Advances in Optical Networking Technologies: Transmission and Switching Techniques for Tb/s of Optical Data

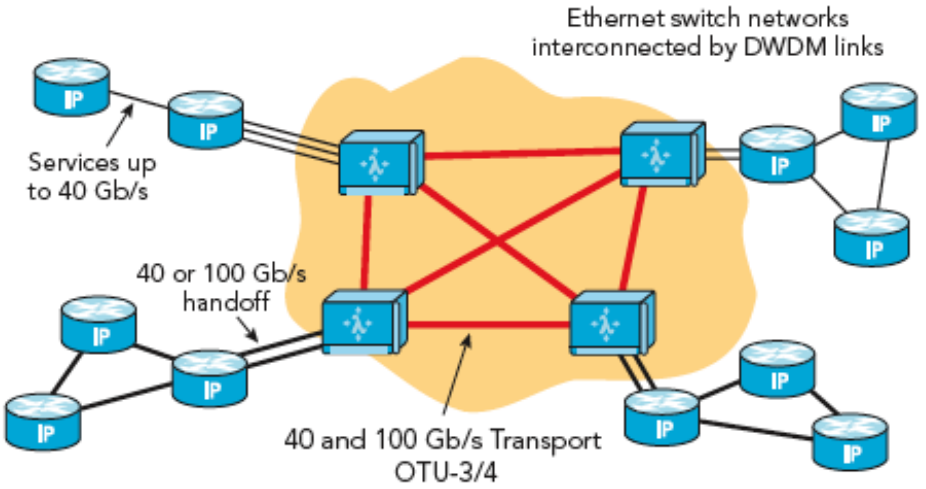
- Dr Colin Wallace
- Product Line Director, Ciena

- 26th June 2009

Overview

- **Need for Speed: 10Gbs – 40Gbps – 100Gbs**
- **Techniques for achieving High Speed Optical Transmission**
- **Automation and Switching of High Speed Optical Lightpaths**

Market Pull for 10



Router-to-Router interconnect

Avoid link aggregation (limited to 8 ports)

Capacity relief on congested links

Avoid cost of turning up a new fiber pair

Improved Data Center performance

High-speed Ethernet network fabric for server virtualization

Specialized applications for Government and Research & Education

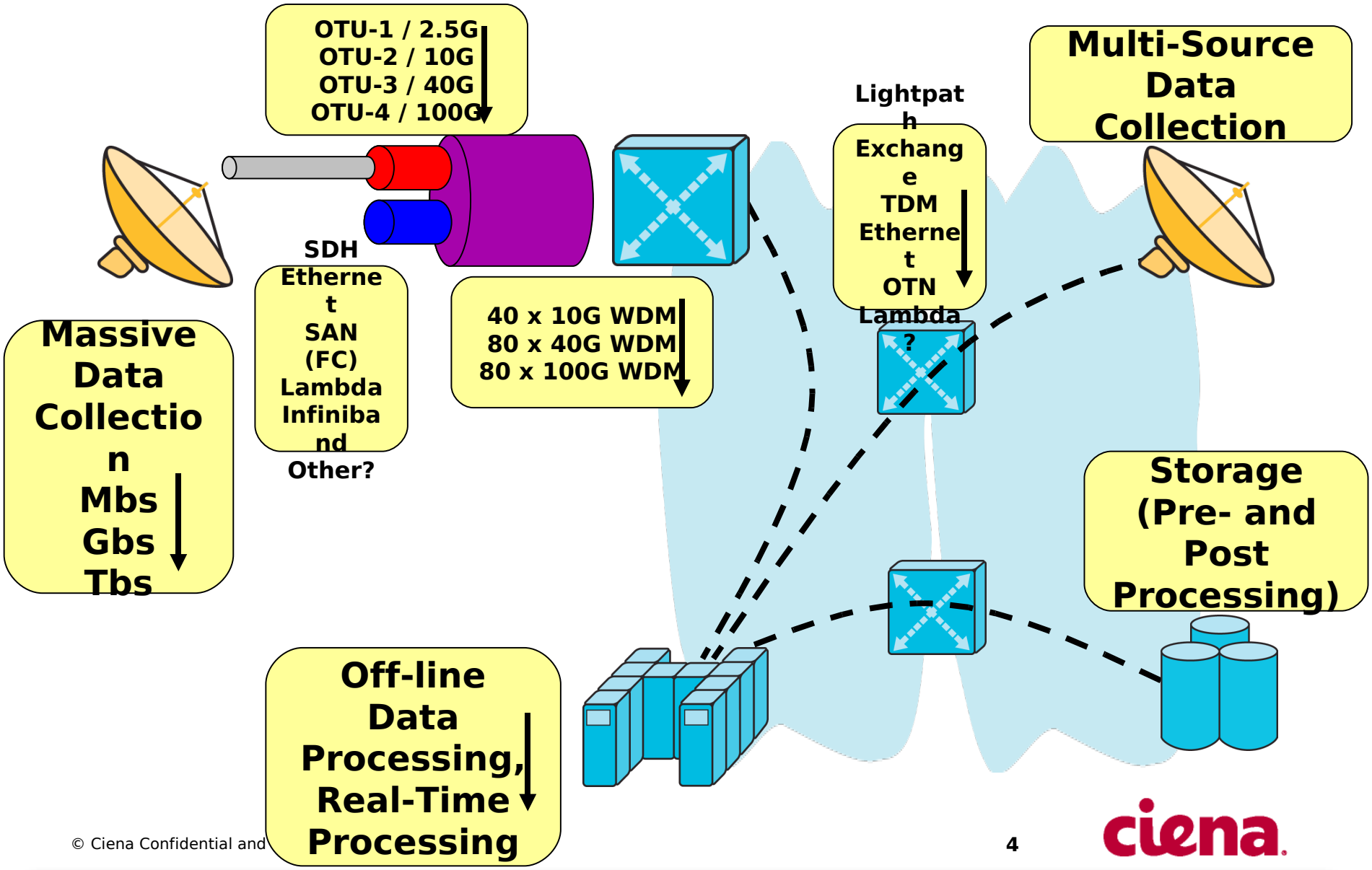
Provide high-speed, high-performance private lines

SDH capped at 40G

Growing demand for 100G

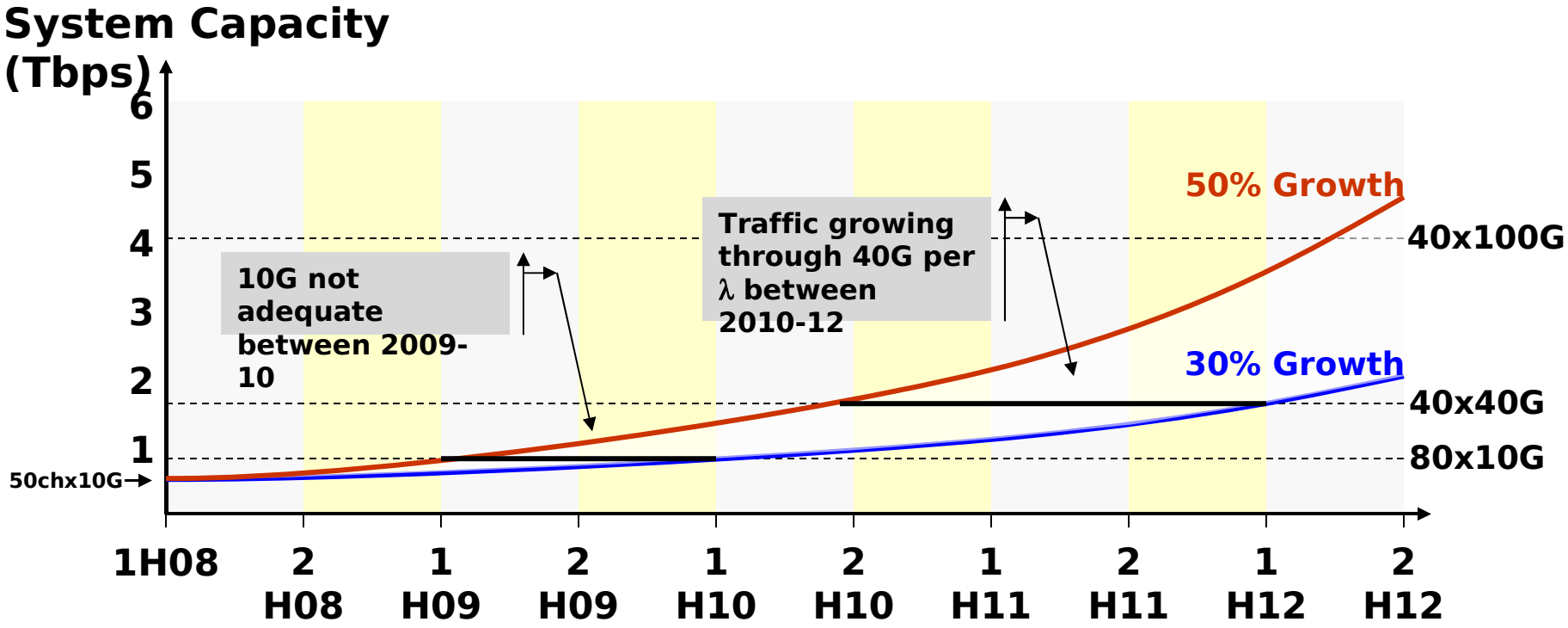
ciena

Scientific Application Pull for 100G



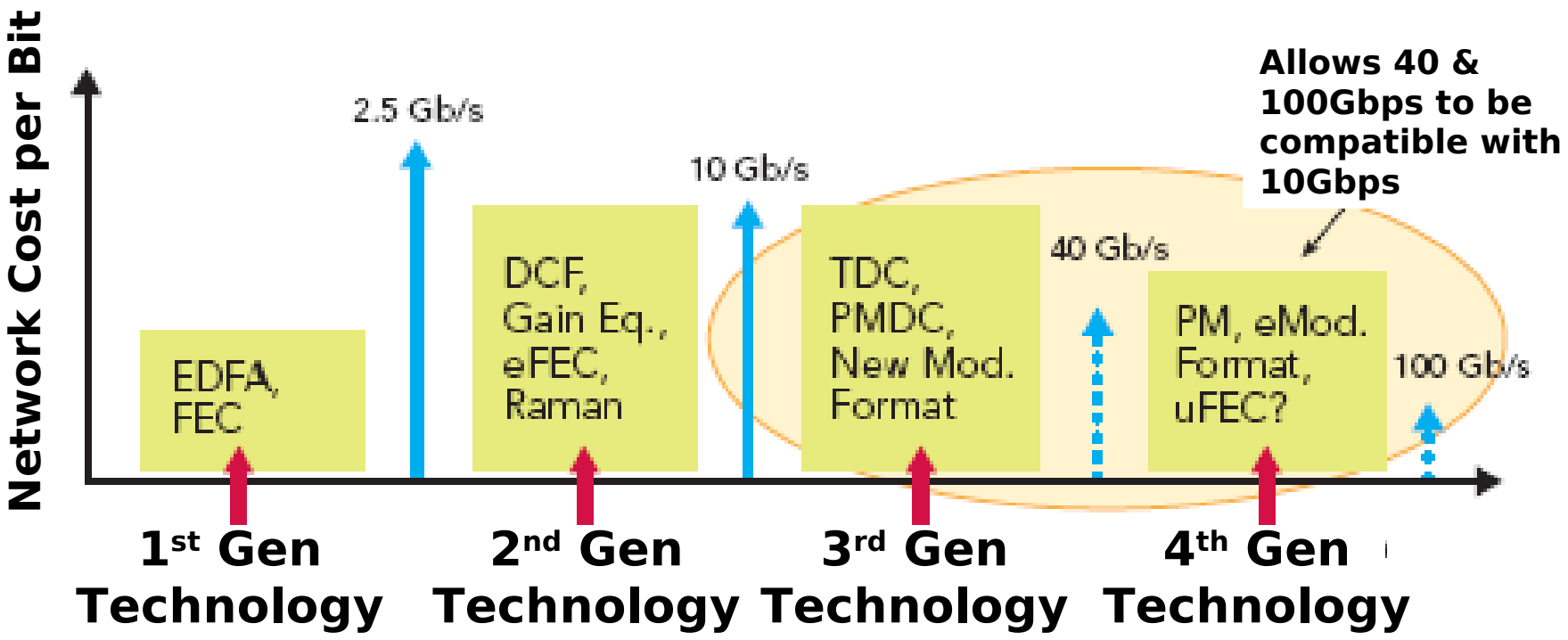
Growth is outpacing optical capacity

And this is just Telco Demand – Science will exceed



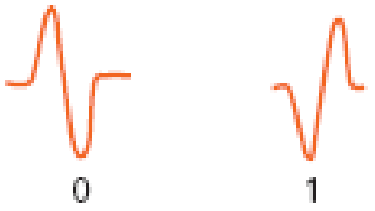
ciena

Evolution of Transmission Technology

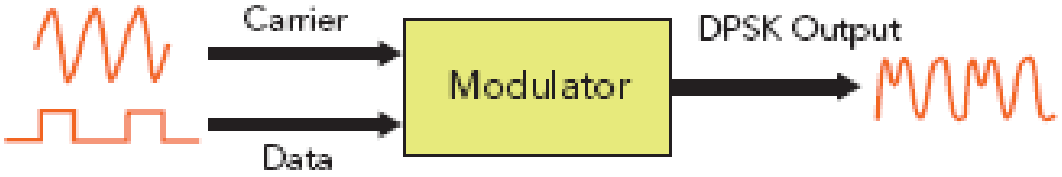


Evolution of Modulation Formats

- **Differential Phase Shift Keying (DPSK)**
  - Data is superimposed on carrier wave and phase-shifted
  - Useful for 40 Gbps
  - PMD issues limit reach at 100 Gbps

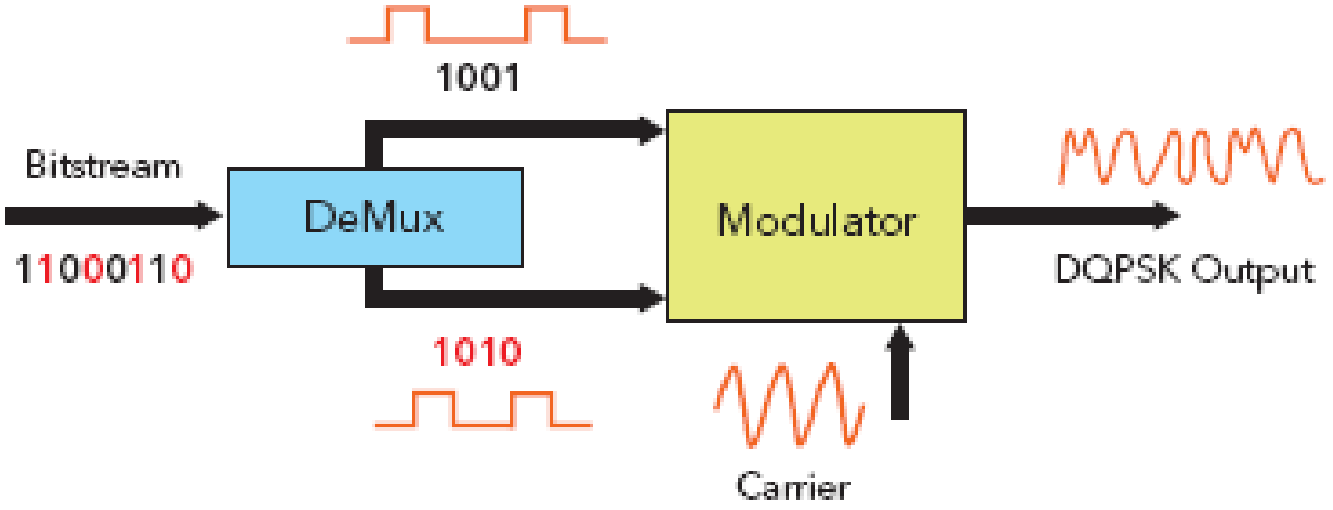


Bit Values defined by Phase of Wave



Evolution of Modulation Formats

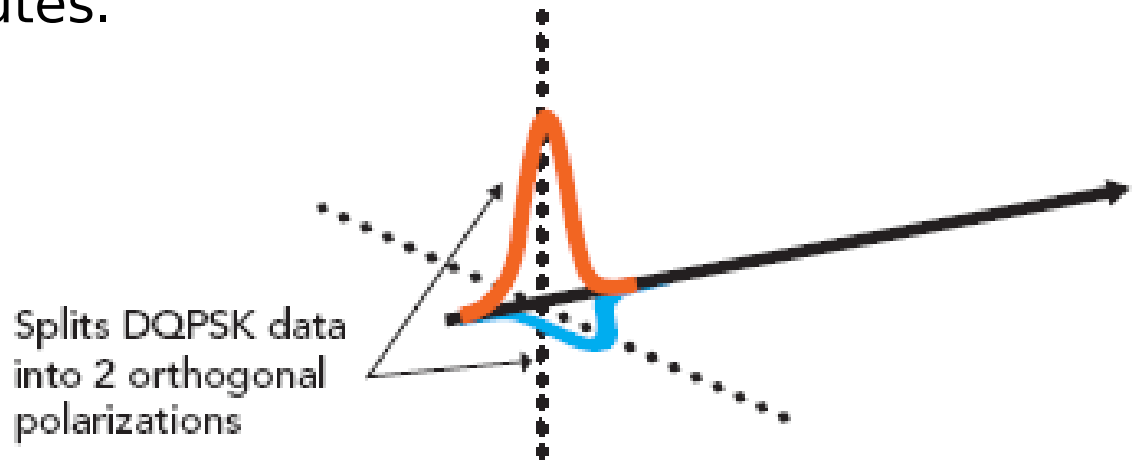
- **Differential Quadrature Phase Shift Keying (DQPSK)**
  - Splits the stream into two data channels
    - **each equivalent to 50Gbps for a 100Gbps line rate**
  - Allows 100 Gbps transmission on fibers not



Evolution of Modulation Formats

Polarization Multiplexing for DQPSK (PM-DQPSK)

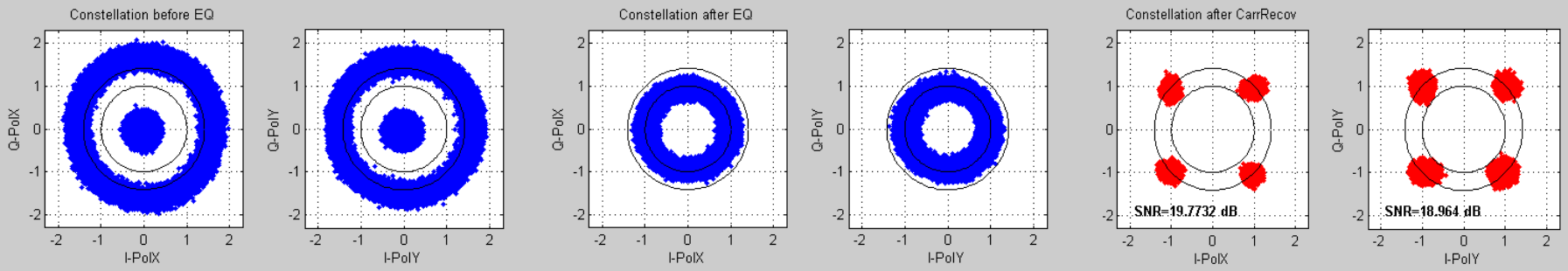
- → Split the DQPSK modulated waves into respective polarizations
- → Effective symbol rate is 25 Gbps for 100 Gbps line rate
- → Improves performance of signal with impaired fiber links
- → PMD compensation required only on PMD-impaired routes.



Evolution of Modulation Formats

Coherent PM-QPSK

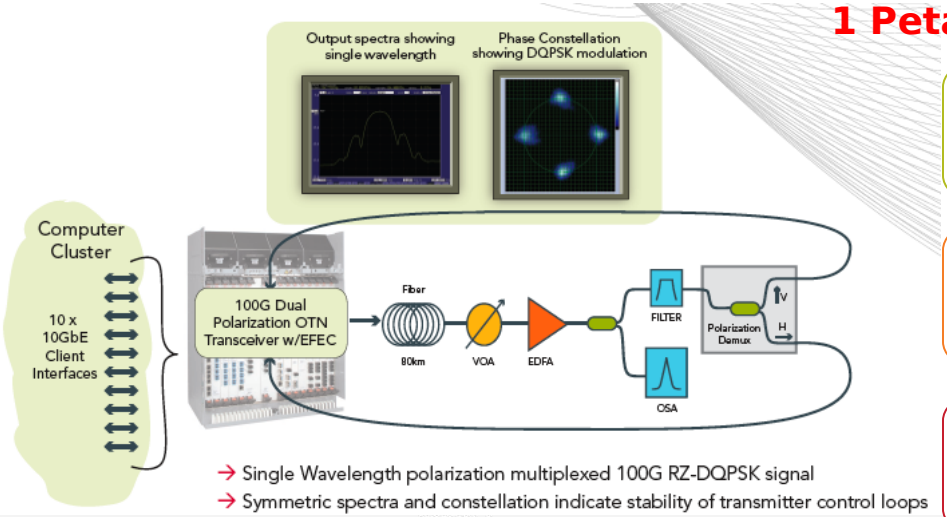
- → Same as PM-DQPSK on the transmitter side
- → Coherent receiver is employed
  - →**incoming signal is coupled with a local oscillator and detected.**
- → Coherent receivers have superior sensitivity over incoherent detection
- → Eliminates the need for dispersion compensation
- → Less sensitive to PMD



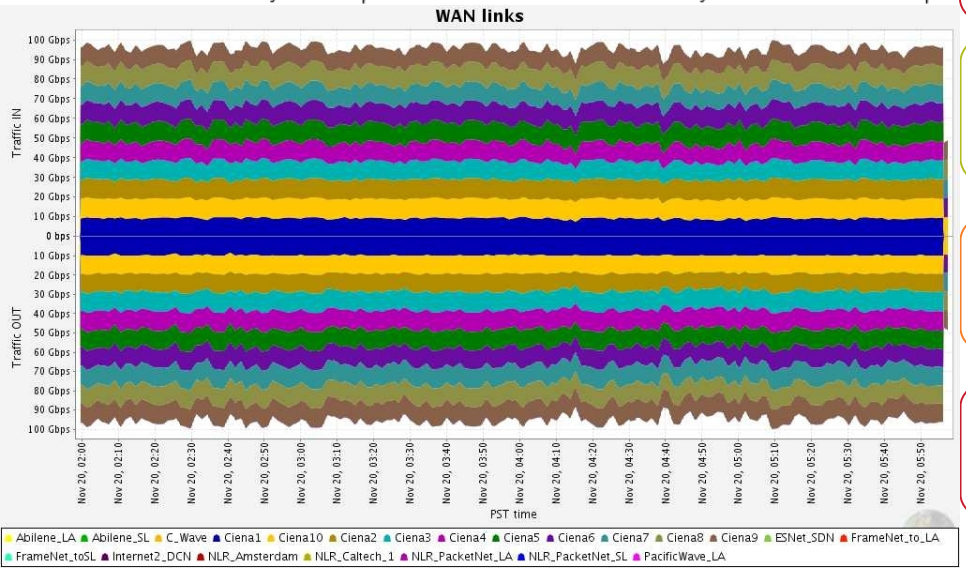
100G & Supercomputing'08 Demo
The Road to 100G: > 8Tb/s with Ciena

CALTECH

1 Petabyte of data transfer in 12hours on 1 wavele



→ Single Wavelength polarization multiplexed 100G RZ-DQPSK signal
→ Symmetric spectra and constellation indicate stability of transmitter control loops



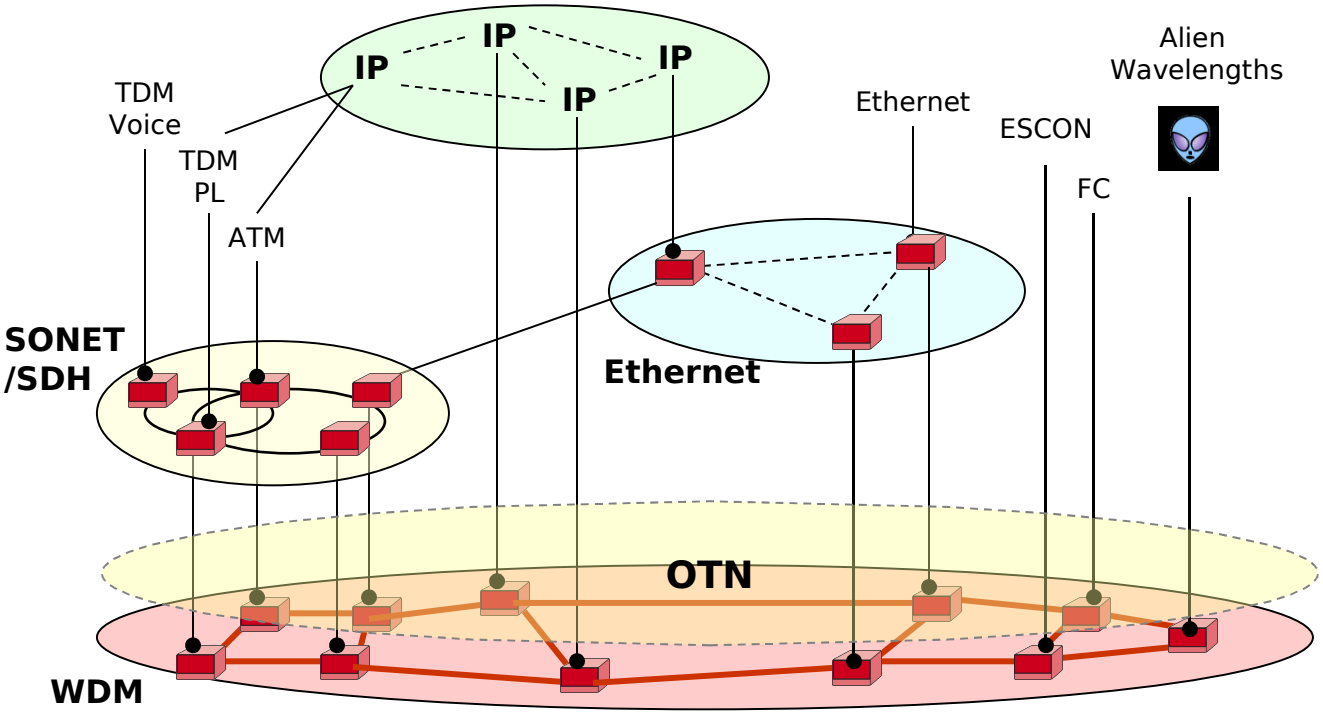
- Single Wavelength 100G @ 50Ghz Spacing
  Full C-Band Tunable, ROADM Compliant (40G width)
- Asynchronous Multiplexing 10x10G (client transparency)
  Any 10G Client on Any Port
- 100G 8dB+ Enhanced FEC
- Polarization Multiplexed
  RZ-DQPSK Modulation Format
- Low Latency
- Commercial Form Factor

ciena

Build this Slide

OTN Simplifies The Optical Infrastructure

High Speed LightPaths with Control



OTN Allows for a Flexible, Multi-Service Infrastructure

SONET/SDH is Managed Transport "Server" layer for existing service "clients"

IP builds over WDM

… so does Ethernet

… and ESCON, FC, λ services

WDM augments SONET/SDH capacity

ciena

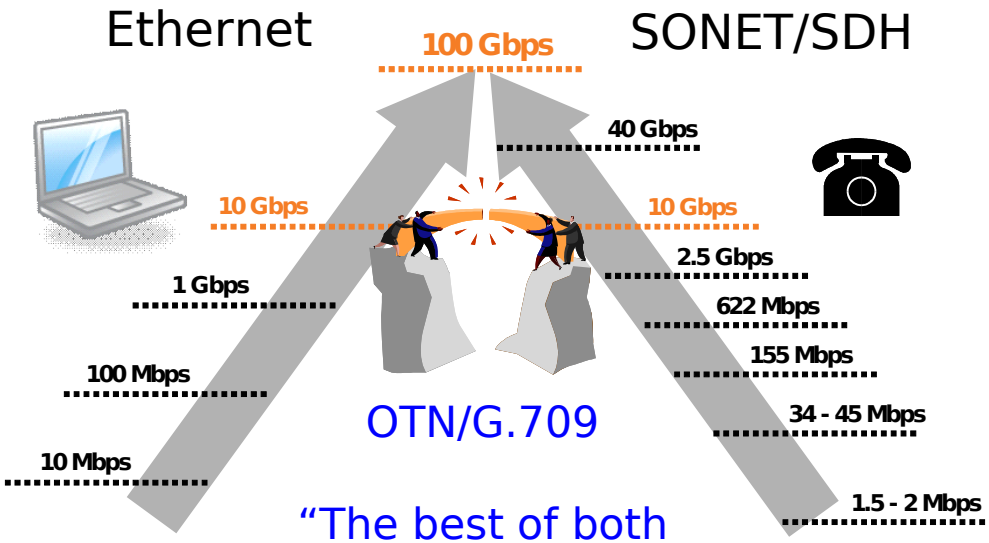
Why is OTN Gaining in Popularity?

Positives

Easy to install
No timing worries
Low cost components

Negatives

No physical layer PM
Poor fault isolation
No legacy service support



Positives

Bulletproof Service
Industry Standard PM
Fault Isolation

Negatives

Complex timing
Expensive
Not designed for today

ulti-service transport for today's networ

Easy to install
No timing worries
Low cost components

Bulletproof Service
Industry Standard PM
Fault Isolation

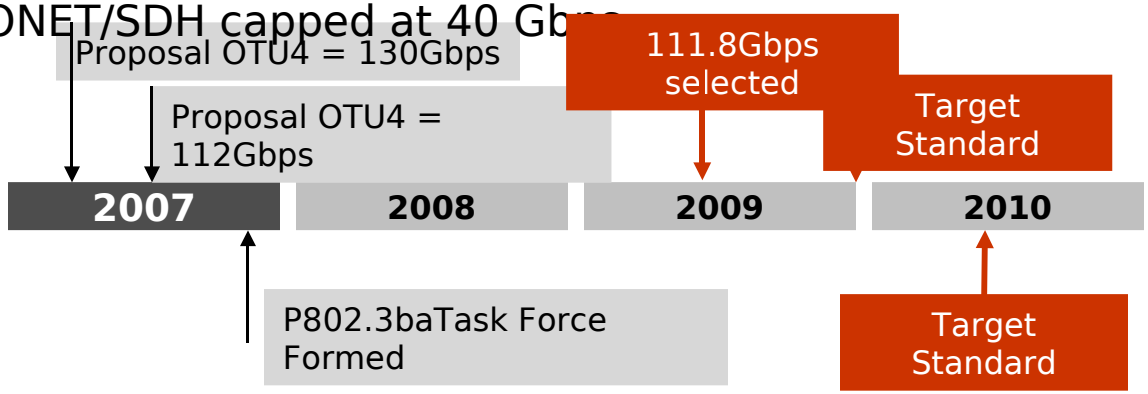
OTN balances the benefits of SONET/SDH and Ethernet

ciena

100G Standards Development

Definition of G.709 OTU-4 — ITU-T Study Grp 15

- Extending G.709 to OTU-4 (June '09 agreed to be 111.809973568 Gb/s)
- SONET/SDH capped at 40 Gbps



Definition of 40GbE & 100GbE Task Force — P802.3ba

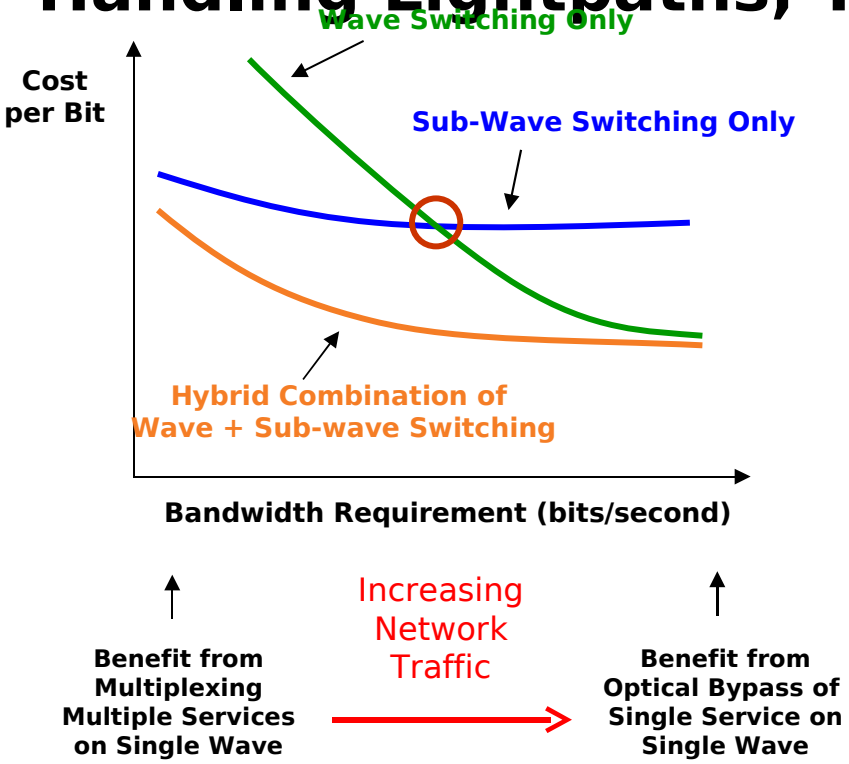
- Preserves 802.3 Ethernet frame
- Supports OTN

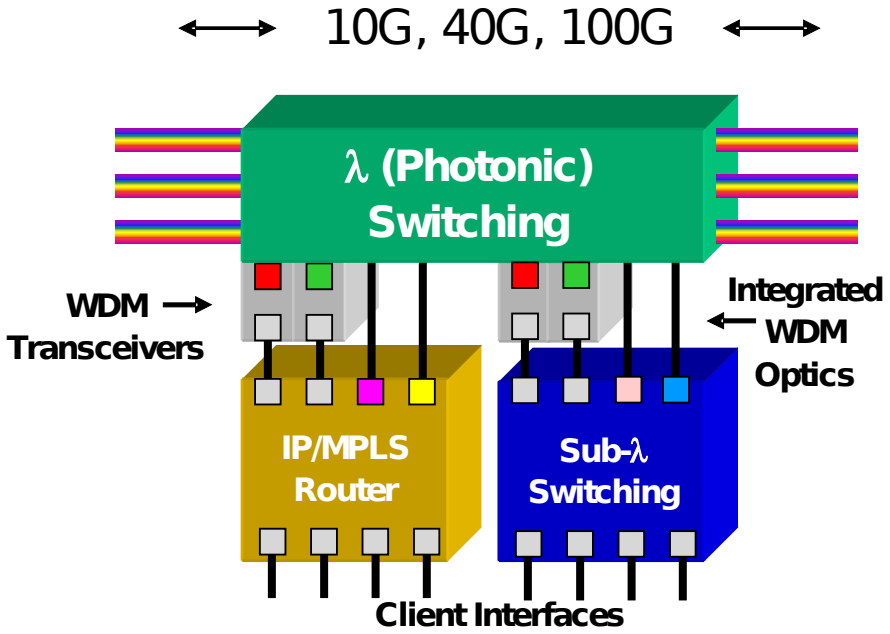
	1m backplane	10m copper	100m MMF	10km SMF	40km SMF
40GbE	✓	✓	✓	✓	
100GbE		✓	✓	✓	✓

Automation and Switching of High Speed Wavelengths

What is the Ideal Optical Exchange Node?

Handling Lightpaths, TDM, IP & Ethernet

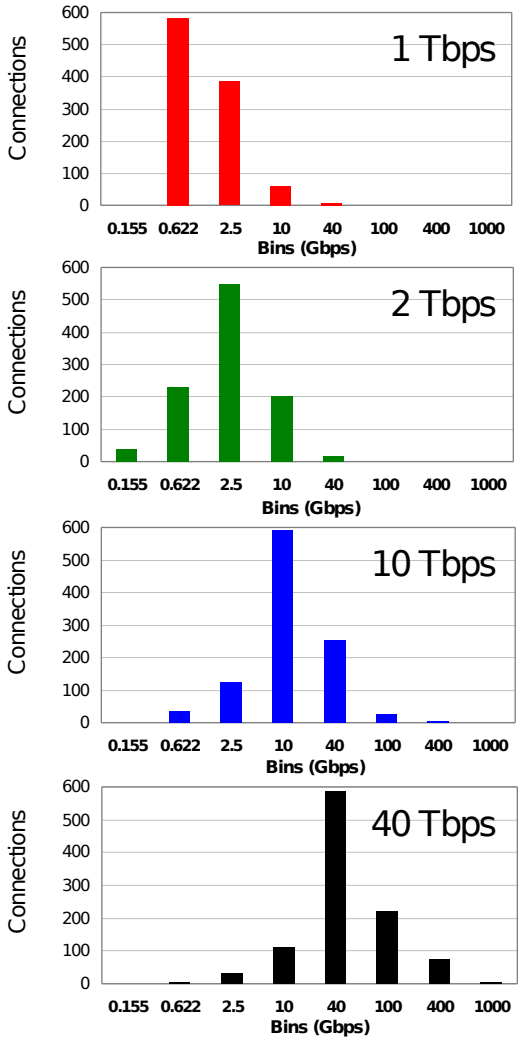


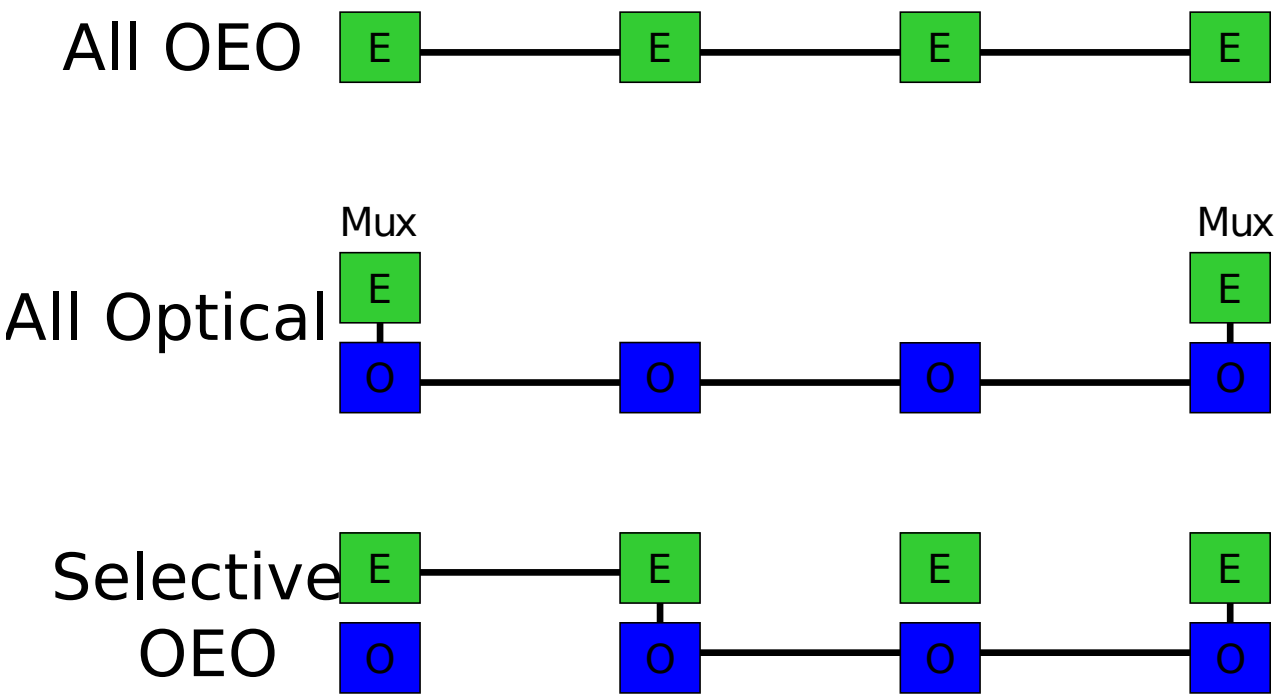


It's not about Optical versus Electrical - Both offer benefits

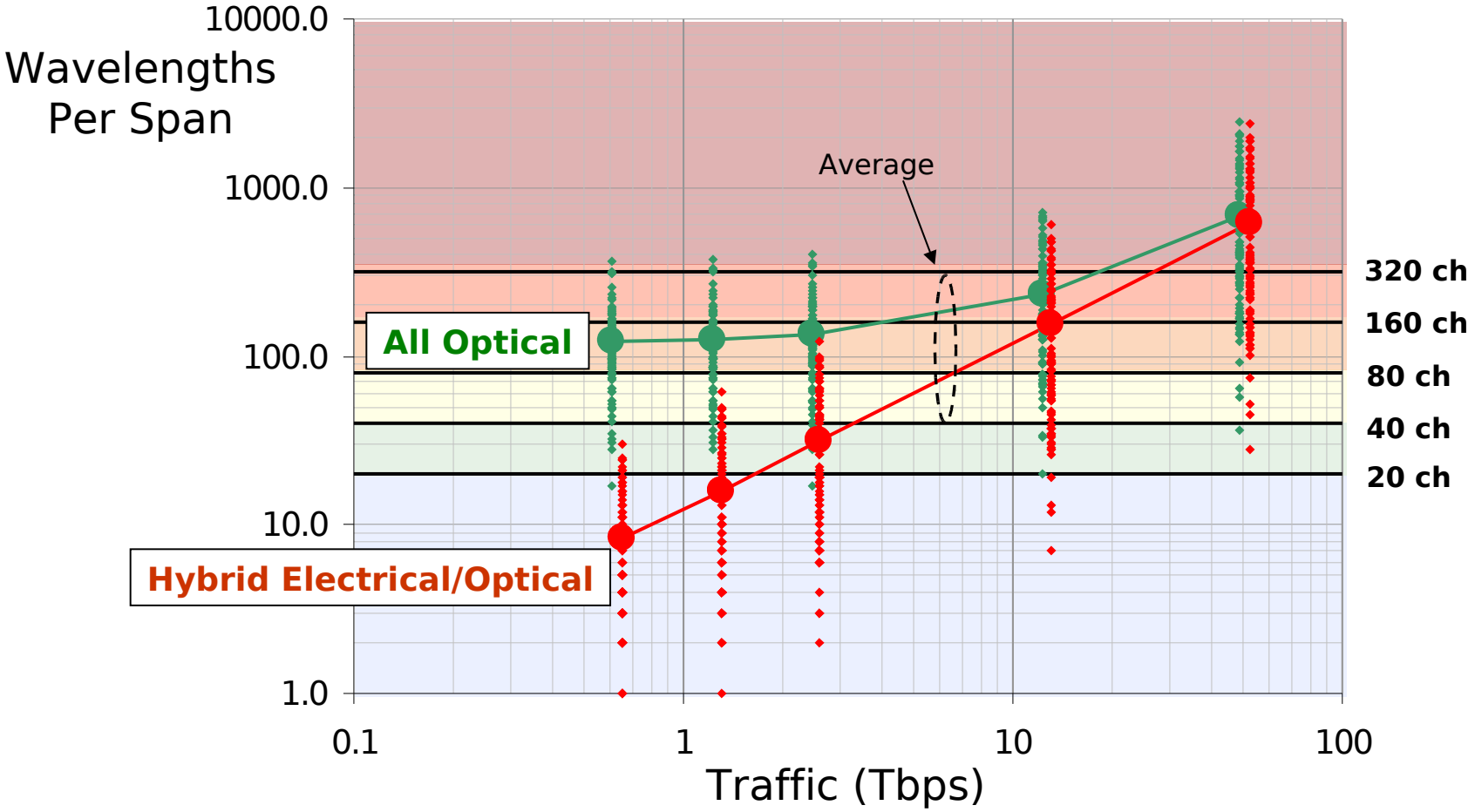
ciena

Optimal Network for High Speed Transport
Switch Optical, Electrical or Hybrid-Selective combination?





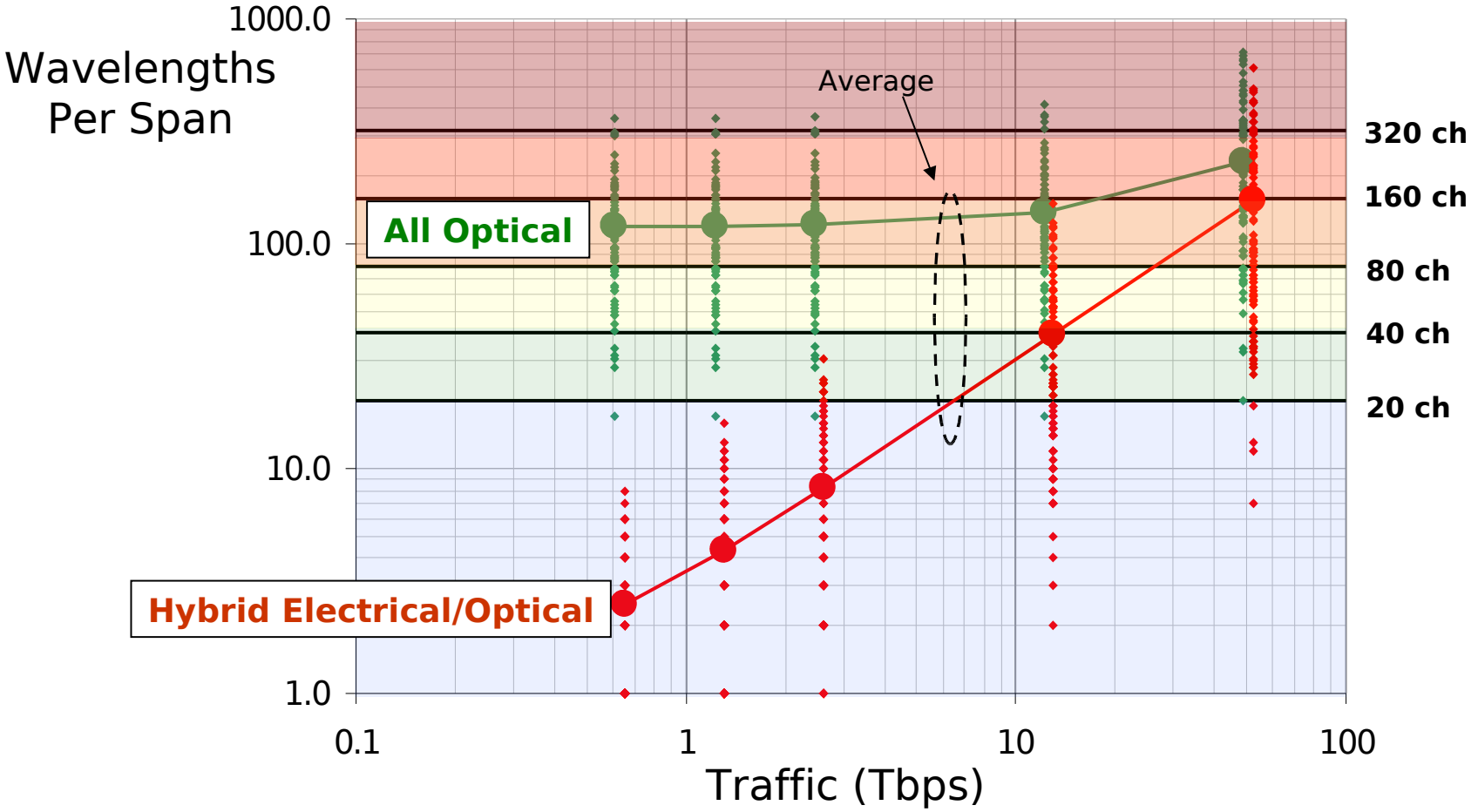
Distribution of Required Span Wavelengths @10G



Note: Because Hybrid Electrical/Optical architecture uses optimized grooming, wavelength count is similar to All-Electrical switching architecture

ciena

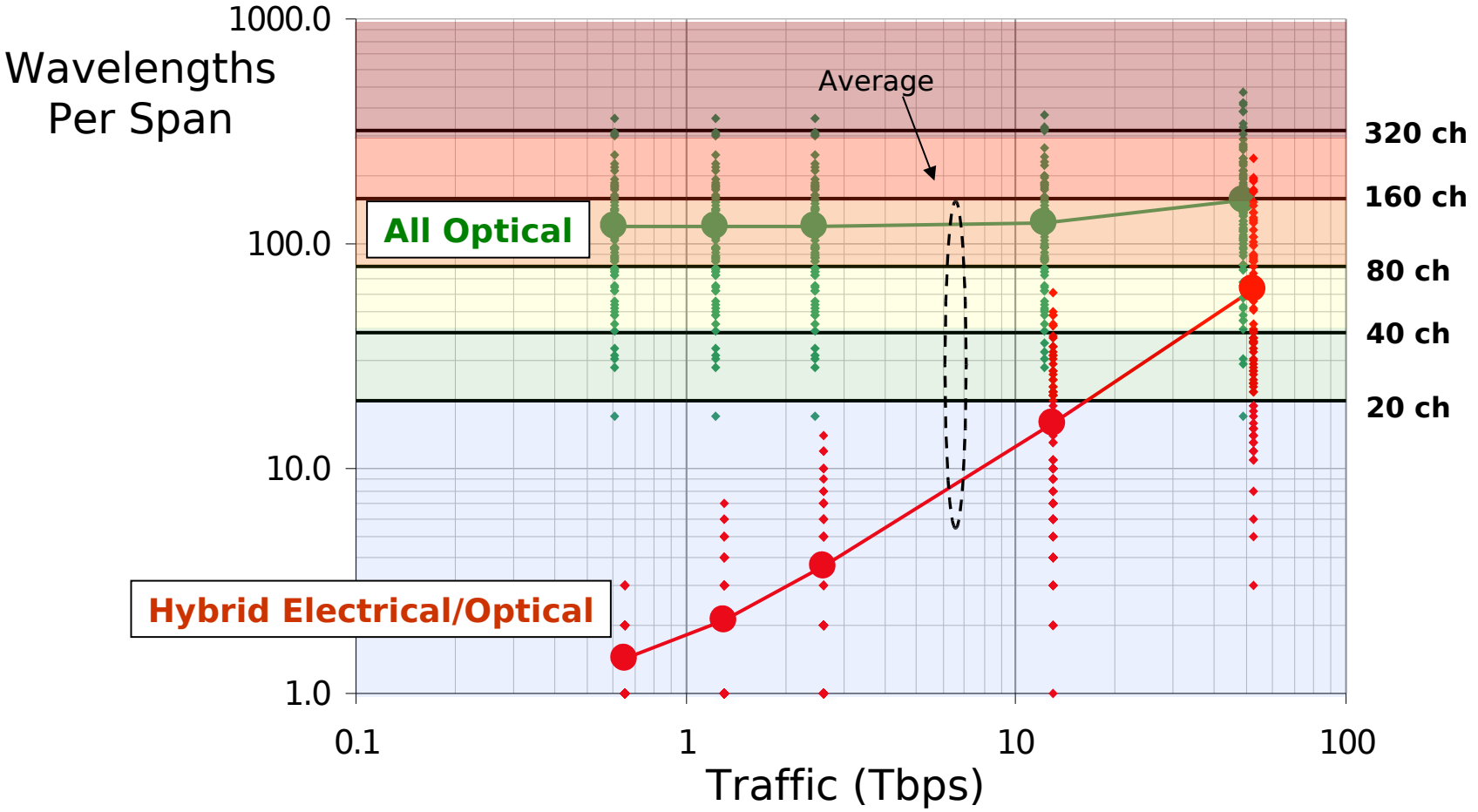
Distribution of Required Span Wavelengths @40G



Note: Because Hybrid Electrical/Optical architecture uses optimized grooming, wavelength count is similar to All-Electrical switching architecture

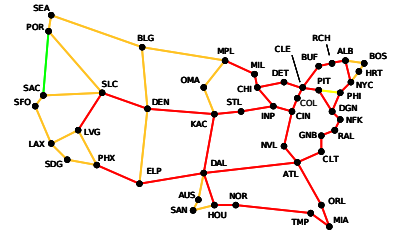
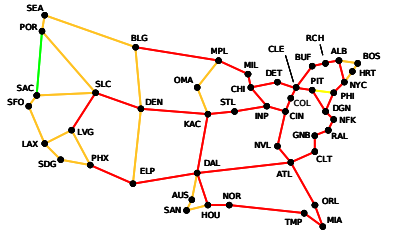
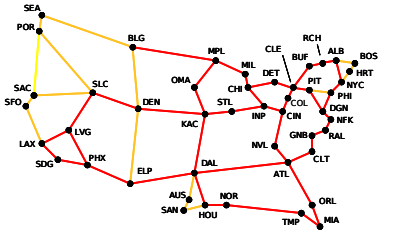
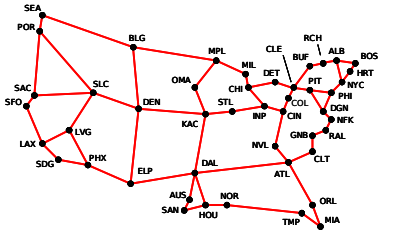
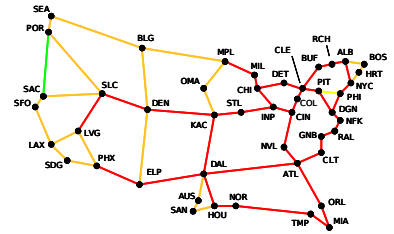
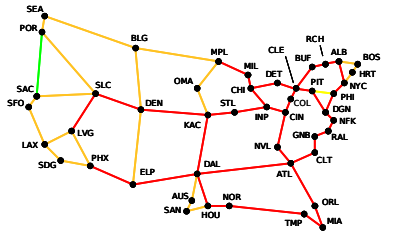
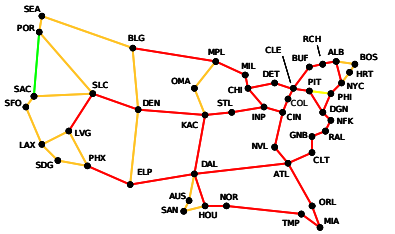
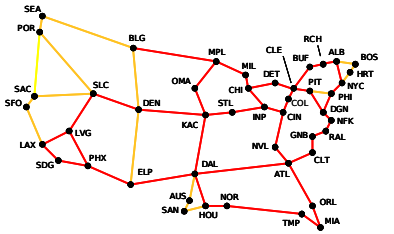
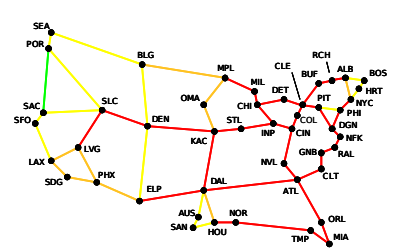
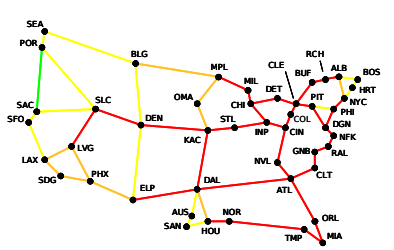
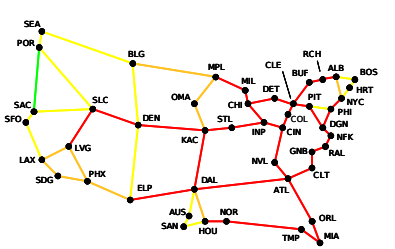
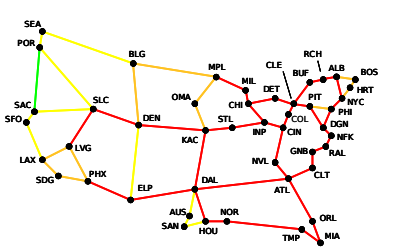
ciena

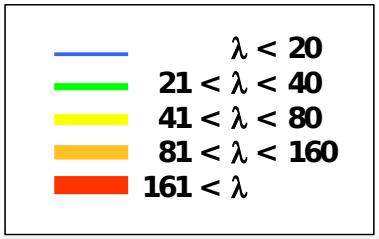
Distribution of Required Span Wavelengths @100G



Note: Because Hybrid Electrical/Optical architecture uses optimized grooming, wavelength count is similar to All-Electrical switching architecture

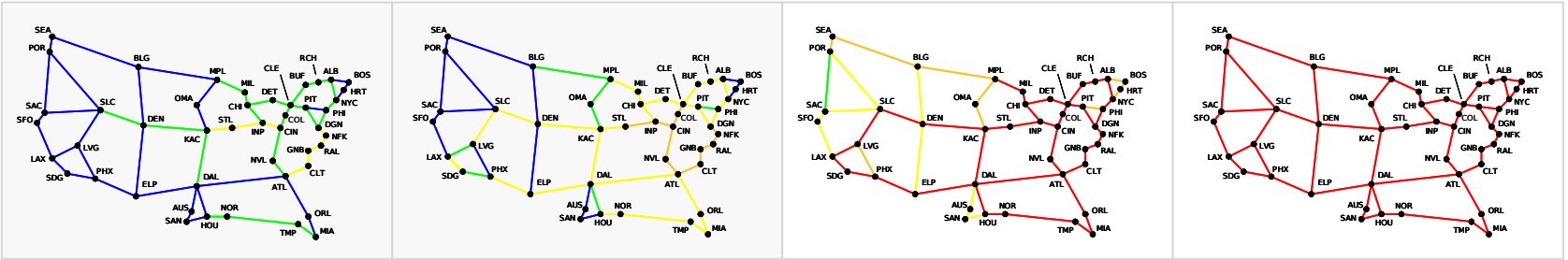
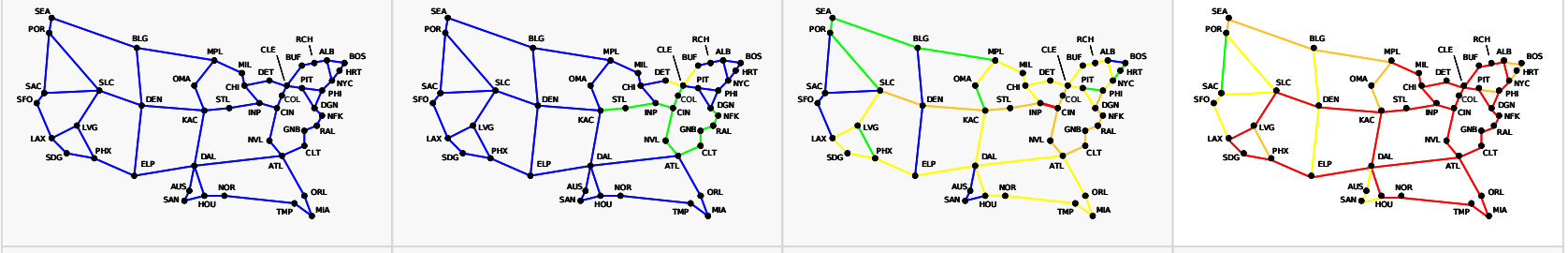
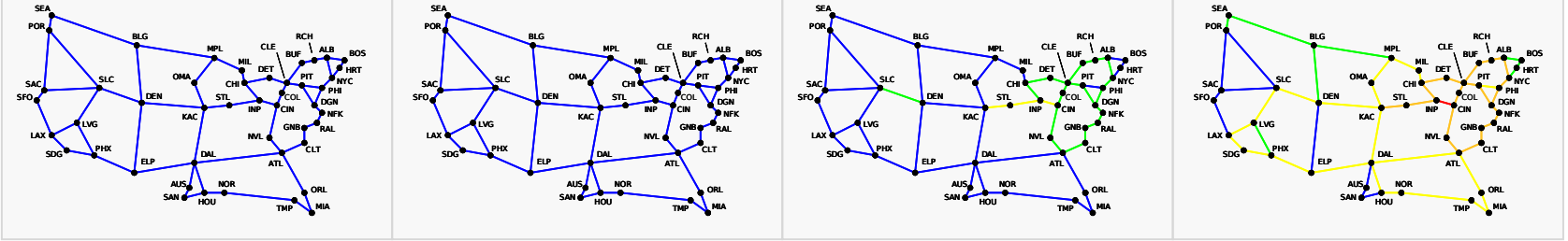
Wavelength Evolution for ROADM Switching Arch. (All-Optical)

	1Tbps	2Tbps	10Tbps	40Tbps
10G				
40G				
100G				



ciena

Wavelength Evolution for Hybrid Switching Arch. (Selective OEO)

	1Tbps	2Tbps	10Tbps	40Tbps
10G				
40G				
100G				

$\lambda < 20$

$21 < \lambda < 40$

$41 < \lambda < 80$

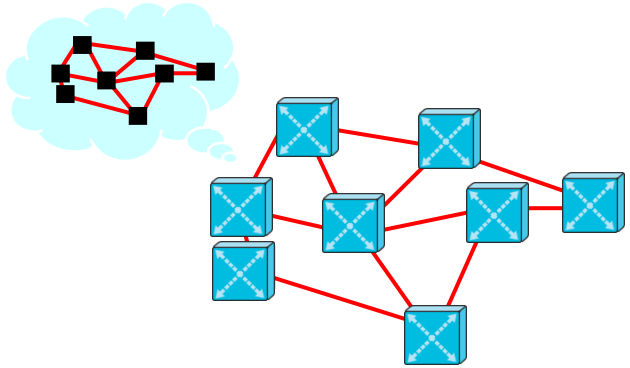
$81 < \lambda < 160$

$161 < \lambda$

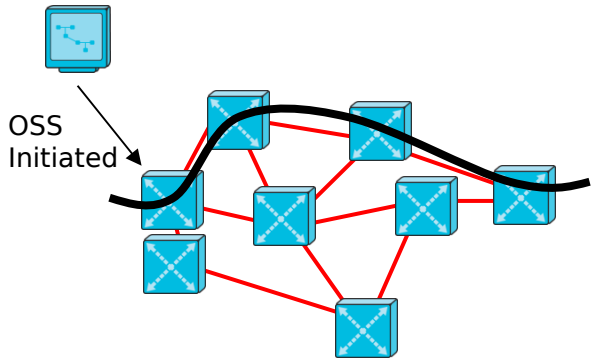
Note: Because Selective OEO uses optimized grooming, wavelength count is similar to All-OEO architecture

ciena

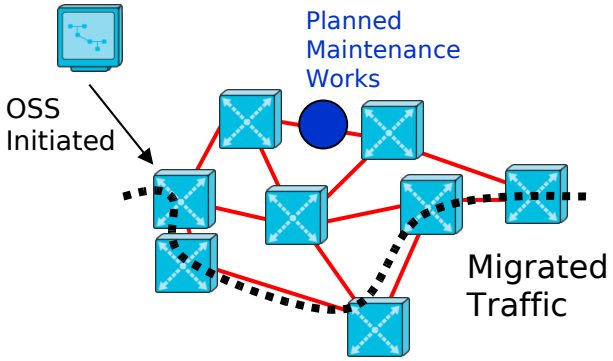
Adding Automation to the Optical Network



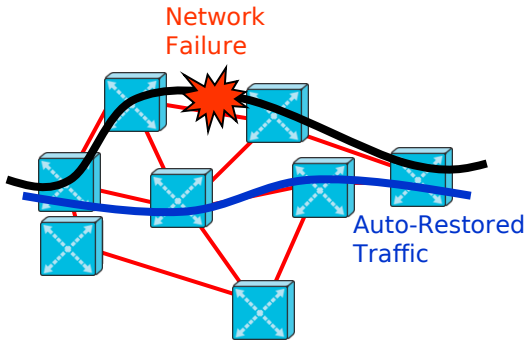
Auto-Discovery of Resources



Rapid Service Turn Up



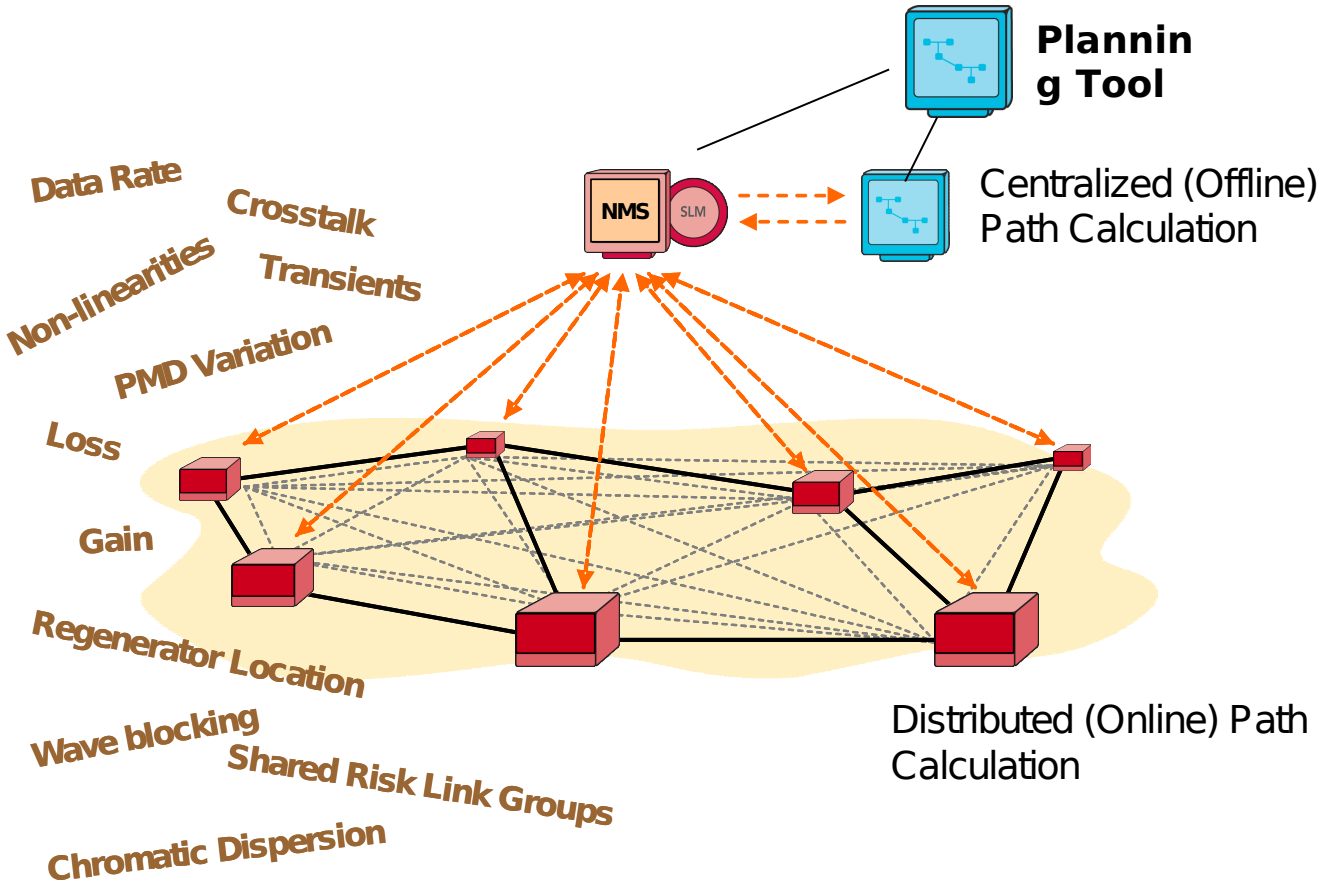
Controlled Traffic Migration



Self-Healing Network

Challenges of All Optical Control Plane Automation

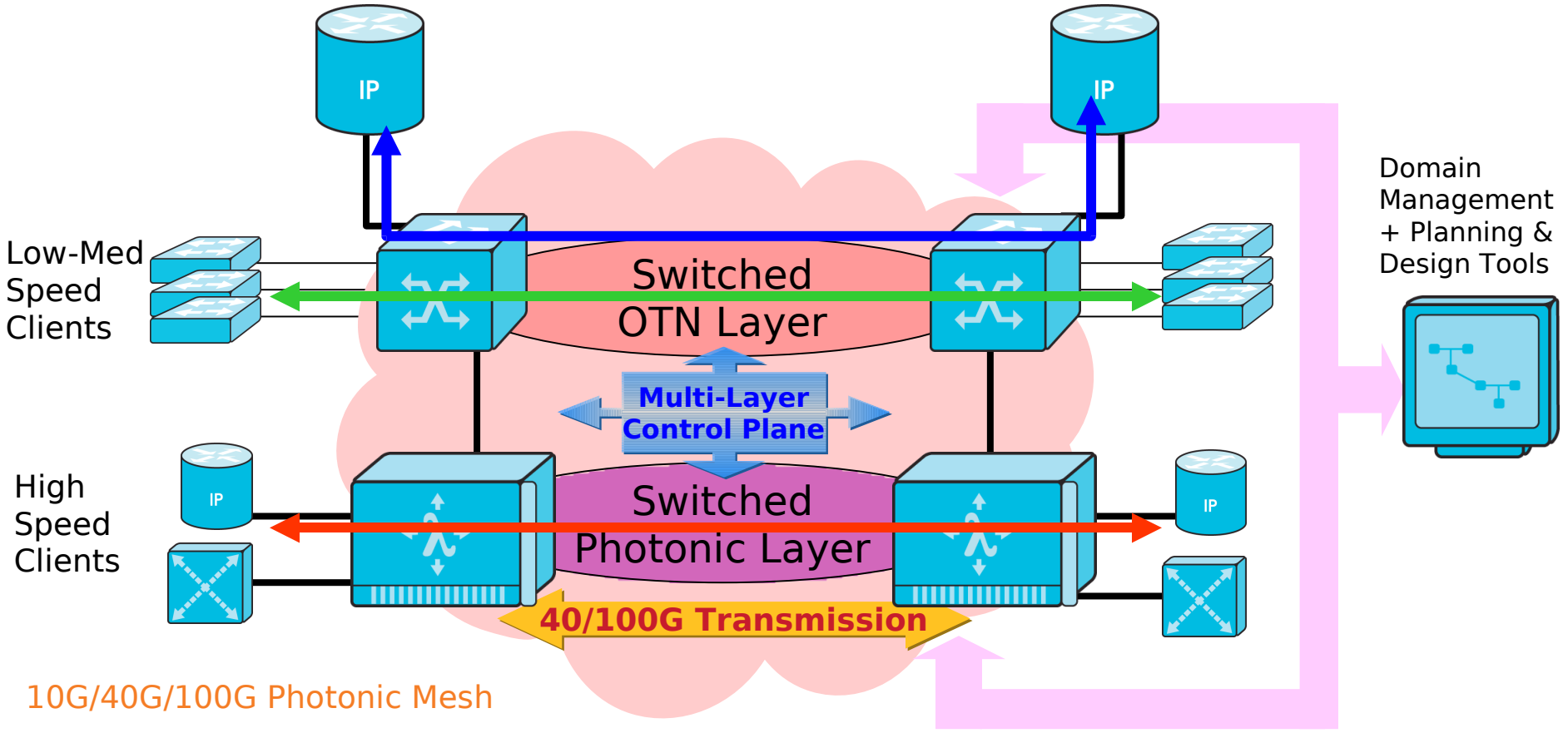
Digital and Analogue Computations



Build this Slide

NextGen Optical Core Architecture

Automated Photonic, OTN, and Packet Switching



10G/40G/100G Photonic Mesh

High Speed Traffic Demands at Photonic Layer

Low-Med Speed Traffic Demands at OTN Layer

Core Router Bypass at the OTN/Packet Tunnel layer

ciena

Summary

- → OTN is already the de facto standard for networks
- → 40Gbps is becoming the norm
- → 100Gbps wavelengths are happening and being deployed now.
  - → Full development with 100GbE client interfaces will be 2011/2012
- → Optical Switching will be deployed as networks grow
- → Optical Control Planes are on their way
  - → But there are still a lot of hurdles
- → The optimal network configuration will be a hybrid Optical Electrical switched network.

Questions