Optical and Hybrid Networks for Research and Education

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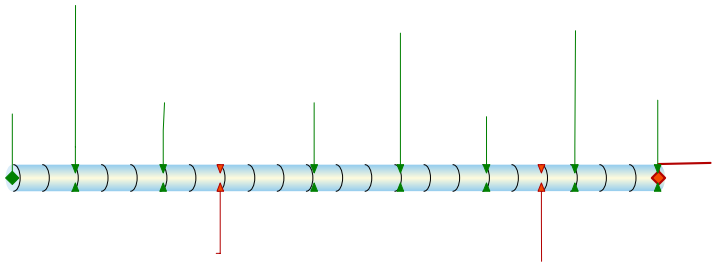
Private, Not for profit Organization

- Established in 1980 as Microelectronics Center of North Carolina; Became MCNC in 1990
  - Founded by NC General Assembly as non-profit, state-funded resource for technology-led economic development

- Expanded in 1985 to include NC Networking
  - Provide high-speed network linking NC universities
  - Provide common platform for statewide research for academic institutions

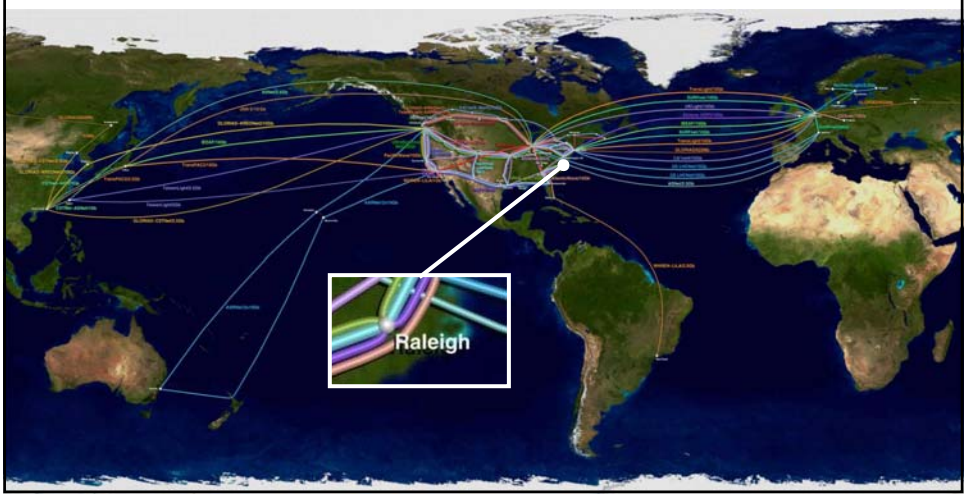
- Operated NC Supercomputing Center 1988 - 2003
- Independent, not for profit organization
- Focus on technology-based economic development

Leadership in contributions to education and economic development in North Carolina in partnership with higher education and the State.



Global Reach

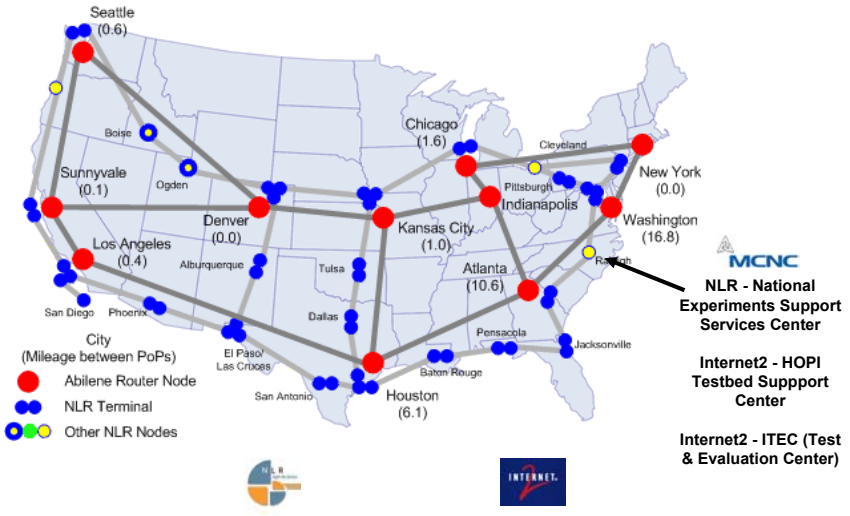
Global Lambda Integrated Facility



First networ

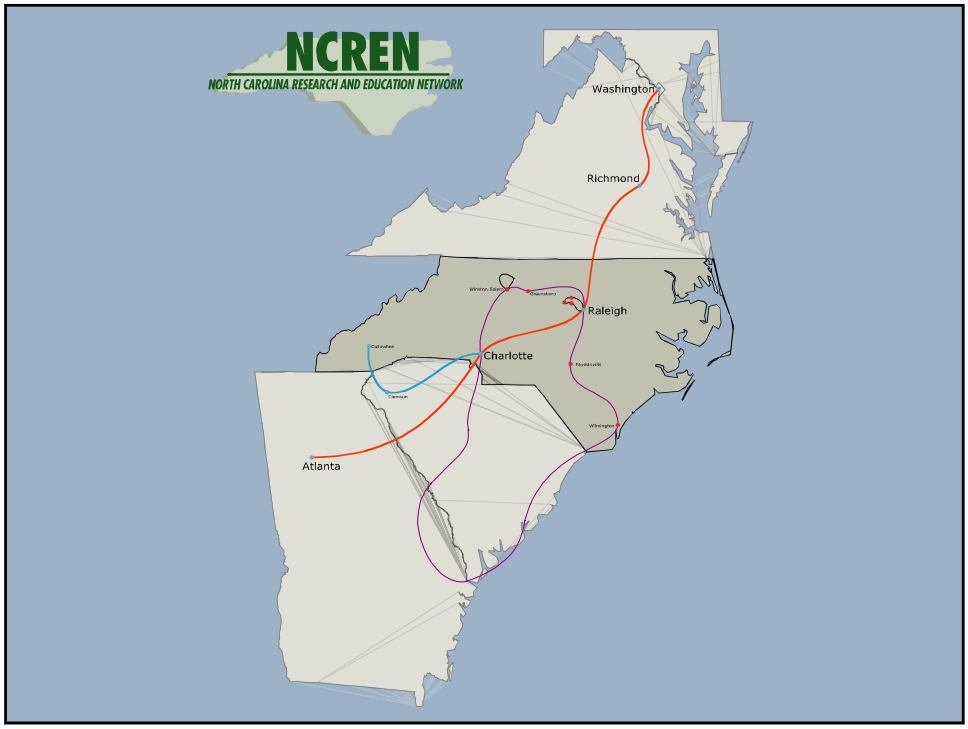
Facilities-Based Regional Networks

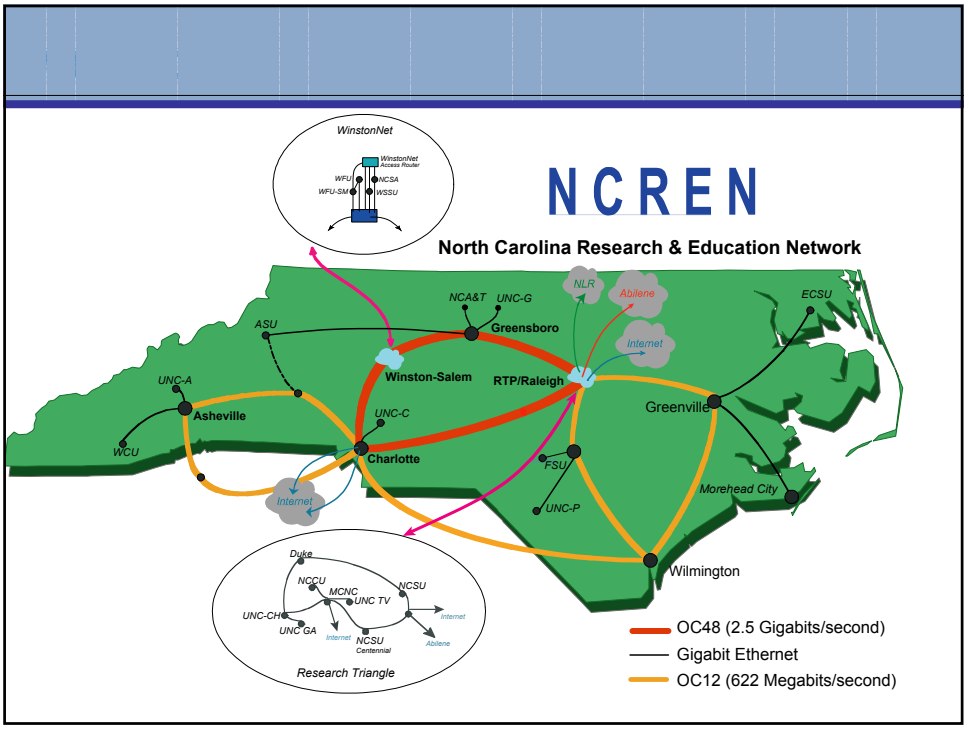
National Reach



Support projects

- NLR Experiments Support Services
  - The primary goal of the National LambdaRail's Experiments Support Services is to provide end-to-end support to the research community's use of NLR. These services include a wide range of support for NLR-based research objectives, with a primary focus on networking research experiments.
- Internet2 HOPI Technical Support Center
  - Develop Core Network Services, provide operations support, and provide applications support and integration
- Internet2 I-TEC
  - provide testing and evaluation services supporting the Abilene Network. The focus of this effort is on optimizing technologies currently deployed in Abilene. The North Carolina ITEC also supports research into new technologies that have the potential to progress the state of the art in networking infrastructure and advanced services.





NCREN Services

All Optical

- 32 channels at 10Gbps Wave Division Multiplexing(WDM) capability within research triangle and to NLR
- NCREN delivers gigabit service to all 16 UNC campuses* and 2 private universities
- Over 3 gigabits per second of Internet service
- 2.4 gigabits per second of Internet2 access
- High quality video network - delivered over IP
- Facilities based network since 1985 (microwave, then fiber)

NCREN: Statewide Video Network

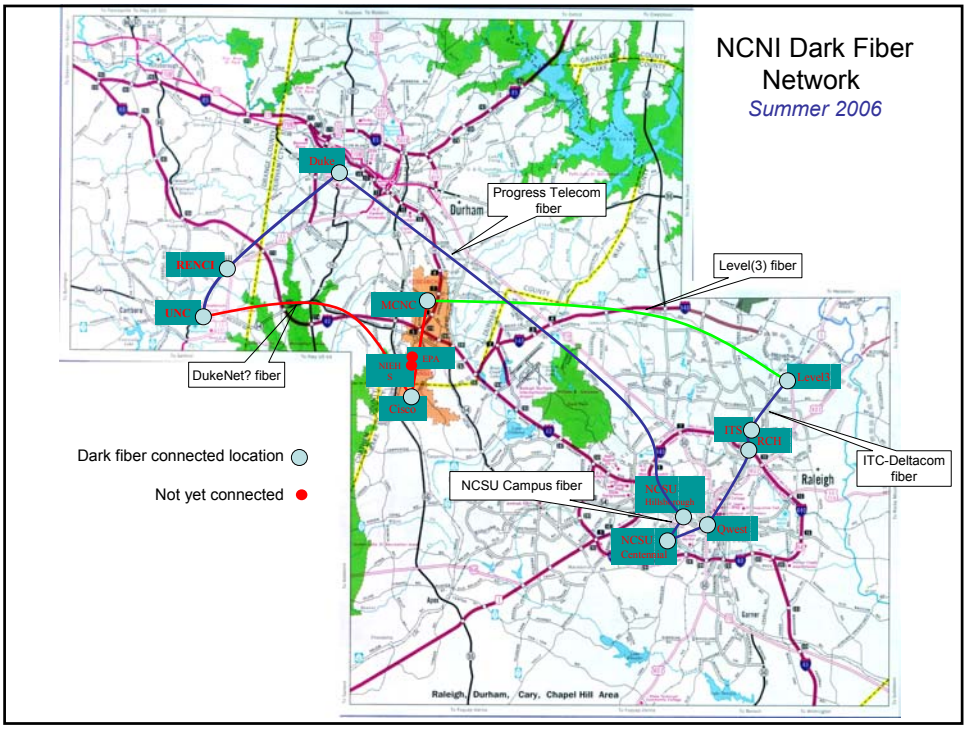
- Provides centrally managed and coordinated services among universities and other institutions
- Enables fully interactive, face-to-face, live discussions among sites
- Supports up to 23 sites in a single conference
- Interoperates 5 different audio/video techniques
- NCREN integration of Video-over-IP (Internet Protocol) provides optimum flexibility:
  - Point-to-point MPEG2 video sessions
  - Point-to-point H.323 video sessions
  - Multi-point H.323 sessions
  - Gateways to NC State Gov't (ITS) network
  - Ability to blend various video technologies

NCREN connectors

Video & Internet
- Appalachian State University
- Duke University
- East Carolina University
- Elizabeth City State University
- Fayetteville State University
- MCNC
- North Carolina Central University
- North Carolina School of the Arts
- North Carolina State Agricultural and Technical University
- North Carolina State University
- University of North Carolina at Asheville
- University of North Carolina at Chapel Hill
- University of North Carolina at Charlotte
- University of North Carolina at Greensboro
- University of North Carolina at Pembroke
- University of North Carolina at Wilmington
- University of North Carolina General Administration
- University of North Carolina Public Television
- Wake Forest University
- Western Carolina University
- Winston-Salem State University

- **Internet Only**:
  - Barton College
  - Bennett College
  - Campbell University
  - Cape Fear Community College
  - Catawba College
  - Central Piedmont Community College
  - Chowan College
  - Davidson College
  - Durham Technical Community College
  - Elon University
  - Gardner-Webb University
  - Greensboro College
  - Guilford College
  - Haywood Community College (backup only)
  - High Point University
  - Johnson C. Smith University
  - Johnson and Wales University
  - Lees-McRae College
  - Lenoir Rhyne College
  - Meredith College
  - Montreat College
  - N.C. Independent Colleges and Universities (Assn.)
  - N.C. Medical Examiner's Office
  - N.C. State University Center for Marine Science and Technology (CMST)
  - Peace College
  - Queens College
  - Salem College
  - Saint Augustine's College
  - Saint Mary's College
  - Shaw University

- **Internet Only**:
  - Shodor
  - St. Andrews Presbyterian College
  - Wake Technical Community College
  - Wingate University
  - A.C.S./N.C. Dept. of Community Colleges
  - Burrough's Wellcome Fund
  - Charlotte Country Day School
  - Charlotte-Mecklenberg Public Library
  - CIIT
  - Cumberland County Public Library
  - Forsyth County MIS
  - Greensboro Public Library
  - Mt. Pisgah Academy
  - National Climatic Data Center
  - National Humanities Center
  - National Institute of Statistical Sciences
  - National Severe Storms Laboratories
  - N.C. Genomics and Bioinformatics Center
  - N.C. State Government ITS
  - N.C. Technology Development Authority
  - North Raleigh Christian Academy
  - NTC/Shentel
  - Providence Day School
  - Research Triangle Institute
  - Roanoke Bible College
  - The Gateway Technology Center at Wesleyan College
  - Wake County Government
  - WinstonNet



So What's Happening?

- At least 26 RON projects in 40+ states
- Nearly 30,000 miles of fiber collectively
- Providing:
  - Internet / Internet2 access
    - Peering for R&E and commodity
  - Circuits (often gigabit Ethernet)
    - Overlay networks
- Lots of learning the stuff the telcos know
  - FIT values, TL-1, etc

Why do we want to do this?

- The limitation of all purchased services is the lack of control!
- Underlying assumption that big science needs big performance
- All science will become information-based*
- Ever increasing importance of collaboration, particularly international
- Cost control/avoidance for commodity services
- Scaling
- Lambda envy

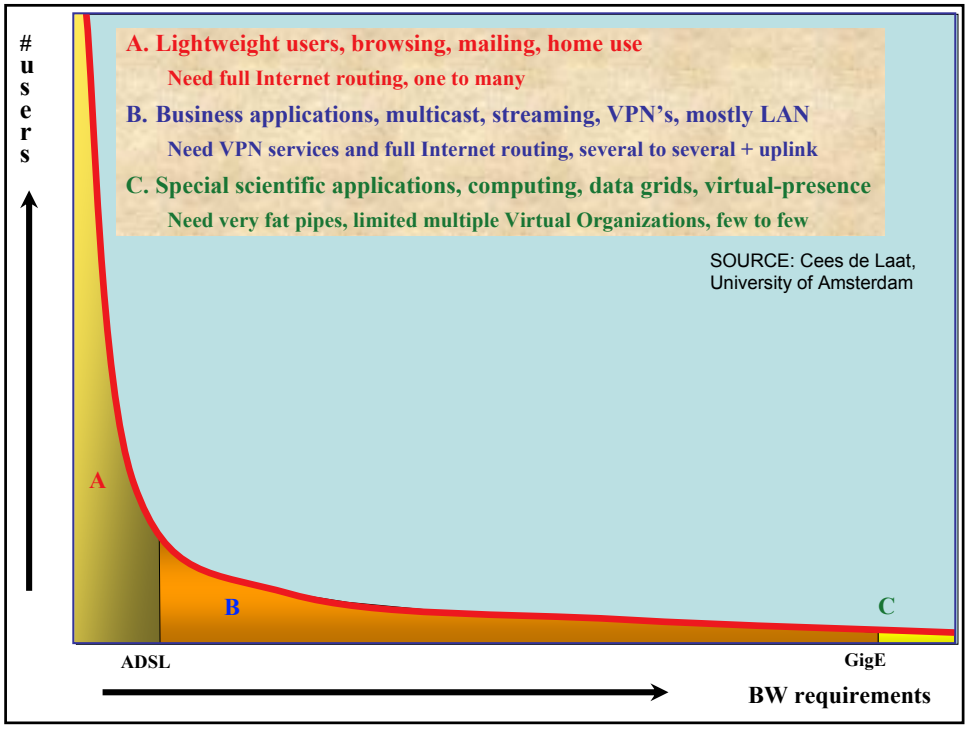
**BillJohnston ESnet*

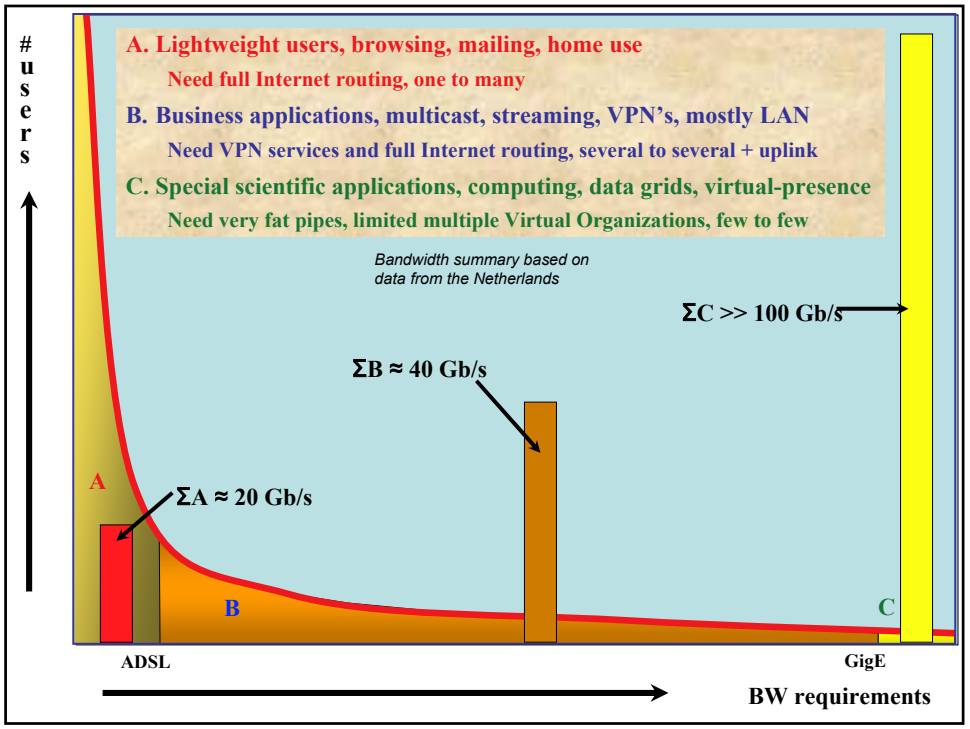
Facilities-based networks

- Regional networks can now afford the first lambda
- Evolution from point solutions (gigapops) to network solutions (RONs)
- Return to favor of circuit-based systems

A little context…

- Research and Education networks serve a different constituency from commercial ISPs
- The scaling requirements are not the same
- Some of our user requirements may be driving changes to the core network architecture

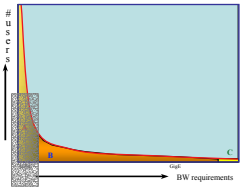




A. Lightweight users, browsing, mailing, home use

Need full Internet routing, one to many

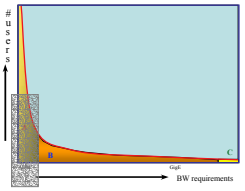
- Not served by NCREN directly
- Other entities driving availability and change for this class of users
- Accommodate through peering relationships with residential access providers, State Government



A. Lightweight users, browsing, mailing, home use

Need full Internet routing, one to many

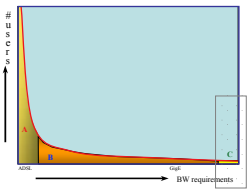
- Areas of Activity:
  - Establish peering with residential access providers
  - Multiple points of connectivity with State Government
  - Initiative to provide comprehensive K-12 network



C. Special scientific applications, computing, data grids, virtual-presence

Need very fat pipes, limited multiple Virtual Organizations, few to few

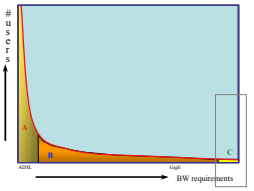
- Grand challenge computing problems, very large instruments
- Dedicated bandwidth
- Long periods of sustained throughput
- Straightforward to provide: build the biggest possible pipes



C. Special scientific applications, computing, data grids, virtual-presence

Need very fat pipes, limited multiple Virtual Organizations, few to few

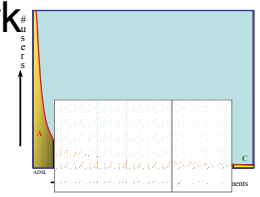
- Create a system capable of supporting this type of user as demands arise
- Areas of activity:
  - Fiber acquisition
  - Optical Wave Division Multiplexing (WDM) systems
  - NLR *Wavenet* Access



B. Business applications, multicast, streaming, VPN's, e-Science

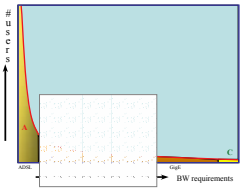
Need VPN services and full Internet routing, several to several + uplink

- Represents the bulk of R&E users
- Range of requirements from Student dorm access to e-science just short of grand challenge issues
- Potential for greatest change and disruption to accepted network architectures



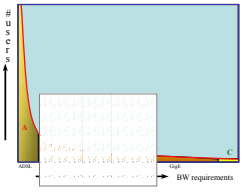
Lower-middle range: High-Performance IP

- Student residents in dorms
- University business applications
- Videoconferencing
- Faculty collaboration
- Most IT in support of research



Lower-middle range: High-Performance IP

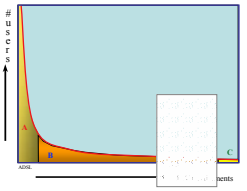
- Areas of Activity:
  - Expansion, enhancement of NCREN
    - Optical technology for added bandwidth
    - Fiber acquisition for redundancy, capacity
    - Geographic expansion into neighboring regions
  - Internet2
    - Access to Abilene
    - Participation in development of best practices, standards through working groups, workshops
  - Quilt
    - Commodity Internet Service contract (10X price/performance improvement)
    - Technical information exchange
      e.g. Optical Workshops
    - Federal Lobbying
  - NLR
    - TransitRail peering project



Upper-middle range: e-Science

High performance limited duty cycle applications

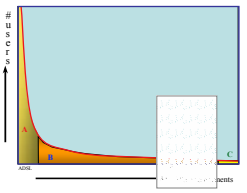
- Applications require very high-performance network for brief periods of time (days or hours)
- Access to scarce resources like instruments or HPC systems
- Network requirements may be determined at run-time
- Currently typical provisioning takes weeks involving many people, emails, phone calls
- End-to-end path may include campus, regional, national networks



Upper-middle range: e-Science

High performance limited duty cycle applications

- Needed:
  - Method of automatically provisioning services
  - Methods for provisioning services across institutional boundaries
- Areas of Activity:
  - Control-plane research e.g. EnLIGHTened Computing
  - HOPI
    - Design team
    - Testbed Support Center
  - Authentication, Authorization, Accounting services
  - NLR
    - Experiments Support Services
    - Engineering team
  - Resource Scheduling
  - Vendor relationships (early field trials, beta tests) of optical network components



MORPHnet

- Supports the notion that the same operator must support research and 'production' users with limited resources
- Defines an approach to building multiple logical networks on the same, shared facility

MORPHnet

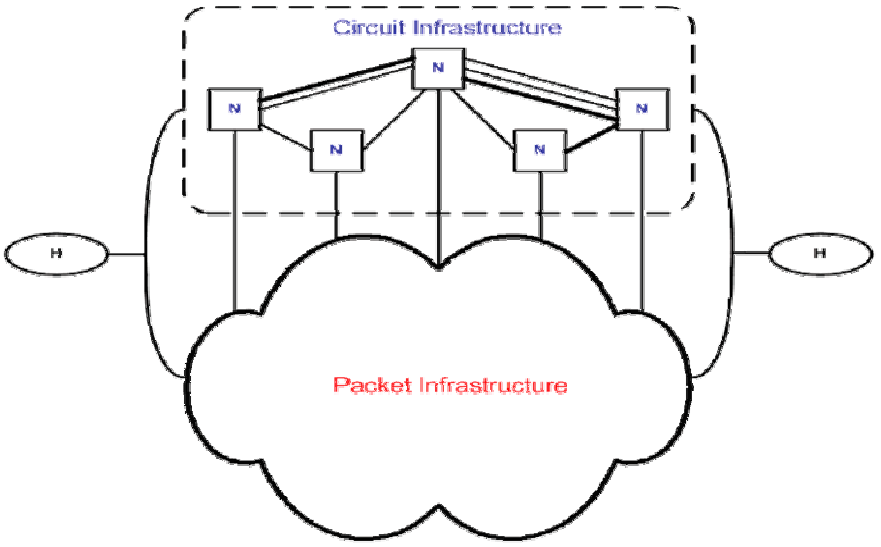
Not a single network but a set of facilities, capabilities and services to build both experimental and production networks at various layers, allowing members to acquire dedicated (project specific) facilities or shared (community specific) facilities as appropriate - NLR

Hybrid Optical and Packet Infrastructure

- Testing the assumption that the same user/application will have access to BOTH an IP network and a circuit-based network AND be able to provision the circuit-based network dynamically to create application specific topologies
- Building on the MORPHnet approach to try this out

Hybrid Optical and Packet Infrastructure

- 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?
- Examine a ***hybrid*** of shared IP packet switching and dynamically provisioned optical lambdas
- HOPI Project – Hybrid Optical and Packet Infrastructure
  - Have created a whitepaper – see http://hopi.internet2.edu
  - Immediate Goals
    - Implement testbed over the next year
    - Coordinate and experiment with other similar projects
  - Design Team, Corporate Advisory Team, Research Advisory Group



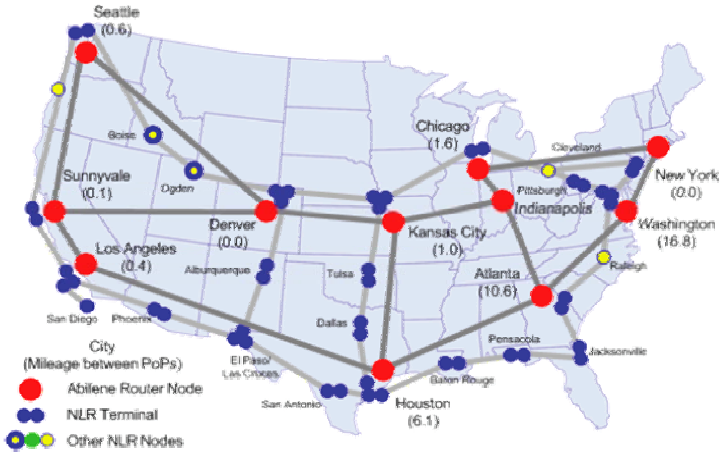
The HOPI Problem

- 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

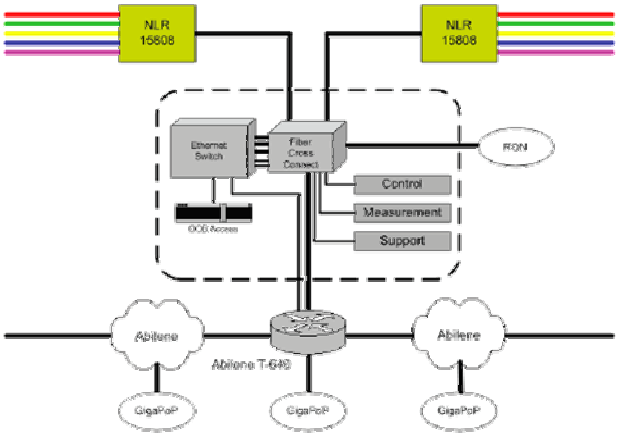
Hybridness

- The original notion was a hybrid of circuits and IP
- Other possible hybrids are becoming apparent
  - E.g. Circuits and packets in the same path

NLR/Abilene Map



HOPI Node



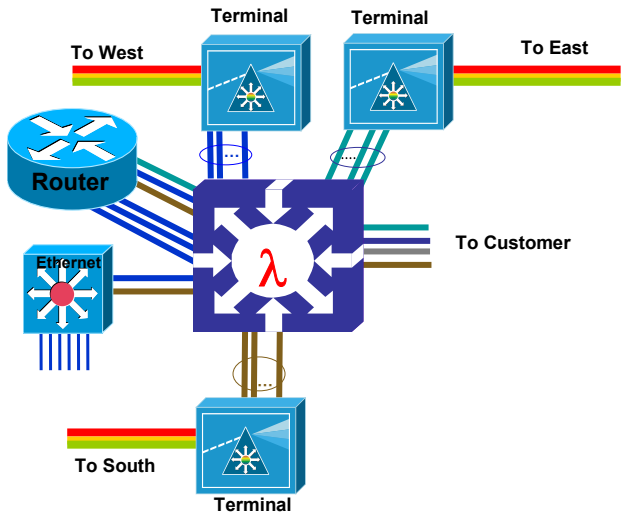
HOPI Node

- 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
- An Ethernet switch device to partition the wave into 1 GigE paths when necessary
- Control devices
  - Ad hoc control plane computer
  - Measurement computer
  - Experimental computer
- Control and data planes must be disjoint
- Out of band access

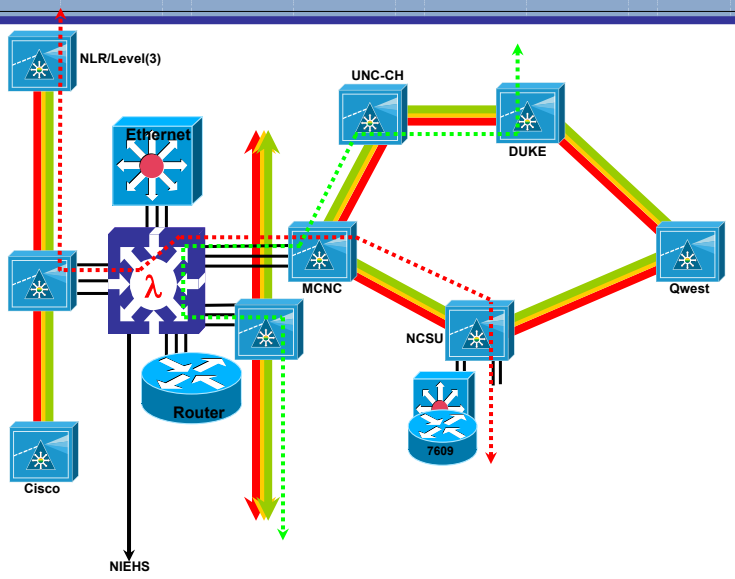
HOPI Status

- Using DRAGON GMPLS control plane
- Demonstrated application-specific topologies with eVLBI
- Seeking additional applications
  - Possibly gaming, haptic feedback systems, HPC
  - Apps guys often don't really want to mess with the network
- Hybridness is very application-dependent and drivers are slow to develop
- HOPI provisioning features to be incorporated into next generation Internet2 network

Optical Switching for NLR



NCNI multiservice network

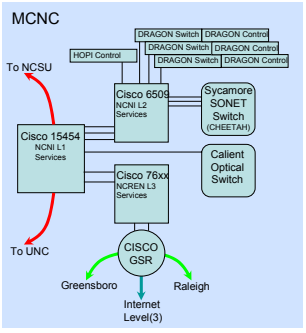


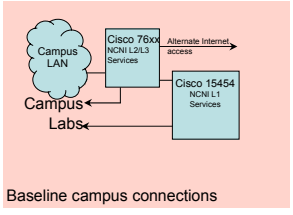
Conclusions

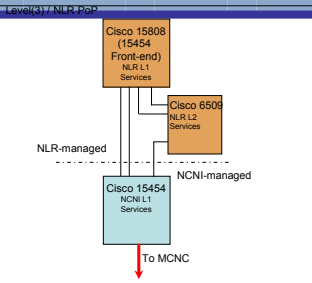
- GMPLS control-planes moving from testbeds to production
- NLR, Internet2, GEANT all pursuing variations
  - Internet2 and GEANT are actively looking at control-plane peering
- Seeking applications to exercise the infrastructure
  - Applications owners have real work to do and are not necessarily interested in playing with networks that might not work well
- R&E needs may not match provider's
  - Vendor's may not be motivated to solve our problems

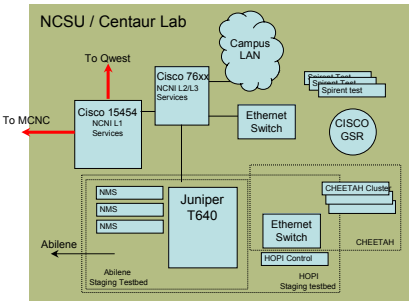
Thanks!

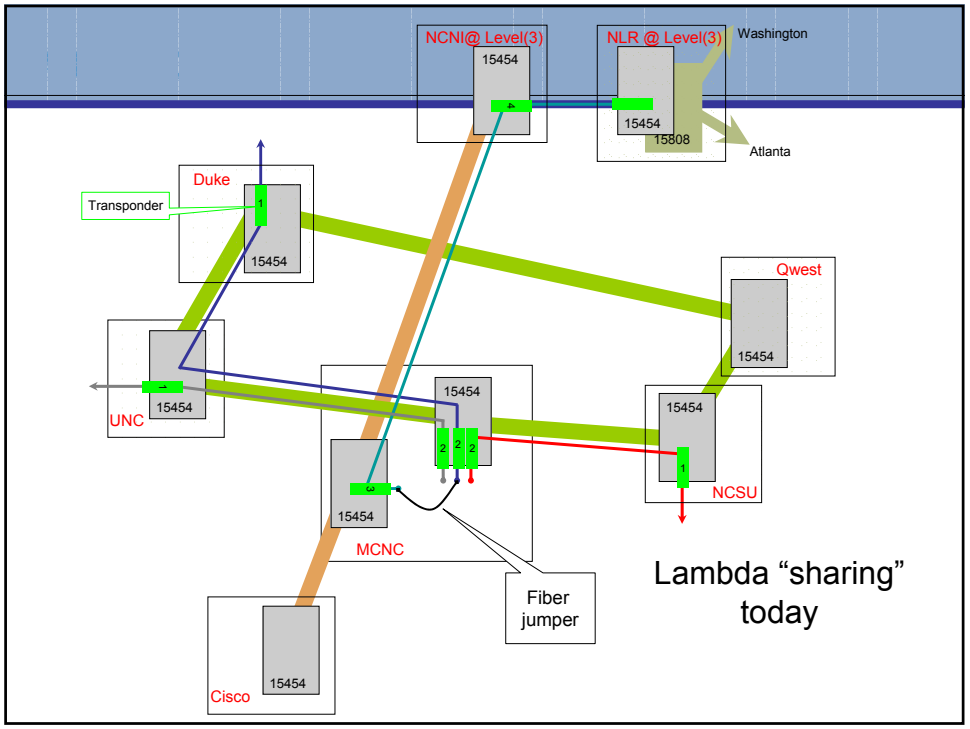
NCNI Optical Capabilities







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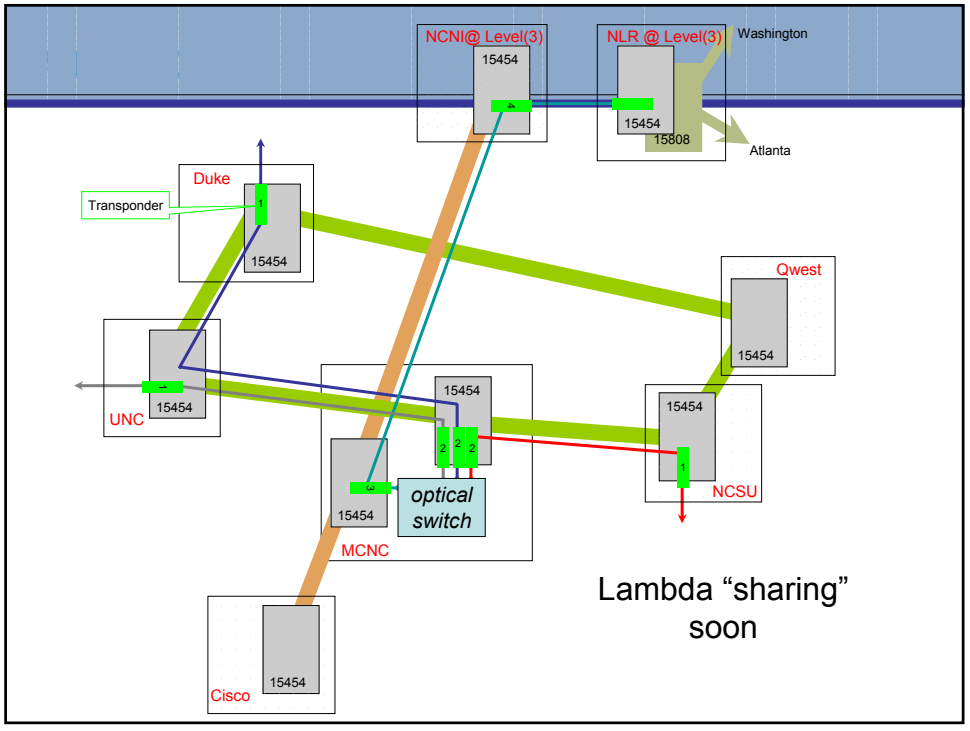
Lambda “sharing”
today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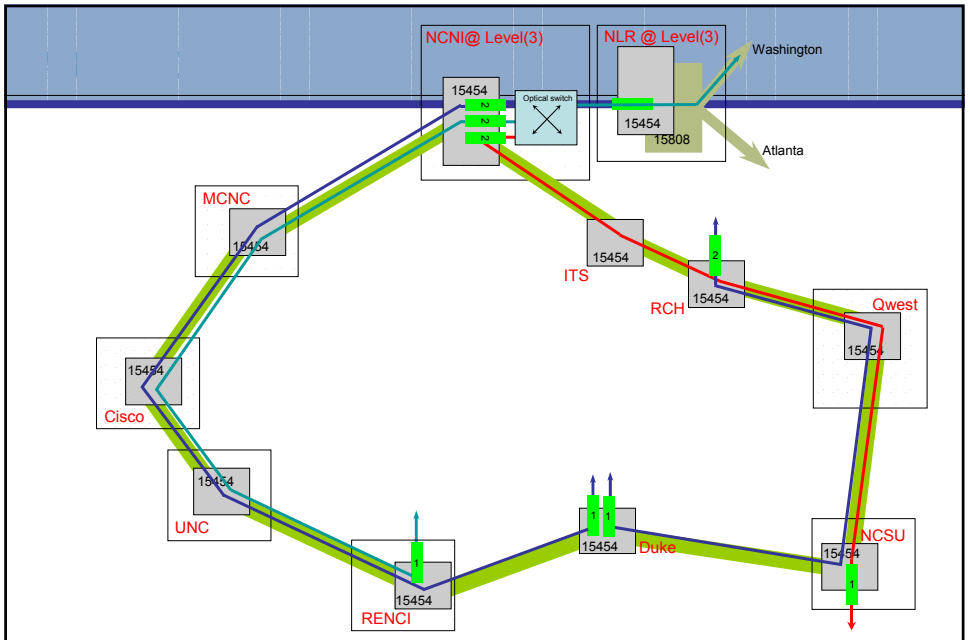
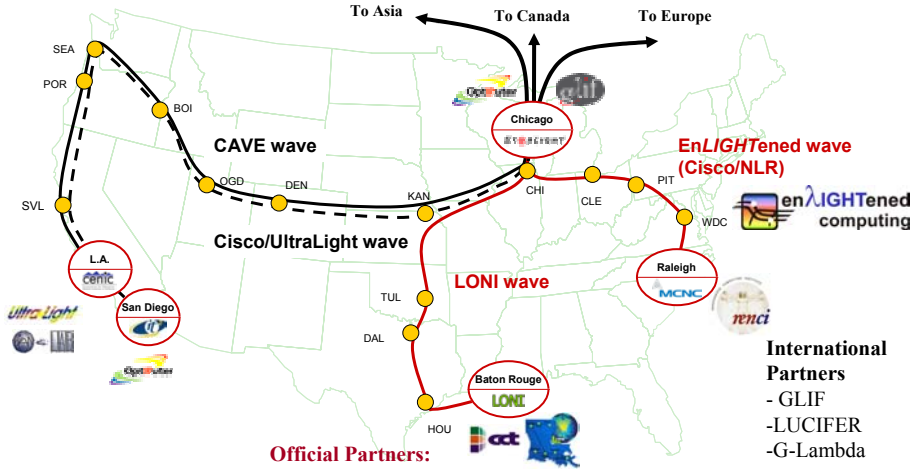


Future Lambda "sharing" scenario

enλIGHTened computing connectivity diagram with partners



Members:
- MCNC
-Renaissance Comp. Inst.
- LSU CCT
-NCSU

Official Partners:
- AT&T Research
- SURA
- NRL
- Cisco Systems
- Calient Networks
- NLR

NSF Project Partners
- OptIPuter
- UltraLight
- WAN-in-LAB
- DRAGON
-Cheetah

International Partners
- GLIF
-LUCIFER
-G-Lambda