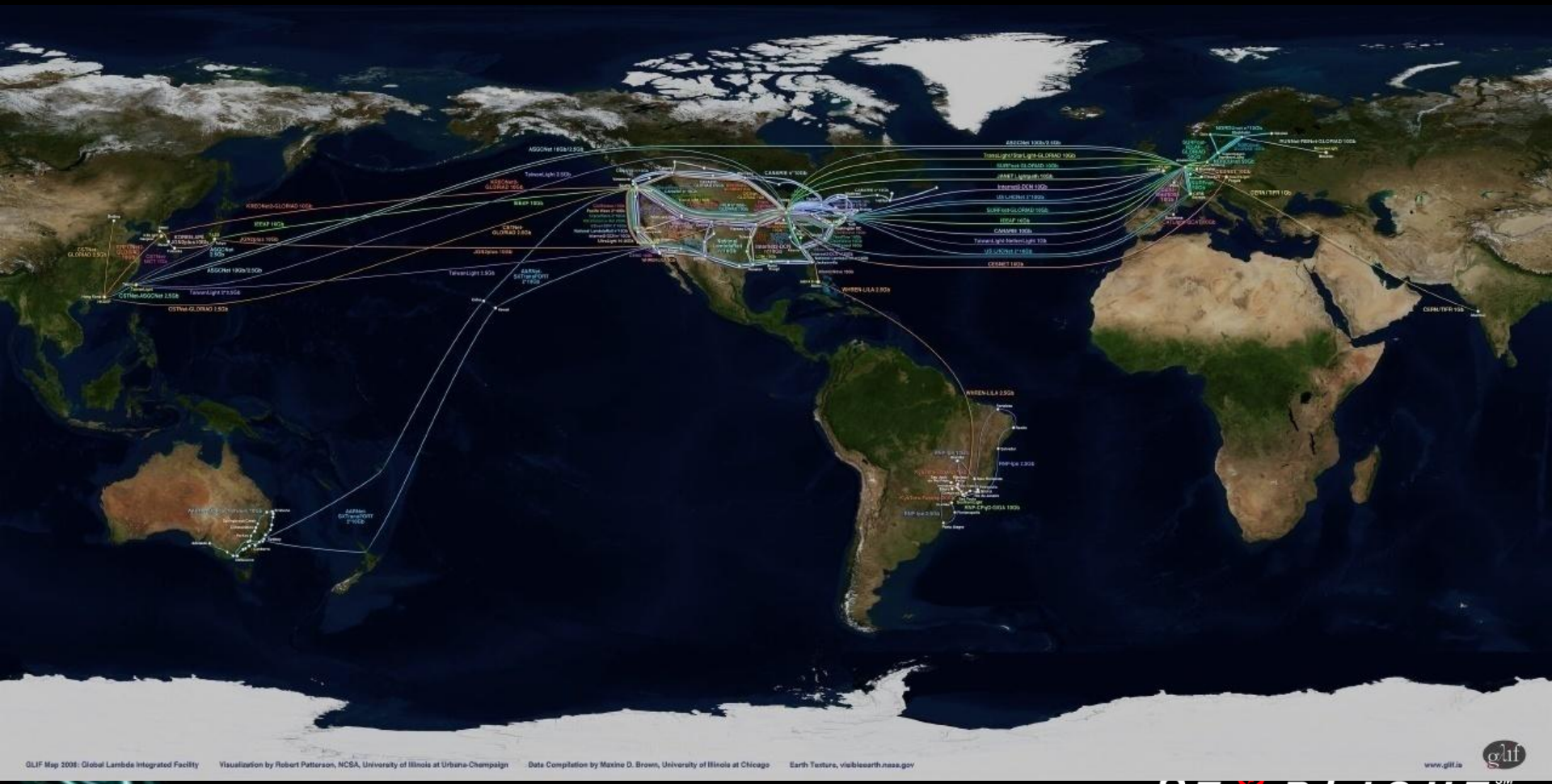
World's "Largest" 10G and 100 Gbps Exchange
Over 150 10 Gbps Channels
Interoperability Services
At All Layers

View from StarLight

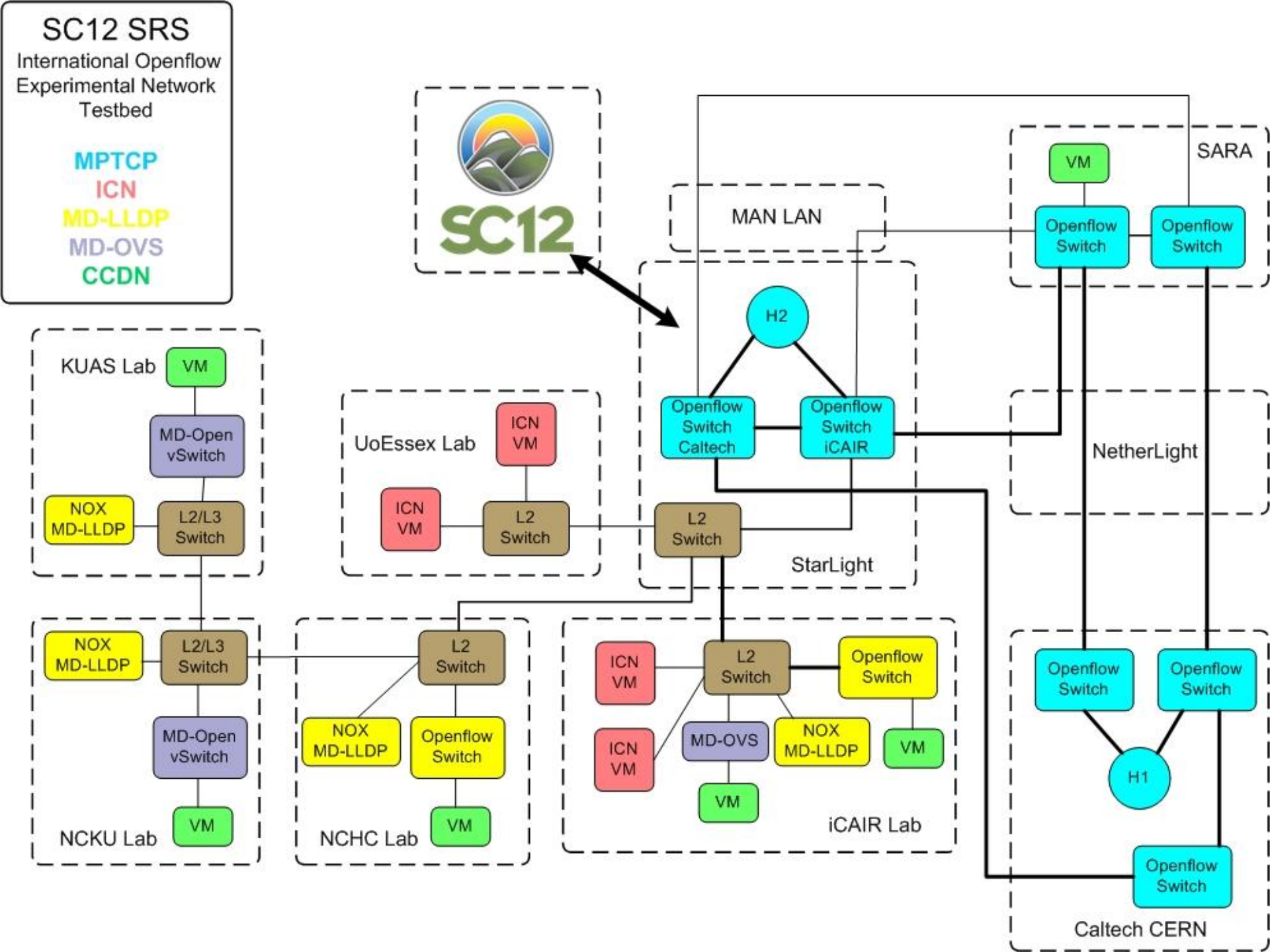
Abbott Hall, Northwestern University's Chicago downtown campus

STARLIGHT℠

The Global Lambda Integrated Facility (GLIF) Provides Advanced Resources and Facilities for Research Foundation Resource!




KUAS
NetFPGA
NOX
OpenFlow
NCKU
NetFPGA
NOX
OpenFlow
ETRI
NOX
OpenFlow
NetFPGA
University of Victoria
GENICloud
OpenFlow
InstaGENI
CRC
NOX
OpenFlow
NetFPGA
NLR
light the future
OpenFlow
JGN-X
東京大学
THE UNIVERSITY OF TOKYO
VNode
KiSTi
NCHC
NetFPGA
NOX
OpenFlow
KRLight
cenic
PACIFIC NORTHWEST GIGAPOP
OpenFlow
aarnet
NICTA
ExoGENI
OpenFlow
APPLIED RESEARCH CENTER FOR COMPUTER NETWORKS
OpenFlow
canarie
GLORIAD
SingLight
Northern Wave
hp
GENICloud
renci
ExoGENI
OpenFlow
SingAREN
OpenFlow
STARLIGHT
The Optical STAR TAP
MREN
OpenFlow
NLR
light the future
OpenFlow
BEN
Breakable Experimental Network
Duke
UNIVERSITY
ExoGENI
OpenFlow
NORTHWESTERN UNIVERSITY
NetFPGA
NOX
OpenFlow
GENICloud
InstaGENI
AMPATH
OpenFlow
INTERNET2
uen
UTAH EDUCATION NETWORK
OpenFlow
CPqD
OpenFlow
RNP
NLLight
NOX
OpenFlow
NetFPGA
THE UNIVERSITY OF UTAH
OpenFlow
InstaGENI
USP
InstaGENI
UNIVERSITY OF AMSTERDAM
ExoGENI
MAGPI
Princeton University
OpenFlow
InstaGENI
GENICloud
TECHNISCHE UNIVERSITÄT KAISERSLAUTERN
DFN
Deutsches Forschungsnetz
GEANT2
ja.net
University of BRISTOL
OpenFlow
University of Essex
OpenFlow
grnet
Belnet
dedicated connectivity
iMinds
CONNECT.INNOVATE.CREATE
InstaGENI


SC12 SRS
International Openflow Experimental Network Testbed
MPTCP
ICN
MD-LLDP
MD-OVS
CCDN
SC12
MAN LAN
SARA
VM
Openflow Switch
Openflow Switch
H2
Openflow Switch Caltech
Openflow Switch iCAIR
NetherLight
KUAS Lab
VM
MD-Open vSwitch
NOX MD-LLDP
L2/L3 Switch
UoEssex Lab
ICN VM
ICN VM
L2 Switch
L2 Switch
StarLight
NOX MD-LLDP
L2/L3 Switch
MD-Open vSwitch
VM
NCKU Lab
L2 Switch
NOX MD-LLDP
Openflow Switch
VM
NCHC Lab
ICN VM
ICN VM
L2 Switch
Openflow Switch
MD-OVS
NOX MD-LLDP
VM
VM
iCAIR Lab
Openflow Switch
Openflow Switch
H1
Openflow Switch
Caltech CERN

Multiple Experiments Share A Persistence International Openflow Testbed

- **MPTCP: Multi-Path TCP**

Lead: SARA, Surfnet, Caltech, CERN

- **ICN: Information Centric Networking**

Lead: University of Essex

- **MD-LLDP: Multi-Domain Openflow Topology Discovery and Management with LLDP**

Lead: NCHC, Taiwan

- **ML-OVS: Multi-Layers Open vSwitch networking**

Lead: KUAS, NCKU, Taiwan

- **CCDN: Content Centric Distributed Network**

Lead: iCAIR

iCAIR

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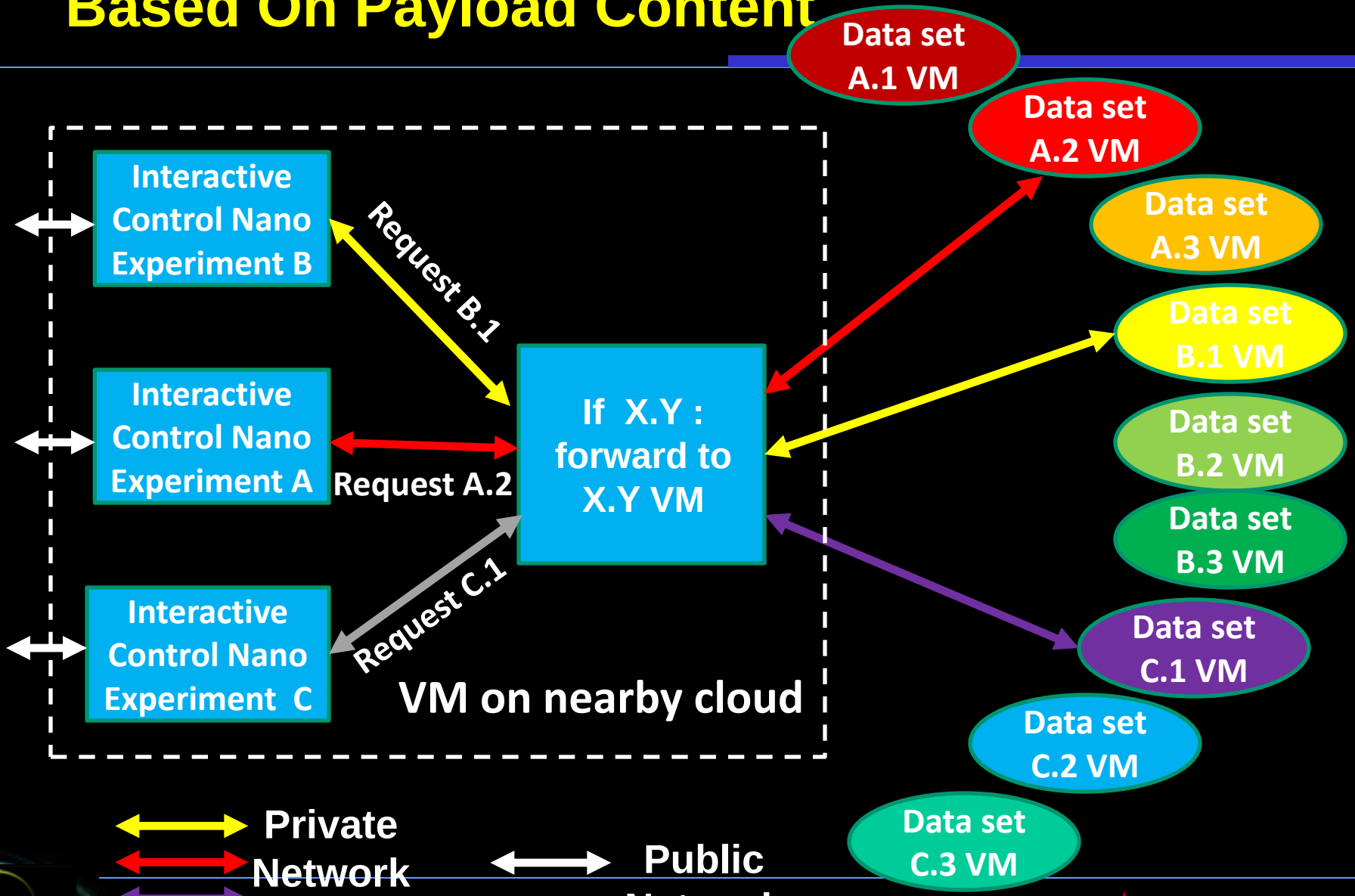
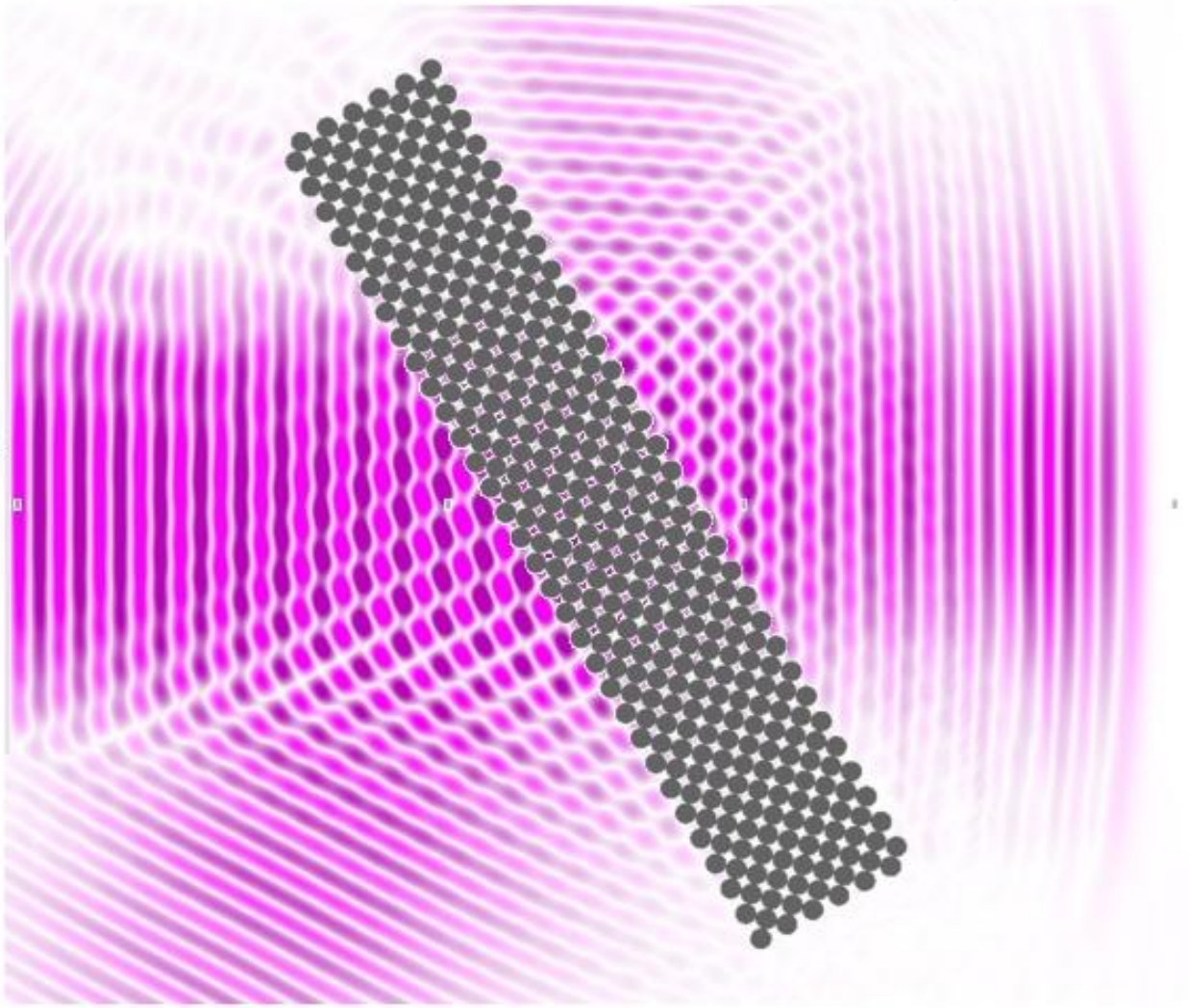
Initial Selected Application: Scientific Visualization For Nanotechnology –Viewing Scope For Invisible Objects

- Creating A Viewing Scope for Invisible Objects
- Based on Ad Hoc Networking Provisioning and Use
- Dynamic Change Including for Rendering in Real Time (e.g., Incorporates Real-Time Data Viewing/Steering)
- Demonstrates Capabilities Not Possible to Accomplish Today Using the General Internet or Standard R&E Networks
- Customizable Networking Specific To Application Requirements -- at Network Edge.
- Resolves A Real Current Challenge, Although The Platform Is Oriented to Providing Suites Of Capabilities

Slice Using Forwarding Rules Based On Payload Content



Photonic Band Gap



← 11140 nanometers →

Click the picture to zoom in (picture will appear in a new window)

1. Choose the color of light source.
Wavelength appears in nm

Violet (380 **nm)**

300 nm 980

Magnitude

\- 0 +

2. Choose particle size in nanometers

particle size is 200 **nm**

200 nm 380

3. Choose incident angle in degrees

Incident angle is 30 °

0 ° 45

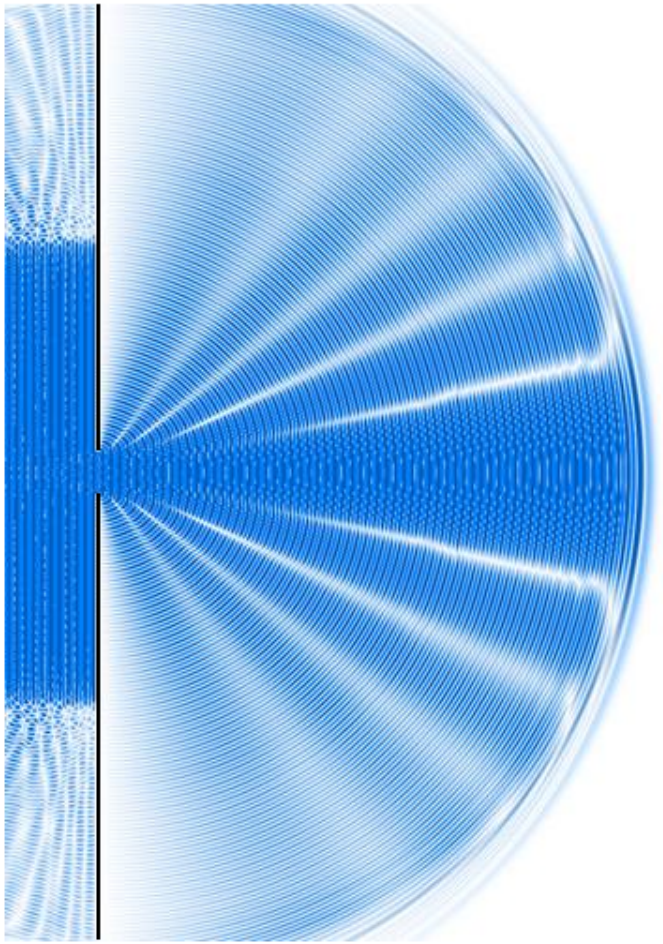
Preview

4. Watch the animation

> ||

1 **Frame # 13 , time is 39 fs** 15

This simple educational tool simulates a single slit experiments for parameters such as different slit size and different incident light wavelength.



Click the picture to zoom in (picture will appear in a new window)

1. Choose the color of light source. Wavelength appears in nanometers

Indigo(465 nm)

380 nm 680

2. Choose slit size in multiples of incident wavelength

Aperture size is 5 λ

0.5λ 10λ

3. Run test and watch the animation

Run Test | Animate | Stop

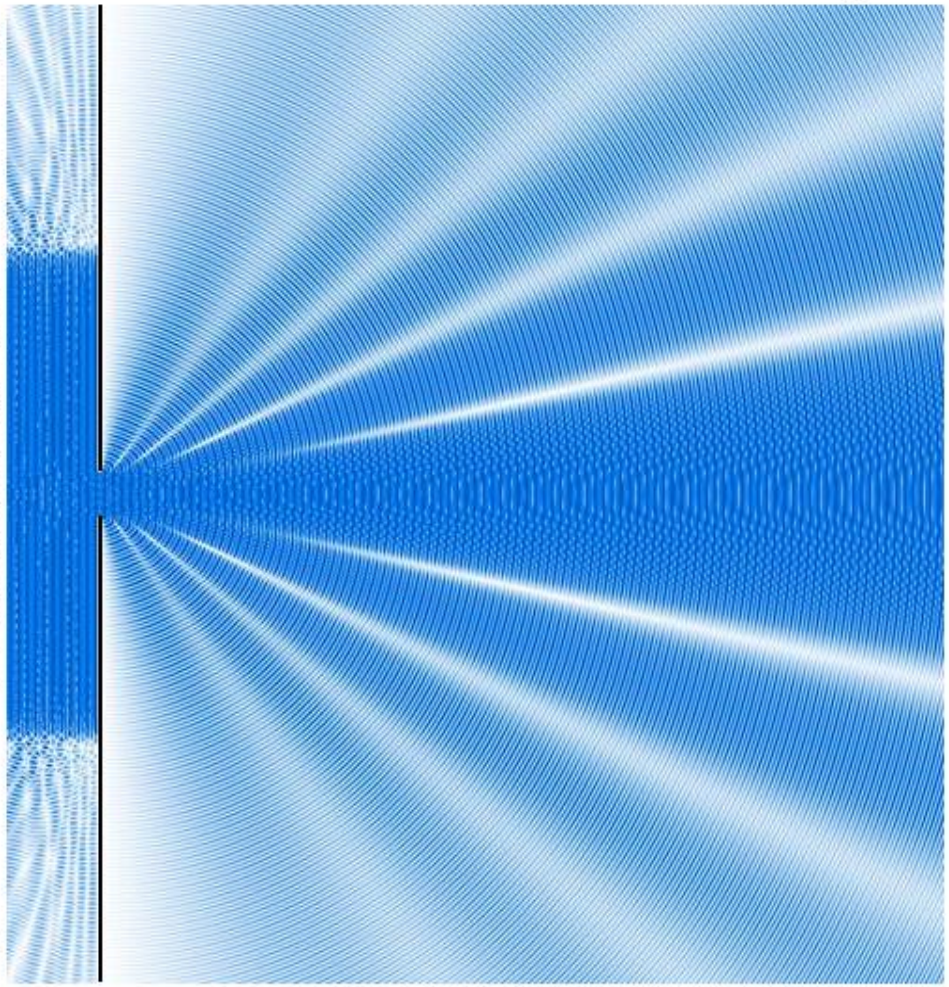
1 15

Frame # 5, time is 115fs

Legend

-2550 0 2550

This simple educational tool simulates a single slit experiments for parameters such as different slit size and different incident light wavelength.



Click the picture to zoom in (picture will appear in a new window)

1. Choose the color of light source. Wavelength appears in nanometers

Indigo(465 nm)

380 nm 680

2. Choose slit size in multiples of incident wavelength

Aperture size is 5 λ

0.5λ 10λ

3. Run test and watch the animation

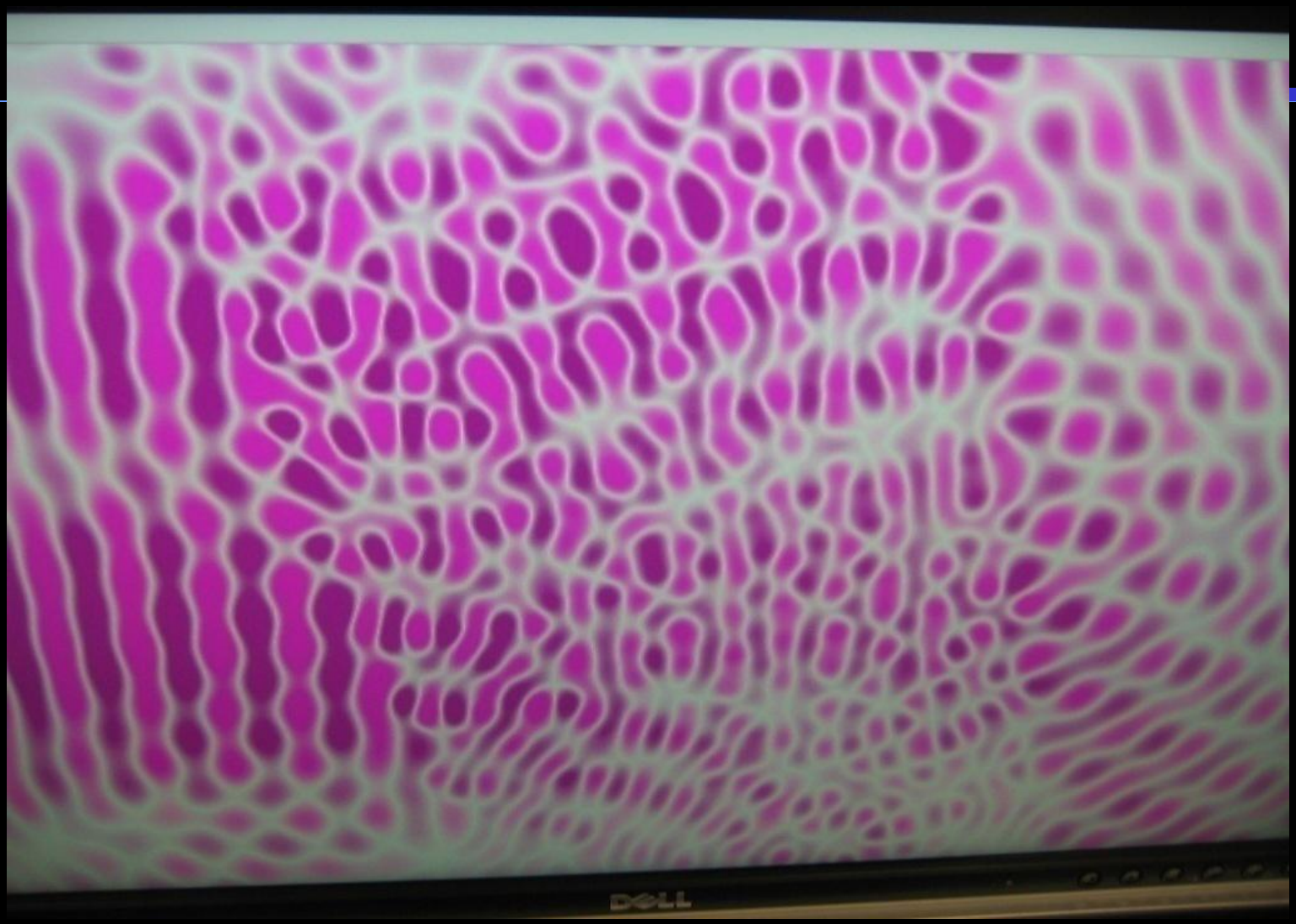
Run Test | Animate | Stop

1 15

Frame # 11, time is 253fs

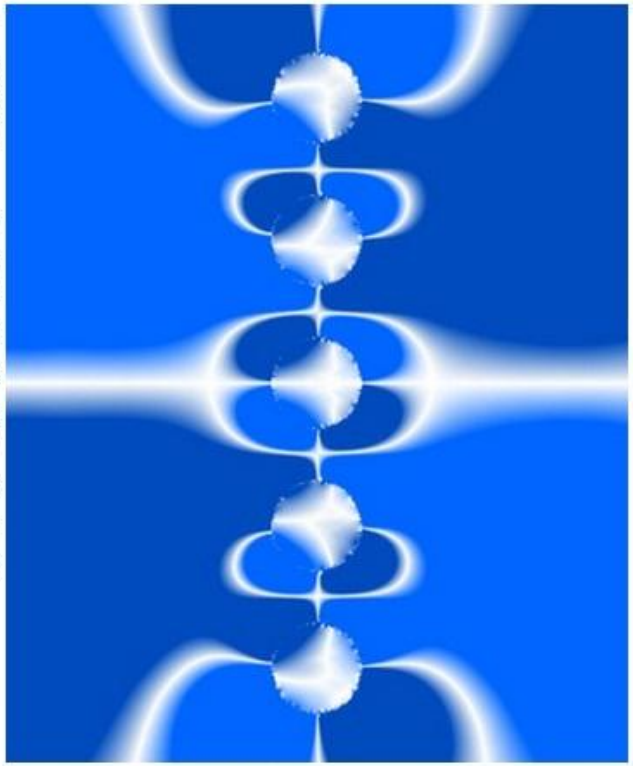
Legend

-2550 0 2550


DELL

Content Centric Distribution Network

Silver nano chain simulation



Click the picture to zoom in (picture will appear in a new window)

1. Choose the color of light source. Wavelength appears in nm

Indigo (460 nm)

300 nm 700

Electric Field

\- 0 +

2. Choose particle radius (in nanometers)

particle radius is 35 nm

5 nm 40

3. Choose distance between nanoparticles in nm

gap is 40 nm

0 nm 50

4. Choose Type of simulation

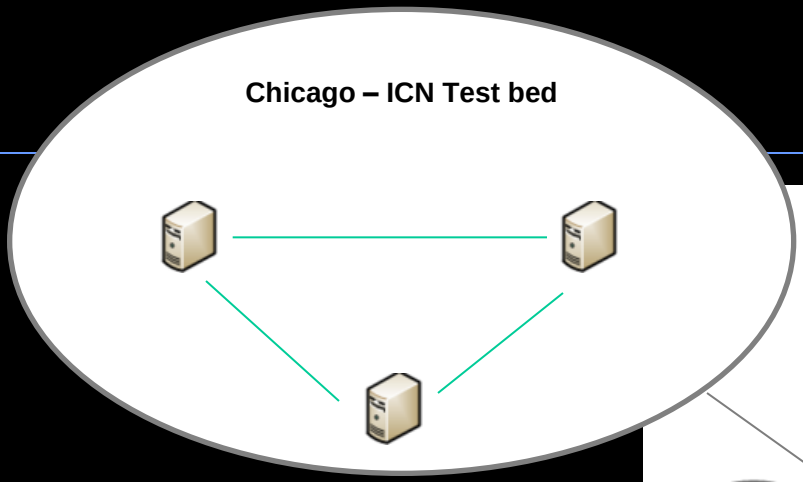
Type is Ey Only

Energy Ex only Ey only

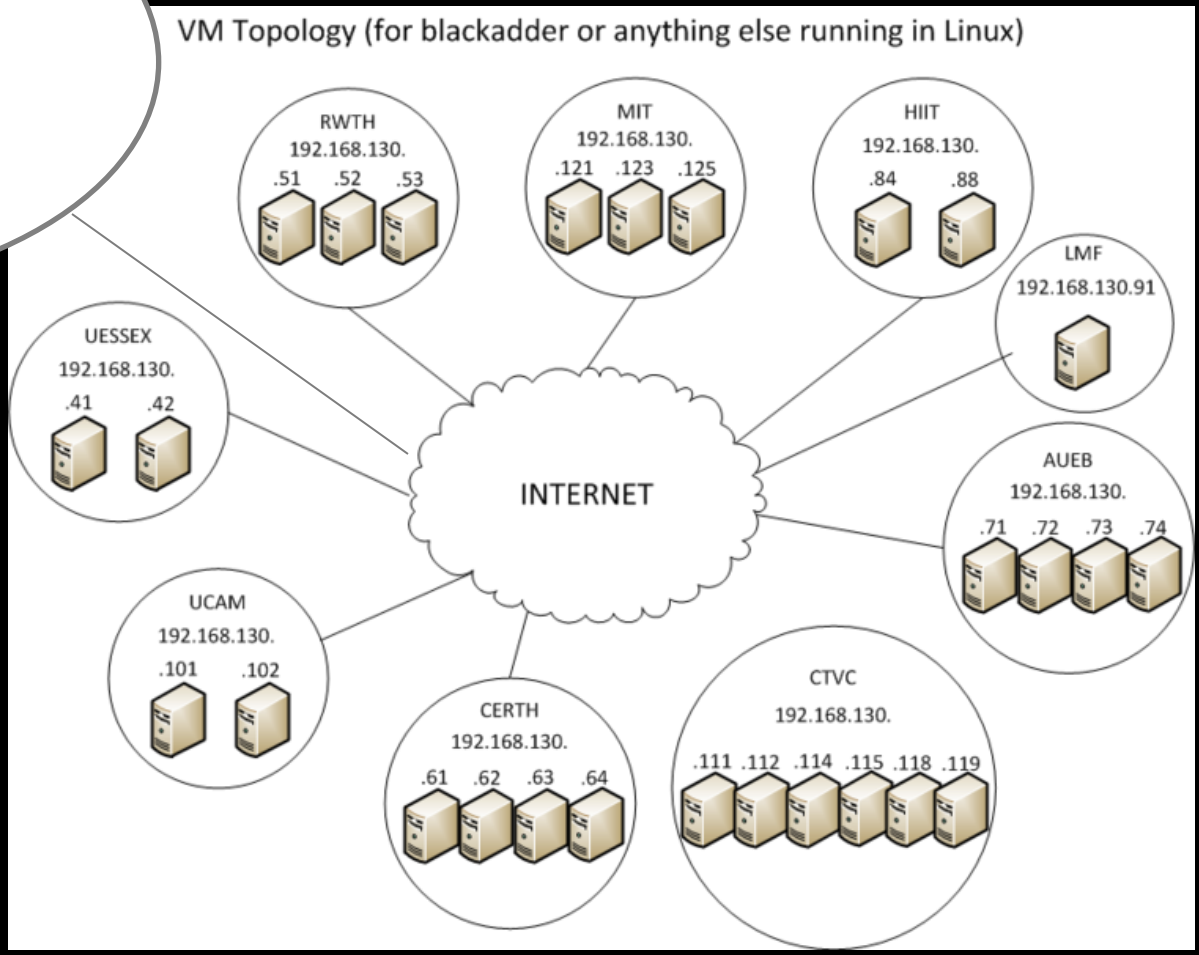
5. Watch the animation

1 **Frame # 37 , time is 5.55 fs** 37 > ||

Information Centric Network



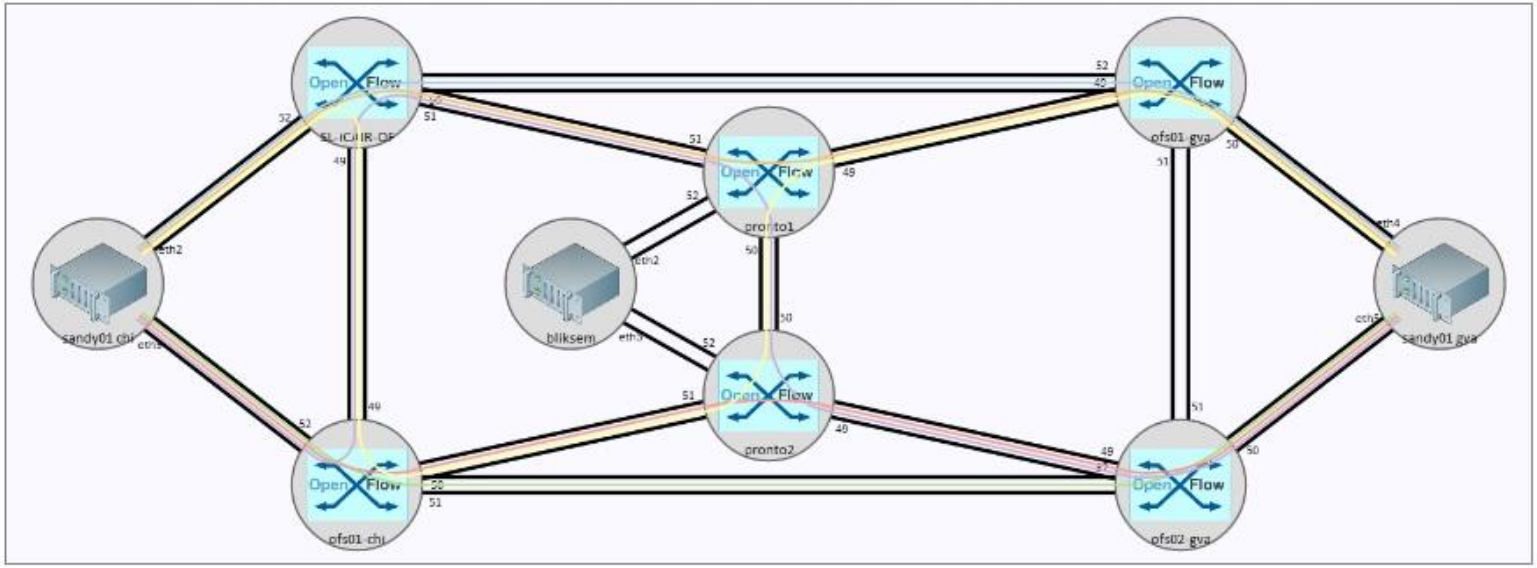
Beyond IP -- Content Routed Networking



Slide Provide by University of Essex

Paper on This Experiment/Demonstrated Accepted By SC Proceedings

Multipath TCP streaming from Geneva to Chicago over OpenFlow controlled paths



Demo partners:

iCAIR

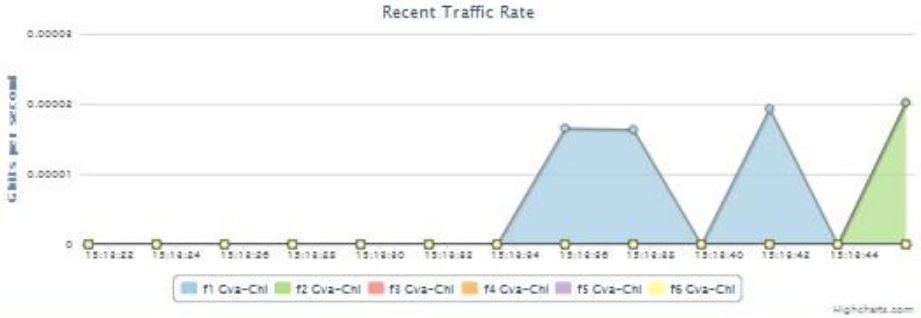
sara

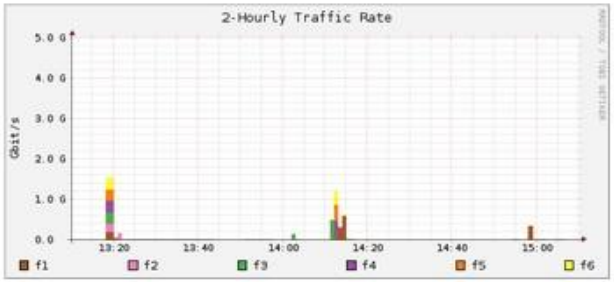
SURFNET

Current Traffic Rate

Name	Bandwidth
f1 Gva-Chi	0.00 b/s
f2 Gva-Chi	20.22 kb/s
f3 Gva-Chi	0.00 b/s
f4 Gva-Chi	0.00 b/s
f5 Gva-Chi	0.00 b/s
f6 Gva-Chi	0.00 b/s
Total	20.22 kb/s

Reset to defaults
Start Measurements
Stop Measurements



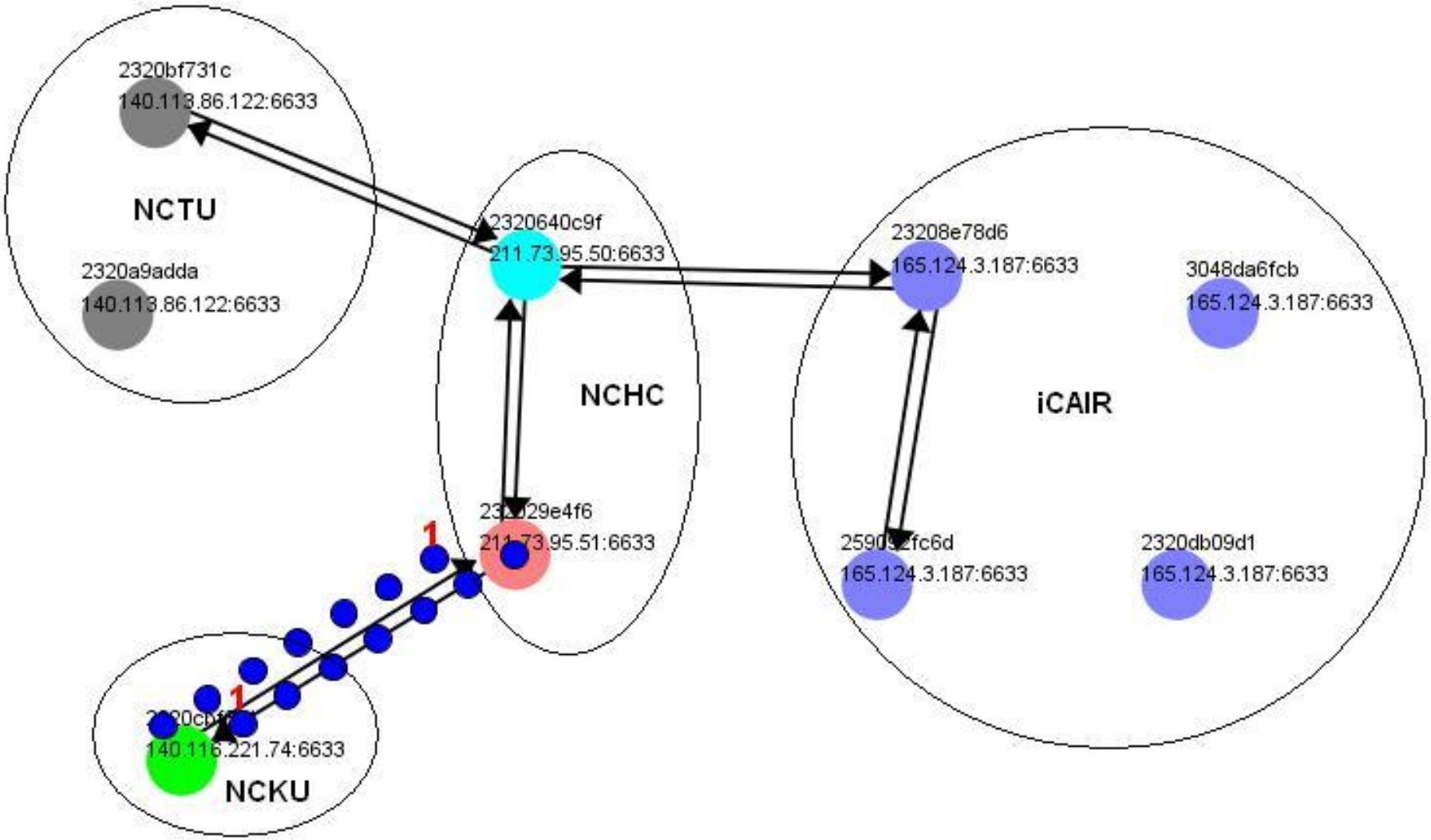


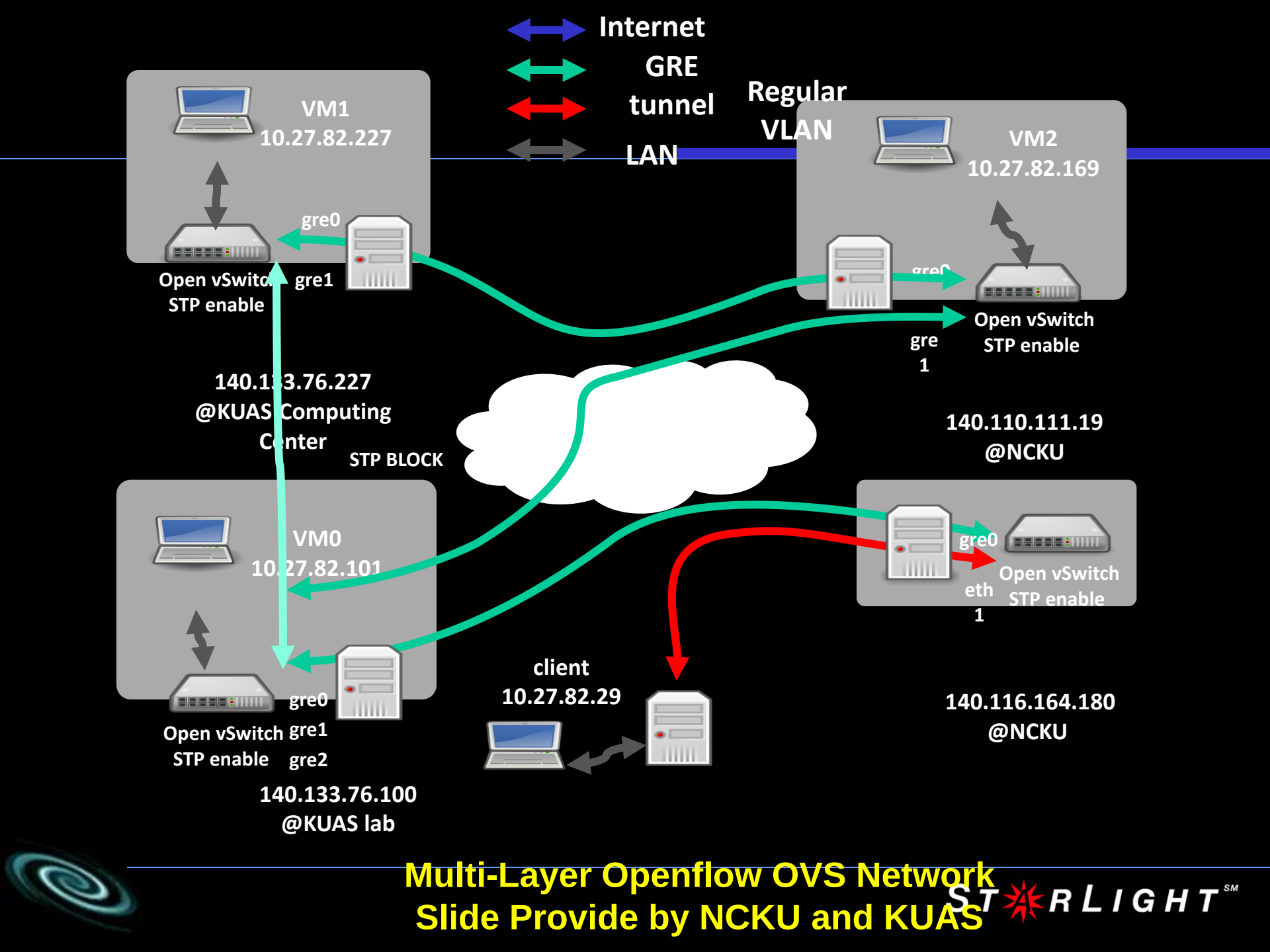
ow f1 Gva-Ams ends at [Port 50 of 00:00:e8:9a:8f:d2:80:57 (ofs01-gva)] (no flow entry for IP 10.0.200.2)
ow f2 Gva-Ams ends at [Port 50 of 00:00:60:eb:69:fe:49:14 (ofs02-gva)] (no flow entry for IP 10.0.201.2)
ow f3 Gva-Ams ends at [Port 50 of 00:00:60:eb:69:fe:49:14 (ofs02-gva)] (no flow entry for IP 10.0.202.2)

Slide Provide by Caltech,SARA, Surfnet

STARLIGHT SM

Inter-Domain Openflow
Topology Discovery & Monitoring
Slide Provide By NCHC (Paper on Technique Accepted for Publication)





Multi-Layer Openflow OVS Network
Slide Provide by NCKU and KUAS

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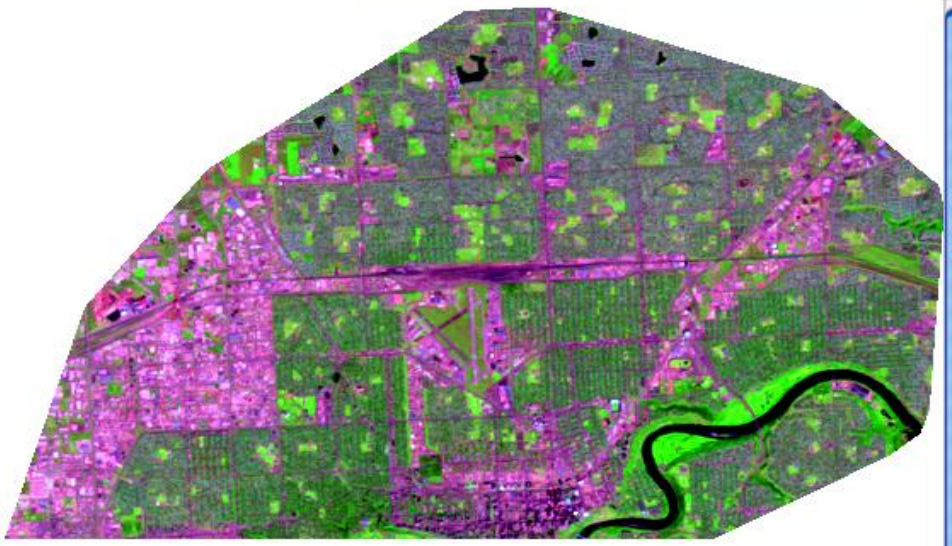
TransGeo: An Open, Distributed, Federated GIS/System Cloud –Rick McGeer Chris Matthews et al

- GIS Data Is Large, Collected By Many Sources, Needed All Over the World
- Use Today Is Mostly Desktop Fat Clients (Quantum GIS, ESRI)
- Many Want to Compute in the Cloud
- Open and Available To Everyone
- Distributed Swift as Federated Store
- Distributed Disco as MapReduce Computation Engine
- Open-Source Standard Tools For Point Computation (GRASS, GDAL)

green.cities.trans-cloud.net:8080/geoserver/www/maps/view.html



GreenCities Demo

A demonstration of TransGeo, an open-source multisite GIS Cloud developed at the University of Victoria

Big Data jobs are a key use case for federating clouds at multiple sites. In this project, we are developing a prototype open-source system to demonstrate Big Data processing at multiple sites. This system uses a single PostGIS database as a repository for meta-data, and landsat (or other) satellite image data in Swift repositories, and distributed Disco jobs to do the analysis

bing™

Image courtesy of NASA © 2012 Microsoft Corporation

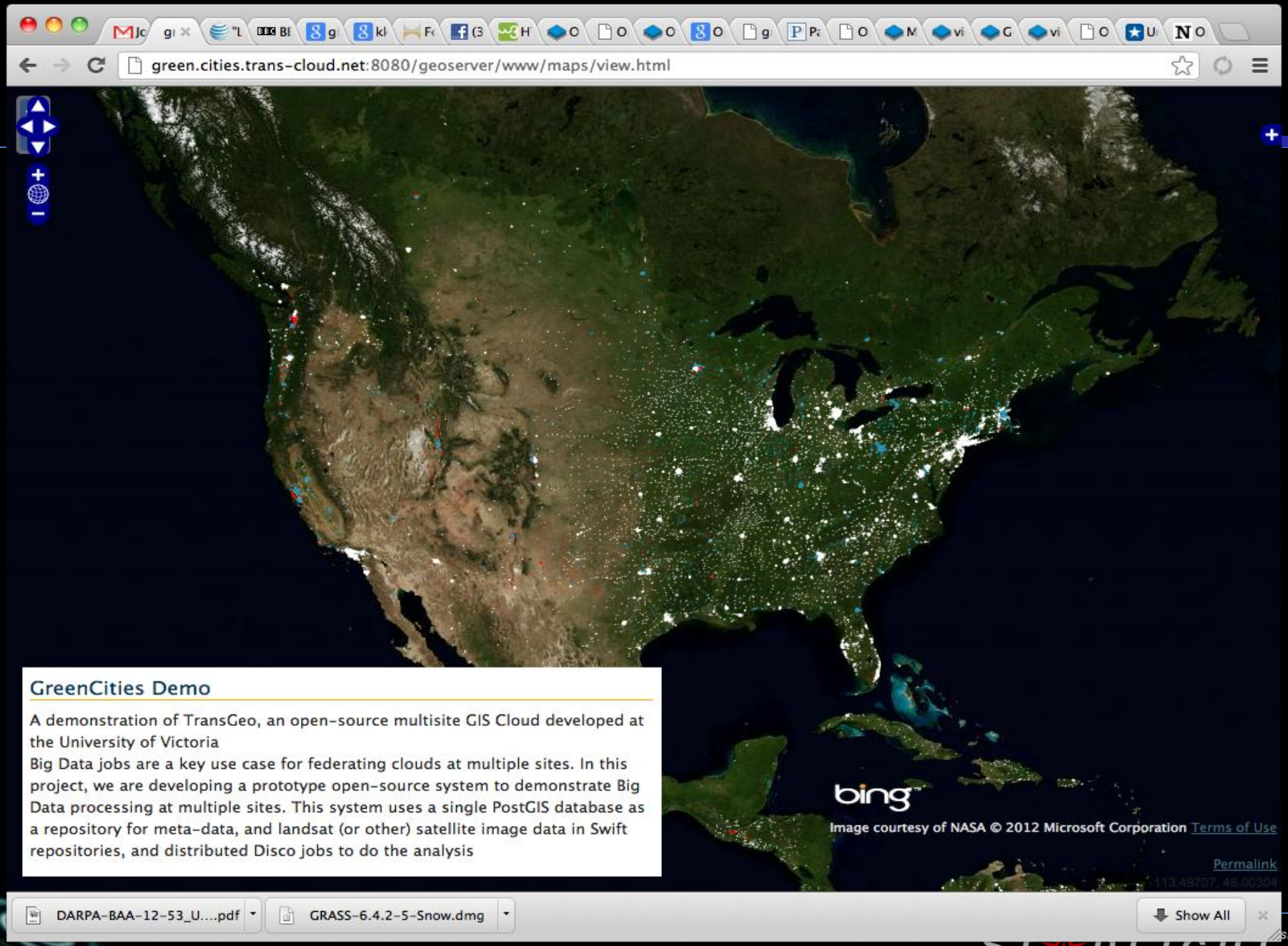
-113.55200, 53.55856

DARPA-BAA-12-53_U....pdf

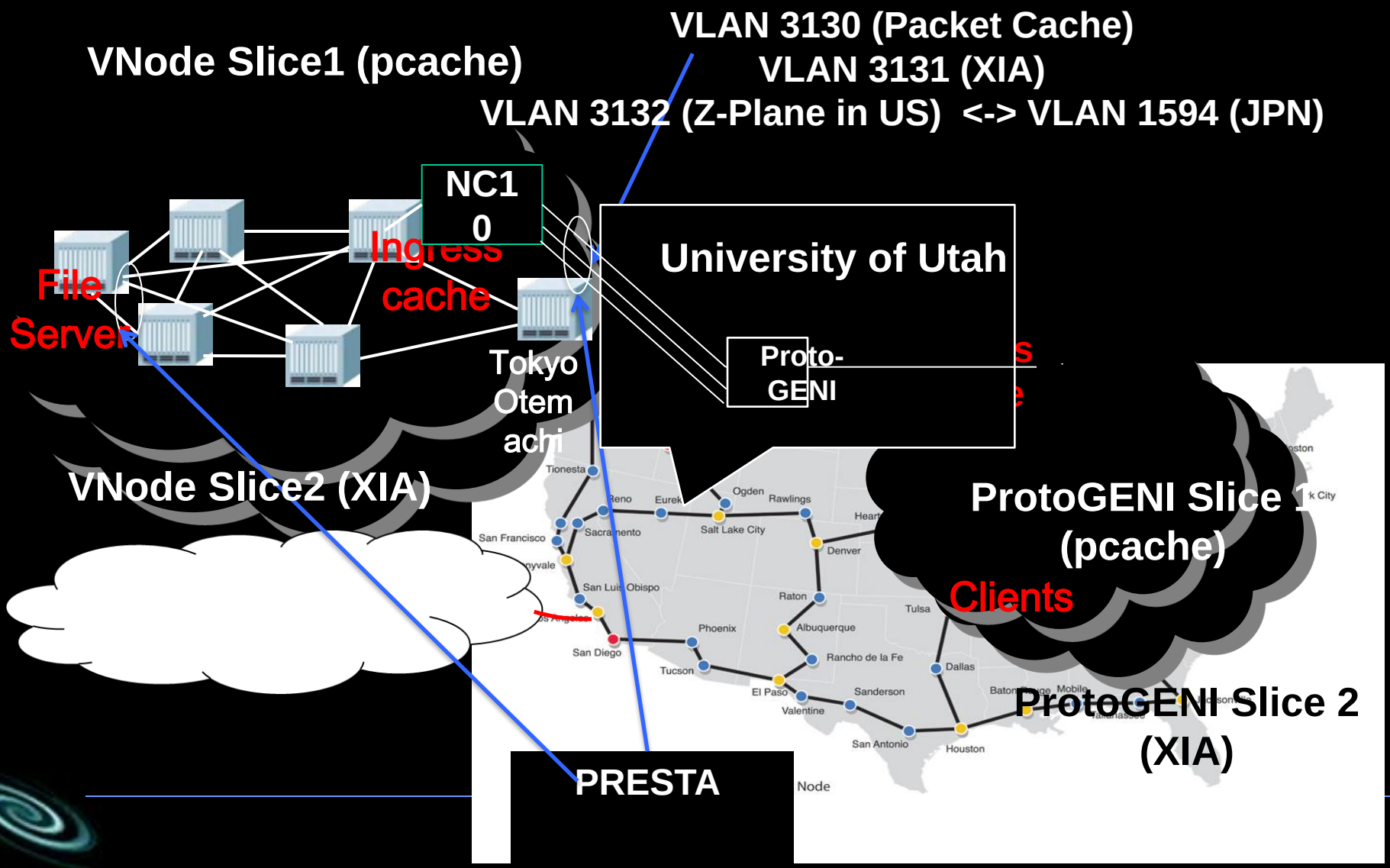
GRASS-6.4.2-5-Snow.dmg

Show All

STARLIGHT SM


green.cities.trans-cloud.net:8080/geoserver/www/maps/view.html
GreenCities Demo
A demonstration of TransGeo, an open-source multisite GIS Cloud developed at the University of Victoria
Big Data jobs are a key use case for federating clouds at multiple sites. In this project, we are developing a prototype open-source system to demonstrate Big Data processing at multiple sites. This system uses a single PostGIS database as a repository for meta-data, and landsat (or other) satellite image data in Swift repositories, and distributed Disco jobs to do the analysis
bing
Image courtesy of NASA © 2012 Microsoft Corporation Terms of Use
Permalink
DARPA-BAA-12-53_U....pdf
GRASS-6.4.2-5-Snow.dmg
Show All

Aki Nakao's Packet Cache and XIA



Demonstrations

- The 14th GENI Engineering Conference (GEC 14) July 9-11 in Boston Massachusetts
- EuroView2012 the 12th Würzburg Workshop on IP: ITG Workshop "Visions of Future Generation Networks“ July 23-24 in Würzberg, Germany, Co-Hosted By G-Lab (Paul Muller)
- AsiaFI Network Virtualization Workshop, Kyoto, Japan, August 23rd, 2012 (Aki Nakao)
- The 1st Federated Clouds Workshop and the 7th Open Cirrus Summit Co-Located With the International Conference on Autonomic Computing on September 21in San Jose, California
- The Global LambdaGrid (GLIF) Workshop in Chicago on October 10-12, co located with the IEEE e-Science Conference , the Microsoft e-Science Conference and the Open Grid Forum (OGF)
- The 15th Annual GENI Engineering Conference (GEC 15) In Oct in Houston, Texas
- The SC12 International Supercomputing Conference on November 10-16 in Salt Lake City. Utah.
- The 16th Annual GENI Engineering Conference (GEC 16) March Salt Lake City, Utah

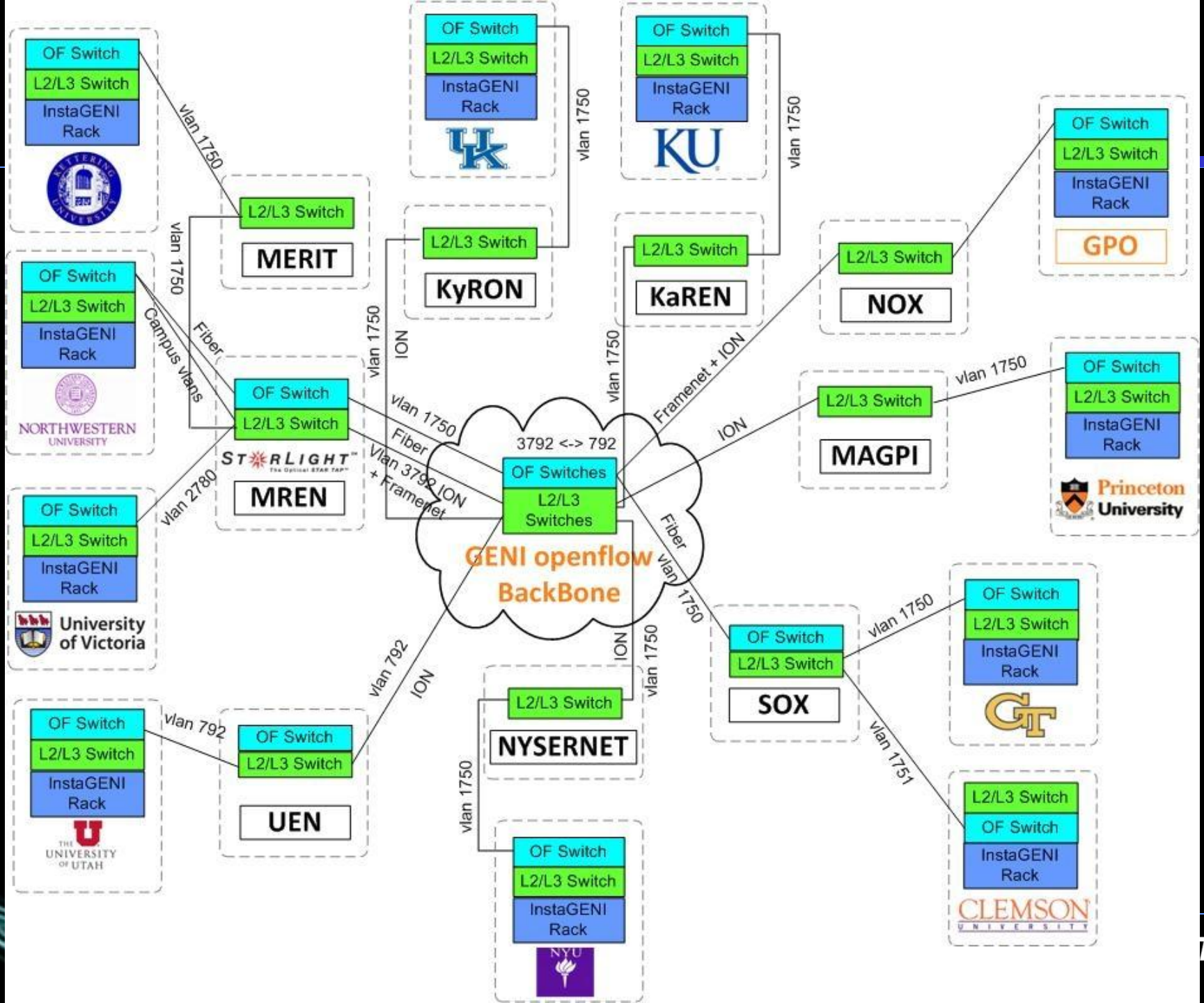
InstaGENI

www.geni.net

LIGHT℠

InstaGENI

- An Innovative Highly Programmable Distributed Environment for Network Innovation
- Ref: Details at the GENI Engineering Conference in LA, in March 2012
- Multiple Organizational Partners
  - HP Research Labs (Rick McGeer et al), iCAIR, Northwestern University, Princeton University, University of Utah, GENI Program Office, New York University, Clemson, Rutgers, Navel Post Graduate School, Virginia Tech, UCSD, UCI, Texas A&M, George Mason University, University of Connecticut, University of Hawaii, Georgia Tech, Vanderbilt, University of Alabama, University of Alaska, Many International Universities, StarLight Consortium, Metropolitan Research and Education Network (MREN), StarLight, MAX, SOX,
  - University of California at San Diego, Stanford, Kettering University, University of Idaho, etc.


OF Switch
L2/L3 Switch
InstaGENI Rack
vlan 1750
MERIT
KyRON
KaREN
NOX
GPO
Campus vlans
Fiber
ION
NORTHWESTERN UNIVERSITY
STARLIGHT
MREN
vlan 2780
vlan 792
Framenet + ION
MAGPI
Princeton University
3792 <-> 792
OF Switches
L2/L3 Switches
GENI openflow BackBone
Vlan 3792 ION + Framenet
University of Victoria
SOX
vlan 1751
NYSERNET
UEN
THE UNIVERSITY OF UTAH
CLEMSON UNIVERSITY
NYU

TransCloud Experiments and Demonstrations

Alvin AuYoung, Andy Bavier, Jessica Blaine, Jim Chen, Yvonne Coady, Paul Muller, Joe Mambretti, Chris Matthews, Rick McGeer, Chris Pearson, Alex Snoeren, Fei Yeh, Marco Yuen

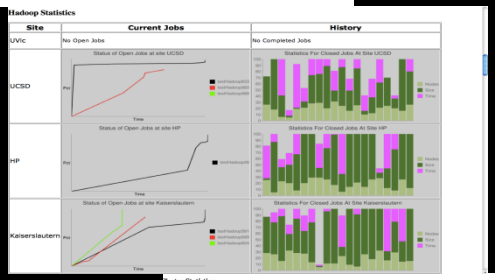
TransCloud Today

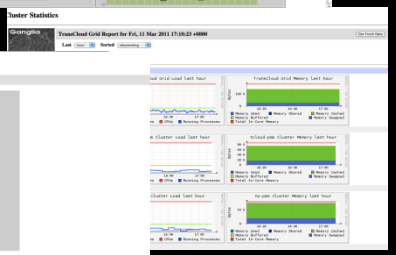
TransCloud: Based on iGENI and GENICloud

- Transcontinental Federation of Cloud Systems
- Slice-Based Federation Architecture for sign on and trans-cluster slice management
- SFA cluster manager at each site
  - Currently, enhanced Eucalyptus
- Private 10 Gb/s transcontinental network linking sites
  - Thanks to GLIF, NLR, NetherLight, CAVEWave, StarLight, DFN

Roadmap

- Accept experimenters ***now***
- Federation expansion
  - TU Amsterdam immediately
  - Brazil, Asia by July
  - All interested parties at any time
- Full integration with PlanetLab Control Framework (July)
- High-level programming environment based on RePy and NaCl
- High-level distributed query environment





Example of working in the TransCloud

[1] Build trans-continental applications spanning clouds:

- **Distributed query application based on Hadoop/Pig**
- **Store archived Network trace data using HDFS**
- **Query data using Pig over Hadoop clusters**

[2] Perform distributed query on TransCloud, which currently spans the following sites:

- **HP OpenCirrus**
- **Northwestern OpenCloud**
- **UC San D**
- **Kaiser**

- **Use By Outside Researchers? Yes**
- **Use Involving Multiple Aggregates? Yes**
- **Use for Research Experiments? Yes**

Also Ref: Experiments in High Perf Transport at GEC 7

Demo: http://tcdemo.dyndns.org/

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GEC 10 Demonstrations
TransCloud: A Distributed Environment Based On Dynamic Networking

Rick McGeer, HP Labs
Joe Mambretti, Northwestern
Paul Müller , TU Kaiserslautern
Chris Matthews, Chris Pearson, Yvonne Coady, Victoria
Jim Chen, Fei Yeh, Northwestern
Andy Bavier, PlanetWorks
Marco Yuen, Princeton
Jessica Blaine, Alvin Au Young, HP Labs
Alex Snoeren, UC San Diego

March 16, 2010

http://www.icair.org

http://www.geni.net

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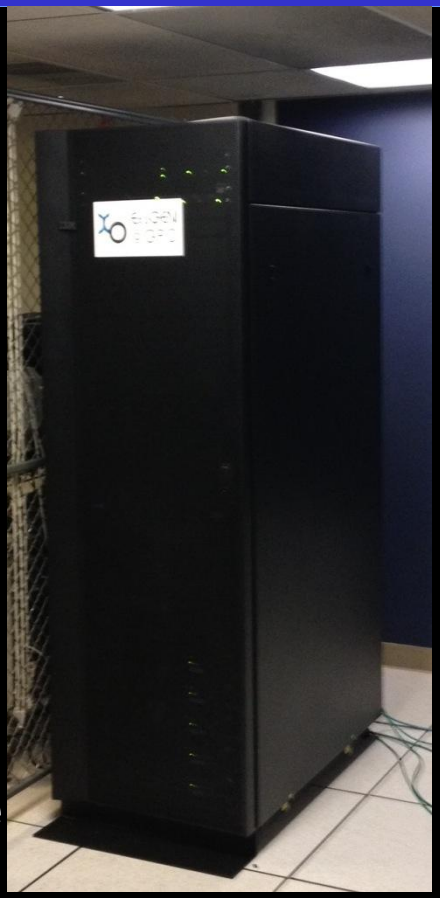
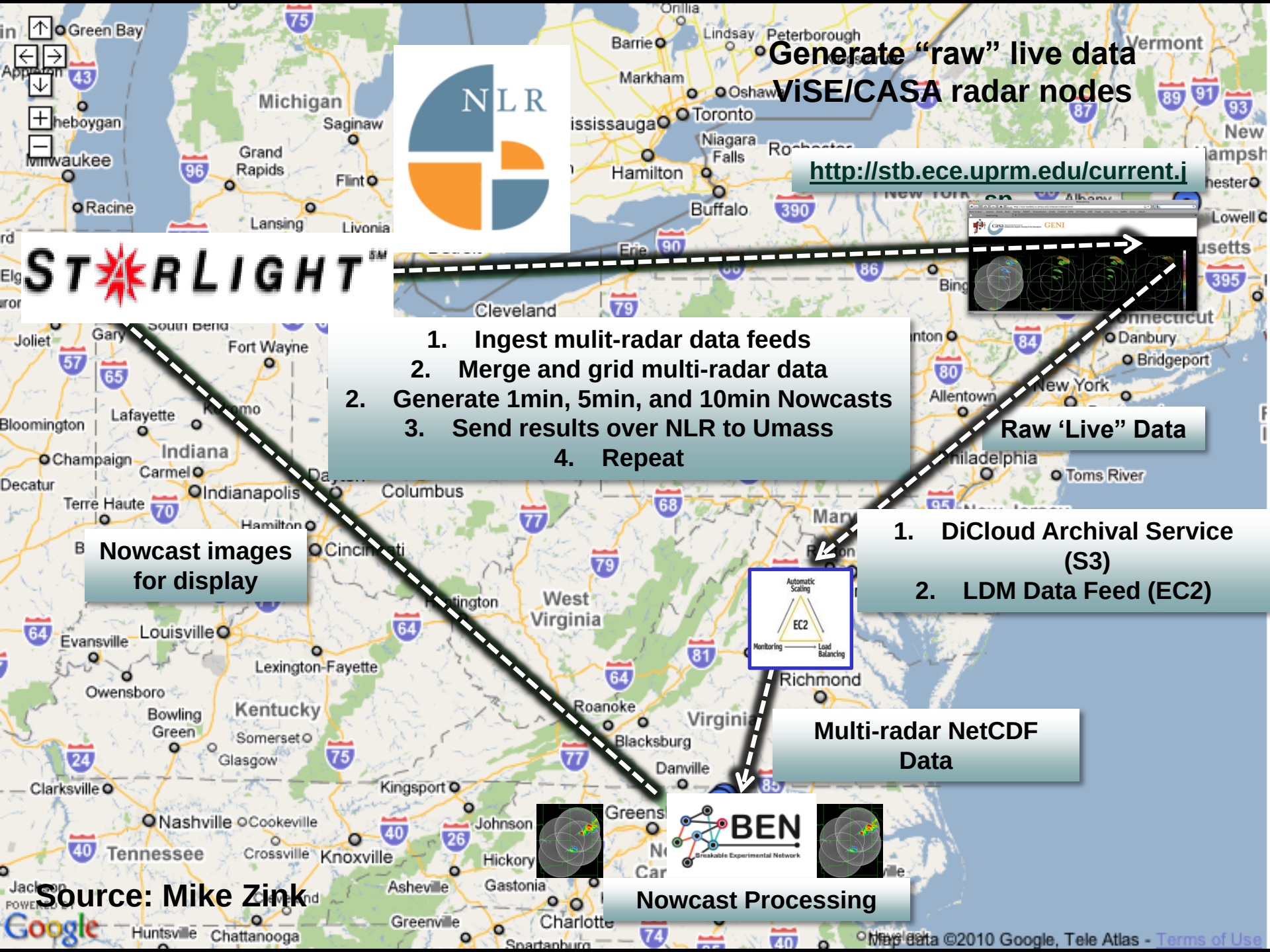
ExoGENI Testbed

- 14 GPO-funded racks
  - Partnership between RENCI, Duke and IBM
  - IBM x3650 M3/M4 servers
    - 1x146GB 10K SAS hard drive +1x500GB secondary drive
    - 48G RAM 1333Mhz
    - Dual-socket 6-core Intel X5650 2.66Ghz CPU
    - Dual 1Gbps adapter
    - 10G dual-port Chelseo adapter
  - BNT 8264 10G/40G OpenFlow switch
  - DS3512 6TB sliverable storage
    - iSCSI interface for head node image storage as well as experimenter slivering
- Each rack is a small networked cloud
  - OpenStack-based (some older racks run Eucalyptus)
  - EC2 nomenclature for node sizes (m1.small, m1.large etc)
  - Interconnected by combination of dynamic and static L2 circuits through regionals and national backbones
- http://www.exogeni.net

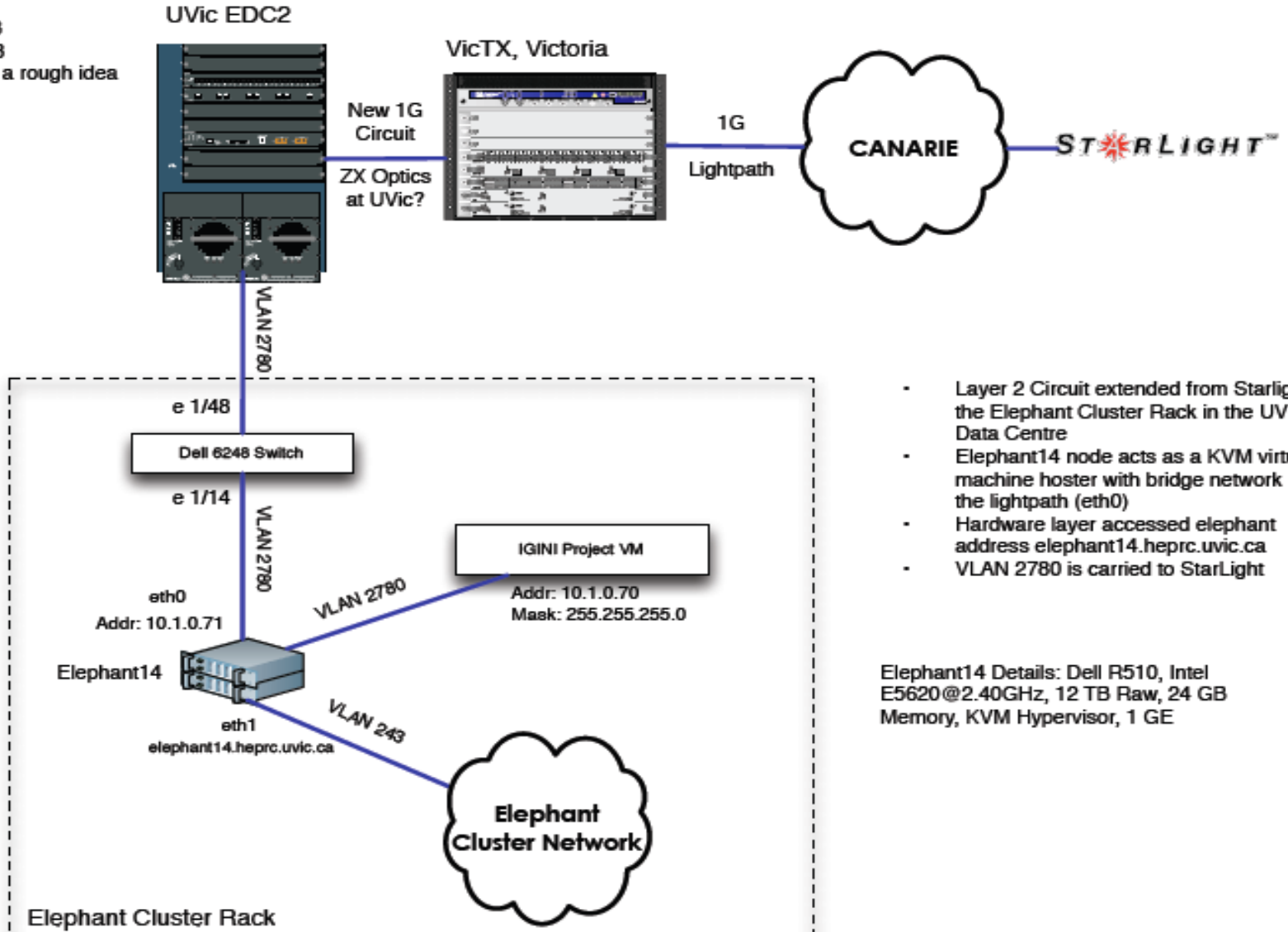


Source Ilia Baldine


Generate “raw” live data
ViSE/CASA radar nodes
NLR
STARLIGHT
http://stb.ece.uprm.edu/current.j
1. Ingest mulit-radar data feeds
2. Merge and grid multi-radar data
2. Generate 1min, 5min, and 10min Nowcasts
3. Send results over NLR to Umass
4. Repeat
Raw ‘Live” Data
1. DiCloud Archival Service (S3)
2. LDM Data Feed (EC2)
Nowcast images for display
Multi-radar NetCDF Data
BEN
Nowcast Processing
Source: Mike Zink
Google
Map data ©2010 Google, Tele Atlas - Terms of Use

IGENI Project
StarLight to Elephant Cluster at UVic

Ian Gable
Version 0.3
2012-06-13
Note: Only a rough idea



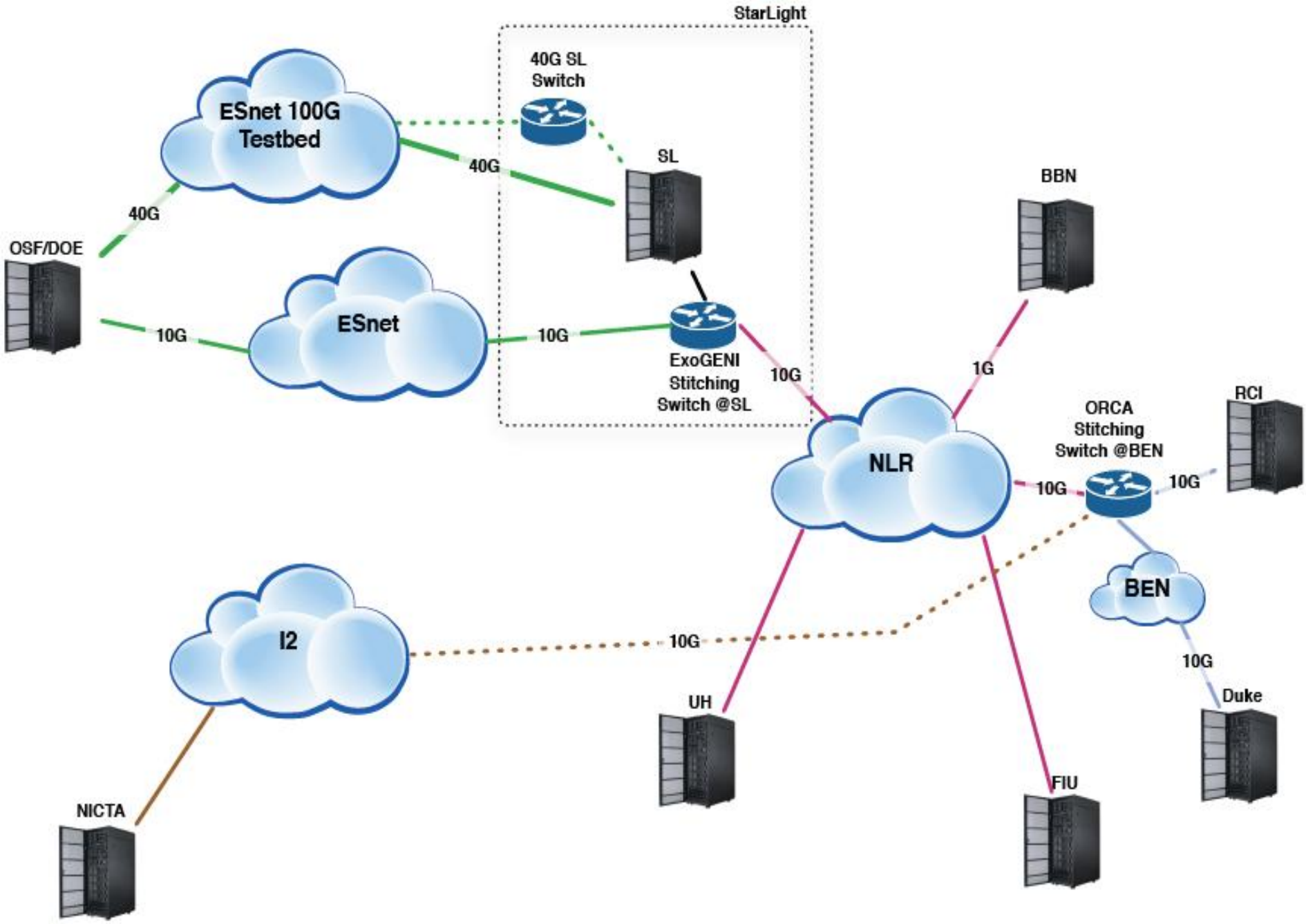
- Layer 2 Circuit extended from Starlight to the Elephant Cluster Rack in the UVic Data Centre
- Elephant14 node acts as a KVM virtual machine hoster with bridge network into the lightpath (eth0)
- Hardware layer accessed elephant address elephant14.heprc.uvic.ca
- VLAN 2780 is carried to StarLight

Elephant14 Details: Dell R510, Intel E5620@2.40GHz, 12 TB Raw, 24 GB Memory, KVM Hypervisor, 1 GE

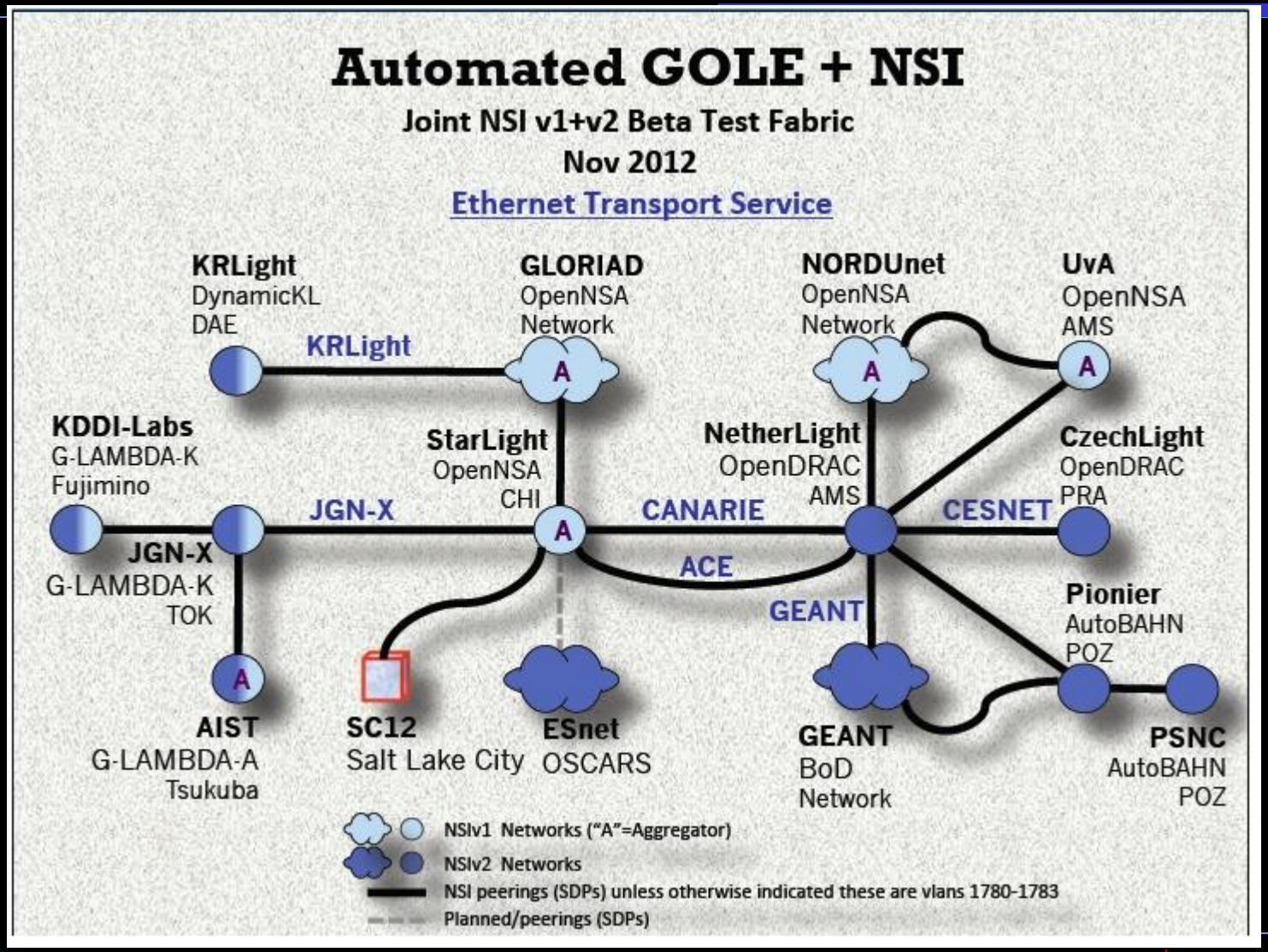
StarWave: A Multi-100 Gbps Facility

- StarWave, A New Advanced Multi-100 Gbps Facility and Services Will Be Implemented Within the StarLight International/NationalCommunications Exchange Facility
- StarWave Is Being Funded To Provide Services To Support Large Scale Data Intensive Science Research Initiatives
- Facilities Components Include:
  - An ITU G. 709 v3 Standards Based Optical Switch for WAN Services, Supporting Multiple 100 G Connections
  - An IEEE 802.3ba Standards Based Client Side Switch, Supporting Multiple 100 G Connections, Multiple 10 G Connections
  - Multiple Other Components (e.g., Optical Fiber Interfaces, Measurement Servers, Test Servers
- Also, ***GENI @ 100 Gbps***

ExoGENI at a glance



Automated GOLE and NSI Demonstration at SC12



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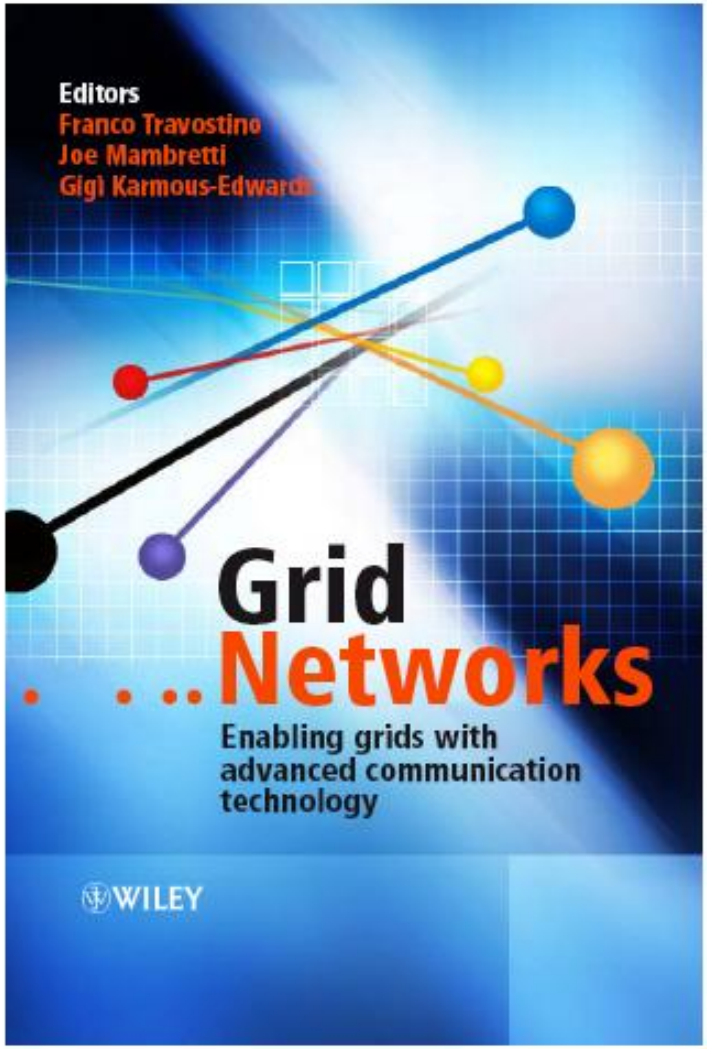
Editors
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Joe Mambretti
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Grid
Networks
Enabling grids with advanced communication technology
WILEY

GLIF/StarLight/StarWave/MREN Continually Progressing Forward!

www.startap.net/starlight