



Hybrid IP-Optical Networking

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Next generation R&E national network infrastructure in US

- In the process of designing, moving to new network architecture
 - Internet2
 - ESnet
 - NLR
- See “Group A” report out of NLR-Internet2
 - <http://www.internet2.edu/resources/GroupAReport200511.pdf>
- Testbeds informing new architecture, services thinking
 - Primarily focus on services that would provide hybrid of shared IP and dedicated paths

- Regional scale:
 - DRAGON (NSF-funded)
 - CHEETAH (NSF and DOE-funded)
 - OMNINET (NSF-funded)
- National scale:
 - UltraScienceNet (DOE-funded)
 - HOPI (Internet2, community-funded)
- <http://www.itrd.gov/subcommittee/lsn/jet/conferences/20050419/>

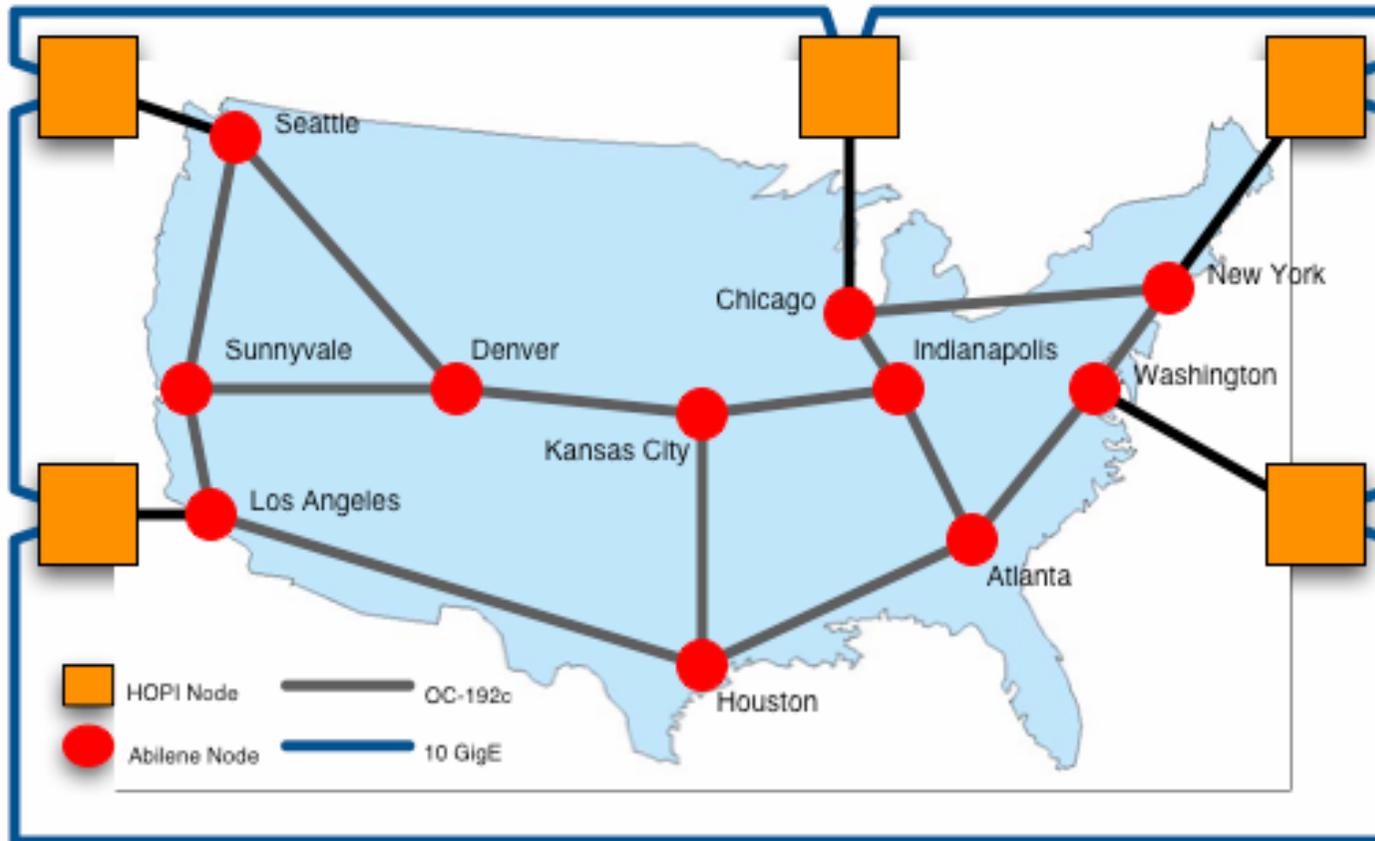
HOPi Questions

- Examine how to build an architecture
 - A lot is known about how to do various pieces
 - The main question is how would one put it all together into a network
- Problems to understand
 - When does a host use the circuit switched infrastructure and when does it use the packet infrastructure?
 - 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, measurement, and control plane across administrative domains?

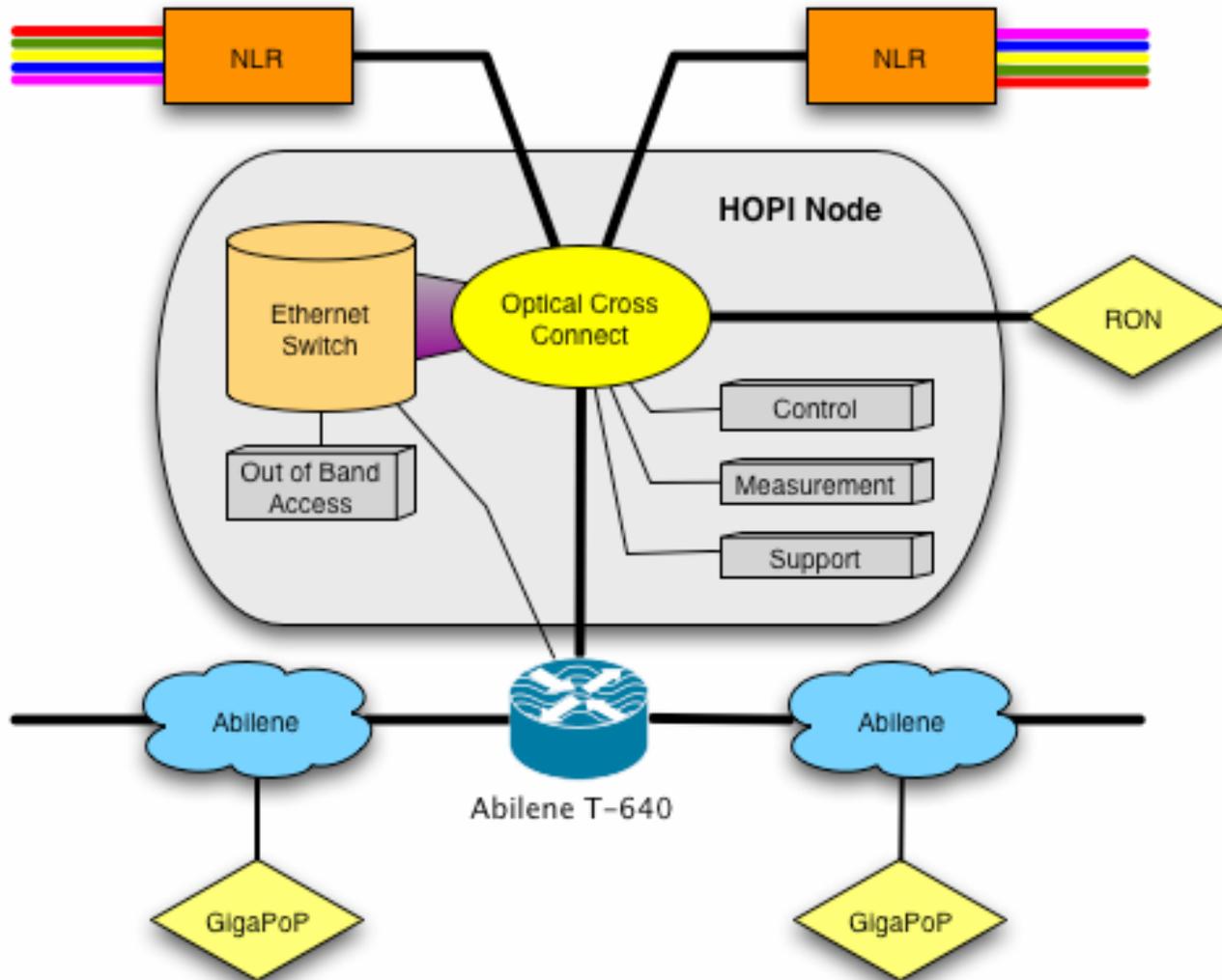
HOPi Testbed Resources

- The Abilene Network – MPLS tunnels and the packet switched network
- The Internet2 Wave on the NLR footprint
- MAN LAN Exchange Facility
 - TYCO/IEEAF 10 Gbps lambda NYC – Amsterdam
 - Nortel and Cisco optical and Ethernet equipment
- Collaborations with Regional Optical Networks (RONs) and other related efforts (GLIF, DRAGON, etc.)
- A 10 Gbps circuit between NYC and London
 - Provides experimental capabilities between Internet2 and GEANT
- Other facilities as they become available

HOPi Topology



HOPi Node





HOPI Deployment

- Node locations
 - Los Angeles Equinix Facility – Support for CalTech and the HENP connection - installed
 - Washington, DC MAX/Dragon facility - installed
 - StarLight in Chicago - end of May, 2005
 - The Pacific Northwest GigaPoP in Seattle - end of June, 2005
 - New York City – NYSERNet area in 32 AoA (Same location as MAN LAN, same building as Abilene Node) - end of July, 2005
 - Many thanks to NYSERNet for donating rack space and power to support the HOPI project
- Circuit from NYC to London
 - By September 2005

- HOPI Testbed Support Center
 - Call for proposals several months ago
 - Received 4 responses
 - All were excellent proposals
 - Will be a difficult decision
 - Soon to be chosen
 - Will develop an MoU agreement with responding groups
 - Advanced engineering and design focus
 - Implement control plane activities
 - Coordinate application activities
 - Manage and engineer the facility

International Collaborations

- MAN LAN exchange facility
- Internet2 transatlantic OC192
- Support for/participation in GLIF forum
 - Inclusive discussion, technical documentation of management, coordination, service model issues
- Specific work with peers
 - BRUW – OSCARS – GEANT2 – UCLP development work
 - As part of ongoing CANARIE/ESNET/GEANT/Internet2 technical coordination efforts
 - NII/SINET collaboration expected/hoped for in this space
- Certainly open to other collaborations



Management, international coordination issues

- Vastly different service, organizational, business models
- Experimental versus Production
- Architecture on international level?
 - Hierarchy of national, multi-national, multiple bilateral peerings
 - To what?

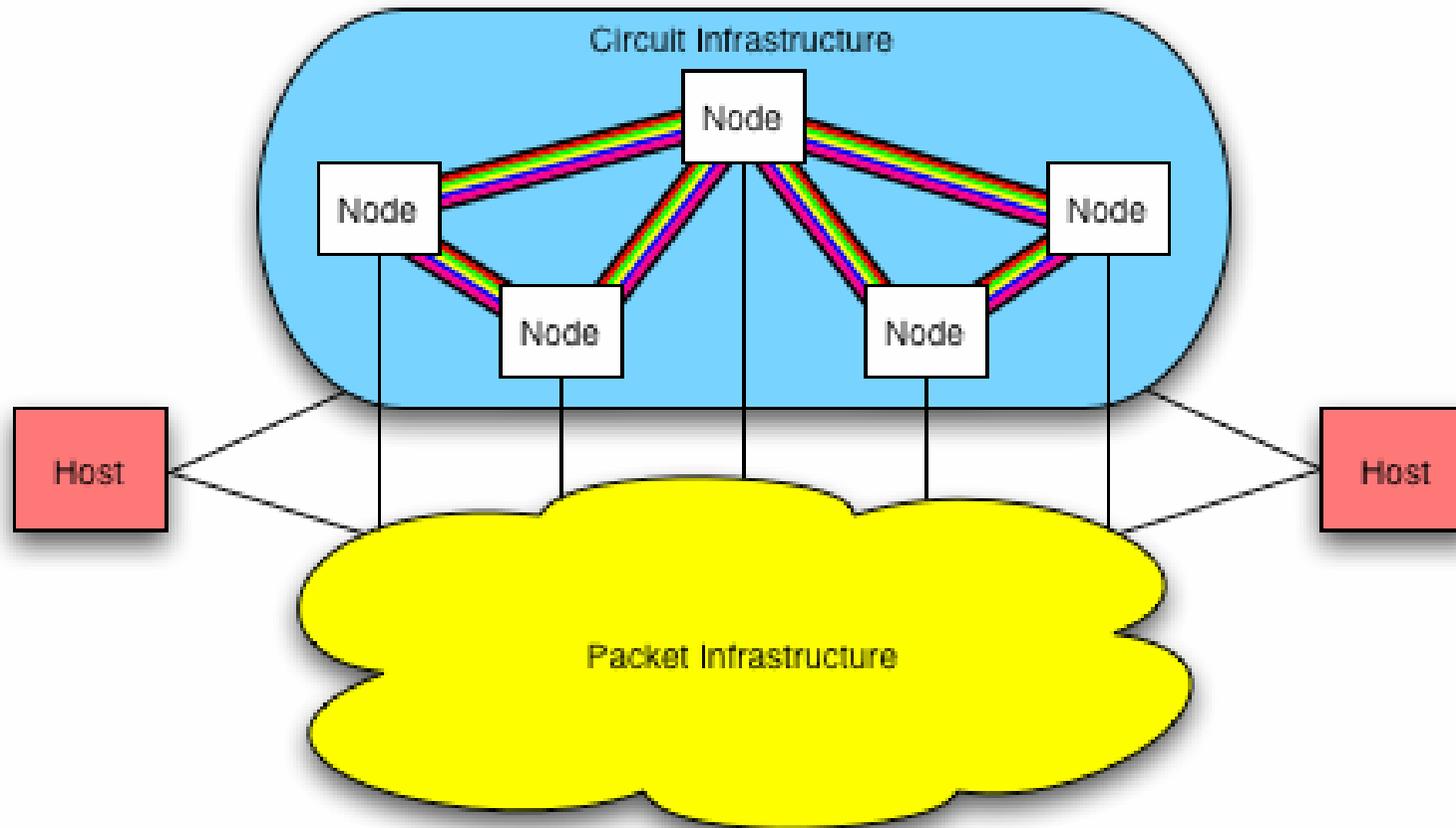


More HOPI details

HOPi Project - Summary

- In the near future we will see a richer set of capabilities available to network designers and end users
 - Core IP packet switched networks
 - A set of optically switched waves available for dynamic provisioning
- Fundamental Question: How will the core Internet architecture evolve?
 - Many options being examined
- Examine a **hybrid** of shared IP packet switching and dynamically provisioned optical lambdas
- HOPi Project – Hybrid Optical and Packet Infrastructure
 - See <http://networks.internet2.edu/hopi/> for documentation.
 - Immediate Goals
 - Implement testbed over the next year
 - Coordinate and experiment with other similar projects

HOPi General Problem

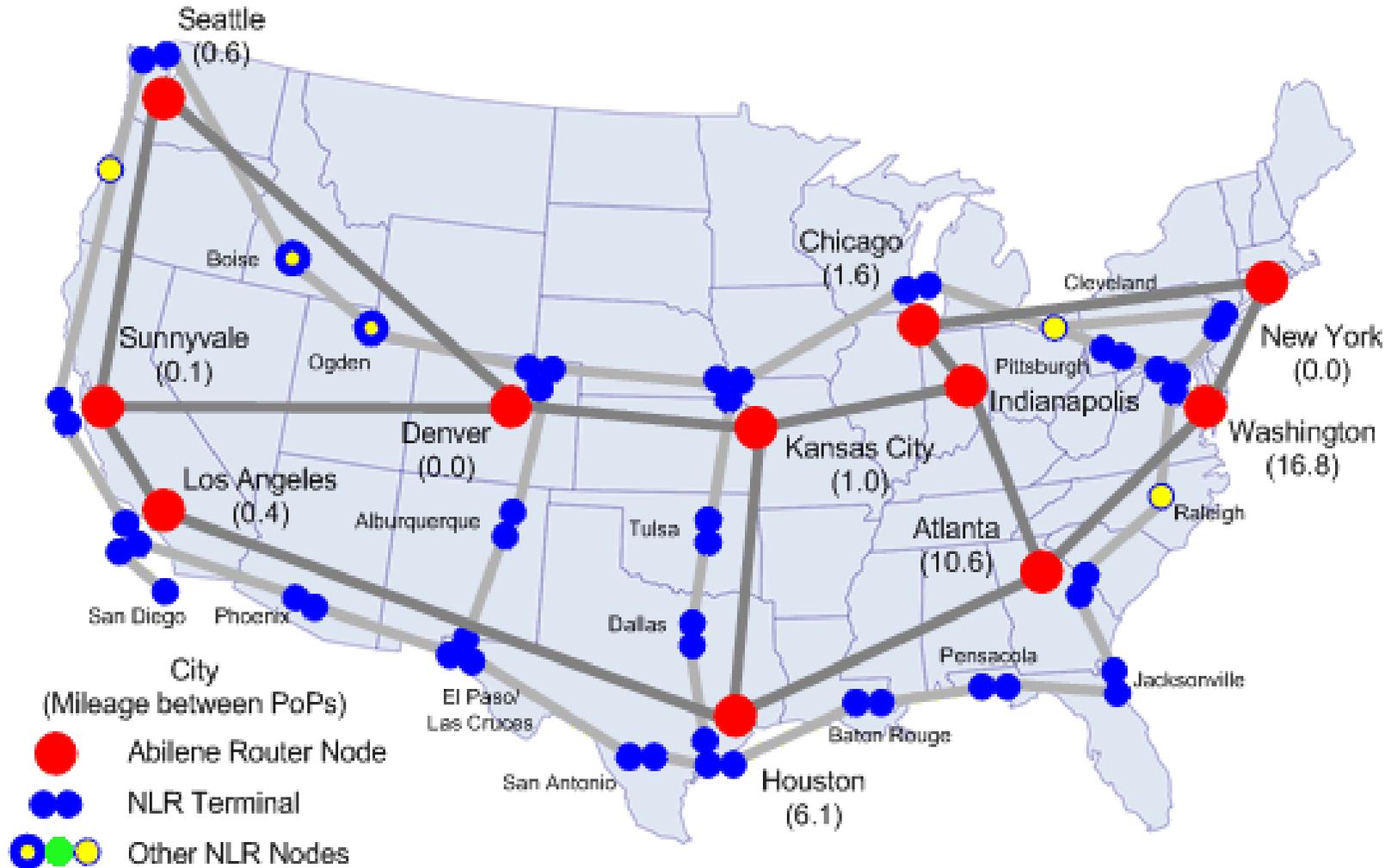


HOPi General Problem

- How would one create a hybrid from these two infrastructures. The Nodes do switching and the links are point-to-point circuit like paths. Each link may have attributes – for example, bandwidth. Attributes may determine the ability to concatenate links. Examples include
 - Nodes are lambda switches with waves forming circuits – attributes include colors and bandwidth, etc.
 - Nodes are SONET switches with paths being SONET links – attributes include channels, etc. For example, OC-3, OC-12, etc.
 - Nodes are Ethernet switches with paths being point-to-point VLANS – attributes include bandwidth, etc.
 - HOPi will use this environment to examine different architectures
 - Nodes are routers on a packet infrastructure and the point-to-point paths are MPLS L2VPNs

- Focus Groups
 - Applications
 - Focus on several applications, examining representatives from different equivalence classes
 - Demos
 - iGrid and SC2005
 - Control Plane
 - Examine different control planes with focus on how the pieces are put together
 - Measurement
 - How and what do we measure in hybrid networks?
 - Security
 - Examine all security aspects as we develop hybrid ideas

Abilene/NLR Map



- Plan to create an open testbed for experimenting with new ideas
 - Start with Optical and Ethernet Devices in an initial configuration
 - Corporate community can locate additional devices to experiment with basic ideas and further the goals of the project
 - Will put out a call for participation in the near future

- A fiber cross-connect switch (a white light switch)
 - Ability to switch the entire NLR wave to Abilene, to a RON, or to pass through the wave
 - Two Glimmerglass switches being installed
- An Ethernet switch device to partition the wave into 1 GigE or to use the entire wave
 - Force10 Ethernet switches deployed
- Control devices
 - Ad hoc control plane computer
 - Measurement computer
 - Experimental computer
- Control and data planes are disjoint
- Out of band access

- **Phase 1 – Manual Configuration**
 - Control of devices that don't support control plane protocols - current phase
 - Understand control plane ideas
- **Phase 2 – Intra-domain Configuration**
 - Automate software control of setup
 - Examine control plane ideas and possibilities - UCLP, GMPLS, ASON, etc.
- **Phase 3 – Inter-domain Configuration**
 - Examination of protocols such as GMPLS and ASON
 - Extensions to standards based protocols
 - Try to create implementations in the near future



Connector Interface and Basic Service

- Basic Service
 - 1 or 10 GigE channels
 - May add to this in the future
- Connector Interface
 - A 1 or 10 GigE connection to the fiber cross connect, either dark fiber or a provisioned service
 - An MPLS L2VPN service through Abilene to the Ethernet switch
 - Provides immediate connection to the Internet2 NLR wave from Abilene
 - Will use these basic services to model more general optical capabilities

- Isn't this just an Ethernet testbed? Are we simply creating an Ethernet network?
- Not really, although Ethernet comes into play. Two features distinguish the testbed from an Ethernet network, however:
 - Dynamic provisioning aspect of the project
 - The hybrid nature of the project



References

- Request for Comment – We would like your feedback on the HOPI testbed
 - hopi@internet2.edu
- More Information
 - <http://abilene.internet2.edu>
 - <http://www.nationallambdarail.org>
 - <http://hopi.internet2.edu>
 - abilene@internet2.edu