



Status Report on National and Regional Optical Networking Initiatives in the United States

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Section 6b: Optical Networks - Practical Experiences

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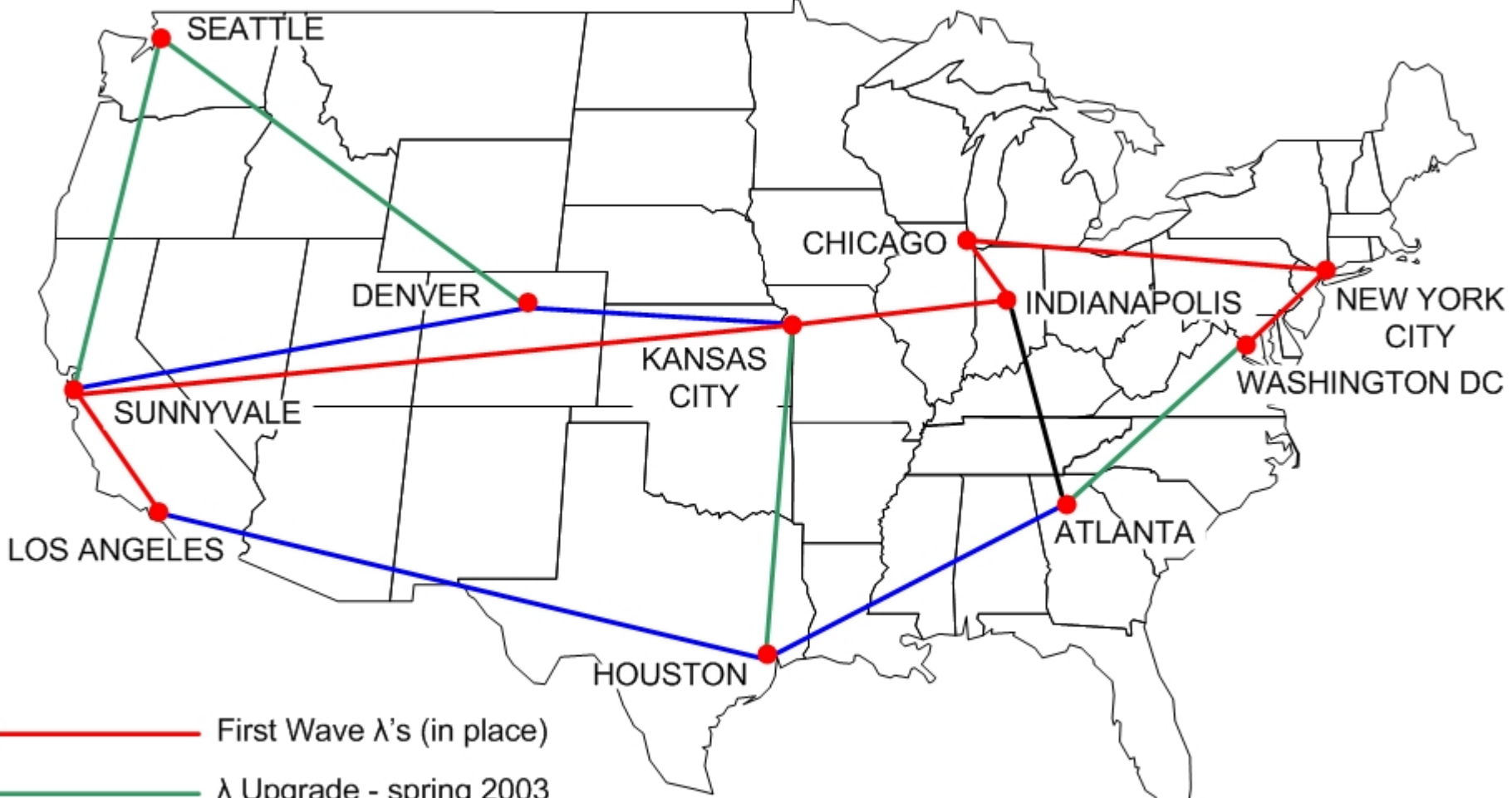
Quick summary





- Need for concurrent national & regional initiatives now widely recognized in U.S.
- Challenges
 - U.S. distance scale – 16,000 km national; 2-D country
 - Need for regional optical networks: 3-layer hierarchy
- National-scale, facility-based λ network for computational science and network research
 - National Lambda Rail (NLR)
- Supporting project for regional optical initiatives – to hold & assign dark fiber
 - Fiberco
- Other complementary efforts in progress
 - USA Waves & Northern Tier

Topics

- Abilene
 - How does it relate?
- Why optical networking?
- Critical importance of regional initiatives
- National efforts

ABILENE NETWORK 10-Gbps OPTICAL UPGRADE - 2002-2003



-  First Wave λ 's (in place)
-  λ Upgrade - spring 2003
-  λ Upgrade - summer 2003
-  OC-48c SONET

Abilene core features

- U.S. higher education's network
 - Natural base for community-wide efforts
 - Native multicast & IPv6, large MTU, measurement, advanced apps
- IPv4+IPv6 common bearer services
- Bandwidth availability & utilization incentive
- Peering limited to U.S. & int'l R&E nets
- Regional aggregation model
 - SONET & DWDM backhaul support
- "4+ Nines" reliability target
 - Advanced service deployment with continuous monitoring
- Open measurement platform

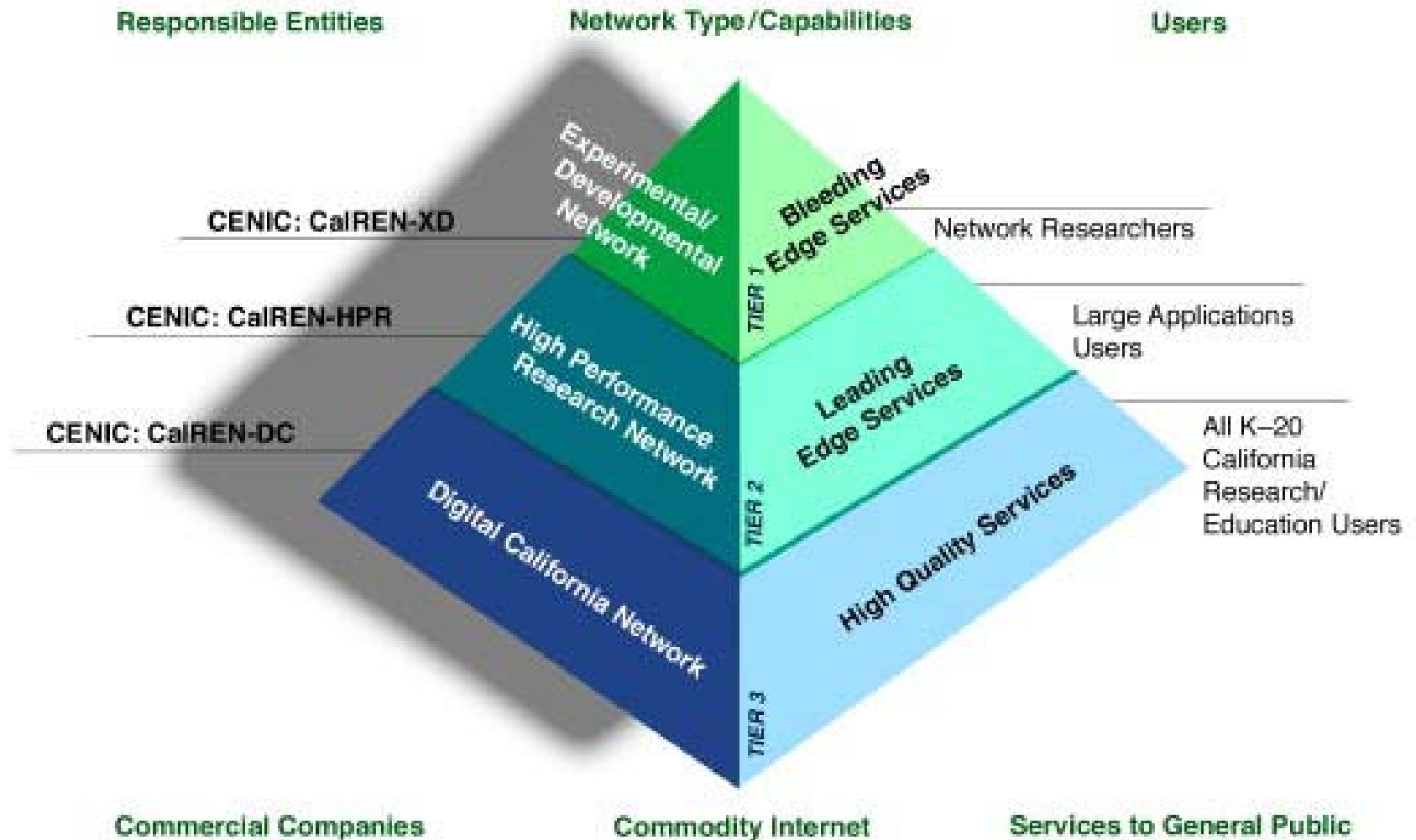
Future of Abilene

- 10-Gbps optical upgrade nearing completion
 - Final backbone λ 's to be installed this summer
- Abilene transport (DWDM & SONET) MoU with Qwest in place through October 2006
 - 2 10-Gbps connections – CENIC and Pacific Northwest
- New Juniper T640 routers deployed in 2002
 - 8-Gbps transcontinental test flows: IPv4+IPv6 mix & all IPv6
- Current peak load ~10% of upgraded bandwidth
 - Traffic doubling time ~ 1 year
- Engaged national user community
 - 221 participants (research universities and laboratories)
- Ensemble of advanced networking projects
 - Abilene Observatory, native IPv6, MPLS VPN test, E2E support

Why a national optical facility?

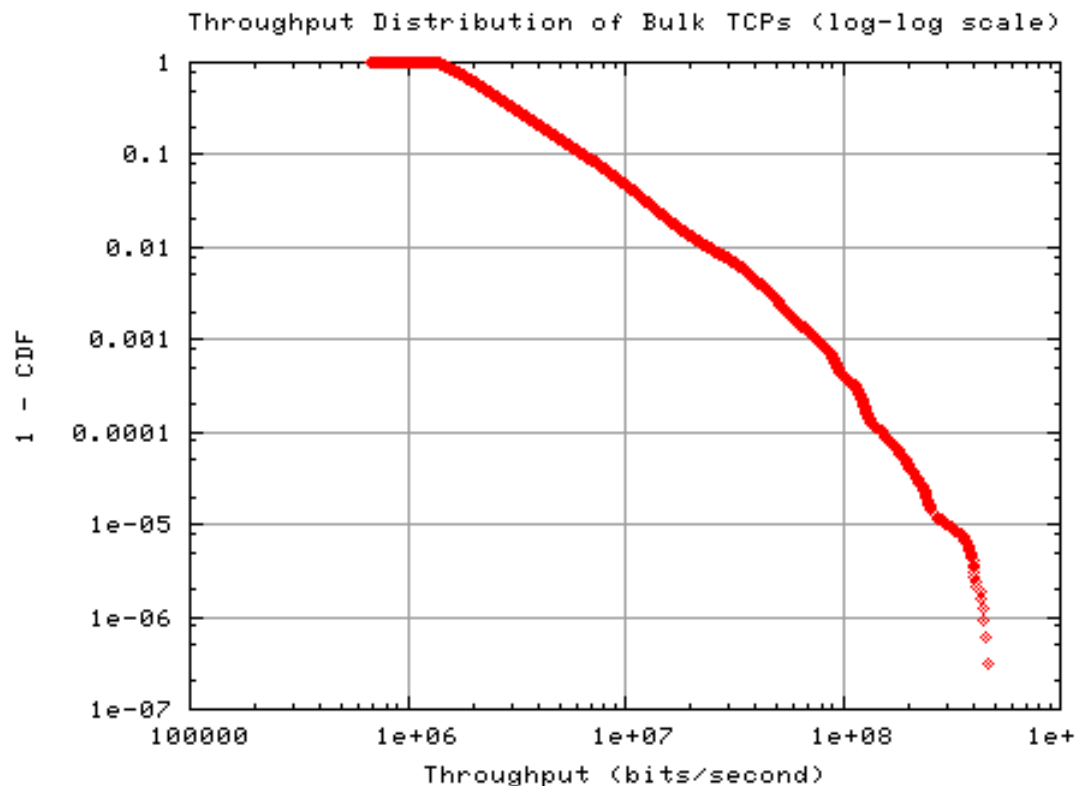
- Control of all network layers on national scale
 - Economic drivers
 - Expansion capability (λ 's) at marginal cost
 - Hedge
 - Technical drivers
 - New technologies: 10 Gigabit Ethernet and *rational* optical switching
 - Influencing development of new protocols at IP/optical interface
- Unprecedented marketplace for both fiber and optical electronics
 - Contrarian opportunity for higher education
- New type of network research testbed
 - Differentiated networks for diverse requirements
- Key enabler for regional optical initiatives

NETWORK DEVELOPMENT AND EVOLUTION FOR CALIFORNIA RESEARCH AND EDUCATION COMMUNITY



The persistent end-to-end performance problem

- ‘Bulk TCP’ flows across Abilene
 - Flows with minimum payload transfer of 10 MB
 - 2.3 Mbps median
 - 6.4 Mbps (90%)
 - 24 Mbps (99%)



netflow.internet2.edu

Persistence of network hierarchy

- Scales of optical network deployments
 - National
 - Regional/State
 - Campus/Metro

Optical network project scale differentiation

	<i>Distance scale (km)</i>	<i>Examples</i>	<i>Equipment</i>
Metro	< 60	UWash USC/ISI(LA), MAX(DC/MD/VA)	Dark fiber & end terminals
State/ Regional	<u>< 500 (LH)</u> <(1.5-2.5k) (ELH/ULH)	I-WIRE (IL), I-LIGHT (IN), CENIC ONI	Add OO amplifiers
Extended Regional/ National	> 500	TeraGrid NG Abilene, Light Rail	Add OEO regenerators & O&M \$'s

Leading & emerging Regional Optical Initiatives

- California (CENIC Optical Networking Initiative)
- Connecticut (Connecticut Education Network)
- Florida (Florida LambdaRail)
- Indiana (I-LIGHT)
- Illinois (I-WIRE)
- Maryland, D.C. & northern Virginia (MAX)
- Michigan
- New York + New England states (NEREN)
- North Carolina (NCNI)
- Ohio (Third Frontier Network)
- Oregon
- SURA Crossroads (southeastern region)
- Texas (Star of Texas)

Current national optical efforts

- National initiatives
 - 1) National Lambda Rail (NLR)
 - 4) USA Waves
- Supporting projects
 - 2) Fiberco
 - 3) Northern Tier

National Lambda Rail (NLR)

- National-scale optical networking facility
 - 4(→40)10-Gbps λ 's over national footprint (16,000+ km)
 - Ability to provision more λ 's at marginal cost
 - Experimental IP and switched Ethernet networks
- Primary objective: support for new forms of network research
 - Both computer & computational science
- Corporate partners
 - Cisco (optical transport/switching/routing)
 - Critical engagement of ARTI group
 - Level 3 (dark fiber & co-location)
- Budget: \$83-100M over 5 years
 - \$50M provisionally raised for Phase 1 build

National Lambda Rail



March 7, 2003
Dark Fiber
Optional Route
Wavelength
Dave Reese (dave@ccmc.org)

National Lambda Rail (NLR)

- Potential participants (Phase 1 in red)
 - CENIC (2 shares – California & Nevada)
 - Pacific Northwest Gigapop (Washington & NW region)
 - NCAR/Front Range Gigapop (Colorado)
 - Pittsburgh Supercomputer Center (Pennsylvania)
 - Virginia Tech (Virginia & Washington D.C.)
 - Duke (North Carolina)
 - Georgia Tech (Georgia)
 - Florida consortium
 - Texas consortium
 - CIC CIOs (Chicago)
 - Internet2 (2 shares – national participant)

NLR participation

■ Benefits

- NLR optical node (terminals or OADM)
- Access to shared experimental services (GigE & IP)
- Ability to provision additional λ 's across NLR at **marginal cost**

■ Responsibilities

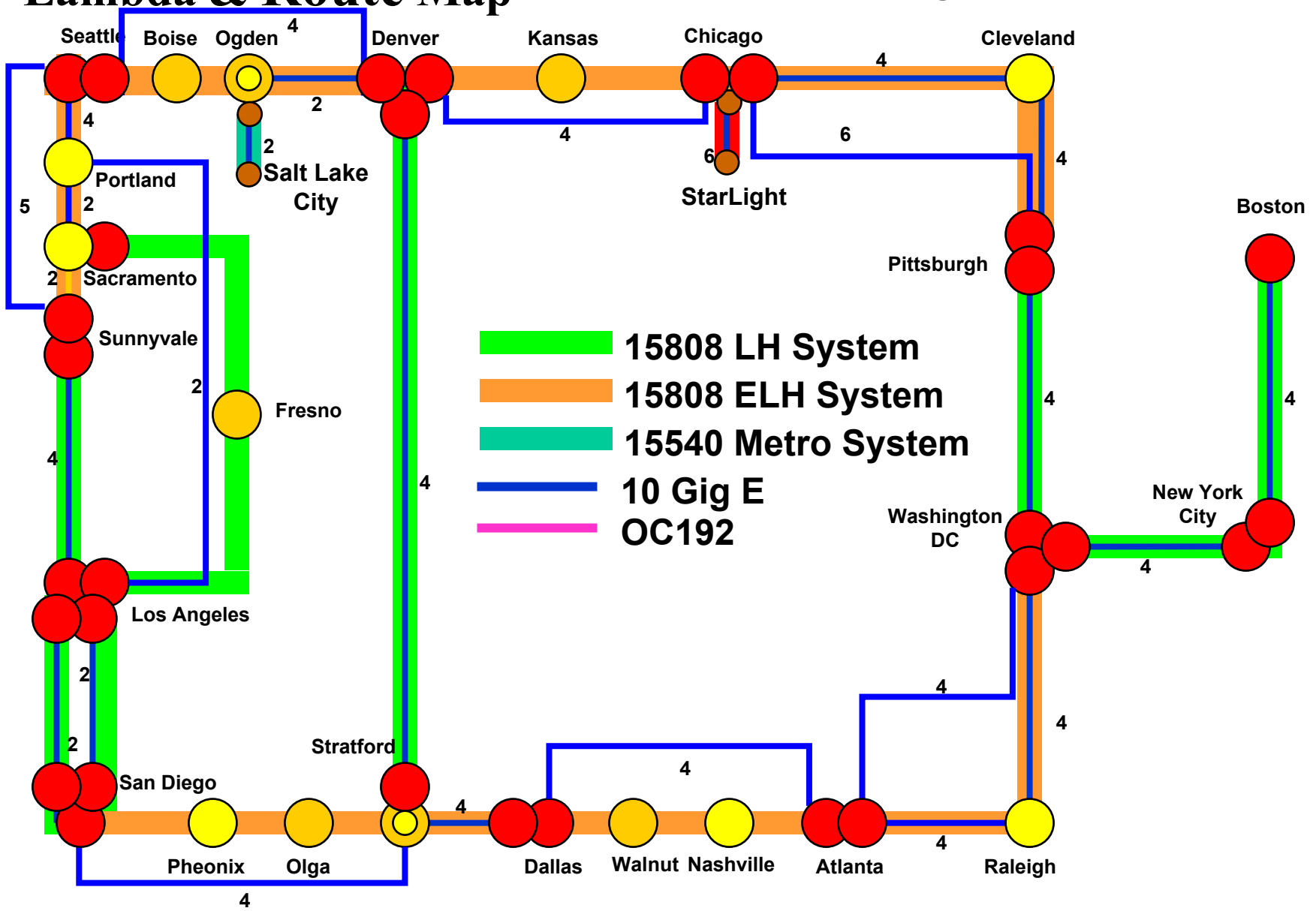
- Fundamental commitment to advancing network research
- Geographic service area – optical capabilities and performance levels
- \$5M over 5 years to capitalize NLR build and operations

NLR technology

- Optical transport
 - Cisco 15808 LH/ELH
 - Preferred tributary: 10 Gigabit Ethernet LAN PHY
- Ethernet switching (GigE VPNs)
 - Cisco 6509
- Routing
 - Cisco 12410

National Light Rail Lambda & Route Map

● **TERMINAL** ● **REGEN** ● **OADM**
● **Metro 10 Gig E**



Abilene and NLR/IP

- NLR/IP will be a fully experimental, interruptible platform
- Abilene has an existing model for interconnecting with this class of network (e.g., DARPA Supernet, TeraGrid)
- Interconnection and limited peering for experimentation and demonstrations

Internet2 and NLR

- Internet2 engaged as collaborator since December, 2001
- Working to become founding member (\$10M commitment) over five years from Abilene Network reserves
- Intend to offer national experimental service over a single λ for first 5 years of operation – lambda grid initially
- Working to complete organizational process this month

- Designed to *support* optical initiatives
 - Regional
 - National
- Fiber options
 - Holding company for any future initiatives
 - Assignment vehicle
 - Regional initiatives
 - National initiatives (e.g., NLR)
- Not an operational entity – supporting project
 - Will not light any fiber
- Internet2 took responsibility for LLC formation
 - Idea was spin-off from NLR formation discussions
 - National Research & Education Fiber Co. incorporated in DE
 - First acquisition of dark fiber for Fiberco on March 21

Fiberco and Level 3

- Level 3 fiber arrangement: bifurcated contracts
 - Preferred provider relationship with Level 3
 - 20-yr IRU
 - Extensible fiber arrangement
 - Minimum commitment of 4,000+ km
 - Initial footprint flexible through September 2003
 - 5-yr renewable fiber O&M and co-location/power
 - Fees not incurred until the fiber is lit (through May 2004)
- Evaluation factors for principal fiber choice
 - National-scale IRU and O&M pricing available through 2006
 - Aggressive open fiber interconnection policy
 - Homogeneous fiber type
 - Co-location space availability
 - Impact of fiber plant on total cost of system ownership (5 years)
 - Hut spacings, directness of fiber routing

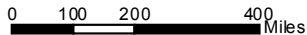
Combined Level 3 / Genuity Networks

(External) February 24, 2003



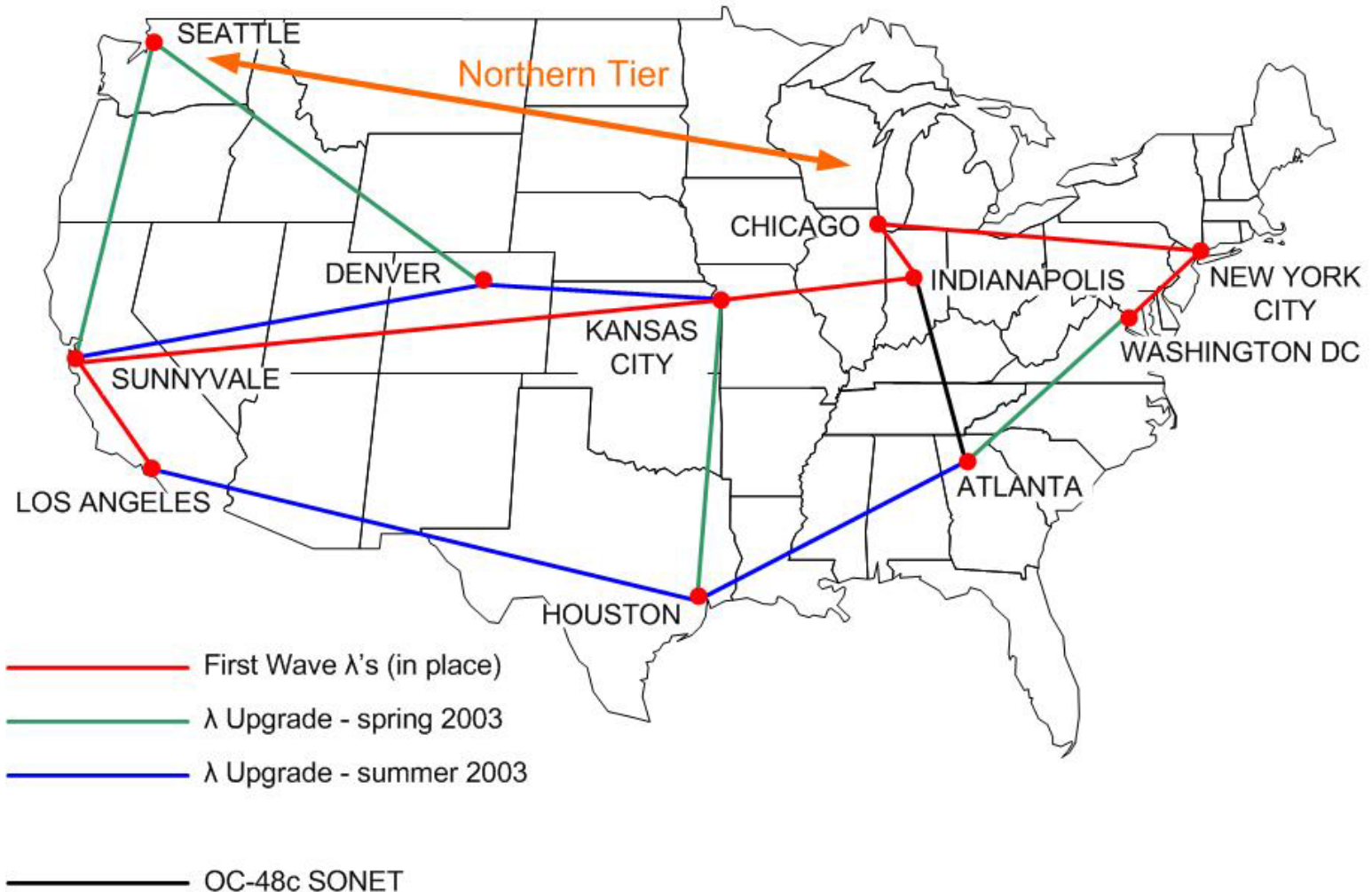
Legend

- ◆ Level 3 / Genuity Services
- Distribution Market Added
- Distribution Market (Likely to be Added)
- Level 3 Intercity Fiber
- Genuity Routes (Retained)
- Genuity Routes (Likely to be Retained)



The Northern Tier project

ABILENE NETWORK AND THE NORTHERN TIER



USA Waves

- Internet2 was an original participant in the SURA National Buyers Consortium
- First phase of cooperative agreement under active discussion between SURA and AT&T
 - Donation of IRU for new dark fiber: 10,000 route-km
 - Use of dark fiber for network research: 3,000 route-km
 - Donation of remaining Velocita optical assets
 - Predominantly Cisco 15800 kit
- Significant opportunity for dark fiber donation
 - Especially in Southeast and western Northern Tier
- Second phase seeks *incremental pricing* model for λ 's with AT&T's existing optronics
 - Managed service

Conclusions

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For more information...

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- <http://www.internet2.edu/fiberco>

Dan Updegrove's Optical Initiative Page

- <http://wnt.utexas.edu/~danu/ren-2003-02.html>

■ NLR information under development

The logo features the word "INTERNET" in white, uppercase, sans-serif font. A large, stylized red number "2" is superimposed over the word, starting from the top left, curving over the "E" and "R", and extending downwards and to the right. A registered trademark symbol (®) is located to the right of the word.

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