

Cost-effective and Scalable Architectures for Multi-granular Optical Networks

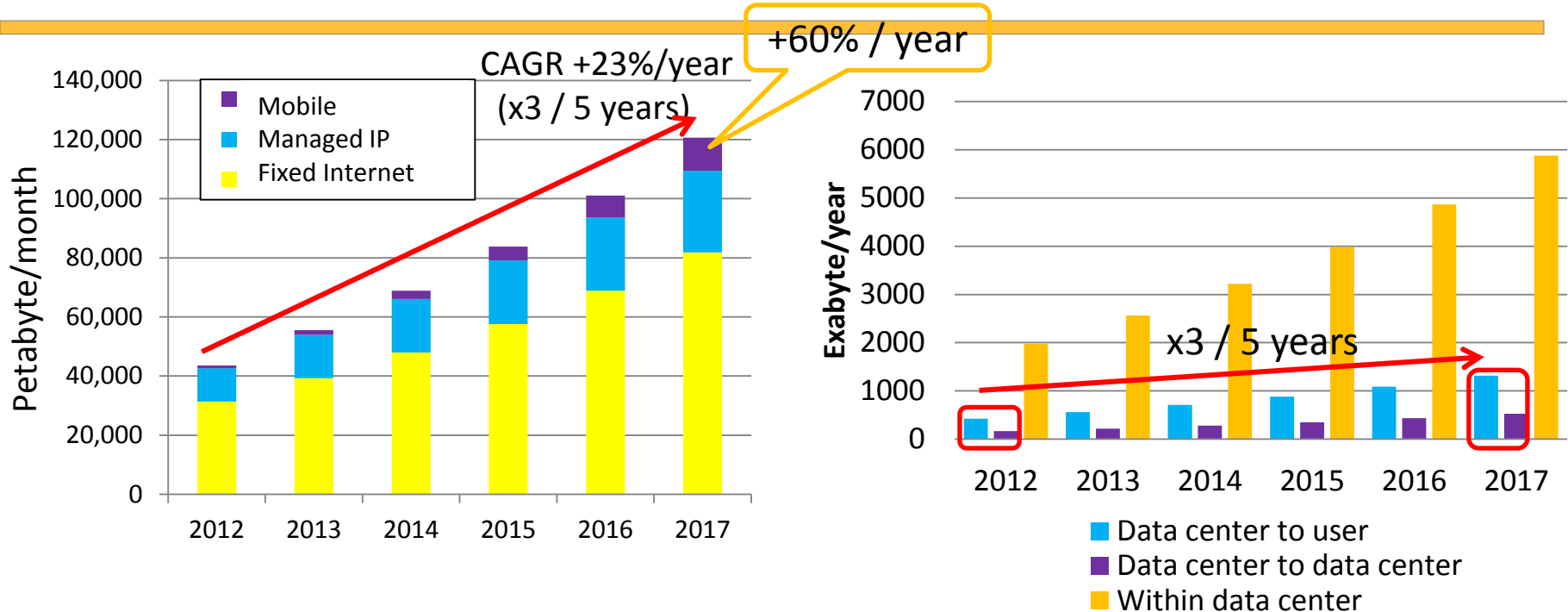
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Outline

- ✓ General Background
- ✓ Proposal: Node Architecture
- ✓ Proposal: Waveband Design
- ✓ Evaluation
- ✓ Collaboration Plan/Time Table

Requirements for Future Networks



Global IP traffic variation [Cisco Visual Networking Index]

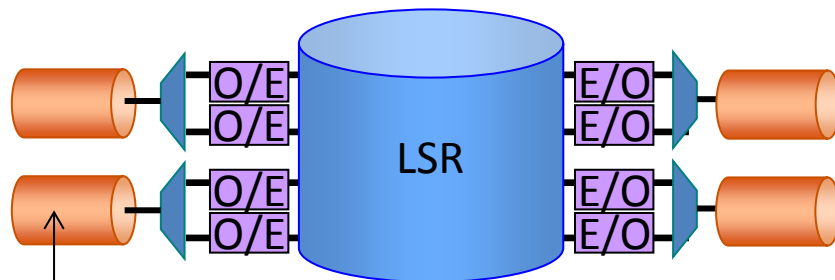
Data center traffic variation [Cisco Global Cloud Index]

- **Broader bandwidth** ← Ultra HDTV (up to 144Gbps, uncompressed), e-science, DC-DC, VPN, etc.
- **Energy efficiency** ← cooling , cost, Router/OXC size etc.
- **Agility** ← Dynamic layer one services, mobile backhaul, ...
- **Reasonable cost and realistic implementation** ← The use of cost effective and reliable devices

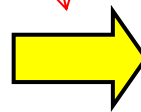
Photonic Networks

- Broader bandwidth
- Energy efficiency
- Agility
- Reasonable cost and realistic implementation

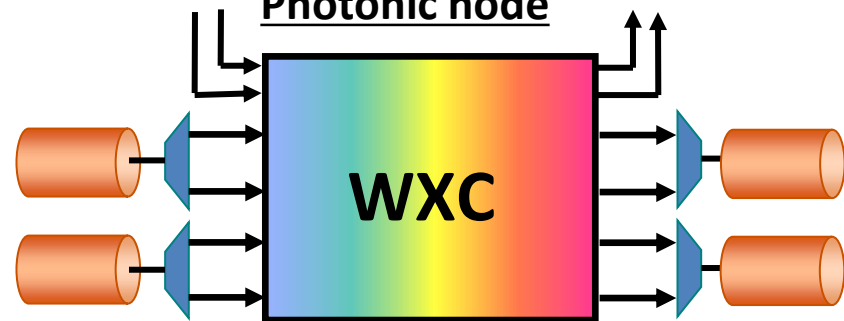
Conventional electrical node



LSR: Label Switch Router



Photonic node



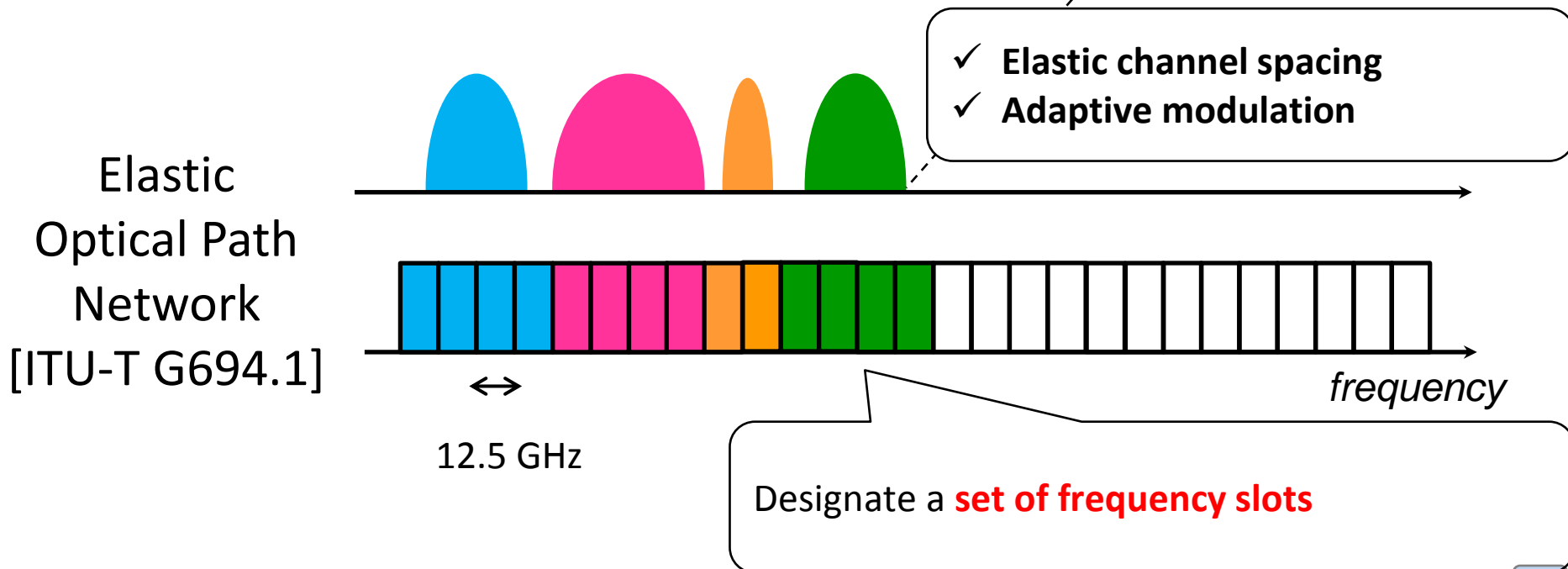
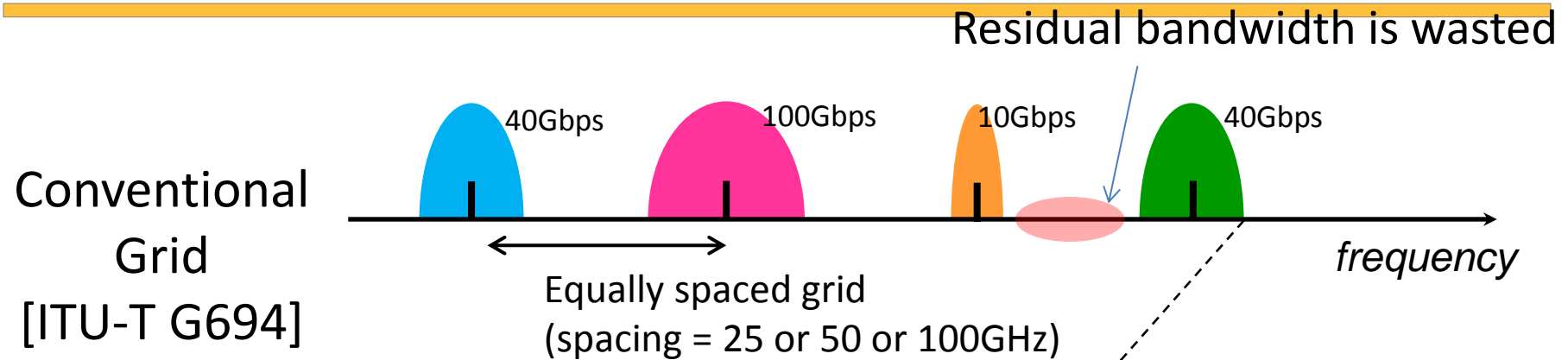
WXC: Wavelength Cross-Connect

No E/O and O/E conversion at intermediate nodes

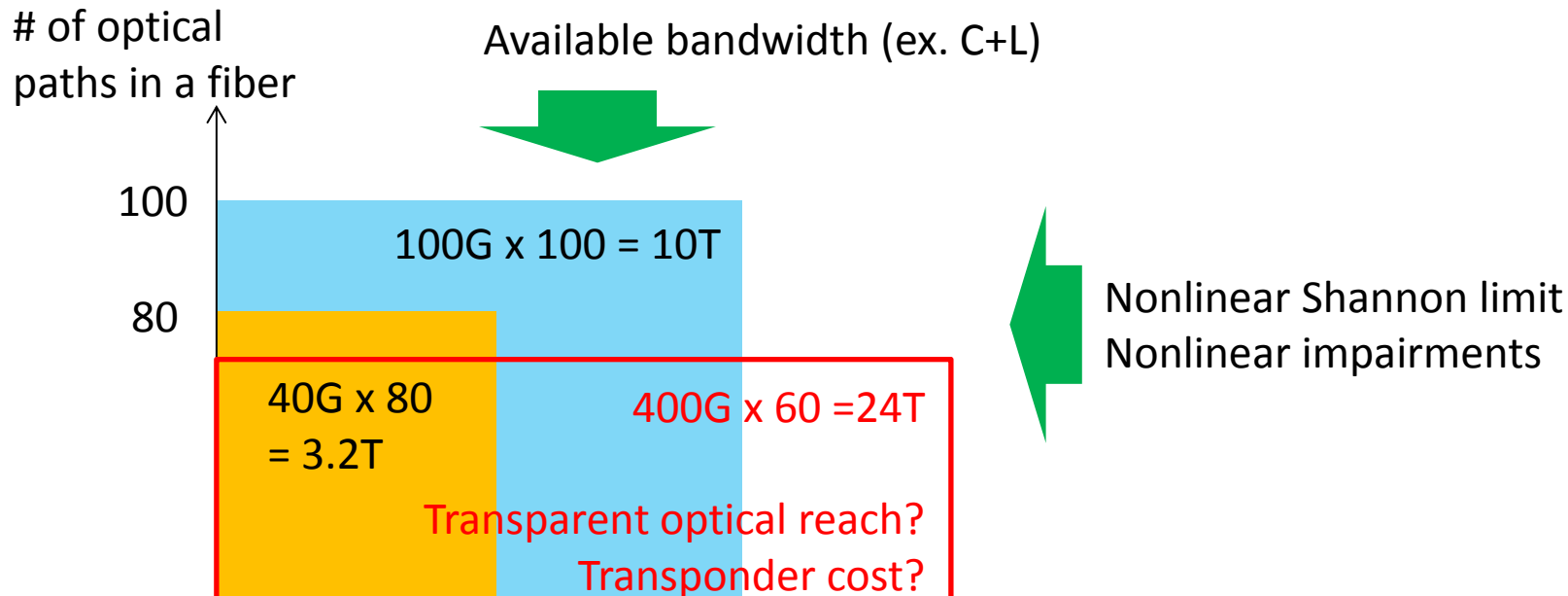
- Wavelengths are used as indexes
- Energy efficiency
- Broader bandwidth
- Transparency on modulation format/speed

40-100 wavelengths in a fiber
(each wavelength carries 10,40,100Gbps)

Improvement of Spectrum Utilization Efficiency



Fiber capacity: hard to enhance



From Transmission Technology Development
To Network Architecture Optimization

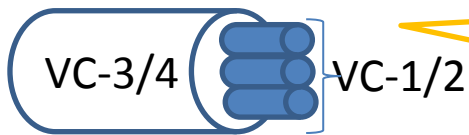
More optical paths, more optical fibers in the network

Transmission on **parallel fibers** is the only possible solution

Optical Path Hierarchy

Path hierarchy: a classical technique to manage many paths

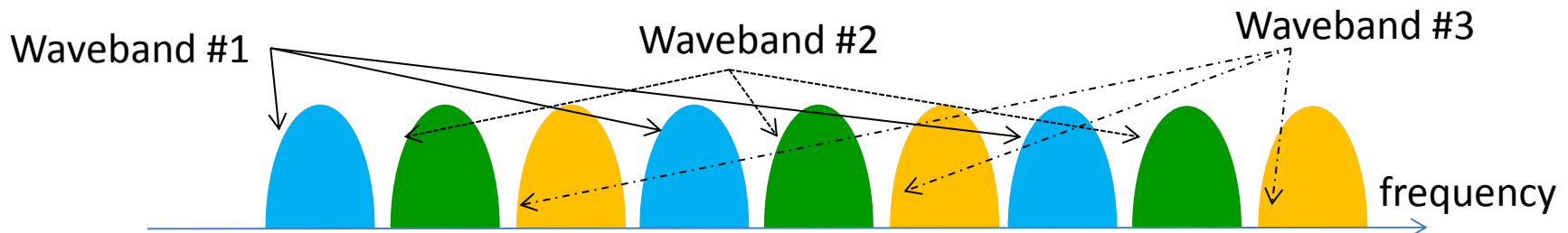
Ex.) VC-3/4 in SDH/SONET



“Less number of coarser granular paths”
simplifies cross-connects.

Introduction of path hierarchy to optical networks

- Path hierarchy has been studied for 15 years (ex. [Hadama et.al. 1999])
- US/Japan PIs have contributed to this area ➡ An ideal collaboration
- Efficient implementation is possible for **conventional fixed grid networks**



Filters with same periodicity achieve compact implementation

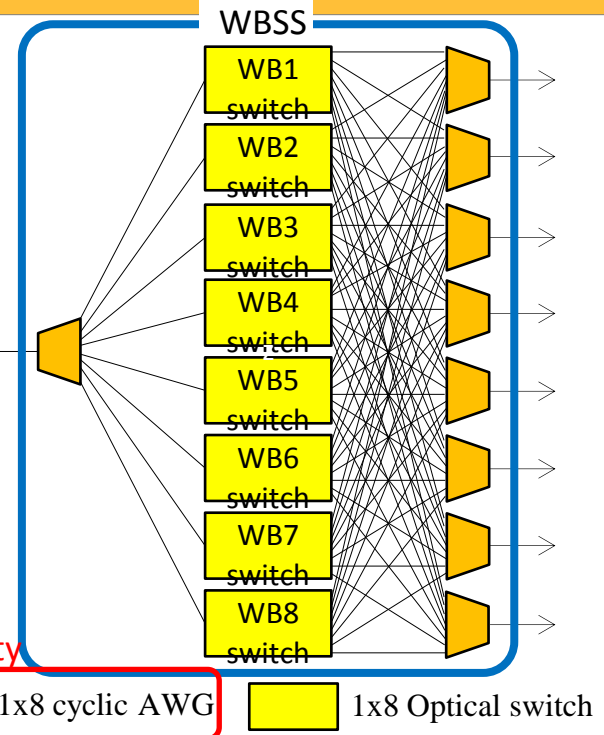
Waveband Selective Switch



1x9 Wavelength Selective Switch
(22cm x 14cm x 3cm)

- Switching granularity: Wavelength
- Space optics based
- Costly aerial beam manipulation and its adjustment are necessary
- Port count is practically limited (up to 1x20+)

Filters having the
desired periodicity



1x8 Waveband Selective Switch
(PLC chip, 7.5cm x 4.9cm x 0.2cm)

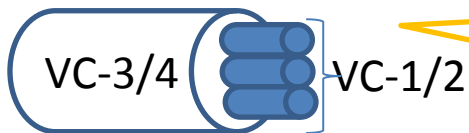
- Switching granularity: Waveband
- Planar lightwave circuit (PLC)
- No adjustment is necessary
- Ultra compact

Compactness relies on the regular
structure in wavelengths

Optical Path Hierarchy

Path hierarchy: a classical technique to manage many paths

Ex.) VC-3/4 in SDH/SONET



"Less number of coarser granular paths" simplifies cross-connects.

Introduction of path hierarchy to optical networks

Unfortunately, **no regular structure** can be assumed in future **elastic optical networks**

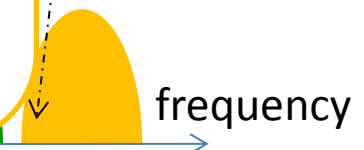
- Flexible bandwidth & center frequency assignment
- Flexible WSS should be utilized considering the latest development and the excellent transmission characteristic achieved

[Lama et.al. 1999])

collaboration

grid networks

Waveband #3



Filters with the same periodicity achieve the compact implementation.

Project Goals

- ✓ Develop cost-effective and scalable node architectures and control algorithms for next-generation photonic networks
- ✓ Jointly develop architectures and optimization algorithms
- ✓ Develop a novel optical routing technique called **flexible wavebanding**
- ✓ Develop a small-scale prototype node architecture
- ✓ Evaluate with small-scale experiments, analytical methods, and simulations