Increasing Capacity in WDM/OTN Optical Transmission System

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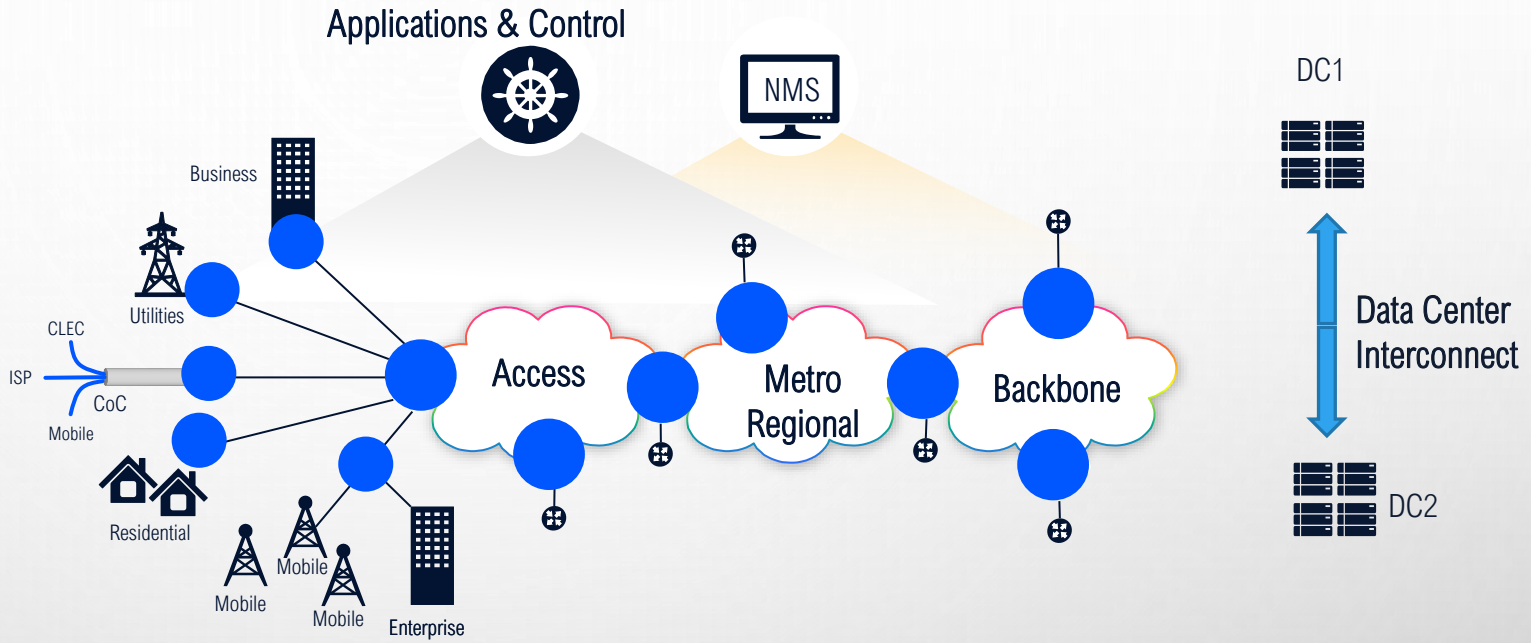
LAYER 1

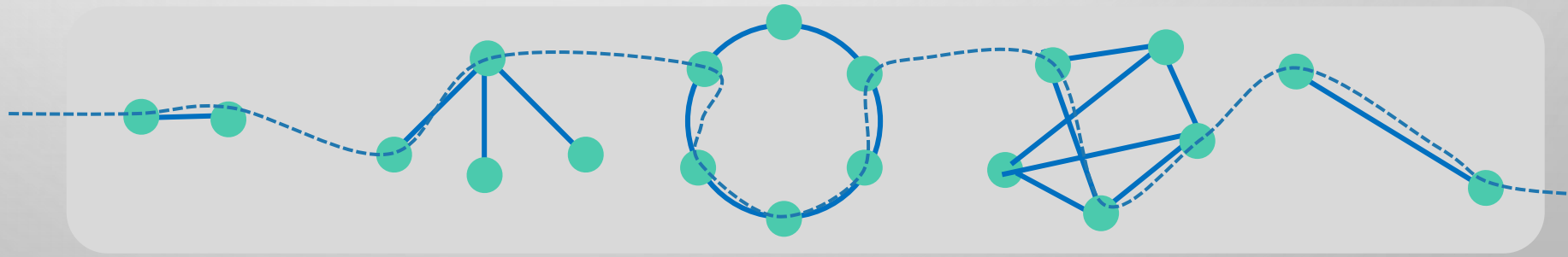
https://www.layer1.fr

Optical Transport is everywhere

WHY ARE DWDM/OTN OPTICAL NETWORKS IMPORTANT?

- Overcoming the Distance
- Transmitting Higher Bandwidth





Different Topologies, Rates, Protection and Scalability

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Different Applications for different criterias

CapEx
OpEx
Other

DCI

Transceiver Cost per Bit
Multi-vendor Interoperability
Pluggability
Encryption
Power Consumption
Footprint

Metro Aggregation

Transceiver Unit Cost
Truck Rolls
Footprint
Eliminate Intermediate Aggregation
Optical Line System Costs
Manageability
Pluggability
Sparing
Power Consumption

Metro Core/Regional

Transceiver Cost per Bit
Optical Line System Costs
Optical Line System Compatibility
Pluggability
Wavelength Capacity-Reach
Supported Client Types
Manageability

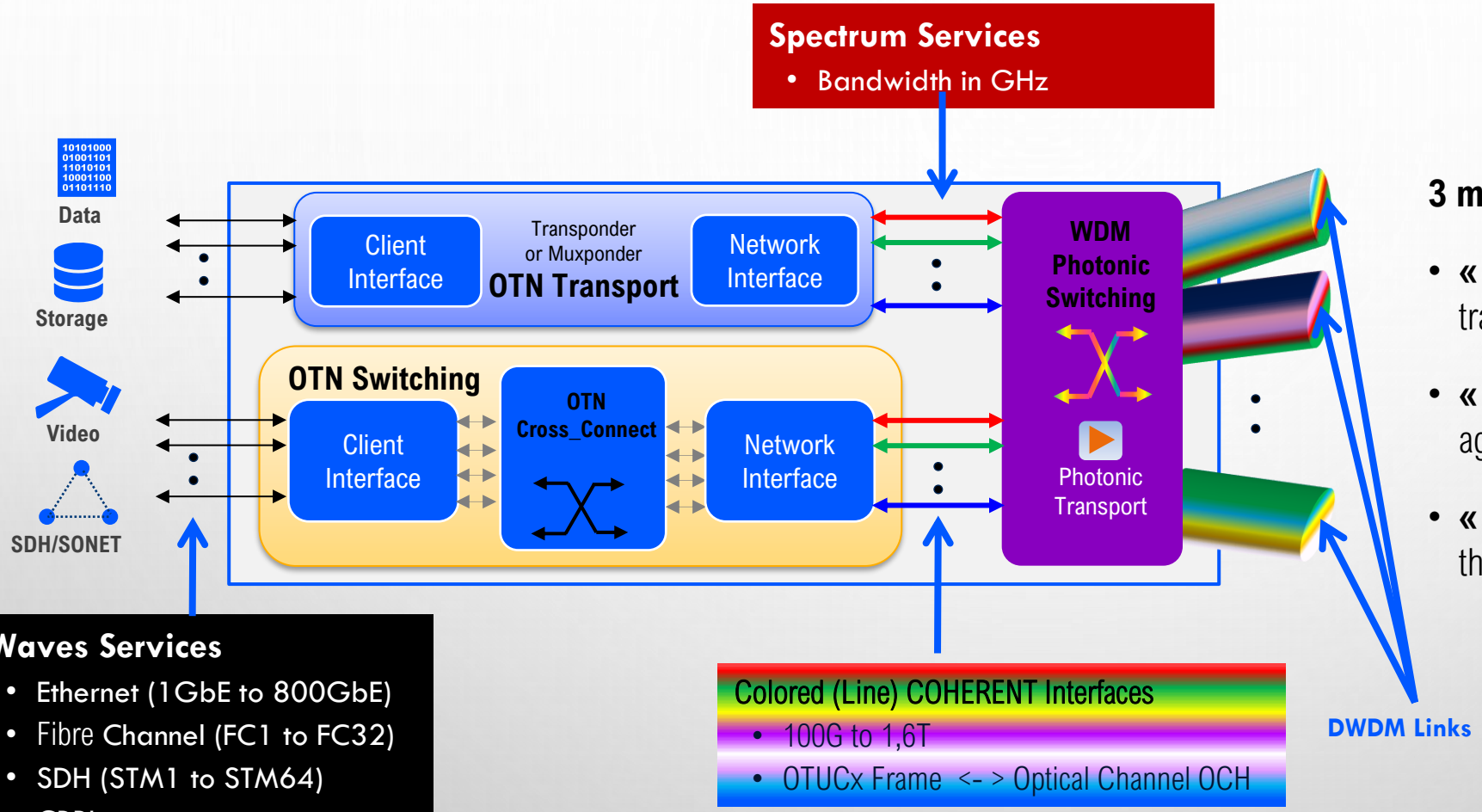
Long-haul

Optical Line System Compatibility
Manageability
Wavelength Capacity-Reach
Lightning Tolerance
Number of Wavelengths
Supported Client Types
Spectral Efficiency

Submarine

Spectral Efficiency
Wavelength Capacity-Reach
Power Consumption
Footprint

Transport Network Building Blocks



3 mains Blocks

- **« OTN Transport »** for High Speed Services transport (Point to Point)
- **« OTN Switching »** for Low Speed Services agreggation (omnibus & meshed architecture)
- **« WDM Photonic Transport & Switching » ,** the fundation of your optical network

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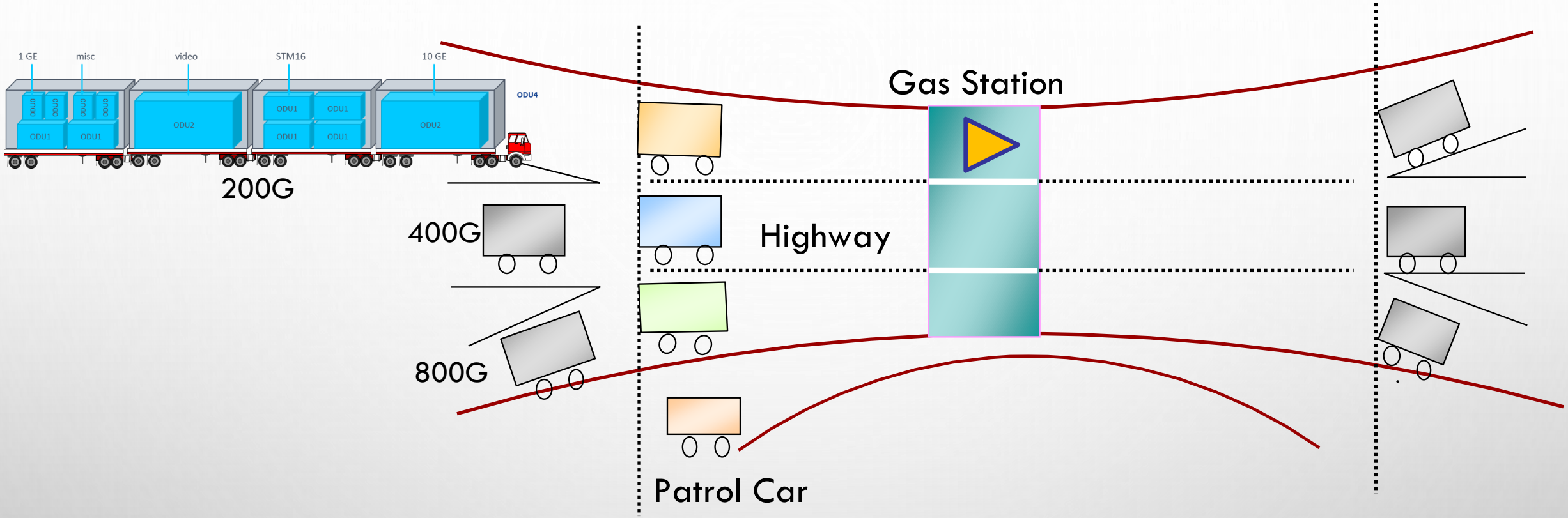
WDM/OTN is similar to HIGHWAY (WDM) / VEHICLE (OTN)



A fiber with multiple channels equivalent to multiple lane highway

- Two fibers vs Two lanes
- Each highway Line = One spectral bandwidth with central Wavelength
- Signal = Vehicle / Amplifier = Gas Station
- OSC = Patrol Car
- ROADM & A/D = Interchange

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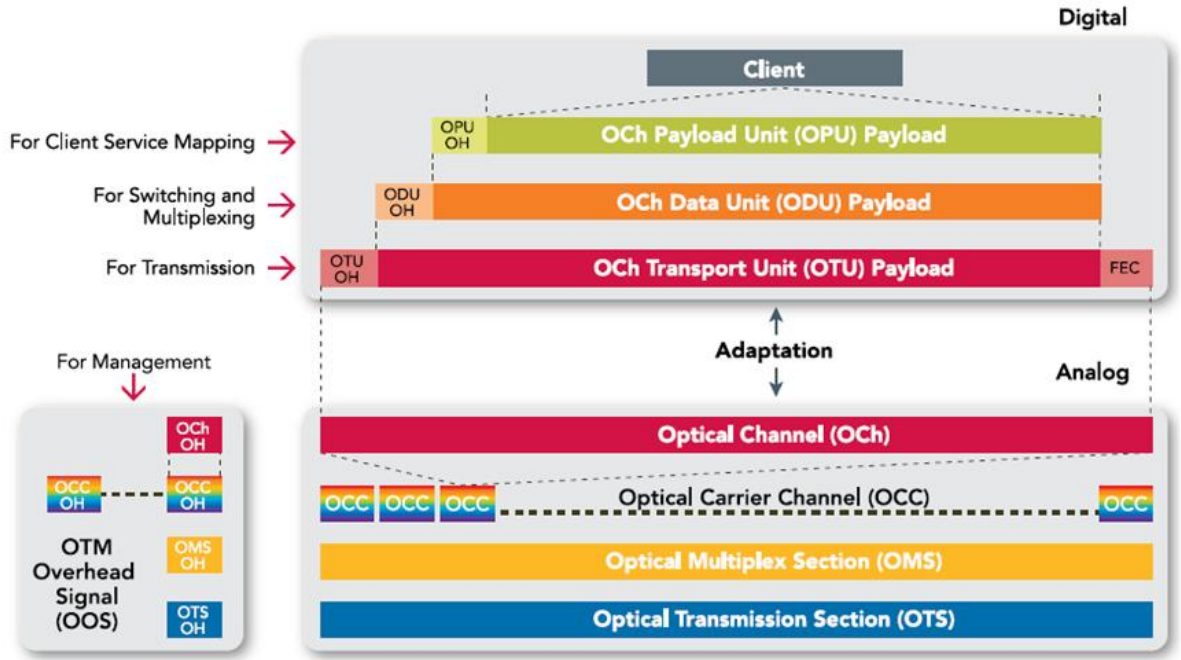
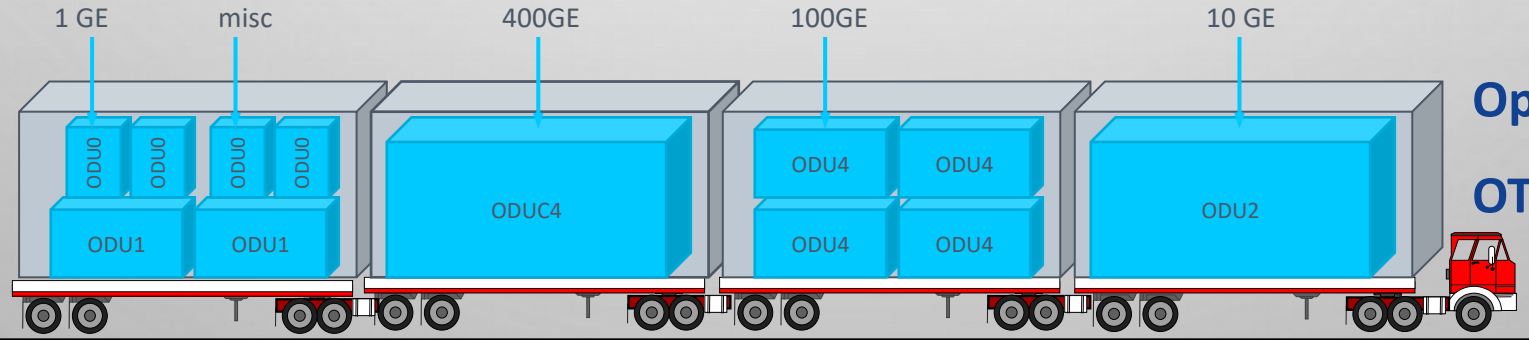
OTN (Optical Transport Network)



- G.709 Industry standard multiplexing method / Interoperabilty
- Universal container for all traffic type
- Improved network efficiency & utilization of wavelengths
- Powerful FEC – Forward Error Correction (from 7% to +35% OH for long-haul performances)
- Protocol agnostic and transparent – carries any traffic type (SDH, packet Ethernet, video, FC, etc.)
- Simplicity - (Asynchrone, native for Eth, support SyncE/1588(PTP))
- Integrated Latency calculation with DM OH byte (without test instrument)
- Common, standardized, well-defined OAM (PM, FEC, protection switching, restoration)



Optical Channel (WAVE)

OTUCx

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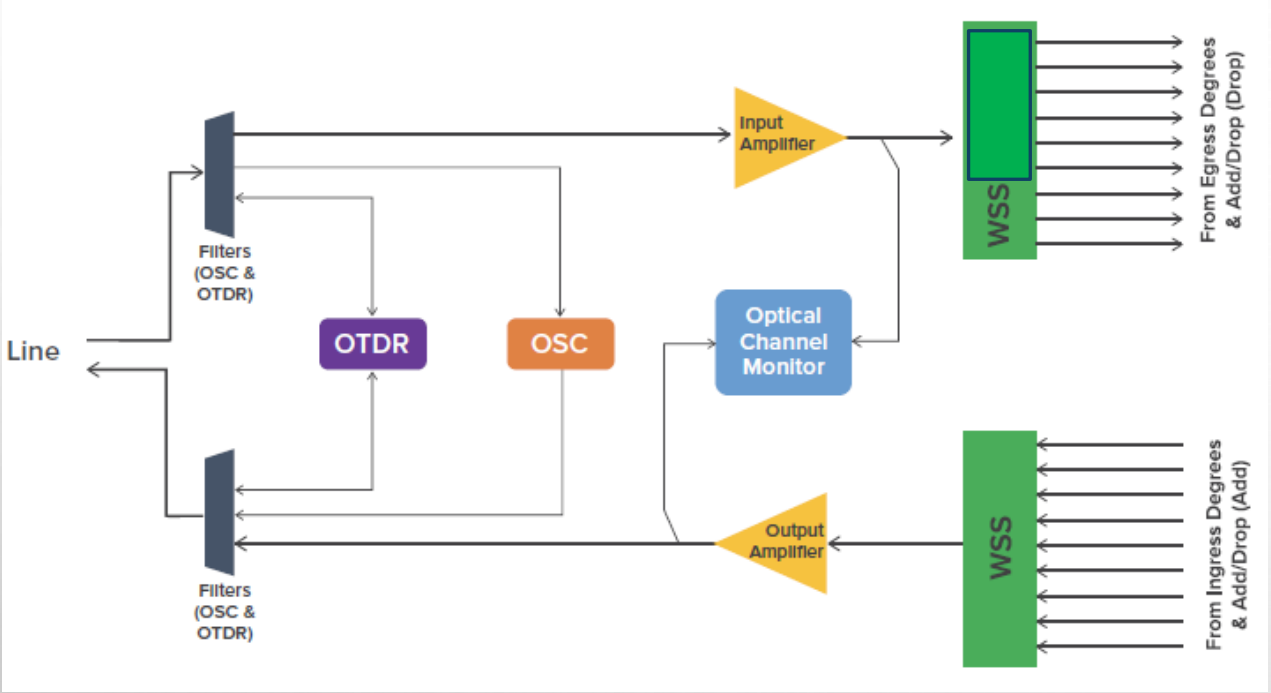
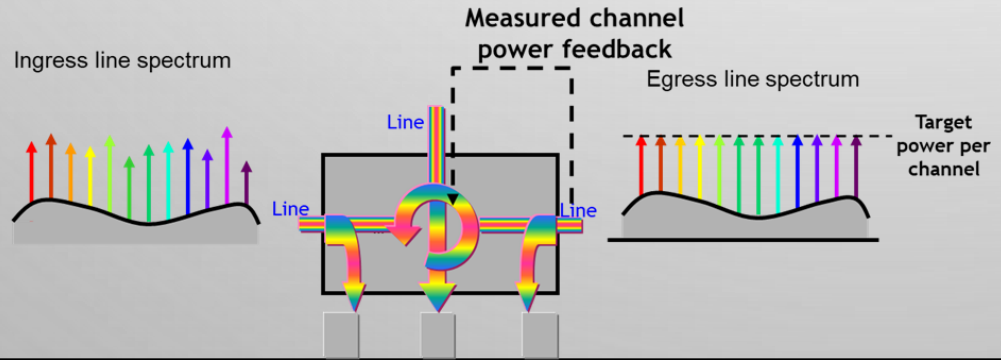
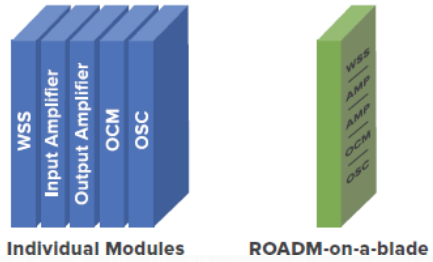
WDM / Optical Line transmission system





- ROADM All-in-One integrated



- Amplifiers
  - Specific to C and/ L band
  - Constant Spectral power density regulation (dB/Hz)
  - ASE optimize (NF)
- OSC (Optical Supervisory Channel)
  - Link Control, In-band mgmt, Control Plane (WSON/GMPLS)
- OTDR (Tx/Rx)
- OCM (Optical Channel Monitor)
  - flexible-grid OCMs and higher-resolution coherent OCMs
  - High accurate of power monitoring of sub-Ghz fine spectral slices
  - Advanced processing of spectral characteristics (center wl, OSNR)
  - DGE (Dynamic Gain Equalization at ILA sites)

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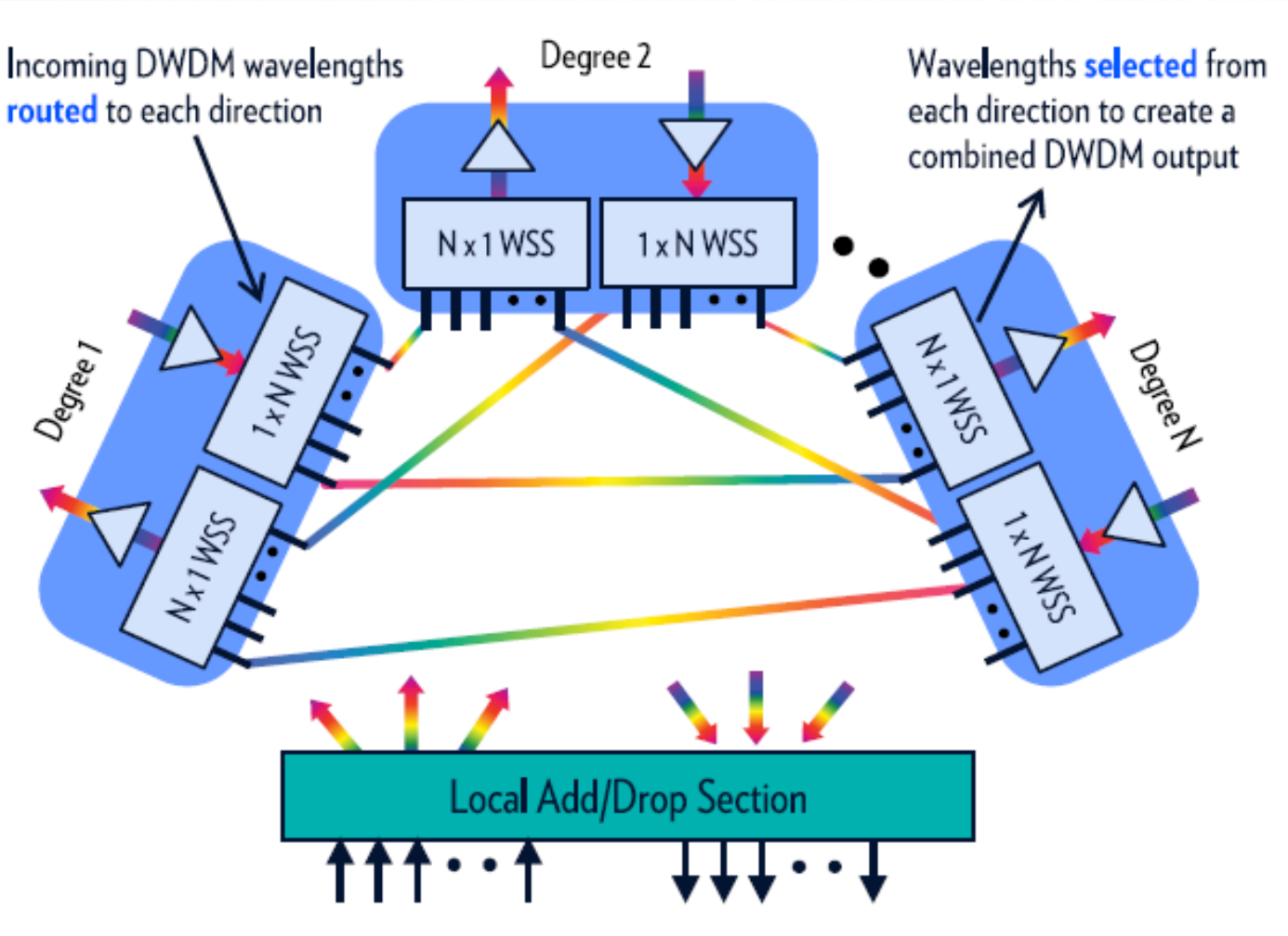
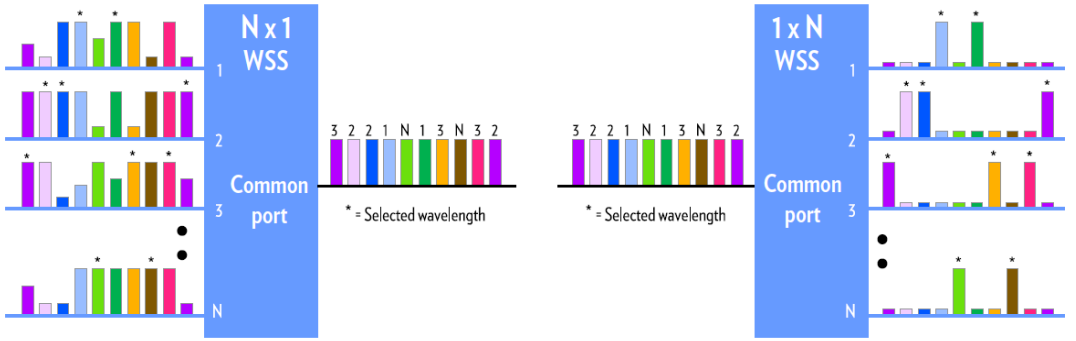
Next Gen ROADM site Configuration (FlexGrid)





WSS : Wavelength Selective Switch

- ROADM Ligne
  - Twin WSS 1x9/1x20/1x32 to high ports count for each direction
  - Channel spacing C/L bands
  - Flexible grid to 6,25 GHz granularity

- Local A&D section (for Transponders connection)

  - Not Protected : Direct on WSS or behind splitter/coupler
  - Restauration : MCS or MxN WSS for directionless (Tp = qqs s)
  - Protection : OCH 1+1 card (P < 50ms)

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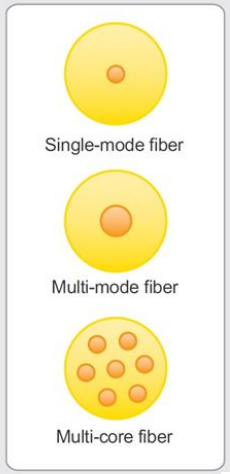
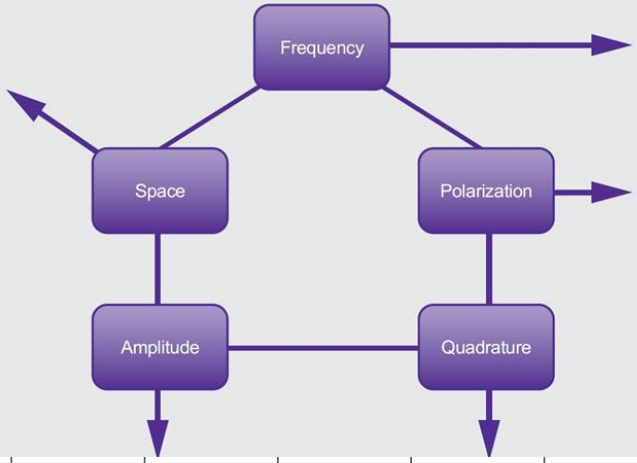
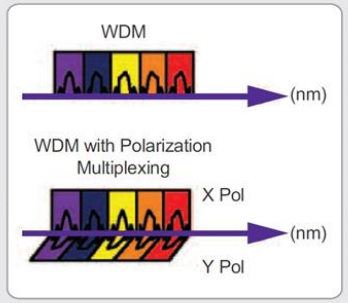
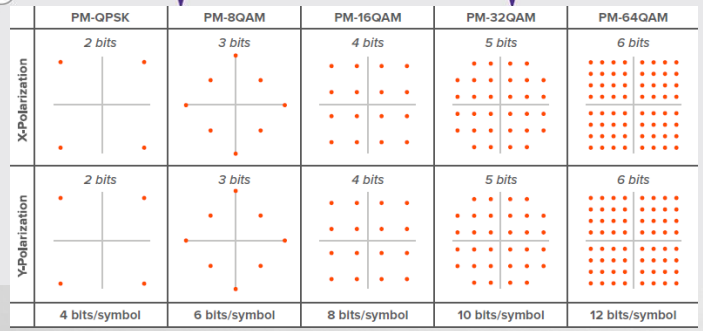
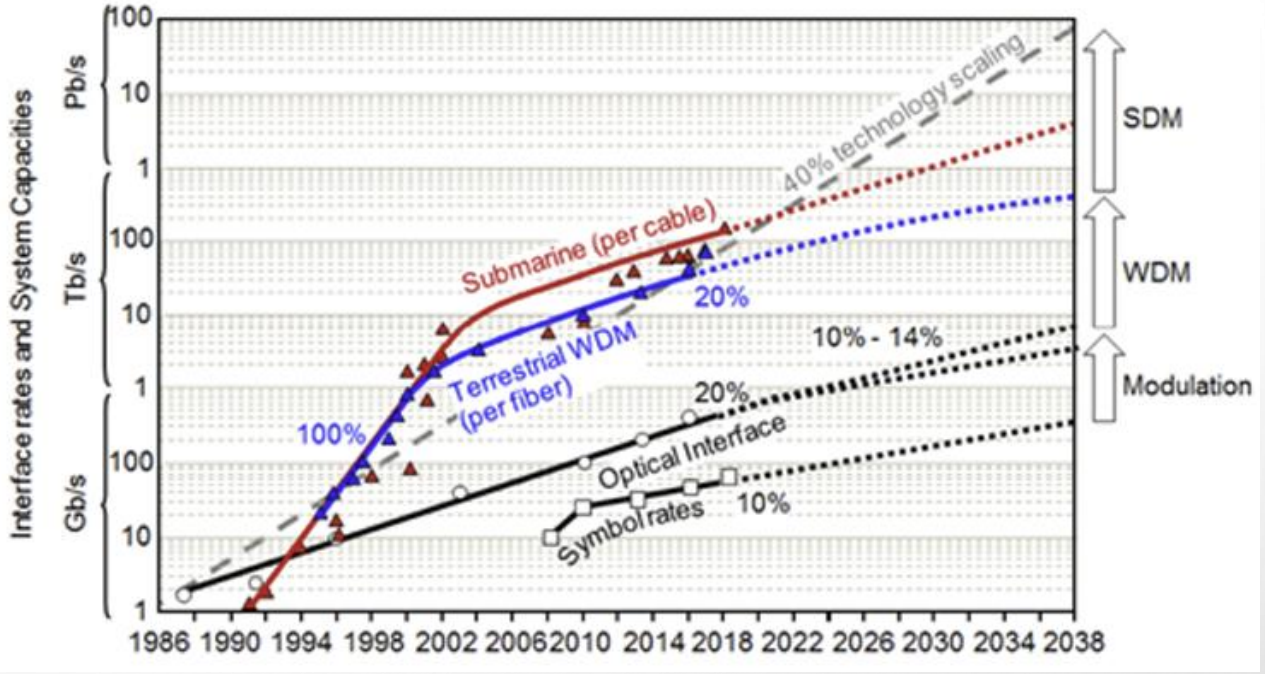
Scaling Transport Capacity







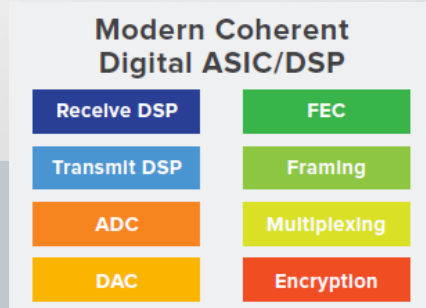




Baud rate — 90 Gbaud/s → 140 → 200 (Impact on channel spacing)

Polarization — Dual Polarization (x2 data transmitted)

Modulation — QPSK (x2) → 8QAM (x3) → 16QAM (x4) → 64QAM (x6) (Impact on distance reach)



Rate (Gb/s) = Baud rate * Polarization (2) * Modulation

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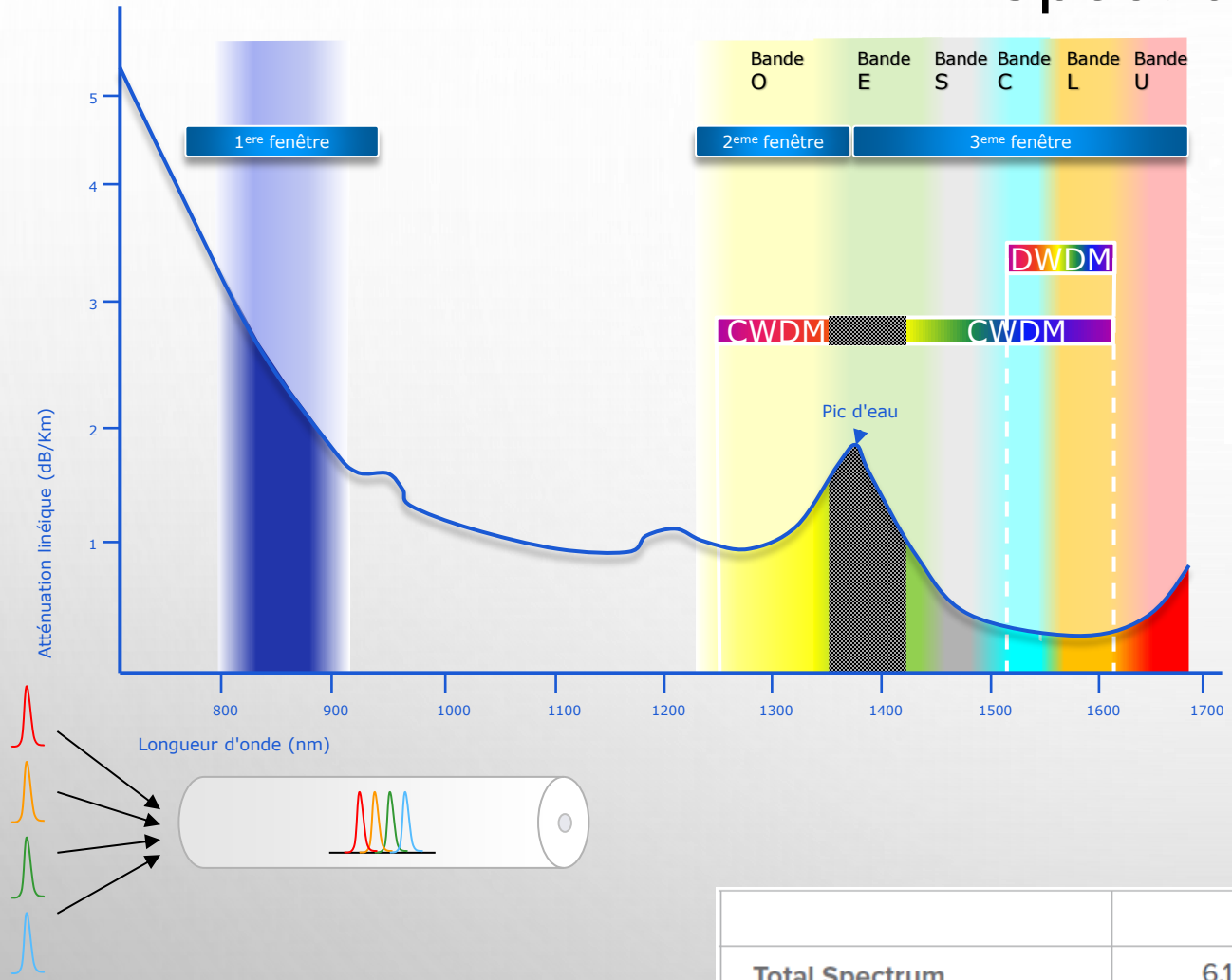
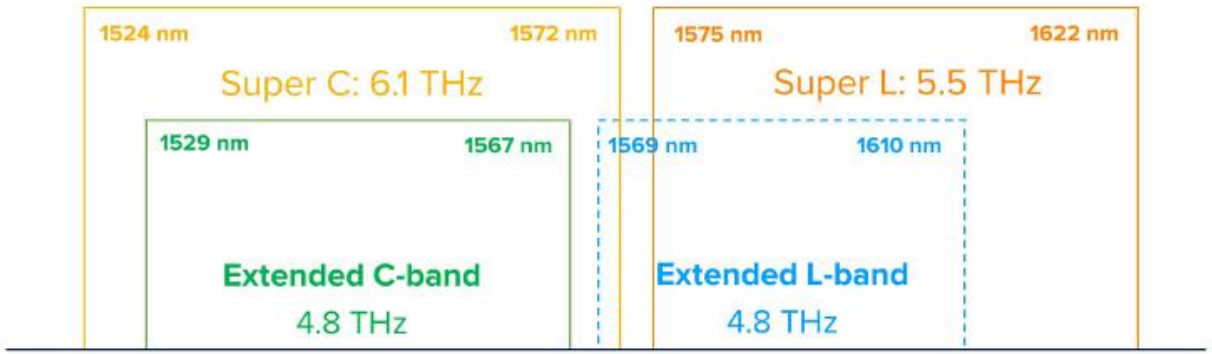
Spectral Grid





- Extended C/L -Band : 4,8 THz
- Super C Band : up to 6,1 Thz
- C + L Band : 9,6 THz
- Super C + Super L = 11,6 THz

	Super C	C+L	Super C + Super L
Total Spectrum	6.1 THz (+27%)	9.6 THz (+100%)	11.6 THz (+142%)
Amplifiers	1x	2x	2x
WSS	1x	2x or 1x (continuous)	2x
SRS Tilt Challenges	x	✓	✓
ASE Idler Hardware	x	✓	✓

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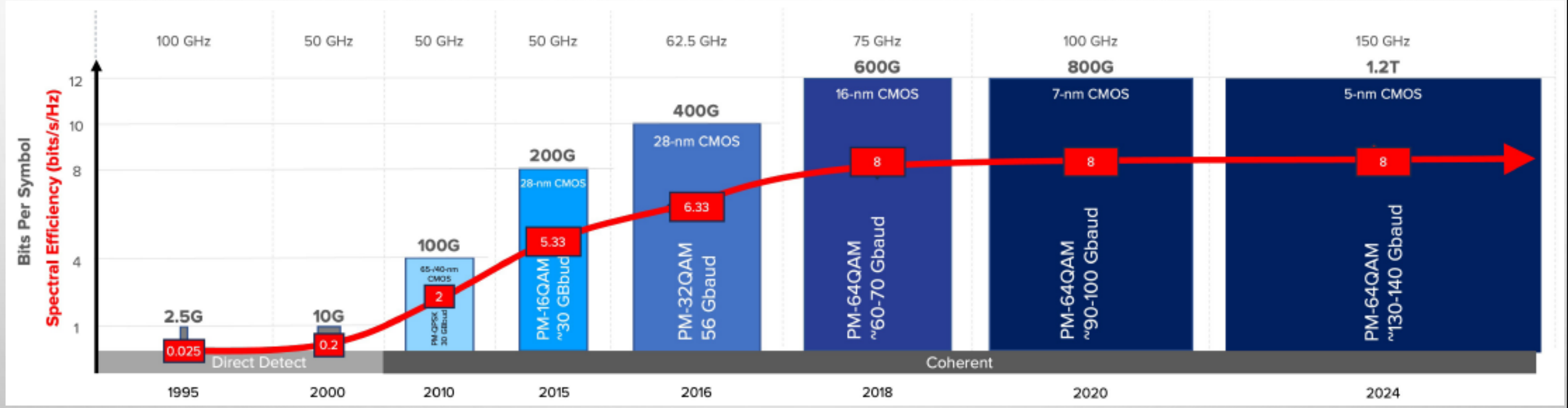
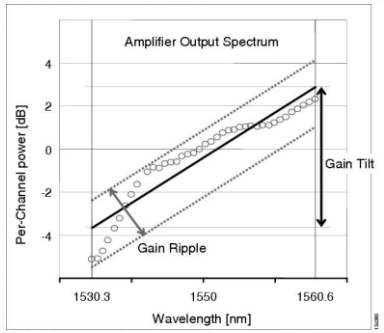
Fiber capacity gains with spectral efficiency



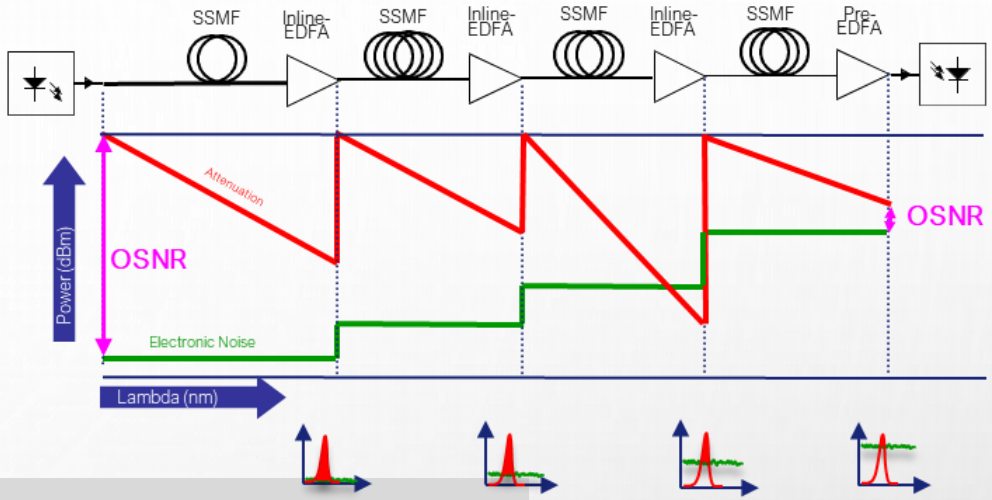
Performances Limiting Effects And Solutions

Optical Amplifier Characteristics

- Noise Figure
- Gain flatness, ripple and tilt



Optical component characteristics (filter shapes, central Fr)



Fiber Effects

- Attenuation (0.14 - 0.22 dB/km typical)
- Chromatic Dispersion
- Polarization Mode Dispersion
- Fiber Non-linearities
  - Stimulated Brillouin Scattering (SBS)
  - Stimulated Raman Scattering (SRS)
  - Cross-phase modulation (XPM)
  - Self-phase modulation (SPM)
  - 4-wave mixing (FWM)

Can compensate for these

→ Amplifiers (ILAs) / ULL fiber

→ Dispersion compensation within DSP of 300k+ ps/nm

→ PMD compensation within DSP of 70 ps+

Cannot compensate for these

- Operate below thresholds
- Non-linear effects vary by
  - Launch power
  - Fiber type / G.652 preferred to G.655 (small CD reduces NL effects)

Dispersion (CD/PMD) is not a bottleneck anymore in coherent systems
Main trade-off is OSNR and NL

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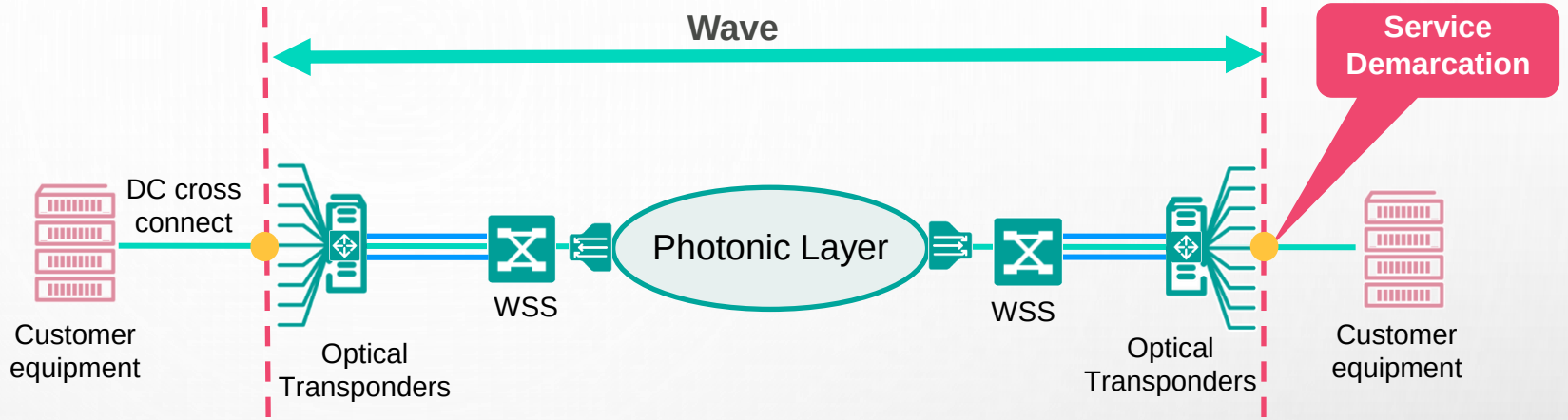
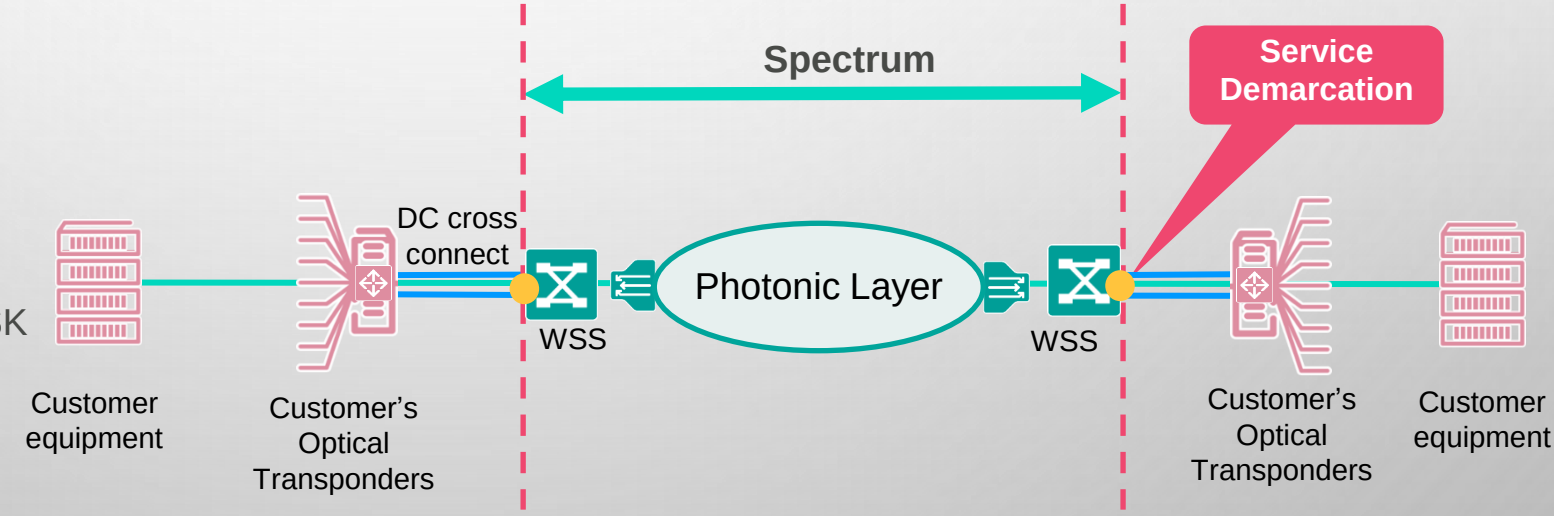
Spectrum versus Wavelengths – what's the difference?

- Delivery fully managed end-to-end wavelength service 10GE/100GE/400GE/800GE
- Wavelengths purchased individually to meet demand



- Customer typically responsible for provision, management and monitoring of transponders within a customer-controlled rack
- Customer may use Spectrum as required QPSK and 8/16/32/64QAM modulation schemes



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