TORREYPOINT
An Information Systems Consultancy

NANOG

KINBER PennREN Network

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KINBER
Juniper Networks
sunesys
ADVA Optical Networking

Enabling the Innovation Economy

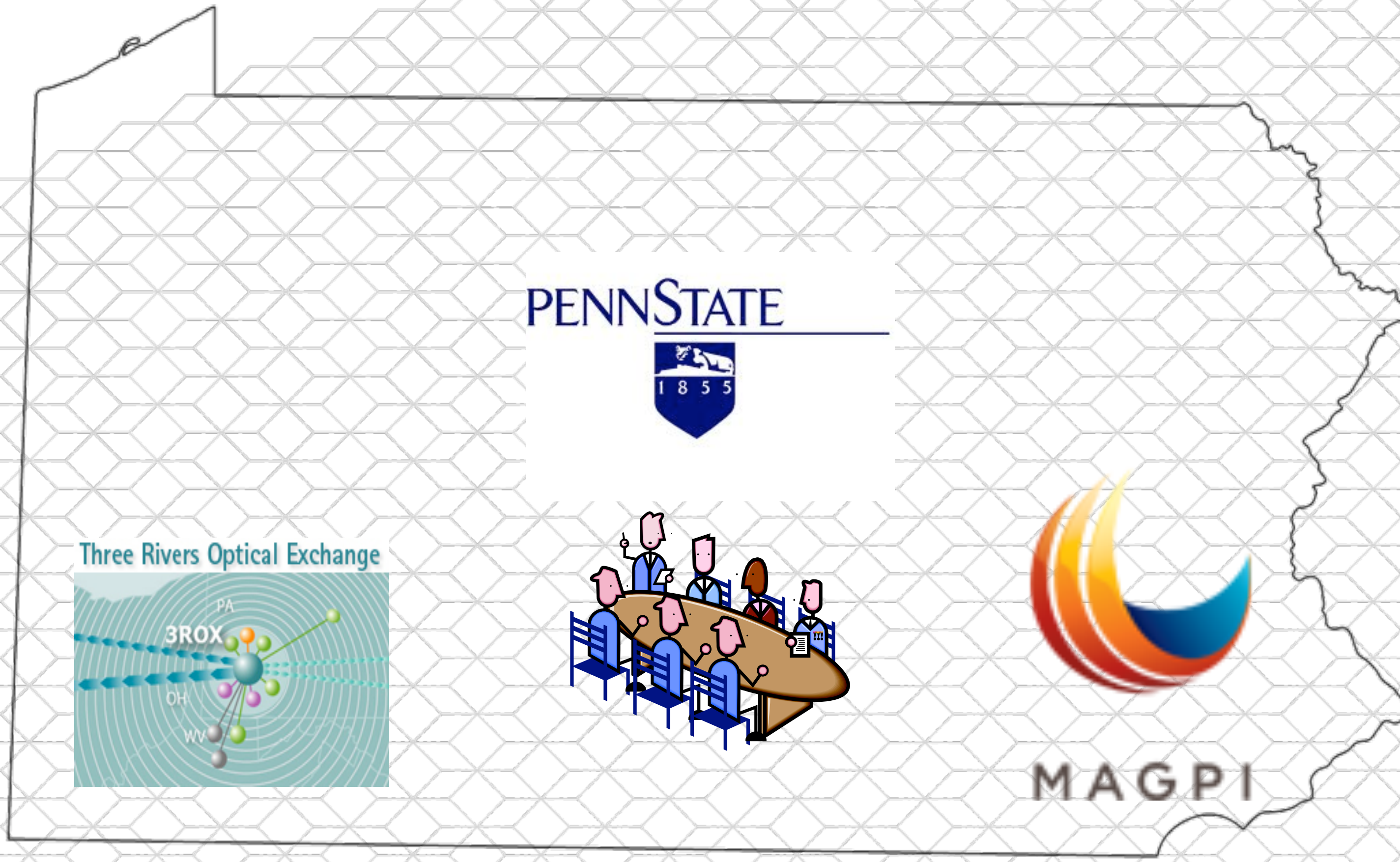
Why Not Pennsylvania?

- Geography – Costly to Install Facilities
- ILEC's and State Legislature Lobbyists
- Cooperation/Collaboration Between State Agencies, Public and Private Concerns
- Ownership/Control/Operation

Opportunity

- **American Recovery and Reinvestment Act**
  - $7.2B for "…complete Broadband and Wireless Internet Access"
    - Department of Commerce
      National Telecommunications and Information Agency
      $4.7B Broadband Technology Opportunity Program
    - Department of Agriculture
      Rural Utility Services
      $2.5B Broadband Initiatives Program

Idea for the PA-HPN…



KINBER


WQLN Radio
LISTEN LIVE
GEISINGER
Association of Independent Colleges & Universities of Pennsylvania
Bucknell
UNIVERSITY
PENNSTATE
1855
University of Pittsburgh
PENNSYLVANIA COMMISSION FOR COMMUNITY COLLEGES
HAP
The Hospital & Healthsystem Association of Pennsylvania
Three Rivers Optical Exchange
3ROX
PA
OH
WV
State System of Higher Education
Carnegie Mellon University
Drexel
UNIVERSITY
MAGPI
Penn

KINBER Organization

Charter Board Members

Bucknell University
Carnegie Mellon University
Drexel University
Lehigh University
University of Pittsburgh
University of Pennsylvania
Pennsylvania State University
Pennsylvania State System of Higher Education
Commission for Community Colleges
Hospital and Healthcare Association of Pennsylvania
Association of Independent Colleges and Universities of PA

Associate Board Members

Pennsylvania Public Media
Geisinger Health System

Associate Members

PA Intermediate Units
PA Library Association
Temple University
University of Scranton

Affiliates

MAGPI, 3ROX

For Profit

Corporate Sponsor

Advisory Councils → KINBER Board and non-profit corporation → PennREN project team

KINBER Organization Staff
- Executive Director
- Operations Director
- 3 Network Engineers
- Administrative Support

PennREN Support Resources
- Project Management
- Accounting Support
- Compliance Support

2/17/10 – KINBER Awarded BTOP Grant to Build PennREN

Mission: To serve Pennsylvania through the establishment and sustainment of a high-speed research and education network that connects our institutions of higher learning with K-12 programs to advance the education, health care, work force development and training programs across the Commonwealth

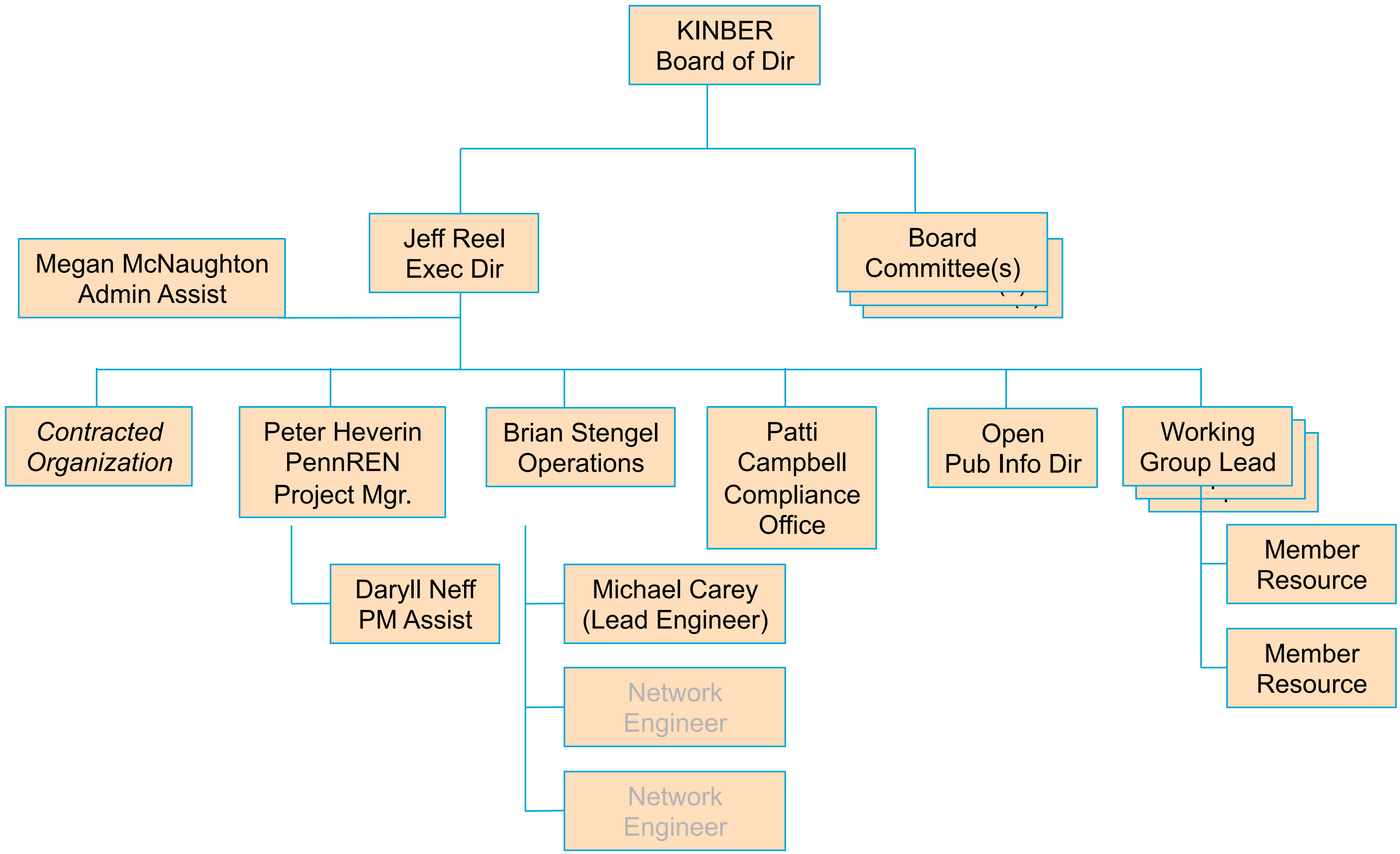
"Once completed, PennREN will not only form interconnections among the vast majority of our institutions of higher learning, but will also provide new opportunities to partner with K-12 schools, increase access to national and federal research centers and enhance the availability of telemedicine and the use of electronic medical records. The quality of life and economic development implications of this network cannot be overstated."

Jeff Reel,
KINBER Executive Director

Network Details

- **Capital Budget - $128,958,031**
  - Federal Stimulus Funds - $99,660,678
  - Matching Funds - $29,297,353
- **48 Strands Constructed for PennREN**
  - Over 1700 Route Miles
  - Outsourced Fiber Maintenance
- **13 Optical Regeneration Service Nodes**
- **56 Service Distribution Access Nodes**

KINBER Organization



Award for Construction

Contracts for the design and implementation of the PennREN project were awarded to Quanta Services, Inc., and its LLC subsidiaries of Sunesys and Blair Park Services, both of which are based in Warrington. Local and regional workers employed by Sunesys and Blair Park Services will install the fiber optic network. Quanta also will provide $24 million in matching funds to supplement the federal award.

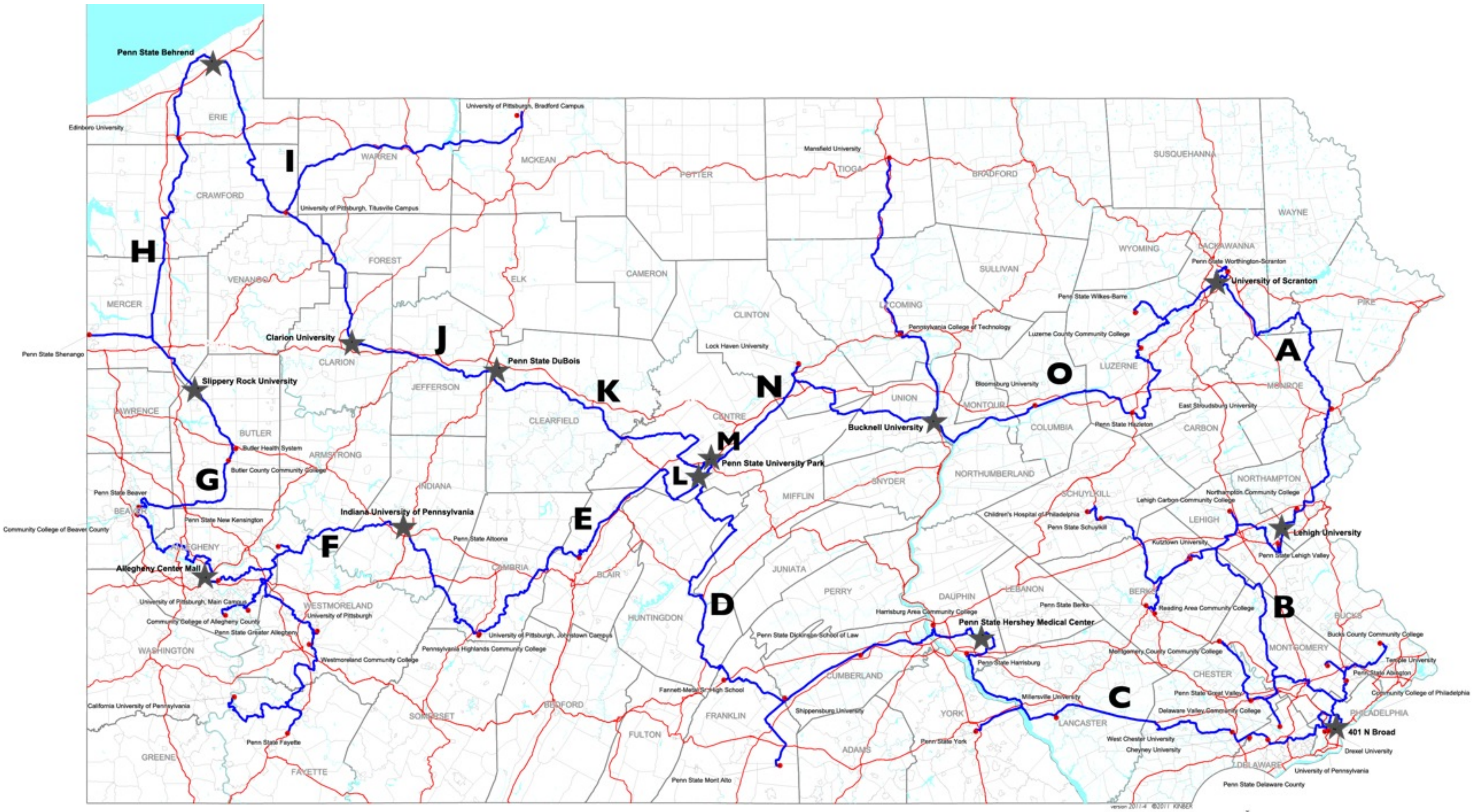
Sunesys is a premier provider of metro-based fiber optic infrastructure services. Sunesys is unmatched in its legacy of scope, speed and stability to build, manage and expand its pervasive network of next generation fiber and fiber-based transport services. Our networks service 4 of the 5 largest Metropolitan Areas of the United States.

BLAIRPARK
HIGH PERFORMANCE CONNECTIVITY

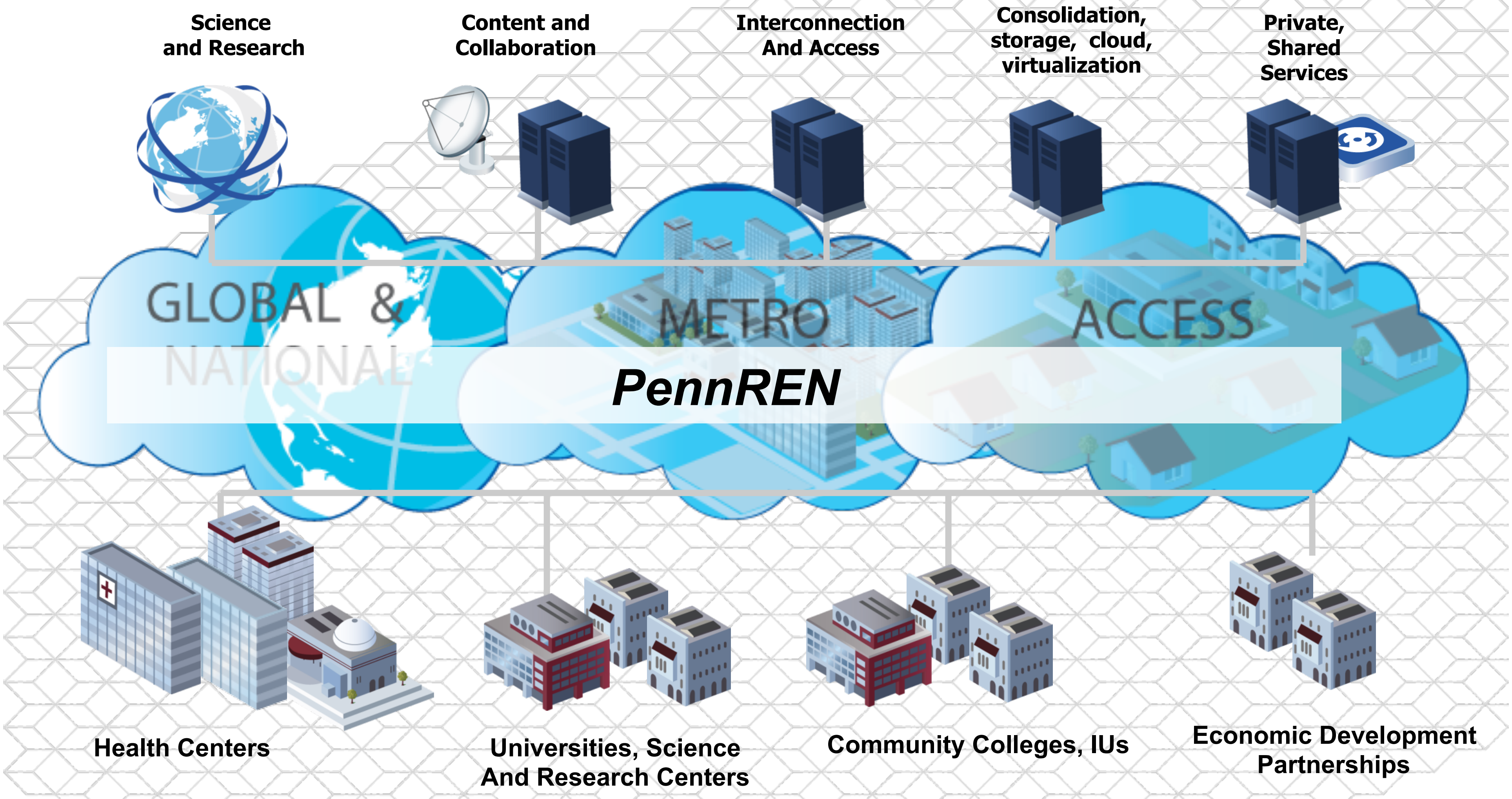
sunesys

Quanta Services, Inc. (NYSE: PWR) is a $3.3B specialized contracting services company, delivering infrastructure network solutions for the electric power, natural gas, telecommunications and cable television industries, with over 15,000 employees and operations in all 50 states and Canada.

Pennsylvania's REN!



Middle Mile Network

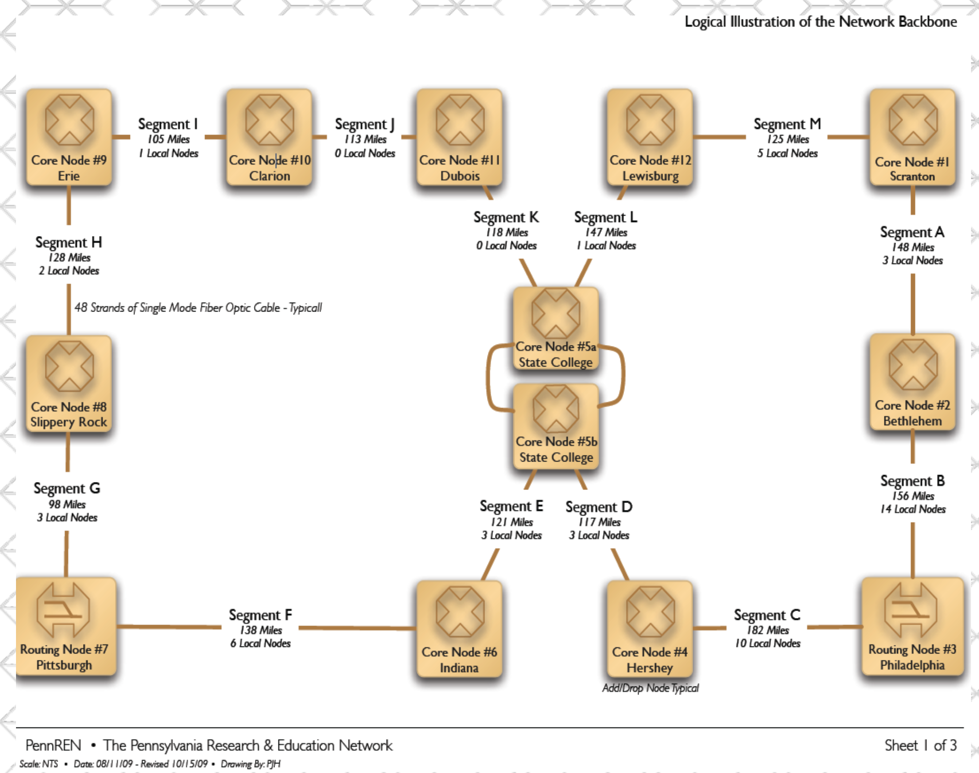


Services and Opportunities for Researchers and Educators

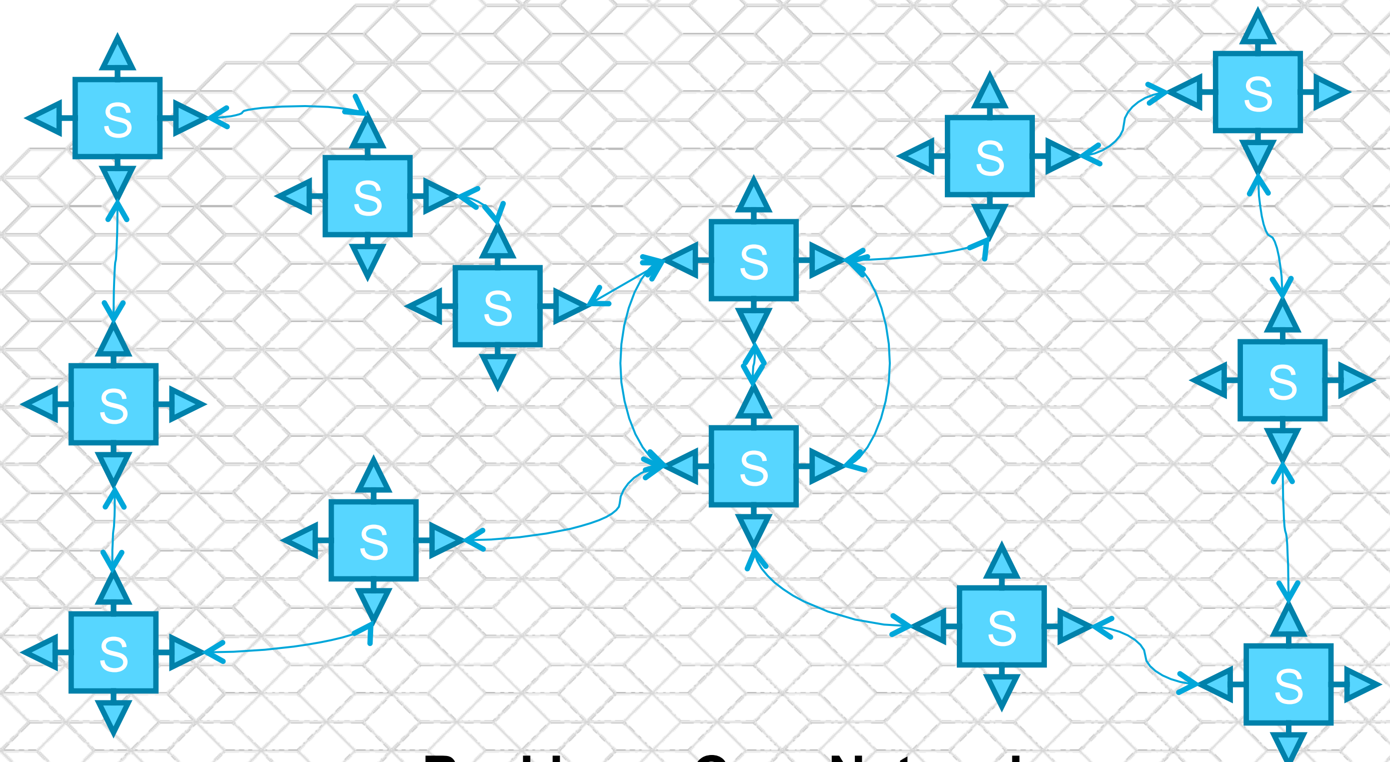
- Dark Fiber (dedicated)
- Dedicated point to point (multipoint) Ethernet
- Connectivity to shared statewide R&E backbone
- Access to National R&E backbones
- Access to commercial Internet

PennREN Logical Design

- **Service Nodes**
  - 13 Service Node locations for backbone connectivity (optical, L2, L3) services
  - Service nodes hosted at member institutions
  - Provides services to access nodes and optical regeneration where necessary
- **Access Nodes**
  - 56 Access Node locations
  - Access nodes hosted at member institutions
  - On ramps and off ramps for access to fiber and services



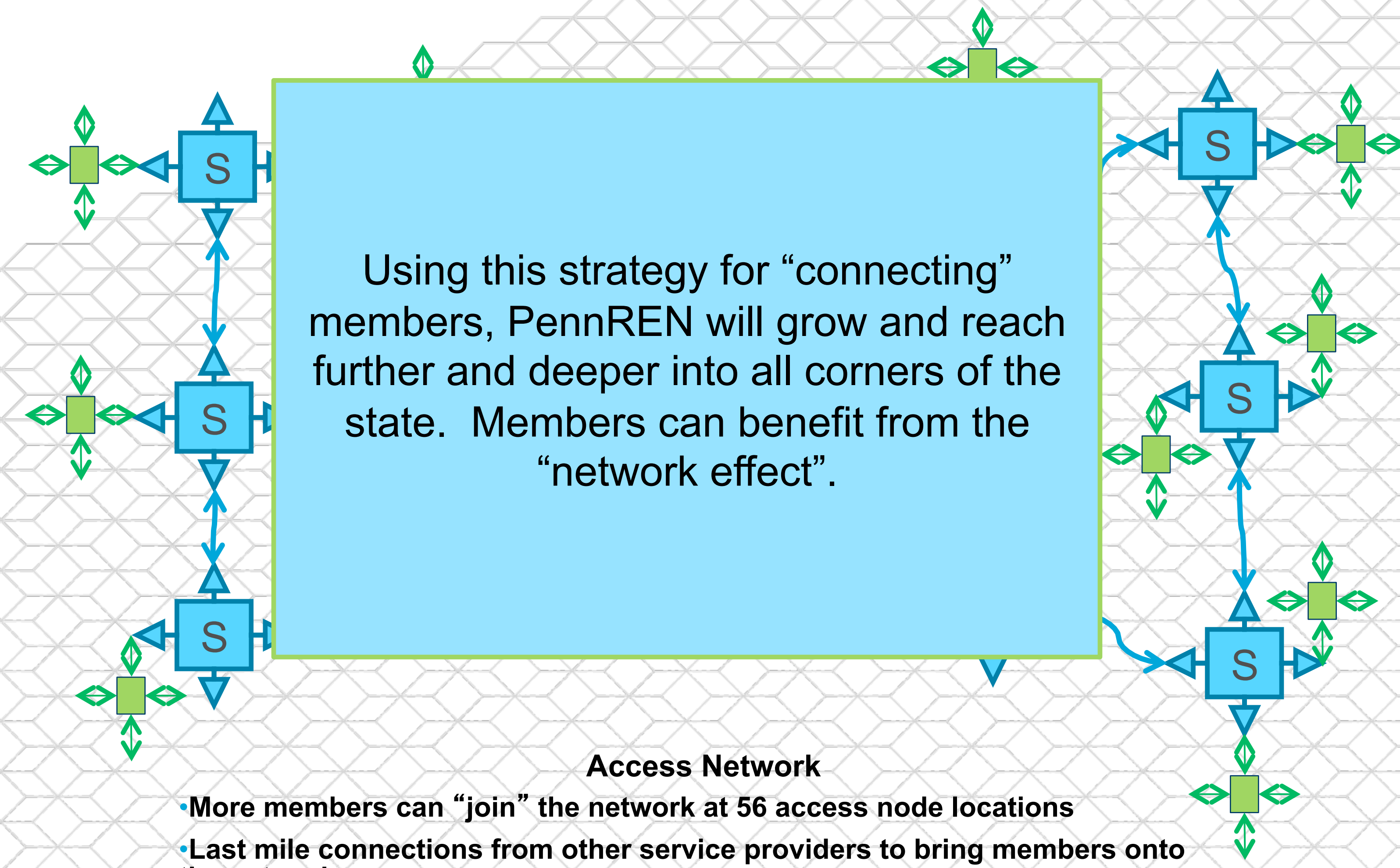
Deployment Strategy



Backbone Core Network

- **Members can "join" the network at 13 service node locations**
- **Last mile connections from service providers**
- **Other RENs will be connected to PennREN at Services Routing Nodes**

Growth Strategy



Using this strategy for "connecting" members, PennREN will grow and reach further and deeper into all corners of the state. Members can benefit from the "network effect".

Access Network

- **More members can "join" the network at 56 access node locations**
- **Last mile connections from other service providers to bring members onto the network**

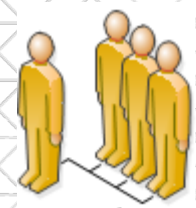
Who is Building PennREN?

Blair Park/Sunesys

Statewide fiber optic network

Blair Park/Sunesys

Fiber from right-of-ways into buildings



Member IT, FM Teams

Rooms to host PennREN nodes

Blair Park/Sunesys

Cabinets, fiber terminations in Service and Access Nodes

TORREYPOINT

Network electronics (optical gear), Layer 2,3

KINBER's Optics: OFS TrueWave® REACH Fiber

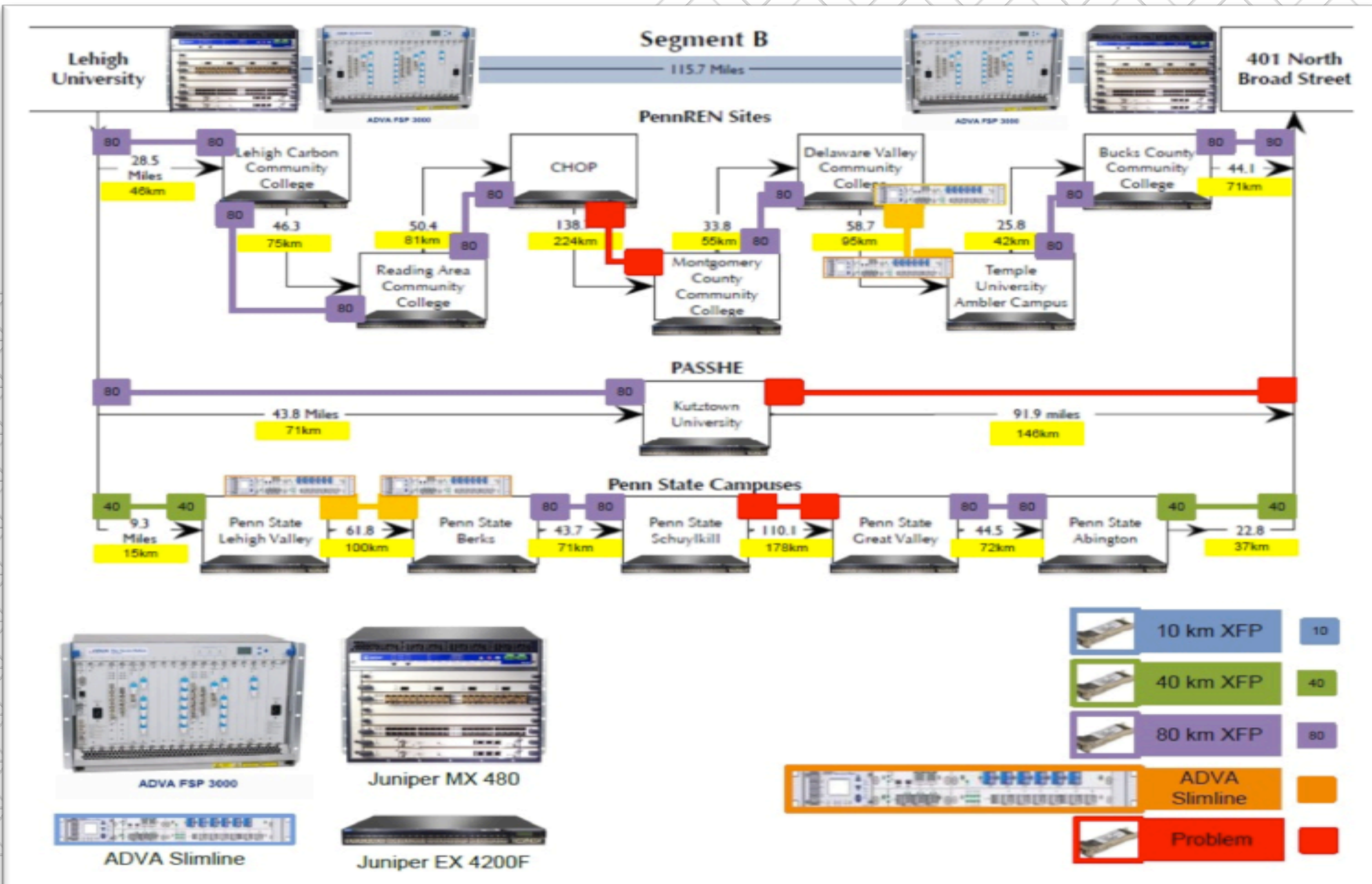
- **Challenges:**
  - A limited number of fibers (48)
  - An open access network
  - High bandwidth needs
  - Significant un-regenerated transmission distances
  - Possibly many technologies and platforms operating over the same optical fiber
  - A need to avoid multiple fiber types under the same cable sheath
- **Solution:**
  - A medium-dispersion NZDF (non-zero dispersion shifted fiber) as defined under ITU G.656
  - Supports the most possible wavelengths using conventional DWDM
  - Can support CWDM
  - Minimal dispersion compensation costs
  - Viable for next-gen 40G and 100G technologies

TrueWave® REACH Fiber
Low Water Peak

PennREN Network

- **Engineered in partnership with TorreyPoint, ADVA Optical, and Juniper Networks**
- **15 segment network**
  - 48 strands of fiber optic cable across 1600 route miles within PA
  - 69 Sites
  - Layer 1 through Layer 3
  - GMPLS Design

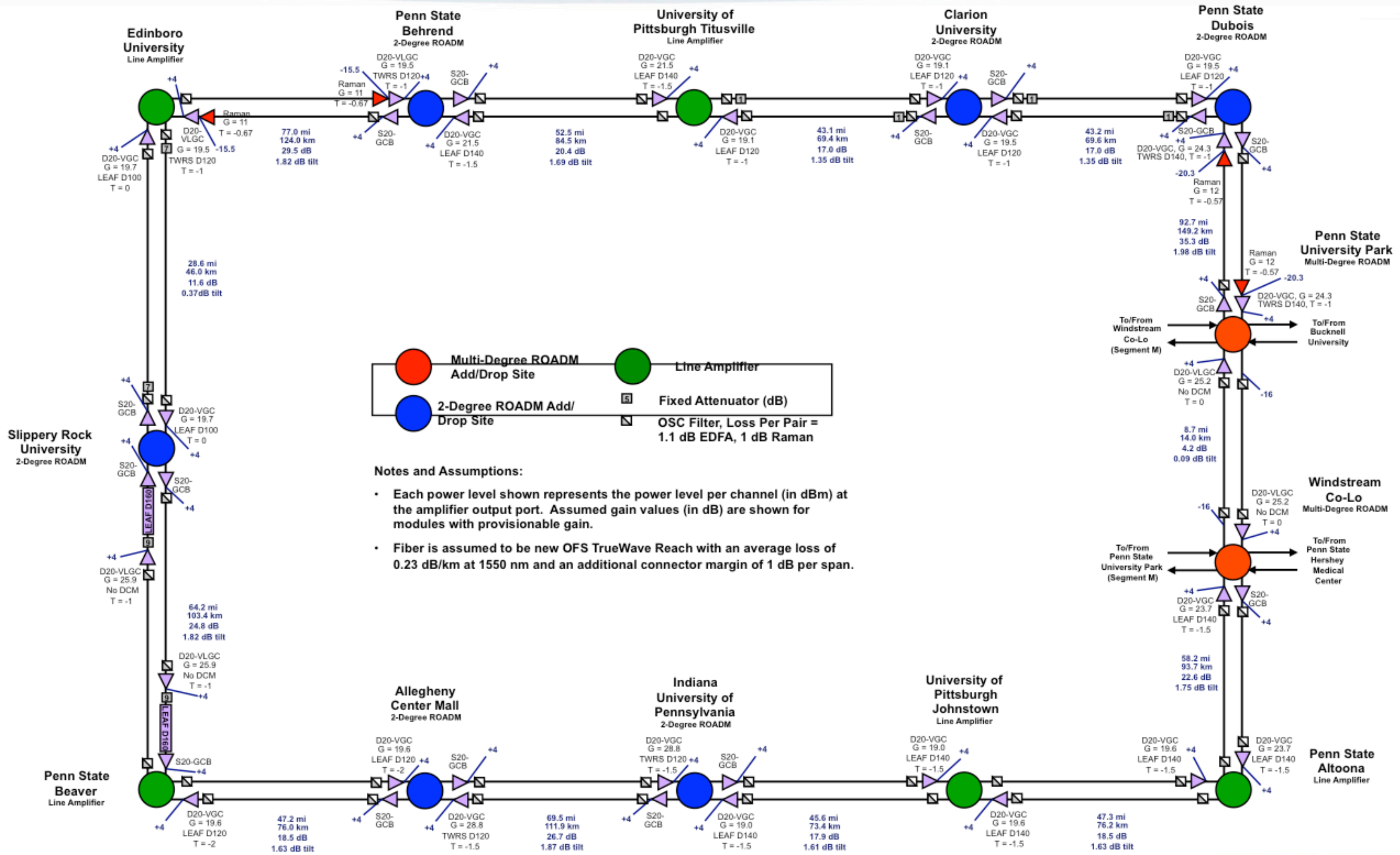
Example Segment



Layer 1

- **ADVA FSP3000**
  - Both 2-degree and 8-degree ROADMs, depending on topology
  - Raman amps where needed
  - 40 channel system
  - 1 100Gb/s lambda (but presented to routers at multiple 10Gb/s using a 10x10 transponder card)

West Ring, DWDM System Design

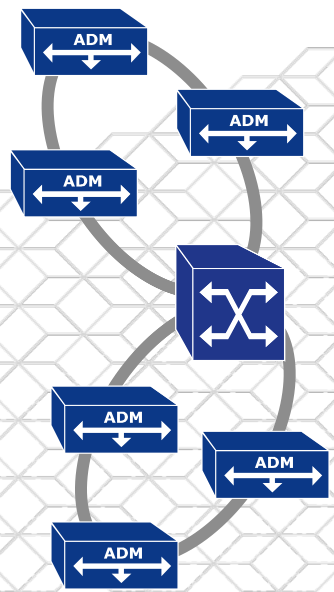


Notes and Assumptions:

- Each power level shown represents the power level per channel (in dBm) at the amplifier output port. Assumed gain values (in dB) are shown for modules with provisionable gain.
- Fiber is assumed to be new OFS TrueWave Reach with an average loss of 0.23 dB/km at 1550 nm and an additional connector margin of 1 dB per span.

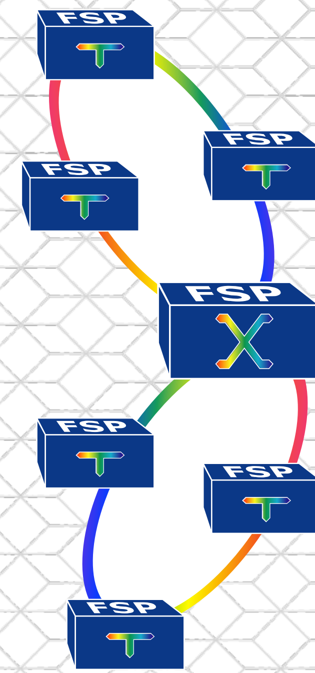
Optical layer - ROADM

Typical Sonet/SDH network
with ADMs and DCS



- **WDM engineering rules and scalability can be quite complex, especially in a metro environment (rings, mesh, every node an OADM)**
- **SDH/Sonet networks much simpler to plan:**
  - Access to entire bandwidth at every ADM
  - Simple engineering rules (single hop only)
  - Easy addition of new network elements
- **Optical layer reconfigurability addresses many, but not all of those issues:**
  - Single wavelength granularity
  - Power budget and dispersion (but not OSNR) reset at every node
  - Reduced module variety (compared to filters dedicated to part of the spectrum)

Reconfigurable WDM network
with eROADMs and SCE-WSS



ROADM simplifies engineering rules; WDM network scales more like an SDH/Sonet ring

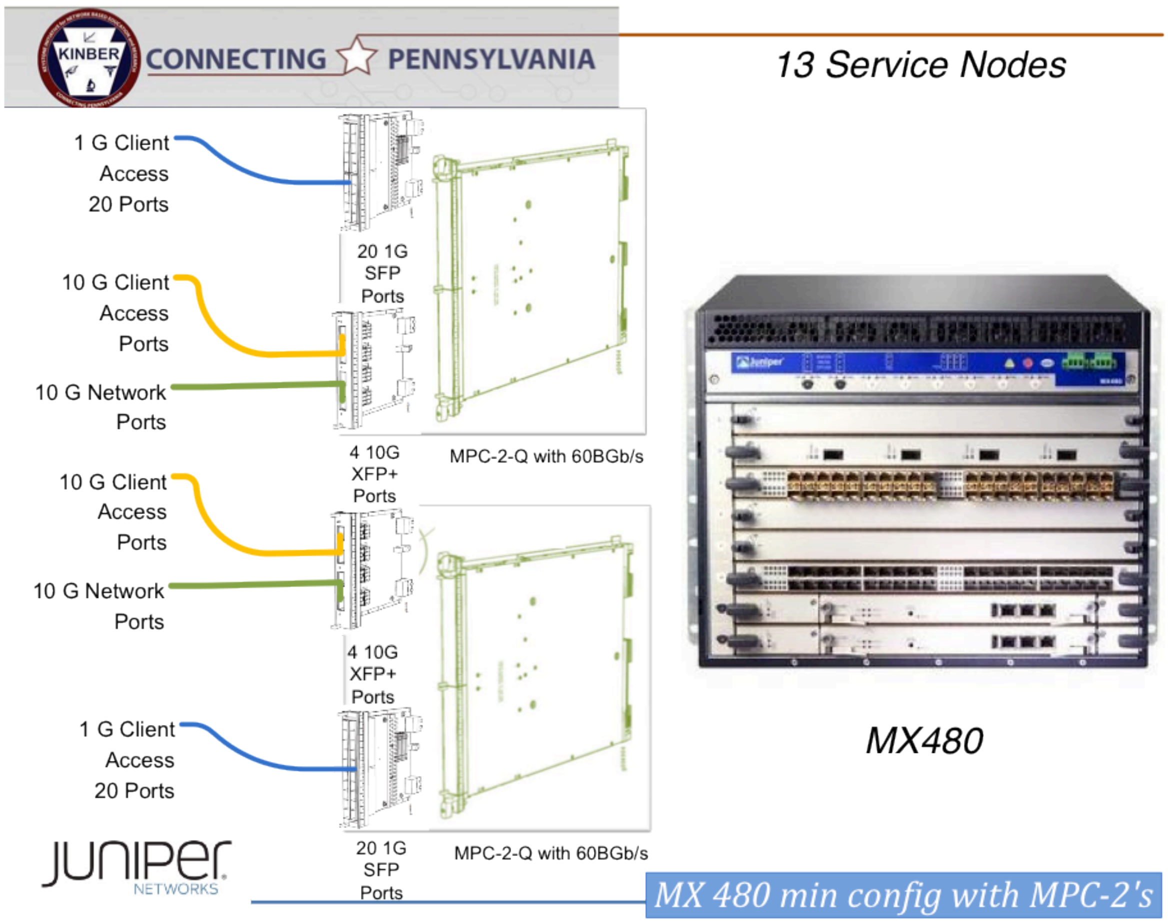
Connection to Routers

- In some places, the routers will have grey 10Gbps Ethernet optics, fed into a transponder card
- Transponder card does OEO and grooms the lambda to the appropriate channel
- Will be done in places where the distances are too far to drive, directly from colored optics on the routers

Connection to Routers

- In places where distances are within limits, the routers will have tunable optics
- Lambdas from the routers will be carried as alien waves across the DWDM infrastructure

Service Node Layer 2/3



Routing Nodes

- **2 of them**
  - 401 N Broad, Philly
  - Alleghany Center Mall
- **Also Juniper MX480**
  - But with “-R” (full BGP routing table) cards
- **IPv6 from day 1**

GMPLS – Layer 1

- **Alien Wavelength Support - ADVA ROADM network provides full support for DWDM alien wavelengths from Juniper route ports**
- **Standards compliant control planes provide automated GMPLS-based cross-platform provisioning and resource management**
- **Single network management solution for Layer 2/Layer 3 provisioning**
- **100G Integration**

GMPLS – Layer 2/3

- **MPLS brings the benefits of Circuits to IP**
  - Supporting network segmentation and privacy
  - Enhancing the end user application experience with traffic engineering that enables fine-tuning of the network to deliver appropriate level of QoS
  - Improving network resiliency with features like MPLS fast reroute, enabling sub 50 millisecond reroute to maintain real-time traffic during a node or link failure

GMPLS – Layer 2/3 (Cont.)

- **MPLS brings the benefits of Circuits to IP**
  - Boosting network scalability and performance
  - Allowing optimal utilization of network bandwidth

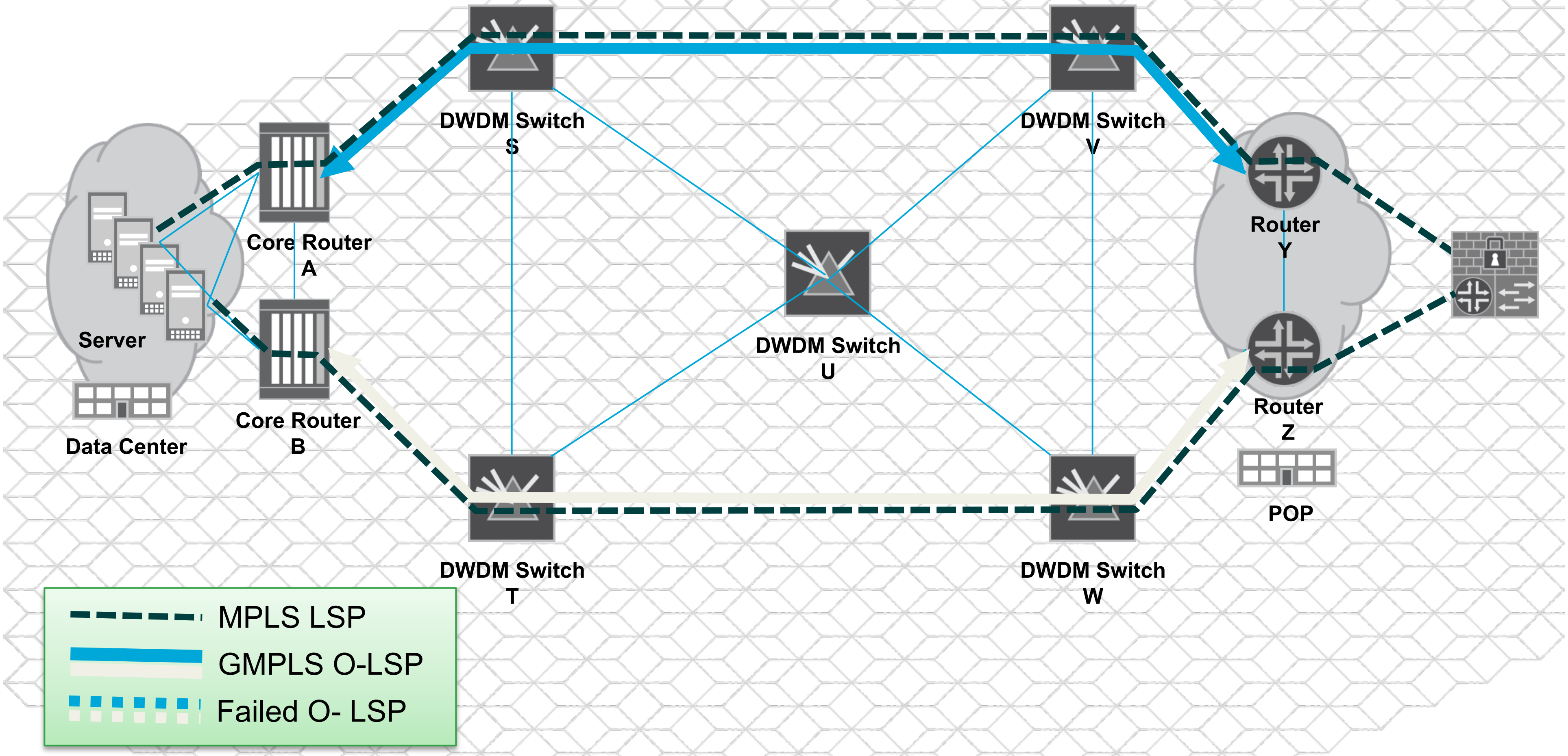
Dynamic Recovery in IP/Optical Benefits

1. **Protection against Data Center / POP Isolation**
2. **<50ms protection against Fiber cut with FRR**
3. **Only 2 Wavelengths needed between Data Center and POP locations**
4. **Zero additional network cost:**
   a. Router Interfaces fully utilized: no need for standby provisioning
   b. Number of Wavelength used is less or equal to provisioned Wavelengths
   c. Optical Network status before and after failure scenario is identical

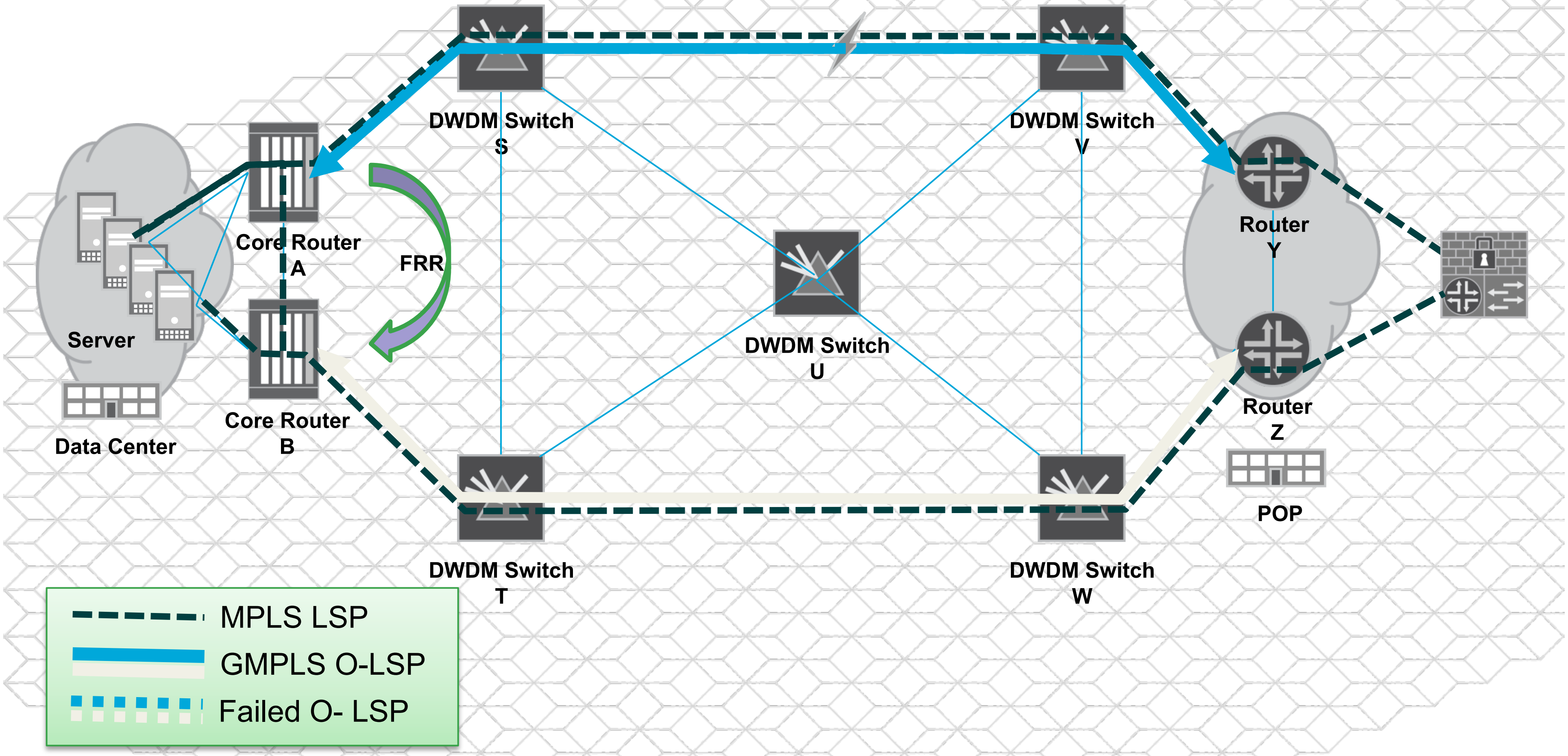
Dynamic Recovery in IP/Optical Scenario

- **Scenario:**
  - Protect a Data Center with dual homed connection from a network isolation
- **Starting condition:**
  - The two core routers are equipped with GMPLS, supporting packet/optical on-demand provisioning
  - The Optical network is capable to react according to routing demand
- **Failure scenario:**
  1. First fiber cut is recovered by routing devices in <50ms by FRR → no consequent action in the optical network required
  2. Node isolation in case of second fiber cut recovered by activating backup path

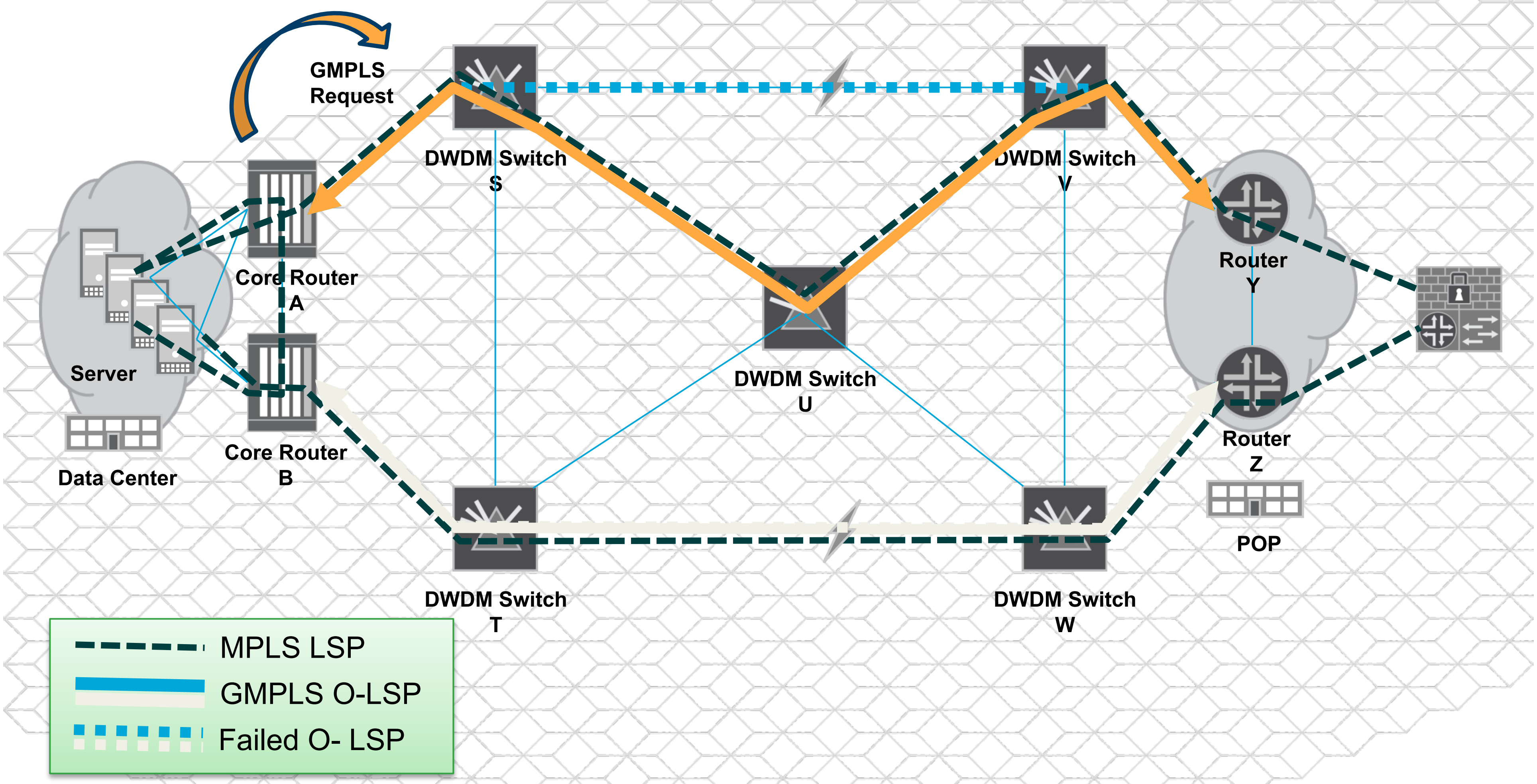
Dynamic Recovery in IP/Optical Network Build-Out



Failure Scenario 1): 1st Cut



Failure Scenario 3): 2nd Cut

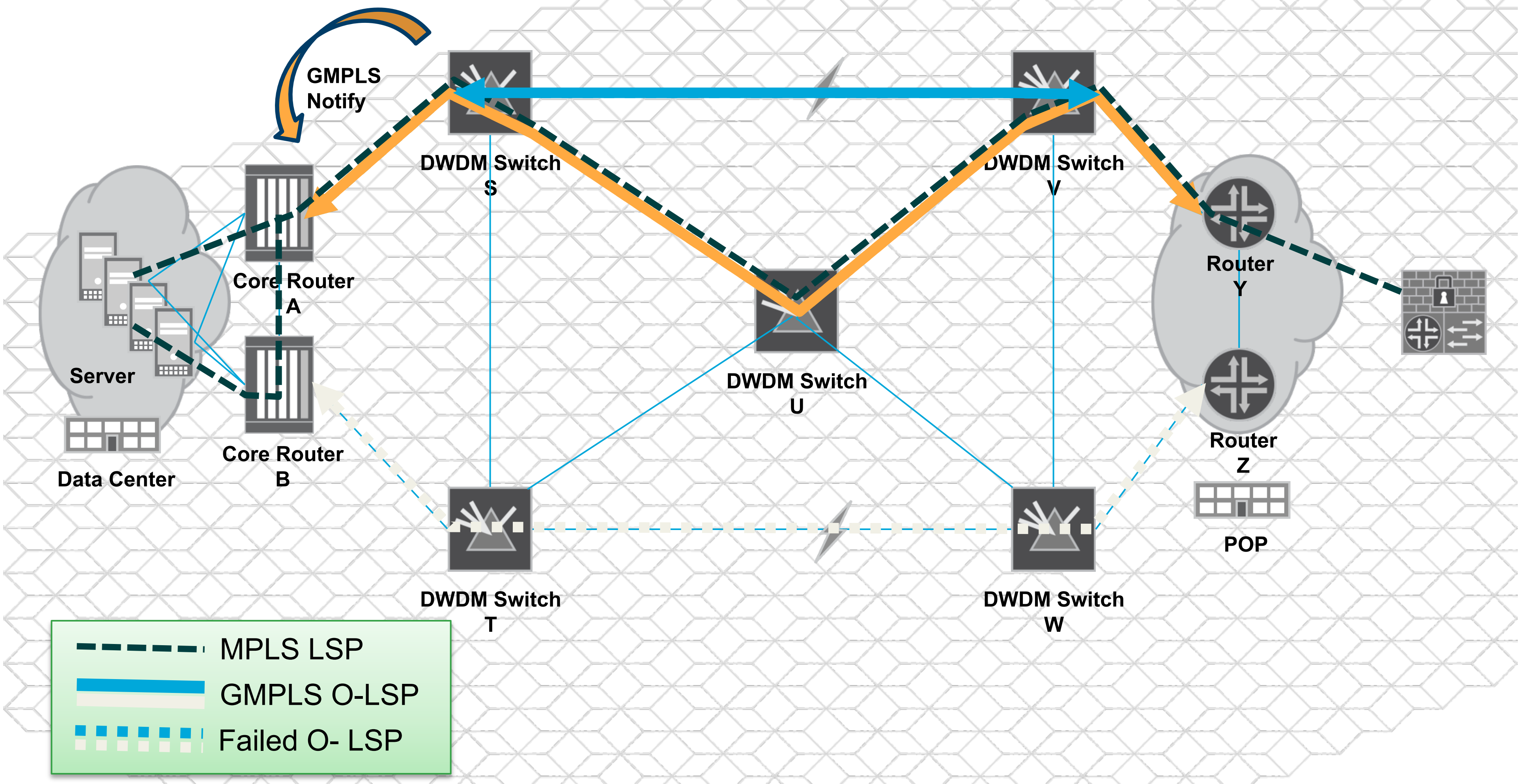


Repair Scenario

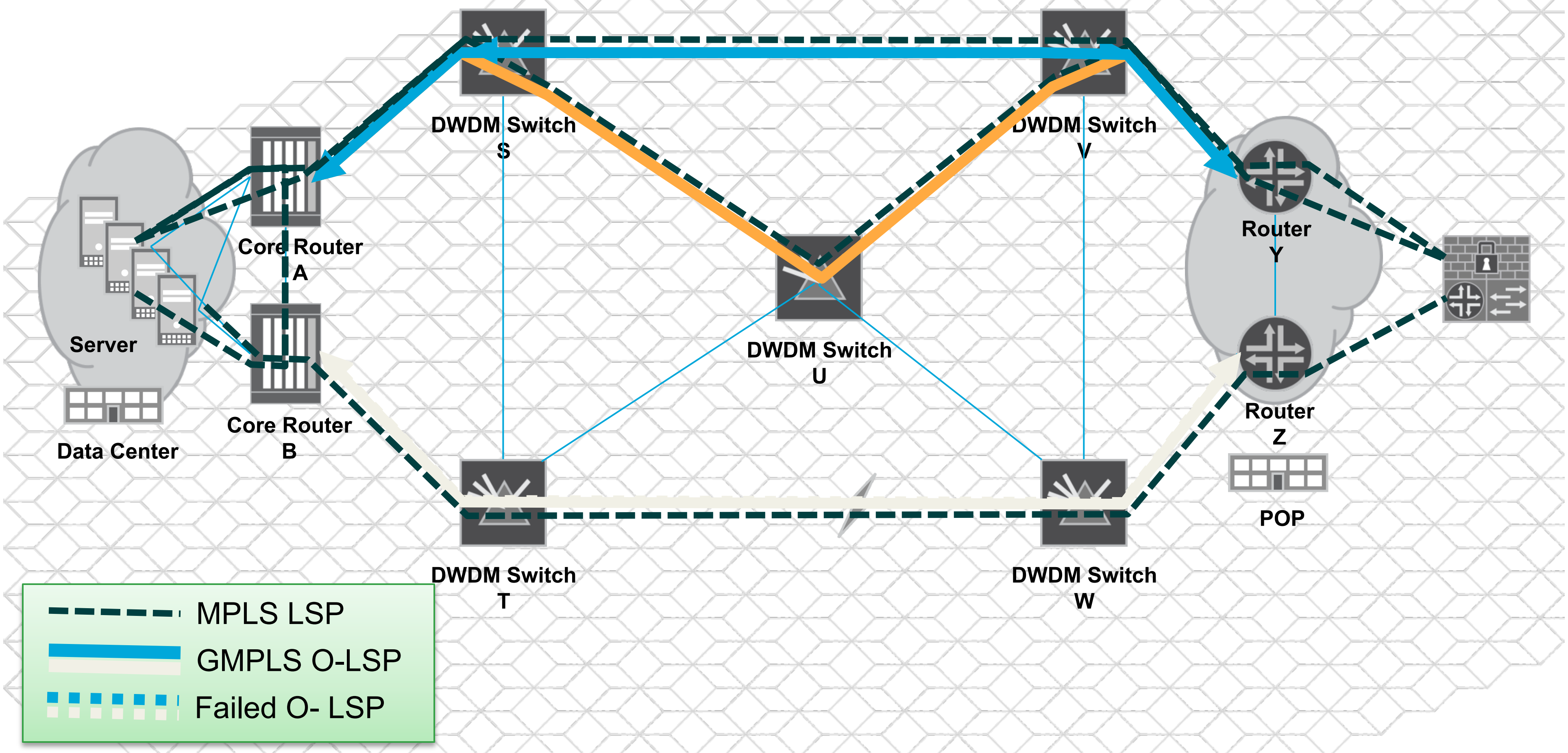
Normalization Scenario

- **Normalization Procedure (packet traffic running on backup)**
  1. 1st fiber cut repaired
  2. Optical LSP can't be used, as end-points are busy
  3. Wait
  4. 2nd fiber cut gets repaired
  5. Packet traffic moved to O-LSP-2 in a make-before-break manner
  6. Optical Backup LSP is torn down
  7. Original O-LSP-2 can be recovered
  8. Packet traffic balanced among available optical LSPs

Normalization Scenario: Repair 1st Cut



Normalization Scenario: Repair 2nd Cut



Dynamic Recovery in IP/Optical Summary

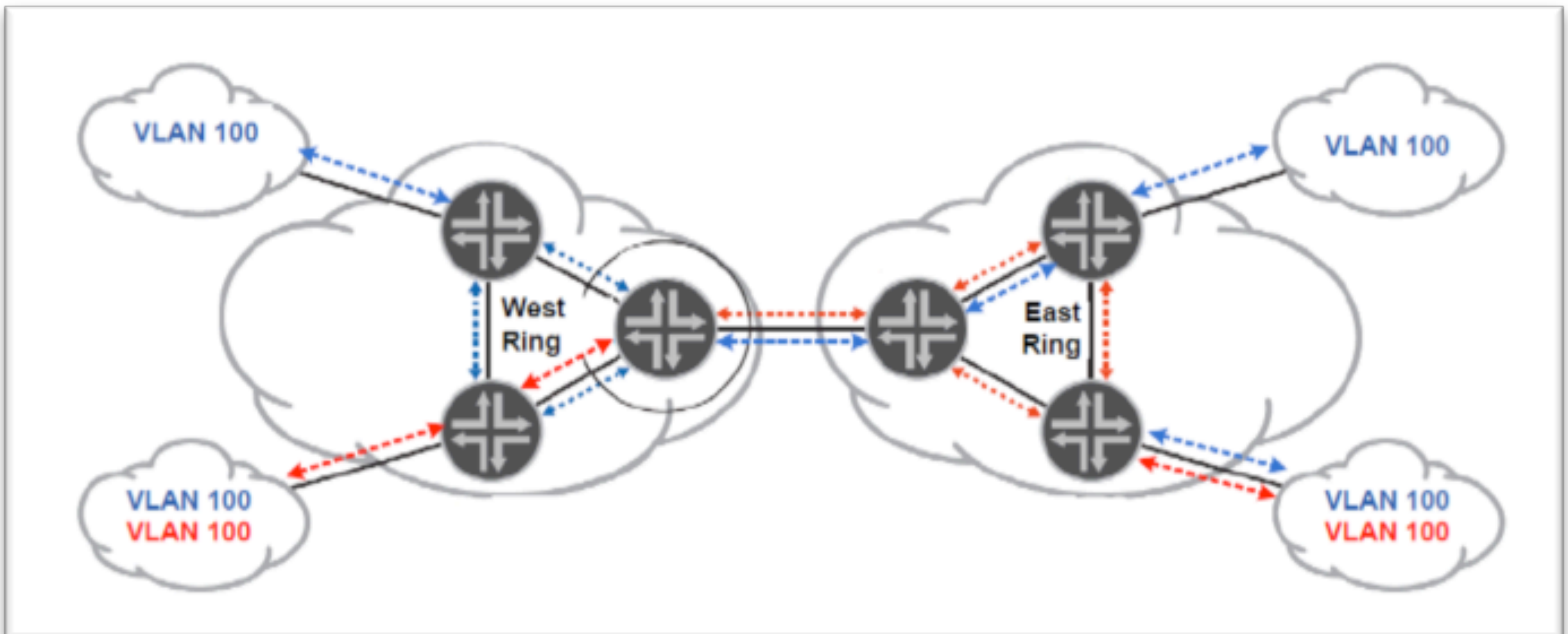
1. IP/Optical Networking enables superior Data Center protection ***without*** installing additional Interfaces

2. Total Cost of Ownership can be tuned to ***lowest cost*** per bit without compromising availability

3. Operating an IP/Optical network combines the ***reliability*** of network planning with the benefits of agile networking

Service Nodes

- **Each service node is capable of providing policy-based MPLS connection**



Expected Deployment

- **Packet Optical Release 1**
  - DWDM XFPs directly on router interfacing ADVA ROADM node
  - Peer-to-Peer CP interoperability
  - Network management visibility of DWDM interface on select routers
- **Packet Optical Release 2**
  - Tunable DWDM pluggable optics interfacing ADVA optical transport network
  - Policy demarcation point for applying protection and restoration in the transport network
  - Network management visibility across entire DWDM domain

Summary

- **GMPLS**
  - Simplified manageability
  - Improved performance and scalability
  - Reduced cost

Questions?

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