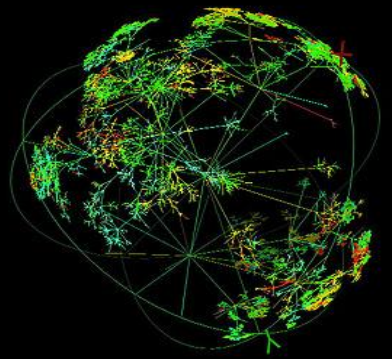
Control Frameworks Based On OpenFlow Integrated Within the NSF's Large Scale Global Environment for Network Innovations (GENI)

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)

LHCOPN and LHCONE Joint Meeting
Paris, France
June 17-18, 2013



iCAIR

STARLIGHT SM

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.

Global Environment for Network Innovations (GENI)

- GENI
  - Supports At-Scale Experimentation on Shared, Heterogeneous, Highly Instrumented Infrastructure
  - Enables Deep Programmability Throughout the Network,
  - Promotes innovations in Network Science, Security, Technologies, Services and Applications
  - Provides Collaborative and Exploratory Environments for Academia, Industry and the Public to Catalyze Groundbreaking Discoveries and Innovation.
- Current Round of GENI Funding Accelerates Prototyping of Suite of Infrastructure for the GENI Project With Federation and Early Experiments to Guide Future GENI System Design.
- GENI To a Large Degree Is Infrastructure-As-A-Service (IaaS)
- Major Potential For Supporting Wide Range of Science Research

iGENI: The International GENI

- The iGENI Initiative Has Designed, Developed, Implemented, and Now Operates a Major New National and International Distributed Infrastructure.
- iGENI Placed 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 Connected Its Resources With The GENI National Backbone Network, With GENI Regional Related Networks, and With International Research Networks and Projects.

Selected GENI/iGENI Components

- GENI/iGENI Core Infrastructure
- L1/L2 Core Paths
- Control Plane
- Management Plane
- Resource Management Processes
- Resource Data Paths
- Core Resources (Including Edge Clouds)
- Experimental Resources
- Overall Architecture – “3 Concentric Spheres”

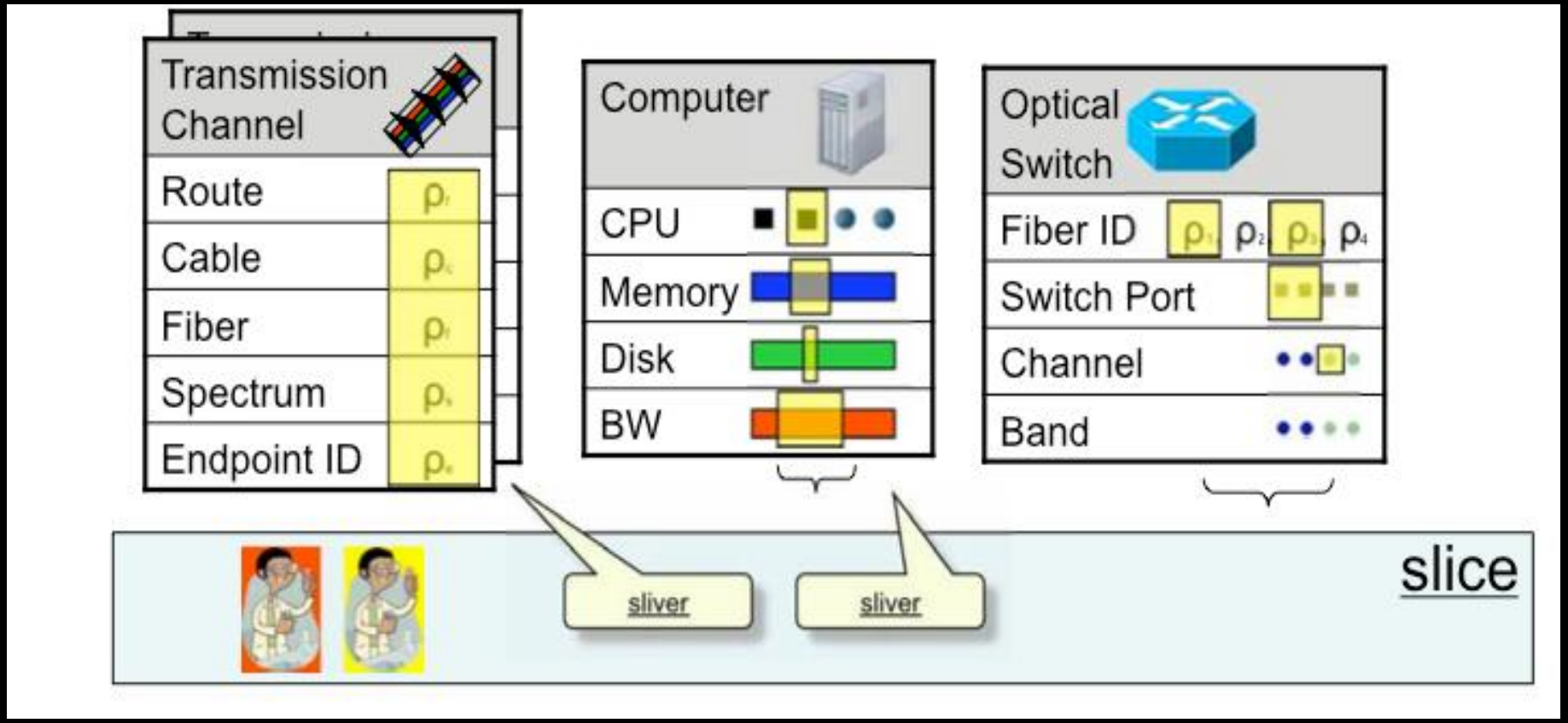
External Aggregate Interfaces Are L1/L2 Paths (e.g., vLANs, Tunnels, Et Al)

- MPLS (L 2.5)
- vLANs
  - Mapped at ingress/egress or
  - Tunneled (Q-in-Q)
- Tunnels
  - Layer 2, such as OpenVPN
- SONET/SDH, GFP, vCAT Channels,
- Layer 1
  - Lightpaths
- Provisioning
  - Statically Provisioned Based on Requirements
  - Partially Dynamically Provisioned Based on Requirements
  - Dynamically Provisioned Based on Requirements

Building Experimental Networks

- GENI Network Abstractions (Provided by Tools) For Experimental Resources
  - Automatic Path Discovery and Allocation
  - Control Over Path/Network Selection for Experimenter
  - Various Parameters, For Example, Bandwidth.
  - Bare Bones Control Over Everything Available to the ER Tools
  - Resource Description Semantics (Rspecs)

GENI Slicers and Slivers



Source: BBN GENI Program Office

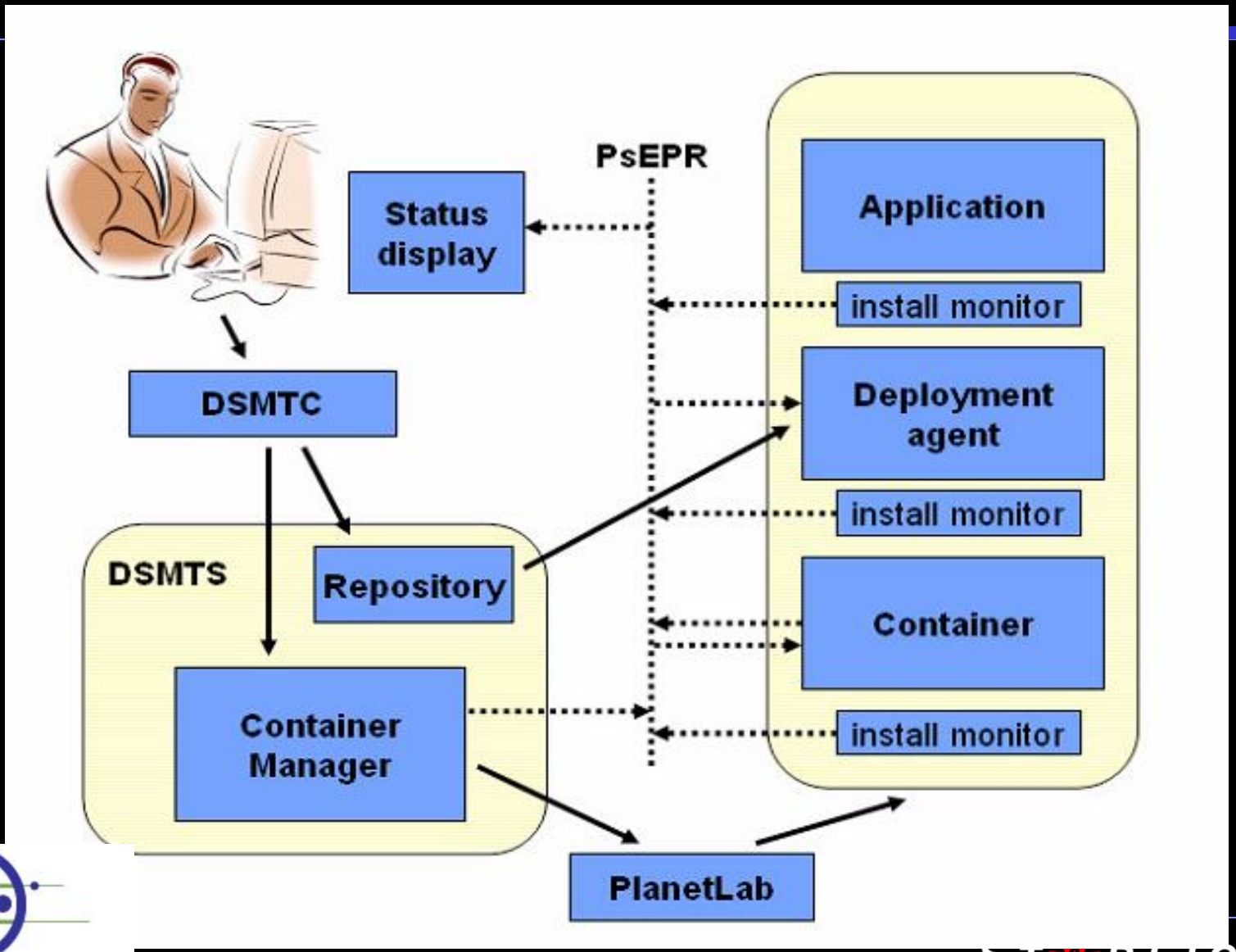
GENI Control Frameworks

- 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

Invocation Mechanism

- A Slice Federation Architecture (SFA) Defines Global Identifiers (GID)
- XML-RPC over HTTPS [RFC 2818] Used As Invocation Mechanism for GENI API operations.
- XML-RPC: Remote Procedure Call Mechanism Using HTTP For Transport And XML As The Encoding.
- XML-RPC: Readily Secured By SSL, Can Be Used From a Variety of Programming Languages.
- Within GENI Used By Specific Control Frameworks.
- However, Can Also Be Used By Alternative Control Frameworks
- Can Also Be Used Independently

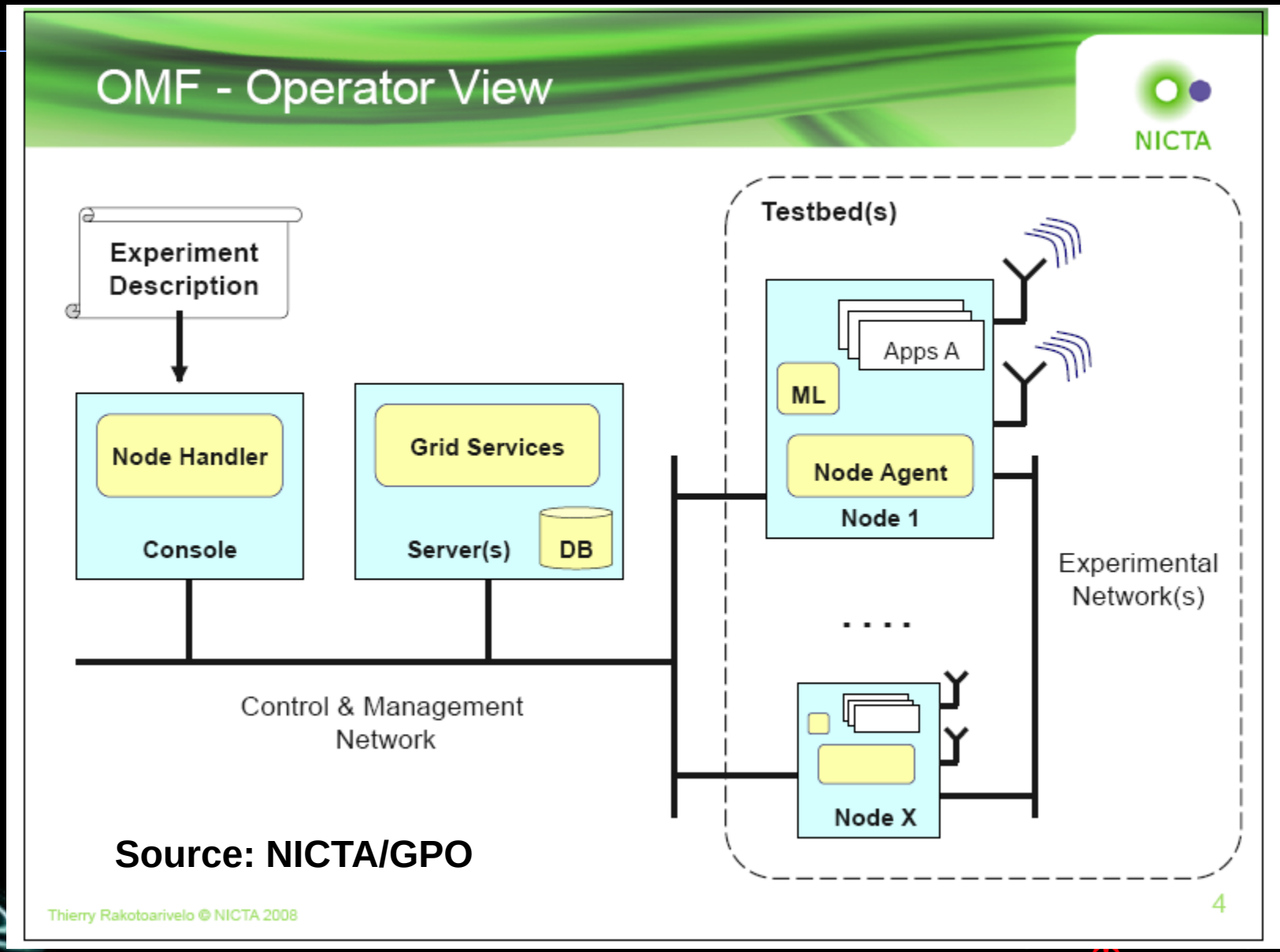
PlanetLab



PLANETLAB

STARLIGHT SM

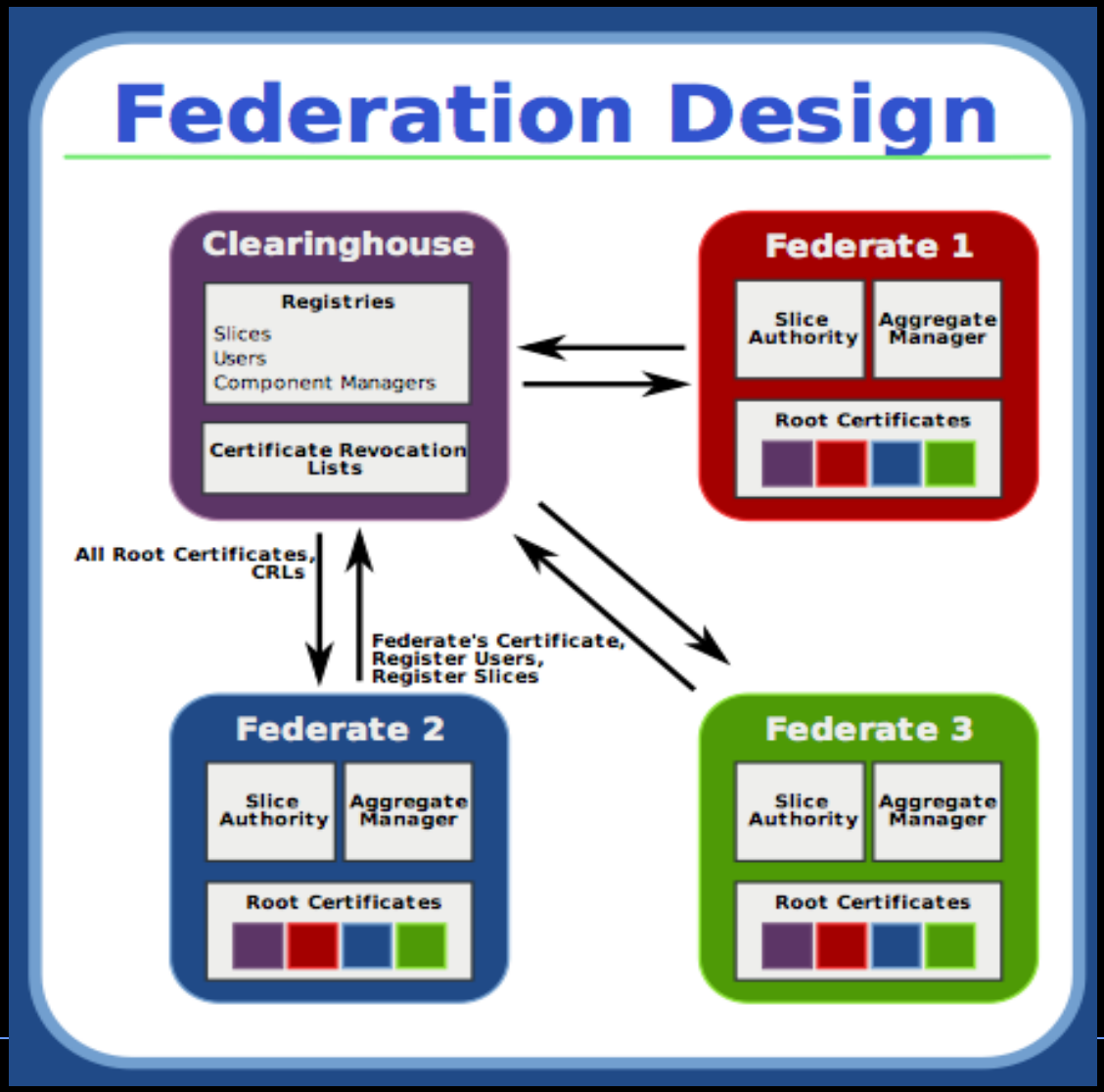
ORBIT Management Framework



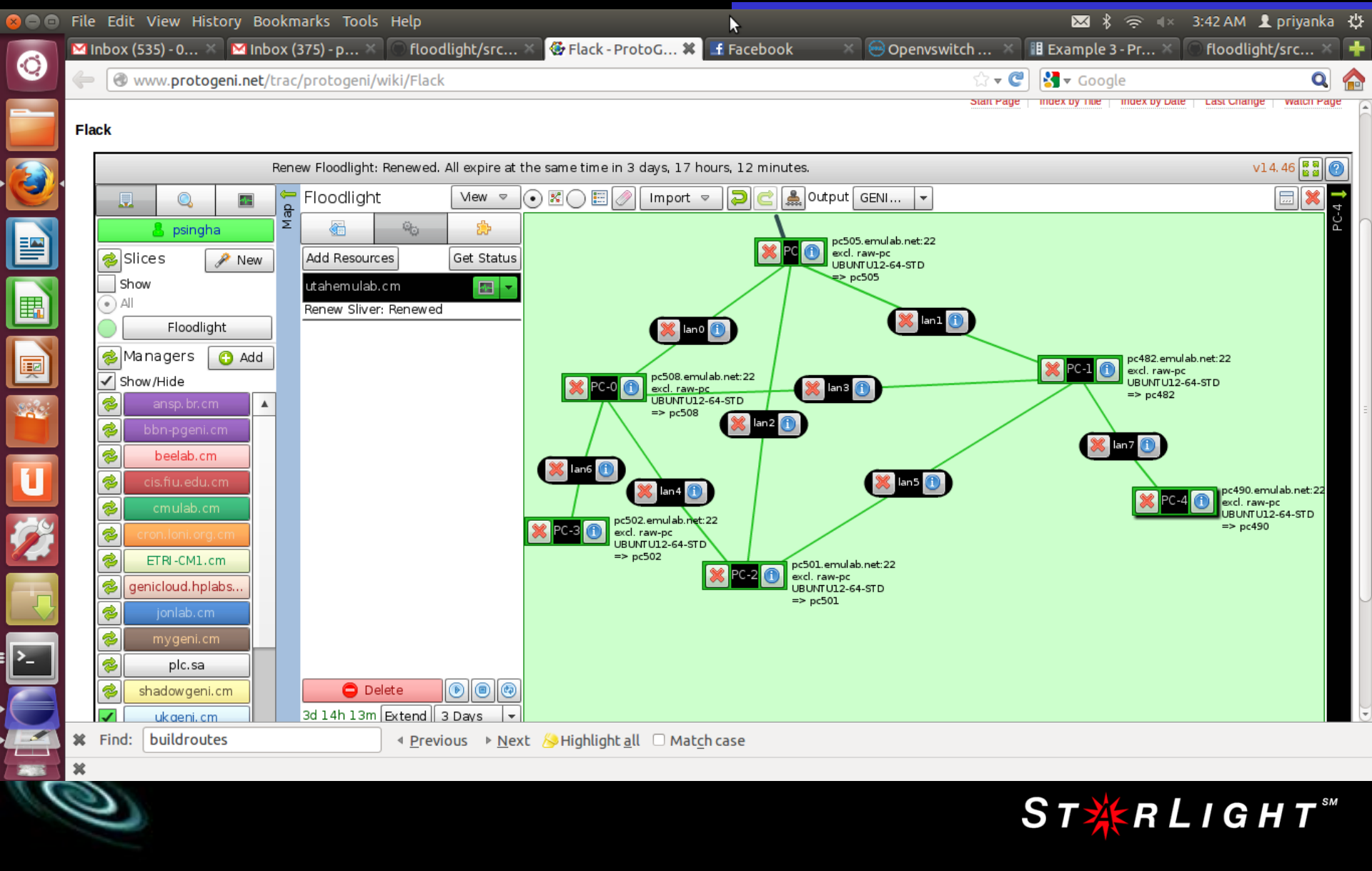
ProtoGENI

- ProtoGENI Is Based On Emulab (Linux Based Experimental Enviroment)
- It Supports Hardware as a Service (HaaS)
- It Is Essential An Instantiation Of Platform as a Service (PaaS)
- It Enables The Installation Of Custom OS Images on Bare Metal
- It Has Been Integrated With FlowVisor OpenFlow Agg Mgr (FOAM)
- It Provides OpenFlow Programmability For Experiment Dataplanes
- It Uses OpenVZ images for Shared Nodes
- It Supports PlanetLab Node Images

ProtoGENI Federation Design



Flack: Experimenter Interface



STARLIGHT SM

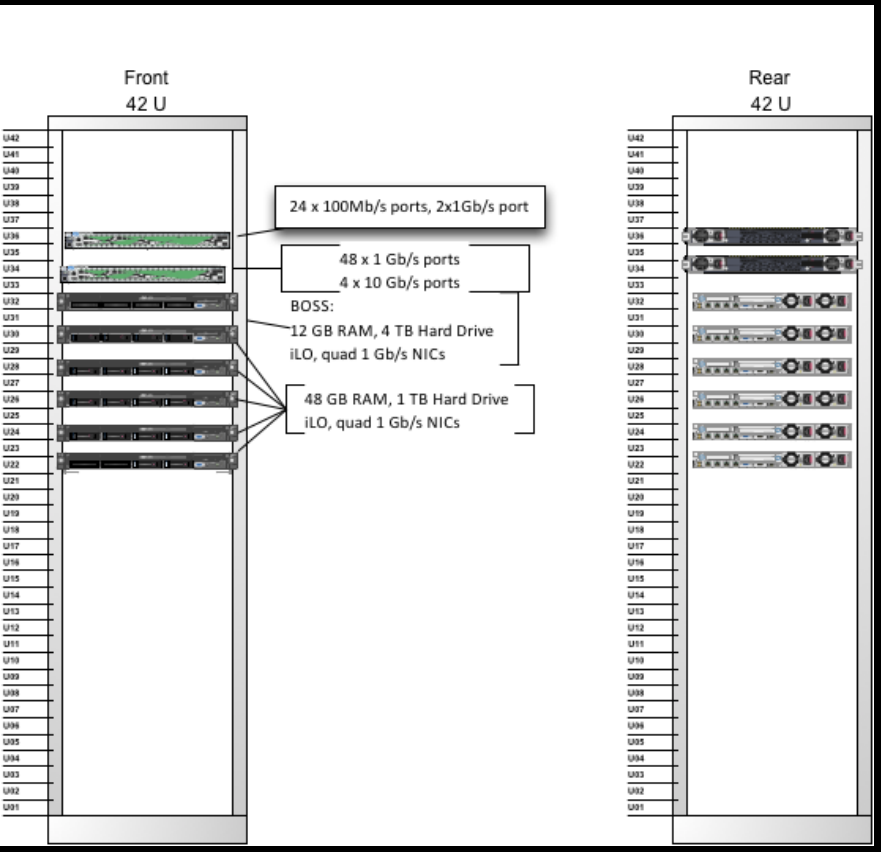
InstaGENI

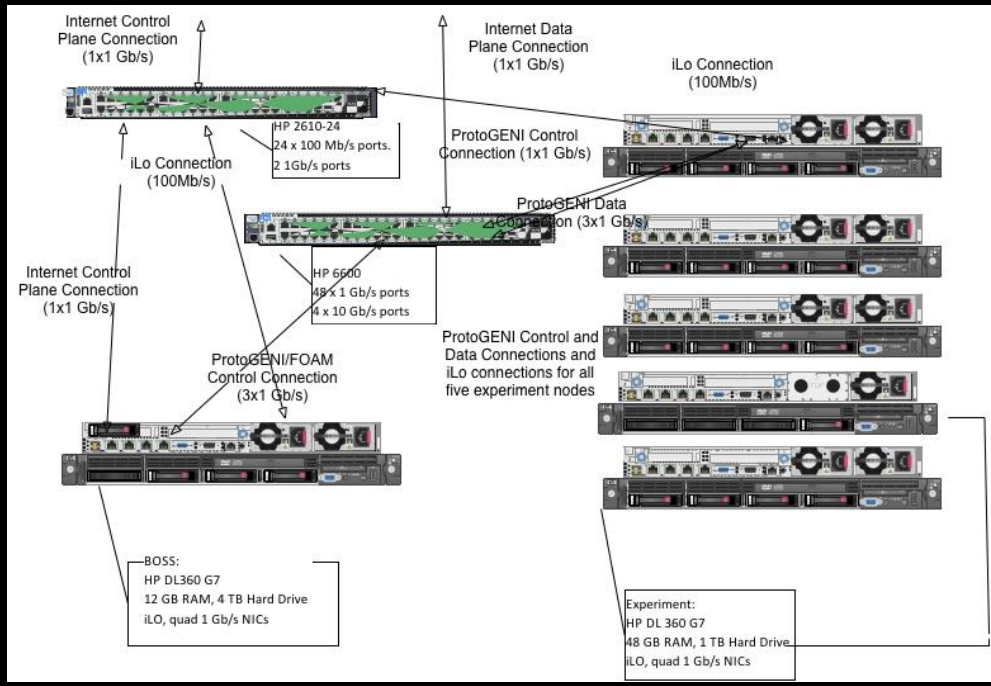
geni
Exploring Networks of the Future

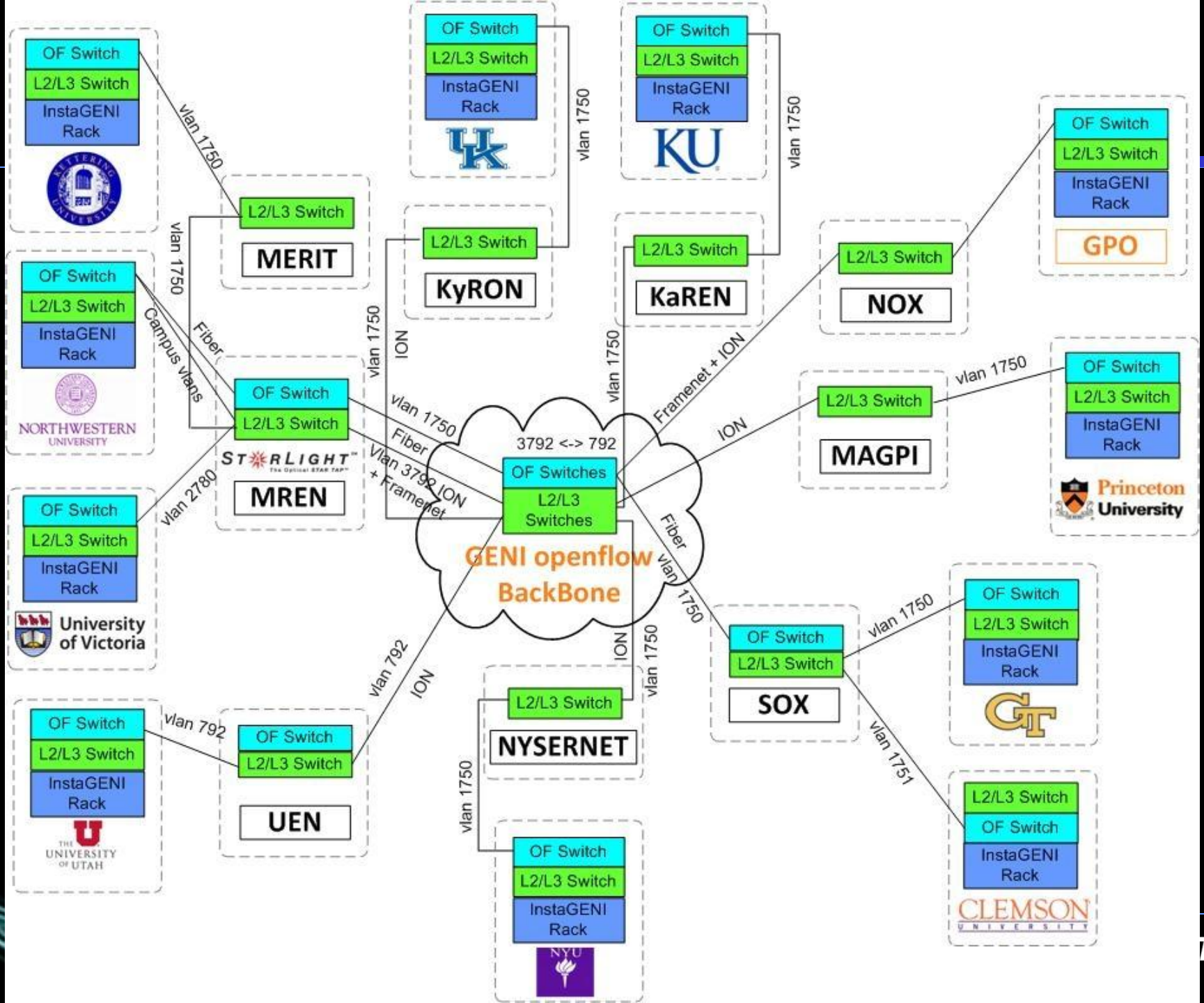
instaGENI

www.geni.net

InstaGENI Racks and Topology





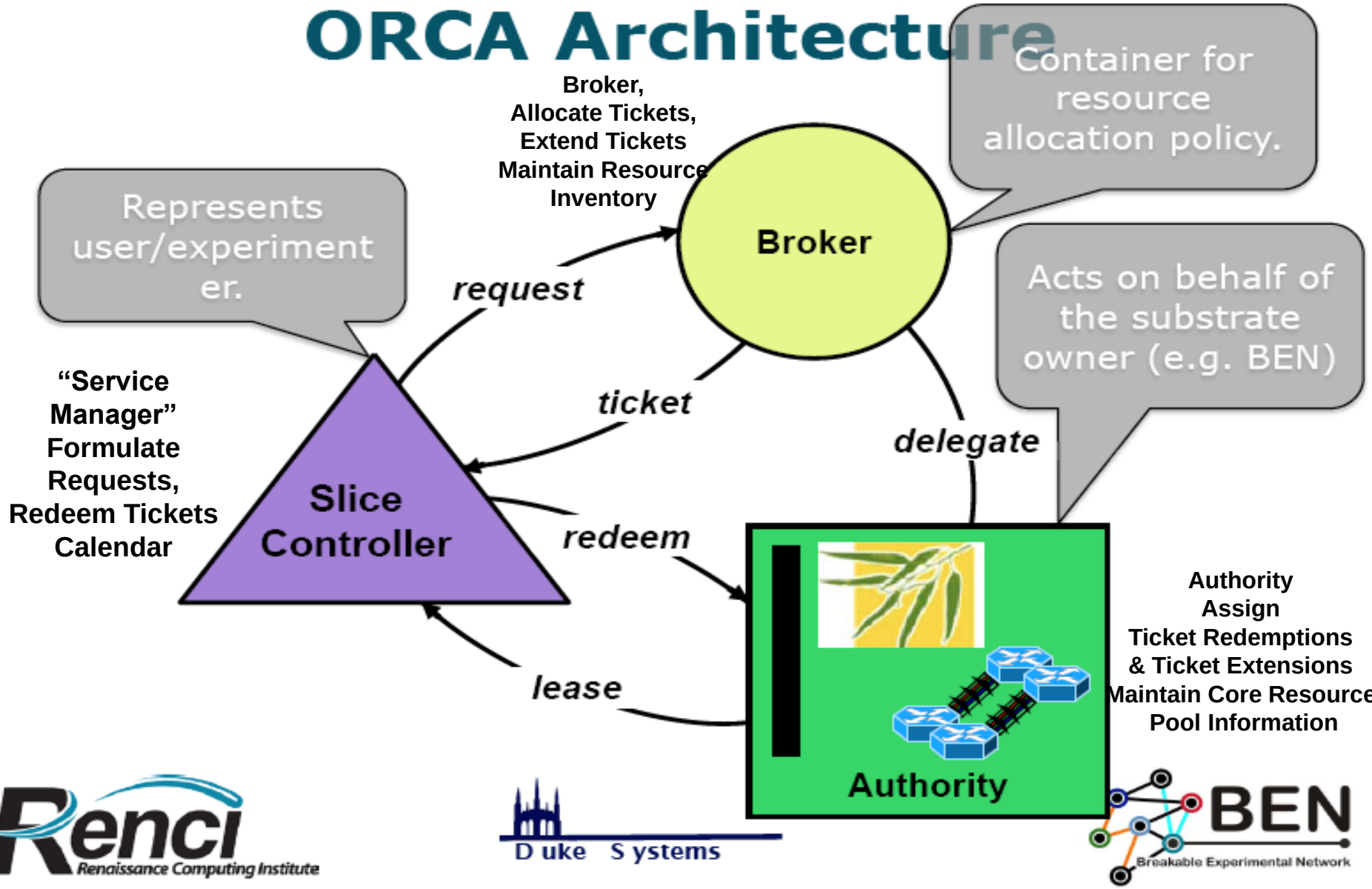

OF Switch
L2/L3 Switch
InstaGENI Rack
MERIT
KyRON
KaREN
NOX
GPO
MAGPI
Princeton University
MREN
STARLIGHT
NORTHWESTERN UNIVERSITY
University of Victoria
SOX
NYSERNET
UEN
THE UNIVERSITY OF UTAH
CLEMSON UNIVERSITY
NYU
OF Switches
L2/L3 Switches
3792 <-> 792
GENI openflow BackBone
vlan 1750
vlan 2780
vlan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

Open Resource Control Architecture (ORCA)

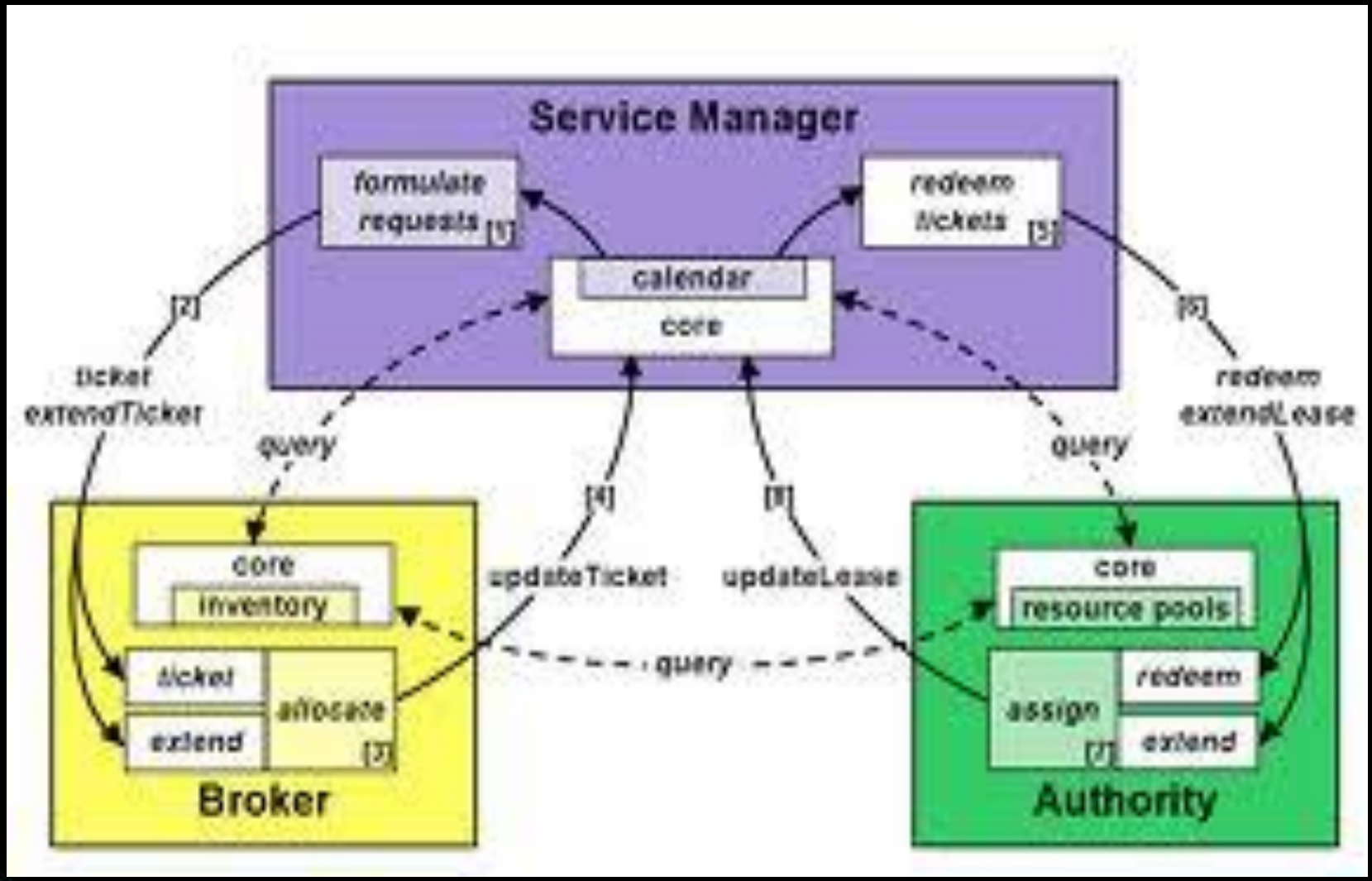
- Cross Cloud Provisioning: Connections, Clusters, and Topologies
- Provisioning Among Multi-Layered Network Domains
- Leveraging Semantic Web Technologies
- API and Resource Description Translation
- ORCA Enables The Creating And Instantiation Of Application Specific Topologies Among Diverse Independent Clouds – Interconnected By Multi-Layer Networks

Being Developed @: RENCI-BEN-Duke-GENI

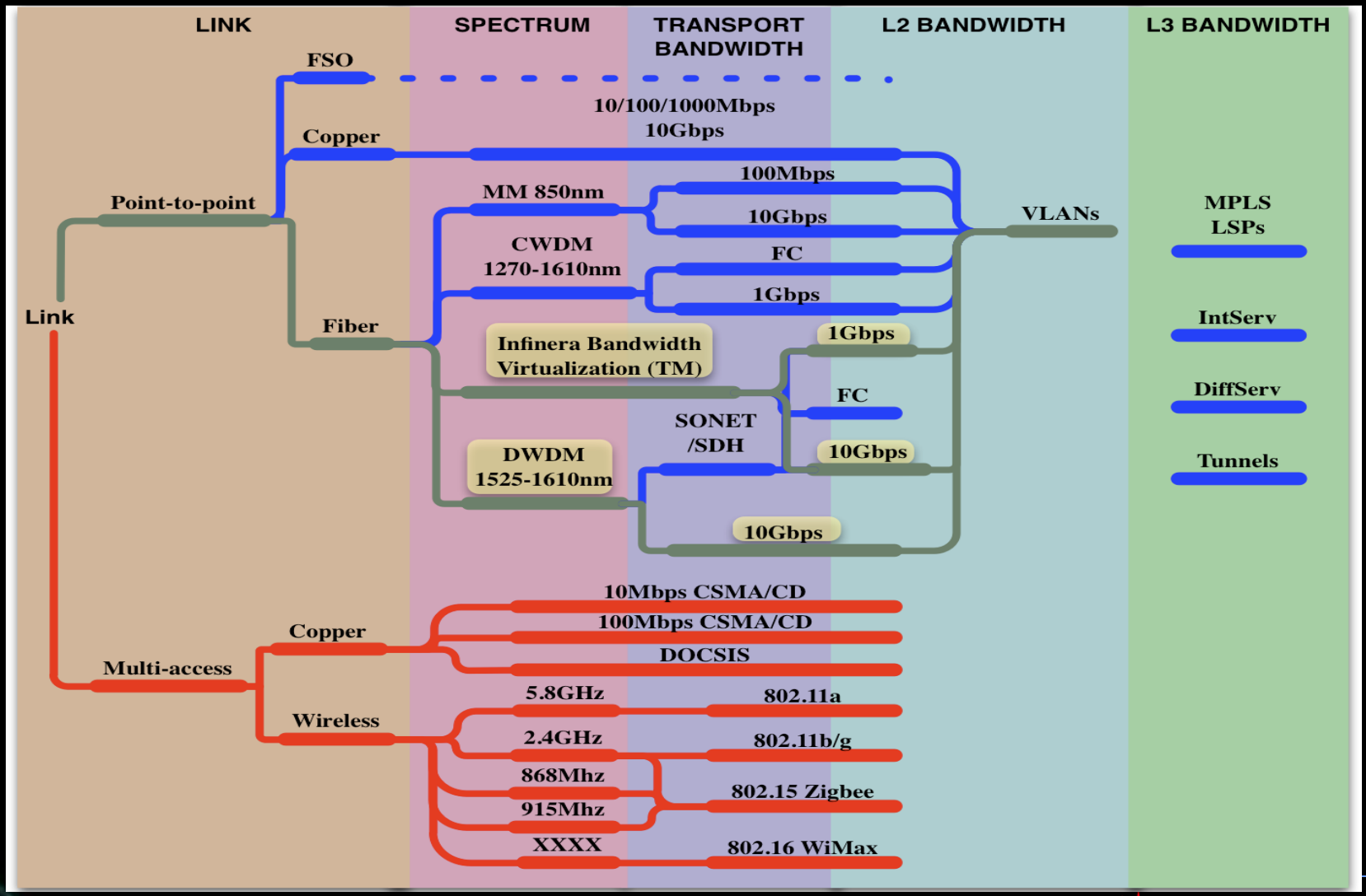
ORCA Architecture



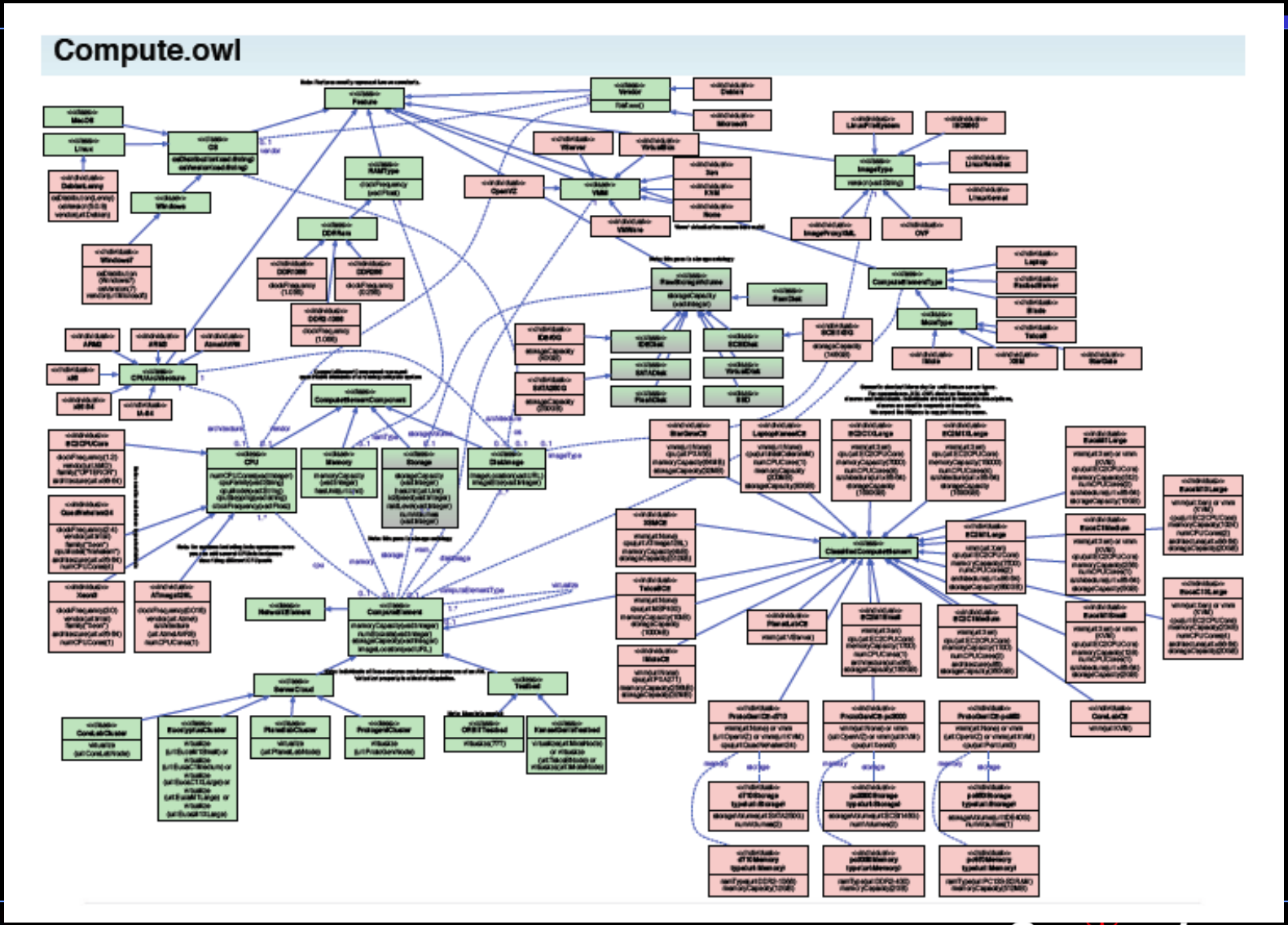
ORCA Architecture



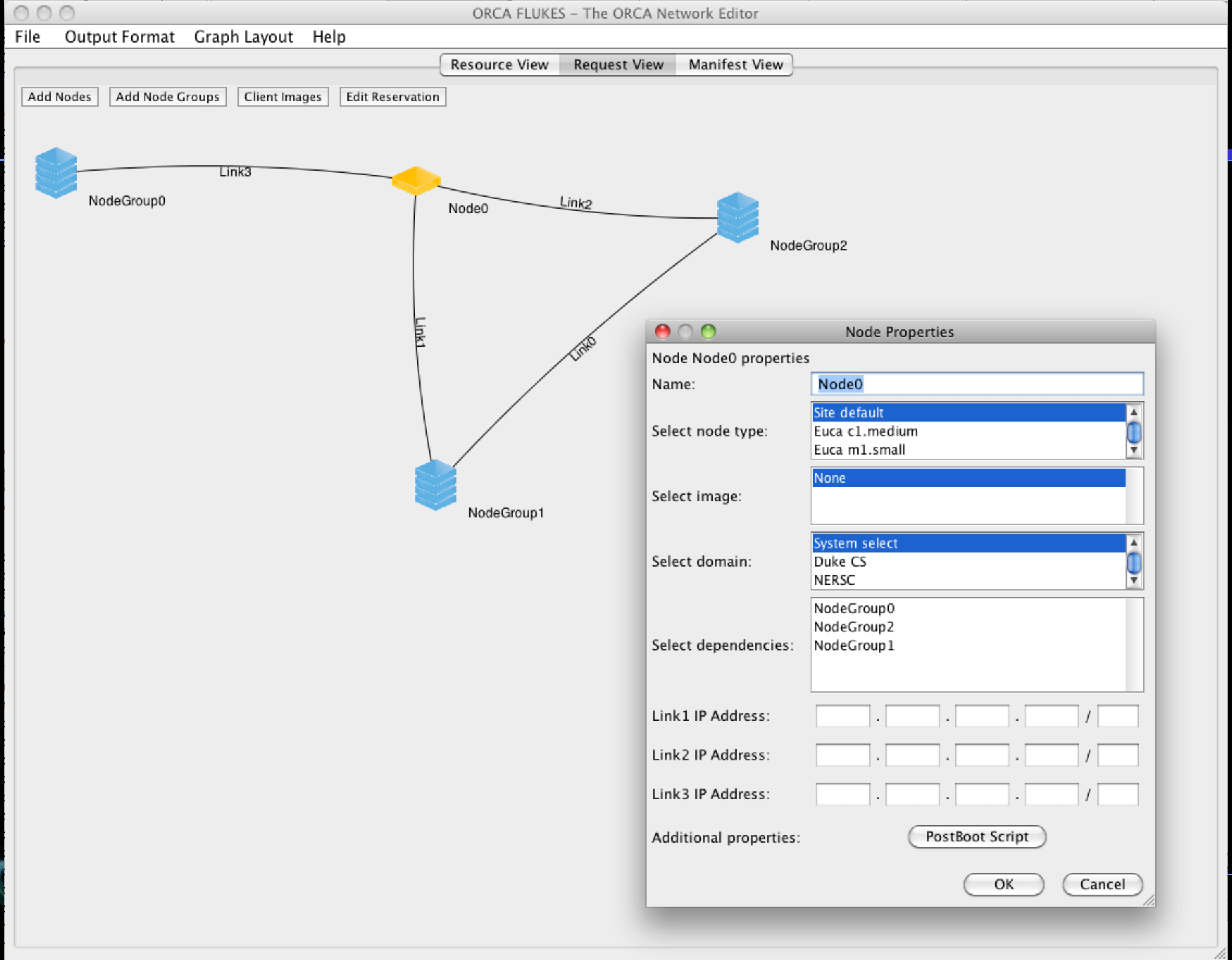
ORCA "Link" Slivering



ORCA Semantics

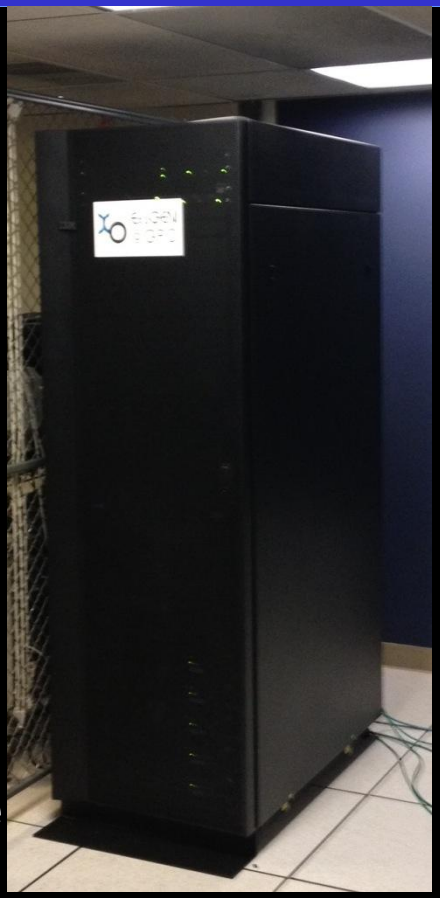


STARLIGHT SM


ORCA FLUKES – The ORCA Network Editor
File
Output Format
Graph Layout
Help
Resource View
Request View
Manifest View
Add Nodes
Add Node Groups
Client Images
Edit Reservation
NodeGroup0
Link3
Node0
Link2
NodeGroup2
Link1
Link0
NodeGroup1
Node Properties
Node Node0 properties
Name:
Node0
Select node type:
Site default
Euca c1.medium
Euca m1.small
Select image:
None
Select domain:
System select
Duke CS
NERSC
Select dependencies:
NodeGroup0
NodeGroup2
NodeGroup1
Link1 IP Address:
Link2 IP Address:
Link3 IP Address:
Additional properties:
PostBoot Script
OK
Cancel

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

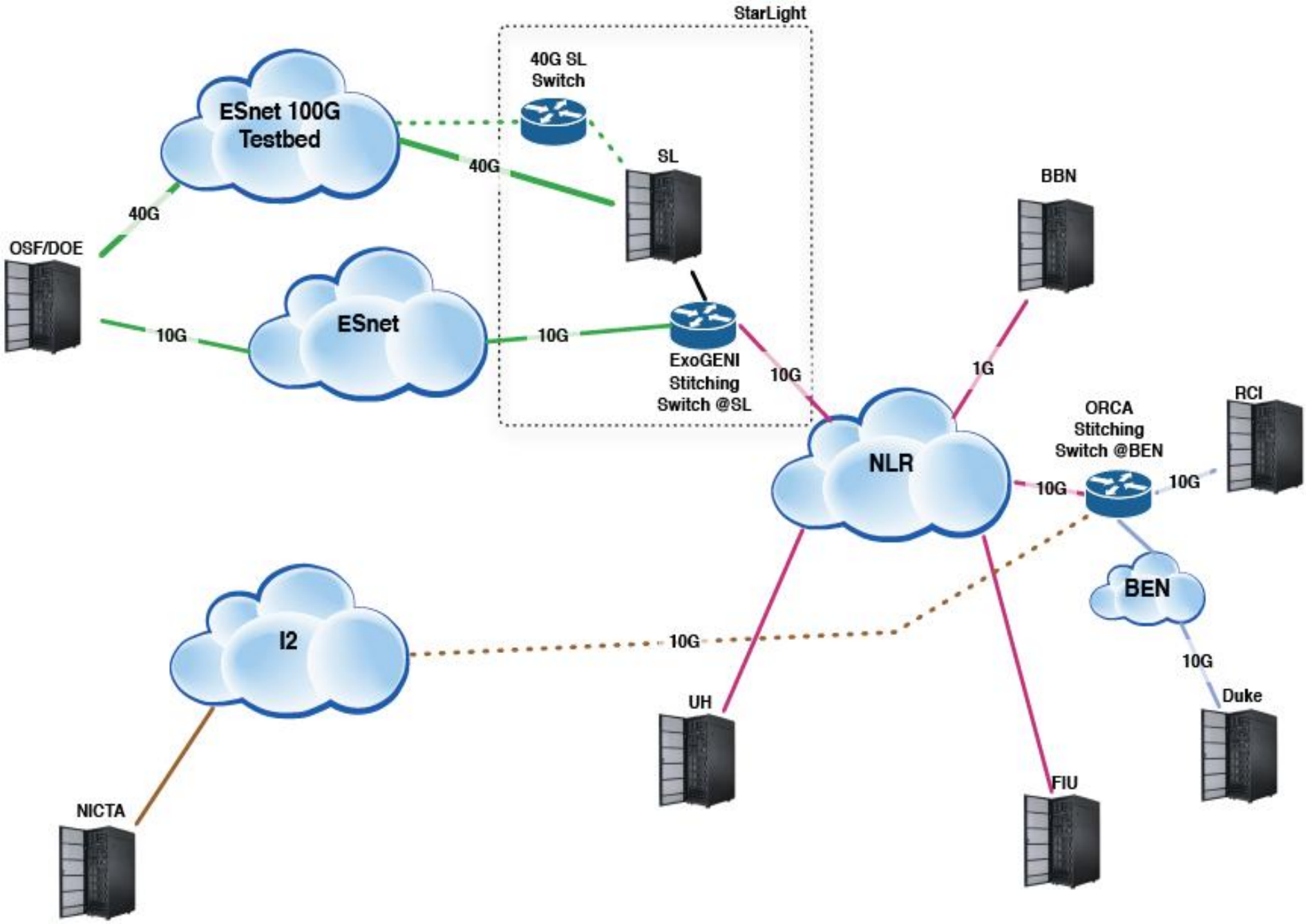


Source Ilia Baldine

StarWave: A Multi-100 Gbps Facility

- StarWave, A New Advanced Multi-100 Gbps Facility and Services Will Be Implemented Within the StarLight International/National Communications 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



iGENI and StarLight

- iGENI Integrates Multiple Network Resources, Including:
  - Resources at the StarLight International Communications Exchange in Chicago - StarLight Current Supports Over 20 Major Network Research Testbeds, Including National and International Fabrics
  - Segments of National Research and Education Network Infrastructures
  - A National Wide-Area Private Testbed Networks
  - Components of the International Optical-Networking -- GLIF Fabric.

StarLight – "By Researchers For Researchers"

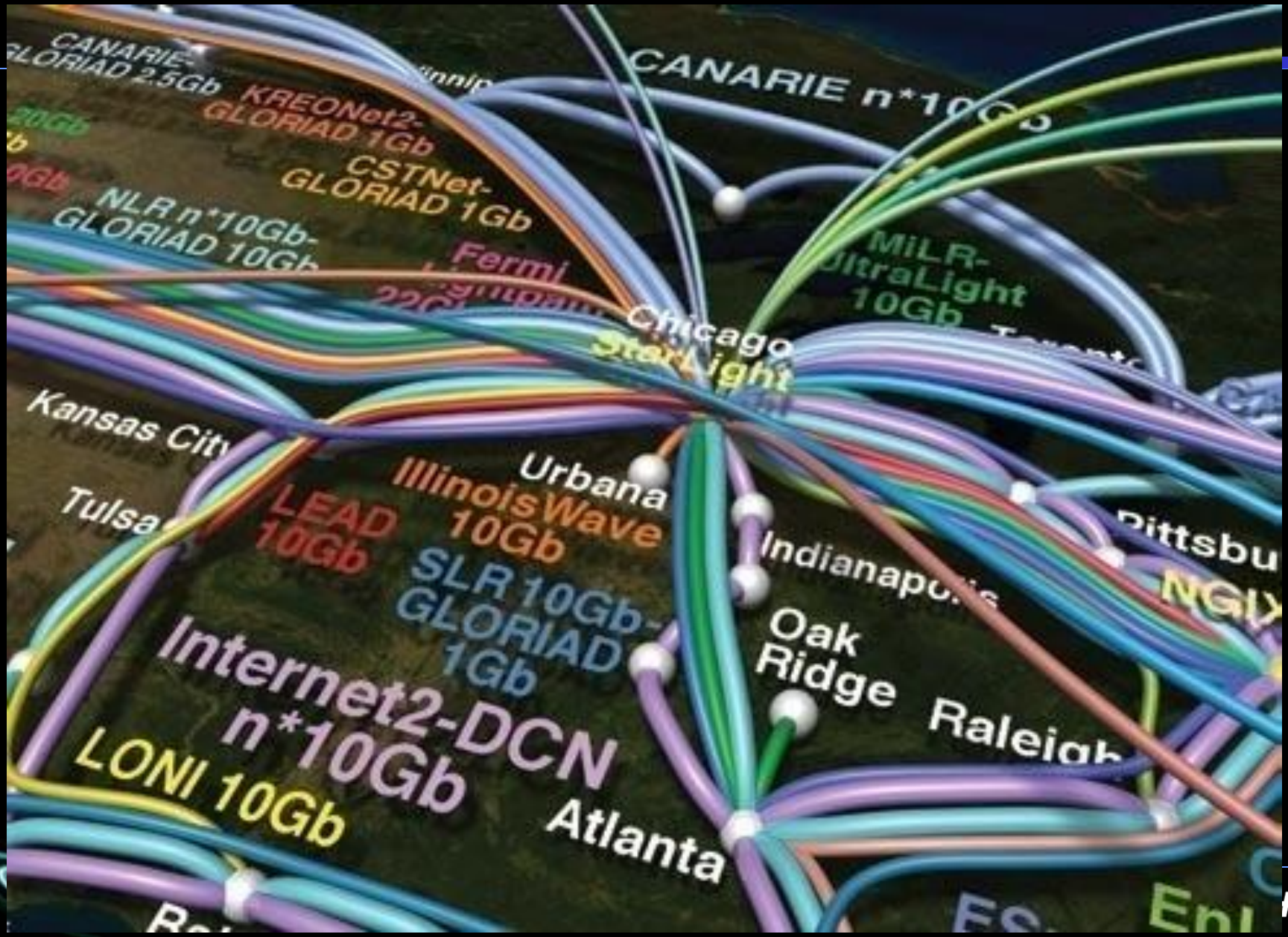
StarLight is an advanced national and international communication exchange facility optimized for high-performance data intensive applications

World's "Largest" 10G and 100 Gbps Exchange
Over 100 10 Gbps Channels
Soon Over 25 100 Gbps Paths
Interoperability Services At All Layers

View from StarLight

Abbott Hall, Northwestern University's Chicago downtown campus

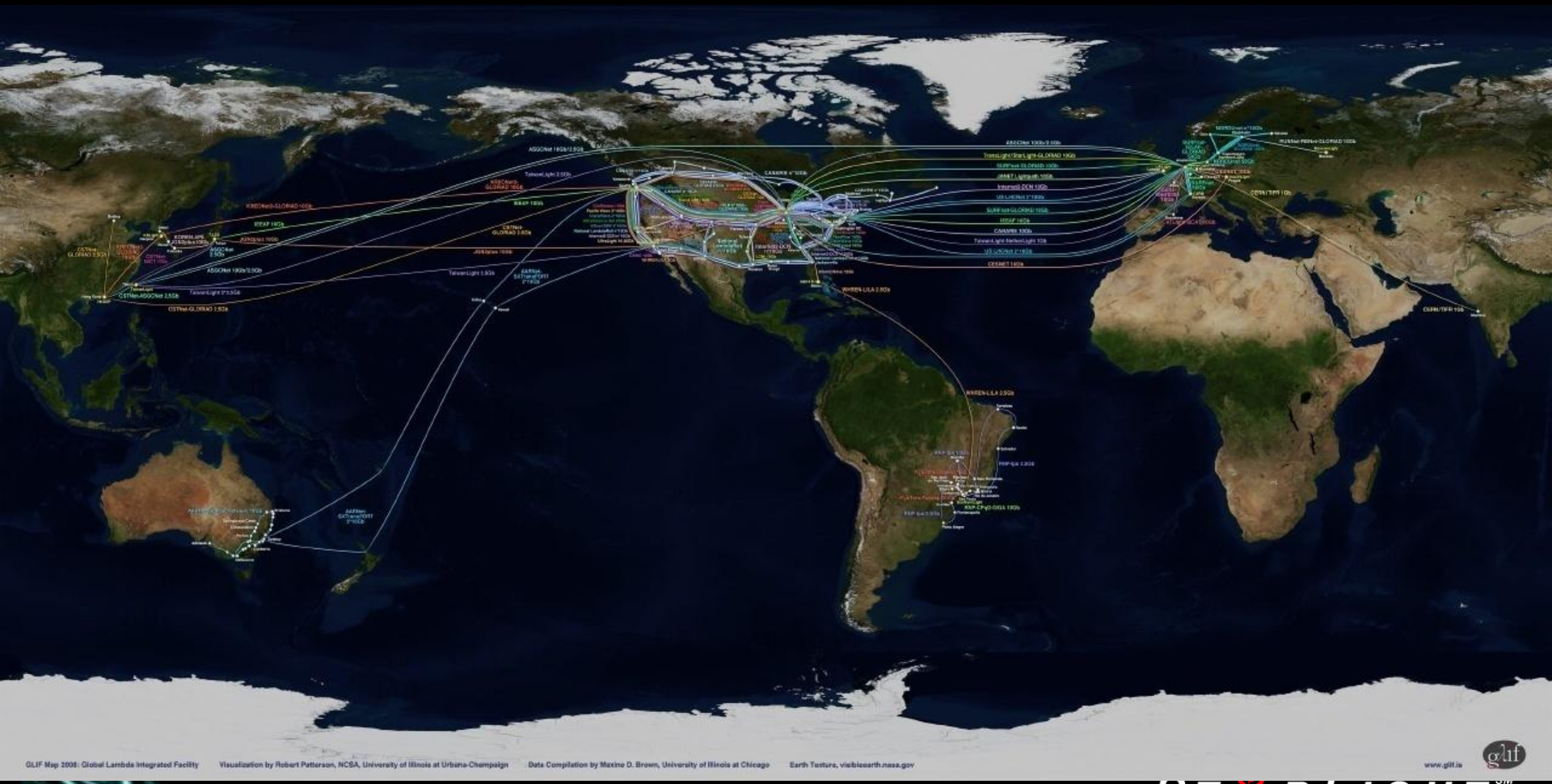
STARLIGHT℠


CANARIE-
GLORIAD 2.5Gb
KREONet2-
GLORIAD 1Gb
CSTNet-
GLORIAD 1Gb
NLR n*10Gb-
GLORIAD 10Gb
Fermi
CANARIE n*10Gb
MiLR-
UltraLight
10Gb
Chicago
StarLight
Kansas City
Urbana
IllinoisWave
10Gb
Tulsa
LEAD
10Gb
SLR 10Gb-
GLORIAD
1Gb
Indianapolis
Oak
Ridge
Raleigh
Internet2-DCN
n*10Gb
LONI 10Gb
Atlanta

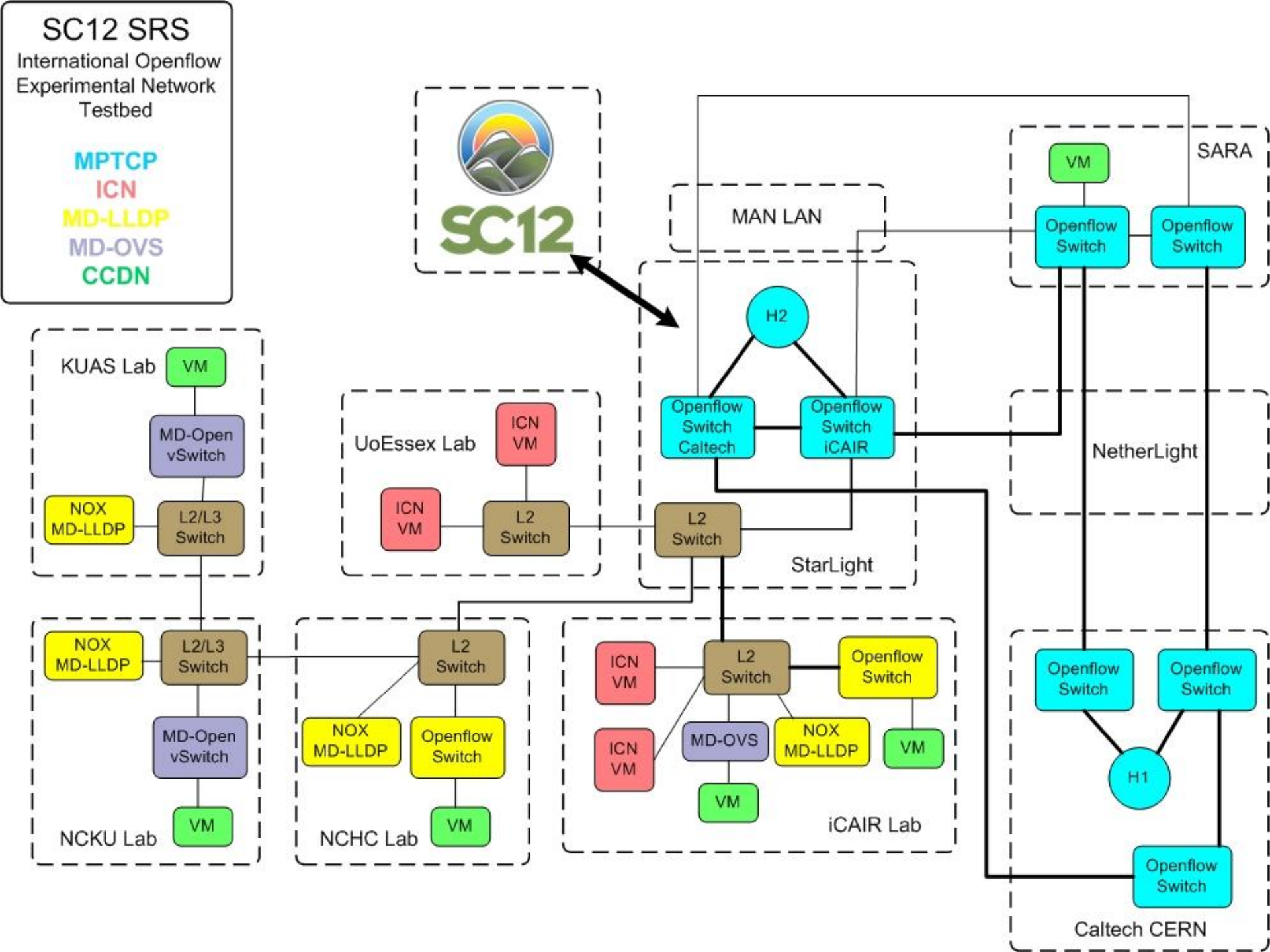
iGENI and GLIF

- iGENI Consortium Members Have Partnered with Many Other Participants of the Global Lambda Integrated Facility (GLIF) To Undertake Multiple Experimental Network Research Projects
- The iGENI Initiative Has Been Building On That Experience To Create and Exploring New Prototypes of Innovative Communication Services and Technologies.

StarLight: Founding Partner of the Global Lambda Integrated Facility
Available Advanced Network Resources



KUAS
NetFPGA
NOX
OpenFlow
NCKU
NetFPGA
NOX
OpenFlow
NOX
OpenFlow
NetFPGA
ETRI
NOX
OpenFlow
NetFPGA
KiSTi
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
OpenFlow
cenic
PACIFIC
NORTHWEST
GIGAPOP
aarnet
NICTA
ExoGENI
OpenFlow
NCHC
NetFPGA
NOX
OpenFlow
KRLight
canarie
APPLIED RESEARCH CENTER FOR COMPUTER NETWORKS
OpenFlow
GLORIAD
Northern Wave
hp
GENICloud
SingLight
SingAREN
OpenFlow
renci
ExoGENI
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
UNIVERSITY OF AMSTERDAM
ExoGENI
MAGPI
Princeton University
OpenFlow
InstaGENI
USP
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

www.startap.net/starlight

STARLIGHT℠