Building 10-Gbps Networks: A few observations on the national and regional scales in the U.S.

Steve Corbató *corbato@internet2.edu*

Director, Network Initiatives, Internet2 &

Visiting Fellow, Center for High Performance Computing, University of Utah

CUDI

Reunión de Primavera 2005

Veracruz, Mexico

29 April 2005

Outline for this presentation

- Abilene Network
- MAN LAN exchange point (NYC)
- National LambdaRail (NLR)
- Testbed for hybrid networking (HOPI)
- Planning for next generation networks and services
- Regional networking and dark fiber

Abilene Backbone

Abilene Participants
February 2005

- IP-over-DWDM (OC-192c)
- 42 (44) direct connections (OC-3c → 10 GigE)
  - 3 (2) 10 GigE connections
  - 6 (6) OC-48c (2 more in the near future)
  - 3 (2) GigE connection
  - 25 (23) connections at OC-12c (13) or higher
  - Cost recovery model reduced to encourage upgrades
- 233 (228) participants – research universities & labs
  - All 50 states, District of Columbia, & Puerto Rico
  - U.S. Census Bureau and World Bank most recent additions; Library of Congress coming soon!
- Expanded access
  - 119 (106) sponsored participants
  - 34 (33) state education networks
- (#): status six months ago

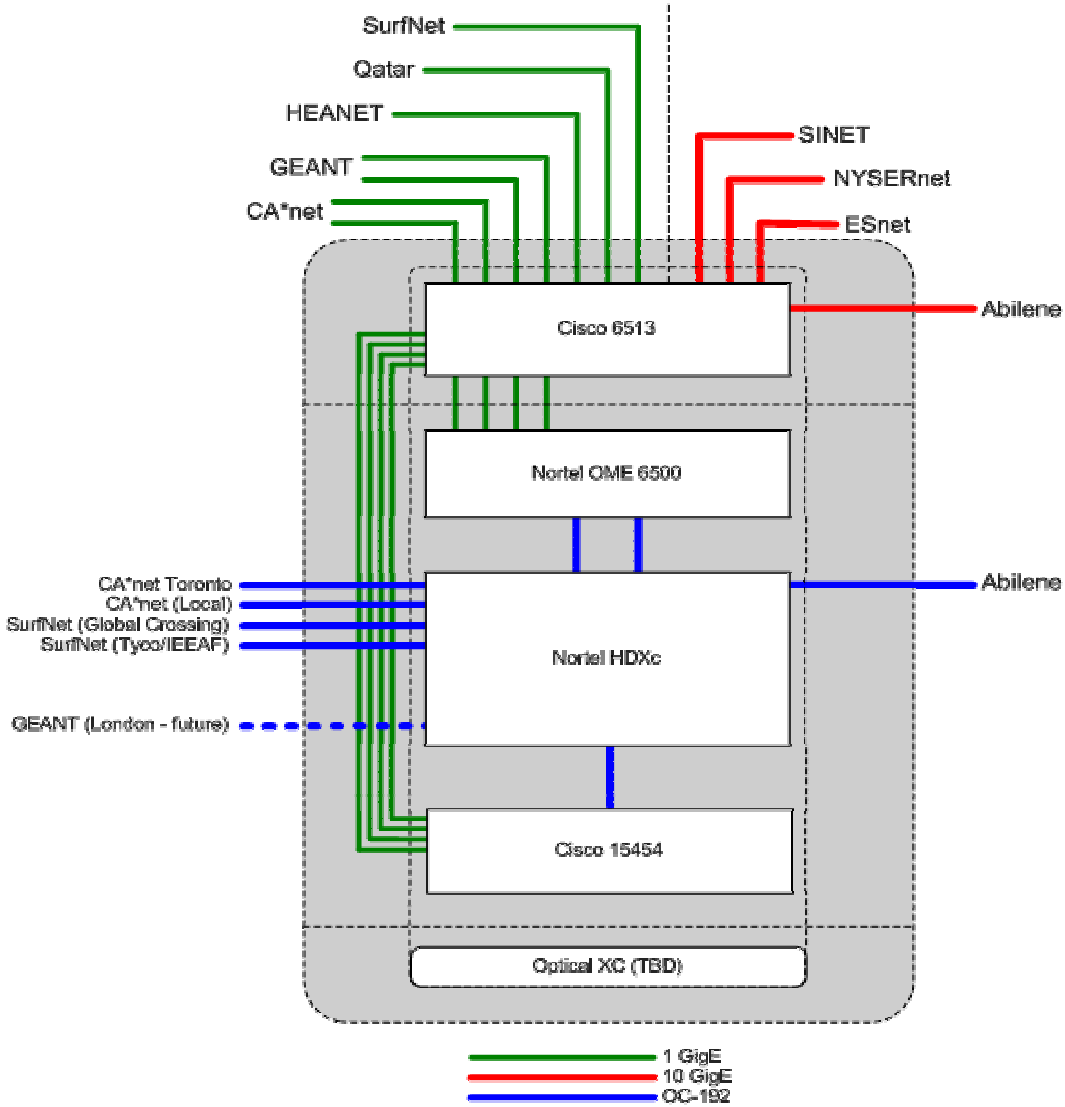
Abilene Peering

- Connectivity to Exchange Points
  - MANLAN (New York City) – 10 GigE
  - PacWave (Seattle) – 10 GigE
  - PacWave (LA) – 10 GigE
  - Starlight (Chicago) – 2 x 10 GigE
  - AMPATH (Miami) – GigE (via SoX and FLR)
  - NGIX East (Washington, DC) – 10 GigE
  - NGIX West (NASA Ames)– 1 GigE
  - PAIX (Palo Alto) - IPv6 and Multicast Peerings

MAN LAN services and capabilities

- Layer 2 - Ethernet switch for IPv4/v6 peering with 1 GigE and 10 GigE interfaces
- Layer 1 – TDM based optical equipment (SONET/Ethernet interfaces)
  - Cisco 15454
  - Nortel OME 6500
  - Nortel HDXc
- Layer 0 equipment to be installed soon
  - Optical cross connect to facilitate changes

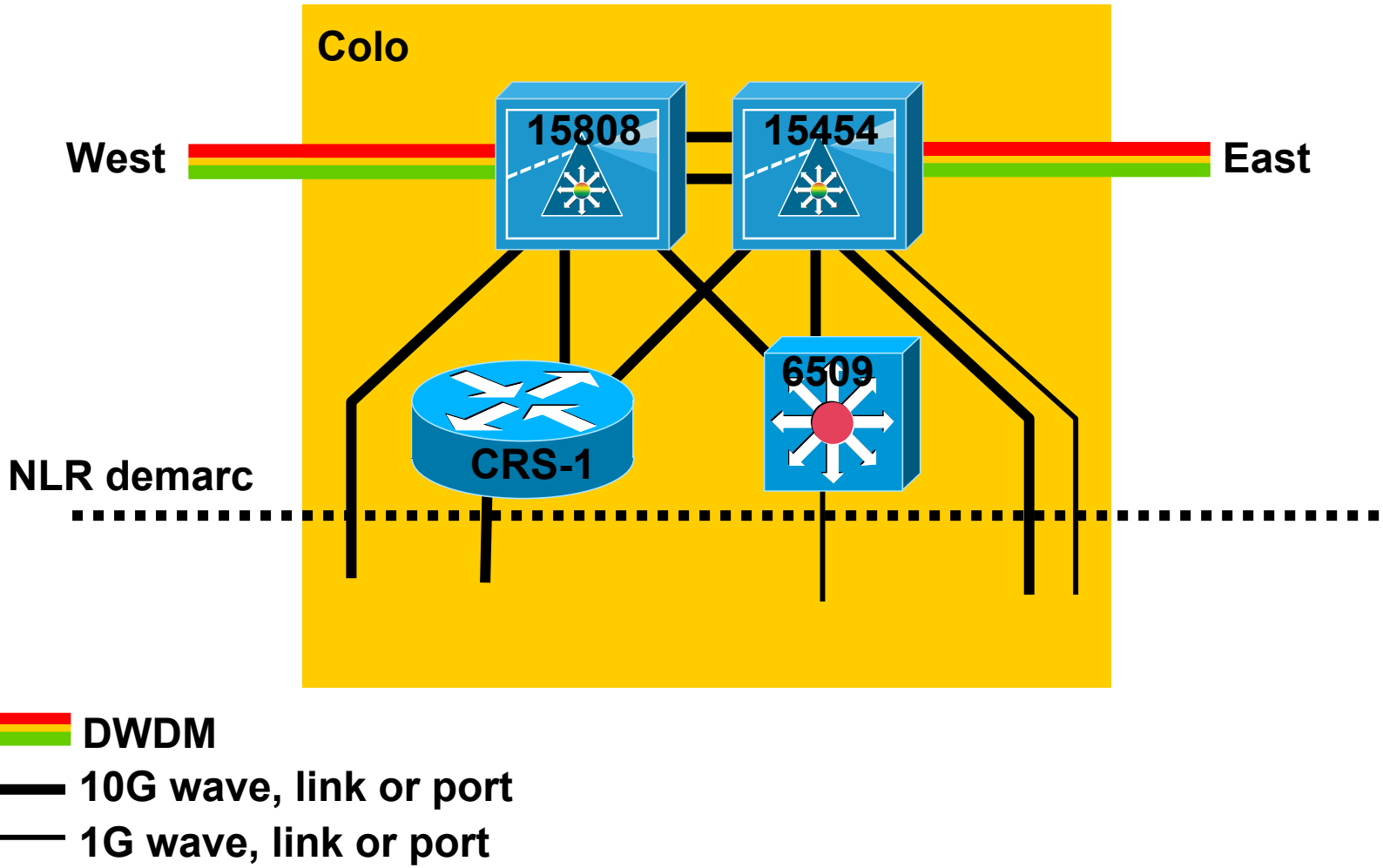
MAN LAN Configuration



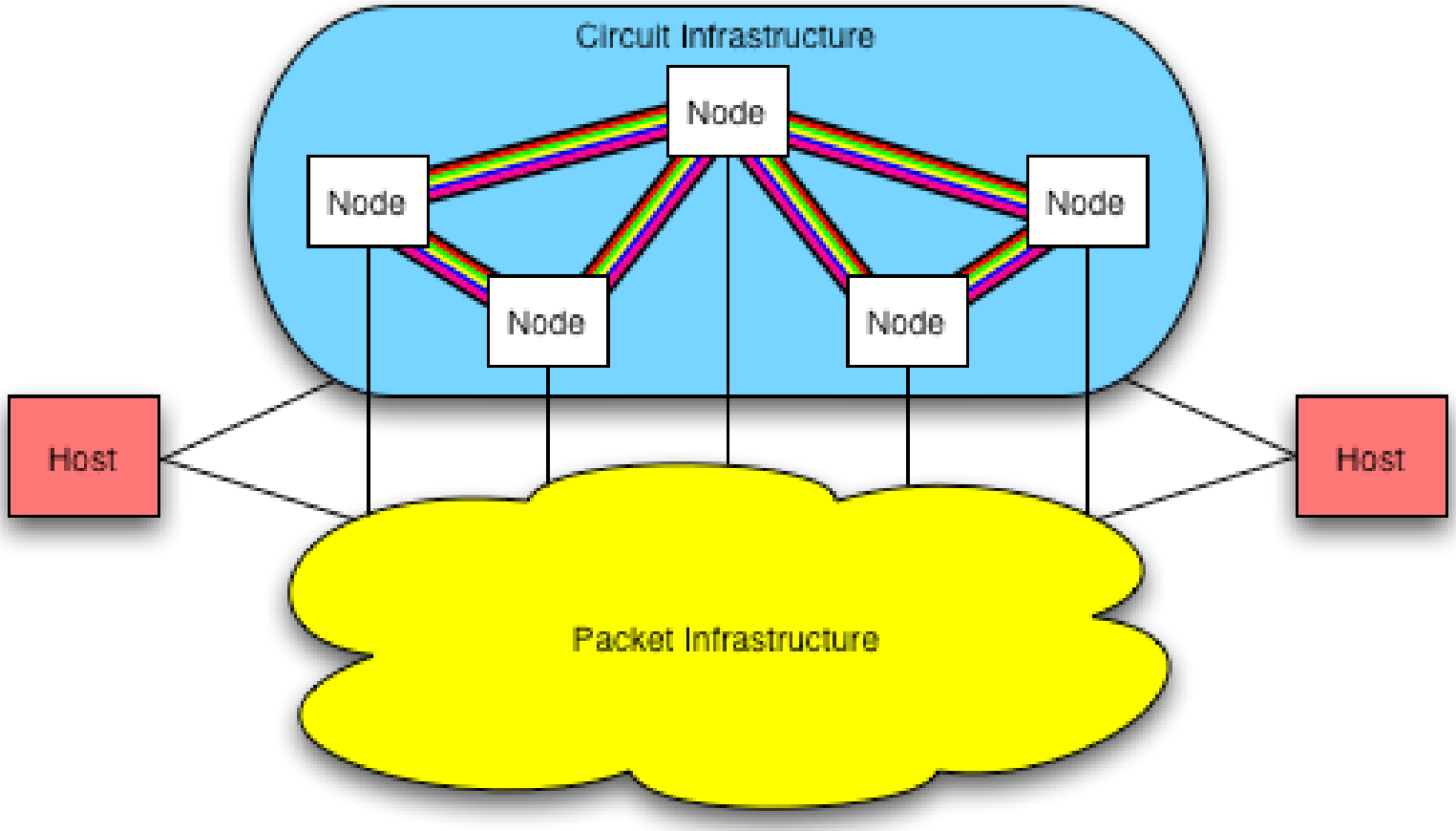
National LambdaRail Architecture

For more information regarding NLR see http://www.nlr.net or contact info@nlr.net

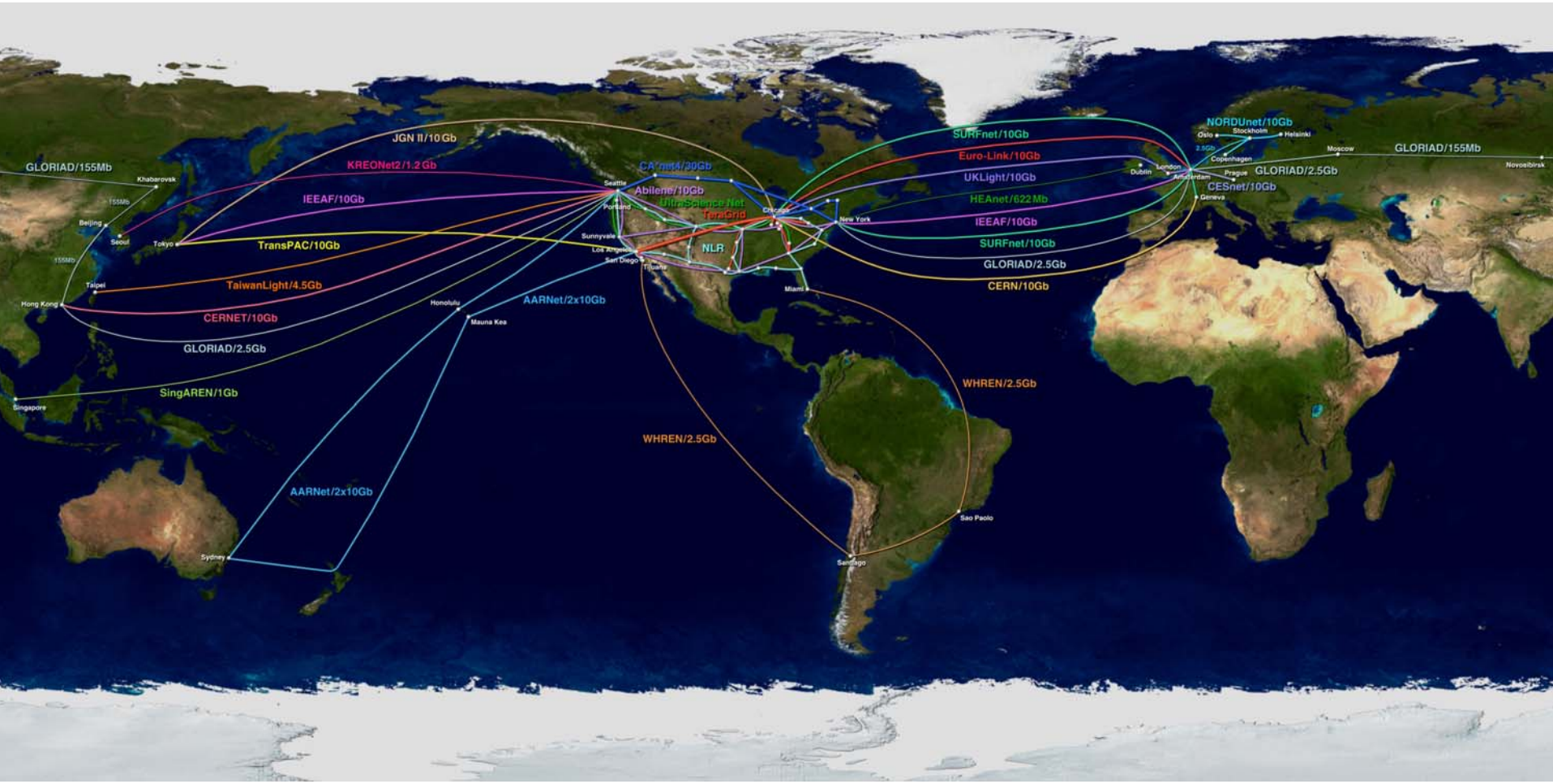
Generic NLR Node Layout – Layer 1, 2, and 3 Capabilities



HOPI Evolving Architecture



Global Lambda Integration Facility (GLIF)



HOPI Project - Summary

- Background:
  - Circuit (lambda) switching can be inefficient and costly
    - If the two end points aren't transmitting, resource is unused
    - Efficient for large file transfers
    - As the cost of optical networks continues to drop, circuit switching becomes more practical
  - Packet switching is more efficient but it is debatable whether it can meet the needs of all researchers

- Question: How will the next generation architecture evolve?

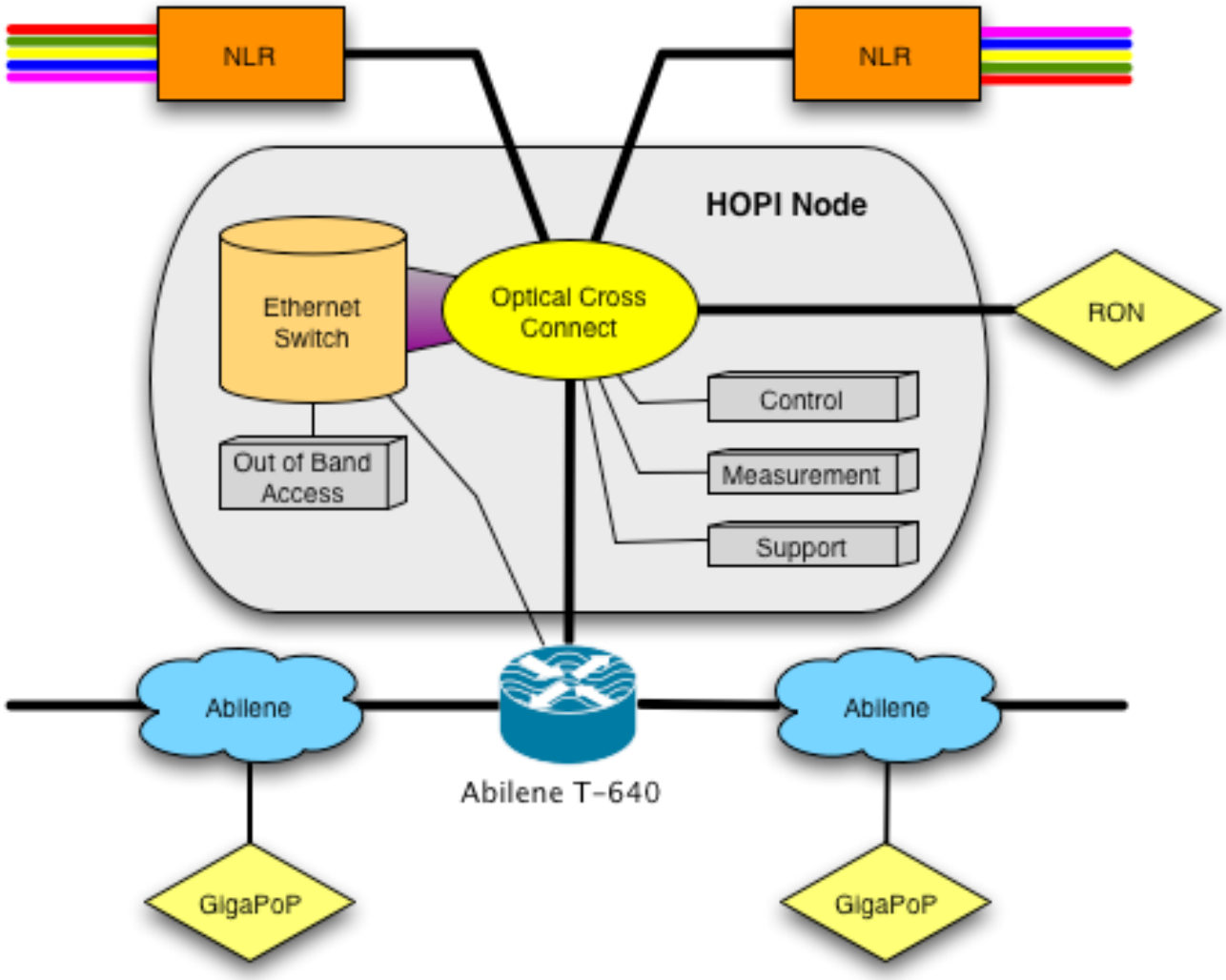
- Objective: Examine a **hybrid** of shared IP packet switching and dynamically provisioned optical lambdas

- HOPI Project – Hybrid Optical and Packet Infrastructure
  - Whitepaper – see http://hopi.internet2.edu
  - Immediate Goals
    - Implement testbed over the next year
    - Coordinate and experiment with other similar projects
  - Design & Corporate Advisory Teams

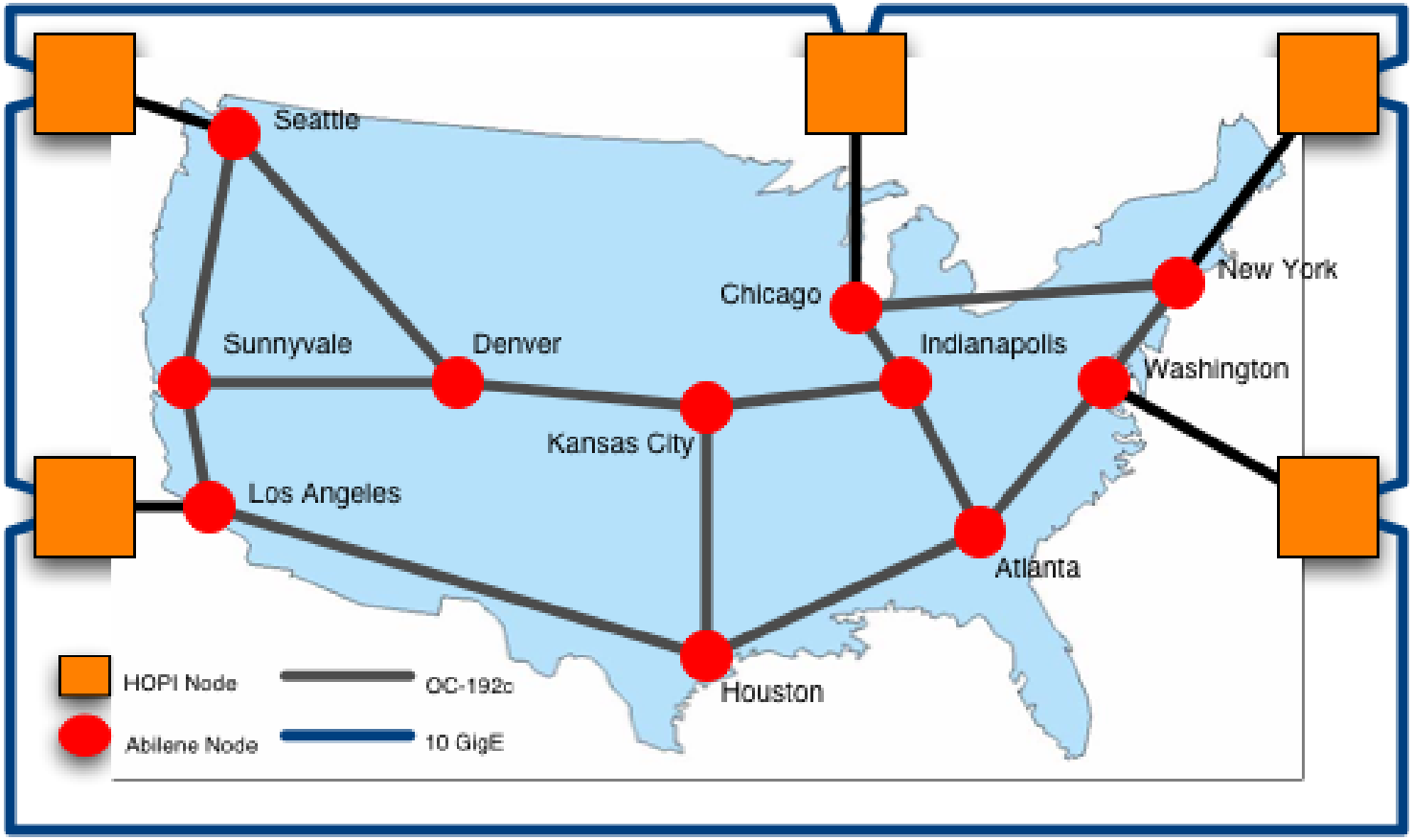
HOPI problem statement

- Problems to understand
  - Goal is to look at fundamental architecture
  - Requirements of dynamic provisioning
  - Temporal duration of dynamic paths and requirement for scheduling
  - Examine backbone, regional, 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?

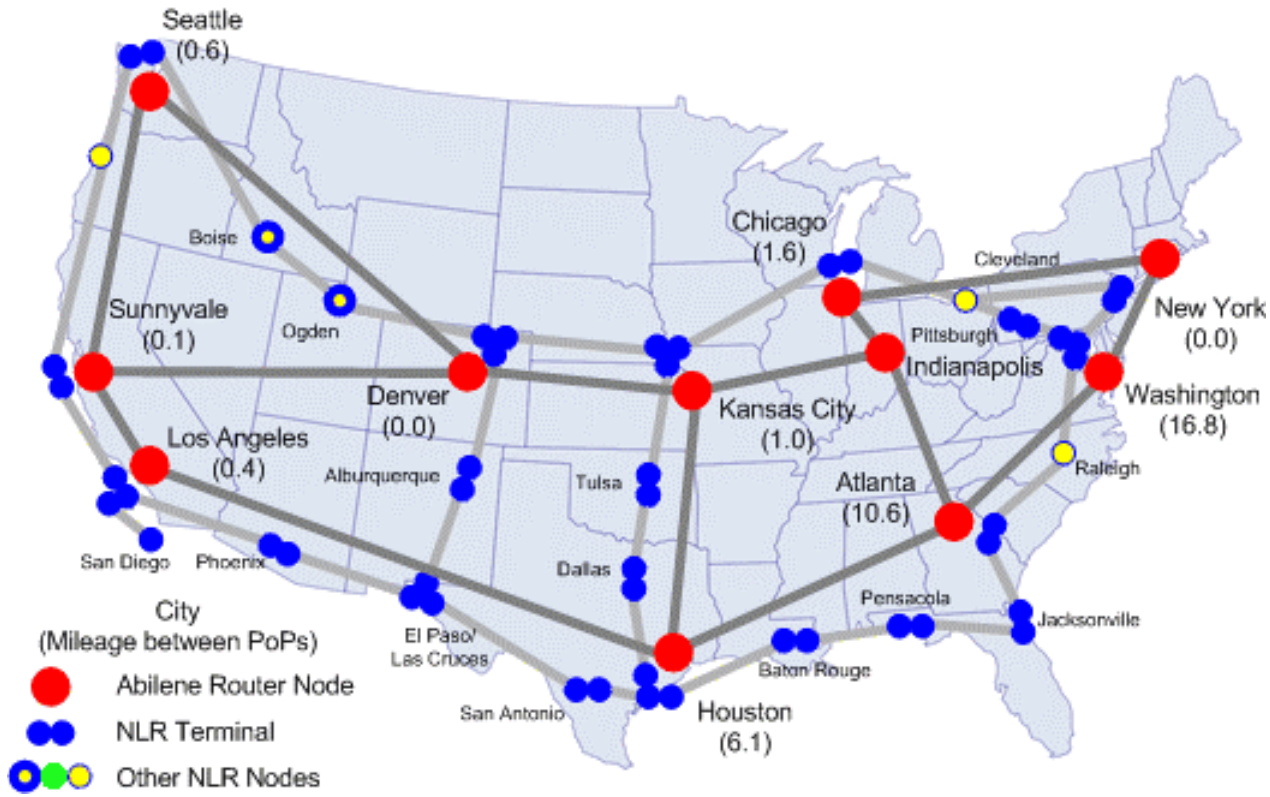
HOPI Node


NLR
NLR
HOPI Node
Ethernet Switch
Optical Cross Connect
RON
Control
Measurement
Support
Out of Band Access
Abilene
Abilene
Abilene T-640
GigaPoP
GigaPoP

HOPI Topology



Abilene/NLR Map



HOPI deployment schedule

- HOPI Nodes
  - Los Angeles (Equinix) - Participation in UltraLight and HENP projects ~ early April, 2005
  - Washington, DC (DRAGON) - Participation in DRAGON and Cheetah projects ~ early April, 2005
  - Chicago (Star Light) - Participation with international partners ~ early May, 2005
  - Seattle, WA (Pacific Northwest GigaPoP/Pacific Wave) - Participation with international partners ~ late May, 2005
  - New York City (NYSERNet) - For connection to MAN LAN and international partners (SURFNet, CANARIE) ~ July, 2005
- OC-192c circuit from NYC to London to interconnect with GEANT2 hybrid ~ July, 2005
  - ESnet and CANARIE participants
  - Complements existing OC192-c (IEEAF/Tyco) from NYC to Amsterdam/SURFnet

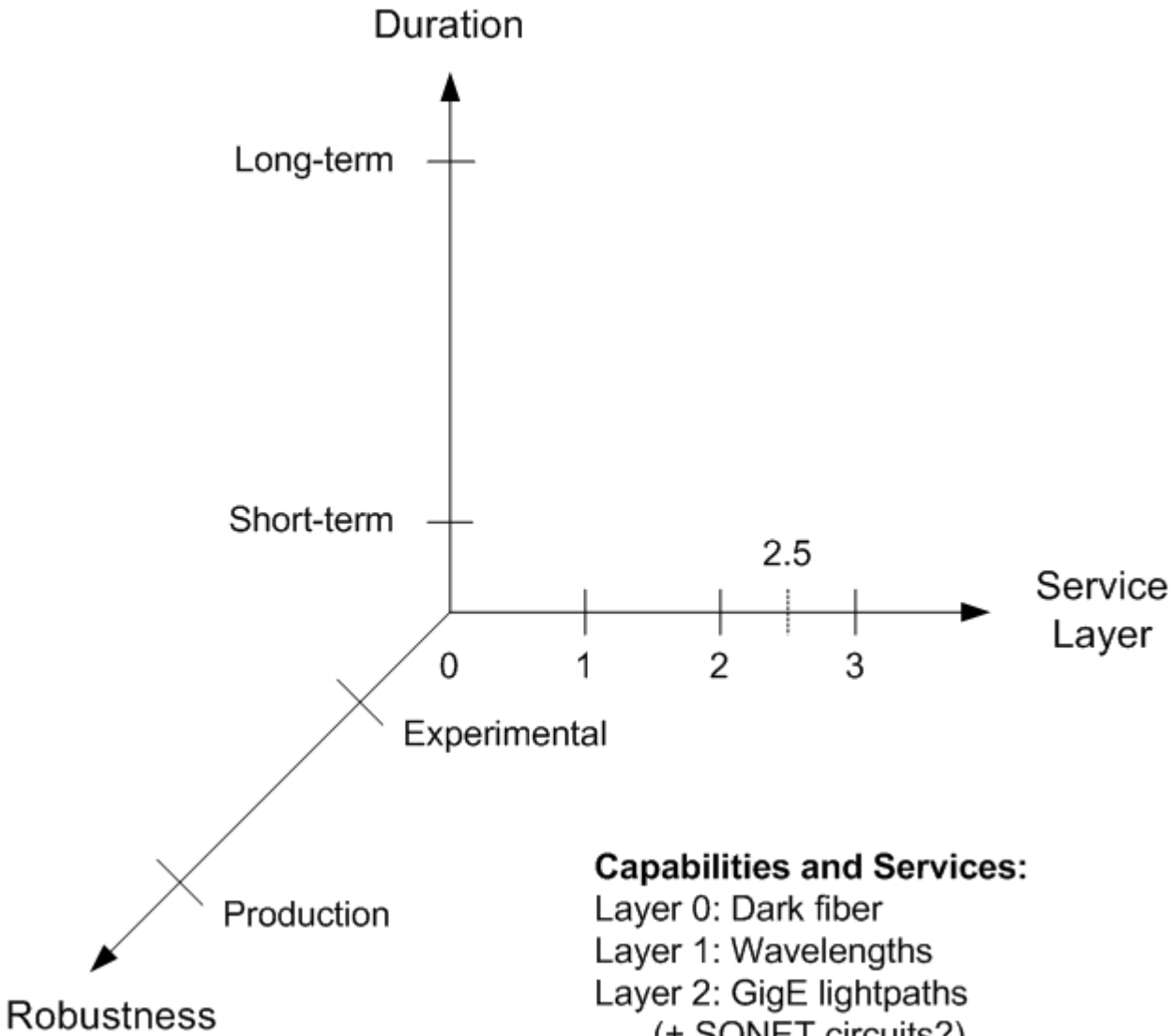
Abilene Network futures

- October 2007 – End of recent 1-year Abilene transport MoU extension
  - Sets 3rd-generation network planning timeline
    - Architecture definition: end 4Q05
    - Transport selection: end 1Q06
    - Router and other equipment selection: end 2Q06
    - Backbone deployed: end 4Q06
    - Connector transition (if necessary): starting 1Q07
  - Concurrently, review overall business plan and management model
  - Network design time frame: 2007-2012

Next Generation Network Design

- Critical factors
  - RON and International integration
  - Advanced service support
    - (Multicast, v6), High Performance Throughput, Measurement
  - Enhanced network research facilitation
  - Network and end-user security
  - Options for increased reliability
- Process
  - Hybrid architecture evaluation (HOPI)
    - IP core using 40?/10 Gbps transport
    - Dedicated capabilities (λ's, MPLS tunnels)
  - Evaluation of optical transport capabilities
    - NLR, commercial providers & RONs
  - Design & planning collaboration
    - U.S. & int'l partners (ESNet, TeraGrid, SURFnet, GEANT-2)

Potential Model for Services and Capabilities to be Offered in Next Generation Higher Education Network Infrastructure



Capabilities and Services:
Layer 0: Dark fiber
Layer 1: Wavelengths
Layer 2: GigE lightpaths
(+ SONET circuits?)
Layer 2.5: MPLS tunnels
Layer 3: IPv4/v6

Service redifferentiation

- Expanded spectrum of potential services and capabilities
  - Dark fiber, wireless spectrum
  - Wavelengths
  - Subchannels
    - Gigabit Ethernet ‘circuits’
    - SONET circuitsgrea
    - MPLS tunnels
  - IPv4/v6
  - Overlay network support
- Need for new model of customer support and end-to-end connectivity delivery assurance
  - Working across campus, regional & national scales
  - Effective campus penetration of new services is a critical issue

Regional Optical Networking

- The fundamental nature of regional networking is changing
  - The *GigaPoP* model based on *provisioned, high-capacity services* steadily is being replaced – on the *metro and regional scales*
- A model of *facility-based networking built with owned assets* – Regional Optical Networks *(RONs)* – has emerged
  - Notably, this change *increases* the importance of regional networks in the traditional *three-level hierarchy* of U.S. R&E advanced networking

Starting a RON … in stages

1. Convene visionary and enthusiastic regional partners
2. Identify scientific and other research drivers – key partners!
3. Assemble a technical working group
4. Develop approaches to governance & capitalization and preliminary business plan
5. Study dark fiber availability and procure fiber
6. Evaluate, select and procure optronics platform (note fiber dependencies)
7. Refine business plan (i.e., λ pricing/cost-recovery model)
8. Focus on means to extend new capabilities to the researchers on campuses
9. Learn how to operate and maintain the system
10. Install and commission optical equipment (co-location)
11. At last, provision λ's and other overlaying services!

Credit: Chris Buja (Cisco Systems) for his insights

For more information…

- http://abilene.internet2.edu (Abilene)
- http://abilene.internet2.edu/observatory (Observatory)
- http://ipv6.internet2.edu (IPv6)
- http://e2epi.internet2.edu (Performance)
- http://networks.internet2.edu/manlan (MAN LAN)
- http://www.fiberco.org (FiberCo and dark fiber)
- http://hopi.internet2.edu (HOPI)
- http://www.nlr.net (National Lambda Rail - NLR)
- http://www.glif.is (Global Lm)


INTERNET®
www.internet2.edu