HOPI Network Update

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Layer1 v. Layer3

- In the US, much effort is being devoted to National Lambda Rail (NLR)
  - regional networks creating optical infrastructures to interconnect with NLR
  - provides dedicated bandwidth for high performance users
- Still much interest in Layer3 routed networks
  - optical networking is expensive
  - lambdas address the needs of a few high-resource users
  - layer1 is not as well-understood
  - lambdas are difficult to monitor
  - interoperability requirements of optical vendors is sometimes challenging
- Some networks want access to both Layer1 and Layer3 services

HOPI Solution

- The HOPI project will attempt to provide both routed and circuit-based functionality
  - Over the next year, the HOPI Design Team will test and evaluate vendor equipment in an effort to define the capabilities and implications of a hybrid network
  - The initial focus will be on "lightpath" creation
- In 2005, a HOPI testbed will be created to answer some core questions
  - What defines a deterministic path through a layer3 network?
    - latency and jitter guarantees? bandwidth protection?
  - What does the network need to do to provide a lightpath?
    - MPLS and QoS and STS/STM and ???
    - What flavor of MPLS? (L2VPN or L3VPN or stitched LSPs?)
  - How dynamic do lightpaths need to be?
  - How will the lightpaths be created?
    - GMPLS? UCLP? Human?
  - How will lightpaths cross administrative boundaries?

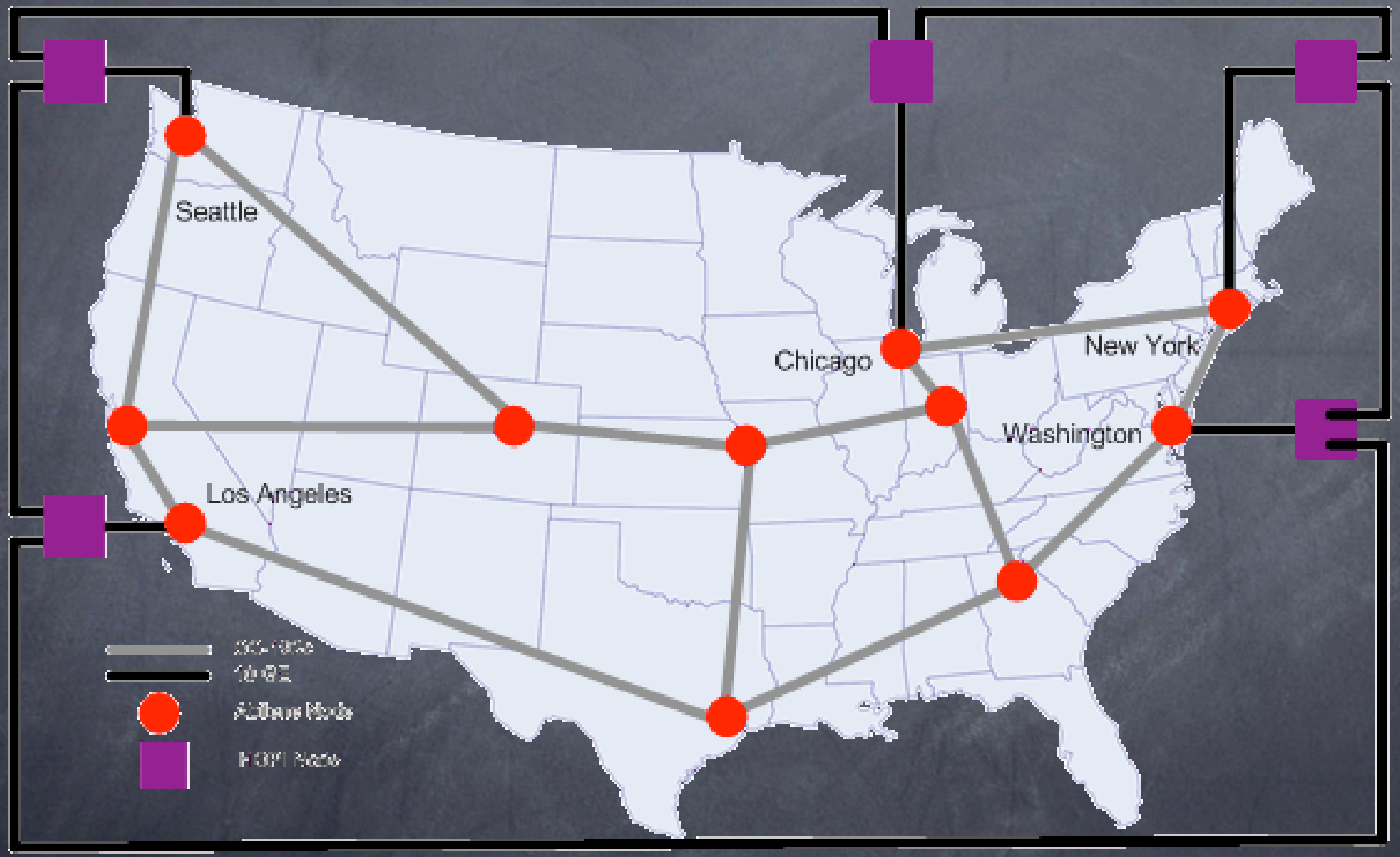
HOPI Resources

- Internet2 Abilene Network
  - provides layer3 components
- NLR 10G lambda
  - Internet2 has purchased a 10GigE lambda on the entire NLR footprint
  - Northern portion of NLR has been installed with the HOPI transponders in place
  - Southern portion to be installed in 2005
  - Discussion of replacing 10GigE with OC-192 on all or part of the NLR network
    - If the southern portion of NLR is OC-192, it will allow for greater testbed flexibility
  - Lambda resource pool is expected to increase as HOPI expands into a production network
- Vendor support
  - Internet2 has been negotiating evaluation and donated equipment from different vendors
  - A HOPI Corporate Advisory Committee (HOPI-CAT) has been formed to solicit industry input

HOPI Testbed Topology

- While the final HOPI network is likely to have nodes in the same cities as the current Abilene network, the testbed will focus on five initial locations
  - Each of these locations has some layer1 or layer2 exchange points to interconnect with the testbed
  - Los Angeles - Pacific Wave
  - Seattle - Pacific Wave
  - Chicago - Starlight
  - New York - MANLAN
  - Washington, D.C. - NGIX-East and the DRAGON project
- HOPI Design Team is currently looking eat each city to determine the best colocation facility for the HOPI node
  - option 1: near Abilene in Qwest space
  - option 2: near the layer1/layer2 exchange point
  - option 3: near NLR equipment in Level3 space

HOPI Testbed Topology

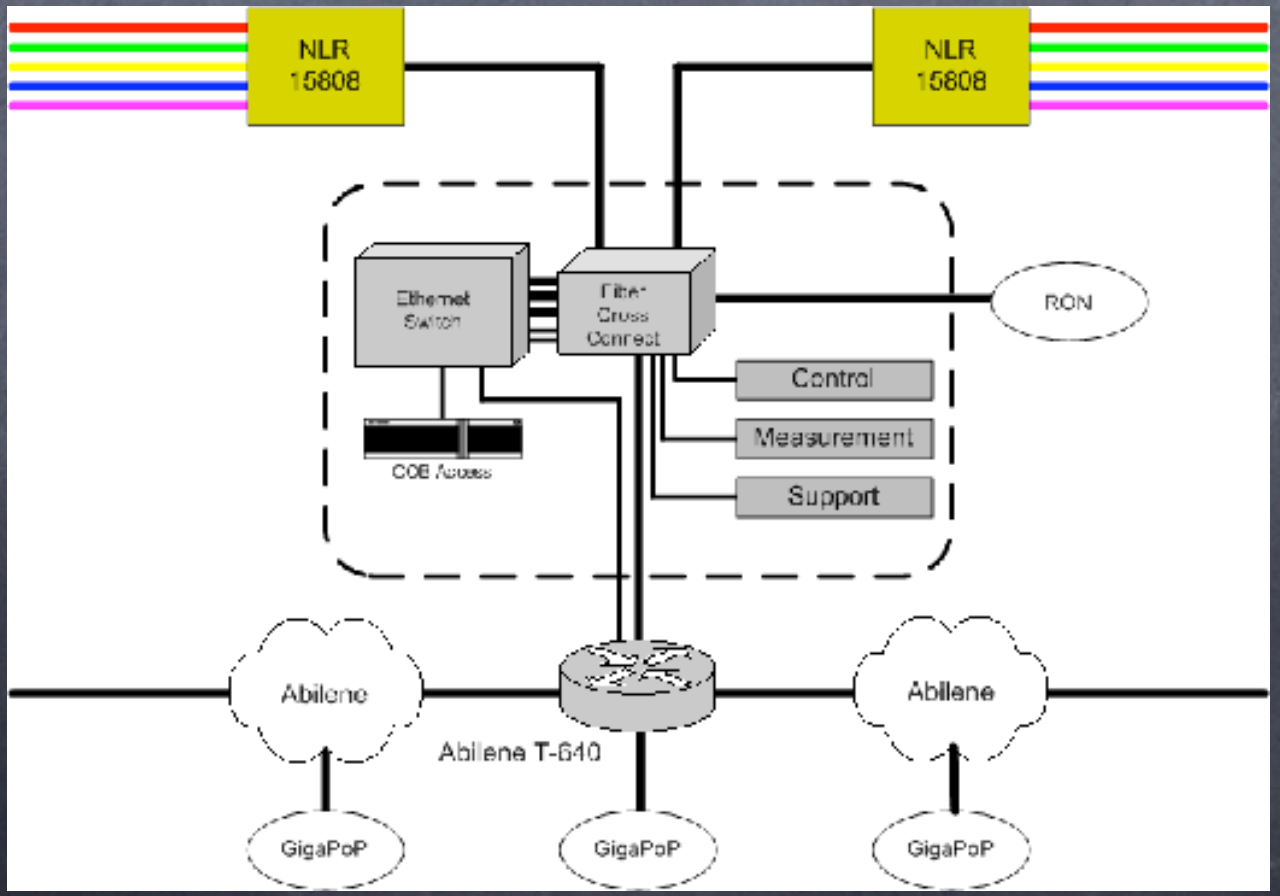


HOPI Node Topology

- Exact equipment topology not yet finalized
  - Since the initial five nodes are meant to be part of a test, there may be dissimilar sets of equipment in each location
- Initial plans call for some or all over the following types of equipment
  - remotely manageable fiber cross-connect device (MEMS switch?)
  - ethernet or TDM switch
    - this will largely depend on the framing of the NLR HOPI wave
  - measurement and control PCs
  - small out of band router and racklan switch
    - if Abilene is used for management channel, possibly a 1550/1310 optical splitter/combiner

HOPI Node Interconnects

- If a MEMS device is installed, all fiber connections will pass through it
  - allows engineers to change termination point of circuit without waiting for hands and eyes
  - NLR east and west lambdas will pass through device so that a node can be dynamically added or removed from the network



Connecting to HOPI

- Two immediate possibilities
  - via existing Abilene connection
  - via direct HOPI node connection
- During the testbed phase, we expect that the majority of connections will be made via Abilene's packet-based network
- As HOPI grows and becomes more production, US regional optical networks (RONs) and international networks will likely move connections to the HOPI node

Connecting via Abilene

- Abilene will maintain a 10GigE or OC-192 connection to the HOPI node via the fiber cross-connect device
- Abilene participants that don't have direct fiber connectivity to a HOPI node will be "piped" across Abilene to the closest HOPI node
  - What flavor of MPLS? GRE tunnels?
  - Creation of MPLS tunnels is currently done by hand, though Internet2 has developed an application that will provide some automation in this area
- Once the tunnel reaches the HOPI node, it will be "cross-connected" to the HOPI network
- The goal is to make the end to end path as seamless and deterministic as possible

Connecting Directly to HOPI

- Direct HOPI connects will land on the fiber cross connect device
  - The network will have access to lightpath "timeslots" on the TDM device
  - Alternatively, their entire lambda can be switched onto the HOPI NLR lambda, bypassing the HOPI equipment completely
    - This will become more practical when HOPI acquires more lambdas betwene node locations
- Many US RONs are already working on dark fiber contracts to NLR locations, so if HOPI is located closeby, the connection is much easier

International Connections

- Since international networks have more expensive connections to the US, the initial connections will likely be via Abilene
  - as trans-oceanic prices drop, it will be more practical for direct HOPI connections
  - additional challenge of obtaining clear-channel SONET service from carriers
  - 10GigE LANPHY connections aren't available
- Some initial work has been done to simulate the HOPI technologies
  - MPLS from Abilene Los Angeles to Abilene Chicago
  - TDM GigE from Canarie to MANLAN
  - TDM GigE from MANLAN to GEANT via SURFNET OC-192
  - IP with QoS across GEANT backbone to CERN
  - multiple technologies used to expose their difficulties and challenges

Abilene-CERN lightpath Lessons Learned

- MPLS
  - no way to guarantee bandwidth unless entire backbone is MPLS-based
  - Juniper CCC has requirements on VLAN IDs at each end (>512)
- TDM
  - international circuits are rarely configured to allow customers to dynamically reconfigure the STS partitioning
- IP with QoS
  - service works OK on uncongested circuits, but needs to be tested when traffic loads are higher
- In general, when working with five different administrative entities, coordination is difficult and time consuming
  - >250 e-mails to set up initial circuit!!

Current Status

- HOPI Design Team will meet in Houston at the end of February 2005
  - initial discussion of installation logistics
  - experiment definition
  - final topology definitions
- HOPI Support Center RFP
  - currently in draft form to be sent out shortly (this week?)
  - Two components
    - operational support
    - software development support

References

- HOPI Testbed Webpage: http://networks.internet2.edu/hopi
  - contains presentations, HOPI whitepaper, and Corporate Advisory Team information
- National Lambda Rail: http://www.nlr.net
- Abilene: http://abilene.internet2.edu