The HOPI Project

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JET Roadmap Workshop

Jefferson Lab

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Outline

- **Resources**
  - Abilene
  - NLR
  - Experimental MAN LAN Facility
  - RONs

- **The HOPI Project – Hybrid Optical and Packet Infrastructure**
  - Architectures based on availability of optical infrastructure
    - Based on dark fiber acquisitions at the national, regional, local level

Abilene Particulars

- **Performance**
  - 6.2 gpbs single flows across Abilene
  - Consistent 9.5 gbps traffic patterns during SC2003 from Phoenix
  - The performance is good, but we need to look to the future

- **Agreement with Qwest ends in 2.5 years**
  - How should we go forward?

NLR Summary

- **Largest higher-ed owned/managed optical networking & research facility in the world**
  - ~10,000 route-miles of dark fiber
  - Four 10-Gbps λ's provisioned at outset
    - One allocated to Internet2
    - One an experimental IP network
    - One a national scale Ethernet
    - One a spare and quick start

- **An experimental platform for research**
  - Research committee integral in NLR governance
  - Advance reservation of λ capacity for research
  - Experimental support center

15808 Terminal
15808 OADM
15808 Regen
Fiber route
Leased waves

Note: California (SAN – LAX – SVL) routes shown are part of CalREN; NLR is adding waves to CalREN systems. Also the CENIC SVL – Sacramento (SAC) ELH route will become part of NLR SVL – SEA in exchange for a SVL – SAC LH route NLR is building (not shown here).

MAN LAN

- **Ethernet Switch**
  - Layer2 Interconnectivity – Classic exchange point
  - VLANs between connectors

- **ONS Cisco 15454**
  - TYCO/IEEAF Circuit moved to experimental facility
    - Circuit was router to router, now is ONS to ONS
    - Ability to map circuits to Abilene or for other experimental reasons
  - OC-192s: CANARIE, Surfnet, Abilene

Leading & Emerging
Regional Optical Initiatives

- **California (CALREN)**
- **Colorado (FRGP/BRAN)**
- **Connecticut (Connecticut Education Network)**
- **Florida (Florida LambdaRail)**
- **Indiana (I-LIGHT)**
- **Illinois (I-WIRE)**
- **Maryland, D.C. & northern Virginia (MAX)**
- **Michigan**
- **Minnesota**
- **New York + New England region (NEREN)**
- **North Carolina (NC LambdaRail)**
- **Ohio (Third Frontier Network)**
- **Oregon**
- **Rhode Island (OSHEAN)**
- **SURA Crossroads (southeastern U.S.)**
- **Texas**
- **Utah**
- **Wisconsin**

Architectural Issues

- **Some discipline specific networks have enormous bandwidth requirements**
  - High Energy Physics and the Large Hadron Collider
  - The Square Kilometer Area (SKA) Community

- **Questions concerning packet infrastructures**
  - The shared packet infrastructure itself – the ability to support multiple large flows on the order of 6 gbps.
  - Unlikely to have 40 gbps or 100 gbps in near future
  - Increasing demands by some for deterministic paths
  - Ability to run transport protocols other than TCP.
  - Demand for more dynamic control of bandwidth and topology

- **Where are we going?**

HOPI Project - Summary

- **Future likely to provide a rich set of switched optical paths**
  - Basic IP packet switched network
  - A set of optically switched waves available for dynamic provisioning

- **Goal – Understand architecture for the future**
  - Examine a Hybrid of shared IP packet switching and dynamically provisioned optical lambdas

- **Immediate Goals**
  - Create a white paper describing a testbed to model the above infrastructure – Internet2 member meeting.
  - Implement testbed over the next year
  - Coordinate and experiment with other similar projects

- **Design Team**

HOPI Project Design Team

- **Linda Winkler (CoChair)**
- **Peter O'Neil**
- **Bill Owens**
- **Mark Johnson**
- **Tom Lehman**
- **Philip Papadopoulos**
- **David Richardson**
- **Chris Robb**
- **Sylvain Ravot**
- **Jerry Sobieski**
- **Steven Wallace**
- **Bill Wing**
- **Cees de Laat**
- **Rene Hatem**
- **Internet2 Staff – Rick Summerhill (CoChair), Guy Almes, Heather Boyles, Steve Corbato, Chris Heermann, Christian Todorov, Matt Zekauskas**

HOPI Resources

- **The Abilene Network – MPLS tunnels**

- **The Internet2 Wave on the NLR footprint**

- **MAN LAN Experimental Facility**

- **The Regional Optical Networks – RONs**

Abilene/NLR Map

HOPI Project
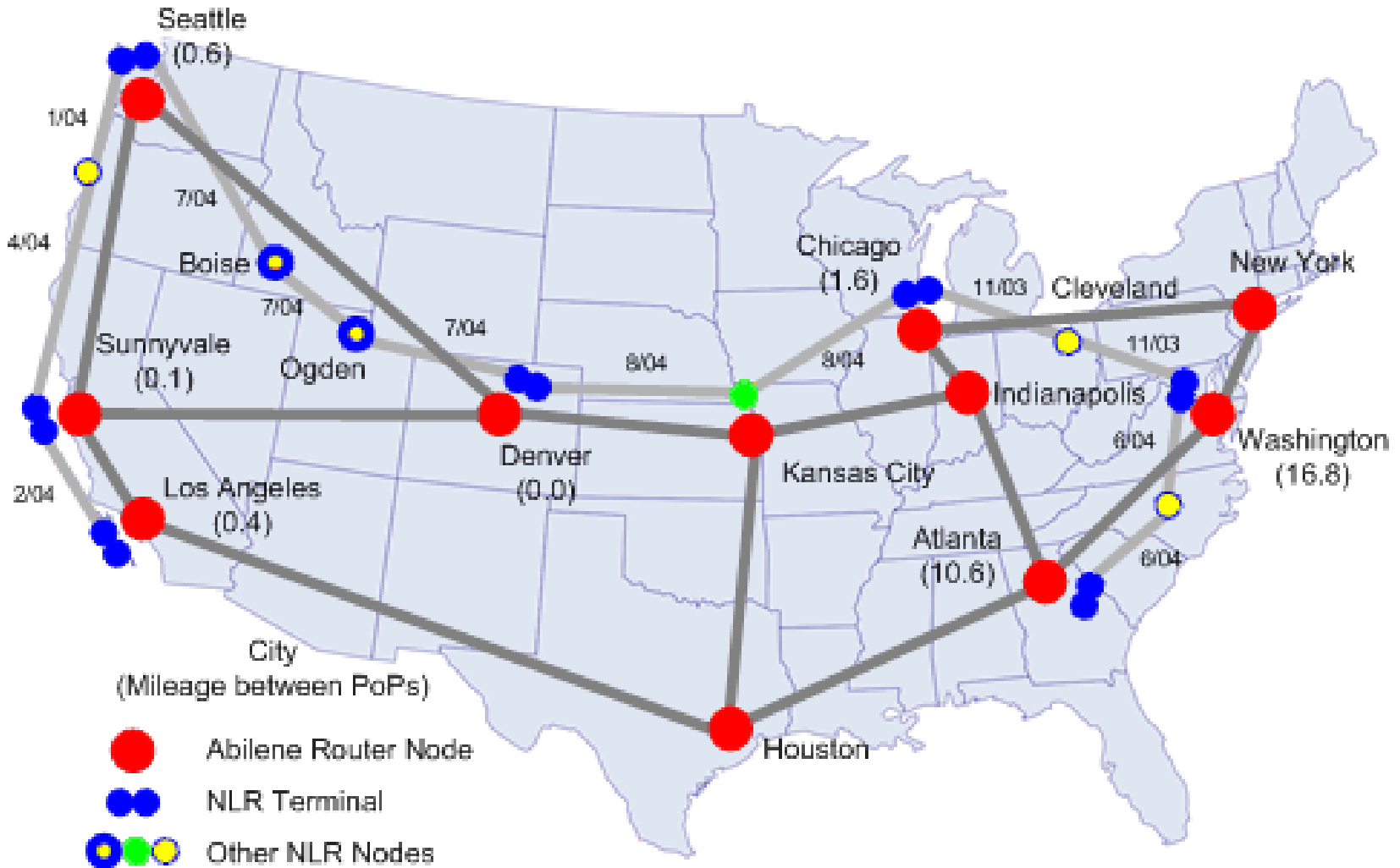
- **Problems to understand**
  - Goal is to look at architecture
  - Temporal degree of dynamic provisioning
  - Temporal duration of dynamic paths and requirement for scheduling
  - Topological extent of deterministic provisioning
  - Examine backbone, RON, campus hierarchy – how will a RON interface with the core network?
  - Understand connectivity to other infrastructures – for example, international or federal networks?
  - Network operations, management and measurement across administrative domains?

HOPI Basic Service

- Given the resources, we cannot use multiple waves to study new architectures – only a limited number of waves are available

- Rather, we'd like to model waves using lower bandwidth "deterministic" paths – paths that look like circuits to some extent.

- Basic service – A 1 or 10 GigE unidirectional point-to-point path with reasonable jitter, latency, and loss properties

- Access – Direct to HOPI node or an MPLS L2VPN tunnel through Abilene

Experiments

- Planned Experiments – 15 to 20
  - Dynamic Provisioning
  - Deterministic Paths
  - Applications Based
  - Miscellaneous

- Encourage use by the community for experimentation – both operational and research communities

- Can start in near future by using MPLS tunnels from Abilene

Recent Activities
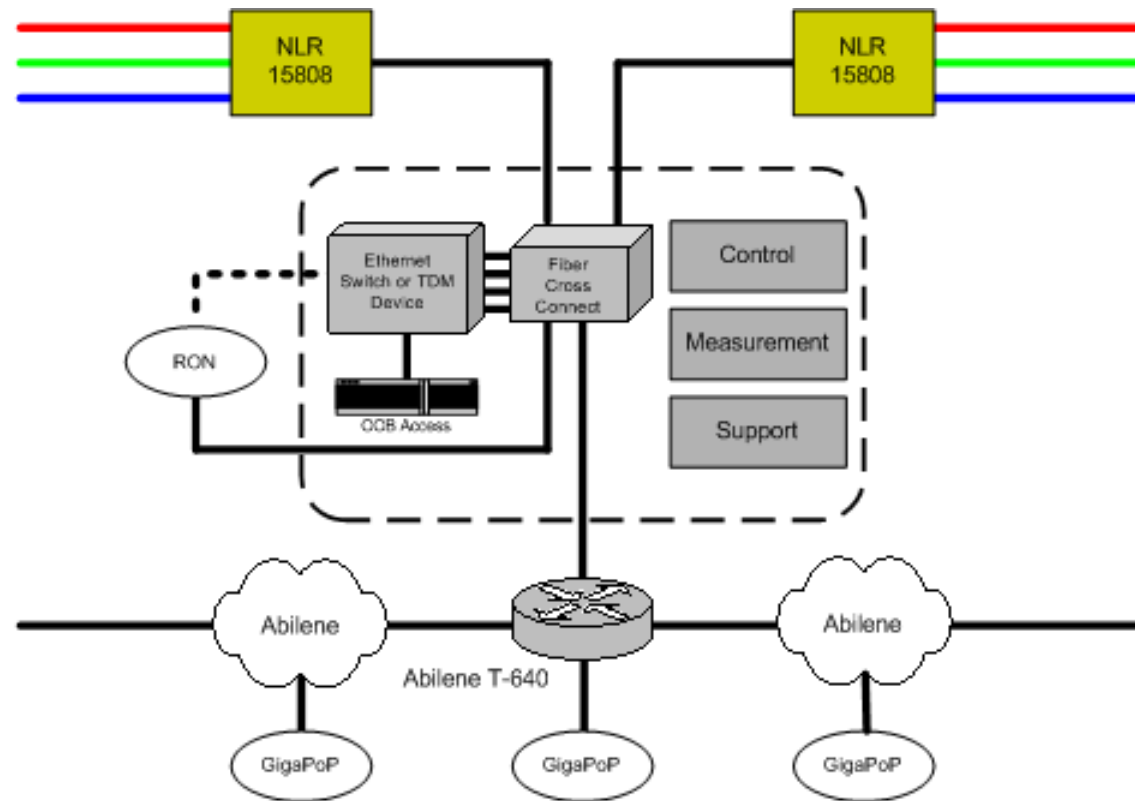
- **Deterministic Path LA to CERN**
  - Internet2
  - CANARIE
  - GEANT
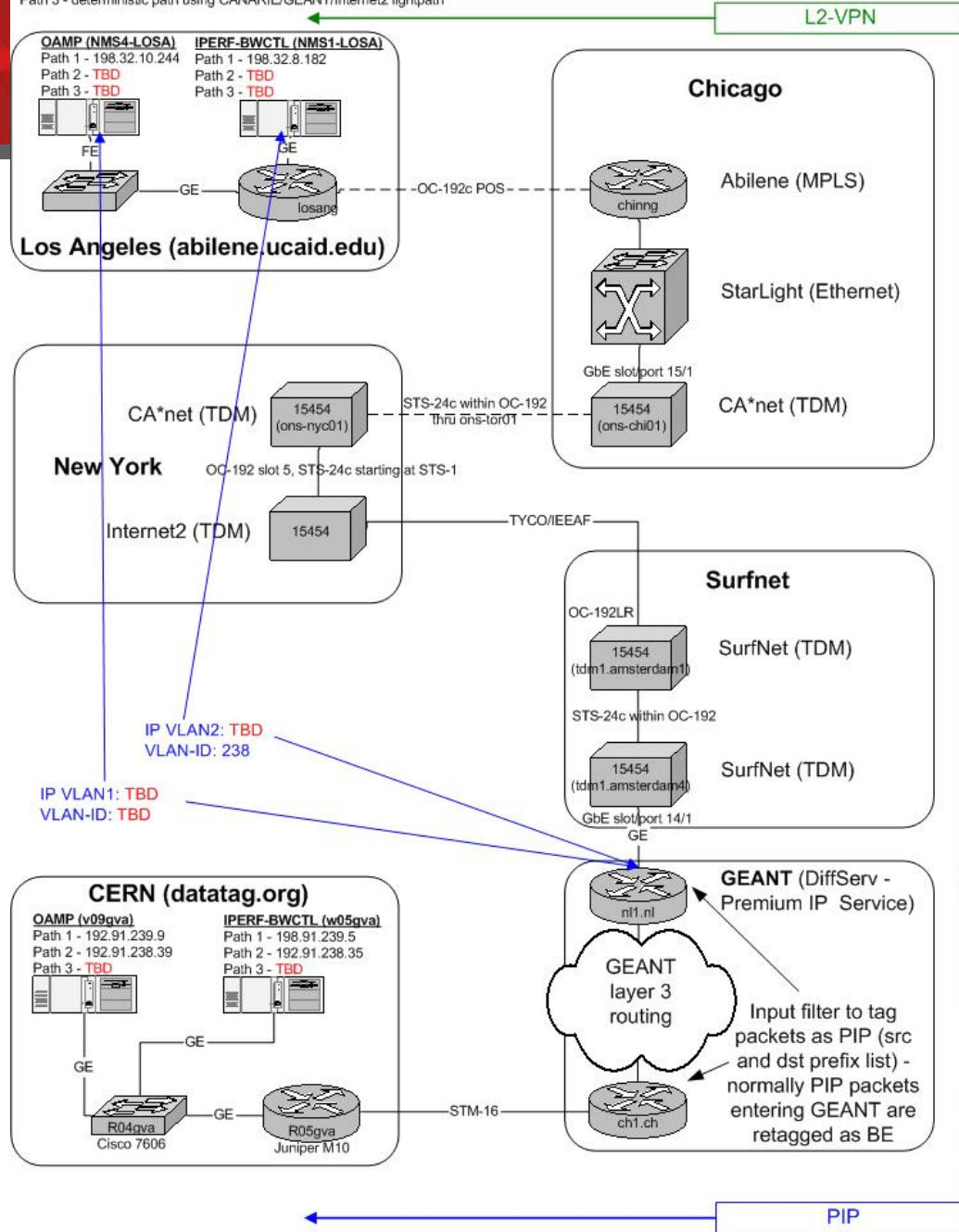 - Others
    - Starlight
    - Surfnet

- **Attempt to Understand Problems**
  - Different Technologies
  - Cross Administrative Domains
  - How could we make this dynamic in some way?

Joint Demo L2 Final Solution

Path legend
Path 1 - routed path using Chicago-CERN direct connection (default)
Path 2 - routed using GEANT-Internet2 MAN-LAN connection
Path 3 - deterministic path using CANARIE/GEANT/Internet2 lightpath

L2-VPN

OAMP (NMS4-LOSA)
Path 1 - 198.32.10.244
Path 2 - TBD
Path 3 - TBD

IPERF-BWCTL (NMS1-LOSA)
Path 1 - 198.32.8.182
Path 2 - TBD
Path 3 - TBD

Chicago

FE

GE

GE — OC-192c POS — Abilene (MPLS)

losang   chinng

Los Angeles (abilene.ucaid.edu)

StarLight (Ethernet)

GbE slot/port 15/1

CA*net (TDM)

15454
(ons-nyc01)

STS-24c within OC-192
Thru ons-tor01

15454
(ons-chi01)

CA*net (TDM)

New York

OC-192 slot 5, STS-24c starting at STS-1

Internet2 (TDM)

15454

TYCO/IEEAF

Surfnet

OC-192LR

15454
(tdm1.amsterdam1)

SurfNet (TDM)

IP VLAN2: TBD
VLAN-ID: 238

STS-24c within OC-192

15454
(tdm1.amsterdam4)

SurfNet (TDM)

IP VLAN1: TBD
VLAN-ID: TBD

GbE slot/port 14/1
GE

CERN (datatag.org)

OAMP (v09gva)
Path 1 - 192.91.239.9
Path 2 - 192.91.238.39
Path 3 - TBD

IPERF-BWCTL (w05gva)
Path 1 - 198.91.239.5
Path 2 - 192.91.238.35
Path 3 - TBD

GEANT (DiffServ -
Premium IP Service)

nl1.nl

GE

GE

GEANT
layer 3
routing

Input filter to tag
packets as PIP (src
and dst prefix list) -
normally PIP packets
entering GEANT are
retagged as BE

GE

R04gva
Cisco 7606

GE

R05gva
Juniper M10

STM-16

ch1.ch

PIP

4/16/2004   18

Control and Management Plane

- **Current Status**
  - Edial – 8 hours of conference calls
  - Email – 500 email messages

References

More Information

- http://abilene.internet2.edu
- http://www.nationallambdarail.org
- http://hopi.internet2.edu
- abilene@internet2.edu

www.internet2.edu