OneTenn

A 21st Century Cyberinfrastructure for Tennessee

A Plan for Creating and Sustaining a 21st Century Infrastructure for Research and Education in Tennessee

John Lankford
University of Tennessee

Co-Chair, Optical Network Team
Cyberinfrastructure Commission of the Tennessee EPSCoR Project

Background – Tennessee State EPSCoR Committee

- According to the National Science Foundation (NSF) Tennessee is an EPSCoR (Experimental Program to Stimulate Competitive Research) State.
- This means Tennessee receives less than 0.75% of the annual NSF Science and Engineering research funding.
- EPSCoR designation intended to promote initiatives that strengthen Tennessee’s science and technology infrastructure.
- Tennessee State EPSCoR Committee has been working to identify key areas of emphasis for enhancing the research and economic development capability for the State of Tennessee.
- Tennessee State EPSCoR Committee is composed of representatives from State Govt., Research, Education, and Industry

Background – State EPSCoR Committee findings

- CyberInfrastructure has been identified as a critical need by the higher education institutions across Tennessee.

- Determined through two venues…

Background – State EPSCoR Committee findings

- First venue - series of focus group meetings held with researchers and industrial representatives across the State
- Common theme emerging was the need for enhanced network infrastructure and shared research computing systems

Background – State EPSCoR Committee findings

- Second venue – create a CyberInfrastructure Subcommittee
- Goal #1 - evaluate current infrastructure situation within higher education in Tennessee
- Goal #2 - develop a conceptual approach for creating a competitive computational infrastructure environment
- Subcommittee finding #1 – Tennessee is behind many of it’s peer states
- Subcommittee finding #2 – a new approach will be required to create a sustainable research network infrastructure for Tennessee.

Background – CyberInfrastructure Commission

- Tennessee State EPSCoR Committee resolution passed March 23, 2004
- Creation of Tennessee Higher Education CyberInfrastructure Commission (CIC)
- Commission empowered to produce the detailed design (technical, financial, and organizational) for a statewide optical network and shared computational systems infrastructure
- CIC Final Report delivered April 6, 2005

CyberInfrastructure Commission

Co-Chairs

- **Brice Bible, University of Tennessee**
- **Paula Short, Tennessee Board of Regents**

- Eric Cromwell (Ex-Officio) , Economic & Community Development

» **Optical Network Team**

» John Lankford (Co-Chair), UT
» Tom Danford (Co-Chair), TBR
» Mike Abney, UTM
» Nasir Ghani, TN Tech
» Jeff Kell, UTC
» Lucinda Lea, MTSU
» Dave Mathews, VU
» Ana Preston, UT
» Predrag Radulovic, UT
» Mark Reavis, UM
» Gregory Schaffer, MTSU
» Taylor Strickland, UTHSC
» Mike Turpin, ORNL
» Monty Wilson, UTC

» **Research Computing Team**

» Doug Hurley (Co-Chair), UM
» Terry Moore (Co-Chair), UT
» Jack Buchanan, UTHSC
» Arlene Garrison, UT
» Edwin Koshland, UM
» Joel Muehlhauser, UTSI
» Jeanne Hermann-Petrin, UTHSC
» Francis Otuonye, TN Tech
» Abdul Rao, MTSU
» Paul Sheldon, VU
» Tim Swafford, UT SimCenter
» Linda Warner, TBR
» Dave Whitfield, UTC
» Michael Woodruff, ETSU

OneTenn Goals

- **Accelerate the growth of statewide research opportunities**
- **Connect state researchers to cutting-edge national and international infrastructure**
- **Support education across the state through the distribution of digital content (video and multimedia)**
- **Expand access to essential research computing resources**
- **Expand research opportunities with Oak Ridge National Laboratory (ORNL)**
- **Raise the level of math, science, and engineering education**
- **Enable innovative approaches to public health care and education**
- **Enhance collaboration among Tennessee institutions**
- **Serve as Catalyst for Economic Development in the 21st Century**

Goals of successful cyberinfrastructure

- **Provide essential resources for shared use**

- **Facilitate collaboration across boundaries**

- **Incorporate innovation**

Key Features of OneTenn

- *it provides* access to large scale essential technology resources for shared use

- *it enables* collaboration across organizational and geographic boundaries and barriers

- *it stimulates and encourages* innovation in scientific, engineering, and medical research

Campus Impact of OneTenn Infrastructure

- **Increased enhancement and utilization of external communications capabilities**

- **Upgrade local campus cyberinfrastructure**

- **Accelerate growth of collaborative campus application communities**

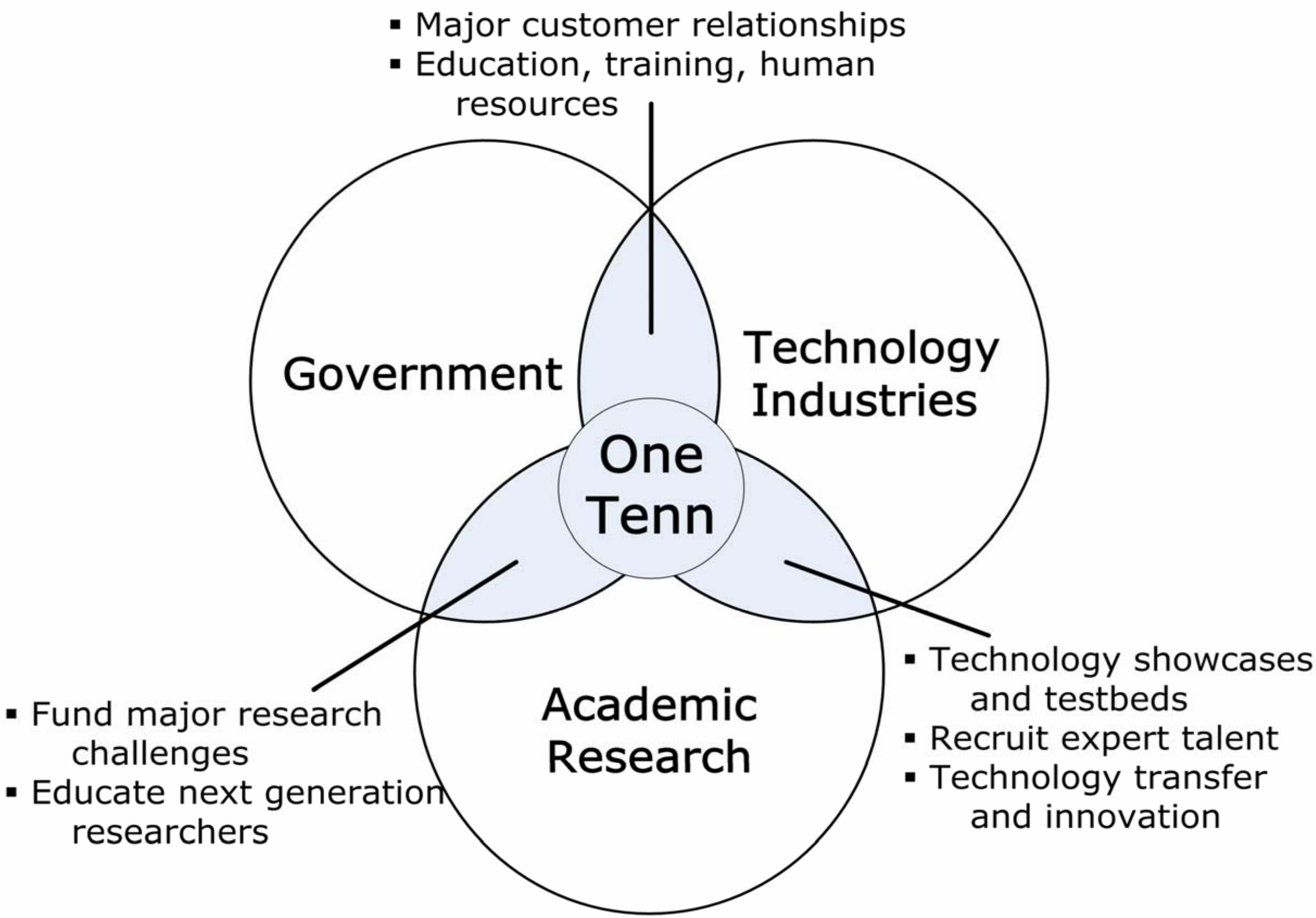
OneTenn Research Leadership Objectives

- **Harness creative energies for OneTenn development**
- **Attract and retain world class research talent**
- **Engage industry participation in leading edge projects**
- **Connect Tennessee to emerging cyberinfrastructure initiatives**

The OneTenn Research Community and Its Applications

- **Computational Analysis of Gene Expression Data (Rob Williams UTHSC; Michael Langston, UT; Jay Snoddy, ORNL/UTK; Yan Cui at UTHSC)**
- **Distributed Visualization of 4D Medical Imaging (Zhaohua Ding and Adam Anderson, The Institute of Imaging Science, Vanderbilt; Jian Huang Computer Science UT,)**
- **3D quantum-docking molecular modeling tools for Nanodesign (Preston MacDougall, Chemistry, MTSU, and Christopher Henze, NASA Ames Research Center)**
- **Integrating High Performance Networking and Mass Archives of Scientific Data (Micah Beck, Computer Science, UTK; Paul Sheldon, Physics, Vanderbilt, Fermi National Laboratory)**
- **Nanoscale Materials Science (Peter Cummings, Chemical Engineering, Vanderbilt, Director of the Nanomaterials Theory Institute, ORNL)**
- **Grid Computing Environments for Research and Education (Jack Dongarra, Computer Science, UTK)**
- **Multilevel Modeling of Electrical Impulse Propagation in the Heart (Jack Buchanan, Biomedical Engineering, UTHSC; Vasilios Alexiades, Mathematics, UT)**
- **Applications of Optical Networking for Remote Instrument Control -- e.g. remote control of SNS instruments, Carl Halford, Electrical & Computer Engineering, UoM; , Jimmy Davidson Weng Kang, A.B. Bonds, Electrical Engineering, Vanderbilt**
- **Bridging Optical Networks and the Internet (Micah Beck, Computer Science, UTK; Nageswara Rao, Computer Science and Mathematics Division, ORNL)**
- **Collaborative Research on Fluid Flow and Heat Transfer Processes in Reduced Gravity (John Hochstein, Jeffrey Marchetta, Mechanical Engineering, UoM; M. Parang, Mechanical Engineering, UTK; B. Antar, Mechanical Engineering, UTSI)**
- **Experimental High Energy Physics (Paul Sheldon, Physics, Vanderbilt; Tom Handler, Physics, UTK)**
- **Distributed Data Mining for Exploring Gene Relationships (Michael W. Berry, Computer Science, UT; Ramin Homayouni, Neurology, Anatomy and Neurobiology, UTHSC)**
- **Neural Networks Analysis of Microarray Data (Jeff Knisley, Karl Joplin, Hugh Miller, The Institute for Quantitative Biology at ETSU)**
- **Percolation Model of Phase Transitions in the Central Nervous System during Sensory Information Processing (Robert Kozma, Paul Balister, Bela Bollobas, U of Memphis, Walter Freeman, UC Berkeley, Jim Houk, NorthWestern University, Lee Giles, Penn State University)**

…and many more. This is not meant to be an exhaustive list. See me if you would like to be added.



▪ Major customer relationships
▪ Education, training, human resources
Government
Technology Industries
One Tenn
Academic Research
▪ Fund major research challenges
▪ Educate next generation researchers
▪ Technology showcases and testbeds
▪ Recruit expert talent
▪ Technology transfer and innovation

- **Optical Networking** — Building on a statewide system of fiber optic lines that it will acquire, OneTenn will deploy leading edge optical networking technology that can create multiple, distinct networks across the same segment of fiber optic cable by using separate wavelengths of light.

- This approach will enable OneTenn to accommodate, on any given segment in the OneTenn “footprint,” both production networks, for ongoing and mission critical projects and activities, and experimental networks, for projects that may have extreme requirements or involve research on networking itself.

- Different networks can be simultaneously deployed to provide precisely the levels of performance, reliability, and security that their users need. For example, wavelengths on particular segments can be dedicated to support special activities, such as remote instrument control, which must be low latency and free of jitter.

- While OneTenn primarily addresses needs of higher education in Tennessee, the presence of a high-speed optically based network across the state can significantly stimulate the development and spread of broadband technologies in Tennessee.

▪**Distributed Storage and Computation** —One unique innovation to OneTenn is its use of *Logistical Networking*, a revolutionary new synthesis of networking and storage technology developed at the University of Tennessee's *Center for Information Technology Research* (CITR) and now in use by research and education groups worldwide.

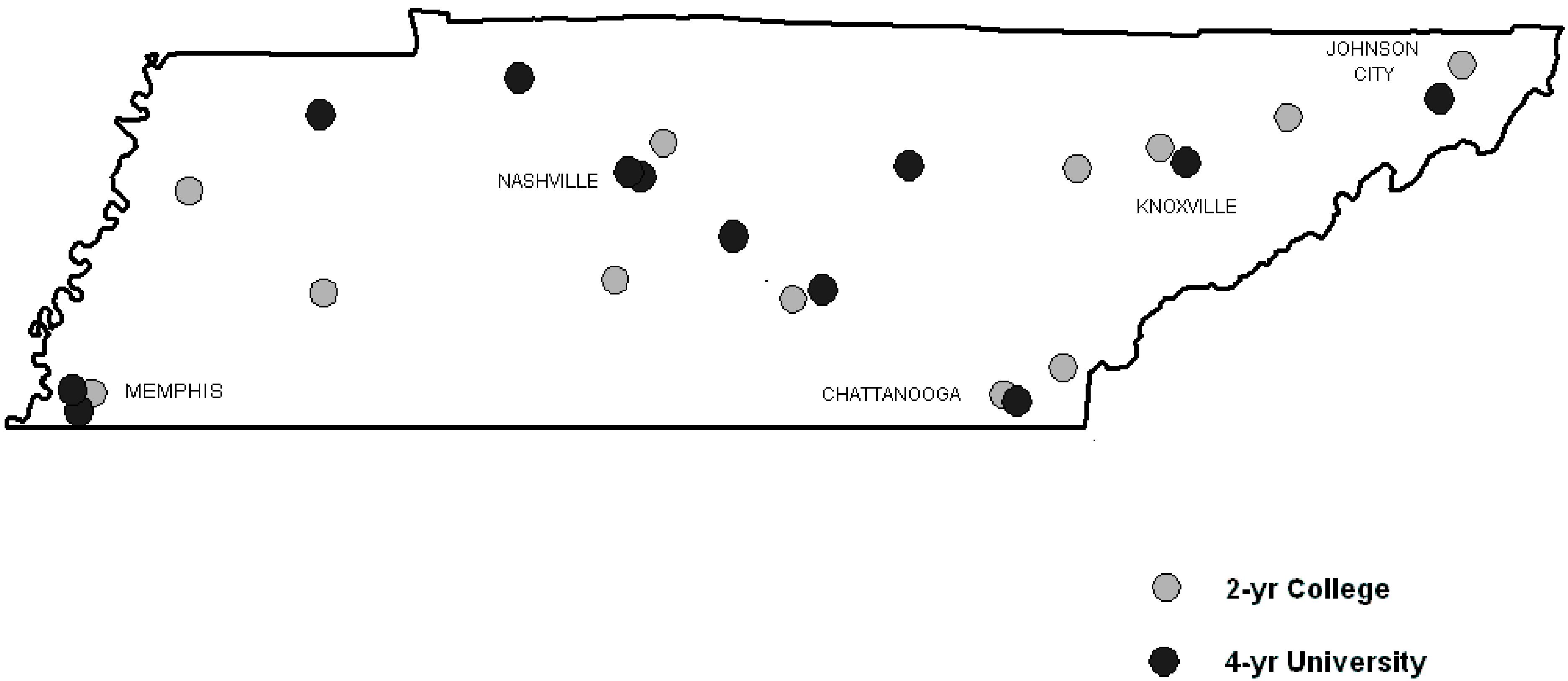
▪Logistical Networking integrates networking and storage for the distribution, staging, and delivery of data. Its key innovation is the *Internet Backplane Protocol (IBP).* IBP extends the Internet design for interoperability to storage resources, making it possible to aggregate and use the resources of widely scattered storage nodes, called "depots," as if they were one giant storage pool.

▪These storage and statewide computational resources will be supplemented with strategically placed computer clusters for distributed use by Tennessee research community.

▪By integrating state-of-the-art optical networking infrastructure and computational systems with high capacity, fully interoperable data depots deployed to every public four year university, as well as Vanderbilt and other private schools, and every public two year college, OneTenn will enable resource sharing, data intensive collaboration and rapid innovation across Tennessee's research and higher education community.

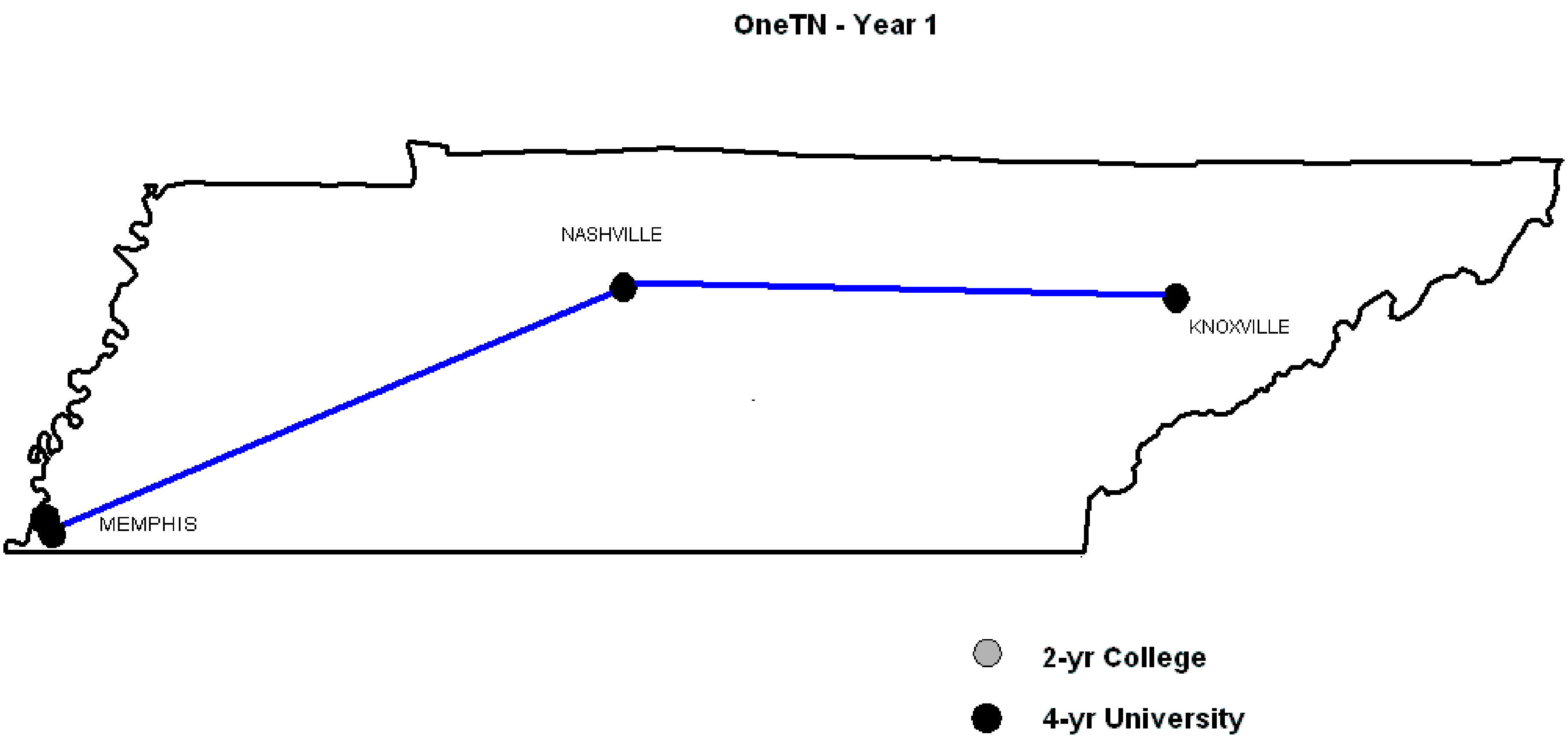
▪Researchers and educators will be able to easily share huge files of scientific data or multimedia and video content without the need to create and manage accounts, to pre-position data for fast, on-demand delivery, and to create flexible and affordable content distribution networks capable of delivering media rich content services statewide.

OneTN Colleges and Universities



Phase 1 Sites

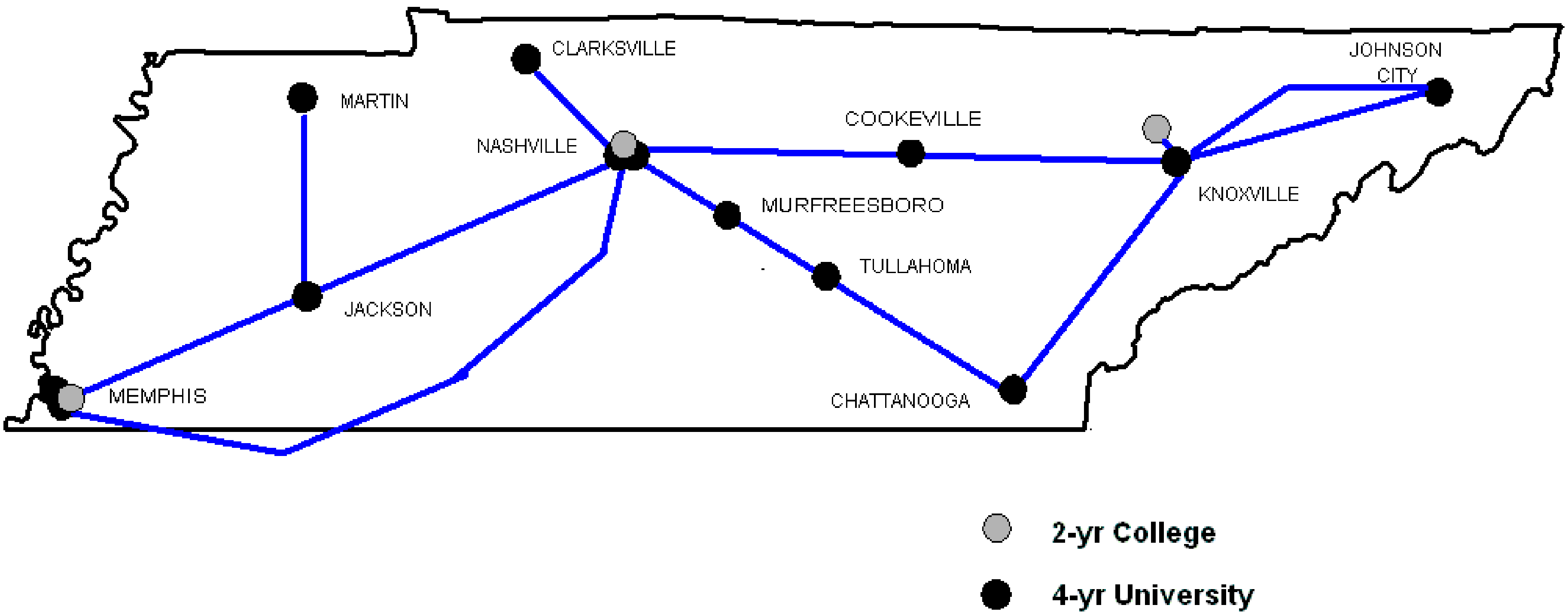
Phase	Institution	City/Location	Gateway
1	Vanderbilt University	Nashville	Nashville
1	University of Tennessee, Knoxville	Knoxville	Knoxville
1	University of Memphis	Memphis	Memphis
1	UT Health Science Center	Memphis	Memphis


OneTN - Year 1
NASHVILLE
KNOXVILLE
MEMPHIS
2-yr College
4-yr University

Phase 2 Sites

Phase	Institution	City/Location	Gateway
2	University of Tennessee – Chattanooga	Chattanooga	Knoxville
2	UT Space Institute	Tullahoma	Nashville
2	Middle Tennessee State University	Murfreesboro	Nashville
2	Tennessee State University	Nashville	Nashville
2	East Tennessee State University	Johnson City	Knoxville
2	Tennessee Technological University	Cookeville	Nashville
2	University of Tennessee – Martin	Martin	Memphis
2	Austin Peay State University	Clarksville	Nashville
2	Pellissippi State TCC	Knoxville	Knoxville
2	Southwest TCC -Macon Cove	Memphis	Memphis
2	Jackson State Community College	Jackson	Memphis
2	Nashville State Tech. Comm. College	Nashville	Nashville

OneTN - Year 3

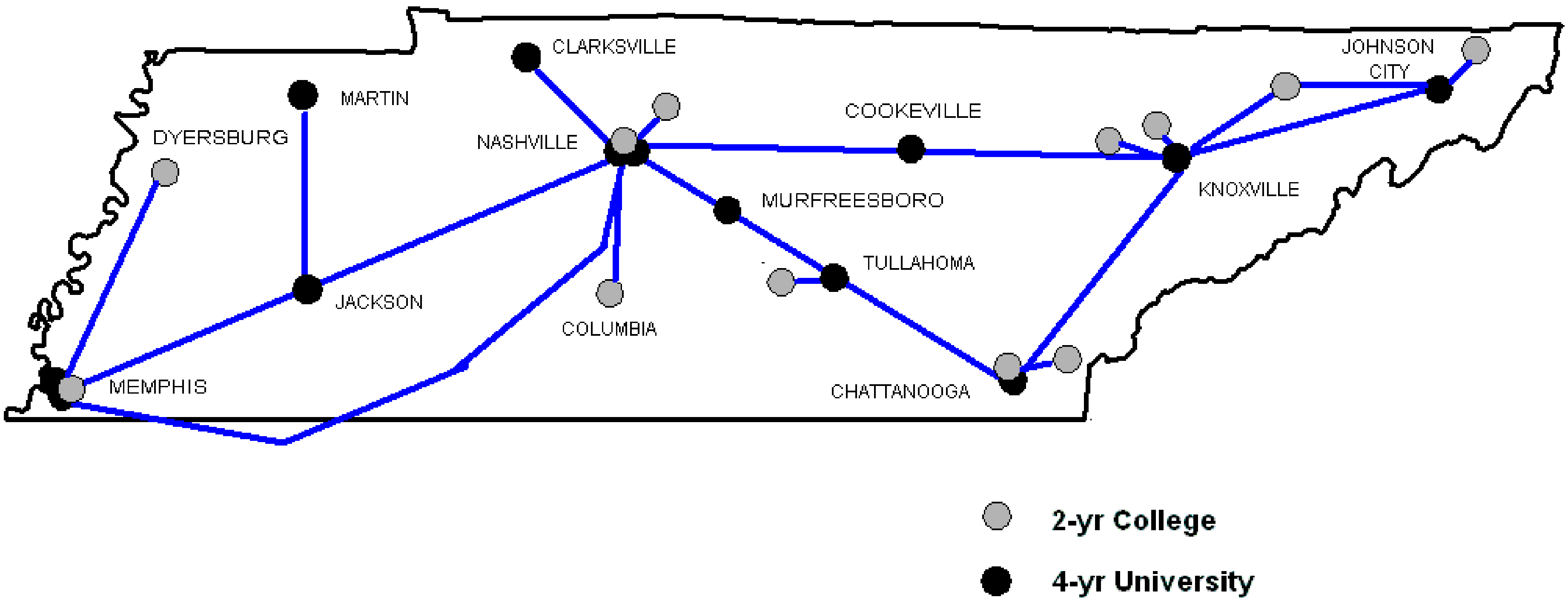


CLARKSVILLE
MARTIN
NASHVILLE
COOKEVILLE
JOHNSON CITY
KNOXVILLE
MURFREESBORO
TULLAHOMA
JACKSON
MEMPHIS
CHATTANOOGA
2-yr College
4-yr University

Phase 3 Sites

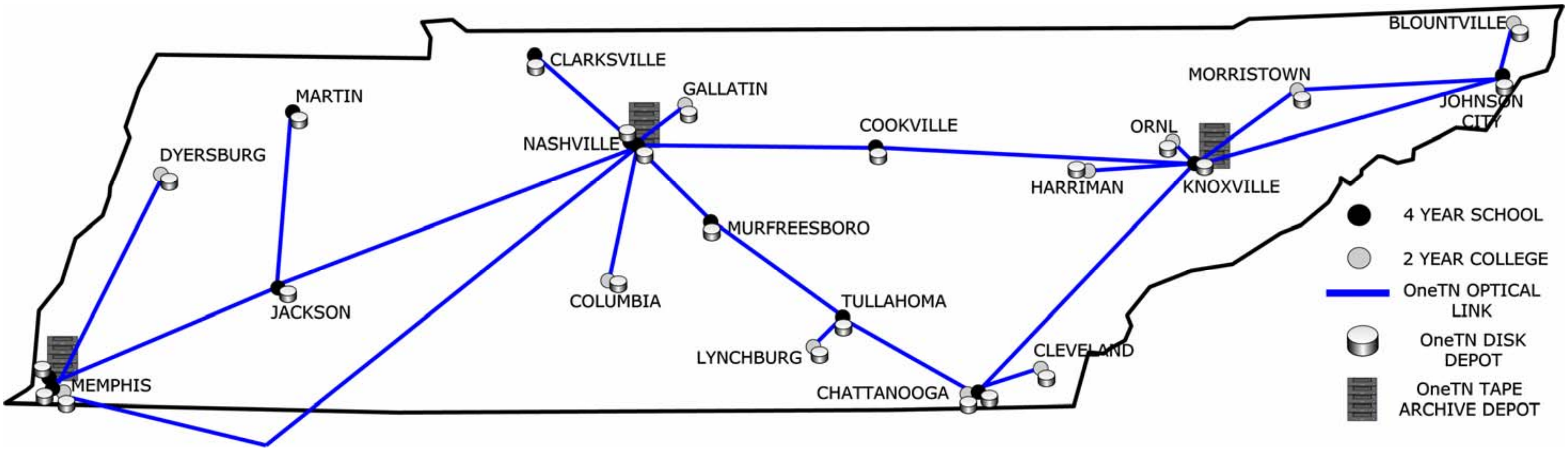
Phase	Institution	City/Location	Gateway
3	Chattanooga State TCC	Chattanooga	Knoxville
3	Motlow State Community College	Tullahoma	Nashville
3	Northeast State TCC	Blountville	Knoxville
3	Volunteer State Community College	Gallatin	Nashville
3	Roane State Community College	Harriman	Knoxville
3	Walters State Community College	Morristown	Knoxville
3	Cleveland State Community College	Cleveland	Knoxville
3	Columbia State Community College	Columbia	Nashville
3	Dyersburg State Community College	Dyersburg	Memphis

OneTN - Year 5

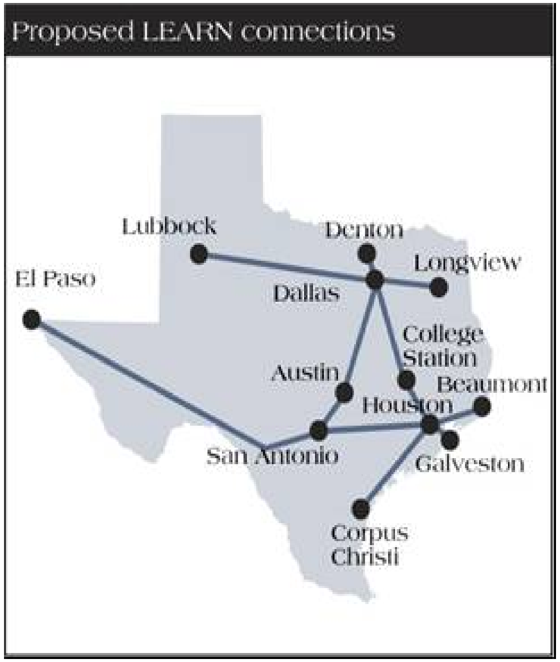


CLARKSVILLE
MARTIN
DYERSBURG
NASHVILLE
COOKEVILLE
JOHNSON CITY
KNOXVILLE
MURFREESBORO
TULLAHOMA
JACKSON
COLUMBIA
MEMPHIS
CHATTANOOGA
2-yr College
4-yr University

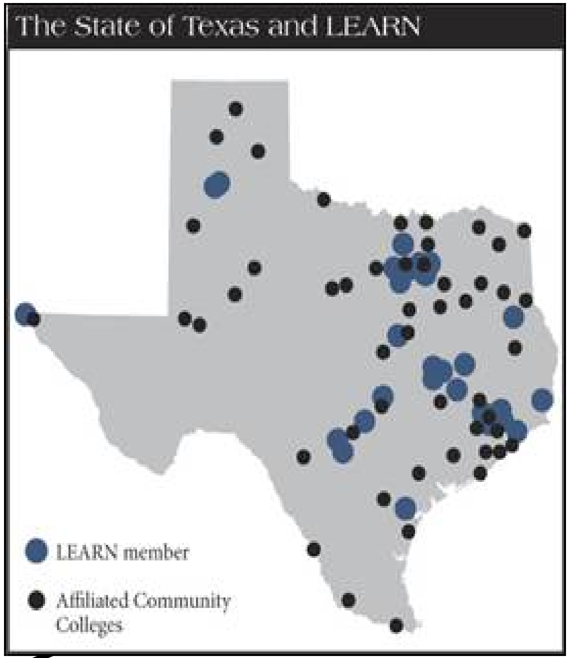
Final Outlook



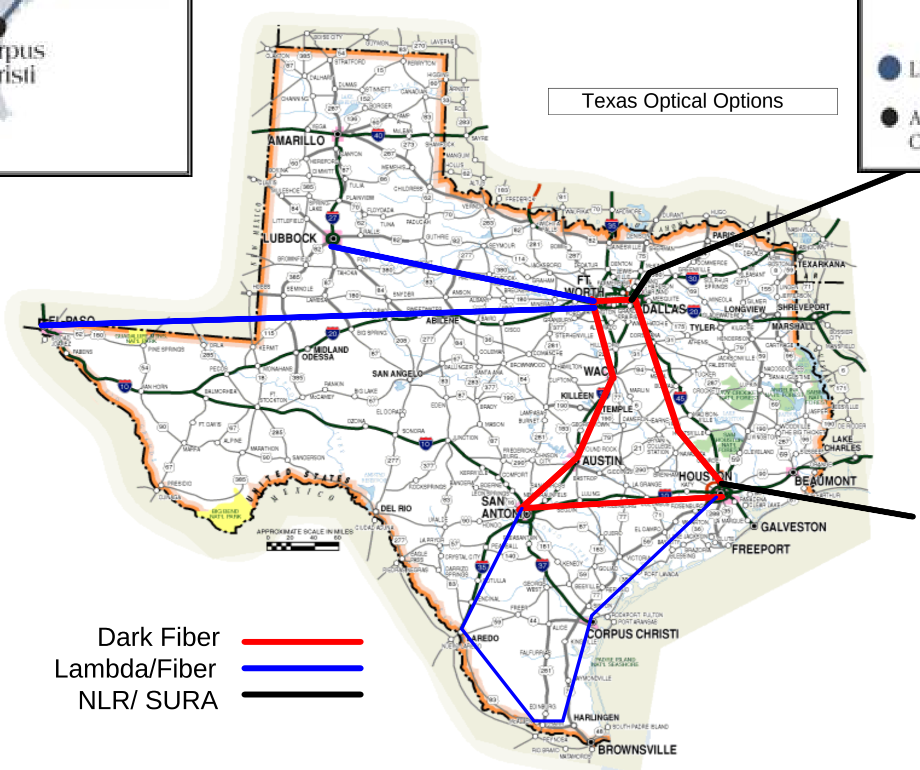
TEXAS



Proposed LEARN connections
Lubbock
Denton
Longview
El Paso
Dallas
College Station
Austin
Beaumont
Houston
San Antonio
Galveston
Corpus Christi



The State of Texas and LEARN
LEARN member
Affiliated Community Colleges



Texas Optical Options
AMARILLO
LUBBOCK
FT WORTH
DALLAS
EL PASO
ABILENE
MIDLAND
ODESSA
SAN ANGELO
WACO
AUSTIN
SAN ANTONIO
HOUSTON
BEAUMONT
GALVESTON
FREEPORT
CORPUS CHRISTI
LAREDO
BROWNSVILLE
Dark Fiber
Lambda/Fiber
NLR/ SURA

CalREN Optical Backbone
Serving California's Research and Education Community

Corporation for Education Network Initiatives in California

CALREN HPR:

- 10G Ethernet over private DWDM fiber; connecting UC, Stanford, USC, CalTech and JPL

DC project:

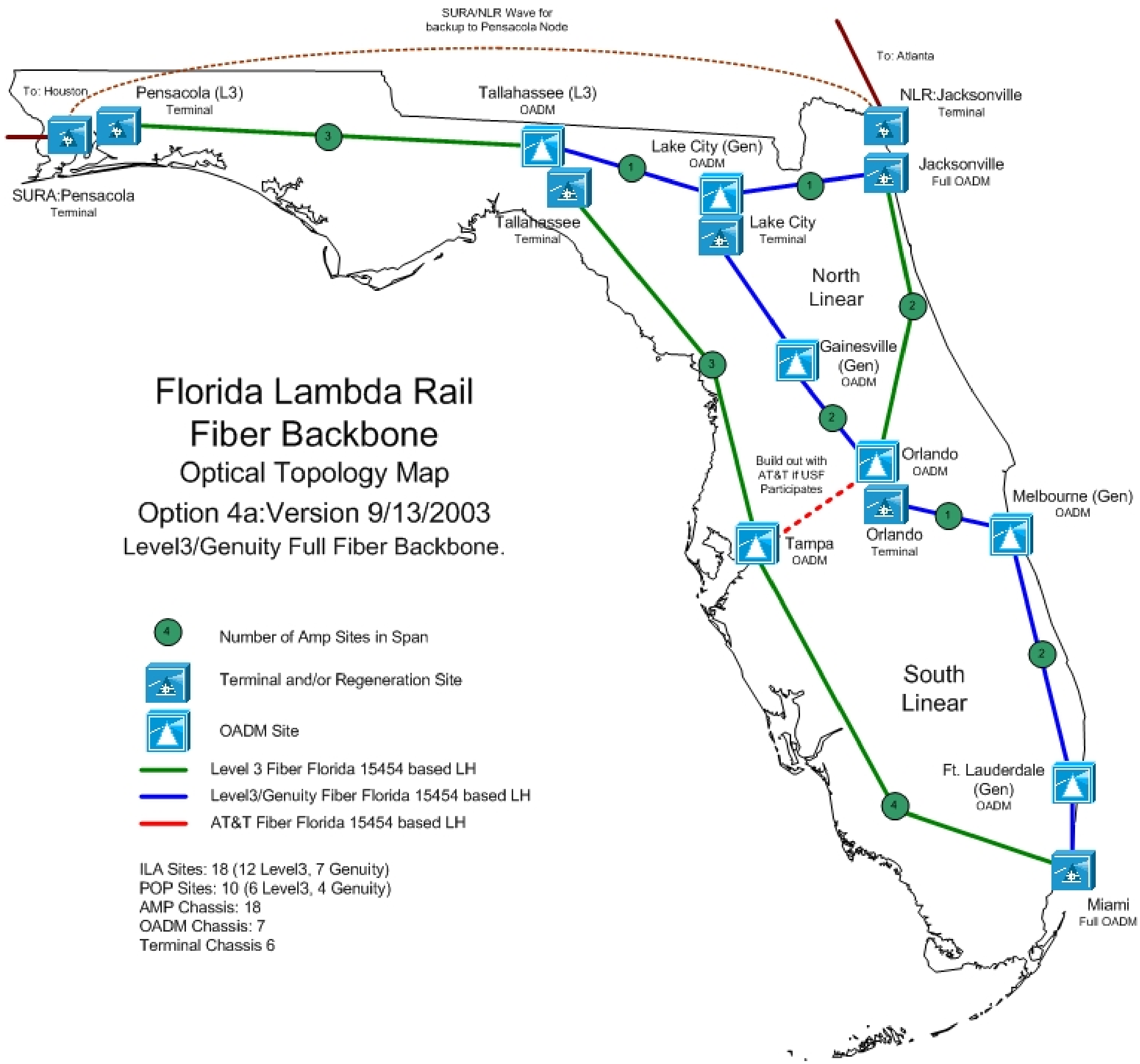
- OC-48c backbone over private DWDM fiber; serves all Cal. State Universities, CA community colleges and UC, and close to 90% of K-12 schools

All managed by CENIC (not for profit) www.cenic.org
CENIC is also founding member of NLR

North Dakota, South Dakota, Nebraska, Kansas, Iowa, Missouri

MIDnet Proposed Backbone

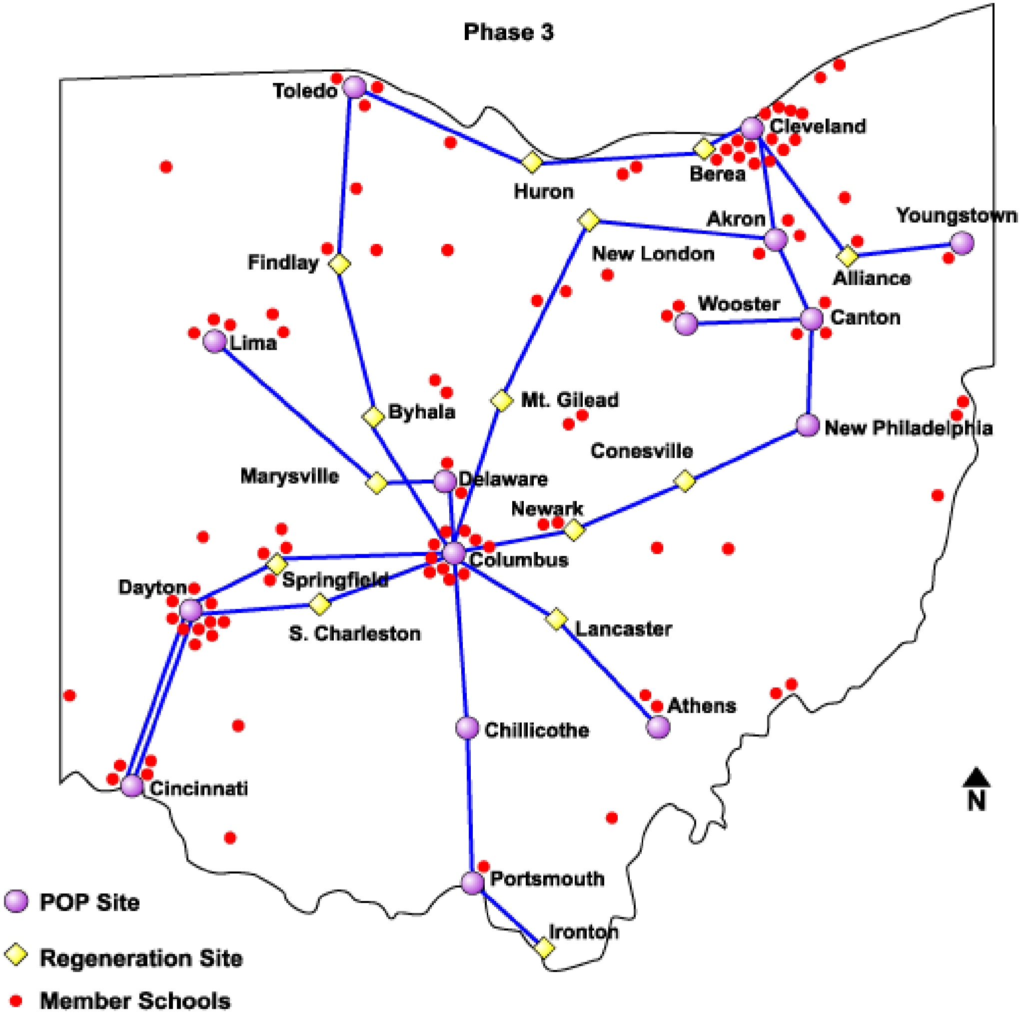
Florida: Florida Lambda Rail



- recently formed consortium; established a a Florida limited liability company
- with the intent of becoming an active player in NLR and get in the map

Source: http://www.flrnet.org/

Ohio: Third Frontier Network

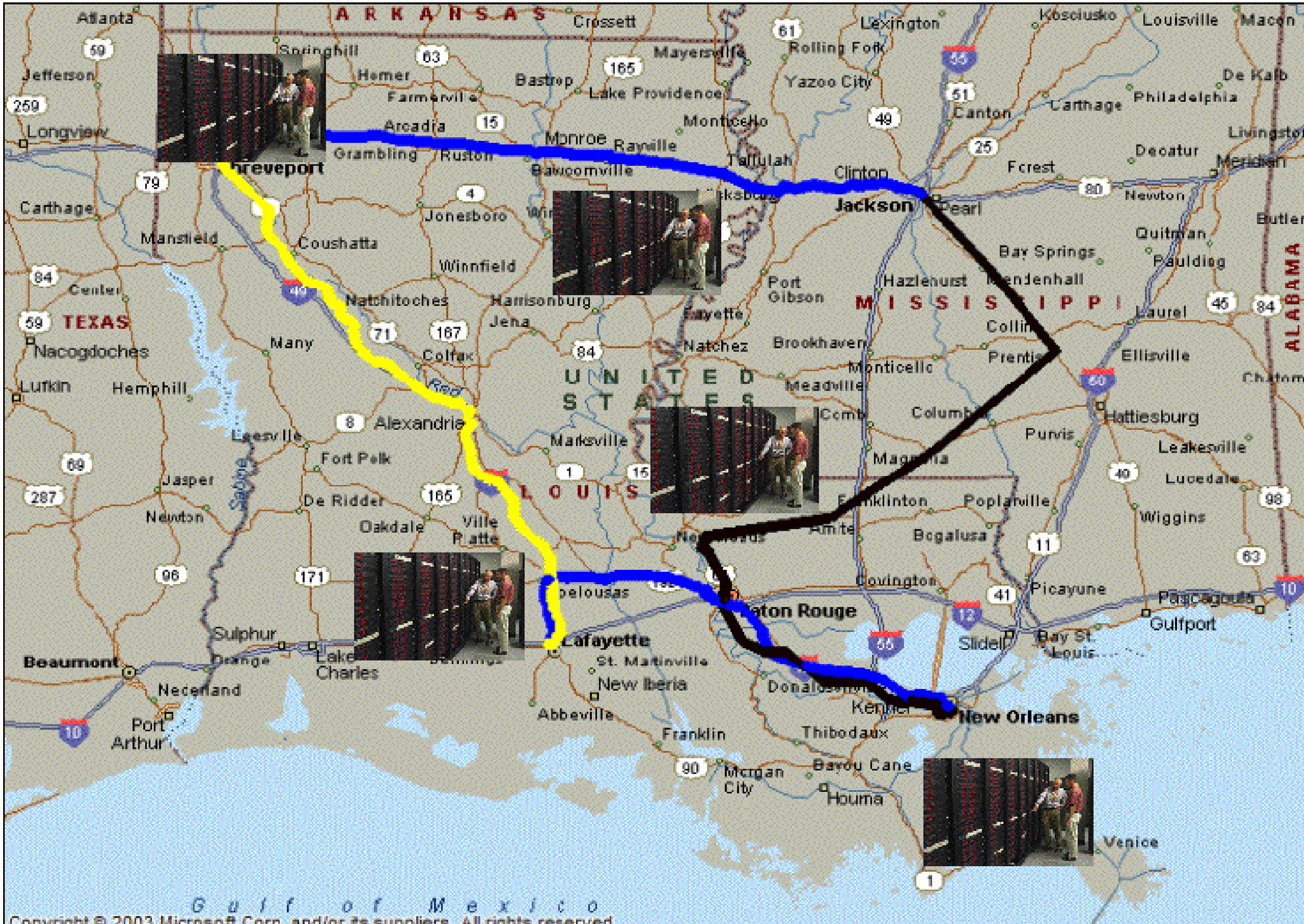


-core fiber backbone in to support advanced high performance network-based applications in higher education and research in Ohio:

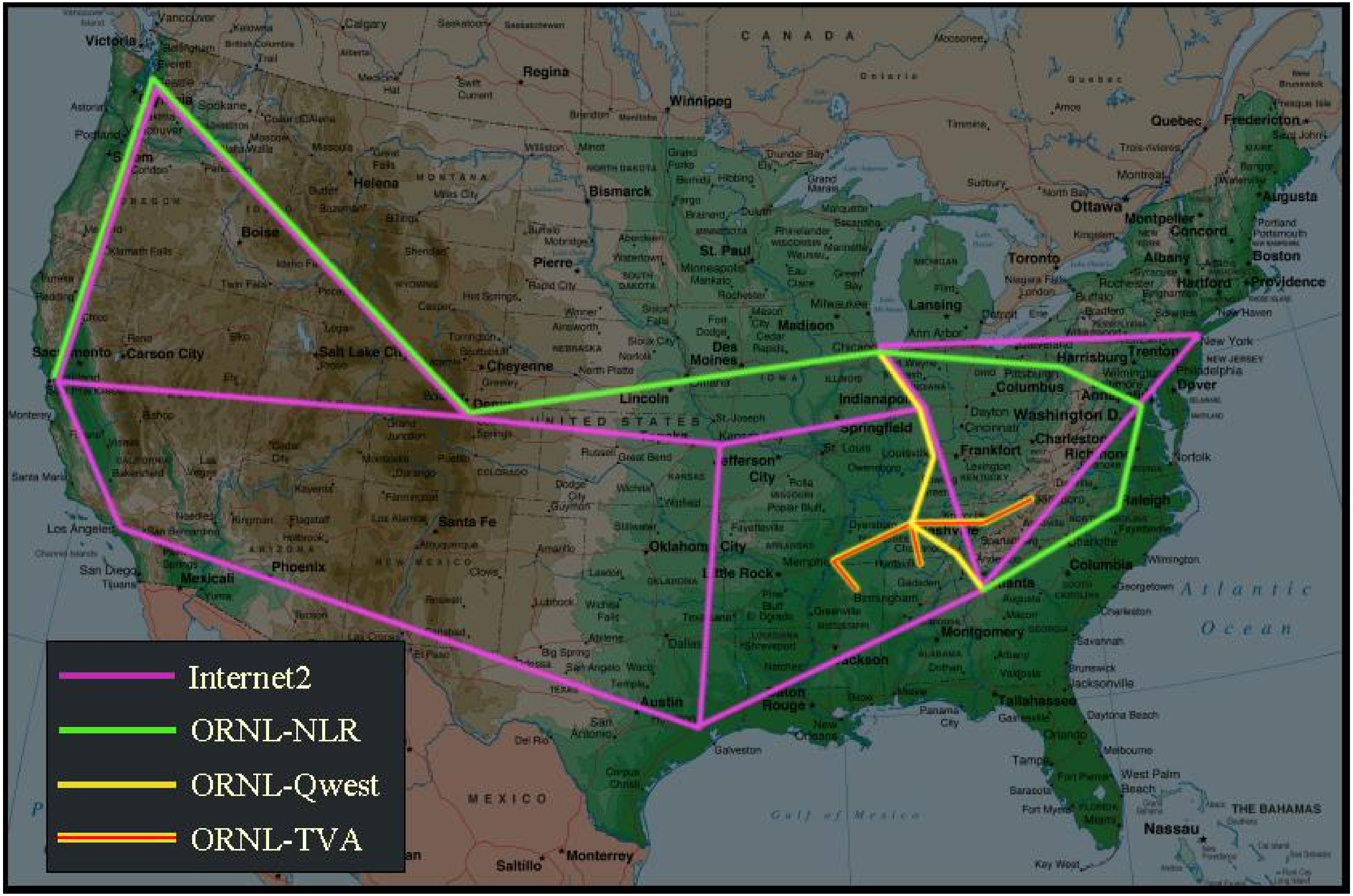
- connect 15 geographically dispersed hubs
- last mile fiber to 17 individual campuses (higher ed)
- further phases expanding to 70 remaining higher education institutions and connecting also Ohio's corporate research centers with Ohio's academic research community

Source: http://www.tfn.oar.net/index.htm

LONI – LOUISANA OPTICAL NETWORK INITIATIVE



ORNL UltraScience Net (FutureNet)



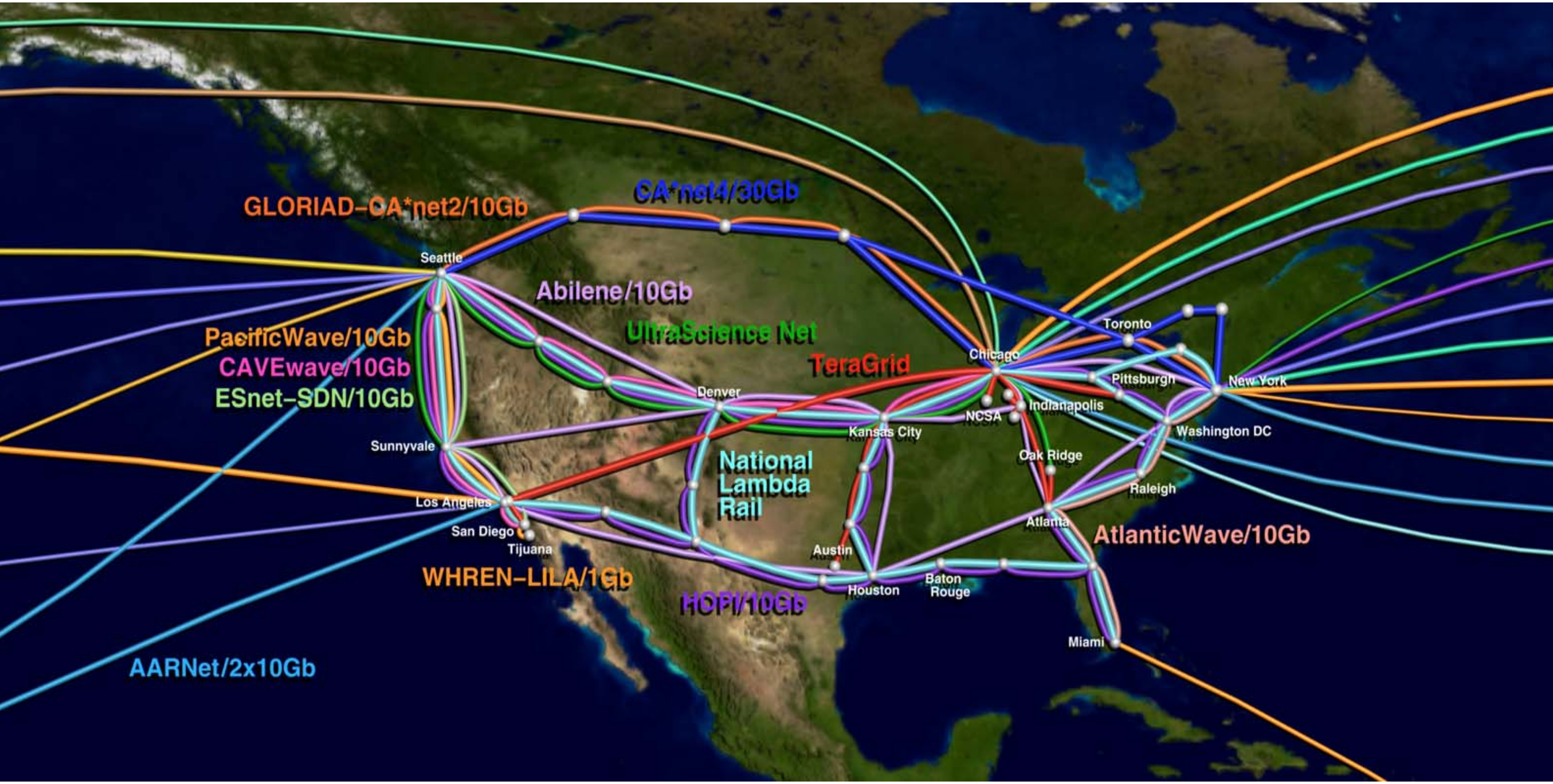
Internet2 / Abilene

National LambdaRail™ Infrastructure

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

Global Optical Ring Network for Advanced Application Development

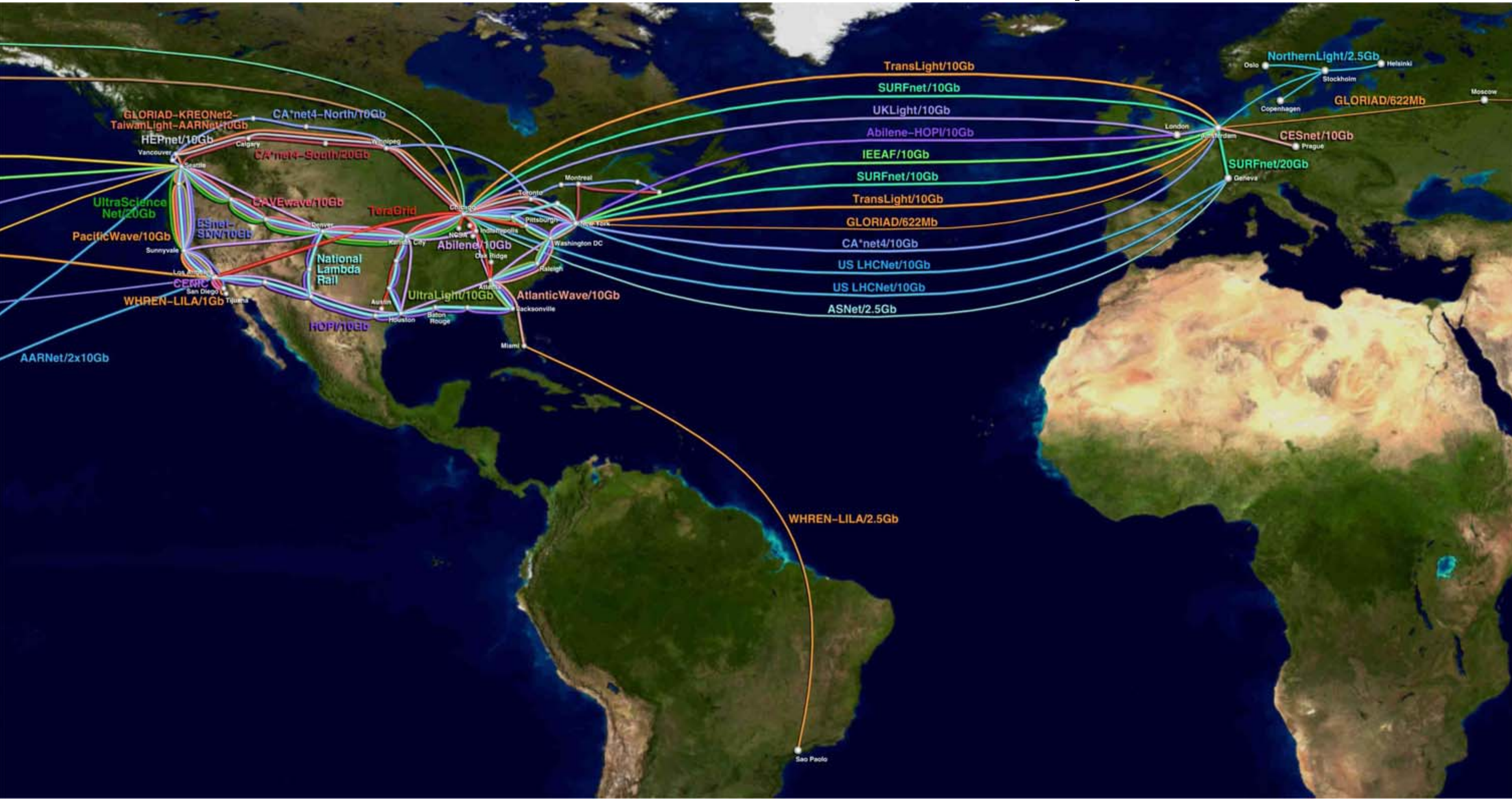
Global Lambda Integrated Facility
North America Map – August 2005
Predicted Bandwidth for Scheduled Experiments



www.glif.is

Visualization courtesy of Bob Patterson, NCSA/University of Illinois at Urbana-Champaign.
Data compilation by Maxine Brown, University of Illinois at Chicago. Earth texture from NASA.

Global Lambda Integrated Facility
Atlantic Map – August 2005
Predicted Bandwidth for Scheduled Experiments



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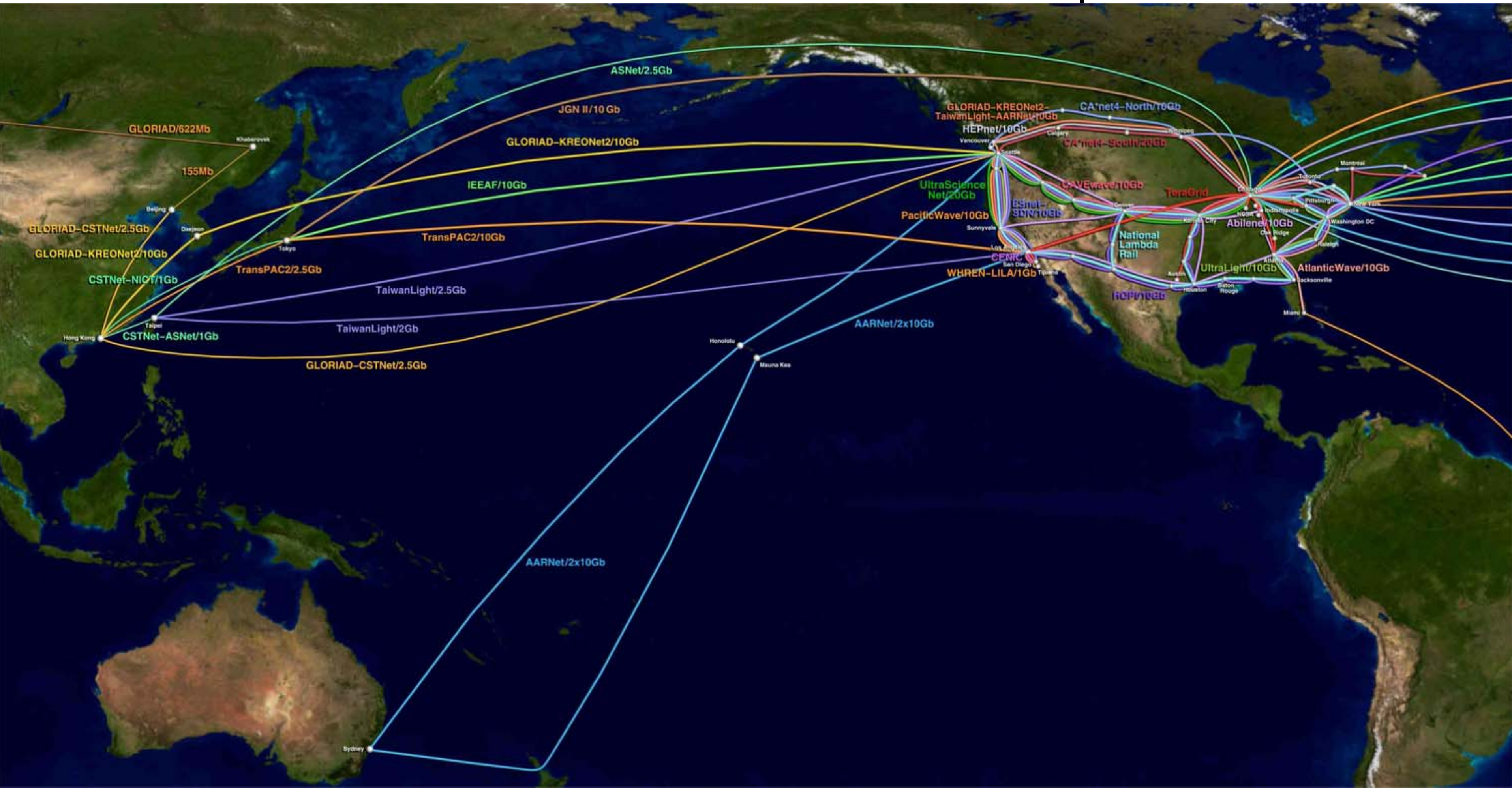
Global Lambda Integrated Facility

Pacific Map – August 2005

Predicted Bandwidth for Scheduled Experiments



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Visualization courtesy of Bob Patterson, NCSA/University of Illinois at Urbana-Champaign.
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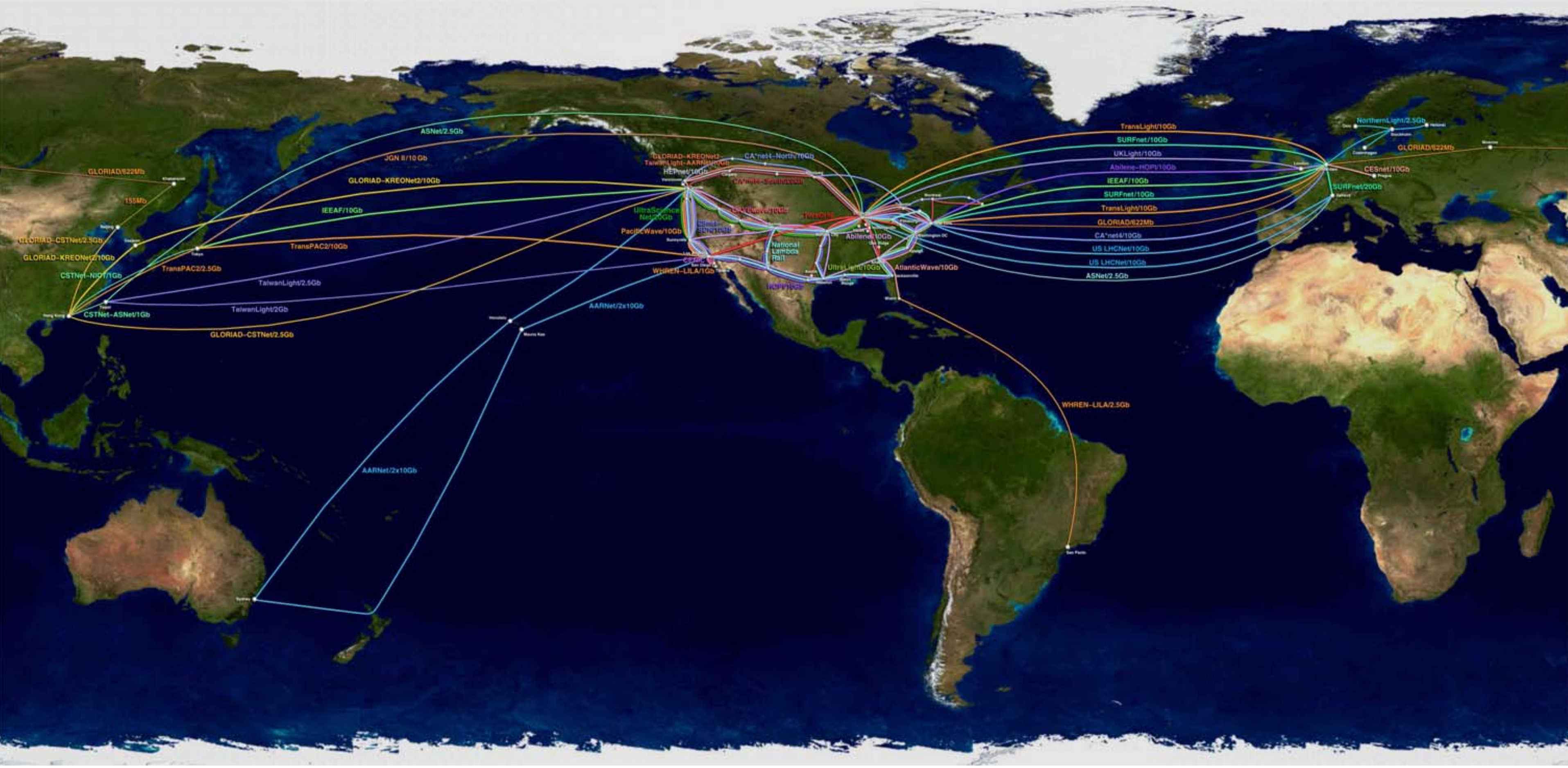
Global Lambda Integrated Facility

World Map – August 2005

International Research & Education Network bandwidth, to be made available for scheduled application and middleware research experiments by August 2005.



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Visualization courtesy of Bob Patterson, NCSA/University of Illinois at Urbana-Champaign.
Data compilation by Maxine Brown, University of Illinois at Chicago. Earth texture from NASA.

Facilities Based Networking Components

- Dark Fiber
- Co-location
- Optronics
- Install and Commission Plant
- O&M (Fiber, Equipment, Remote Eyes/Hands, NOC)

Dark Fiber

- Based on 20-year IRU (Indefeasible Right to Use)

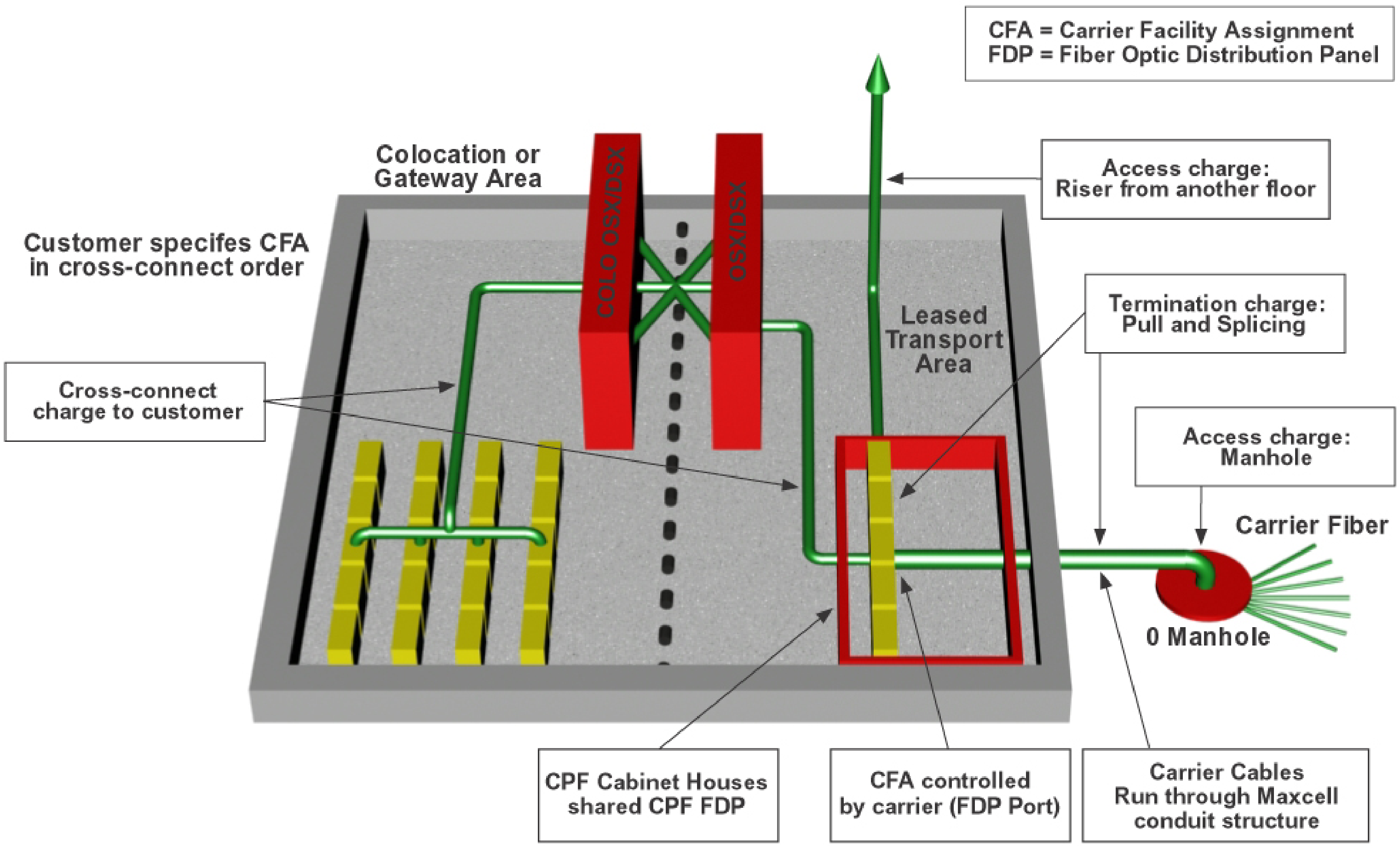
- Lump Sum Payment for IRU (per strand mile)
- O&M paid annually

- Inter City Fiber (Long Haul)
- Metro Fiber Laterals (Fiber Loops)

Dark Fiber – Splicing and Construction

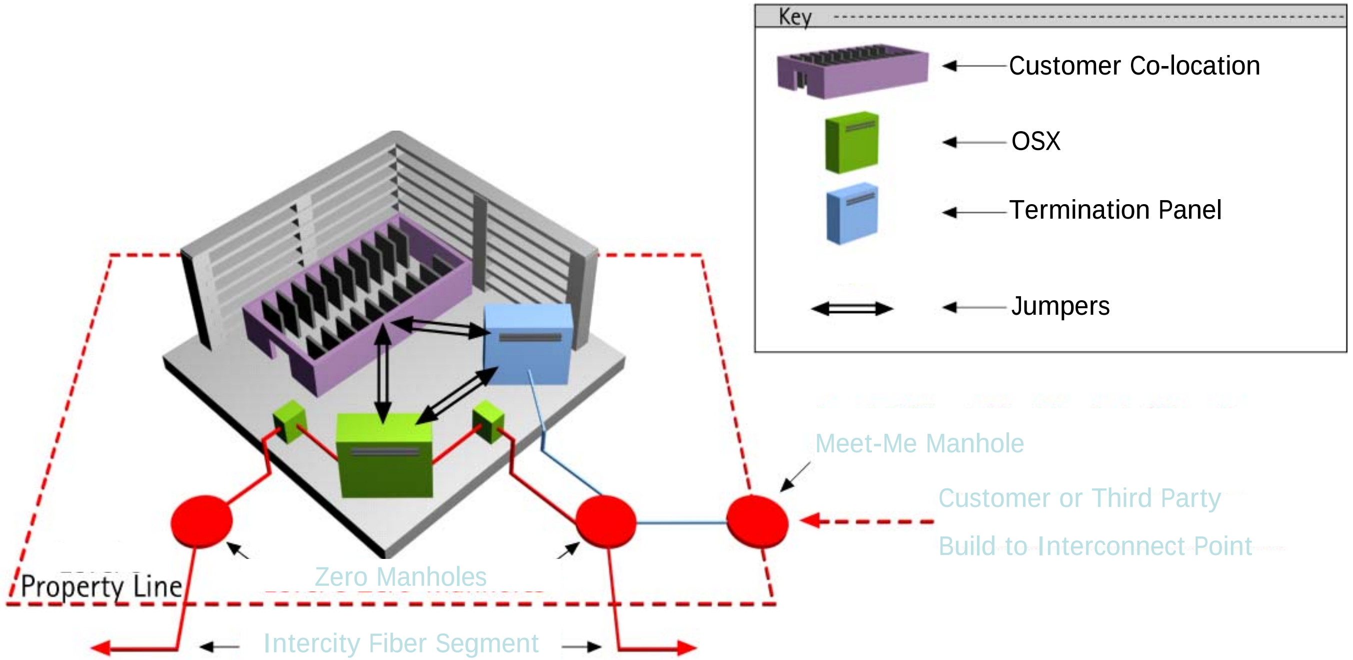
Service	**Price**
Manhole/Handhole Access	Non-recurring charge (NRC)
Manhole Access Using Existing Knock-Outs	NRC
Site Survey – For interconnection feasibility (per location)	NRC
Site Survey – For Pre-Sales Lateral Build Estimate	NRC
New Manhole – Concrete	NRC
New Manhole – Fiberglass	NRC
Add Splice Case	NRC
Splice 1-6 fibers (per incident)	NRC
Splice 7-12 fibers (per incident)	NRC
Splice 13-18 fibers (per incident)	NRC
Splice 19-24 fibers (per incident)	NRC
Splice 25-30 fibers (per incident)	NRC
Splice 31-36 fibers (per incident)	NRC
Splice 37-42 fibers (per incident)	NRC
Splice 43-48 fibers (per incident)	NRC
Fiber Termination (Connectorization) Set-Up, One-Time Fee per Site	NRC
Per Fiber Termination	NRC
Non-CPF Cross-Connects Set-Up (per fiber)	NRC
Non-CPF Cross-Connects Monthly (per fiber)	MRC
Unauthorized Access to the Provider system: ▪1st Occurrence ▪Each subsequent occurrence after the 1st	 NRC NRC
Build to the Edge of the ROW or Extending from Provider manhole to Additional Manhole/Handhole	Cost-plus or individual case specific

Co-location:
Terminal / PoP Location



Visualization Courtesy of Steve Cotter, Internet2

Co-location:
Line Amplifier Site



Visualization Courtesy of Steve Cotter, Internet2

Co-location - Footprints, Cabinets, and Cages

Footprint and Cabling Installation Charge	MRC	NRC
Footprints for Dark Fiber Colocation in Network Centers (20 Amps A&B Feeds DC Power, racks not included)		
Footprints for Dark Fiber Colocation in Transmission Sites (20 Amps A&B Feeds DC Power, racks not included)		
(Rack install is charged separately per standard charges below)		
Cabinet and Cabling Installation Charge per Cabinet	**MRC**	**NRC**
Footprints with additional space for customer provided cabinets for Dark Fiber Colocation in Network Centers		
Footprints with additional space for customer provided cabinets for Dark Fiber Colocation in Transmission Sites		
Cage Charge Network Centers Only	**MRC**	**Cage NRC**
10x10 cage (fencing only)		
10x20 cage (fencing only)		
(Rack install is charged separately per standard charges below)		

Co-location – Additional Power

Additional Power Charges	MRC	NRC
10 amps of -48 volt DC Power (A&B feeds up to 60 amps per rack/cabinet maximum)	per 10 Amps	per 10 Amps
5 amps of 120 volt AC Power (up to 60 amps per rack/cabinet maximum) Network Centers Only		
DC or AC power over 60 amps per rack/cabinet	ICB	ICB
Multiple DC power feeds to one rack (per feed)		
AC power standard install fee (up to 15 Amps per feed)		

Co-location – Cross Connects

Cross Connects to Third Party Vendors	MRC	NRC
DSx Level		
OCn Level		
Cat5		
3rd Party Dark Fiber Cross Connects		

Co-location – Other Charges

Other Charges (Racks, Cages, Cabinets)	NRC
Rack Install Fee	
Rack Install Expedite Fee	
Cross connect or Cabling Expedite Fee	
Supplement of Colocation Service Order ("CSO") (prior to specification being written and prior to Colocation Effective Date)	
Supplement of Colocation Service Order (after specification has been written, but prior to Colocation Effective Date)	
Installation of Dark Fiber Jumpers, per pair, Network Center	
Installation of Dark Fiber Jumpers, per pair, Transmission Sites	
Installation of Dark Fiber Jumpers, per pair, for "Glass Through" sites	

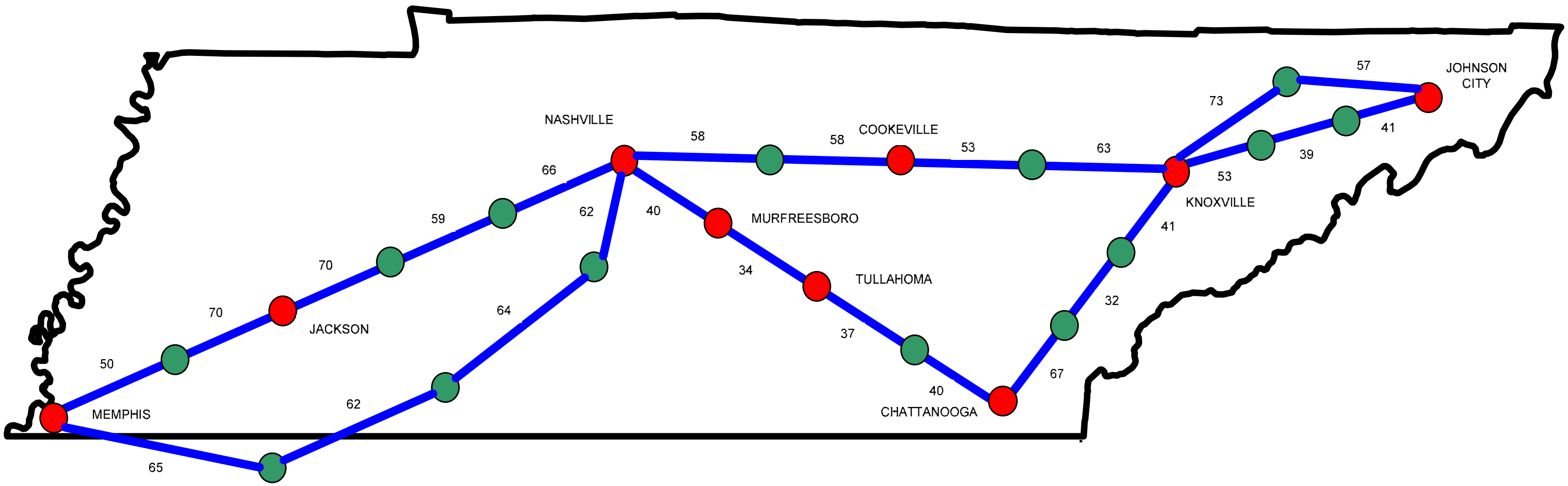
Co-location – Dispatch Escort Charges

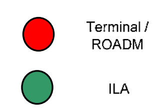
Dispatch Escort Charges	Minimum hours	Hourly Rates
Monday-Friday 8:00am to5:00pm local time (2 hour minimum)	1 hour	
Monday-Friday 5:01pm to 7:59am local time (4 hour minimum)	2 hours	
Saturday & Sunday & Holidays (4 hour minimum)	2 hours	

Co-location – Standard and Special Tech Assist Services

Standard Tech Assist Services	Minimum Hours	Hourly Rates
Monday – Friday (Business Hours 8:00am – 5:00pm)	1 hour	
Monday – Friday (Off hours 5:01pm –7:59am)	2 hours	
Saturday and Sunday (Weekend Hours)	2 hours	
Special Tech Assist Services		
Monday – Friday (Business Hours 8:00am – 5:00pm)	1 hour	
Monday – Friday (Off hours 5:01pm –7:59am)	2 hours	
Saturday, Sunday (Weekend Hours) and Holidays (see below) (Holiday Hours)	2 hours	

Fiber Optic Backbone
1,354 Route Miles



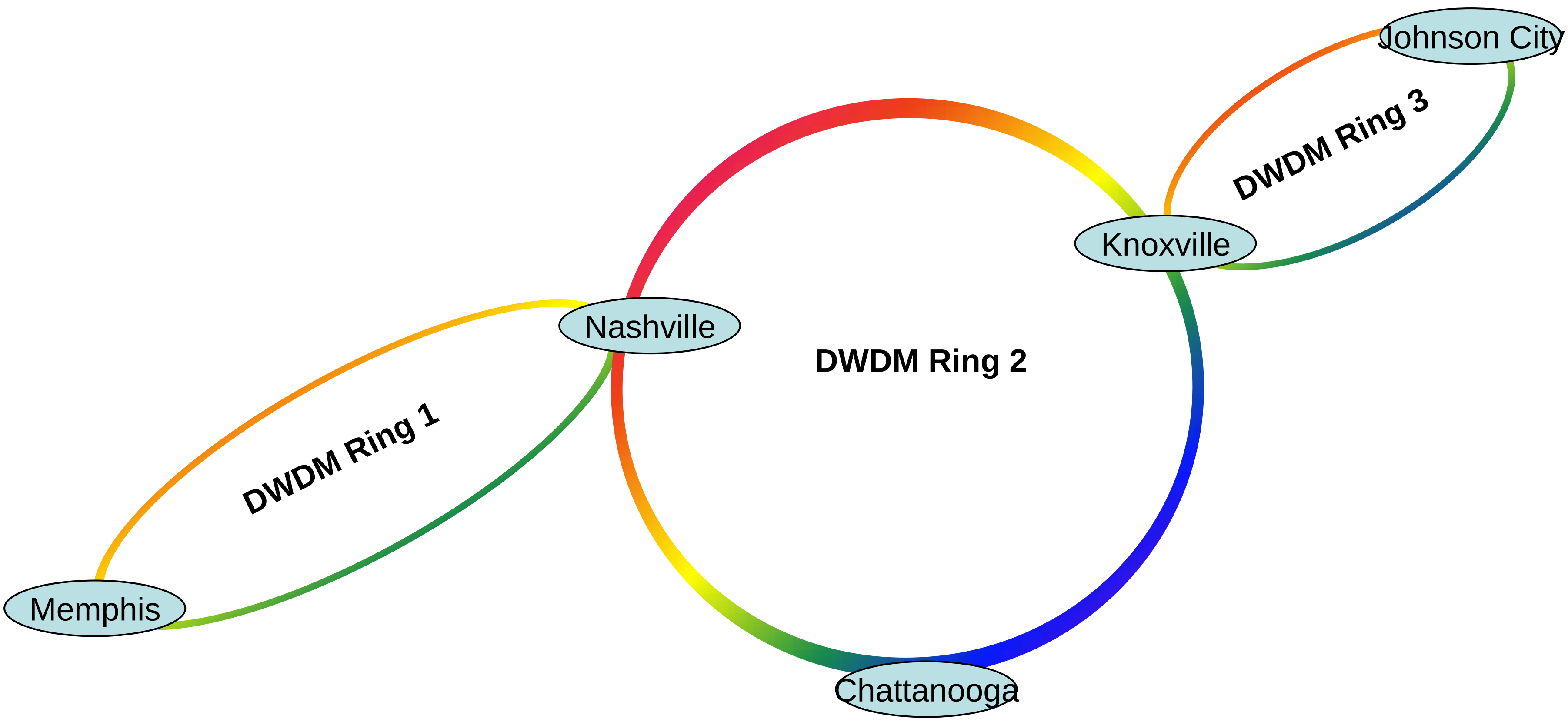


MEMPHIS - NASHVILLE	315 mi
MEMPHIS – NASHVILLE (ALT)	253 mi
NASHVILLE - KNOXVILLE	232 mi
NASHVILLE – CHATTANOOGA	151 mi
CHATTANOOGA – KNOXVILLE	140 mi
KNOXVILLE - JOHNSON CITY	133 mi
KNOXVILLE - JOHNSON CITY (ALT)	130 mi

OneTN – Fiber Map

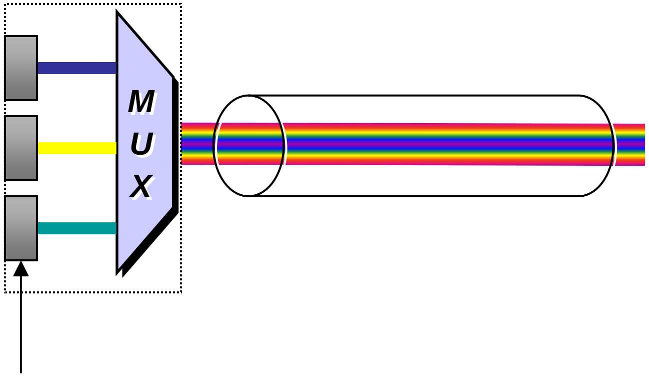
1/3/2005

The Three Core DWDM Rings of OneTenn

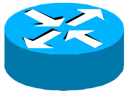


Layer 0 (Wavelength)

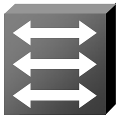
WDM Terminal



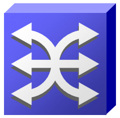
WDM Laser



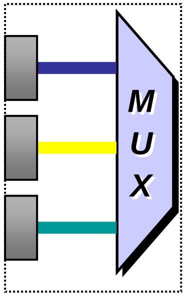
IP Router



Ethernet Switch

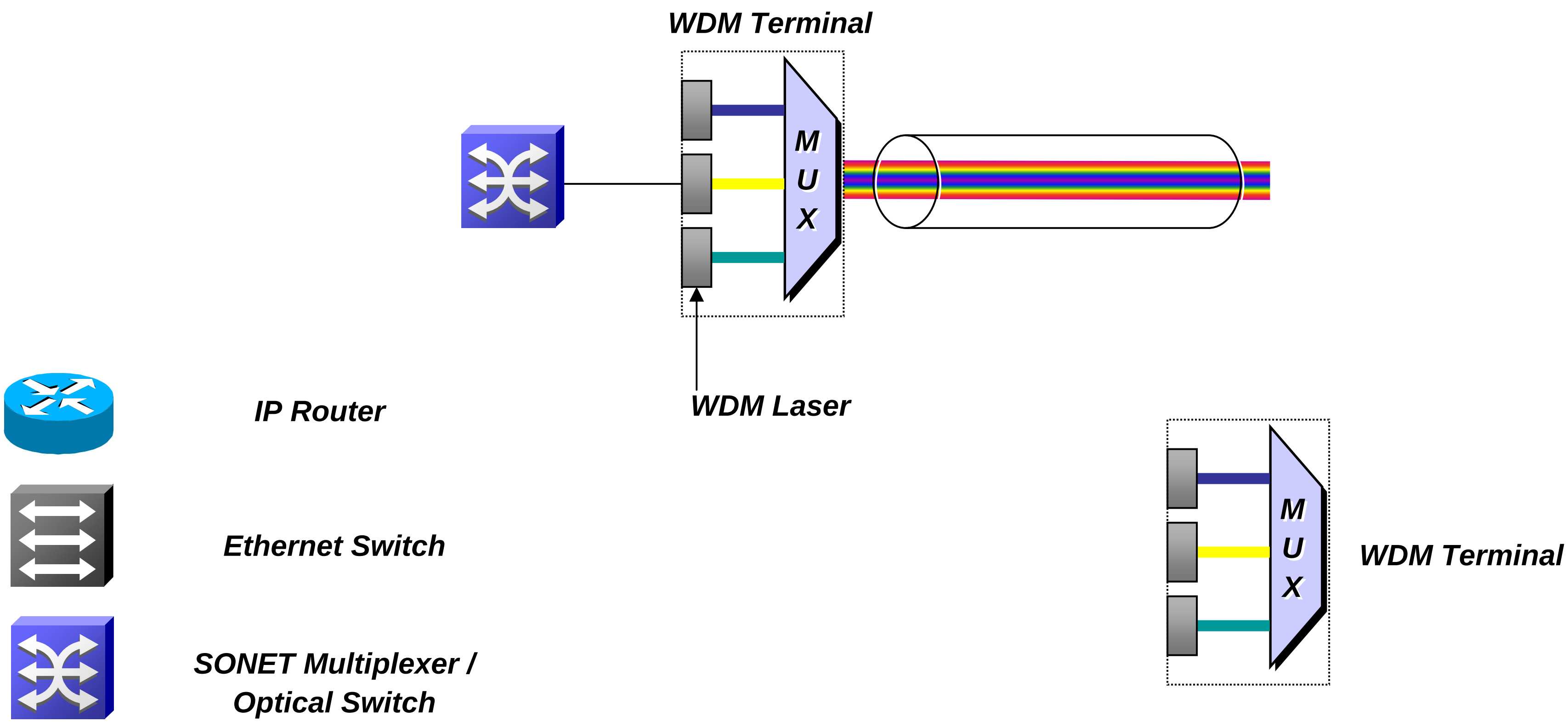


SONET Multiplexer / Optical Switch

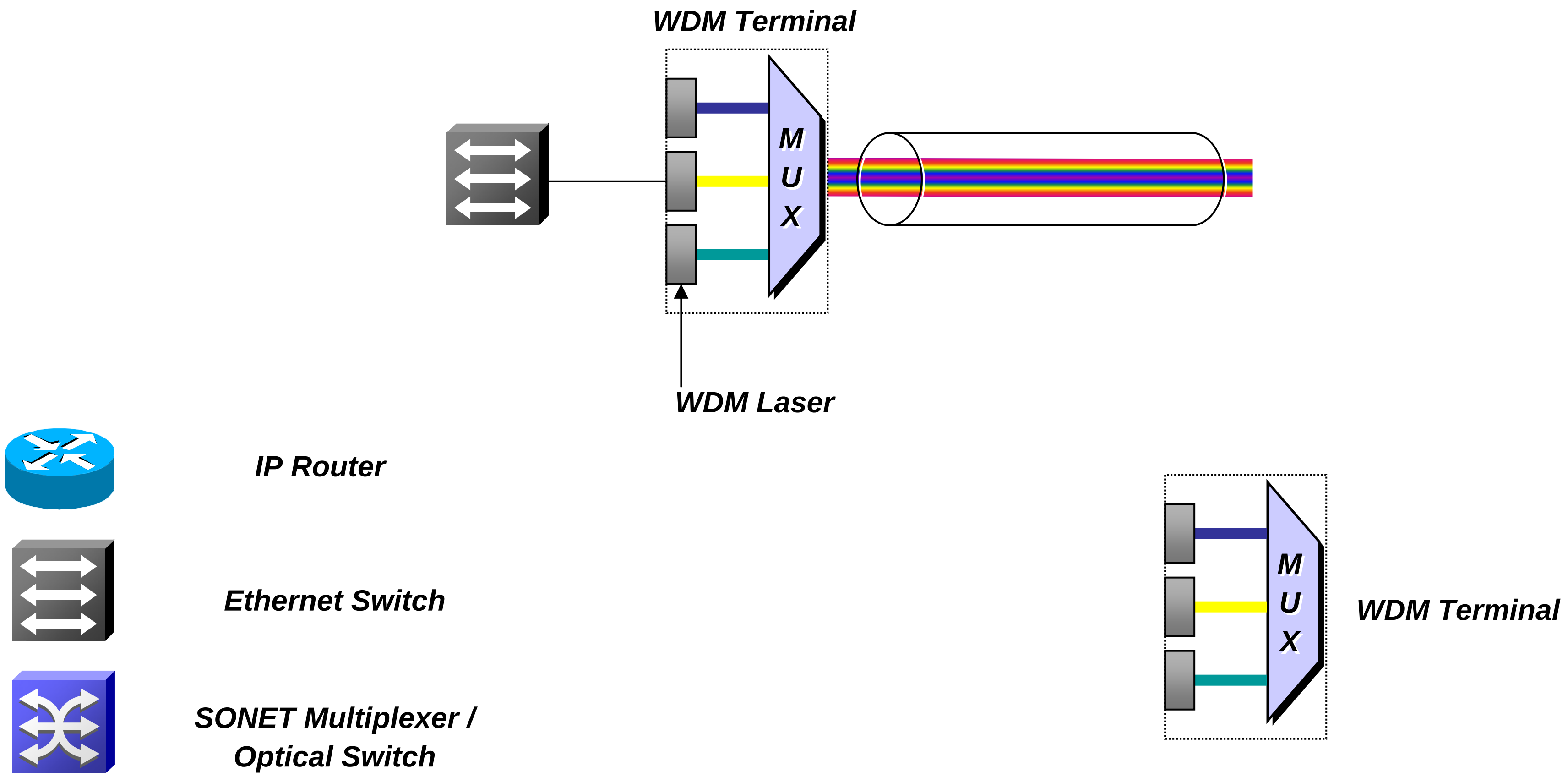


WDM Terminal

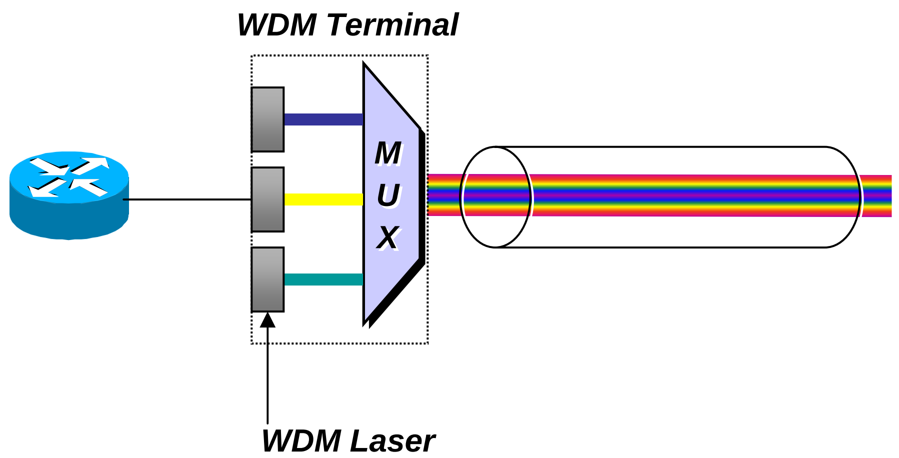
Layer 1 (SONET / OTN)

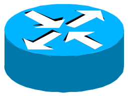


Layer 2 (Ethernet Switching)

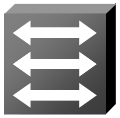


Layer 3 (IP Routing)

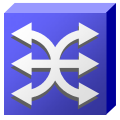




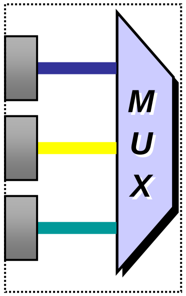
IP Router



Ethernet Switch

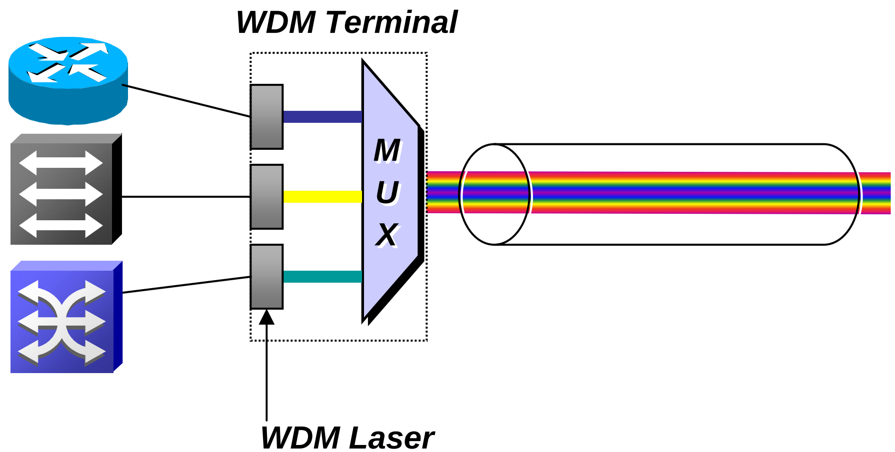


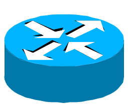
SONET Multiplexer /
Optical Switch



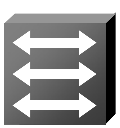
WDM Terminal

Layers 1, 2, 3

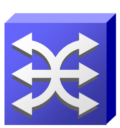




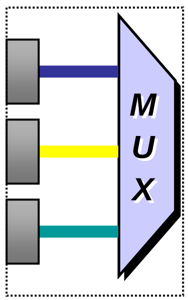
IP Router



Ethernet Switch

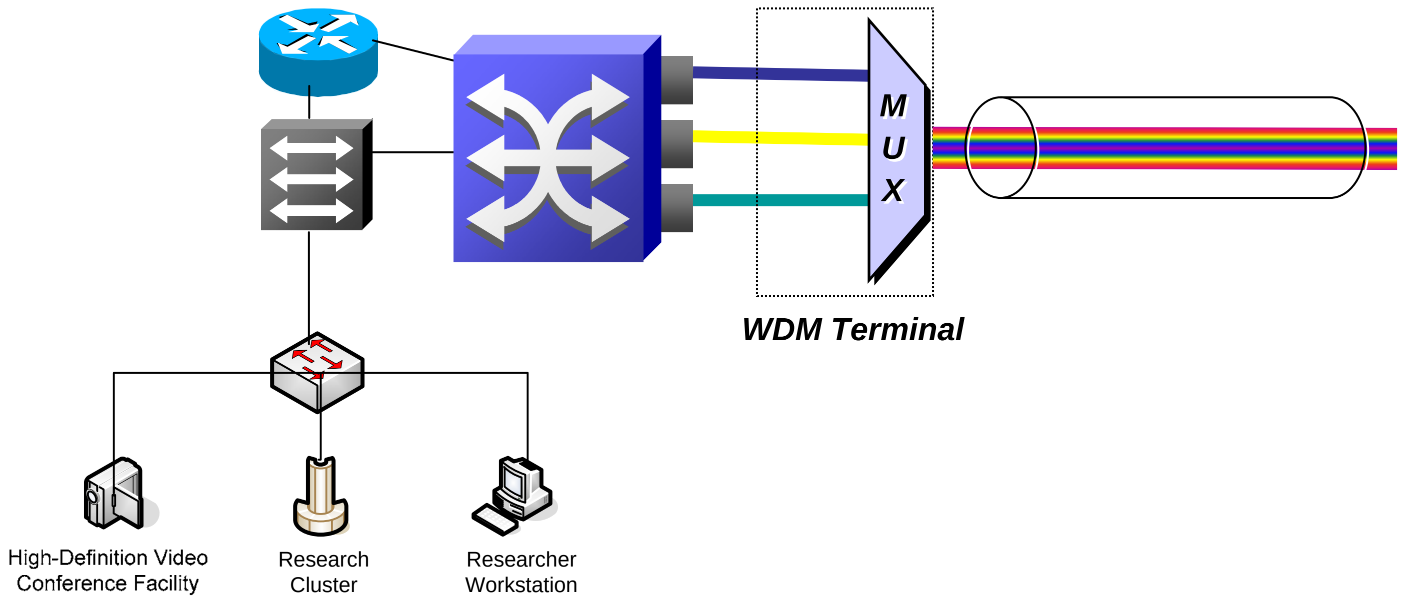


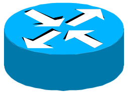
SONET Multiplexer / Optical Switch

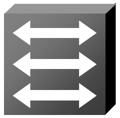


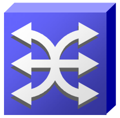
WDM Terminal

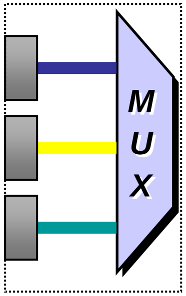
Customer Connection Design Scenario #1




IP Router

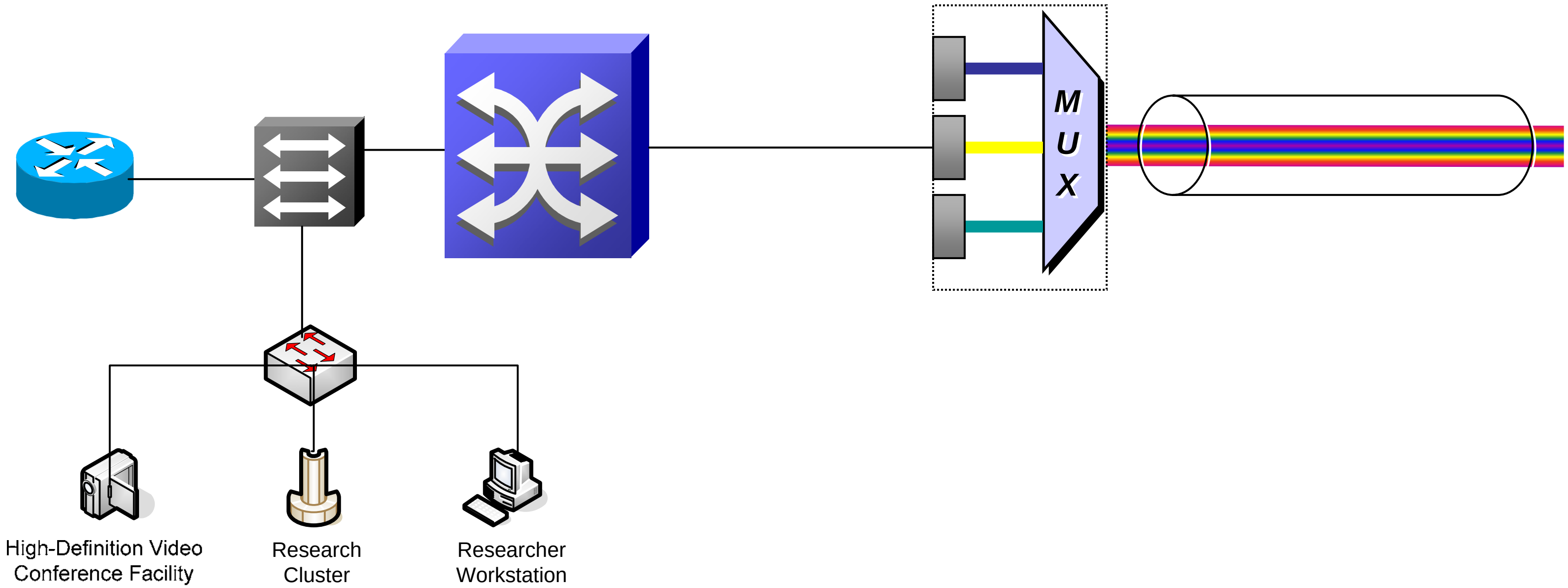

Ethernet Switch

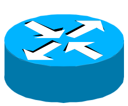

SONET Multiplexer / Optical Switch



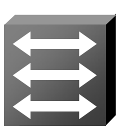
WDM Terminal

Customer Connection Design Scenario #2

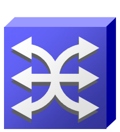




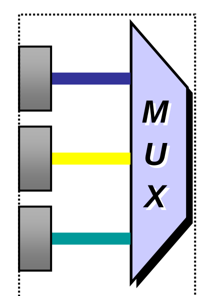
IP Router



Ethernet Switch

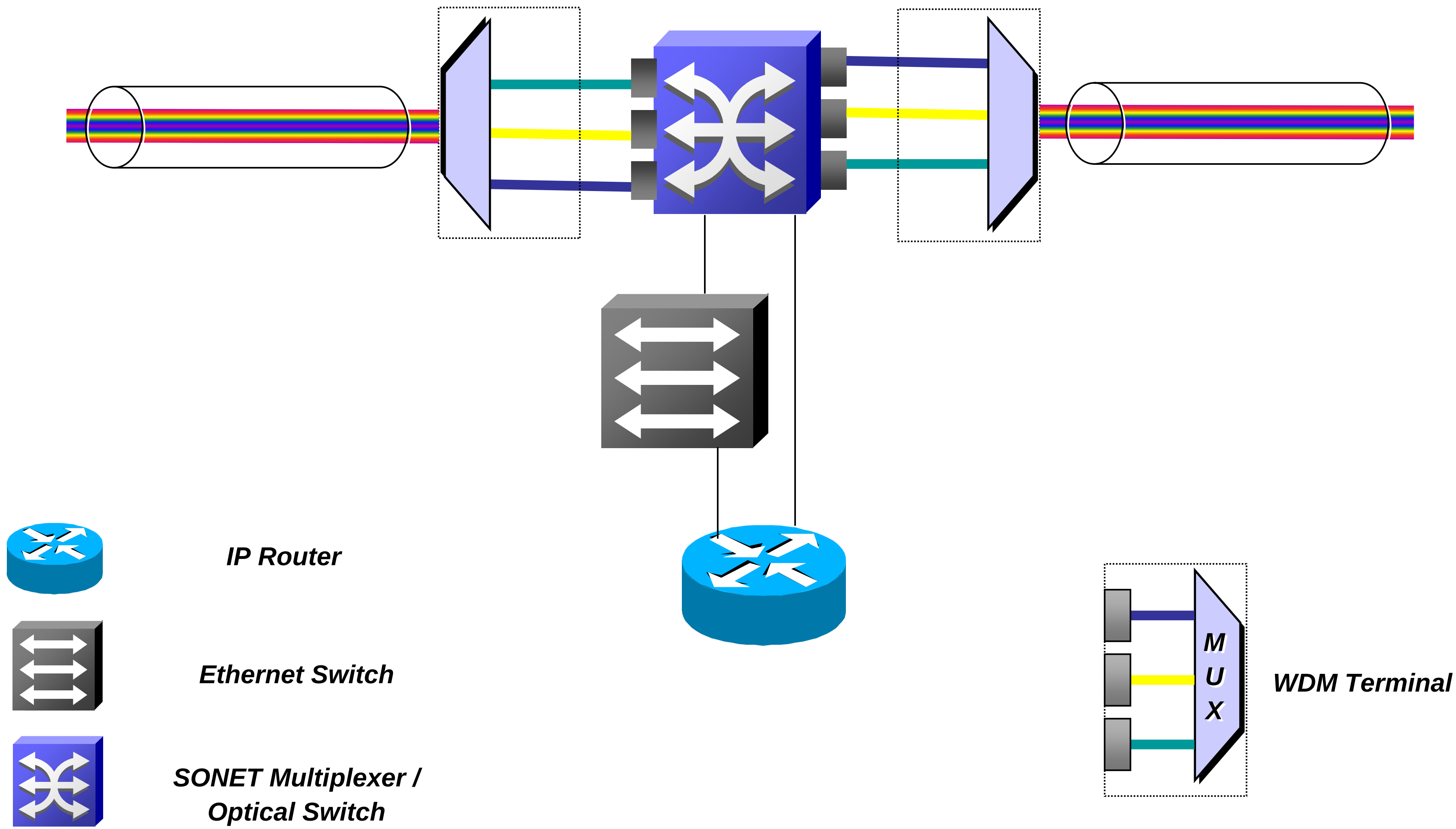


SONET Multiplexer / Optical Switch

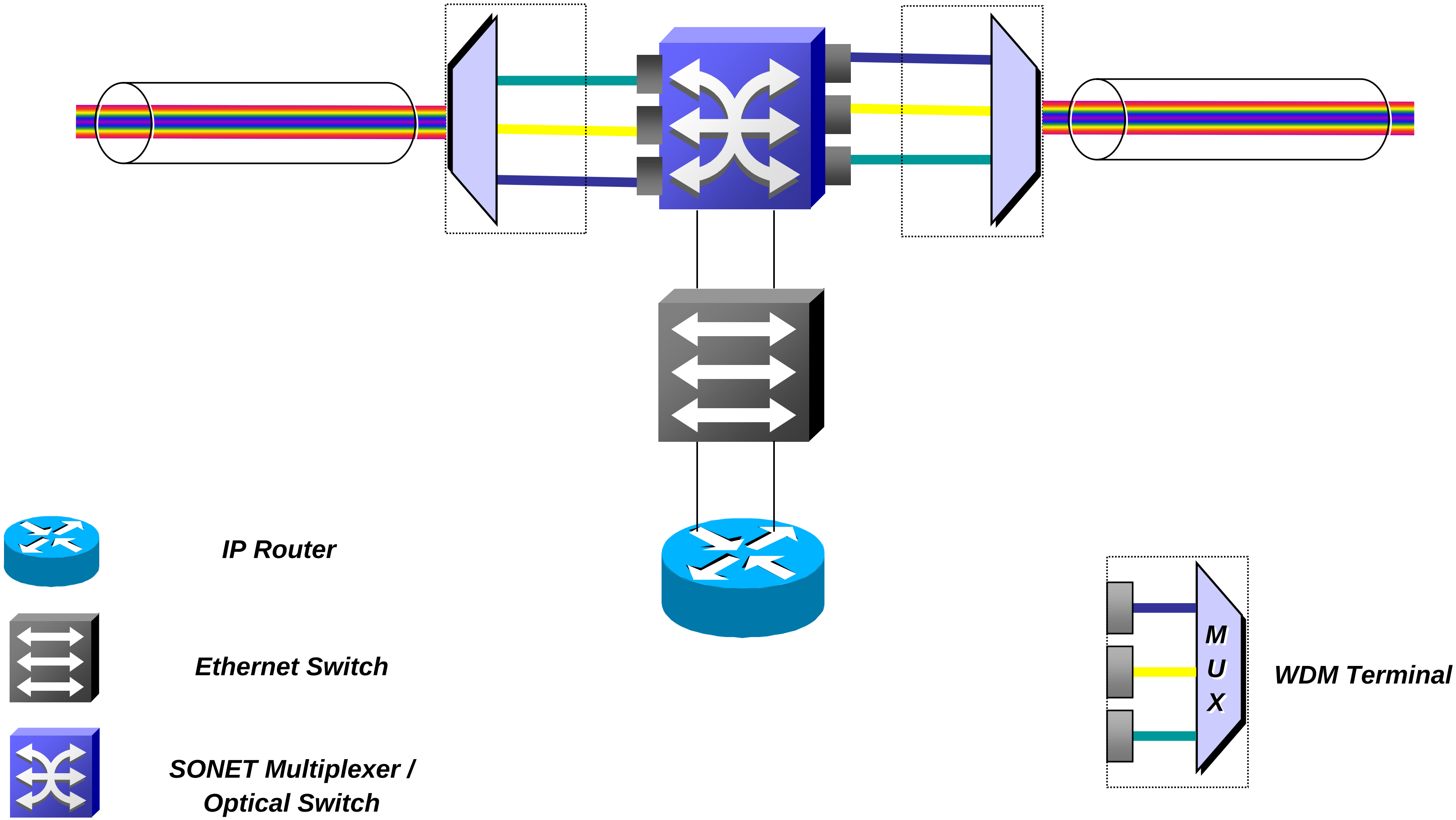


WDM Terminal

Hybrid PoP Design Scenario #1



Hybrid PoP Design Scenario #2



OneTenn Enabling Technologies - WDM

- DWDM (Dense Wave Division Multiplexing)

- CWDM (Coarse Wave Division Multiplexing)

OneTenn Enabling Technologies - OTN / G.709 / Digital Wrapper

- OTN (Optical Transport Network)
- OTU1 (2.5G Digital Wrapper)
- OTU2 (10G Digital Wrapper)

OneTenn Enabling Technologies - SONET

- SONET
- GFP (Generic Framing Procedure)
- VCAT (Virtual Concatenation)
- LCAS (Link Capacity Adjustment Scheme)

OneTenn Enabling Technologies - Control Plane

- GMPLS (Generalized Multiprotocol Label Switching)
- O-UNI (Optical User Network Interface)
- ASON (Automatically Switched Optical Networks)
- UCLP (User Controlled Lightpath Provisioning)

Optical Lightpath Service Matrix

Transport	#	Interface	Bandwidth
STS-24c	1	GigE	1000.00 Mbps
2 x STS-24c	2	GigE	2000.00 Mbps
STS-48c	1	SONET OC-48	2488.32 Mbps
8 x STS-24c	8	GigE	8000.00 Mbps
STS-192c	1	SONET OC-192	9953.28 Mbps
STS-192c	1	10 GigE WAN	9953.28 Mbps
G.709 / OTN	1	10 GigE LAN	10000.00 Mbps

1 SONET STS-1 = 51.84 Mbps

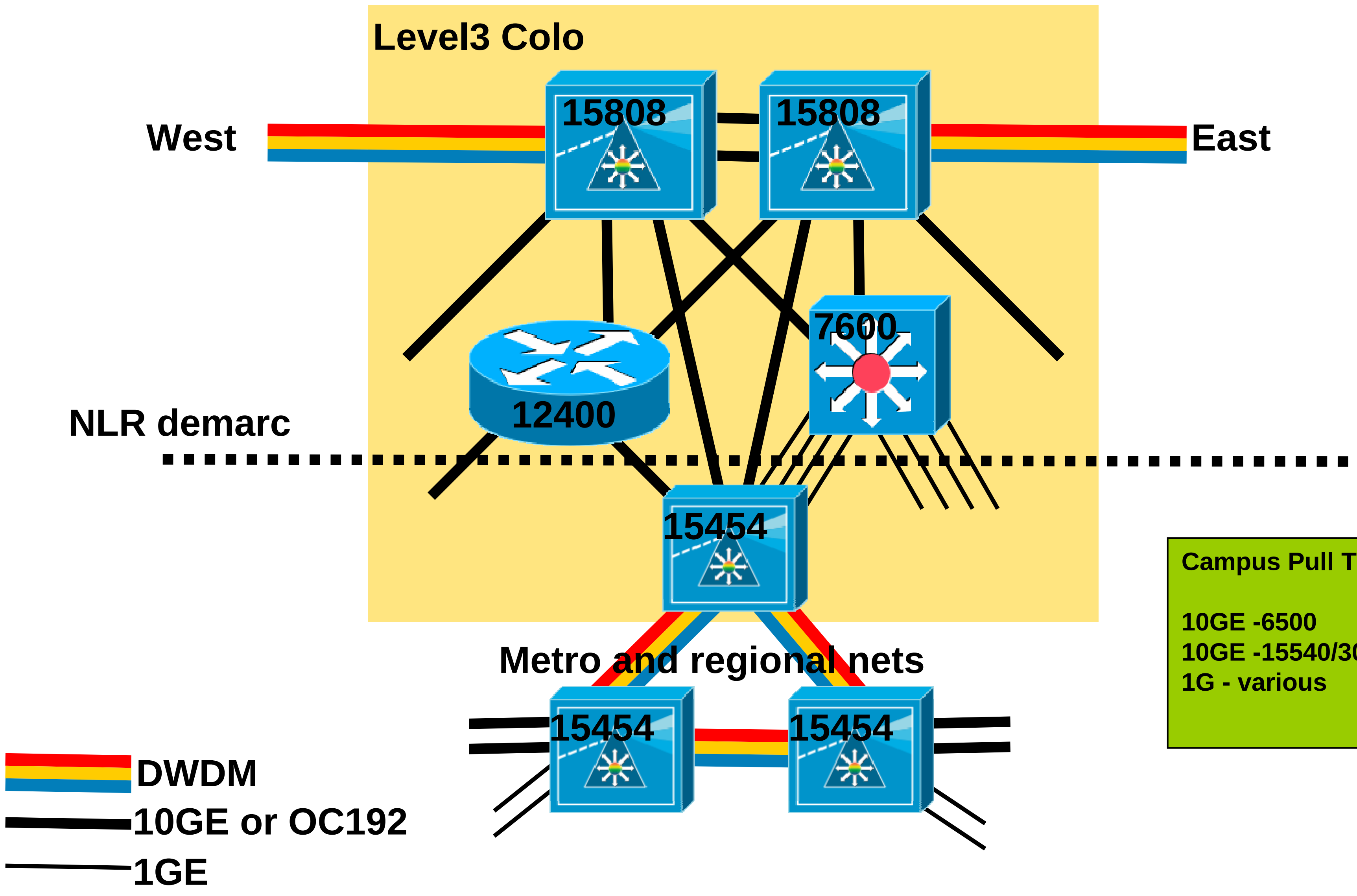
Services

- SONET Private Line
- Ethernet Private Line
- Transparent LAN via VLAN
- Distributed Peering via VLAN
- L1, L2, L3 Transit to Regional (surrounding states) , National (NLR, Internet2, etc.) and International (GLIF, GLORIAD, etc.) R&E Networks

Security

Enclave Security Architecture

NLR PoP Architecture



Campus Pull Thru

10GE -6500
10GE -15540/30
1G - various

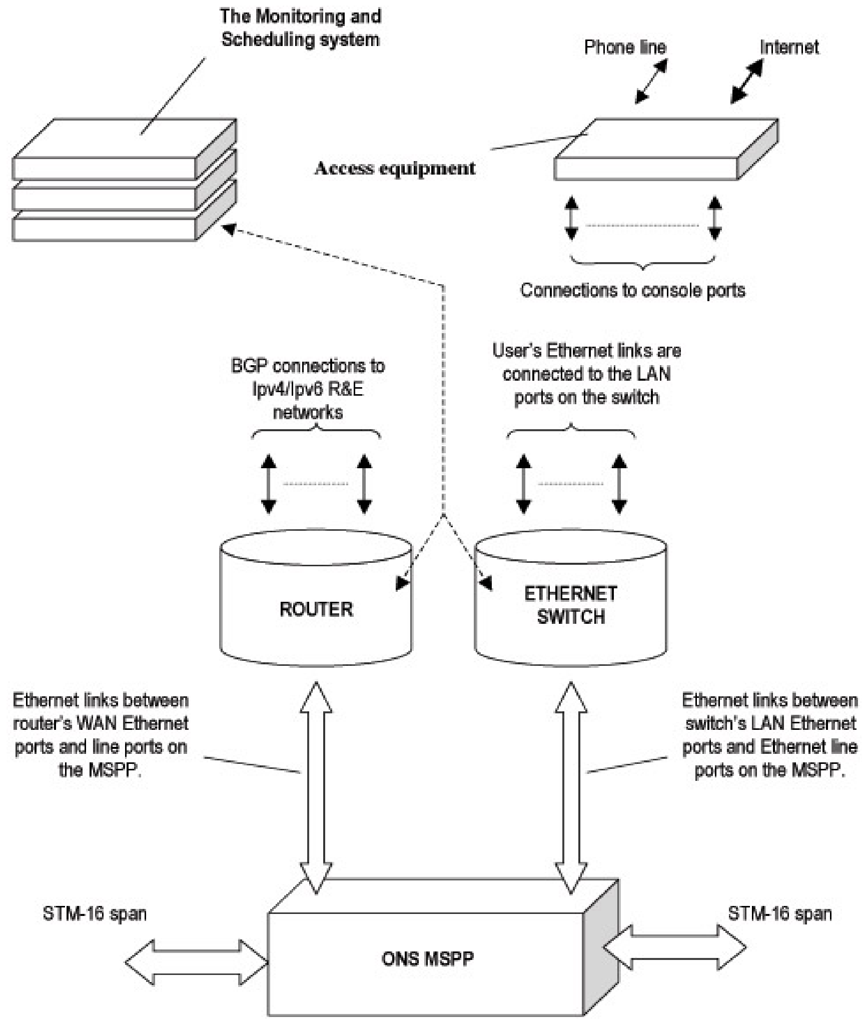


Fig.3. Structure of GLORIAD's PoP at Phase I

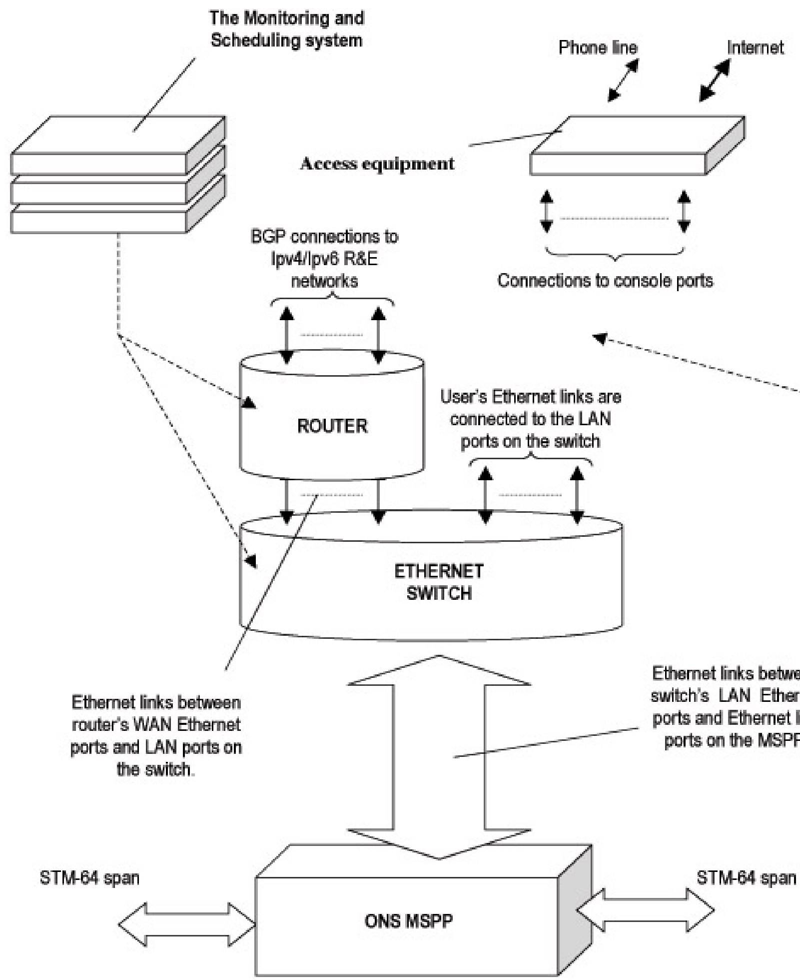


Fig.4. Structure of GLORIAD's PoP at Phase II

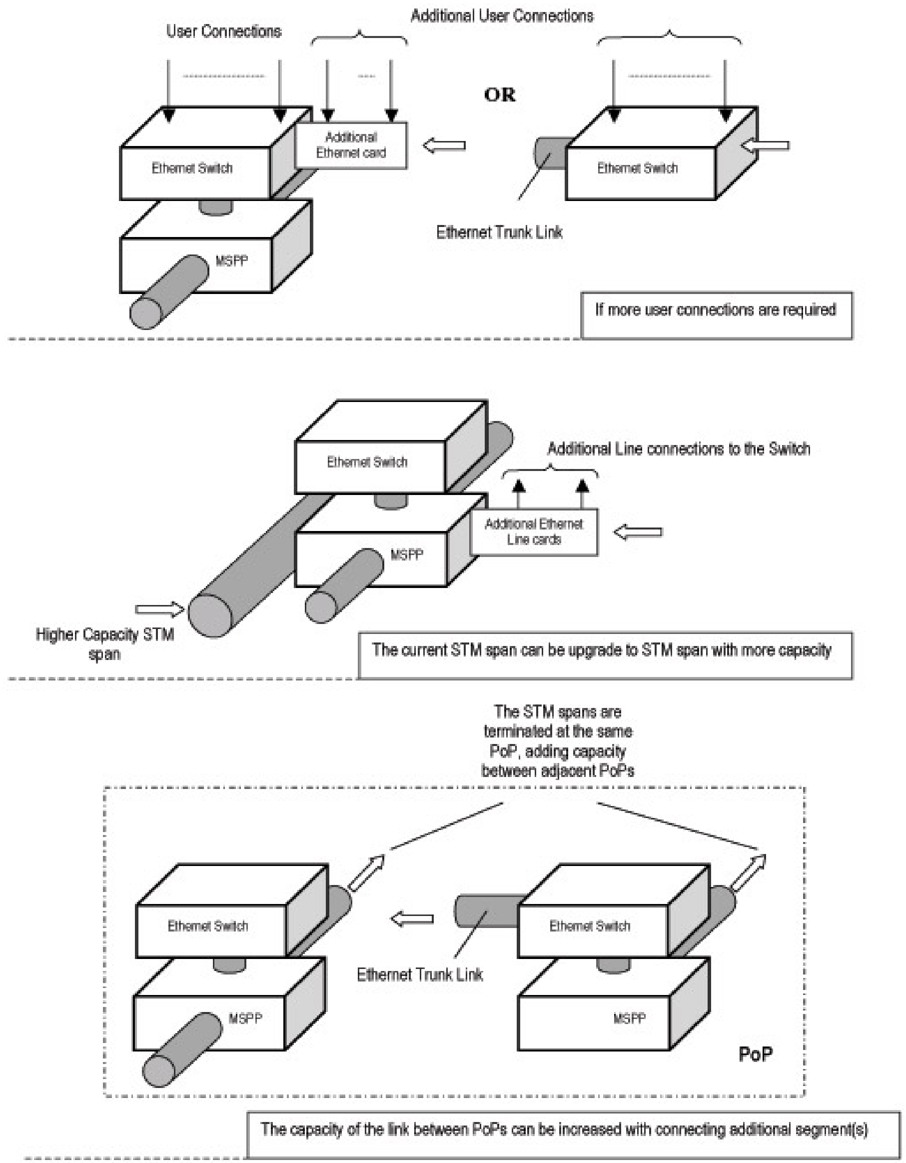


Fig. 7. The mechanism of scaling

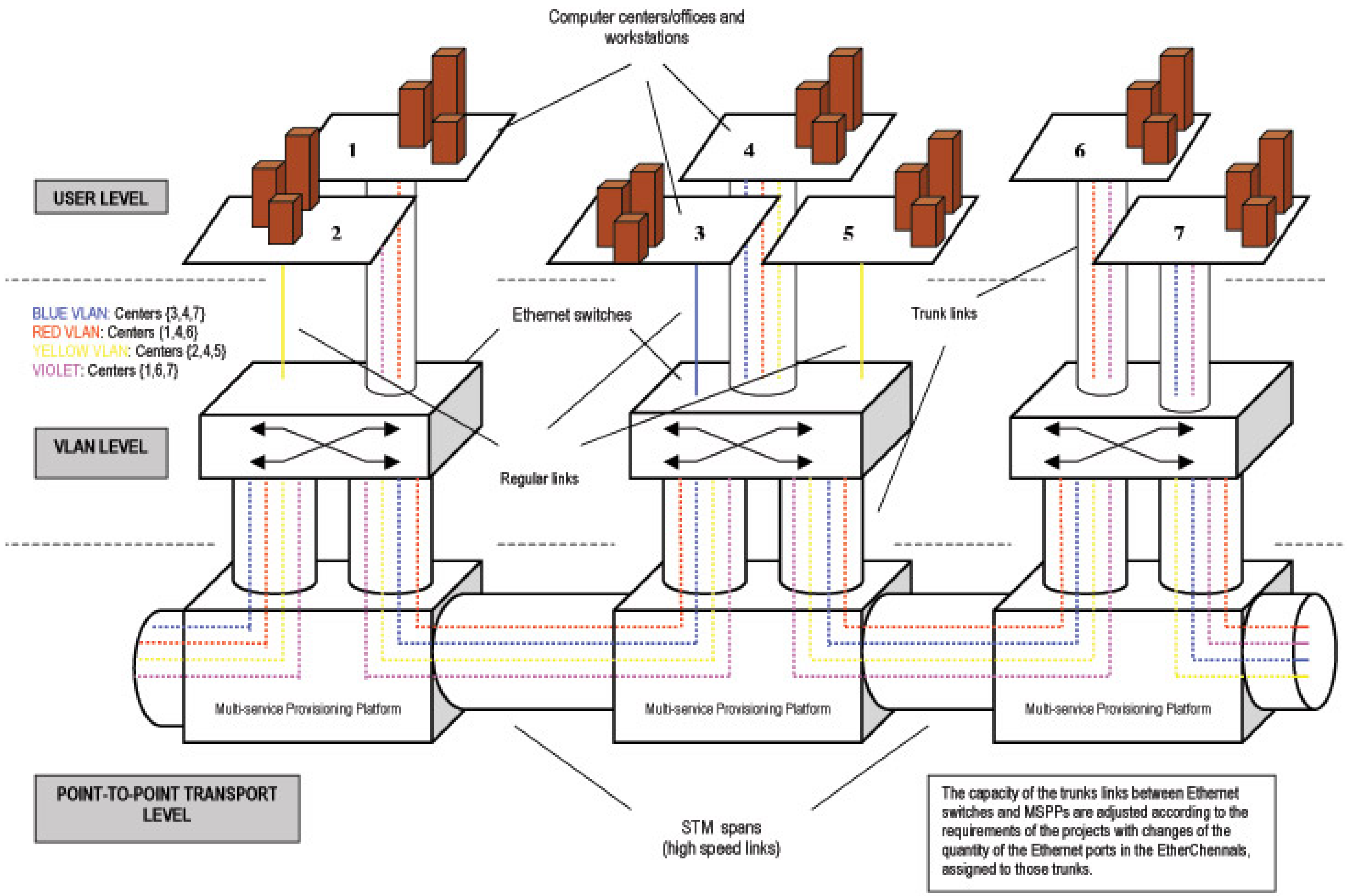
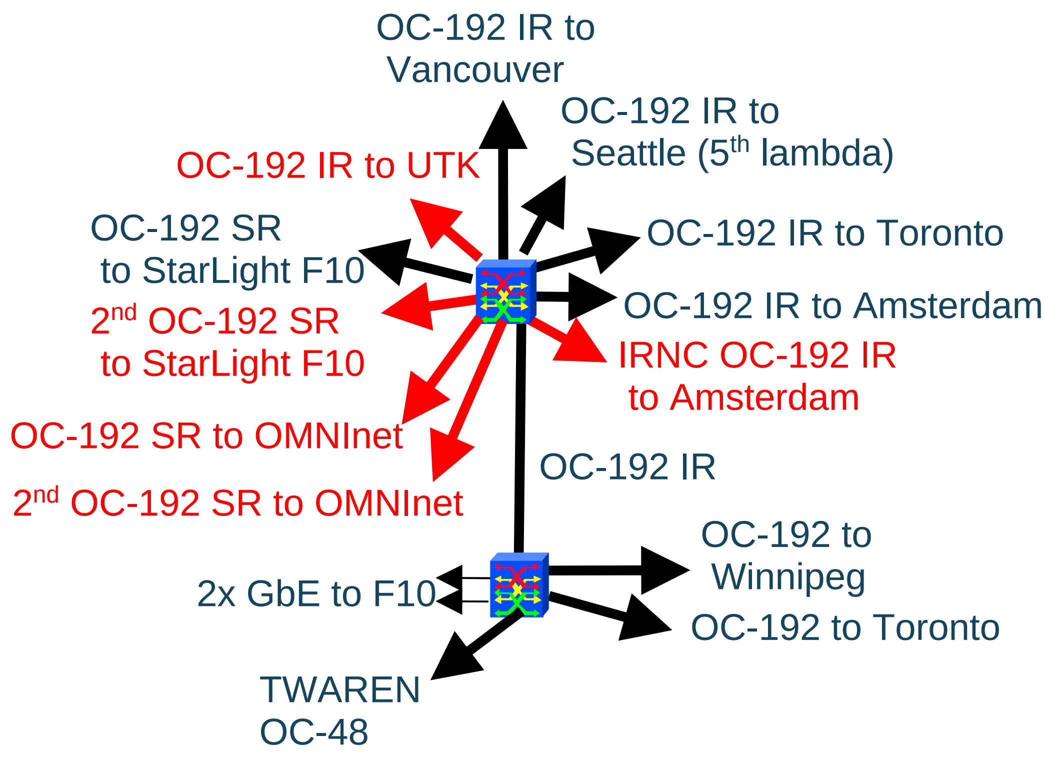


Fig. 2. The diagram of interconnecting computer centers/offices with VLAN's.

GLIF node @ StarLight Chicago



GLIF node: CANARIE HDXc + SURFnet 15454

OneTenn Goals

- **Accelerate the growth of statewide research opportunities**
- **Connect state researchers to cutting-edge national and international infrastructure**
- **Support education across the state through the distribution of digital content (video and multimedia)**
- **Expand access to essential research computing resources**
- **Expand research opportunities with Oak Ridge National Laboratory (ORNL)**
- **Raise the level of math, science, and engineering education**
- **Enable innovative approaches to public health care and education**
- **Enhance collaboration among Tennessee institutions**
- **Serve as Catalyst for Economic Development in the 21st Century**

Thank You!