Some challenges for Optical Networking

David Boyle

Agenda

- Challenges of deploying 40Gb/s and beyond
- Ethernet for optical transport networks
- Brief overview of Internet2 activities

Deploying 40Gbps Wavelengths and Beyond

Agenda

- What are the future requirements?
- What are the options for upgrading capacity?
- Challenges of deploying 40Gb/s wavelengths over 10Gb/s Infrastructure
- What about 100G+ ?

Requirements

- **Transparency**
  - Carry any service (Ethernet SONET, SAN) at wire speed from GigE to 10GigE and beyond.

- **Capacity Growth**
  - Seamless and cost effective capacity growth which supports emerging 40G wavelength technologies.
  - Ability to add wavelengths at any supported data rate without affecting existing traffic.

Options for Future Capacity Growth

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Capacity Growth in RONs

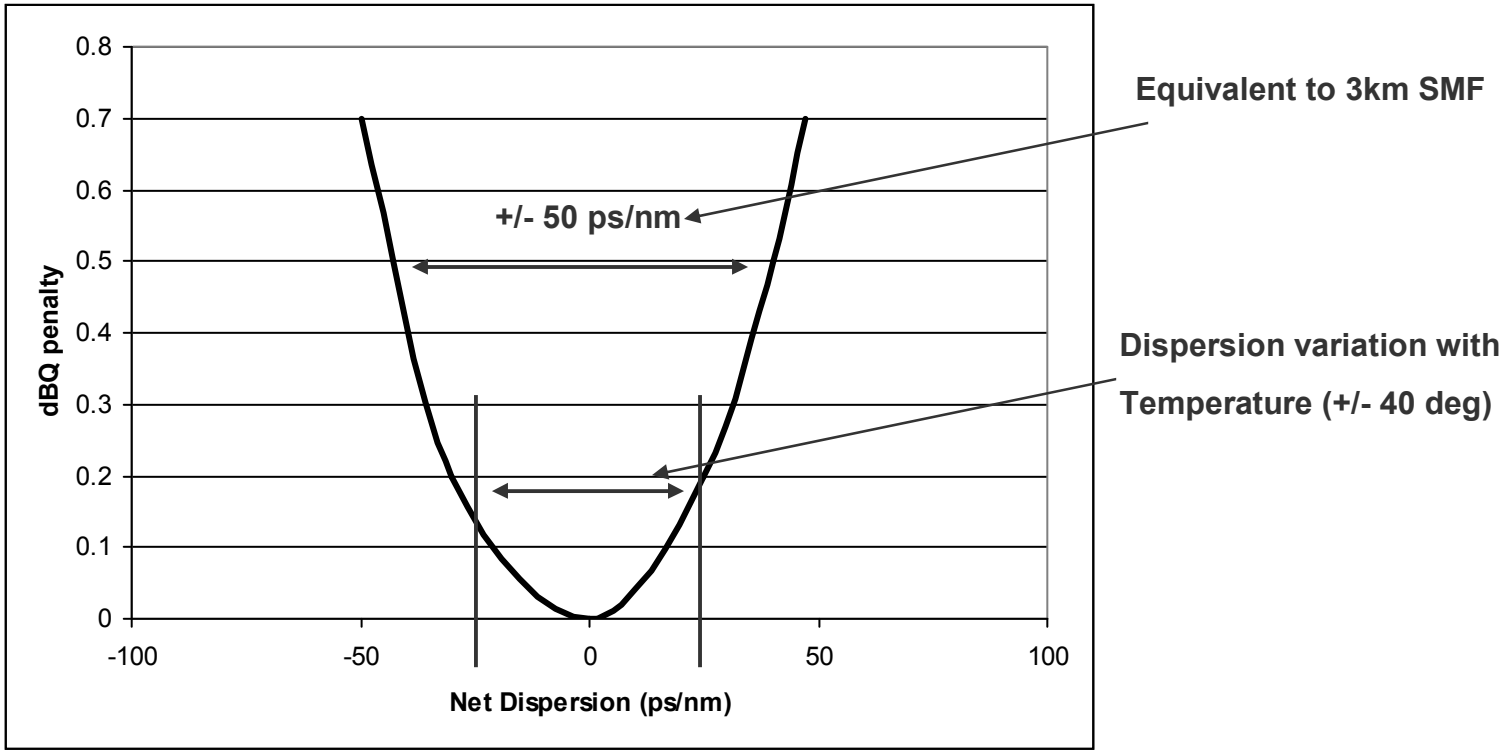
- **Continue to add 10G wavelengths in existing infrastructure.**
  - Up to 400Gb/s capacity with 100GHz spaced DWDM.
  - Accelerates fiber exhaust
- **Upgrade to 50GHz 10Gbps system**
  - Up to 800Gb/s capacity with 50GHz spaced DWDM.
  - Needs new terminal equipment.
  - Service disrupting
  - Cost effective in the longer term ????
- **Overlay 40Gb/s wavelengths in existing 10G infrastructure.**
  - No service disruption
  - Expands system capacity – delays requirement to light new fiber.

40Gb/s Challenges

- Tolerance to Chromatic Dispersion (CD)
- Tolerance to Polarization Mode Dispersion (PMD)
- OSNR Tolerance
- Spectral Width

Tolerance to Chromatic Dispersion – 40G

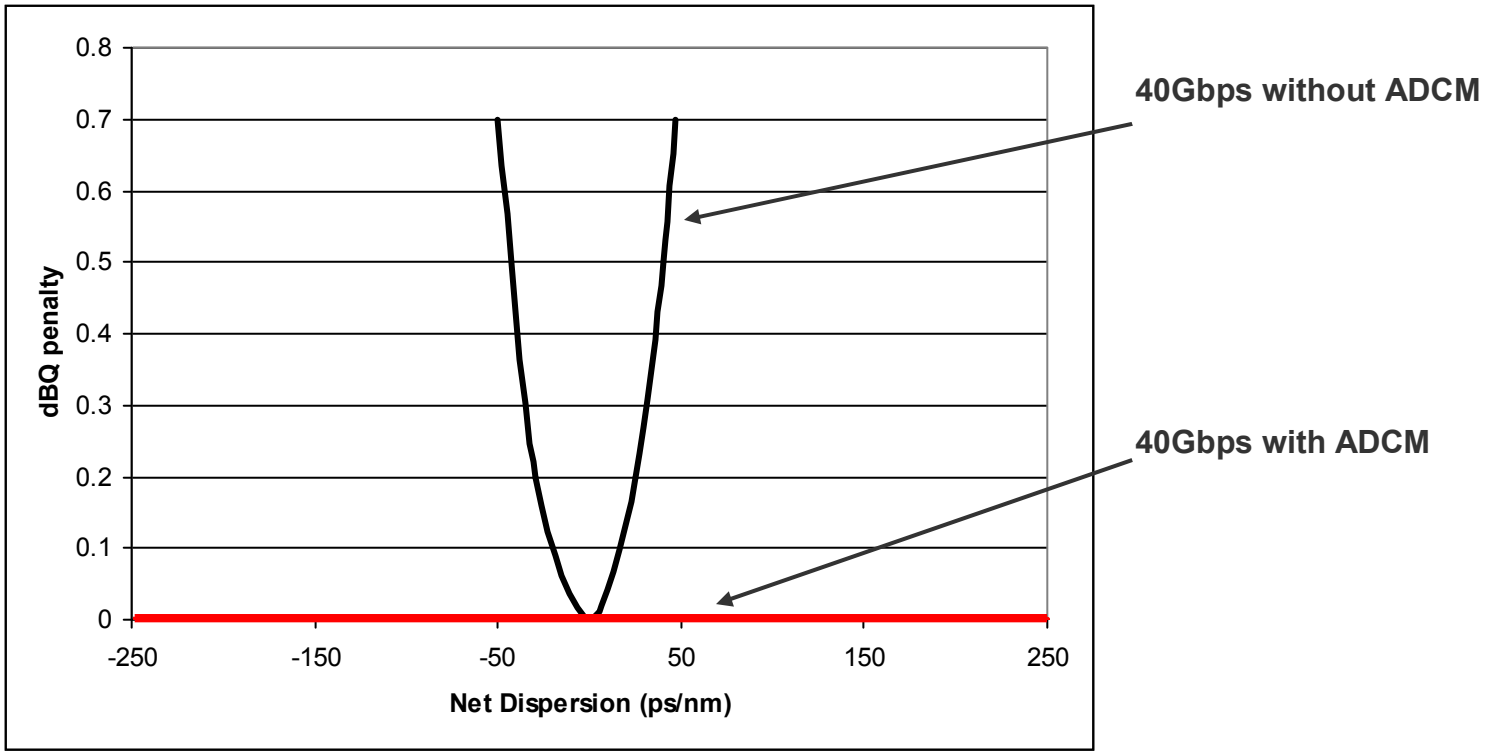
- 6 spans x 80km x 26dB SMF-28 : 32λ.
- NRZ modulation format, zero chirp, +FEC.



Impact of Dispersion Tolerance at 40Gb/s

- **So what does this mean ?**
  - 40Gb/s wavelengths need to have adaptive dispersion compensators.
  - If you plan to deploy 40Gb/s in the future, consider measuring the net dispersion as accurately as possible
  - Using other modulation formats (such as Duo-binary) increases the dispersion tolerance window by 3-4 times. Adaptive DCM can increase the dispersion tolerance significantly . . .

Impact of Dispersion Tolerance at 40Gb/s



Adaptive DCM significantly widens the dispersion tolerance of 40Gb/s systems

Adaptive DCM also tracks and cancels temperature related dispersion fluctuations

PMD Tolerance

- **Some examples**

PROTOCOL	Max PMD (1dB penalty)	Average PMD
GigE	220	60
OC48	115	30
10GigE	27	8
40G (NRZ)	7*	2*

*** Other modulation techniques can increase the PMD tolerance for 40Gb/s**

PMD Tolerance

- **So what does this mean ?**

  - Take the 6 spans x 80km SMF-28 example.

Dark Fiber Age	Average link DGD (ps)
>1995	2
<1995	10

  - With *older* fiber, the 10GigE traffic may see PMD hits on traffic
  - With *new* fiber, the 40G traffic can be supported.

  - Performing a PMD measurement on your fiber plant will define whether 40Gb/s traffic can be supported or not !

OSNR Tolerance

- OSNR required for 40Gb/s is larger than that for 10Gb/s for the same BER.
- Reach for 40Gb/s reduced compared to 10Gb/s
- CS-RZ modulation format and enhanced FEC coding on the 40Gb/s wavelengths reduces the mismatch in required OSNR.

Spectral Width

- The modulation format used for 40Gb/s will determine the spectral width.
- Wavelengths in a fully dynamic network will traverse a cascade of ROADM – Leading to filter pass-band narrowing.
- The 40Gb/s modulation format chosen (NRZ, CS-RZ Duo-binary) must be able to pass through the cascade without distortion.
- For this reason, it is likely that the 40Gb/s in a dynamic network will use spectrally efficient modulation formats (Duo-binary, CS-RZ)

What about 100Gb/s + ?

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100Gb/s

- **Native 100Gb/s transmission is not likely in the near term**
  - Development costs are high and market doesn't exist yet
  - Electrical Mux and Demux very challenging at this rate
  - Availability of optical modulators with sufficient electrical bandwidth
  - Clock recovery and FEC at this rate is difficult
- **If electro/optic components do become available . . .**
  - Spectral width ~ 150GHz so wouldn't fit into a 100GHz pass-band (<80GHz). Would need >1 bit/symbol coding
  - Dispersion tolerance ~ ± 10ps/nm. Needs ADCM !
  - PMD tolerance < 1ps
- **OTDM techniques are only approaches currently being developed for ultra high speed transmission.**

Summary

- Regional Optical Networks will require Seamless Capacity Growth and Dynamic Light-path Control.
- Deploying 40Gb/s wavelengths in existing 10G networks offers reductions in the cost per GigE as capacity grows.
- 10G switching will evolve towards Electronic ROADM as component costs continue to fall – Optical ROADM more cost effective for 40G traffic.
- If 40Gb/s is to be added to 10Gb/s infrastructure
  - Need accurate measurements of Dispersion and PMD

Summary

- 40Gb/s modulation formats are available that
  - Improve the OSNR, CD and PMD tolerance
  - Allow transport through cascaded optical ROADM
- The technology for 100Gb/s line rates is under development but not available.
- OTDM is the current approach used for single channel ultra high speed transport

Ethernet for Optical Transport Networks

Summary of Ethernet Solutions

LAN Environment for WGs, campus, etc.

WAN Infrastructure
(e.g. L2 transport & Aggregation)

WAN Enterprise Services
(e.g. P-to-P or virtual LAN)

Ethernet over Fiber
Ethernet over Wavelengths
Ethernet over SDH (GFP/VCAT)

802.3 CSMA/CD (1983)
802.1D Bridging
802.1Q VLAN

802.1ad Provider Bridging (Q-in-Q)
802.1ah Provider Backbone Bridging (Mac-in-Mac)

Provider Backbone Transport (PBT – provisioned Ethernet)

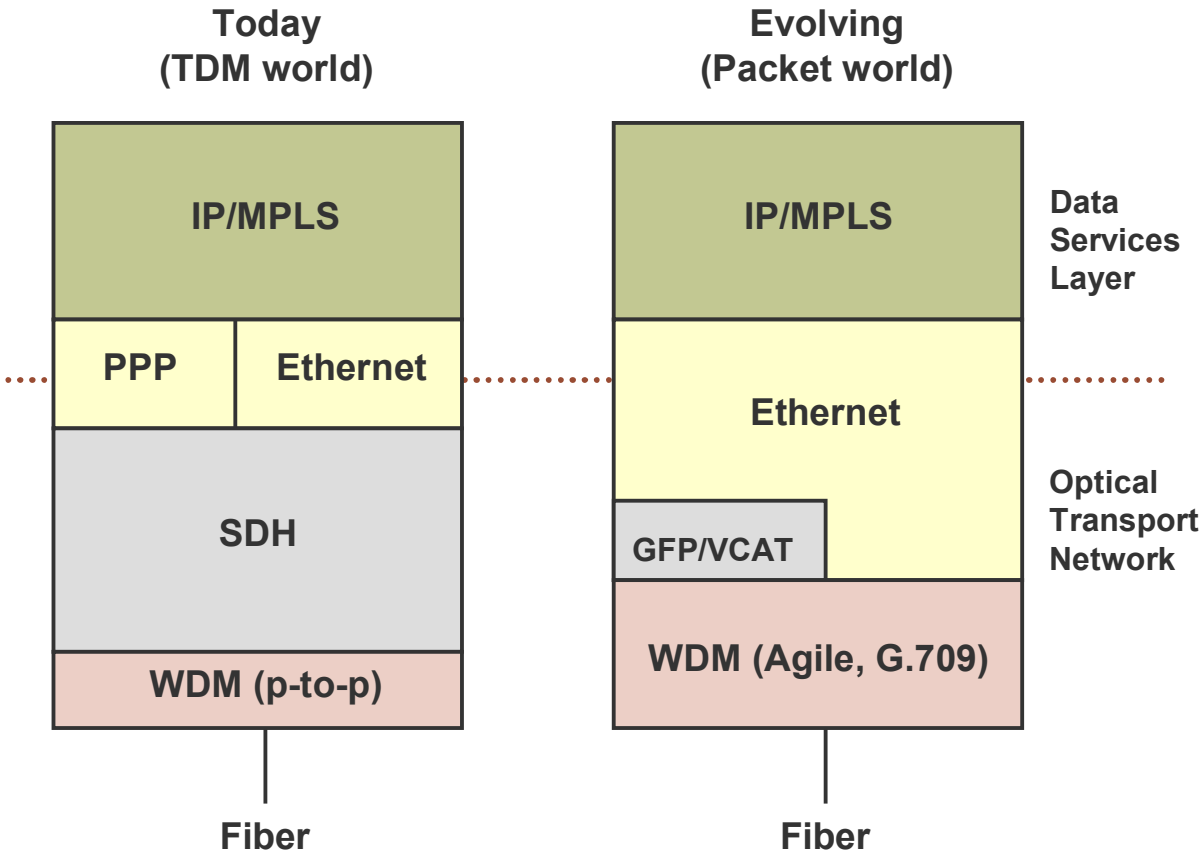
Transparent LAN Services (SONET, FR/ATM)

VPWS/E-Line services

VPLS/E-LAN services

How will Ethernet integrate/evolve into optical networks and how will it provide value?

Networking Layers for IP Traffic

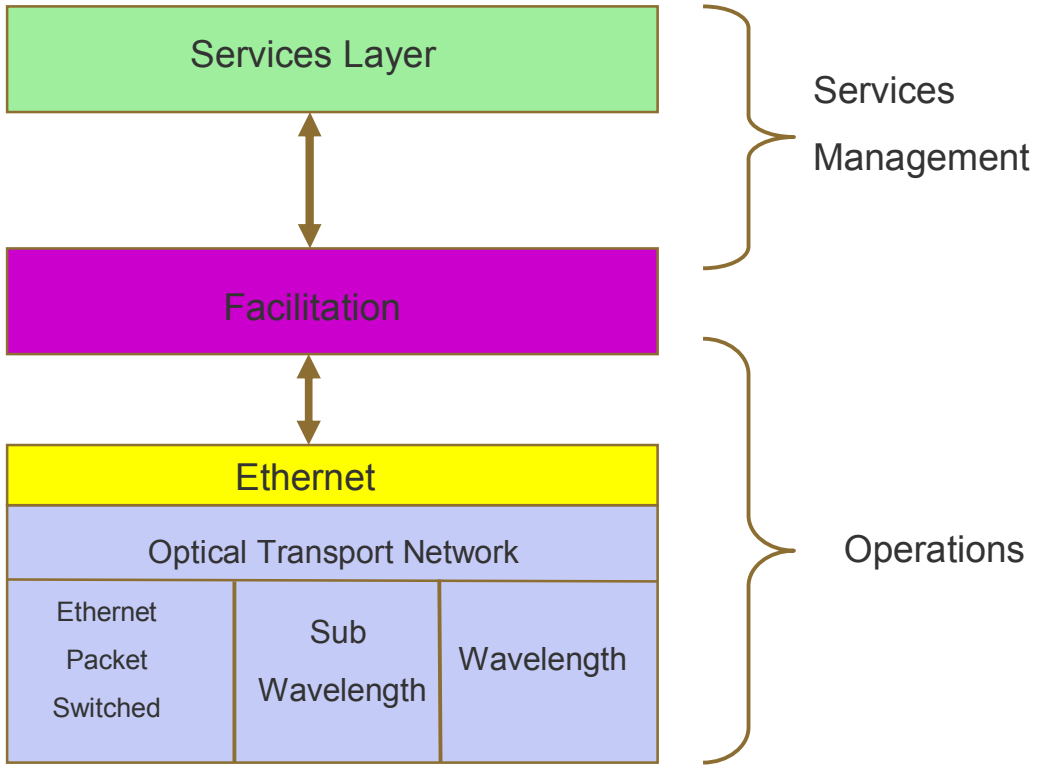


- The evolution is happening due to the major shift of traffic from TDM to IP
- Ethernet will become a major transport interface and assume more networking responsibility
- The WDM layer will become more agile and intelligent (e.g. G.709, ROADM, GMPLS)

Ethernet For Optical Transport Networks

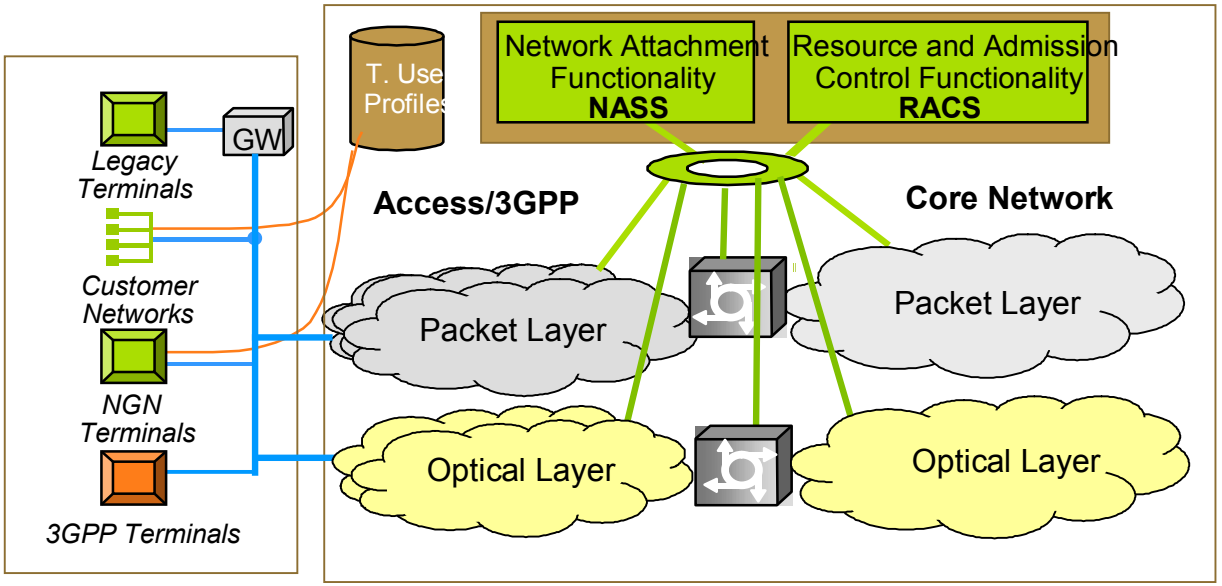
- **Network operators looking to leverage Ethernet in their networks**
  - Standardize on Ethernet as an interface
  - Leverage cost advantages of Ethernet
  - "Optimize" Ethernet networking functions for optical transport networks
    - Not all Ethernet "Enterprise networking" functions optimal for network operators
- **Use Ethernet as a "Tunnel Support" protocol**
  - Creates "circuit orientated" end to end Ethernet tunnels
  - Single service facilitation methodology for service delivery
  - Precedent set with IP core networks where MPLS is used
- **Range of standards based Tunnel methodologies under discussion**
  - IEEE: Provider Backbone Transport; 802.1ah
  - IETF: Pseudowire, T-MPLS

Ethernet & Service Layer Abstraction



- Abstract direct connection between Service Management & Operations for network infrastructure
- Service Management Object operationalization
  - Map service to “artifact” (Tunnel/Circuit)
  - Map artifact to Optical Transport Network infrastructure
- Facilitation Layer provides
  - Common methodology for the delivery of services
  - Circuit/Tunnel based networking
    - Standards based
    - Inter operator handoff
  - End to end tunnels that are business routable
- Ethernet used as the common interface to the network infrastructure

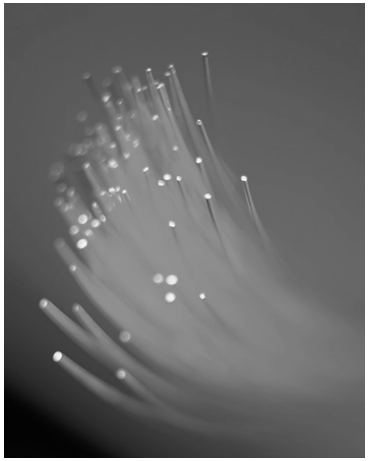
New NGN Transport Stratum



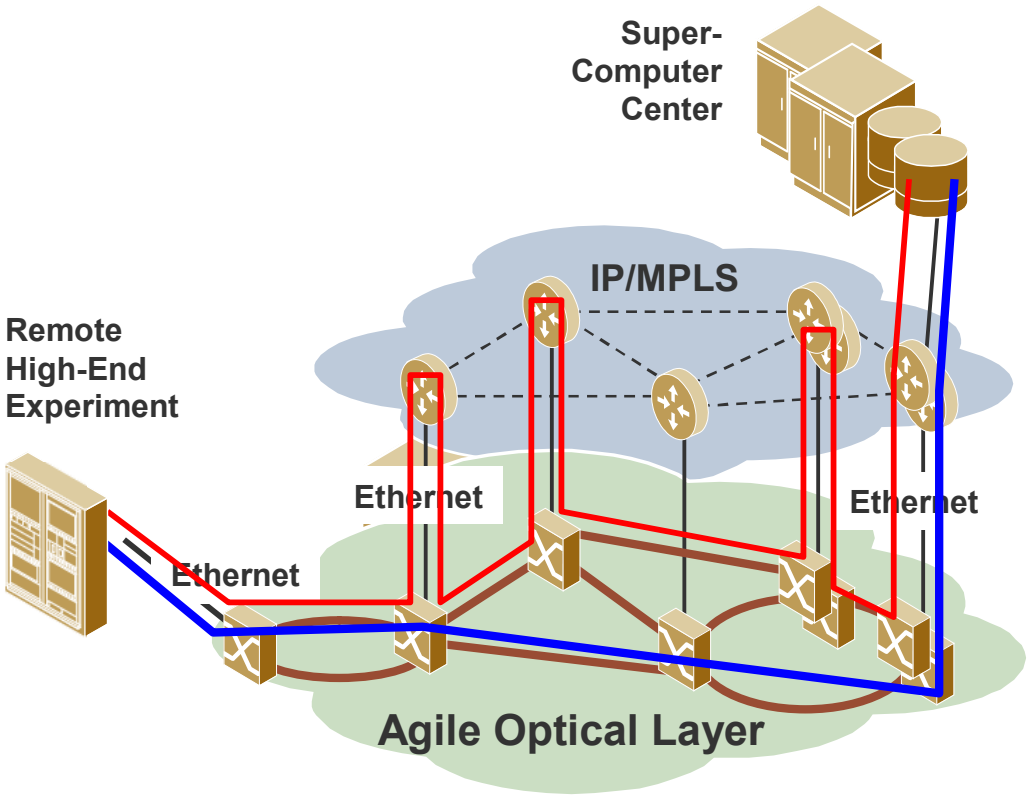
- **Transport Stratum Will Require Packet & Optical Layers**
- **Common Service facilitation methodology will enable services to be delivered from both the Packet & Optical layers within the Transport Stratum**
  - **Service delivered from optimal transport layer to match required service attributes**
- **In this dynamic environment we should not link functional components to h/w platforms**
  - **Historical precedent says that abstraction provides scalability and flexibility**

Ethernet Optical Transport Networking (L0/L1)

- **P-to-P transparent Ethernet transport in optical layer**
  - High QoS (i.e. low latency and delay)
  - Reliability, security, simplicity, etc
- **Wavelength level**
  - P-to-P full-rate transport
  - GigE, 10GigE, 2:1GigE muxponder, 10:1 GigE muxponder, etc
  - Provisioning & protection via intelligent point & click NMS or GMPLS
- **Sub-wavelength level**
  - P-to-P full and partial rate transport (e.g. 150 Mb/s granularity)
  - GFP/VCAT – N x Ethernet on 2.5G & 10G wavelengths
  - Networking via mature SDH/SONET HO network switching technology
  - Provisioning & protection via intelligent point & click NMS or GMPLS



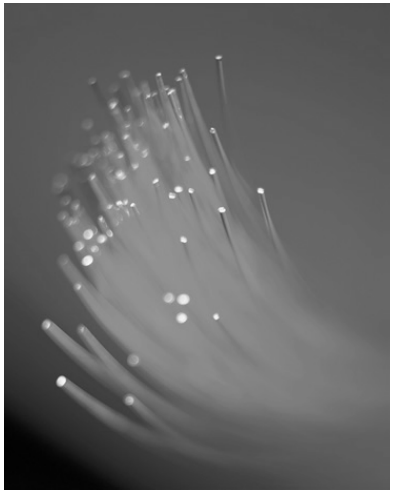
Ethernet/L1 Optical Transport
- High capacity circuits with predictable QoS



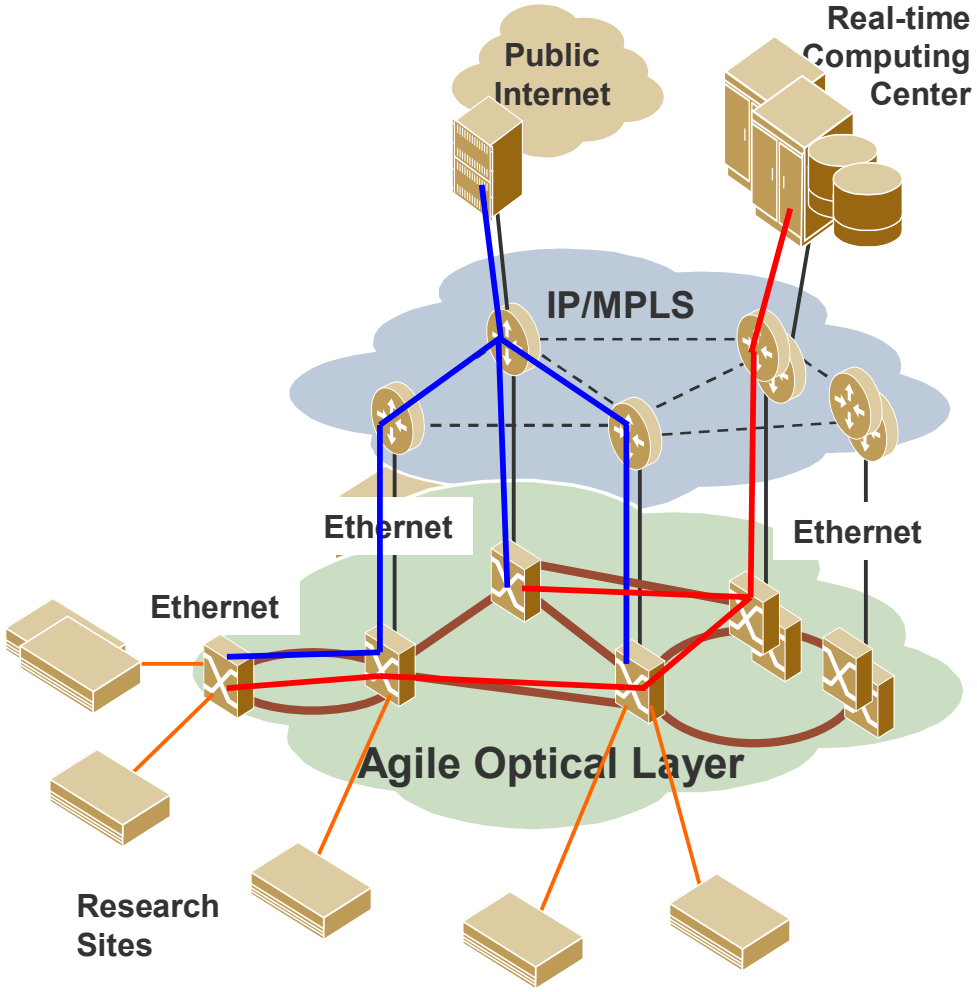
- **Some applications require an optical network that can deliver flexible high QoS GigE optical paths**
  - Low latency & jitter
  - Predictable QoS
- **End-to-End path management of individual GigE optical paths**
  - Point and click provisioning
  - Protection & Bridge-and-Roll of Ethernet paths

Why focused L2 functionality into Optical Transport Networks

- **Major traffic evolution to packets over Ethernet**
- **Ethernet is becoming a key transport bearer interface**
  - For overall network optimization, the optical WDM network needs to provide some Ethernet functionality at the packet level (e.g. aggregation, switching, restoration) much the same way that SDH/SONET transport did for TDM traffic
- **Optimize the hand-off to data services layer**
  - e.g. eliminate potential port explosion issue, optimize use expensive router ports, etc
- **Off-load some L2/Ethernet functionality from data services layer (e.g. bulk forwarding, simple p-to-p E-Line services)**
- **Summary: CAPEX & OPEX savings, and reliability advantages**
- **Evolution Of Optical Layer Intelligence**
  - Ethernet Gateway functions in the optical layer
  - Optimize handoff of Ethernet from Optical layer



Agile Optical/Packet Networking
- Wavelength and Optical Ethernet



- **802.1ad VLAN tagging can be a starting point for small access network**
  - MPLS to scale and interconnect VLAN domain
- **Evolve to Tunnels**
  - Scalability
  - Ethernet End-to-end
  - OAM
  - Security
  - Network operations and maintenance (deterministic)

Summary: Agile Optical Networking

- **Agile/flexible WDM layer**
  - No single topology (ring, linear, mesh etc)
  - CWDM, DWDM, and/or ROADM
  - End to end optical path planning and management
- **Ethernet wavelength-level networking**
  - Transparent P-to-P full rate Ethernet circuits
- **Ethernet sub-wavelength networking**
  - End-to-end predictable Ethernet paths (i.e. TDM-like)
- **Ethernet L2 aggregation and distribution**
  - Optimize hand-off to data services layer
  - Intelligent bulk traffic distribution at packet level

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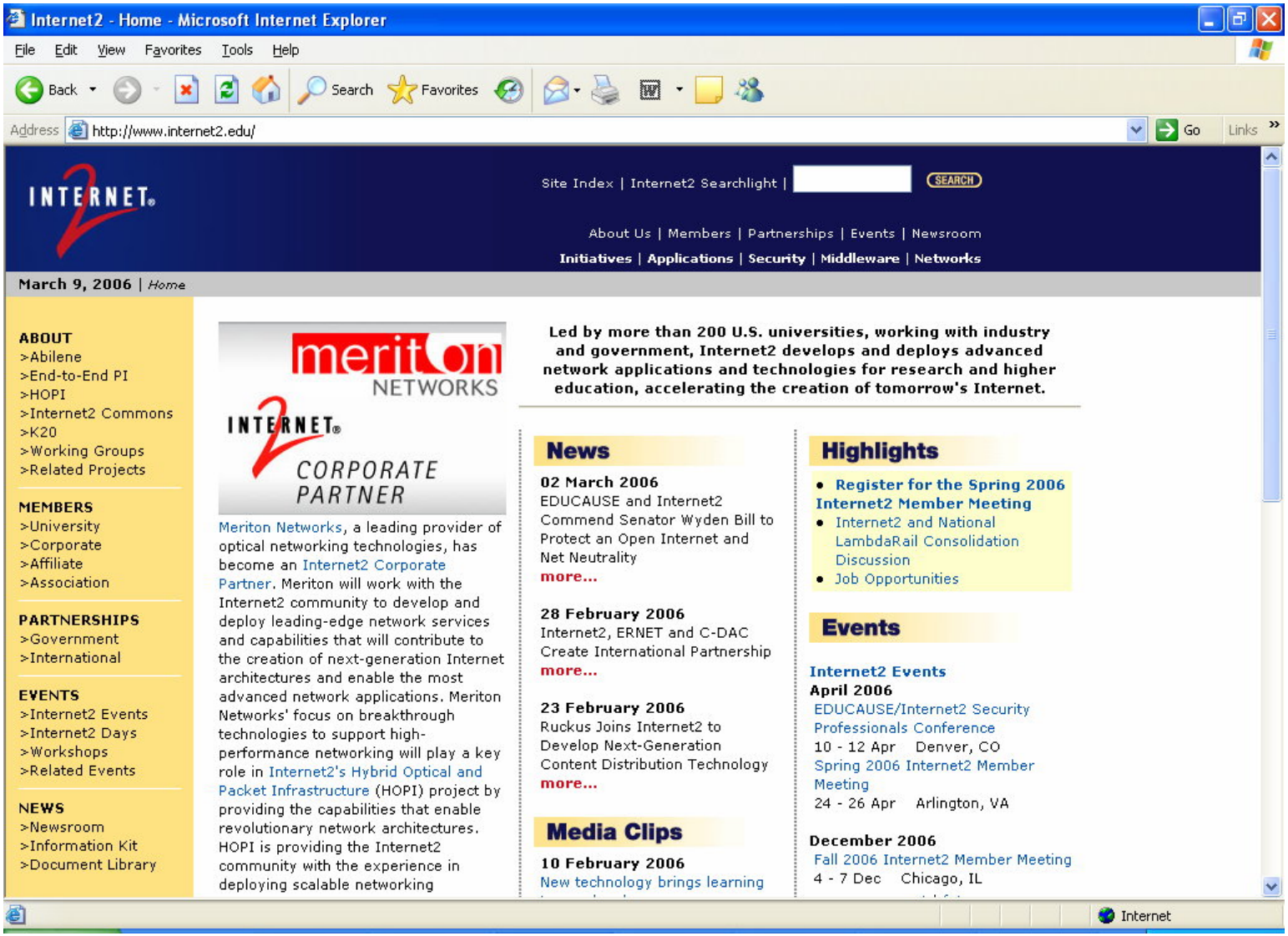
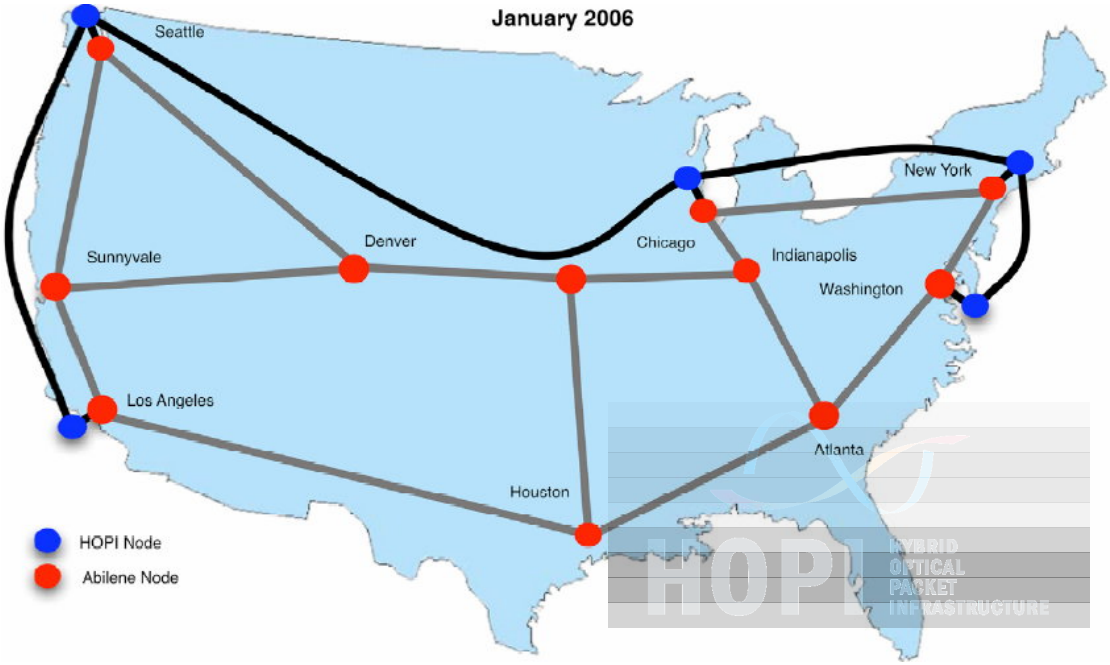
Meriton and Internet2

Meriton and Internet2



HOPI



Internet2's HOPI Overview:

In planning for architectures needed beginning in 2007, we are aiming at designing and building **a hybrid of shared IP packet switching and aggressive use of dynamically provisioned optical lambdas**. We use the term HOPI (for hybrid optical and packet infrastructure) to denote both the effort to plan this future hybrid and the set of testbed facilities we will build to test various aspects of candidate hybrid designs.

The eventual hybrid will require a rich set of wide-area lambdas with IP routers and lambda switches capable of very high capacity and dynamic provisioning, all at the national backbone level.

The HOPI Corporate Advisory Team

The HOPI Corporate Advisory Team

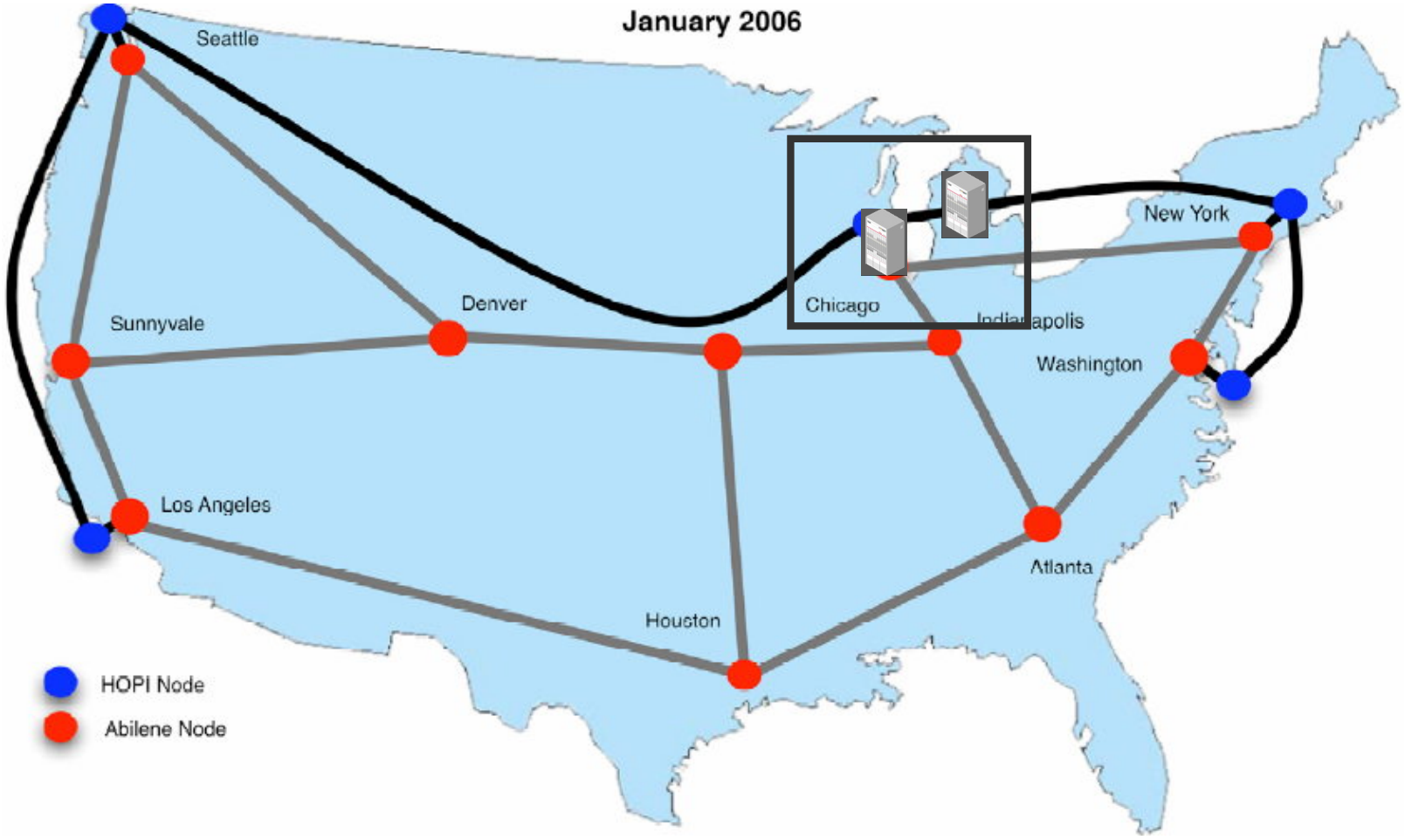
The HOPI Corporate Advisory Team is a distinguished panel of Internet2 corporate members that advise both the HOPI Design Team and Internet2 on the HOPI project. The team brings technical expertise in packet and circuit switched technologies, control plane design and implementation, measurement technologies, and management of hybrid networks. An important aspect of the HOPI CAT will be promotion of technology transfer including implementation of innovative ideas in test bed environments, testing basic principles and features, engaging standards bodies to create viable operation standards, and promoting the transfer of new ideas to the marketplace and community.

Members of the HOPI Corporate Advisory Team

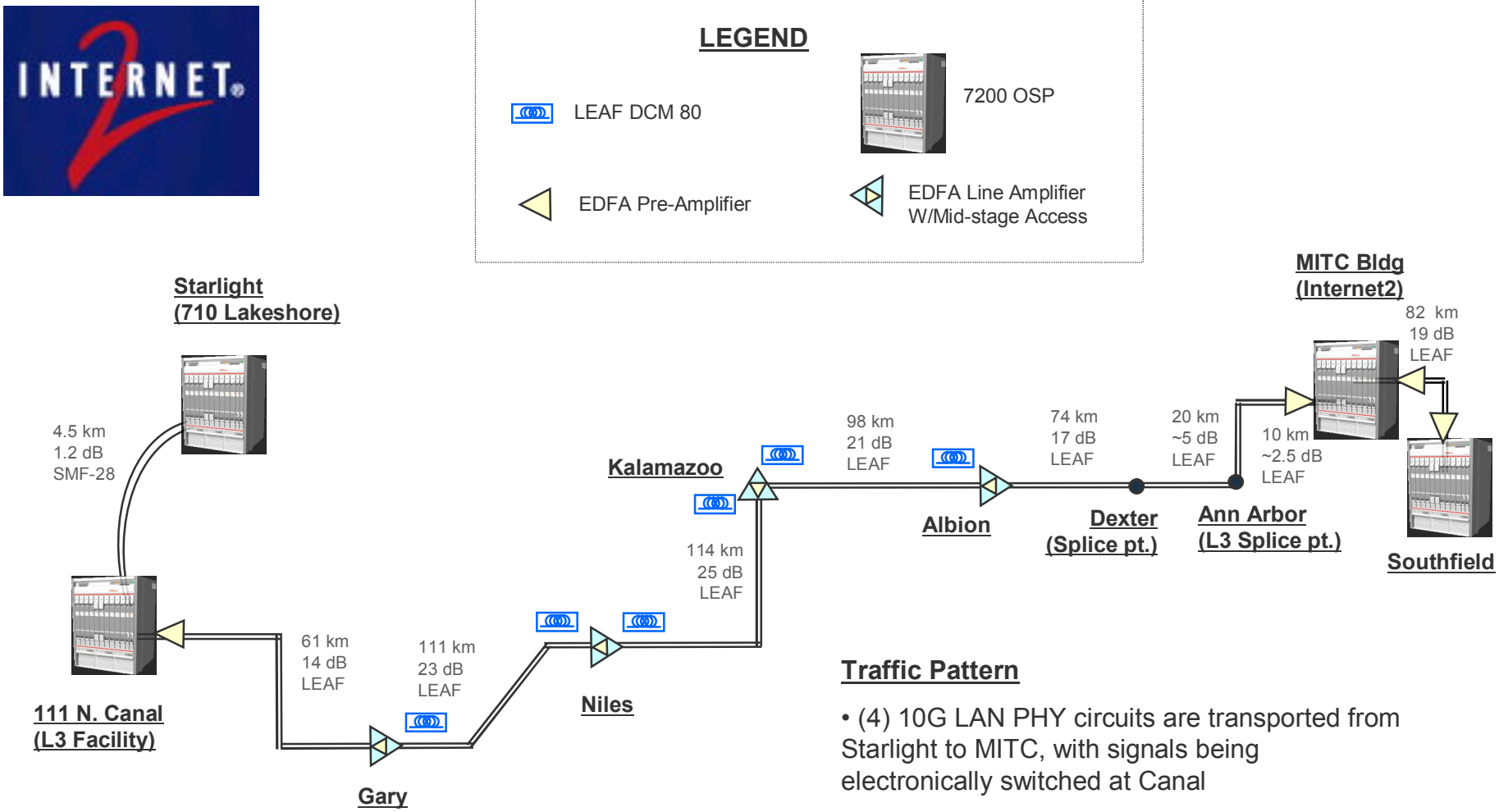
Here are the current member of the HOPI Corporate Advisory Team:

- Scott Beaudoin - Wiltel Communications
- Eric Bernier - Nortel Networks
- Javad Boroumond - Cisco Systems
- Jeffrey Burgan - Comcast Cable
- Dennis Gallant - Meriton Networks
- Abdul Kasim - ADVA
- Waqar Khan - Qwest Communications
- Puneet Sharma - HP
- Shiro Ryu - Japan Telecom
- Marty Schulman - Juniper Networks
- Raju Shah - Force10
- Madan Shastri - Global Crossing
- Richard Solis - Movaz Networks
- Jeff Verrant - Ciena
- Kennard White - Glimmerglass Networks

Meriton Deployment at Internet2



Electronic ROADM Option
10G Transport - Chicago to Ann Arbor



Traffic Pattern

- (4) 10G LAN PHY circuits are transported from Starlight to MITC, with signals being electronically switched at Canal
- (4) 10G LAN PHY circuits are transported from Starlight to Southfield , with signals being electronically switched at Canal and MITC Bldg

Details of Internet2 Application

- **Traffic Pattern**
  - (4) 10G LAN PHY circuits are transported from Starlight to MITC, with signals being electronically switched at Canal
  - (4) 10G LAN PHY circuits are transported from Starlight to Southfield , with signals being electronically switched at Canal and MITC Bldg
- **Design assumes all-inclusive losses and fiber types as indicated**
- **Design assumes two fibers are available per span**
- **Network will support growth to 40 lambdas**
- **Network is 2.5G and 10G-ready**
- **All traffic is unprotected by the DWDM equipment**

Summary

- Challenges of deploying 40Gb/s and beyond
- Ethernet for optical transport networks
- Brief overview of Internet2 activities

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Thank You!
Any questions?

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