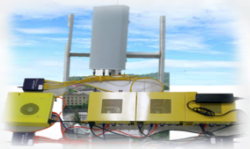
geni
Exploring Networks of the Future

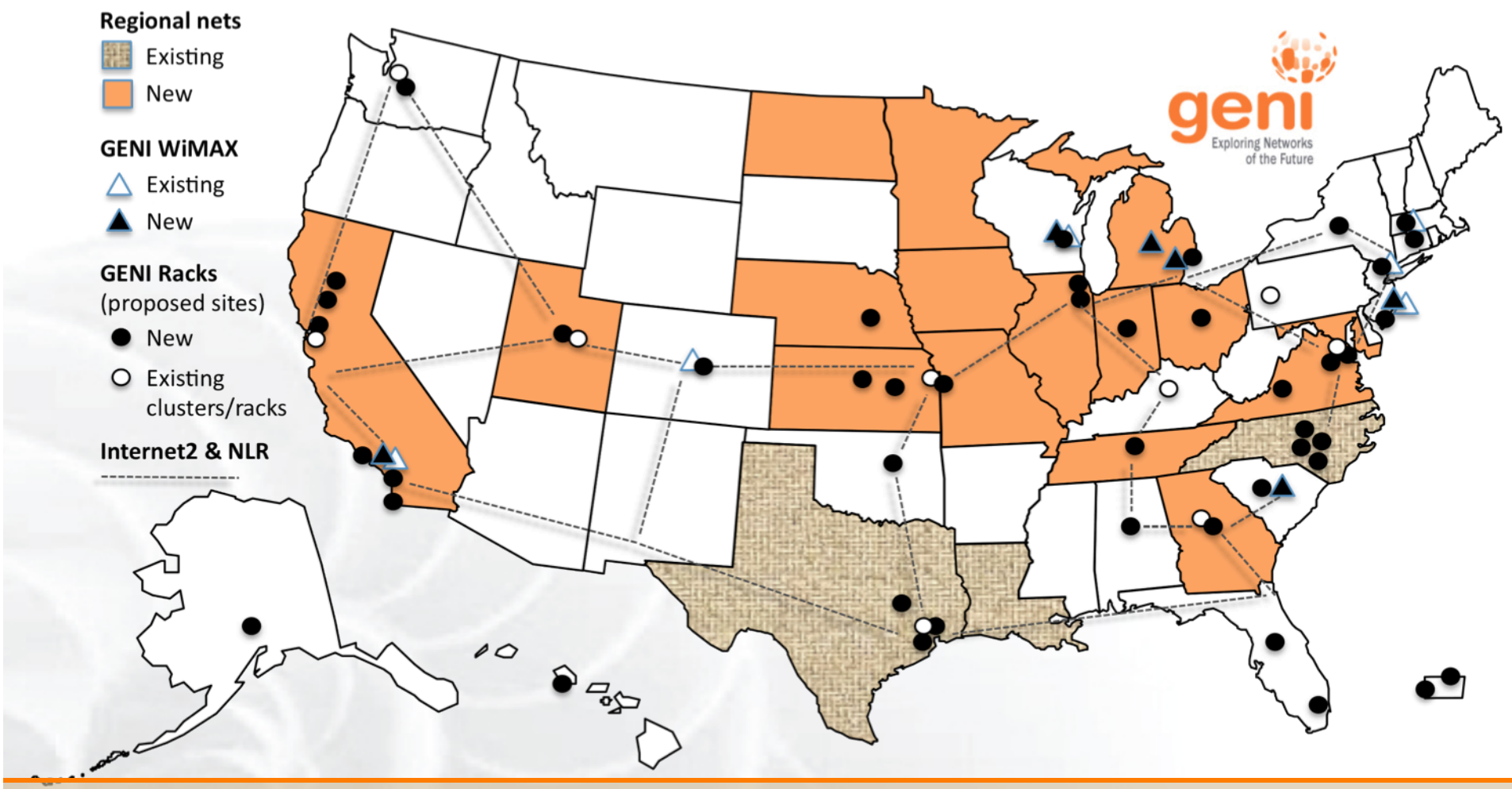


Introduction to **GENI** Network Architecture

www.geni.net

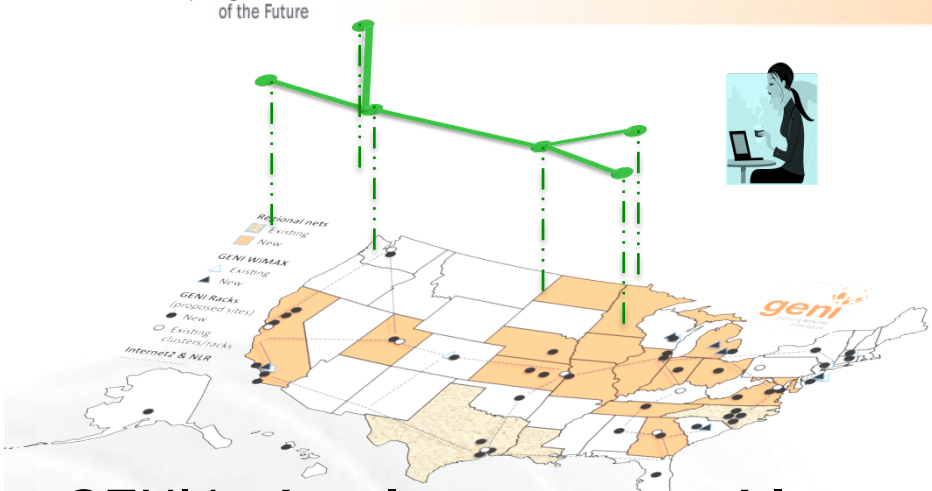
Sponsored by the National Science Foundation

GENI: Infrastructure for Experimentation

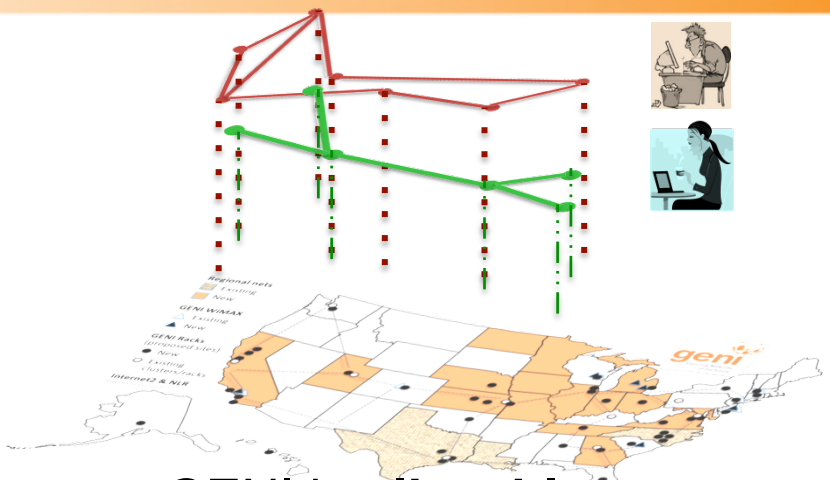


GENI provides **geographically distributed** compute resources that can be connected in **experimenter specified Layer 2 topologies**.

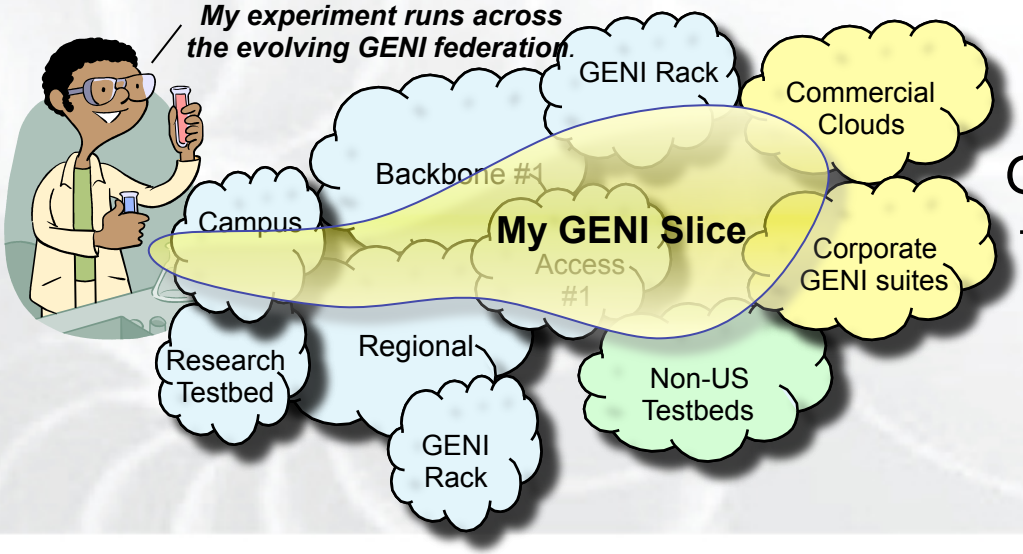
GENI Key Concepts



GENI is **deeply programmable** – experiments control forwarding

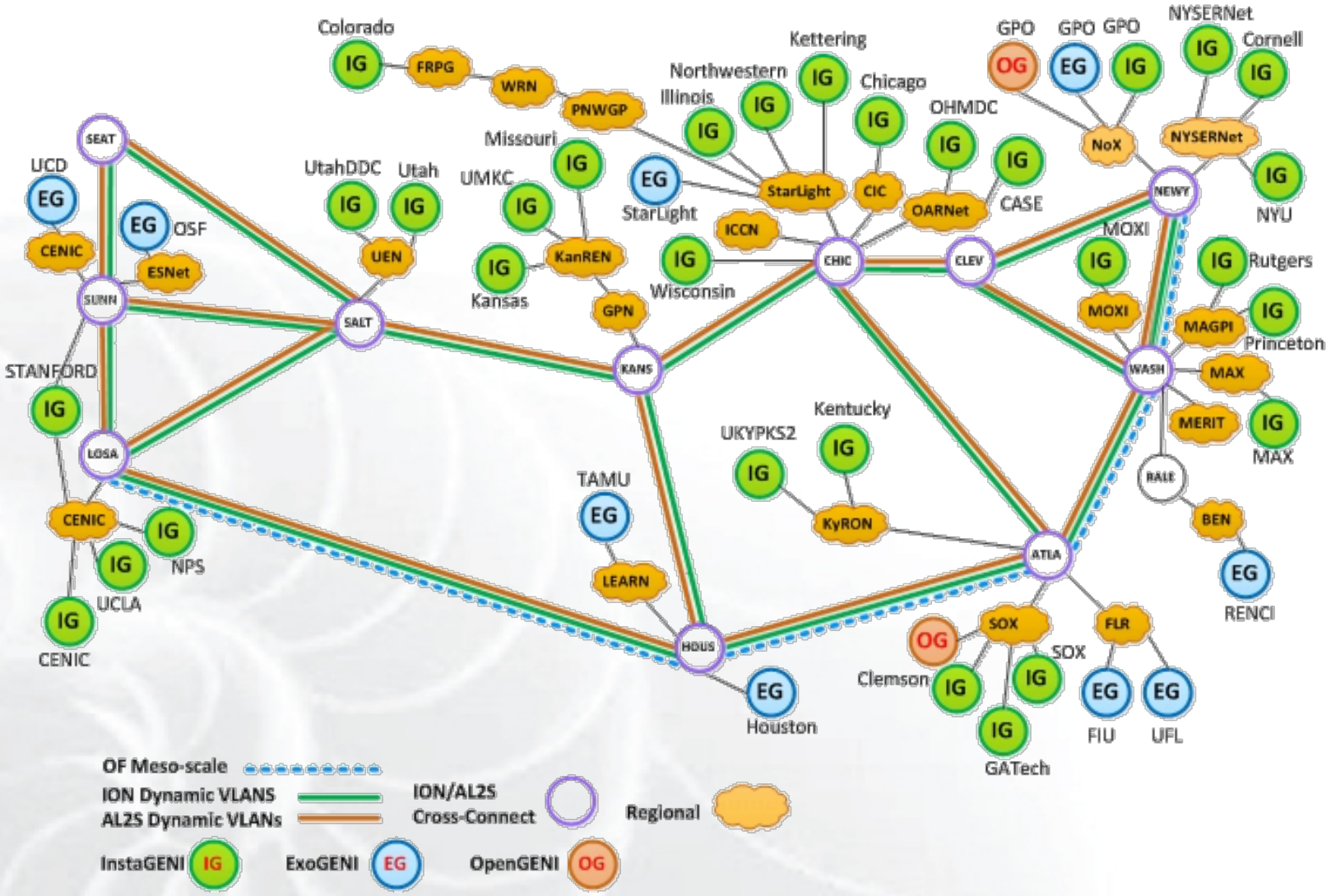


GENI is **sliceable** – supports concurrent experiments

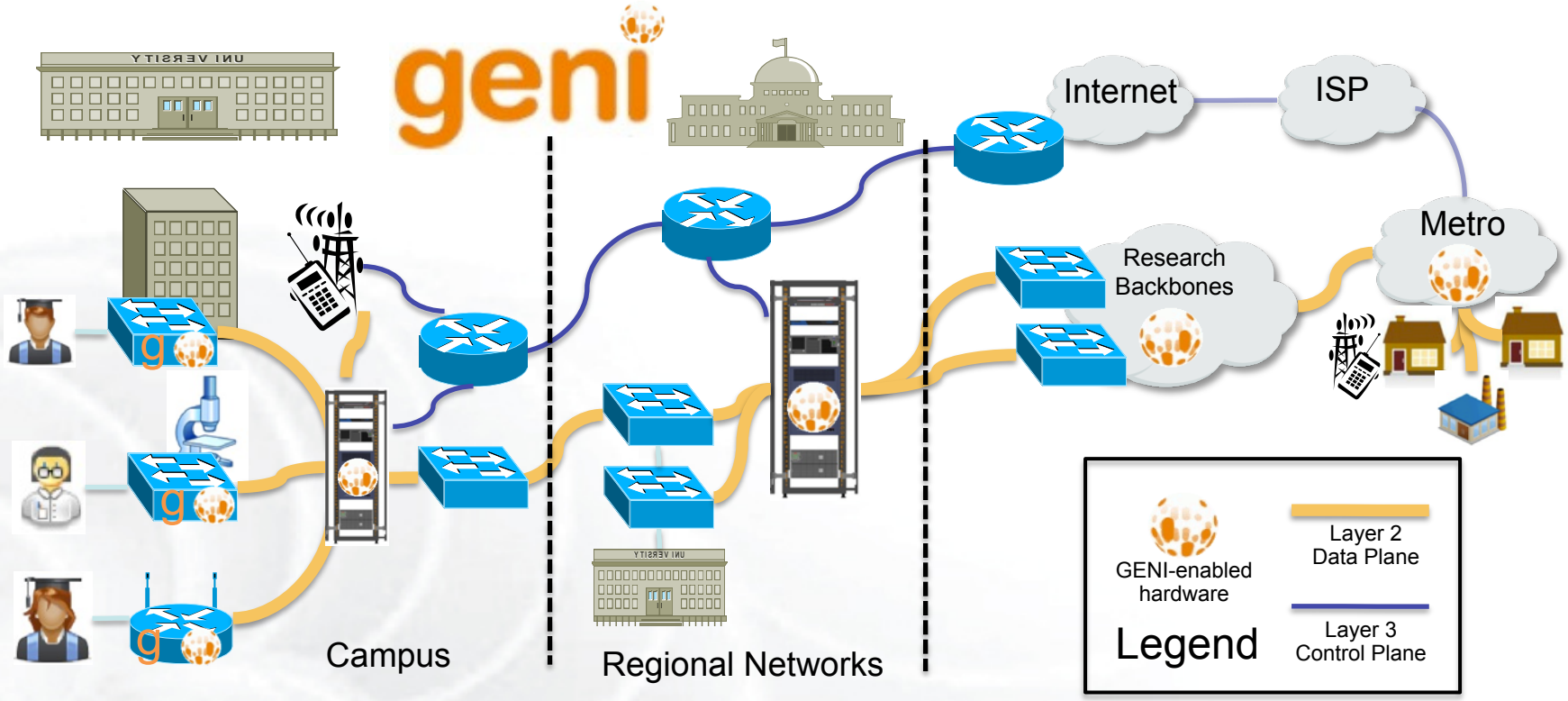


GENI is a **Federation** – to the user appears as one testbed

GENI Network Map

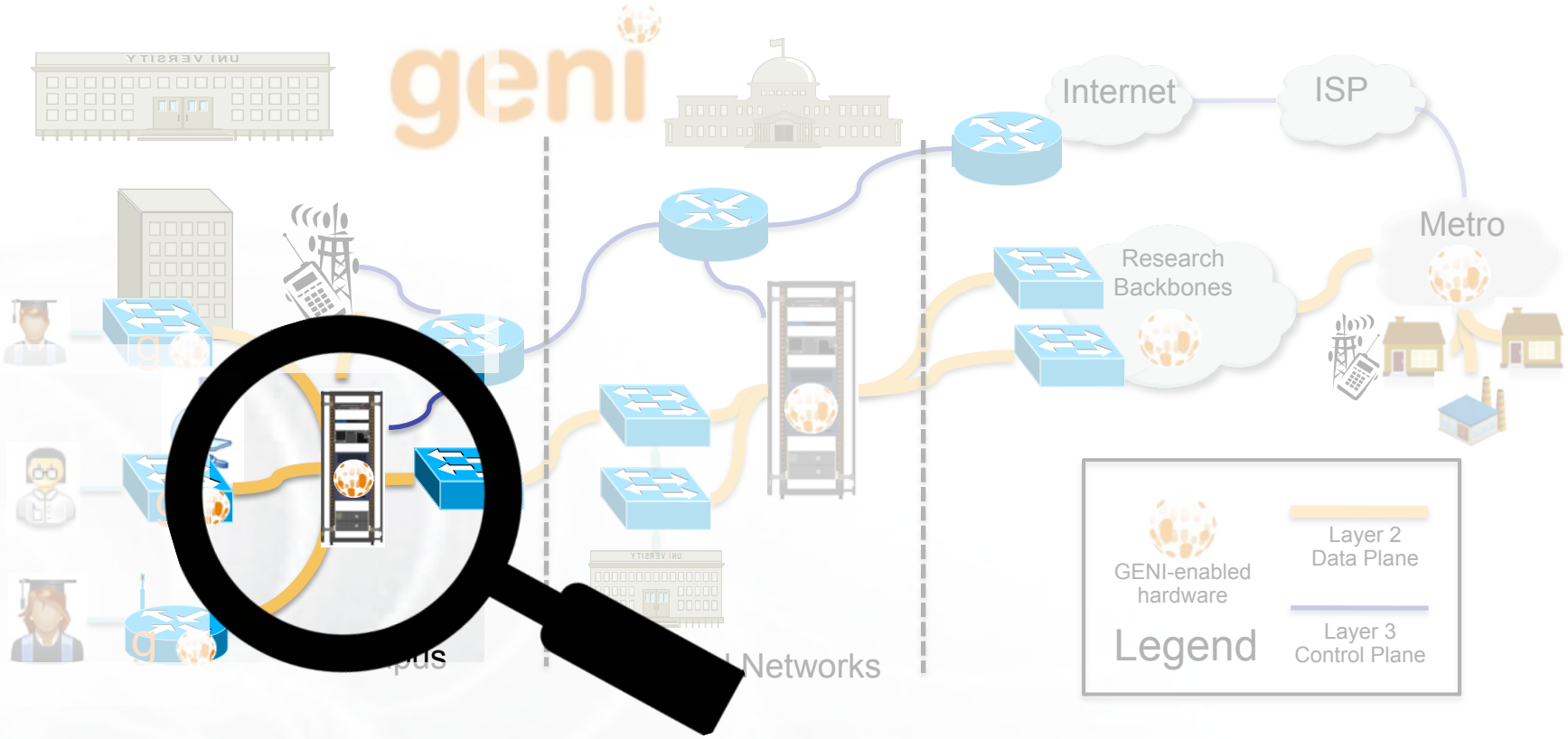


GENI Network Architecture Overview

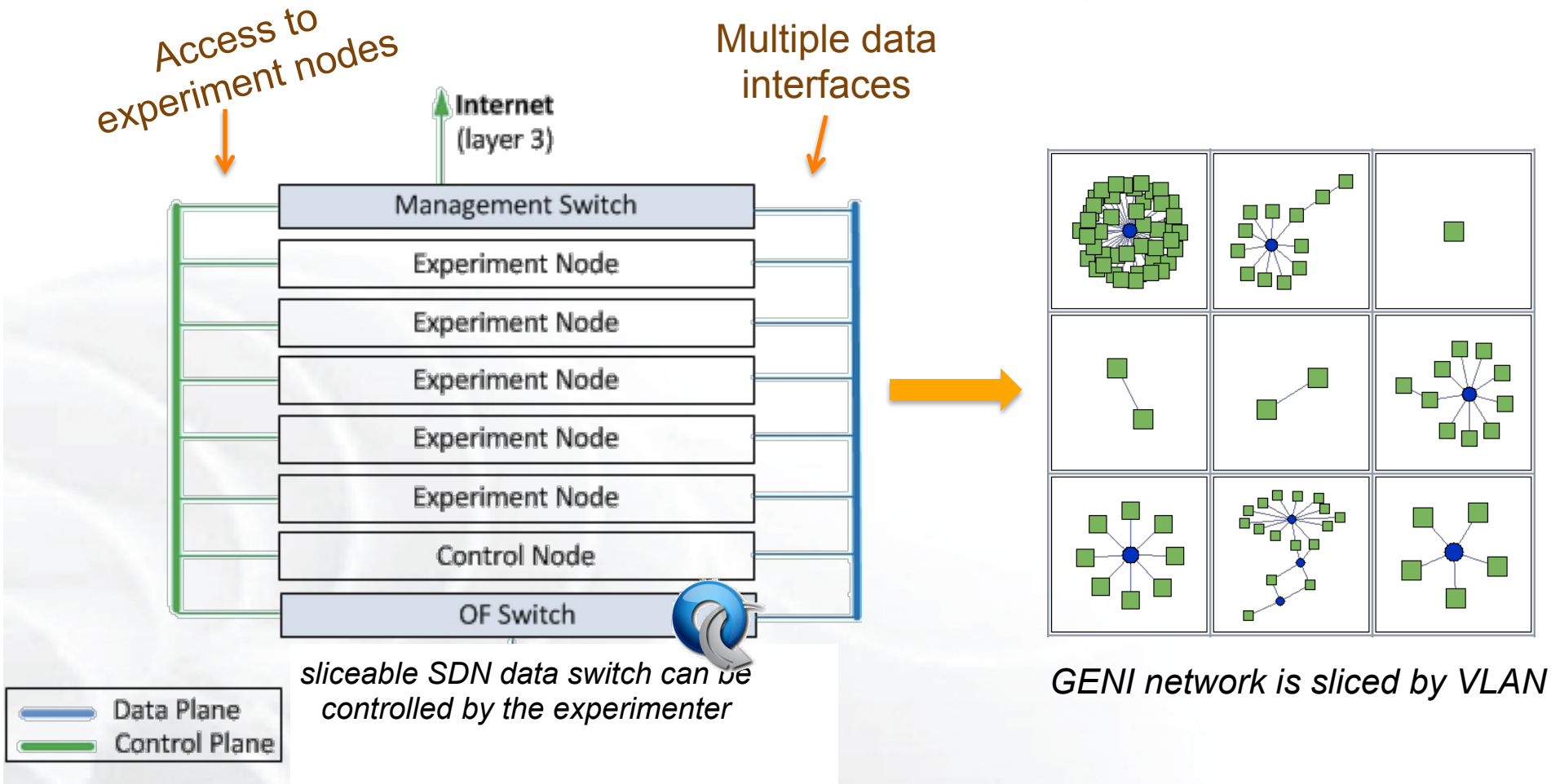


- Spans campus/metro, regional, and nationwide networks
- GENI relies on participants to contribute compute and network resources
- Includes VMs, bare metal nodes, SDN switches (OpenFlow 1.0), WiMAX/LTE base stations and clients, L2 network access

The GENI Rack



GENI Rack Network

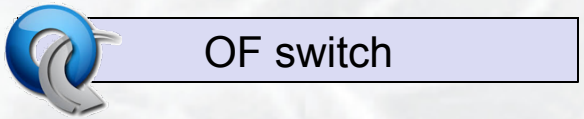


*Embed a variety of topologies within one rack **sliced by VLAN***

GENI Rack OpenFlow switch

Different OpenFlow modes

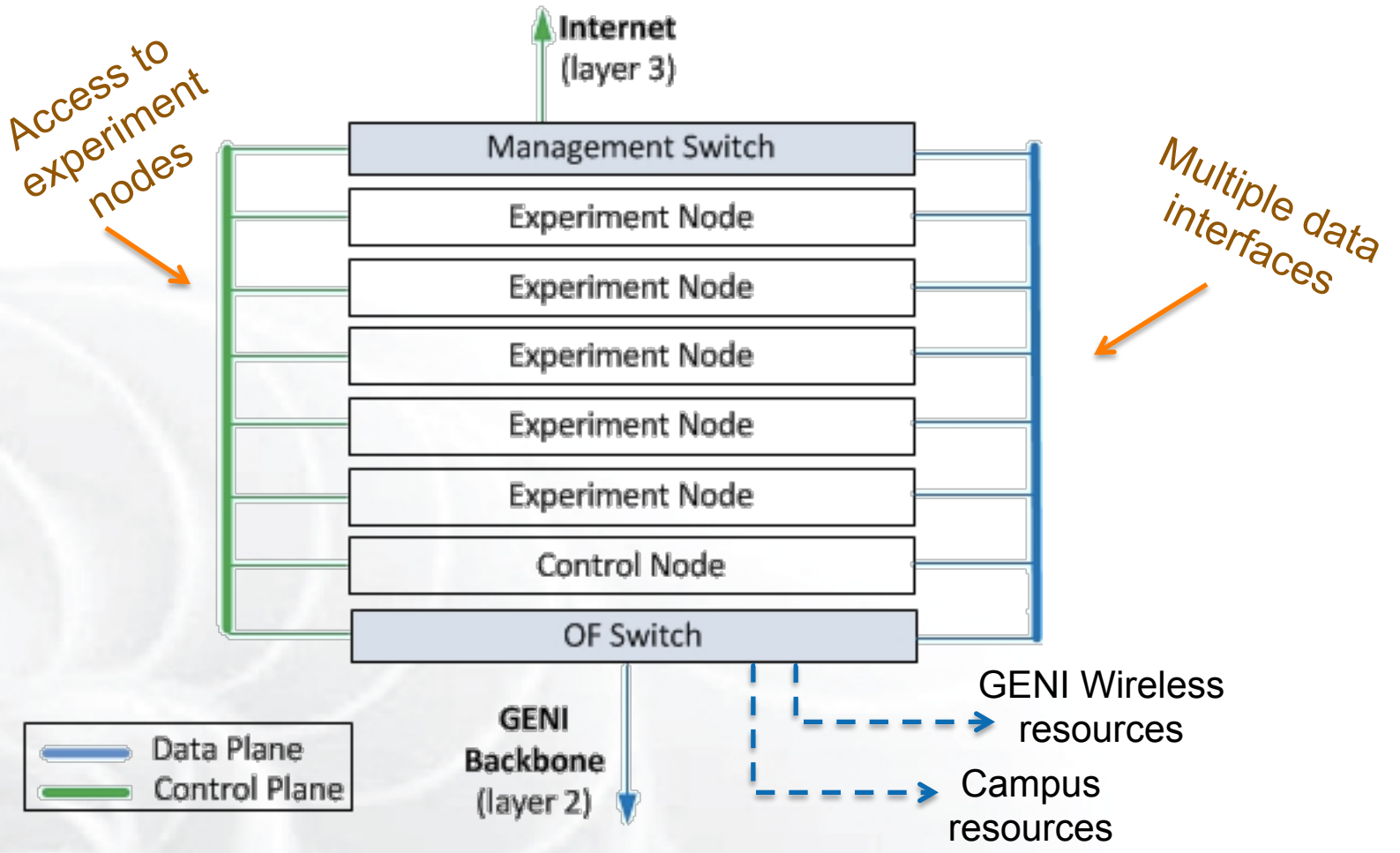
- switches in **pure OF** mode are acting as one datapath
- **Hybrid VLAN switches** are one datapath per VLAN *(sliced at the switch)*
- **Hybrid port switches** are two datapaths (one OF and one non-OF)



- Need slicer for **pure OF** and **port hybrid**
  - FlowVisor, FlowSpace Firewall

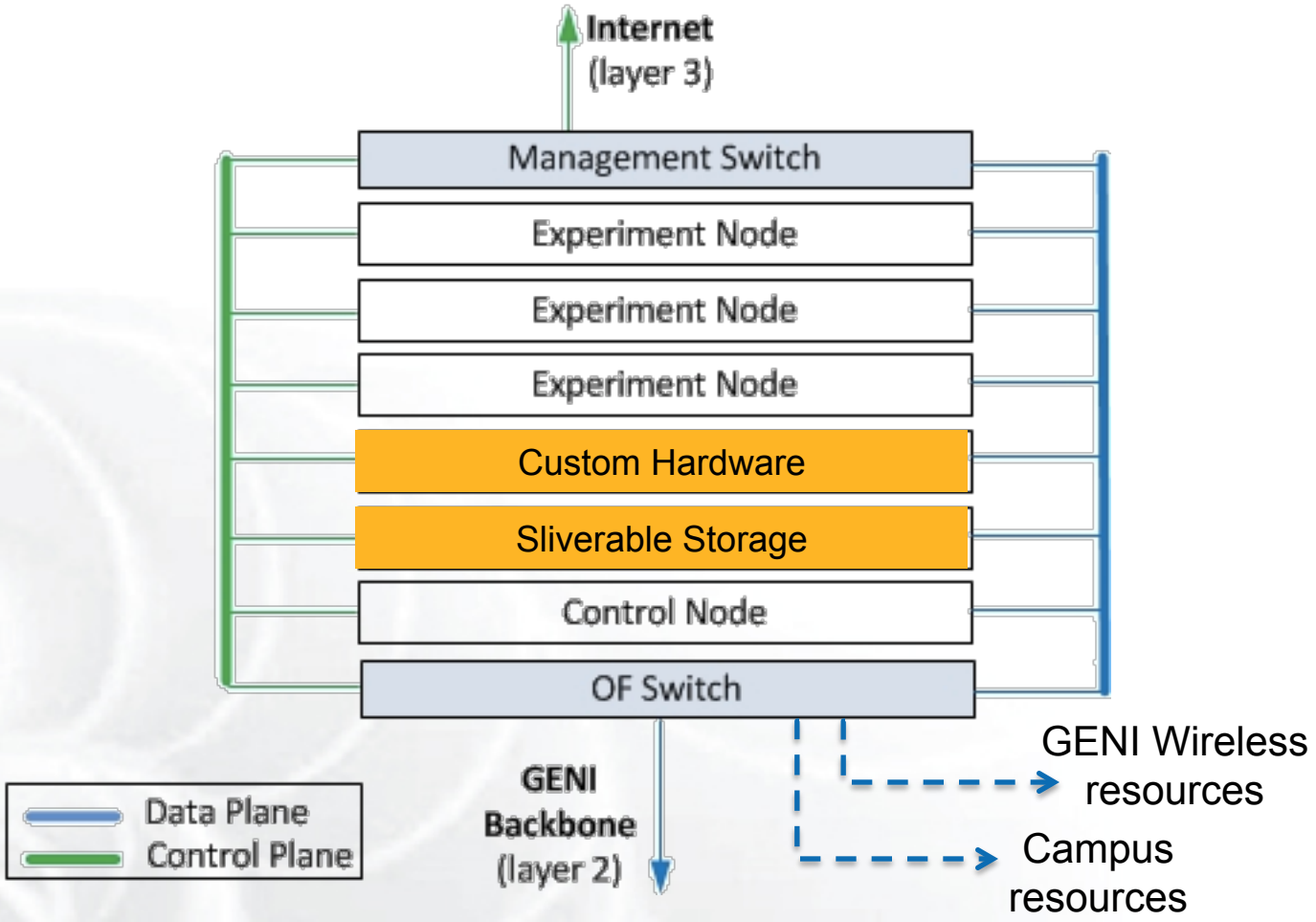
*Embed a variety of topologies within one rack **sliced by VLAN***

GENI Rack Network



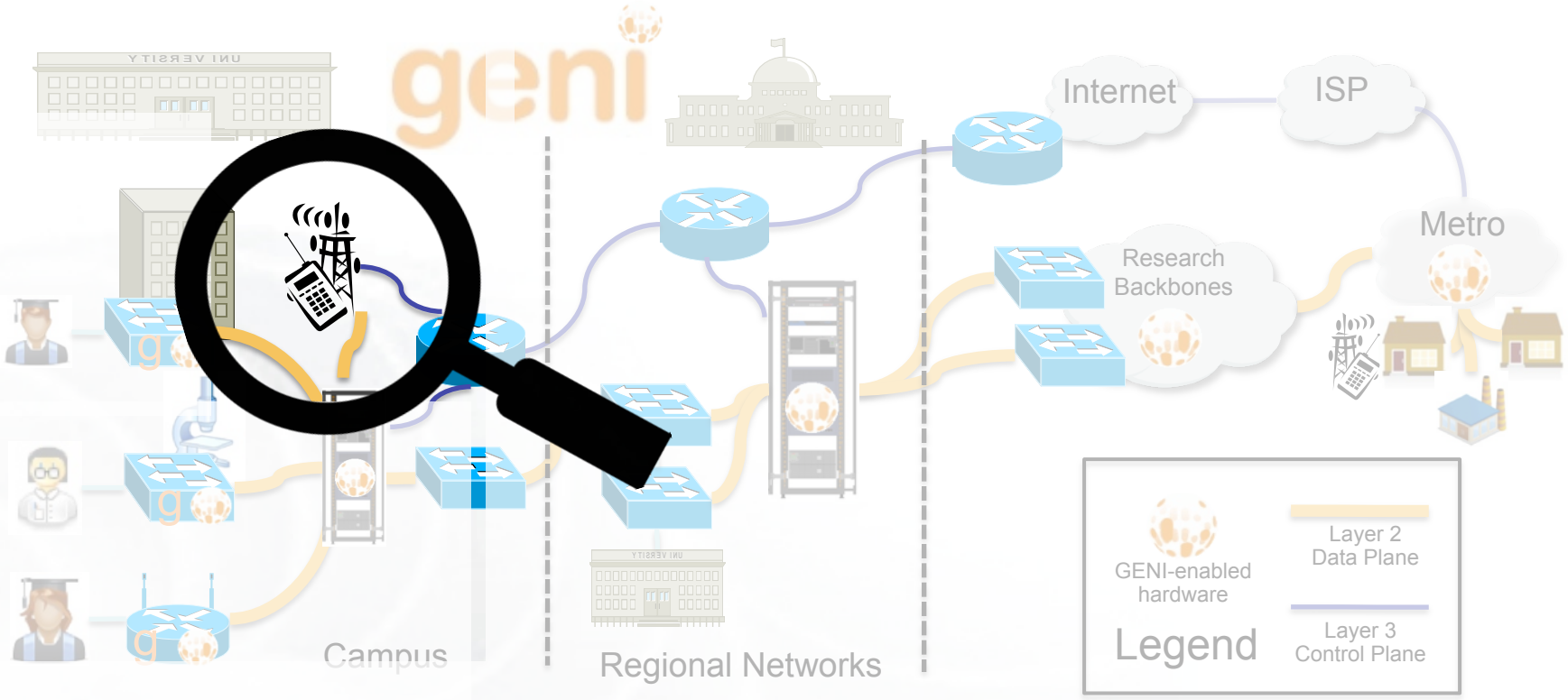
Each Rack is a separate AM that ensures that experiment nodes are connected to the appropriate external resources

Extra Devices in a Rack

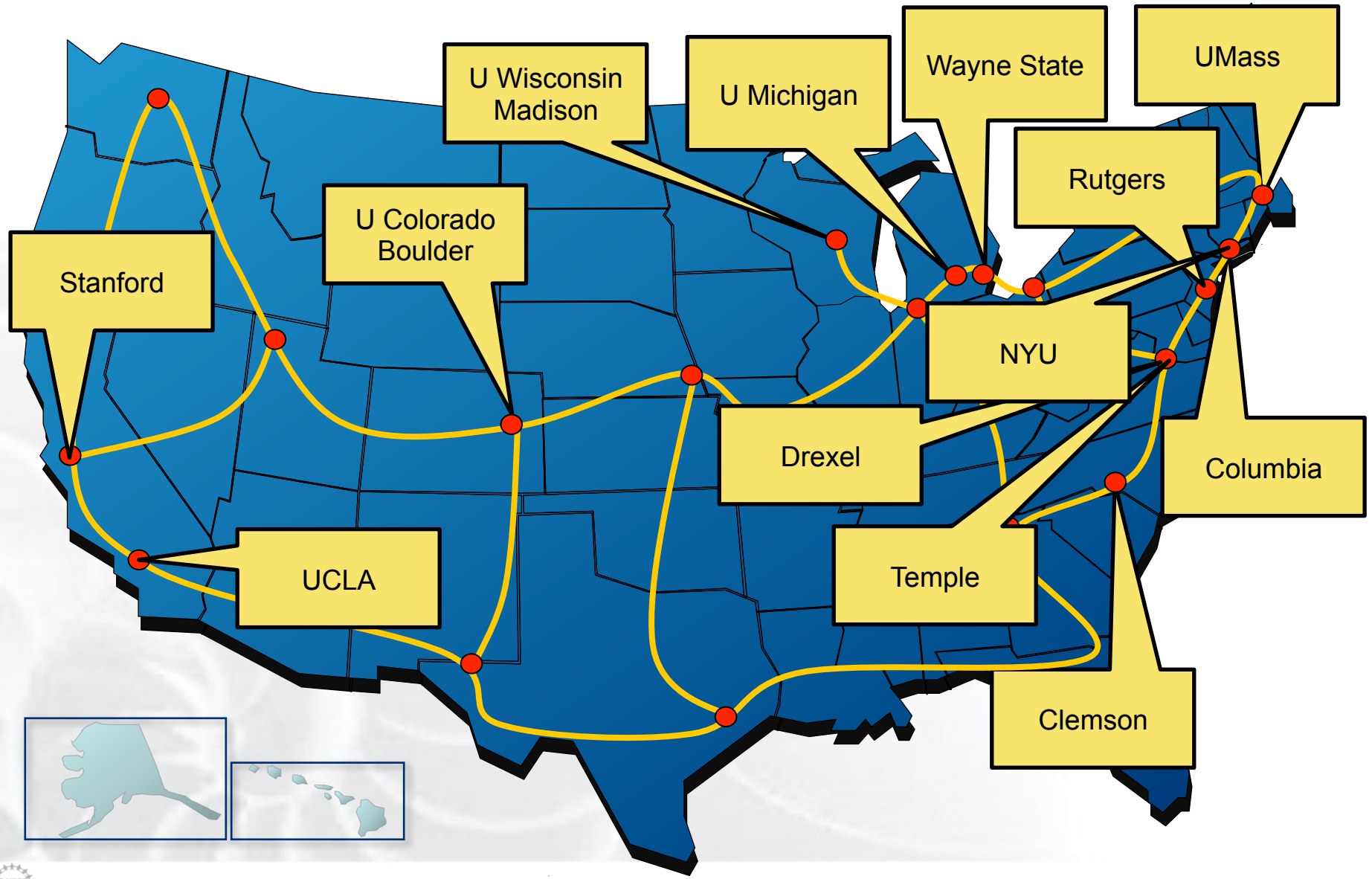


AM may control extra devices or just provide connectivity

GENI Wireless



GENI WiMAX Deployment 2014

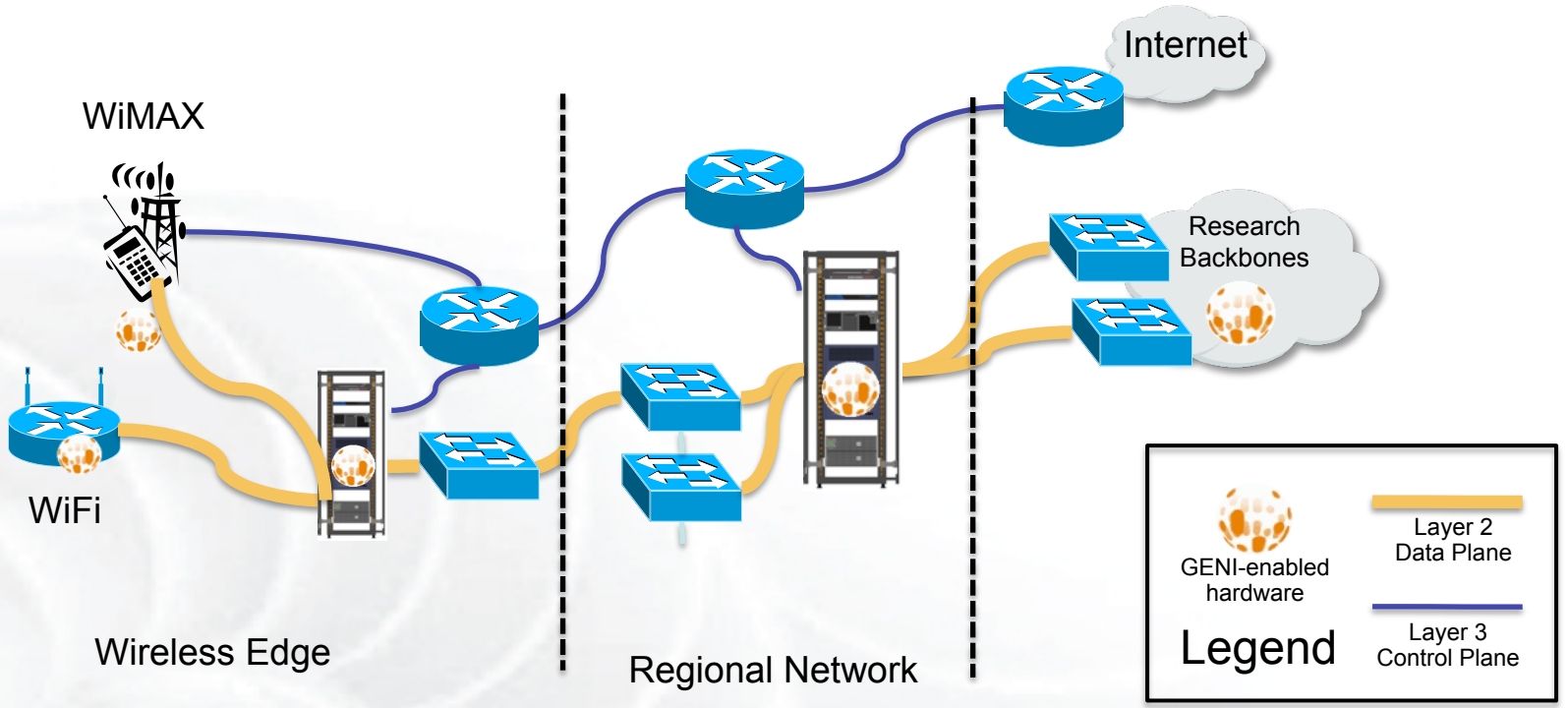


GENI WiMAX

- **Agreement with Sprint**
  - Sprint and Rutgers University have signed a **master spectrum agreement**
  - encompassing all WiMAX sites, to ensure **operation in the EBS Band**.
  - An **emergency stop procedure**, in case of interference with Sprint service, has been agreed upon.

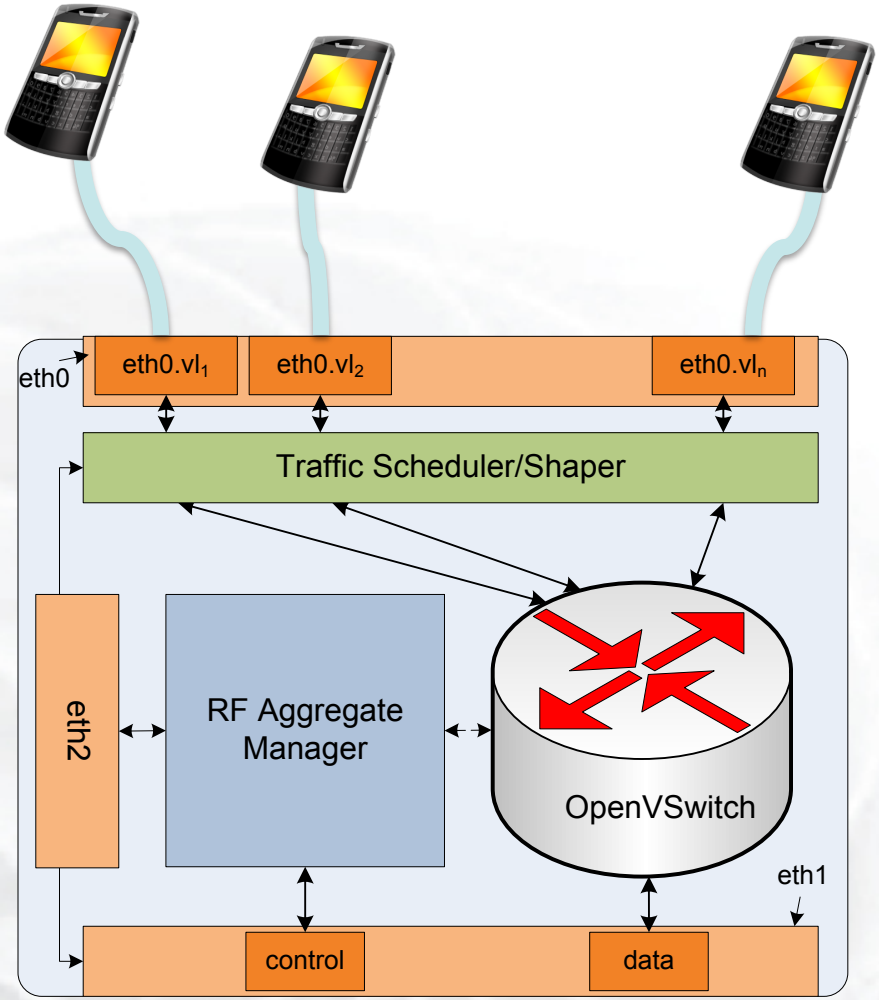
- **SciWinet GENI Mobile Virtual Network Operator (MVNO)**
  - Partner with Sprint and Arterra (a Sprint partner) to create and operate an (**MVNO**) that serves the academic research community
  - The effort is led by Jim Martin and Ivan Seskar, to learn more: http://sciwinet.org

GENI WiMAX Site Network Architecture



- WiMAX and Wifi edge networks.
- Layer 2 dataplane connectivity to GENI racks.
- Multi-point VLAN interconnecting all WiMAX sites via racks.

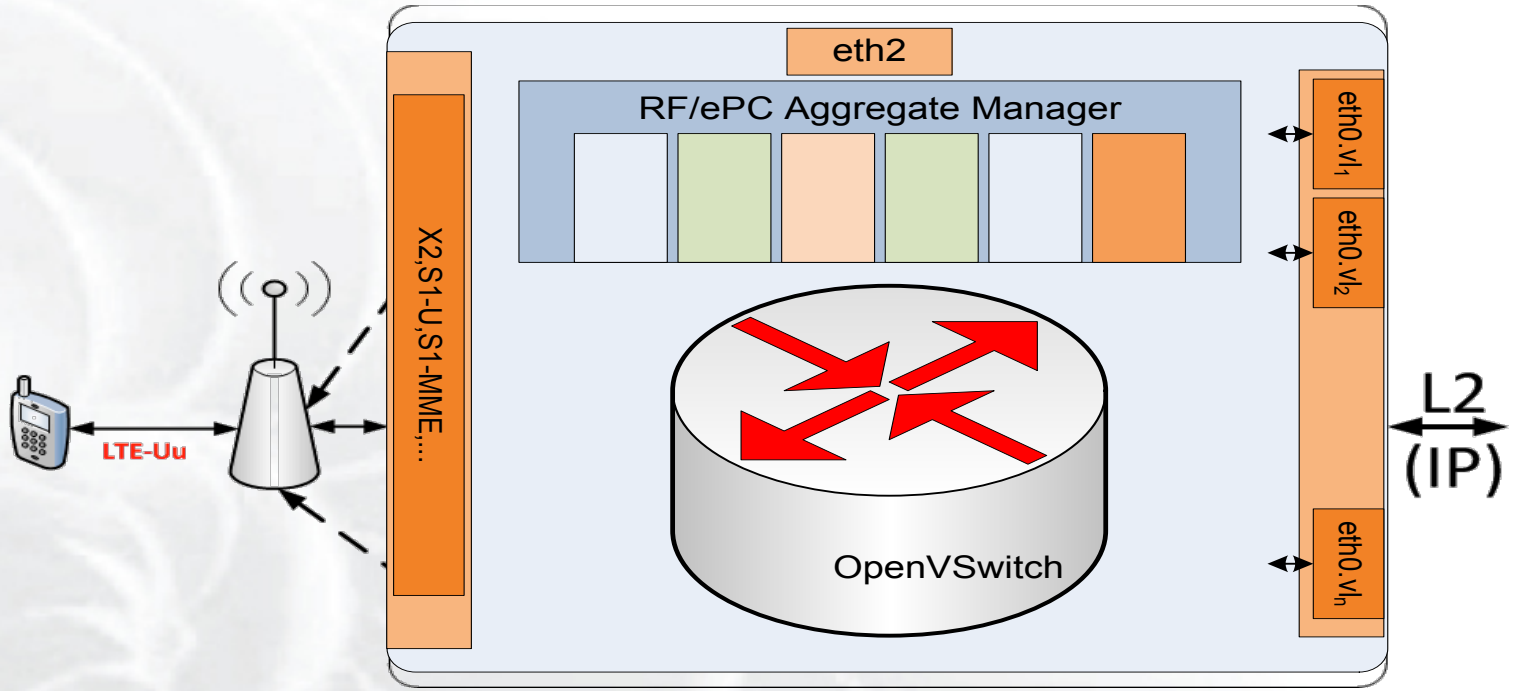
OPEN BTS Software: WiMAX



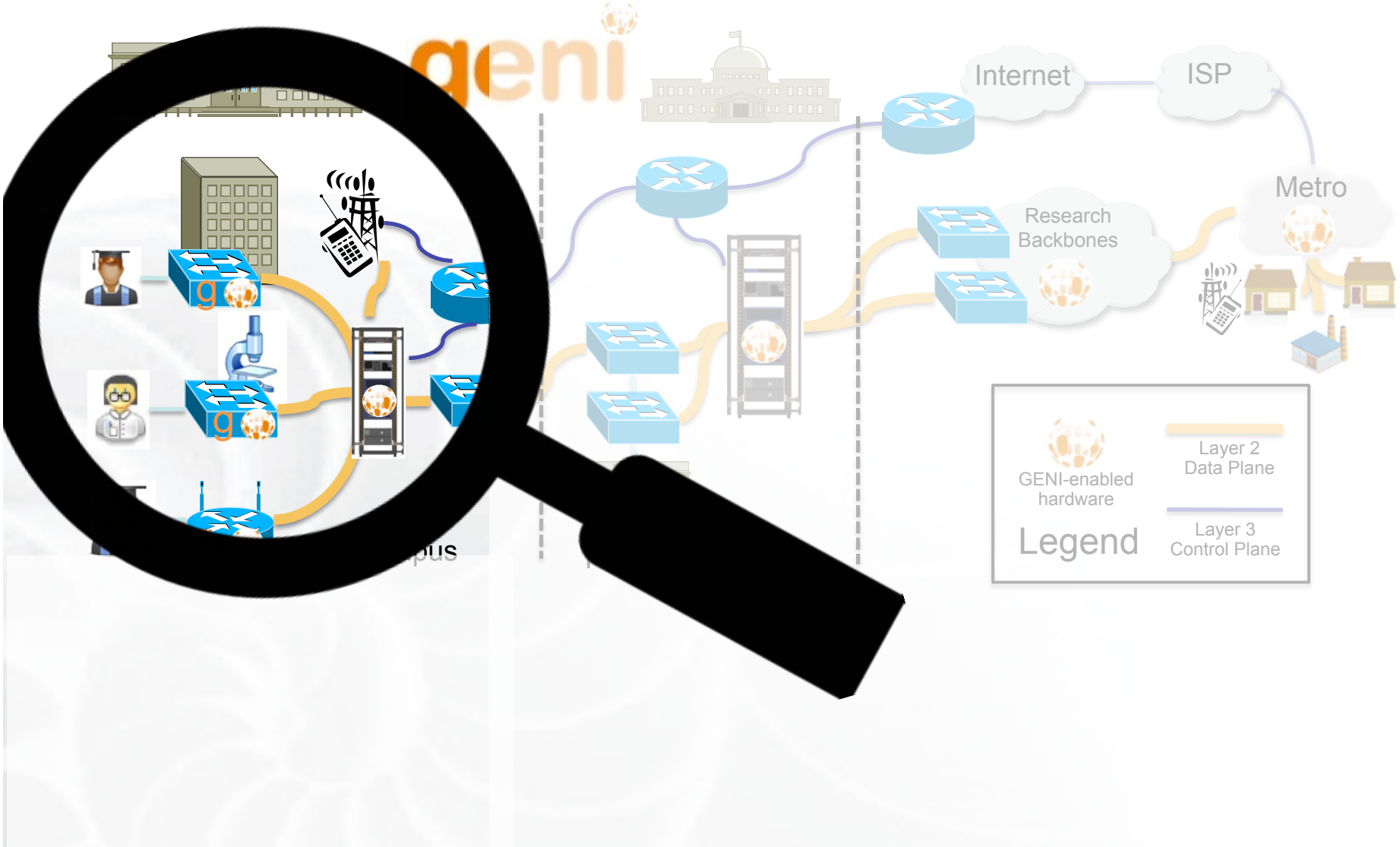
- OMF AM REST Interface
- Each slice contains a sw router (click or OVS)
- Slicing of OFDMA resource blocks by mapping client MAC to VLANs
- Clients are mapped to VLANs

OPEN BTS Software: LTE

New LTE Base station has it own AM to manage the slicing



The GENI-enabled Campus



GENI – Enabled Campus

- Layer 2 transport through the campus
  - Usually statically provisioned
  - Might provide access to programmable switches

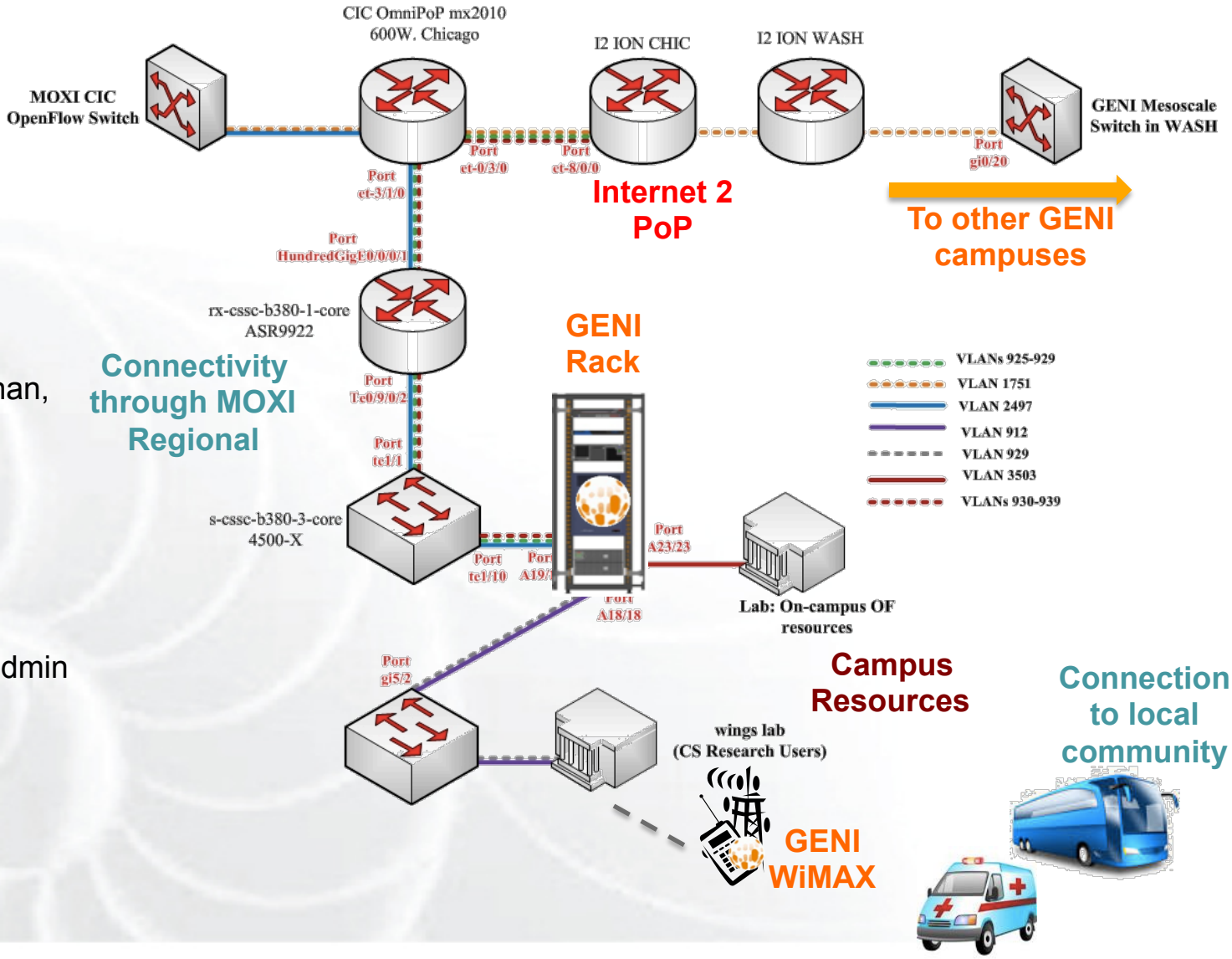
- Layer 2 connectivity to:
  - to GENI wireless resources
  - local resources (university labs, specialized equipment)
  - to local community tesbeds (e.g. ORBIT)
  - to metro networks

Wisconsin: a great example

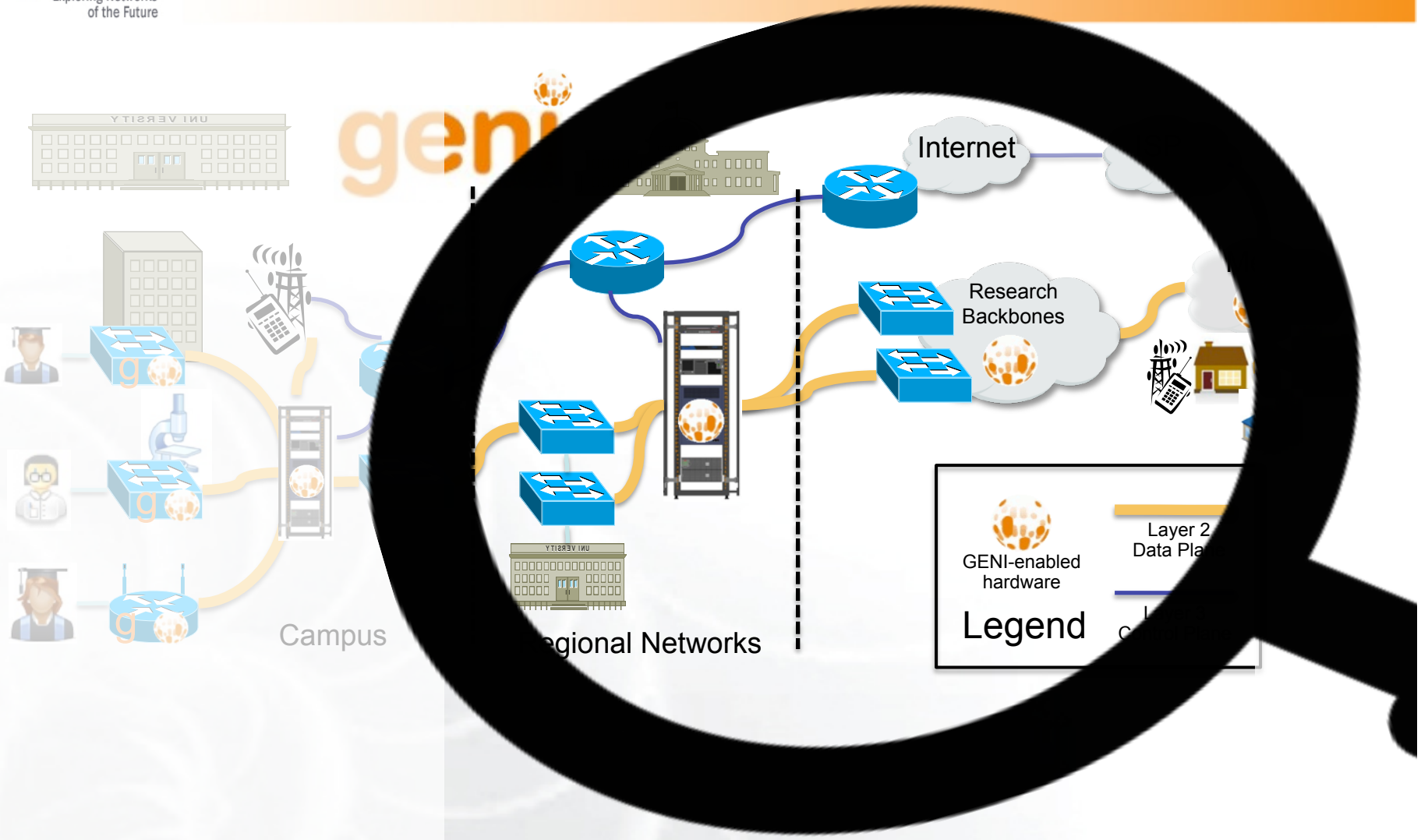
Suman Banerjee, PI

Parmesh Ramanathan, PI

Dale W. Carter, Campus admin



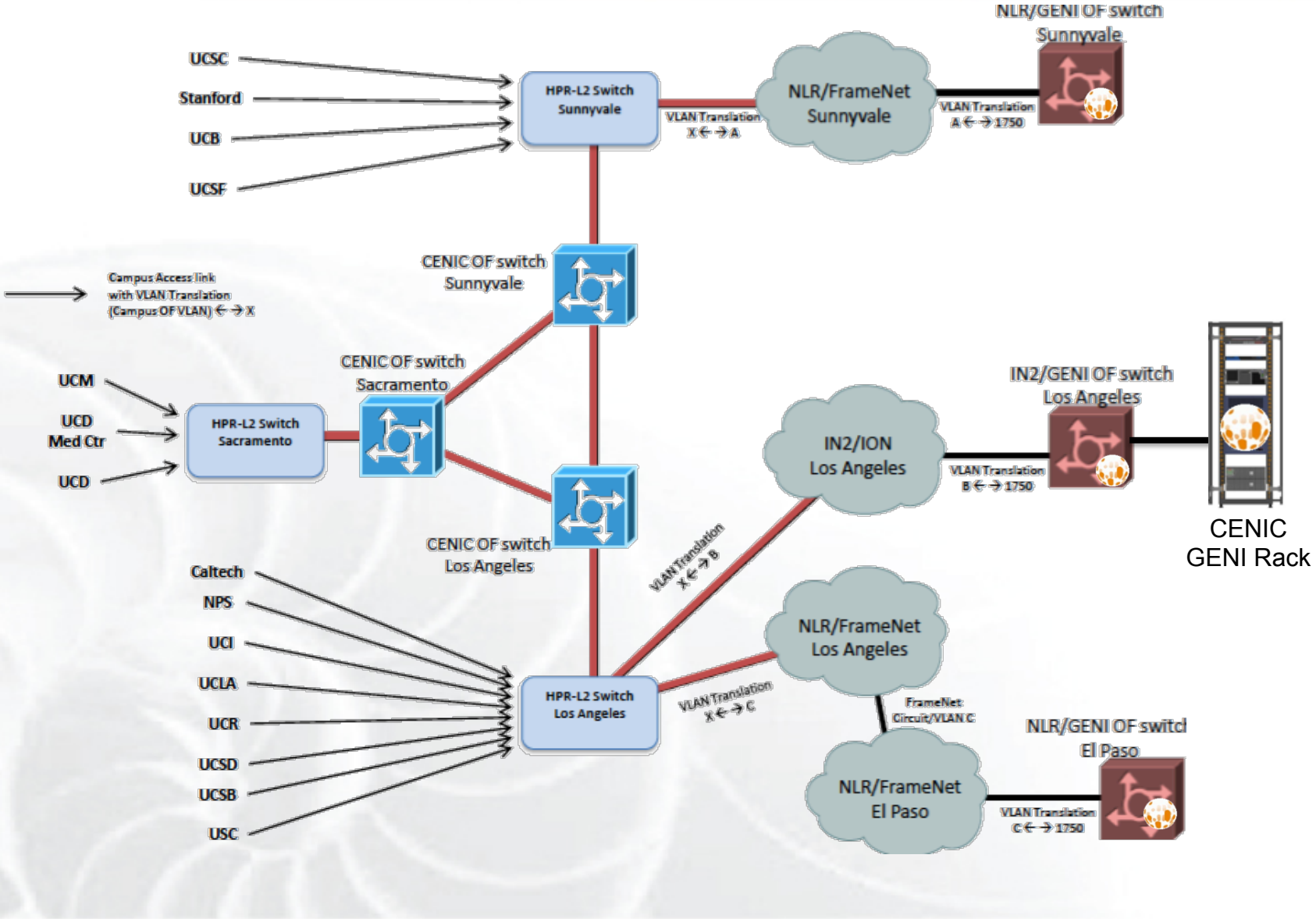
The GENI Core Network



GENI Regionals

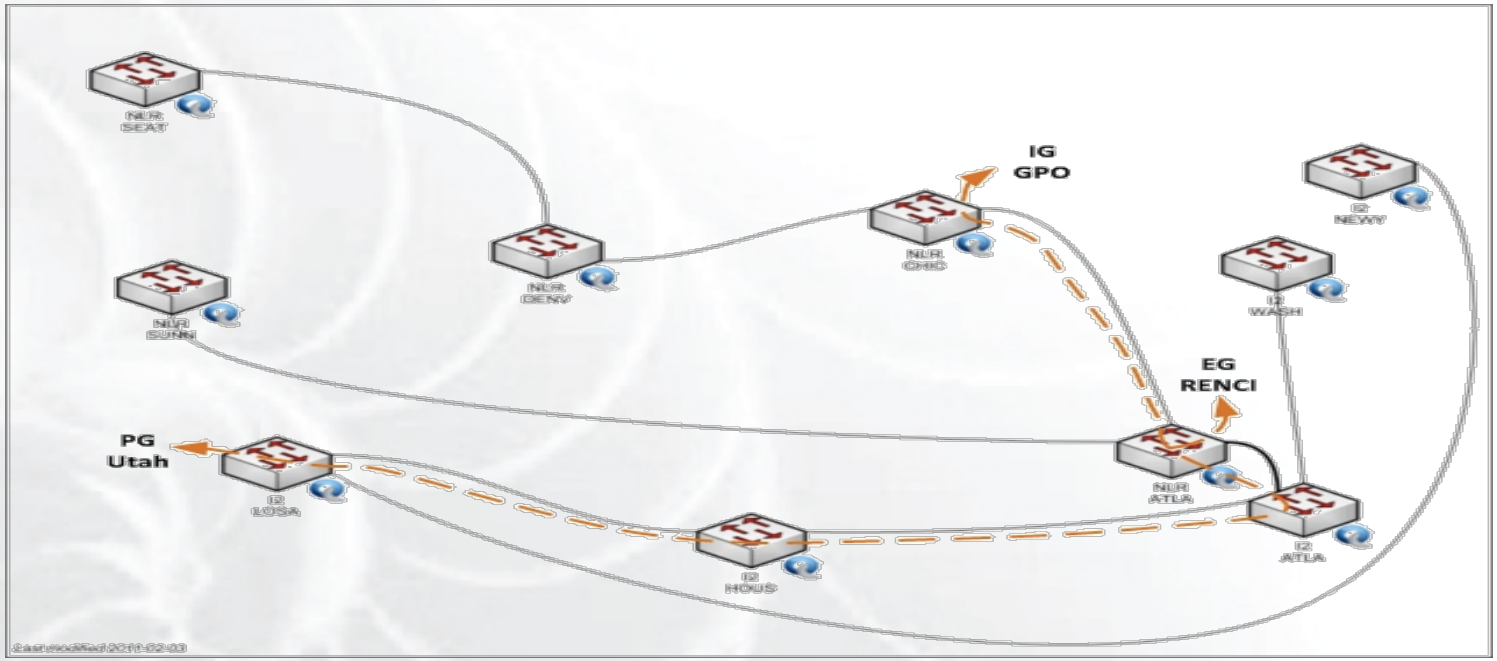
- Provide simple transport
  - static network configuration of multiple connections managed by edge Aggregate Managers (e.g. NOX)
  - May provide dynamic circuit provisioning (e.g. MAX)
- Provide access to routing to experimenters through SDN capable devices (e.g. StarLight)
- Provide access to compute and storage through a co-located GENI Rack (e.g. Cenic)

Example regional network
CENIC OpenFlow buildout



GENI Core Network History

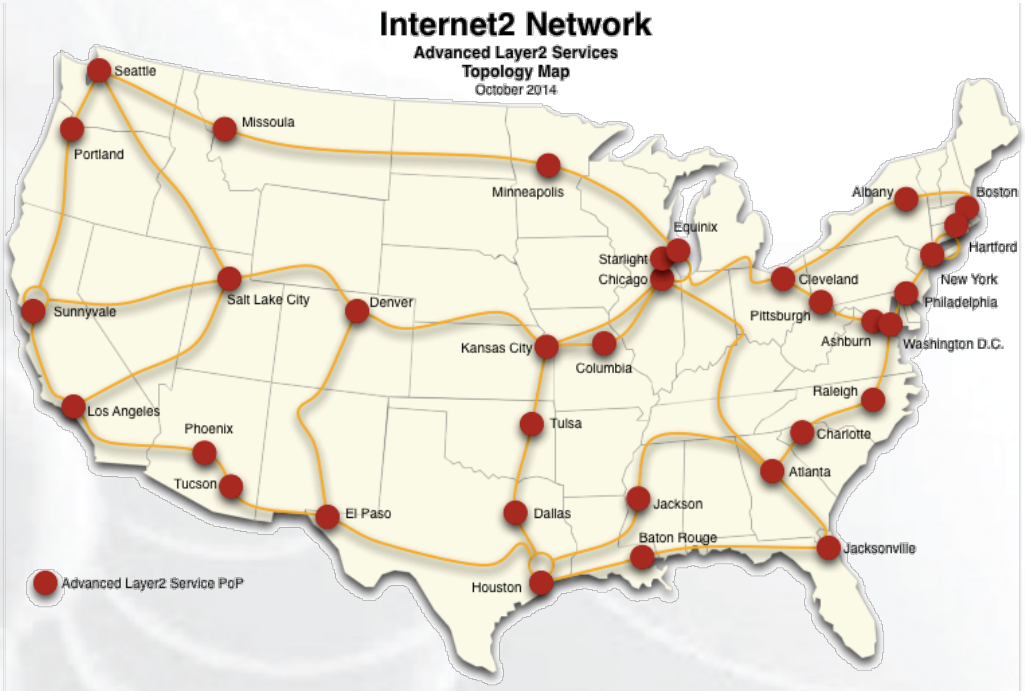
- Non-programmable dynamic Layer 2 transport through ION
- Prototype static programmable backbone with SDN capable devices (decommissioning)



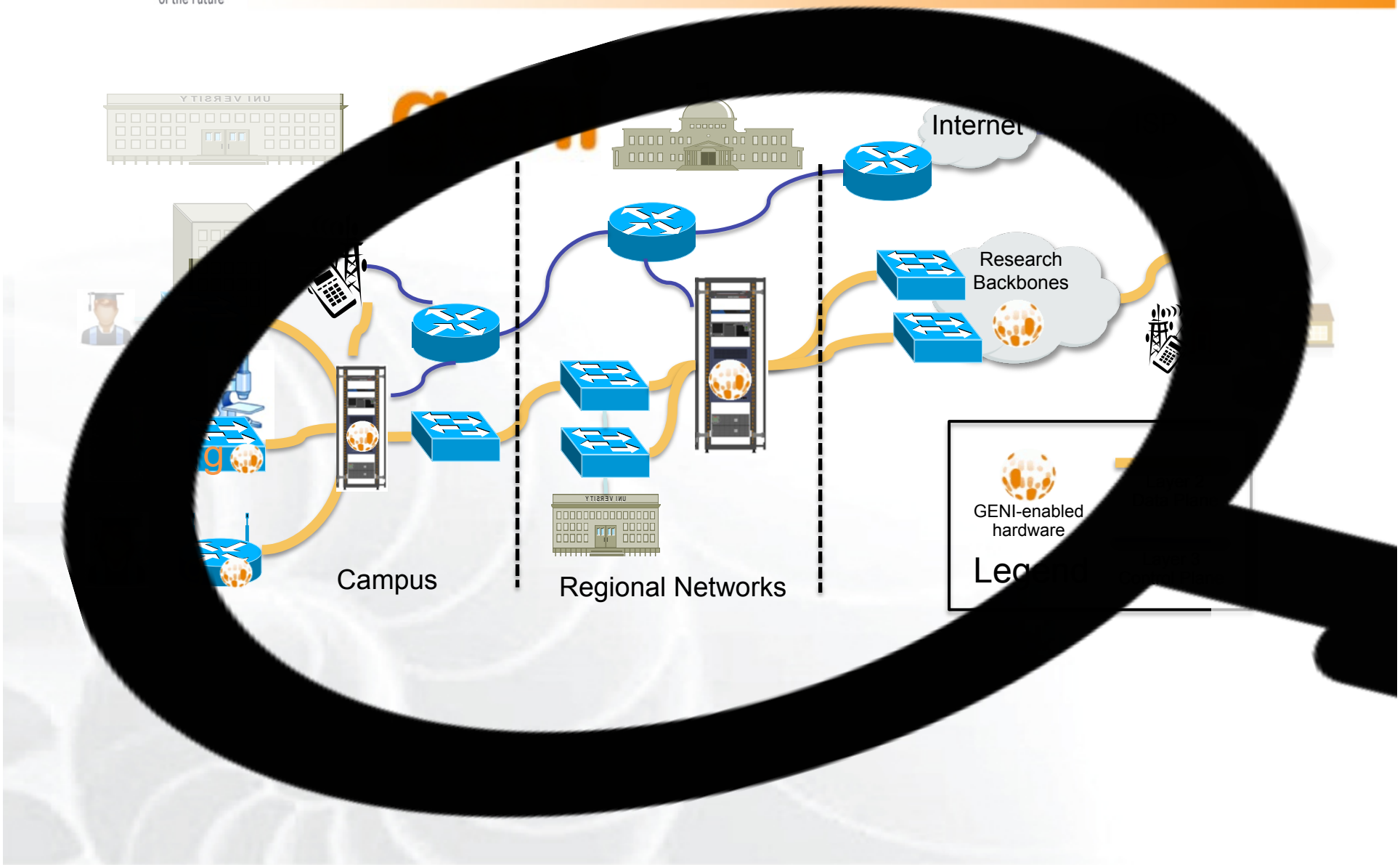
Prototype GENI Backbone over I2 and NLR with 10 OpenFlow Switches

GENI Core network moving to AL2S

- In-progress migration from “prototype GENI” to AL2S production system
  - Testing GENI dynamic provision on AL2S AM
  - Testing Experimenter OpenFlow controllers on AL2S

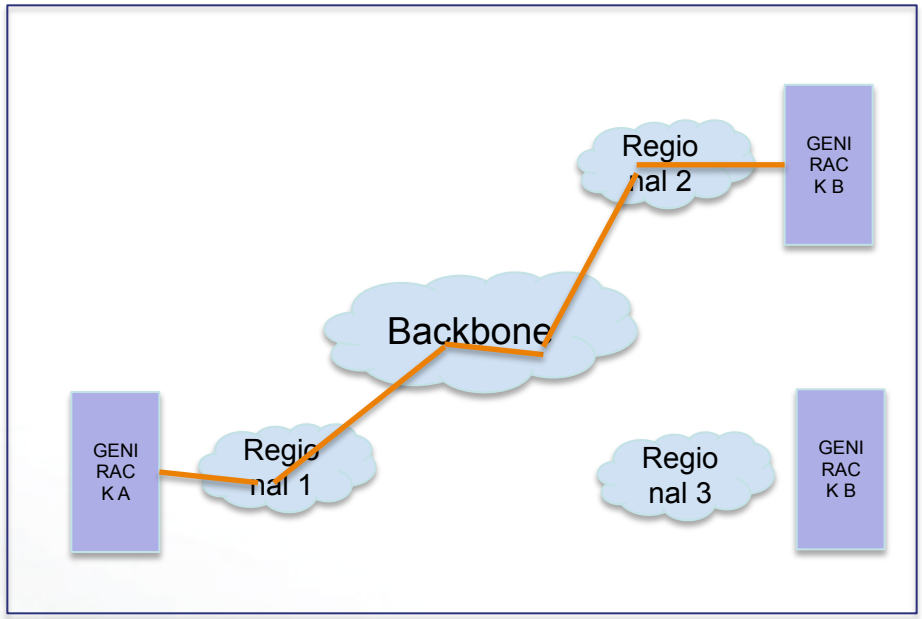


Creating Inter-Aggregate Experiments



GENI Stitching

- Setup point-to-point VLANs
  - Between hosts on different Ams
    - One host/per AM/per stitch
  - Not a broadcast domain
- Dynamic, real-time setup
  - Need to coordinate multiple AMs
  - Takes time
  - Can fail
- Provides traffic isolation and bandwidth constraints



A common concept used in other networks, applied to GENI, e.g. OSCARS, GLIF

GENI Stitching: Under the Hood

How does GENI Stitching Work?

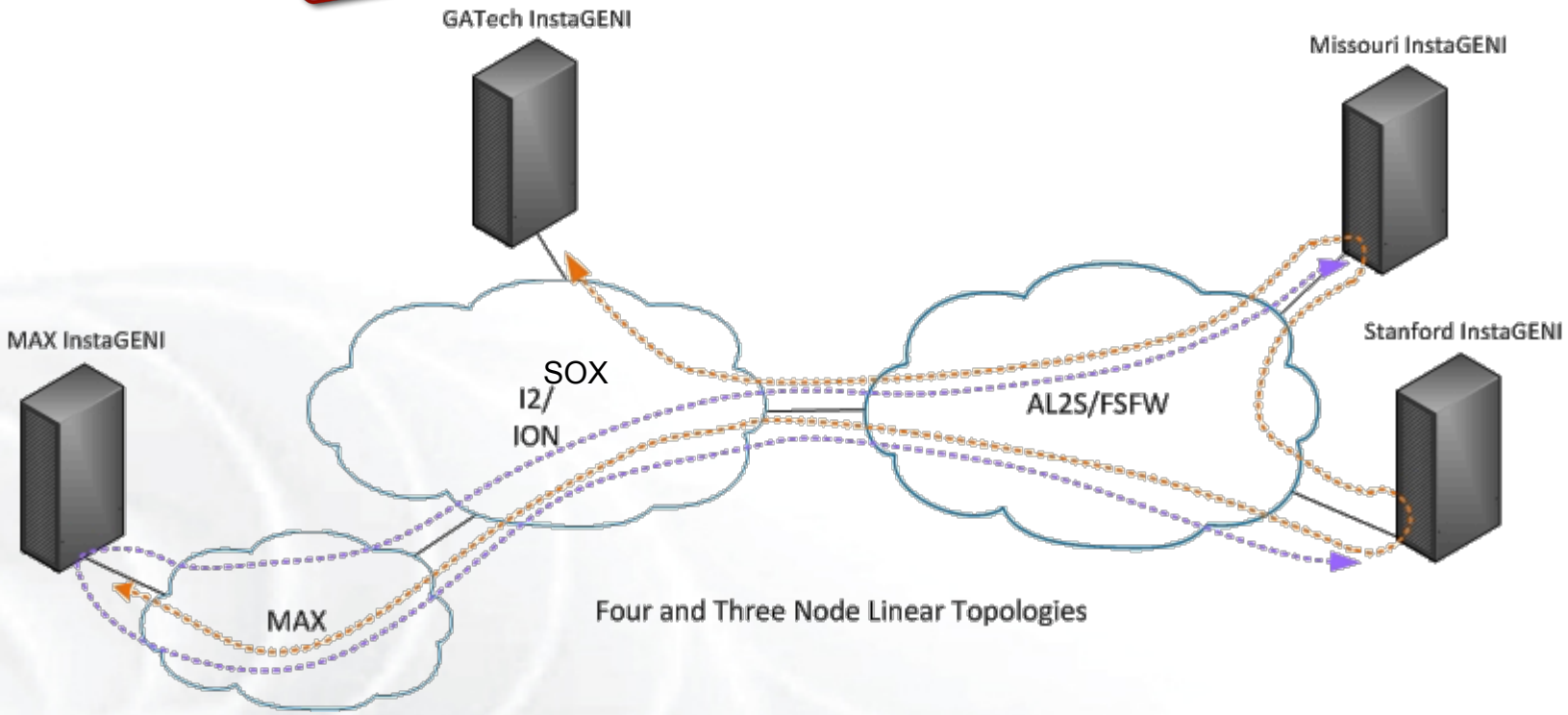
1. Rack Configuration (network admins)

- Long process (~weeks, months)
- Done once in advance
- Manual

2. Inter-aggregate link reservations (experimenters)

- Automated (tools can make them)
- Quickish (usually a few minutes)
- Live, Easy
- Repeatable

Example "Pre-work" for End-to-End Data Connections

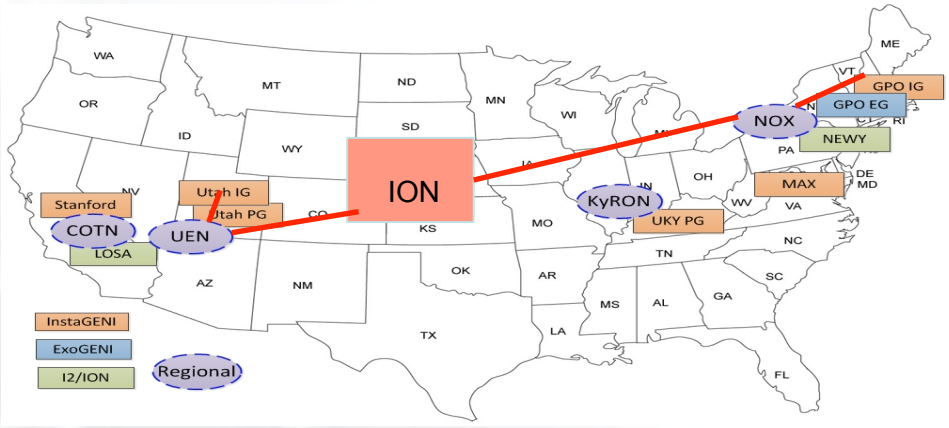


- Identify paths from a rack to GENI core
  - Identify the network providers
    - Typically a campus, a regional, a nationwide provider(GATech, Missouri, Stanford, MAX, SOX, ION, and AL2S)
  - Identify **endpoints** and allocate **VLAN to GENI** that can be used to connect to the rack
- Configure racks with VLANS for GENI stitching
- Test for connectivity

Stitching Computation Service

Finding a workable path, and the right reservation order can be hard.

- Stitching Computation Service (SCS) for path and workflow computation
  - Tom Lehman and Xi Yang wrote this optional service
  - Includes many heuristics to optimize path, chance of success
  - Allows excluding particular connection points, VLANs
- Other tools may use different heuristics
  - Stitcher uses the SCS



https://wiki.maxgigapop.net/twiki/bin/view/GENI/NetworkStitchingAPI

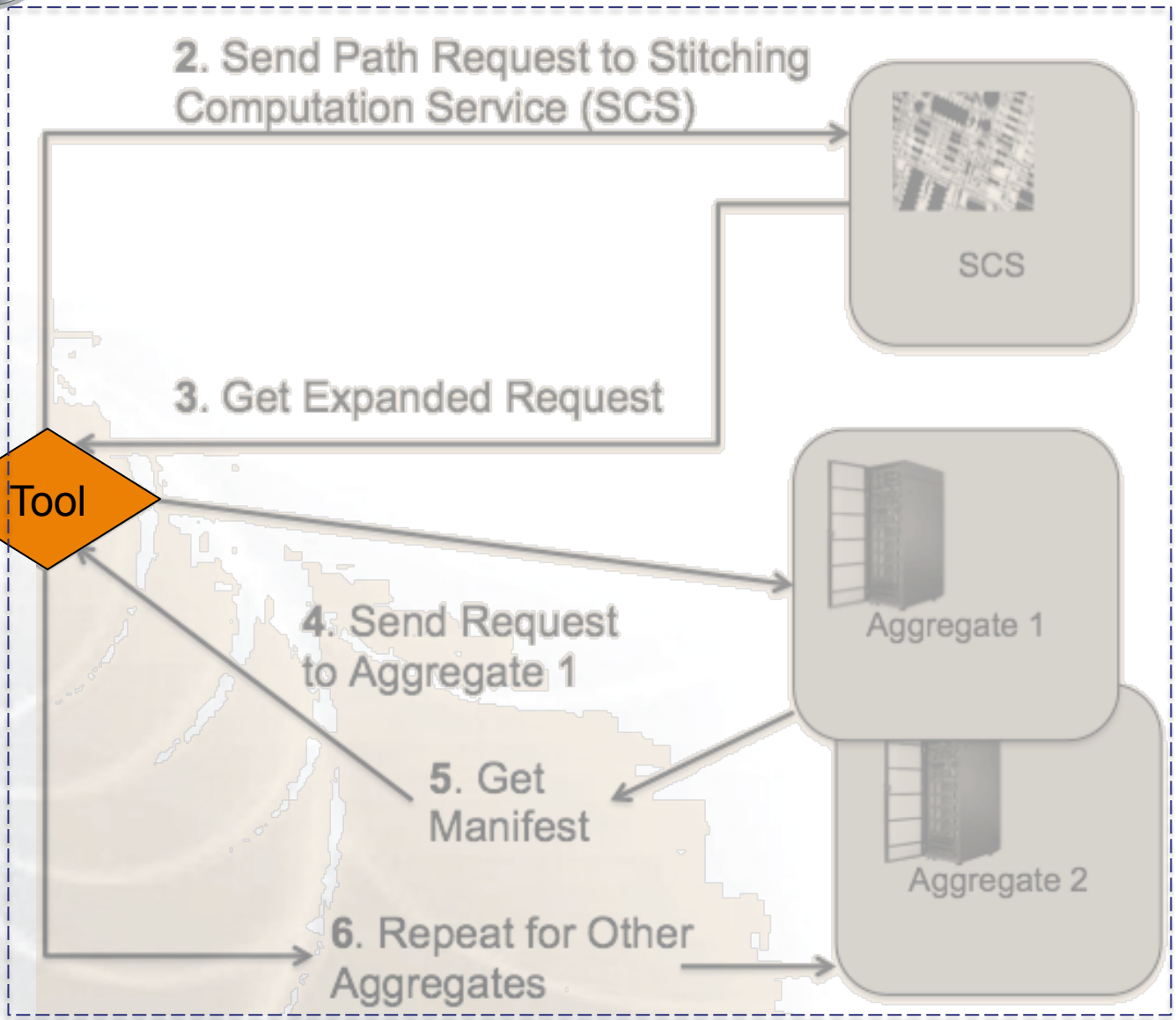
Experimenter: Creating a Circuit

Automated by the tool

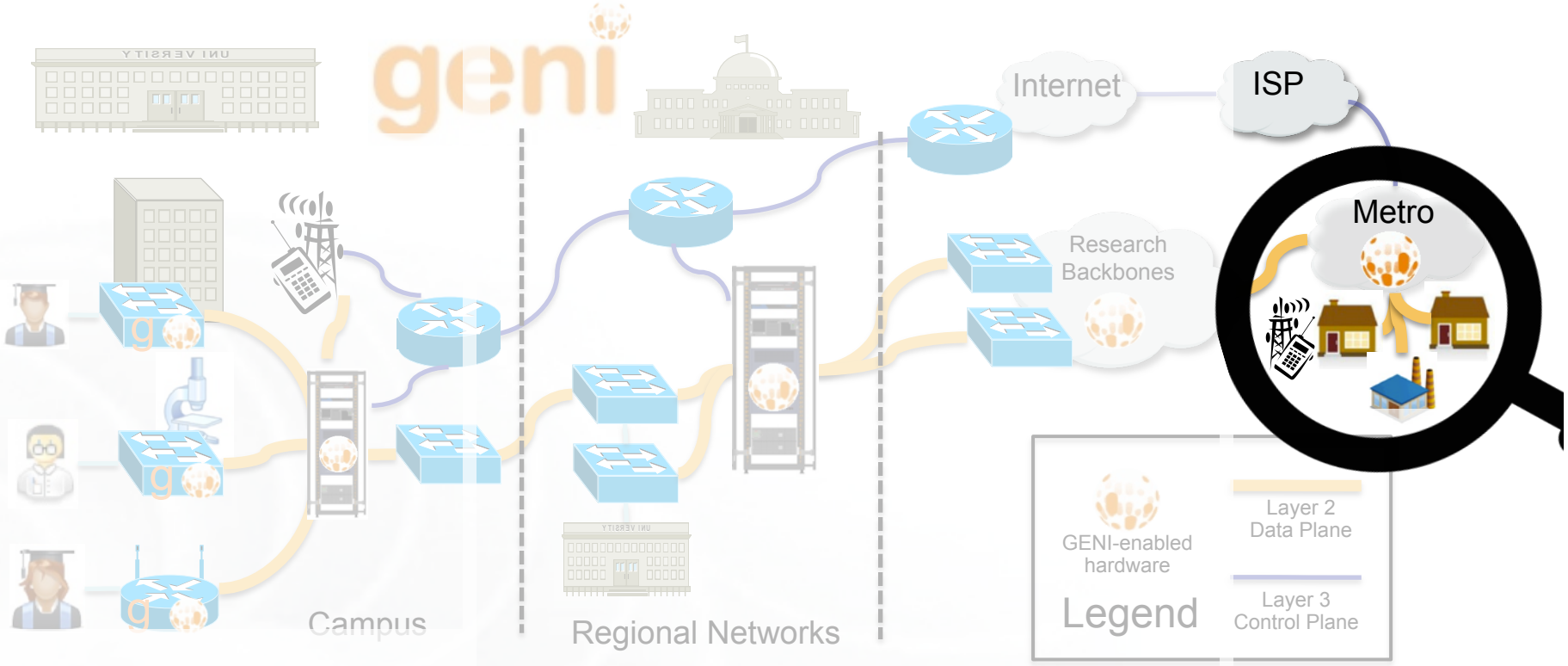
1. Simple Request

7. Manifest Back

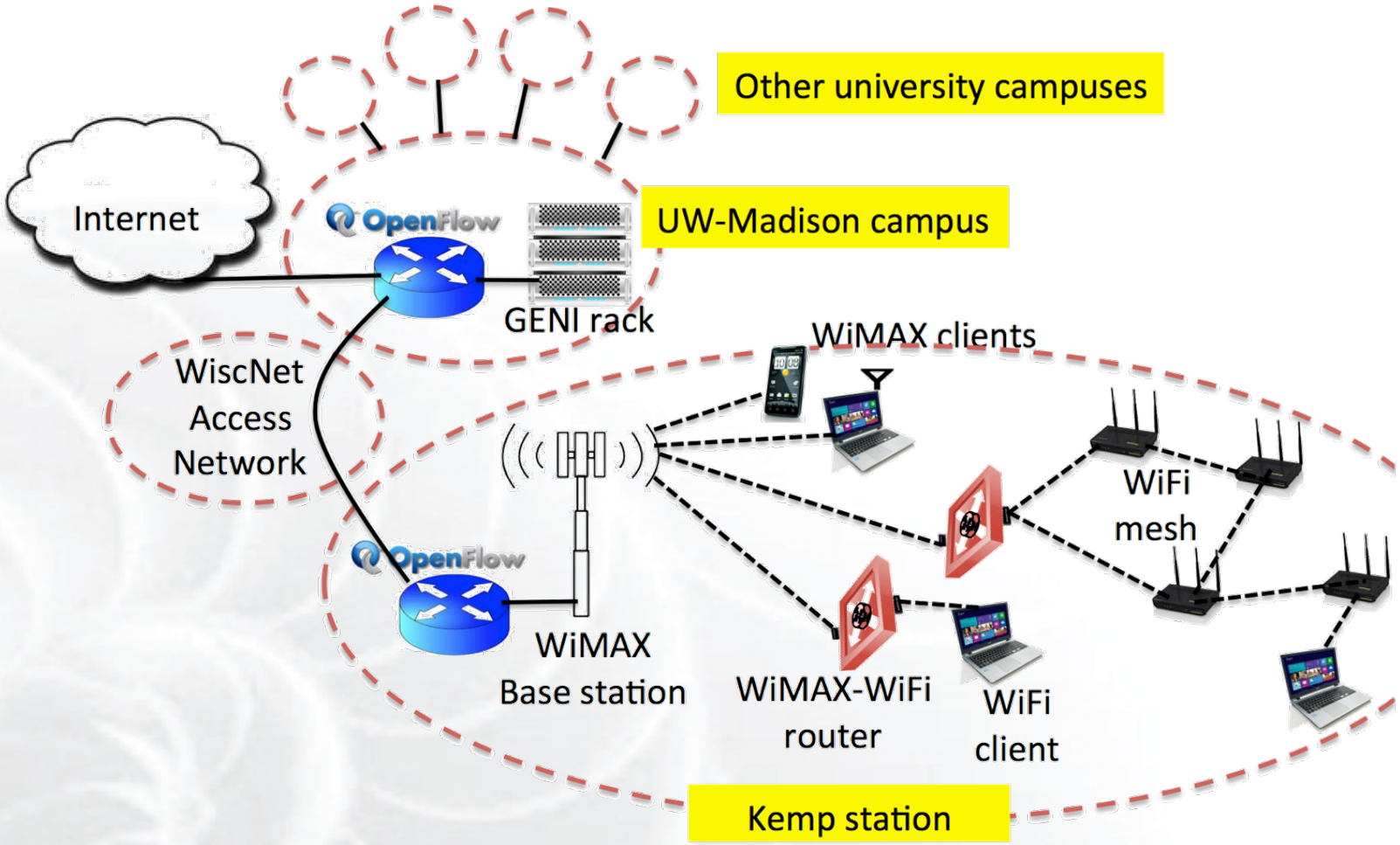
Over 16,000 stitched slivers since November, 2013



Running Services for non-GENI users



Access to the local community through GENI resources



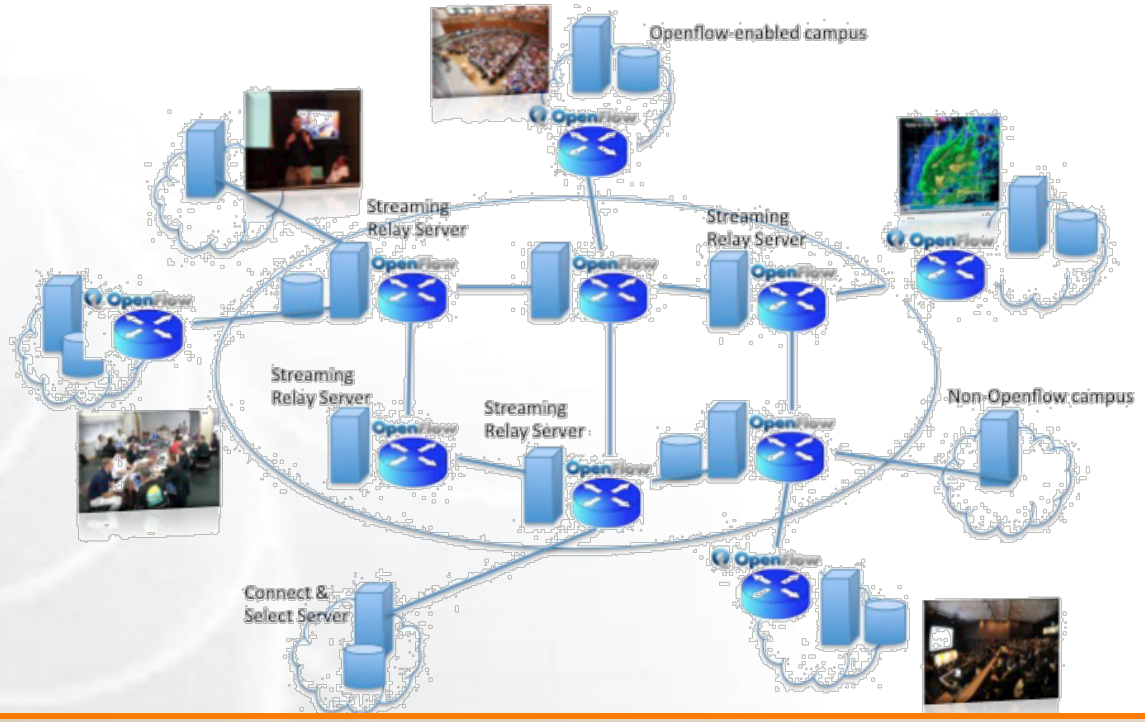
Use the commodity Internet

Parmesh Ramanathan
U. Wisconsin

KC Wang
U. Clemson

GENI Cinema

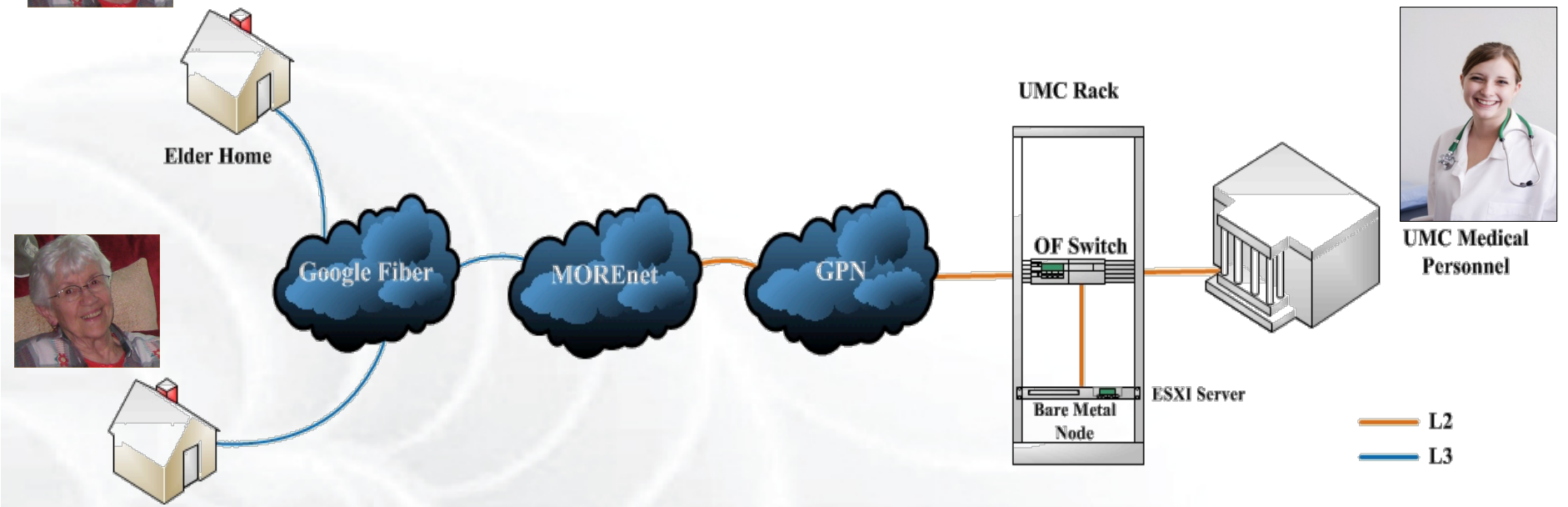
Persistent live video streaming service over GENI



Opt-in users can view and source live streams

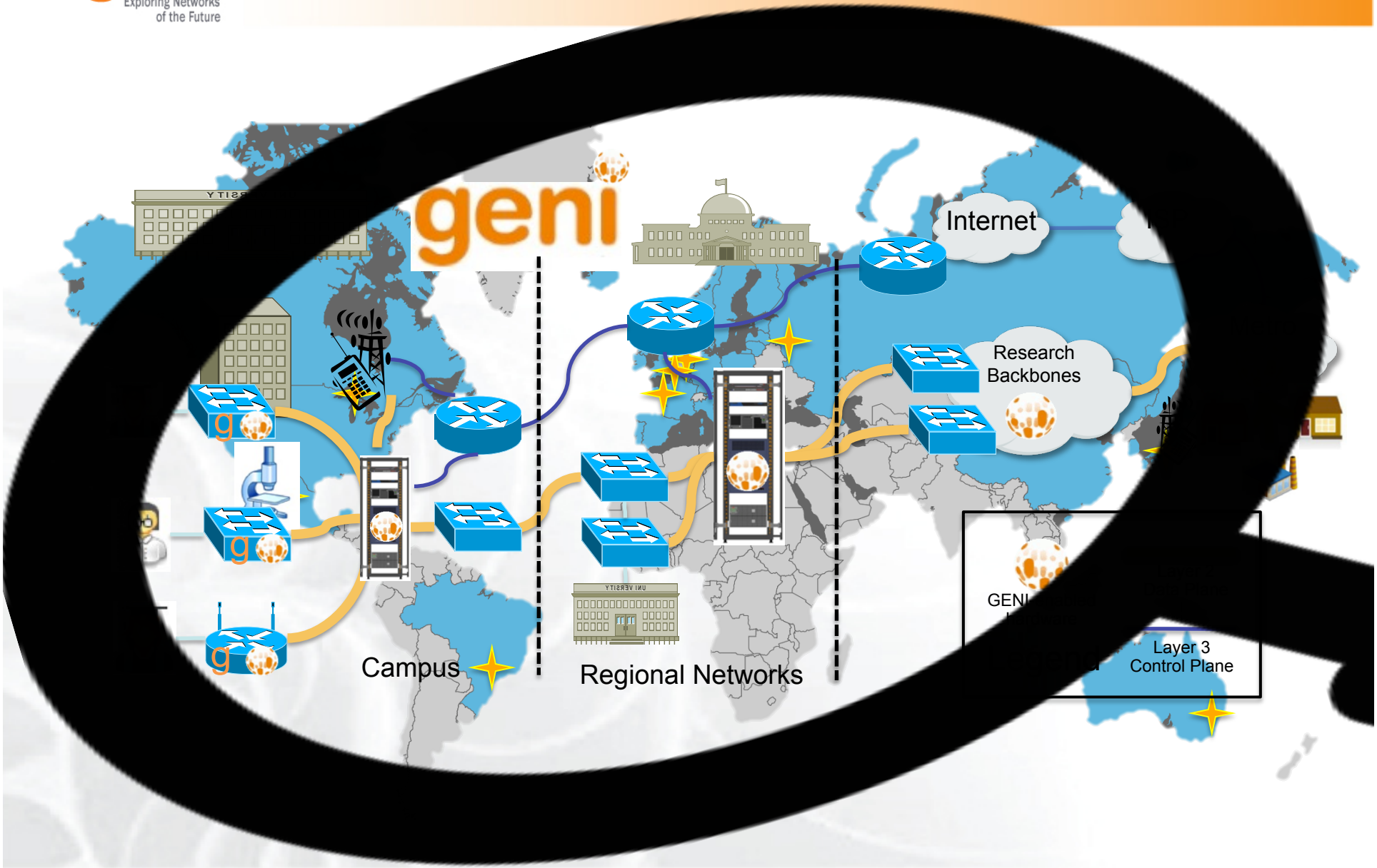
Custom L3 Dataplan e Connectivity

ElderCare as a Service



Providing service to the community.

GENI's International Collaborations

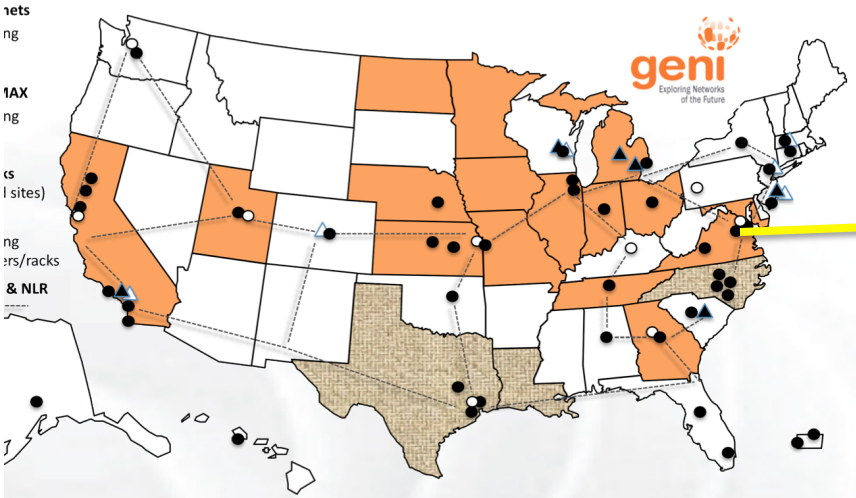


GENI's International Collaborations

GENI is working actively with peer efforts on five continents to define and adopt common concepts and APIs.

GENI – FIRE Federation

GENI – FIRE Federation

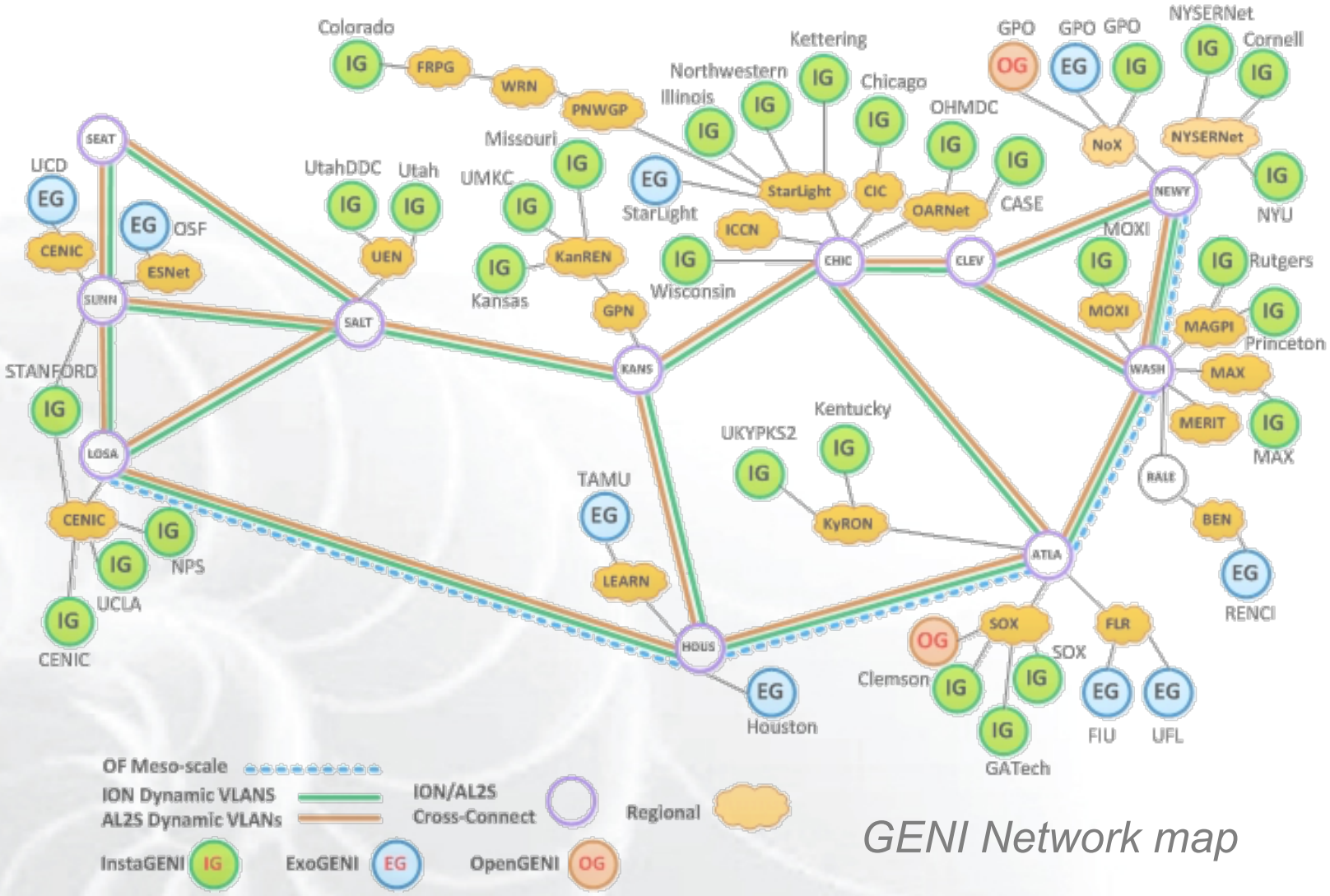


50 VLANS

50 Vlans between I2 PoP@ NY and iMinds

- use stitching with FIRE or GENI account
- look for the demo on Tuesday evening

Questions?



GENI Network map

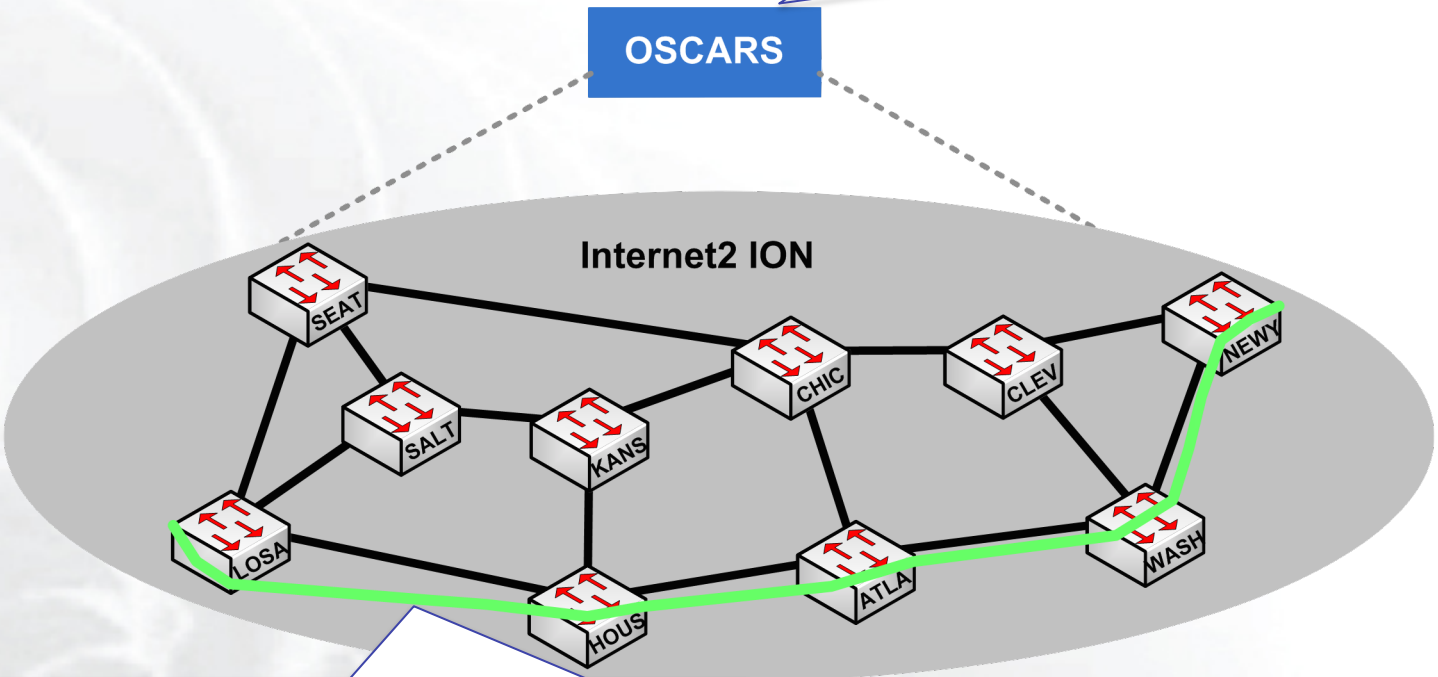
BACKUP SLIDES

GENI Network map

Internet2 ION Service

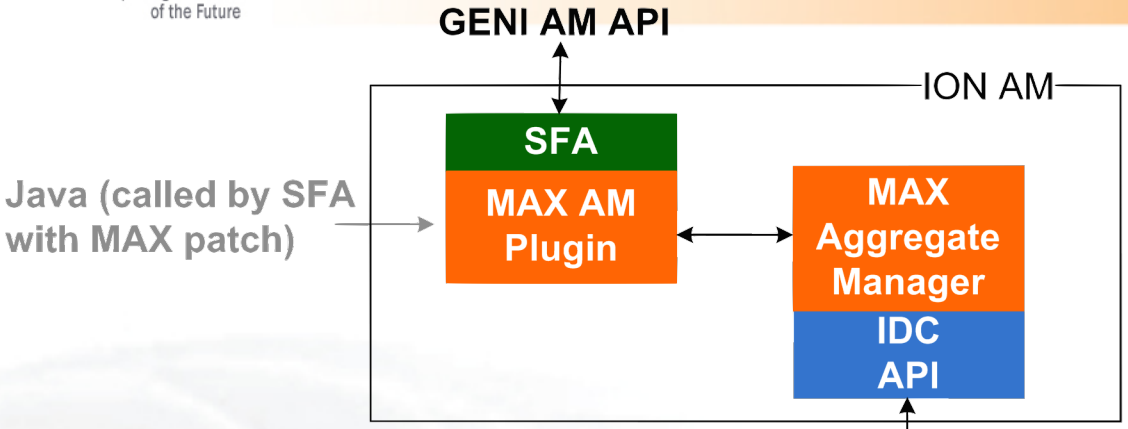
OSCARS (On-Demand Secure Circuits and Advance Reservation)

- Dynamically provisions circuits on the Internet2 production Juniper routers
- Uses JunOS scripts



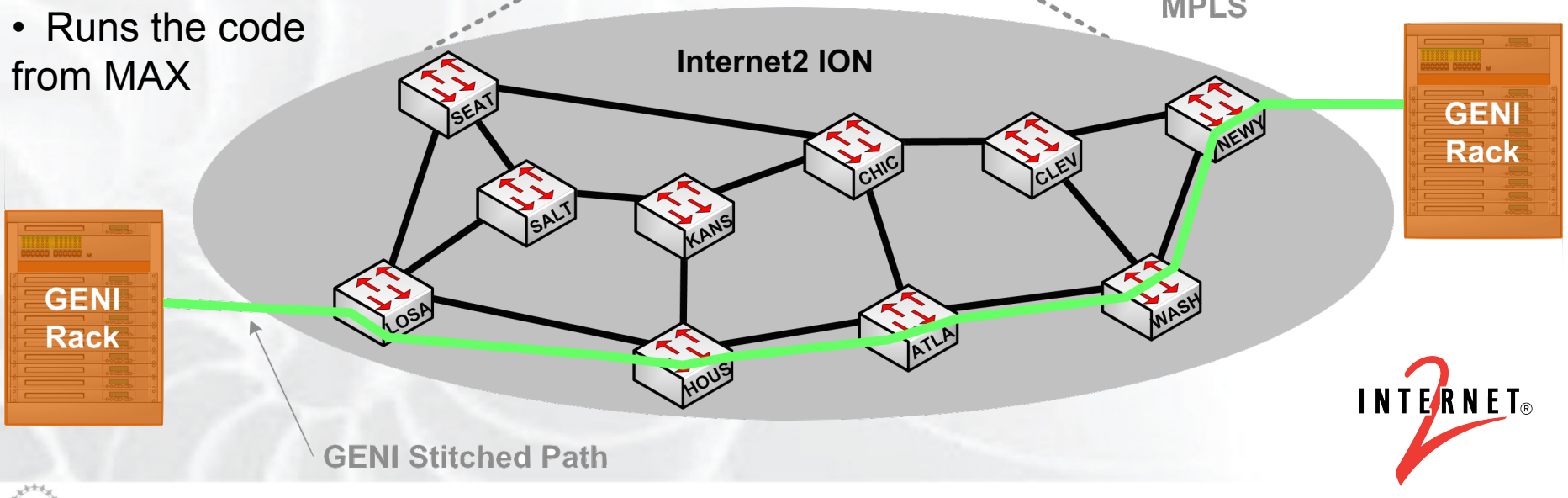
- **L2VPN**, i.e. point-to-point Ethernet circuit, i.e. Ethernet tunneled **via MPLS**
- Bandwidth guaranteed circuits

Internet 2 ION Aggregate Manager



- ION AM maps GENI calls to OSCARS calls
- Runs the code from MAX

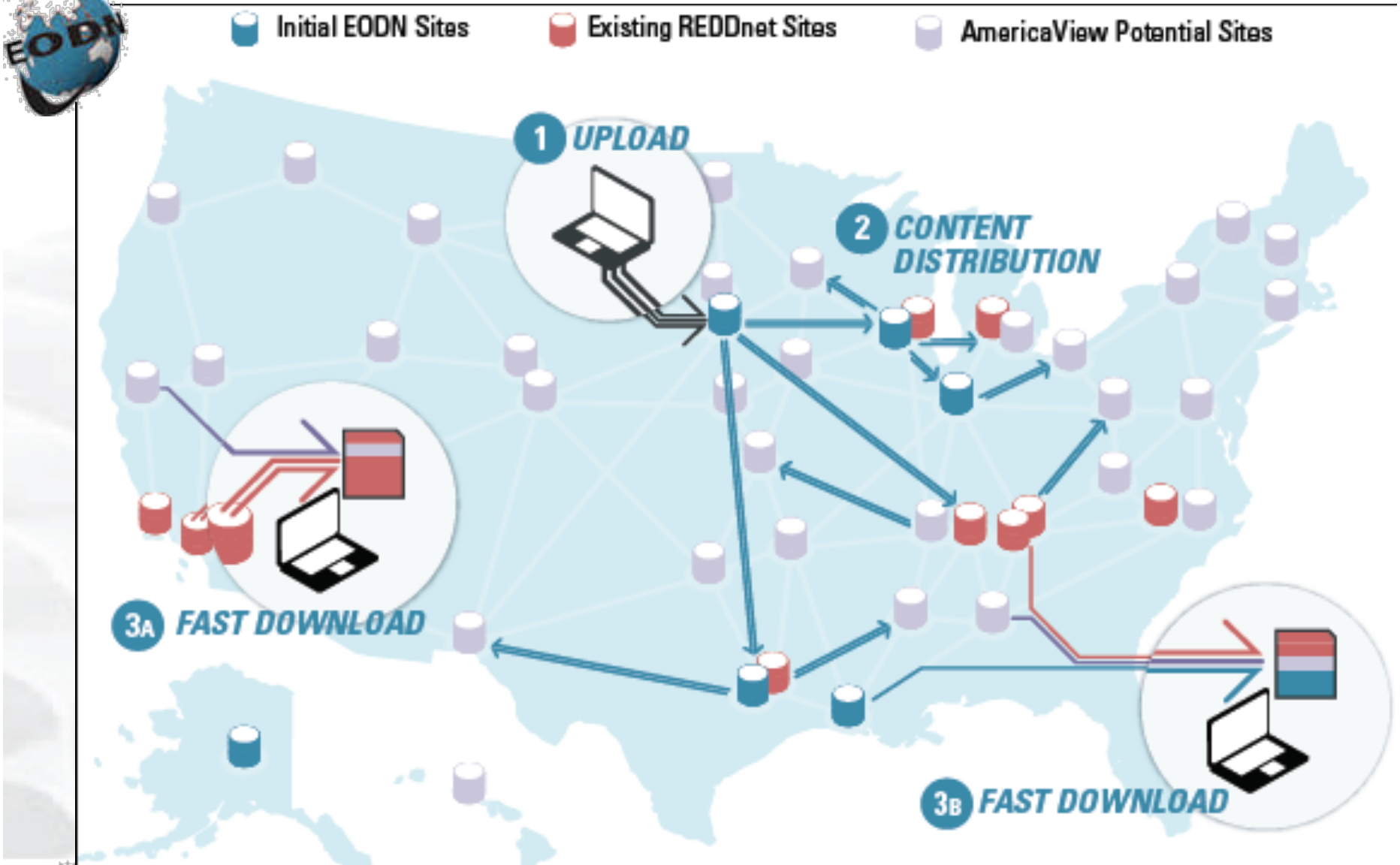
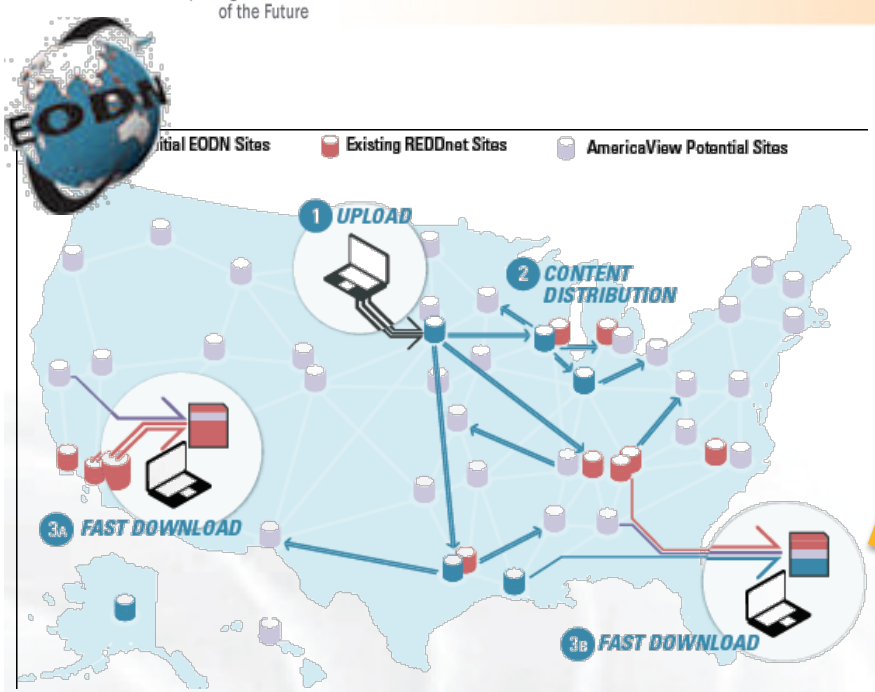
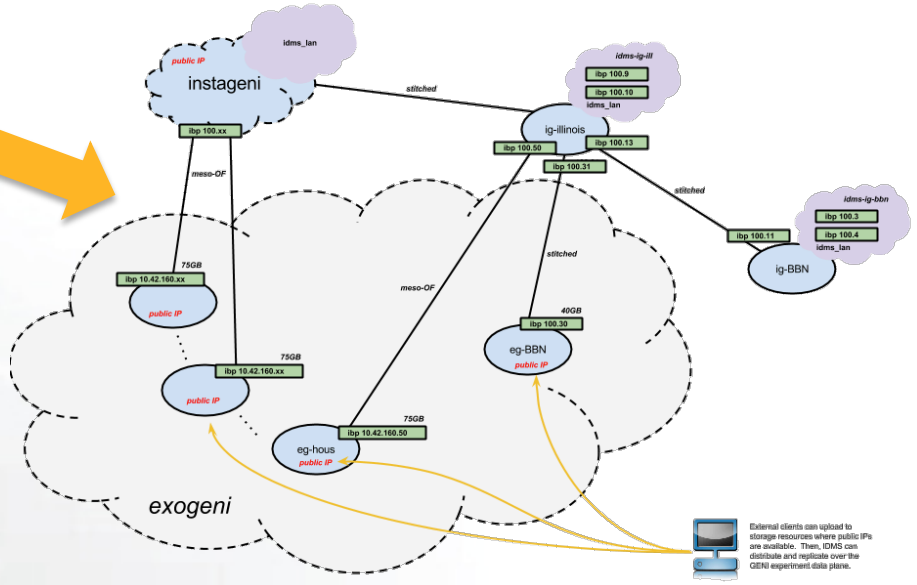
JunOS Script to provision Juniper Routers
-L2VPN
-Ethernet tunneled via MPLS



Coming Soon: Internet2 OESS

- Upcoming replacement for ION
  - Different dataplane technology: OpenFlow VLANs vs MPLS L2VPN
- Supports multipoint circuits
  - We hope to support that in GENI at some point
- AL2S Aggregate Manager
  - Will control OESS as the ION AM controls ION
  - Developed by Internet2 based on FOAM and OESS
- Can use GENI AM API to stitch between ION and AL2S

Custom Engineering



Custom Dataplane Engineering