TWNOG - Presentation Submission
The Industrial Technology Update

April 2024

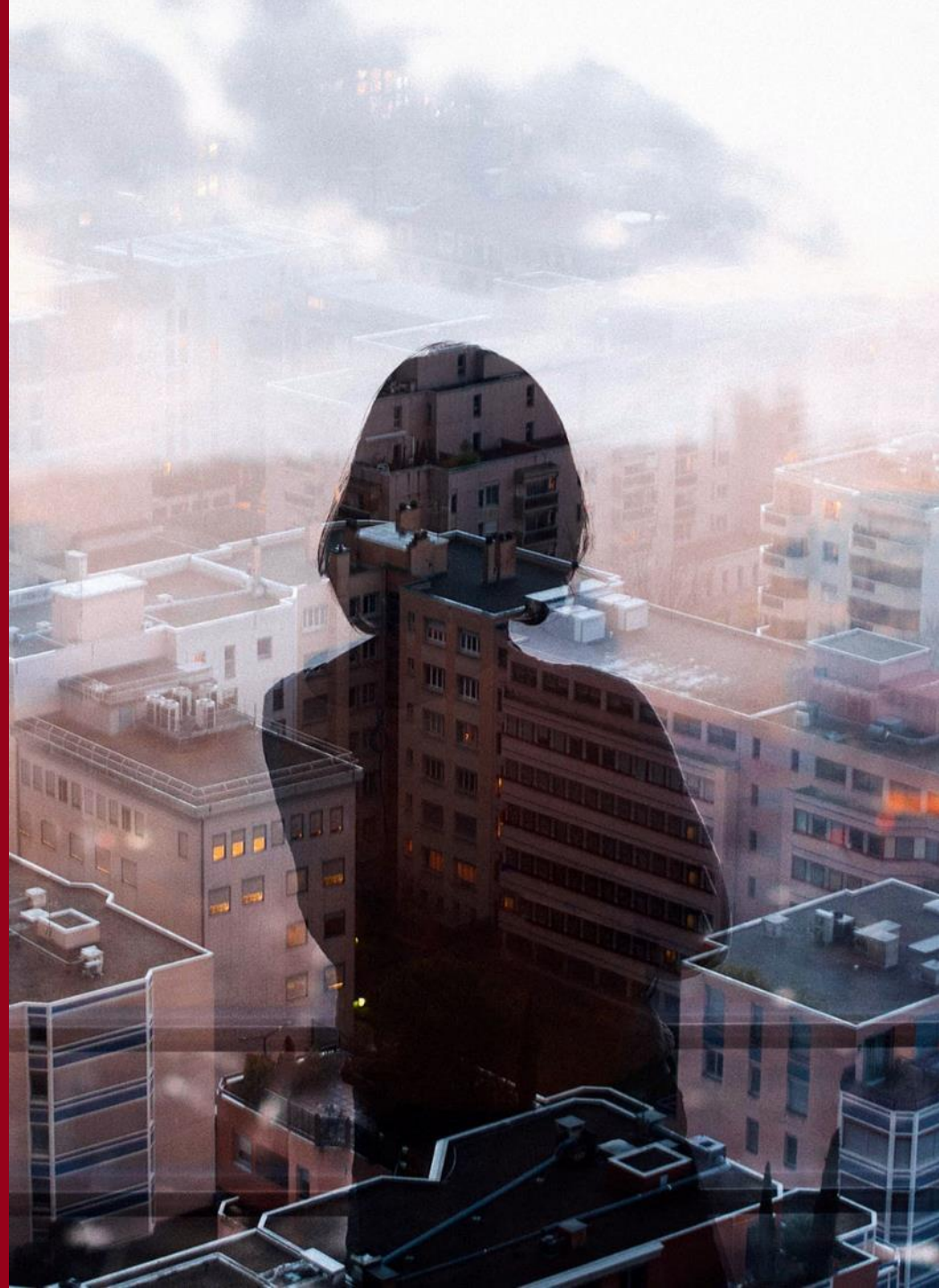
Agenda

1 Technology update

- Photonics & Modems
- Coherent Pluggable
- NMS Evolution
- 3nm CMOS
- Network Management Evolution
- Evolution of the Submarine Network Wetplant
- Repeaterless System

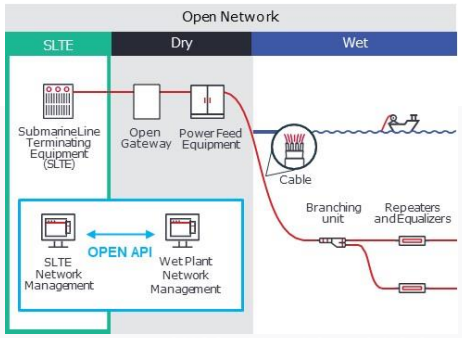
2 Q&A

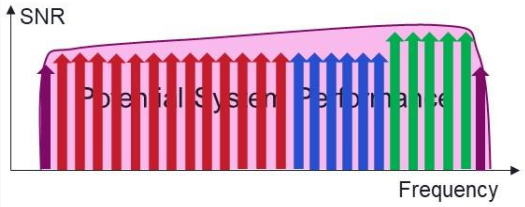
Technology Update

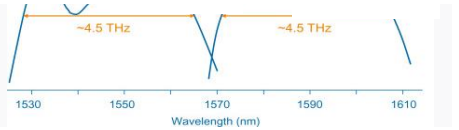


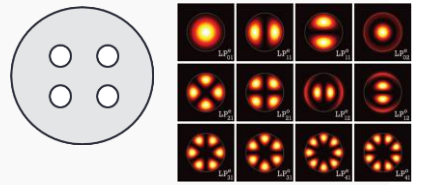
Submarine Cable Industry Current Trends

Open Networks	• Evolution of Open Cables to Open Networks • Open APIs on wet plant NMS to allow integration with SLTE NMS • Industry Standardisation of APIs and Cable Model to follow
>1Tb/s high baud modems	• Target up to 1.6Tb/s with 3nm CMOS – 800G anywhere on submarine • Spectral efficiency improvement and fewer modems, reducing cost/bit • Green solution reducing capex and opex with space & power optimisation
Automation	• For validation and acceptance of open systems – optimiser tool • Maximum capacity from upshifting channels with margin • Continuous monitoring of multiple parameters from today's modems
C&L band	• C+L terrestrial backhaul to satisfy backhaul demand with SDM systems • Terrestrial backhaul with reduced fibre count • Regen optimization can reduce overall system cost significantly
Multi-core & multi-mode fibre	• Increase capacity through single fibre • Multi-core fibre (MCF) first stage, 2-4 cores, trial in 2024 • Multi-mode and higher count MCF significant R&D challenges to overcome
Coherent Pluggables	• 400G and 800G client everywhere • Extreme low power consumption 15W/24W to make CLS Regeneration possible • High performance for BH/Metro/Regional ROADM networks • Retaining Design capacity from Wetplant

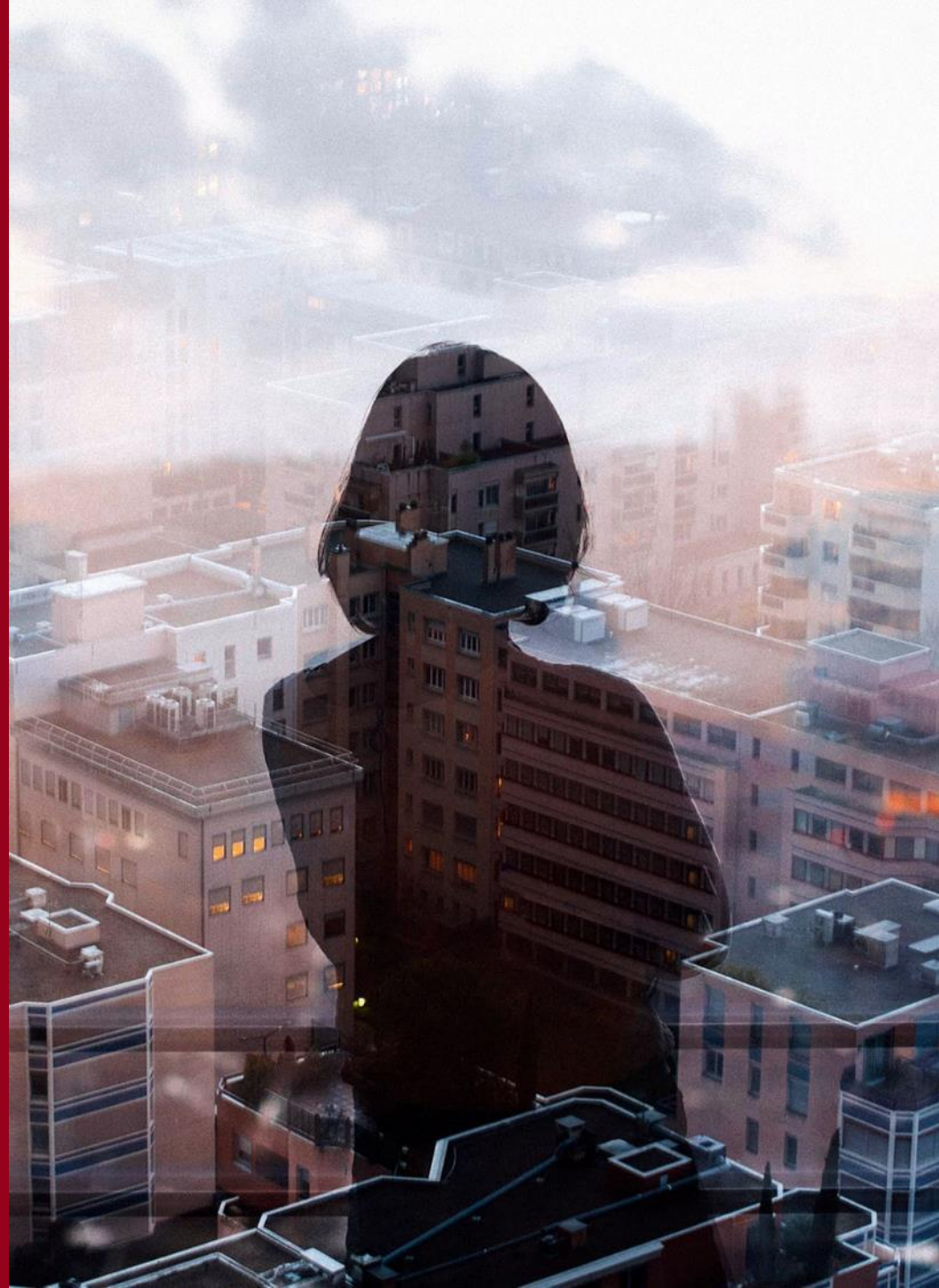








Photonics and Modems



Coherent optics becoming ubiquitous choice in transport – various designs required

Unamplified single channel	Access (DAA, 5G)	Metro DCI	Multi-span Metro	Long Haul	Submarine
10s km	10s km	100 km	10s to 100s km (Tier 2 city – Metro City)	100s to 1000s km	10,000km
• PT-to-PT, 10s km	• PT-to-PT or OADM • High loss spans • Outside plant • Scarce fiber	• PT-to-PT, 100km • High Capacity DWDM	• Highly Mesh • Cascaded ROADMs • Protect/restoration key	• Spectral Efficiency • Long reach, light mesh • Protect/restoration key • C&L-band	• Reach & spectral efficiency paramount • Compensated and uncomp'd cables
• Rx dynamic range	• Set central freq. • Adjust. output power • Monitor SNR • I-temp	• Power dissipation • Ethernet Support	• Ethernet + OTN clients • Adjustable line rate • CD/PMD/SOP comp. • L0 CP, line protection • Spectral shaping for ROADM tolerance	• PCS/FEC for reach • Different Link modes • L-band	• Adjust. baud • Extreme CD, cycle slip tolerance • Monitor SOP • Nonlinear comp. • Link optimization modes for diff. cable env

Application requirements

Coherent Optic requirements

Coherent Technology Evolution

Objective: Continued cost/power per bit reduction through technology innovation

End Goal

- Scale
- Reduction in $/bit and W per km
- Operational Simplification
- Adaptability
- Ability to innovate

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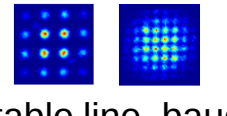
2 Distinct Designs

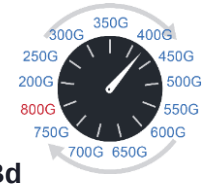
INDUSTRY LEADING TODAY

Performance

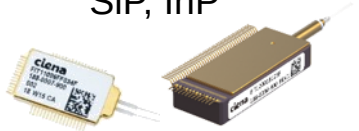
- PCS
- FDM
- Adjustable line, baud
- Throughput-optimized FEC
- Rich metrics, monitoring



7nm CMOS 90-110GBd

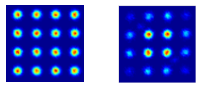


Photonic integration: SiP, InP



Footprint

- Interop
- High perf. w/PCS
- Low power design
- Packaging key focus



7nm CMOS 60-70GBd

Photonic integration SiP

NEAR FUTURE 2-3 designs

5nm CMOS

3nm CMOS

- New CMOS gen.
- New materials
- Higher baud, capacity
- More intelligence, programmability
- Latency

Choice in technology, DSP algorithms and implementation/co-design dictate performance & savings

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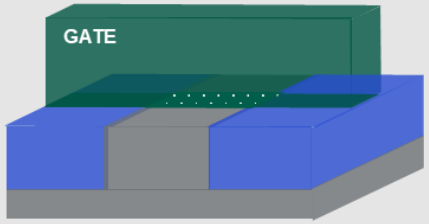
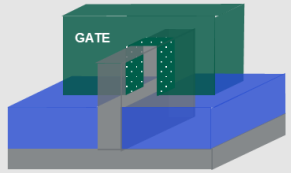
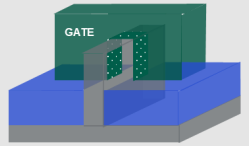
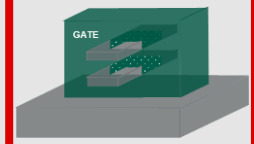
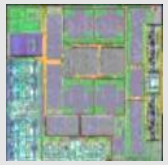
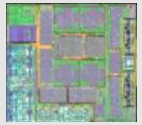
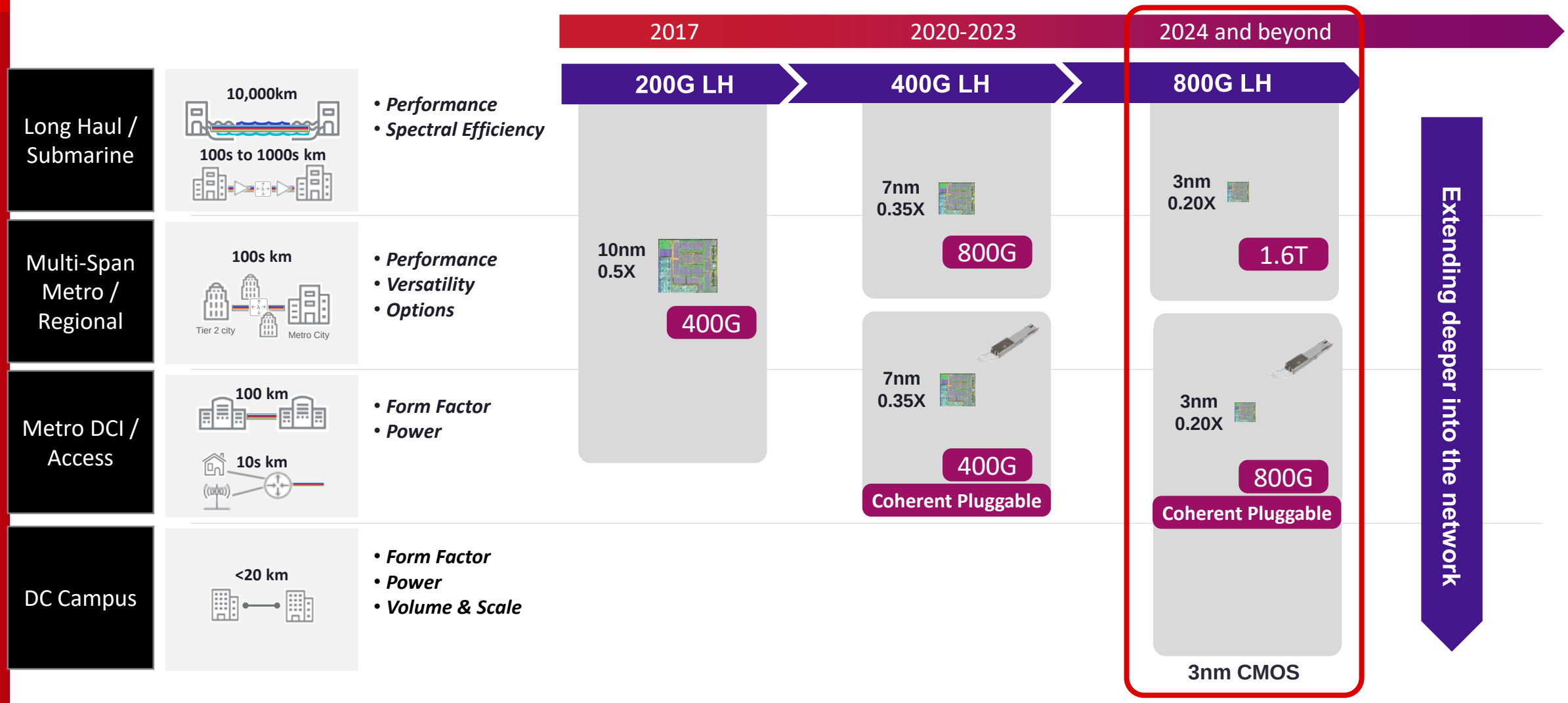
Appropriate CMOS technology for DSP

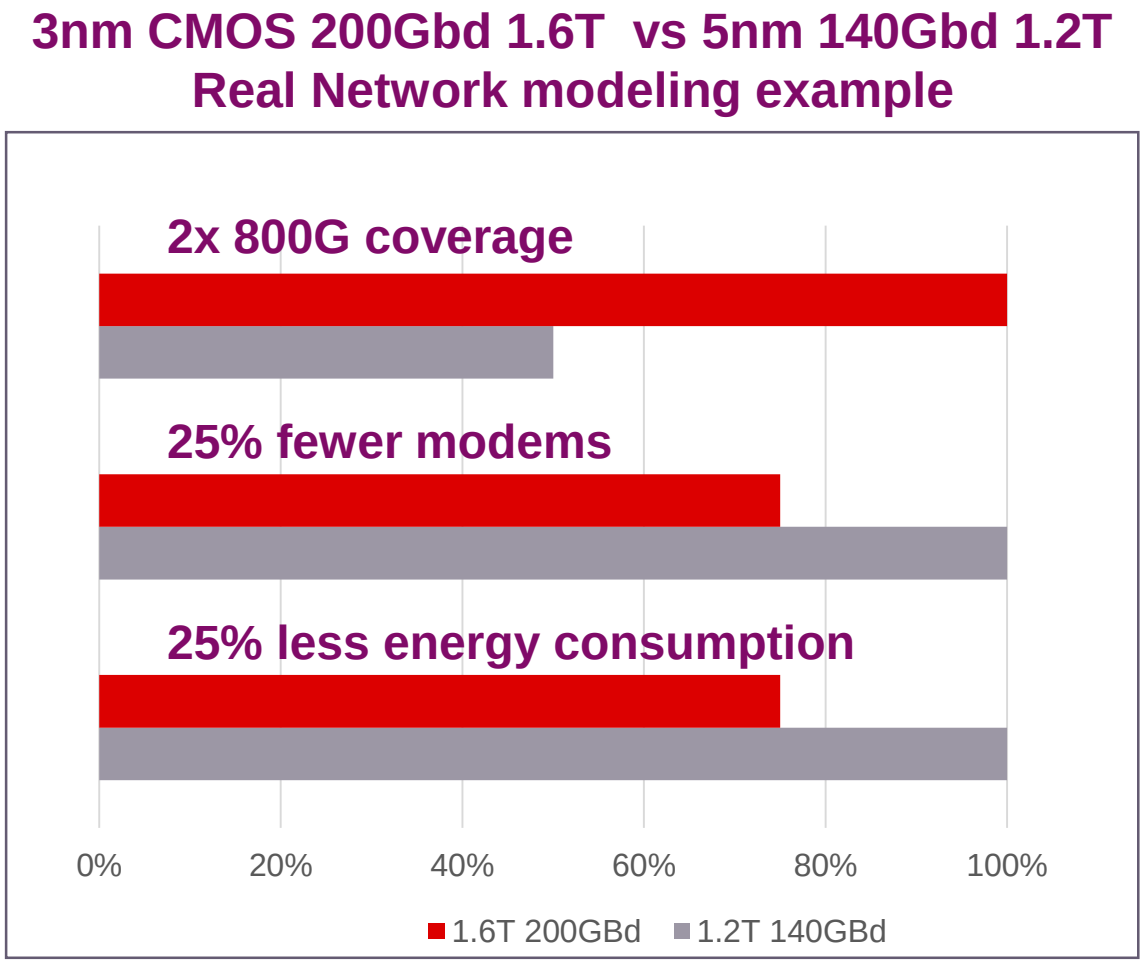
Driven by → 1. Power consumption considerations → 2. Die Area (cost)

Structure	Planar CMOS technology	finFET CMOS technology			finFET or GAA CMOS technology	
Transistor						
Digital gate shrink ratio	 28nm 1X	 16nm 0.7X	 10nm 0.5X	 7nm 0.35X	 5nm 0.30X	 3nm 0.20X
Heat ratio	1X	0.28X	0.18X	0.11X	0.065X	0.049X

Industry Expands upon already rich portfolio offering with Latest CMOS development

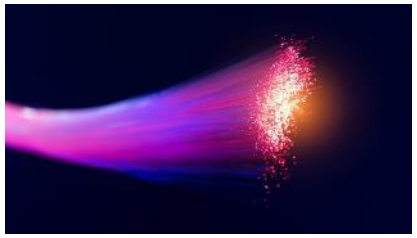


200GBaud design enables 800G network coverage over virtually all links, as well as improved cost and power efficiencies



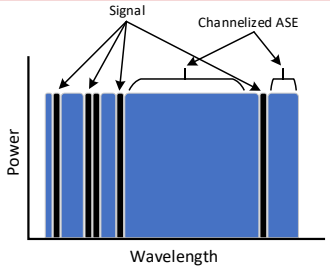
Next Generation Photonic System
What will be the requirement nowadays?

Ultra-dense design for optimal scale and efficiencies



- Ultra-dense configurations
- Future-proof design, ready for 100Gbaud signals
- Optimized for Uncompensated Open Submarine Cables
- C&L Band Ready Platform
- Ultra low power and small footprint

Simple to Deploy and Operate



- Integrated channelized ASE source in every ROADM blade
- System is kept in constant loading condition by filling any empty channel slot with ASE
- Common submarine and terrestrial operation

Advanced Programmability and Openness

netconf GRPC Open ROADM bp MCP { REST } SNMP OPENCONFIG CLI

- Model-driven config and streaming telemetry
- Multi-model
- Multi-protocol
- Architected for 3rd party SW with SDK

Delivering scale and programmability required for a more adaptive network

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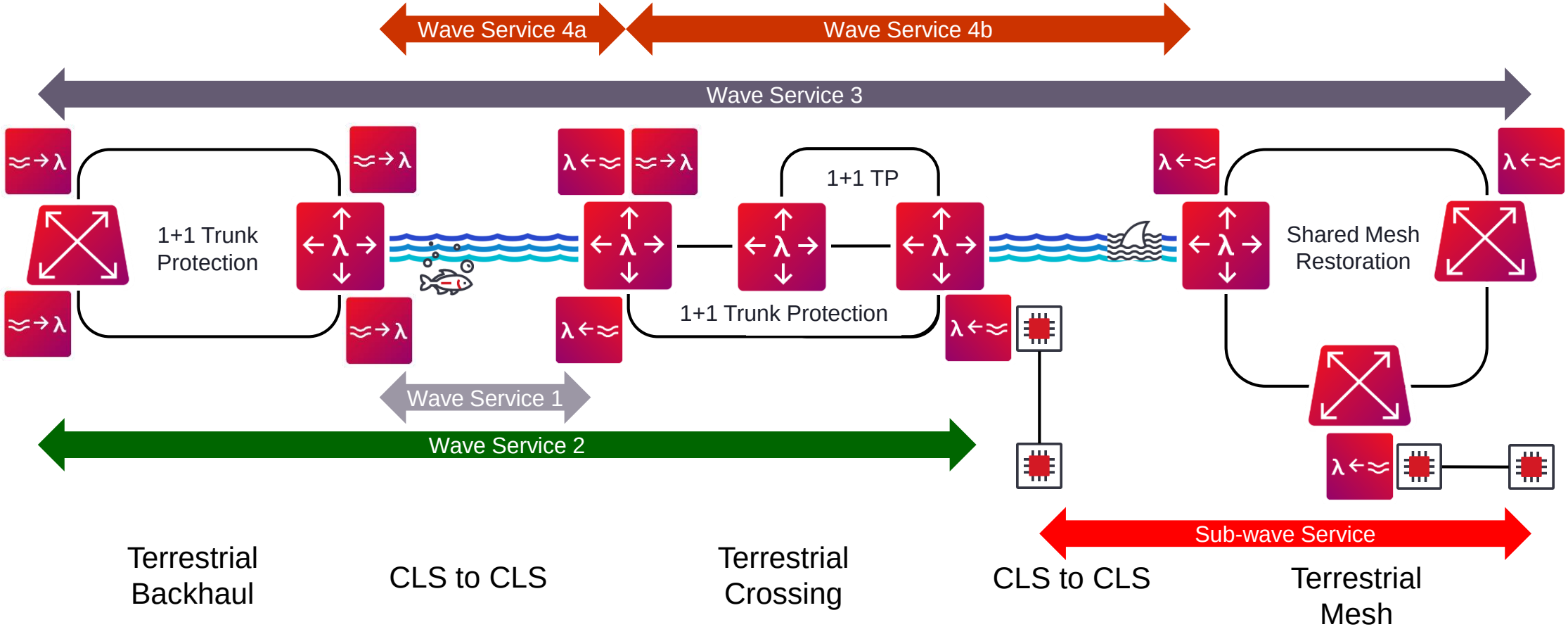
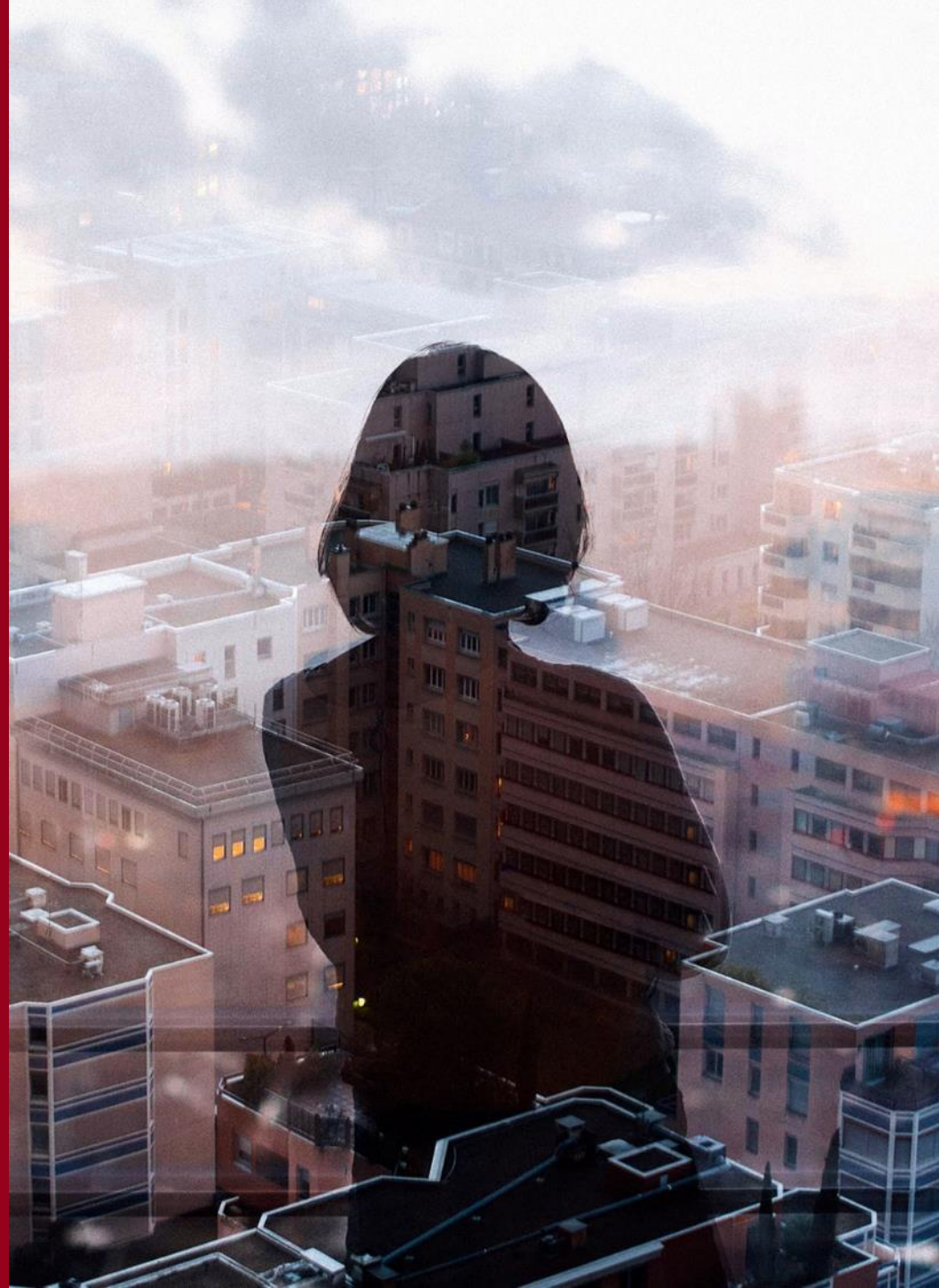
Wide Range of End-to-end Photonic Application Connectivity



400G/800G coherent pluggable - today and tomorrow



Drivers for the next generation of coherent pluggables

Ciena leading contributor in standards bodies/forums defining new rates

400ZR (OIF) optimized for 12.8 / 25.6T switch

800ZR (OIF) optimized for 51.2T switch

400ZR+ for interoperable converged IP/Optical – metro

400G (ITU-T / Open ROADM) for metro transport ROADM networks

B400G (ITU-T / Open ROADM)
800G packet-optimized metro
800G transport ROADM metro networks
400G, 600G long haul transport

400G high performance for metro/regional ROADM networks

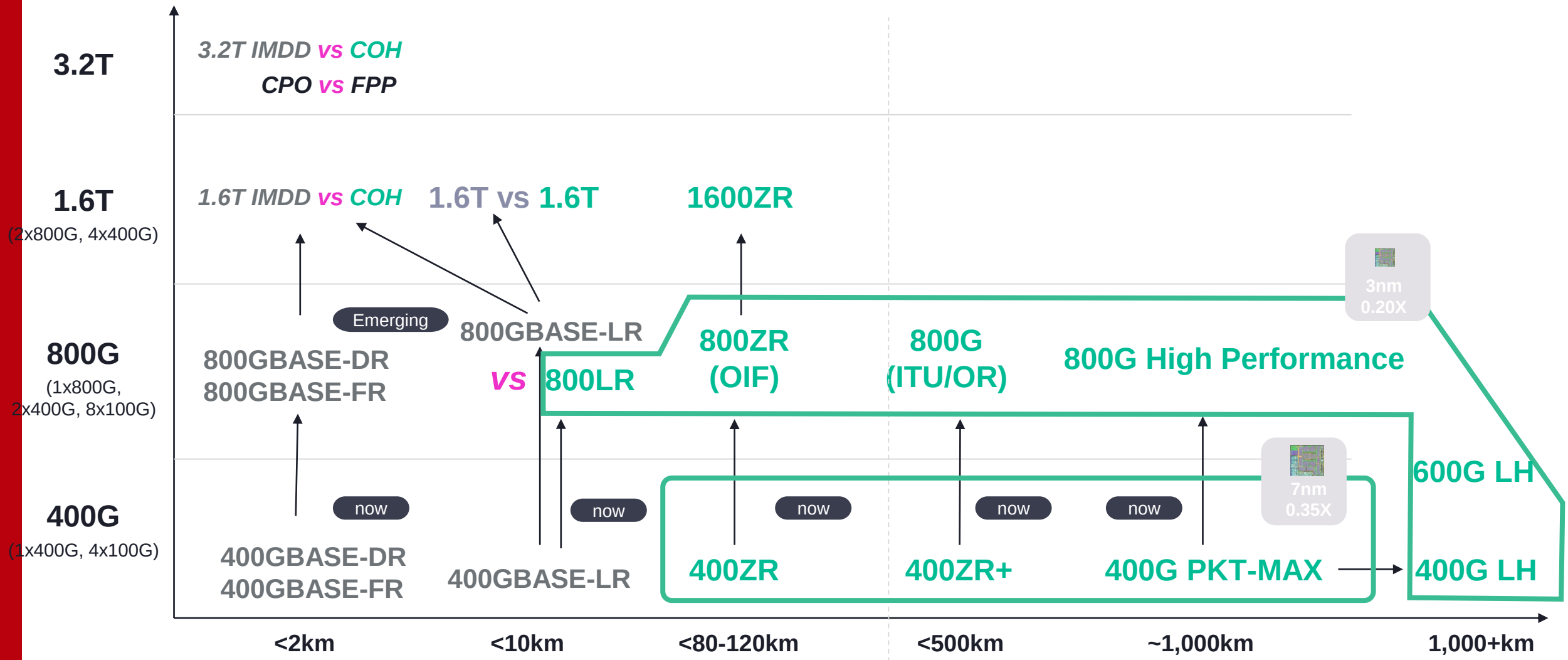
800G high performance for metro/regional ROADM and converged IP/Optical transport

IMDD hitting physical limits

Discussions in standards on using coherent for 800G LR **(800LR)** and higher speeds

IMDD vs Coherent Transition and Evolution

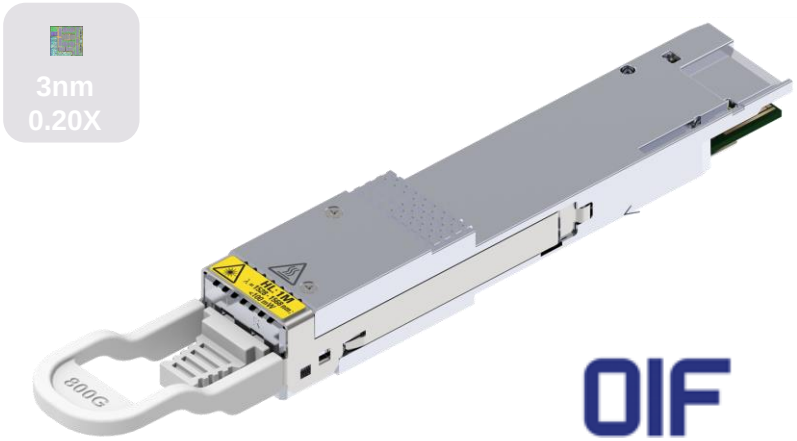
IMDD: Intensity Modulation – Direct Detection
COH: COHerent
CPO: Co-Packaged Optics
FPP: Front Panel Pluggables



WL6n 800ZR QSFP-DD

Overview

- 800ZR coherent optics
- OIF 800ZR IA compliant
- Ciena 3nm CMOS WL6n DSP
- Ciena high speed electro-optics
- Fully integrated design for optimal performance



Module Specifications

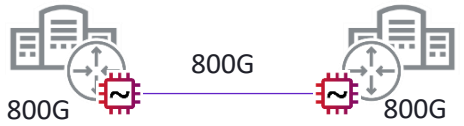
- Single carrier, 150GHz grid compliant transmission
- 100GE, 200GE, 400GE, 800GE clients
- 8x112G electrical lanes
- Standard operating temperature
- I2C, CMIS compliant
- QSFP-DD800 MSA compliant (OSFP1600 also supported)

Optical Specifications

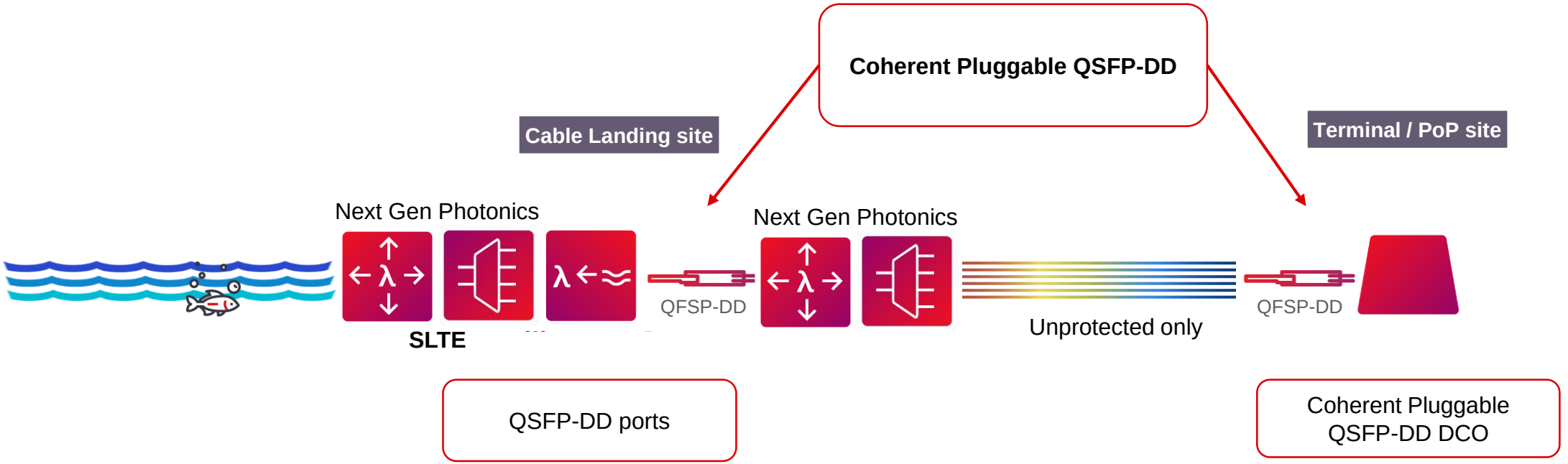
- 800G 118GBd DP-16QAM
- OFEC
- Full C-Band tunable DWDM
- Up to 120 km single span amplified

Primary Use Case

- Data Center 120 km Interconnect

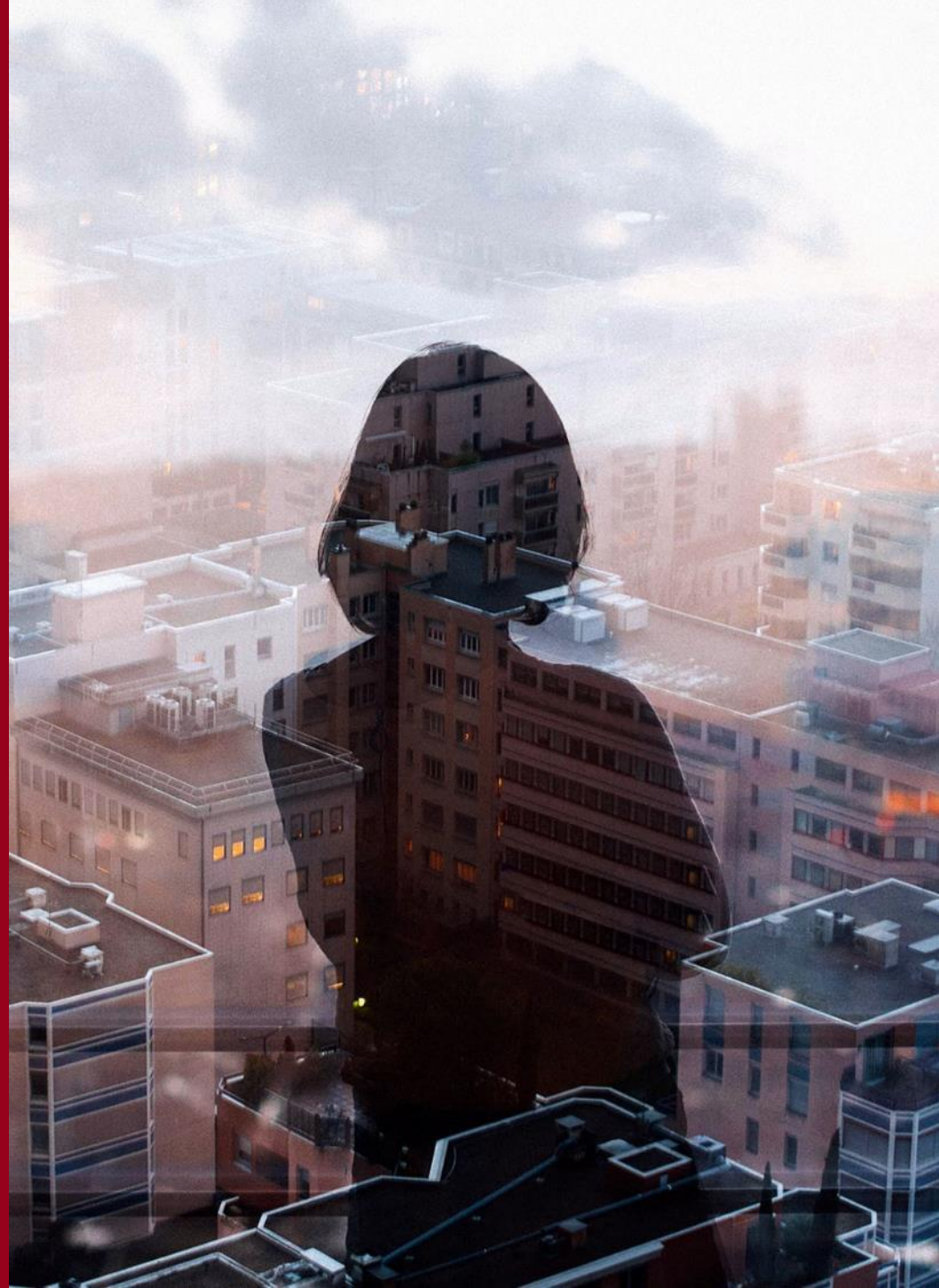


High Level Design – Low cost and Power for Regeneration at CLS

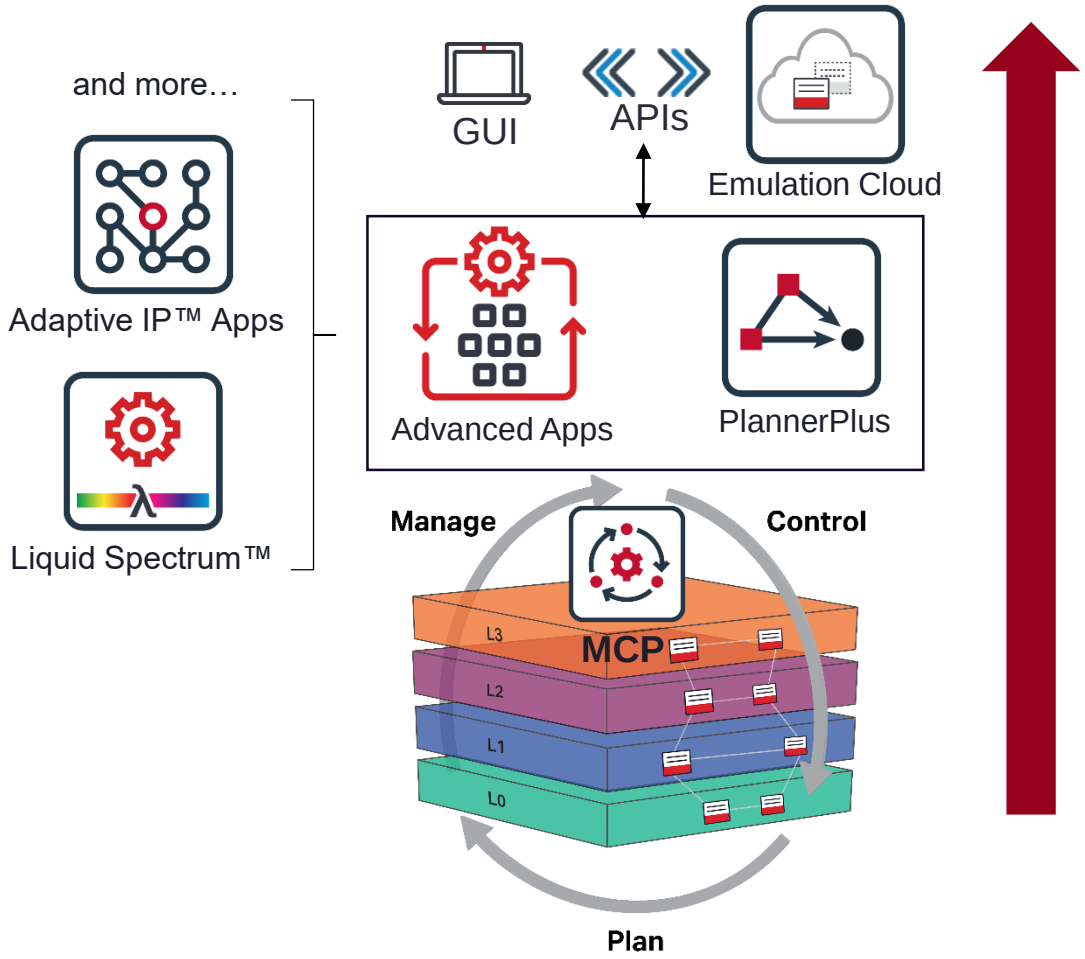


To maintain end to end design capacity with low cost and power pluggable

Network Management Evolution



New NMS – More than a Network Management System



Emulation Cloud
Open environment for training, integration testing, and deployments

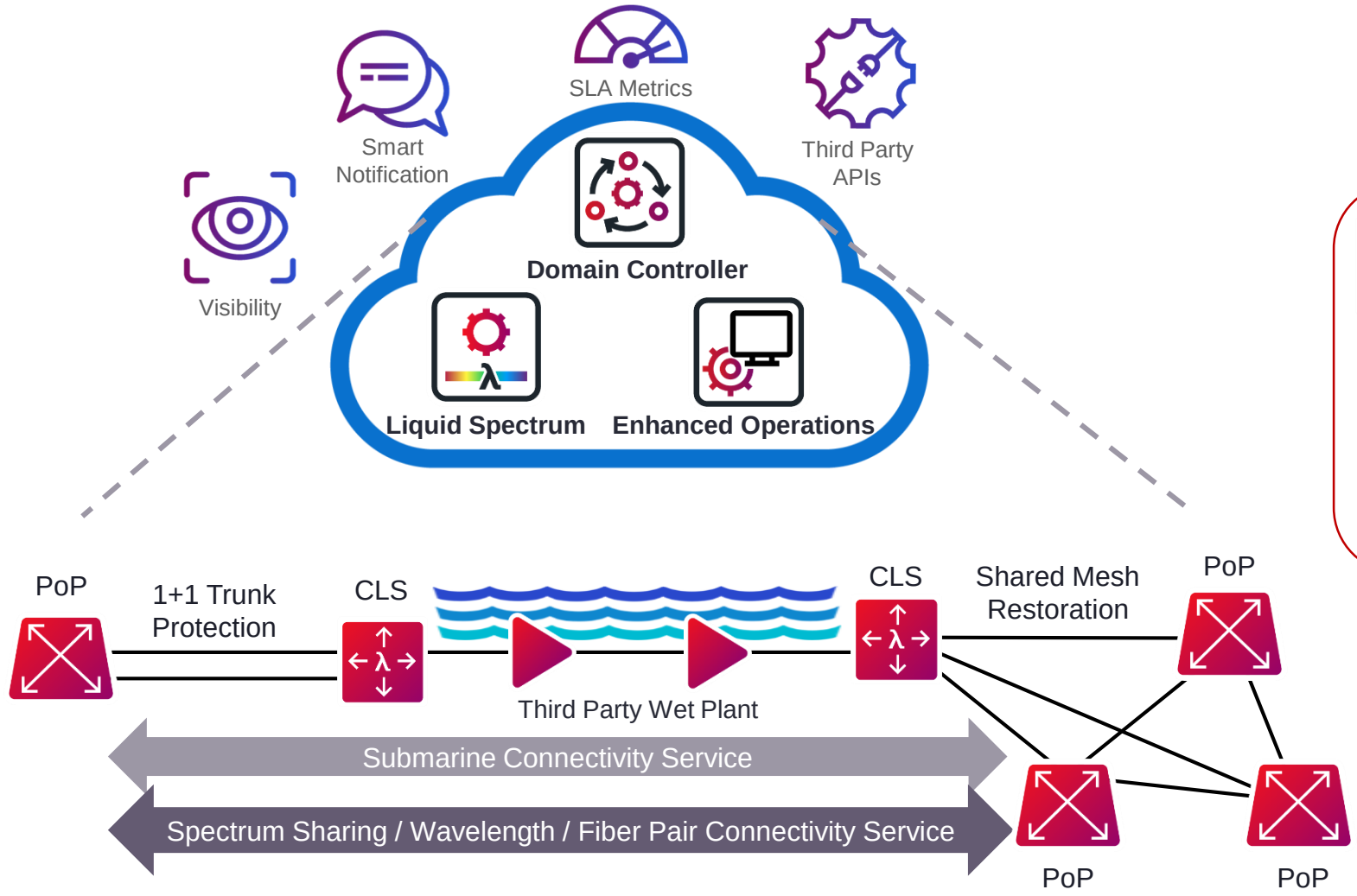
Advanced Apps
Apps to enhance operations and simplify user experience
Liquid Spectrum applications driving intelligent optical management and optimization

PlannerPlus, Channel Planner
Planning for accurate network design, wavelength assignment

Manage, Control and Plan
Multi-layer domain controller for automated network and service lifecycle operations

MCP multi-layer domain control enables advanced apps to accelerate operations & optimize infrastructure

Network Visibility & Intelligent Control Across Entire Submarine Network



Remote Optical Add/Drop Multiplexor (ROADM)

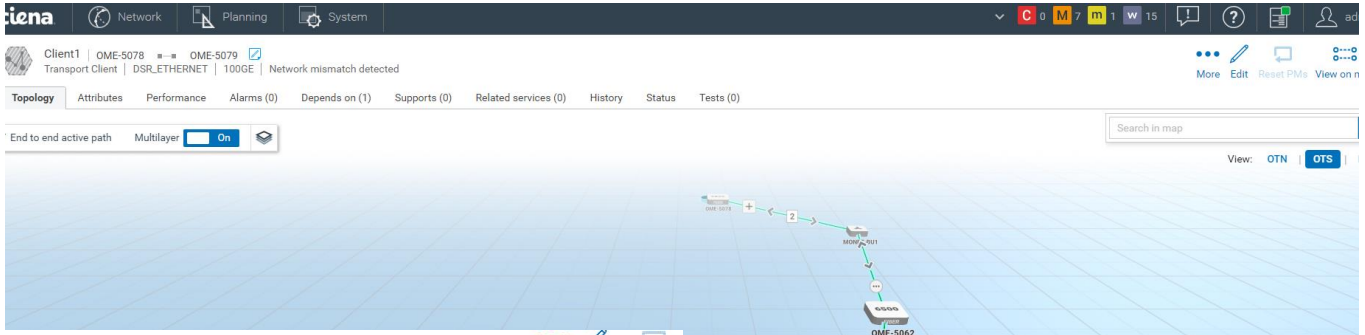
Submarine Line Terminal Equipment (SLTE)

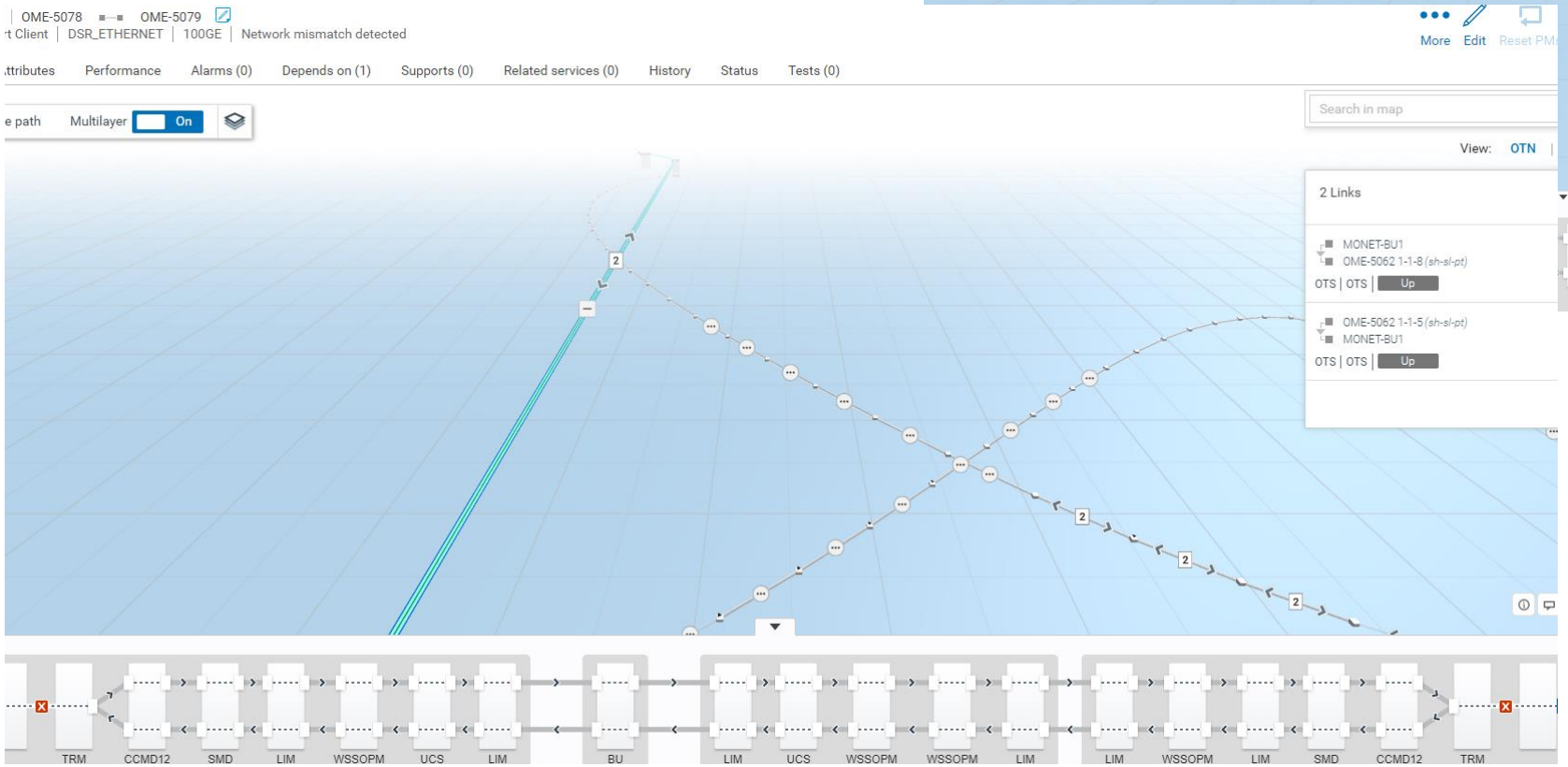
Cable Landing Station (CLS)

Point of Presence (PoP)

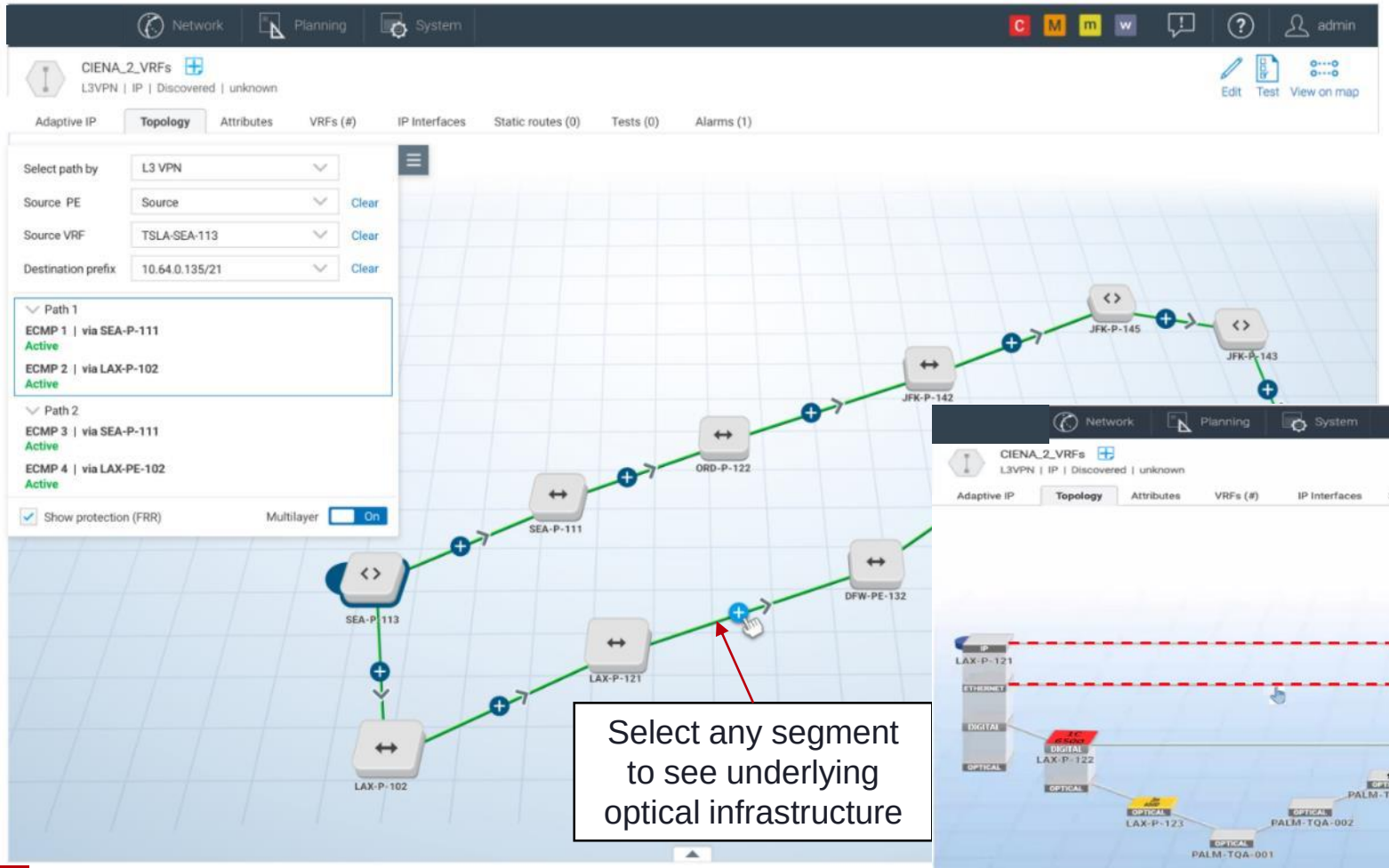
Multi-Layer Visualization of Submarine Networks

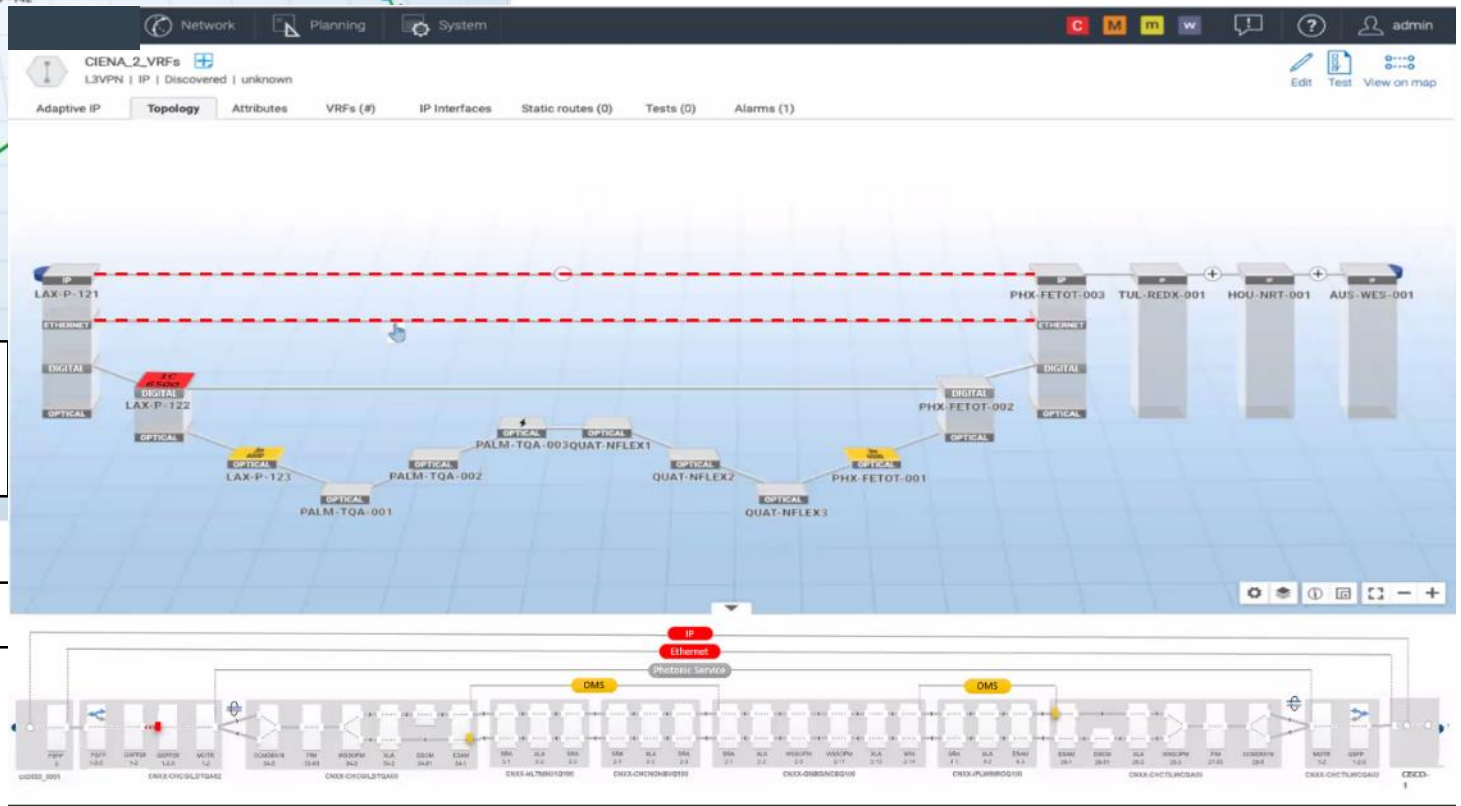
- Physical layer including repeaters
- OTN layer to show client traffic





Multi-layer modelling and visualization from layer 0 to layer 3





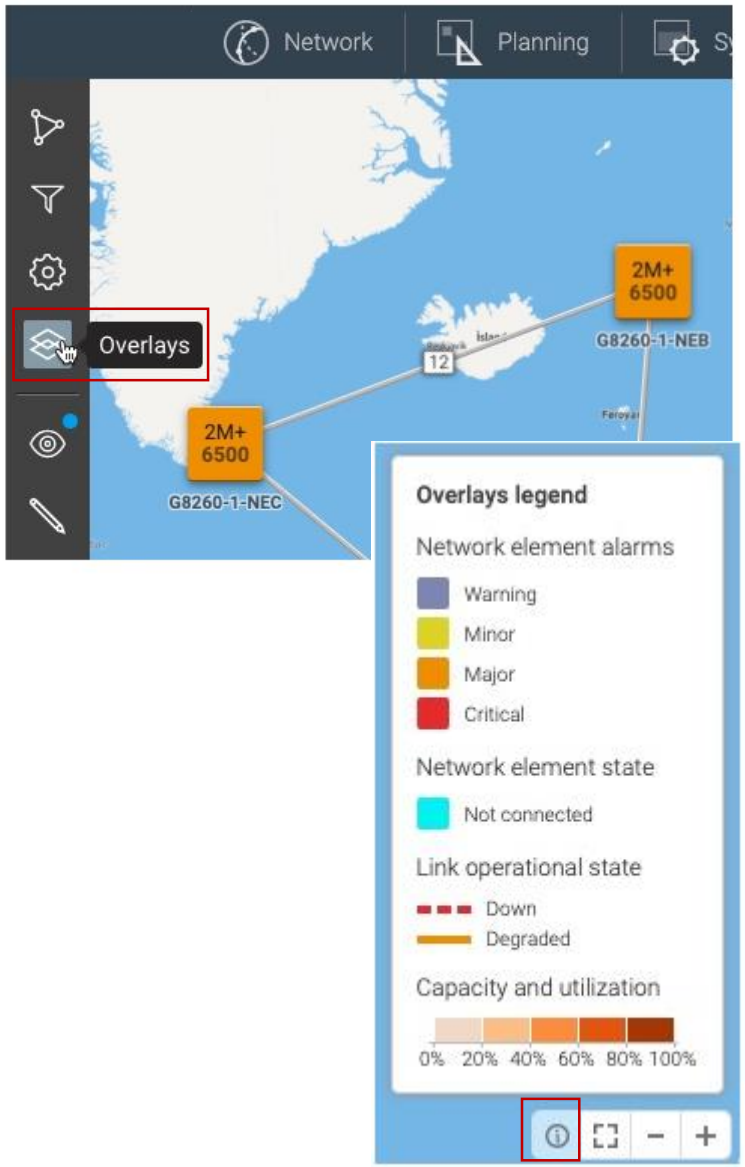
Subway view of selected infrastructure

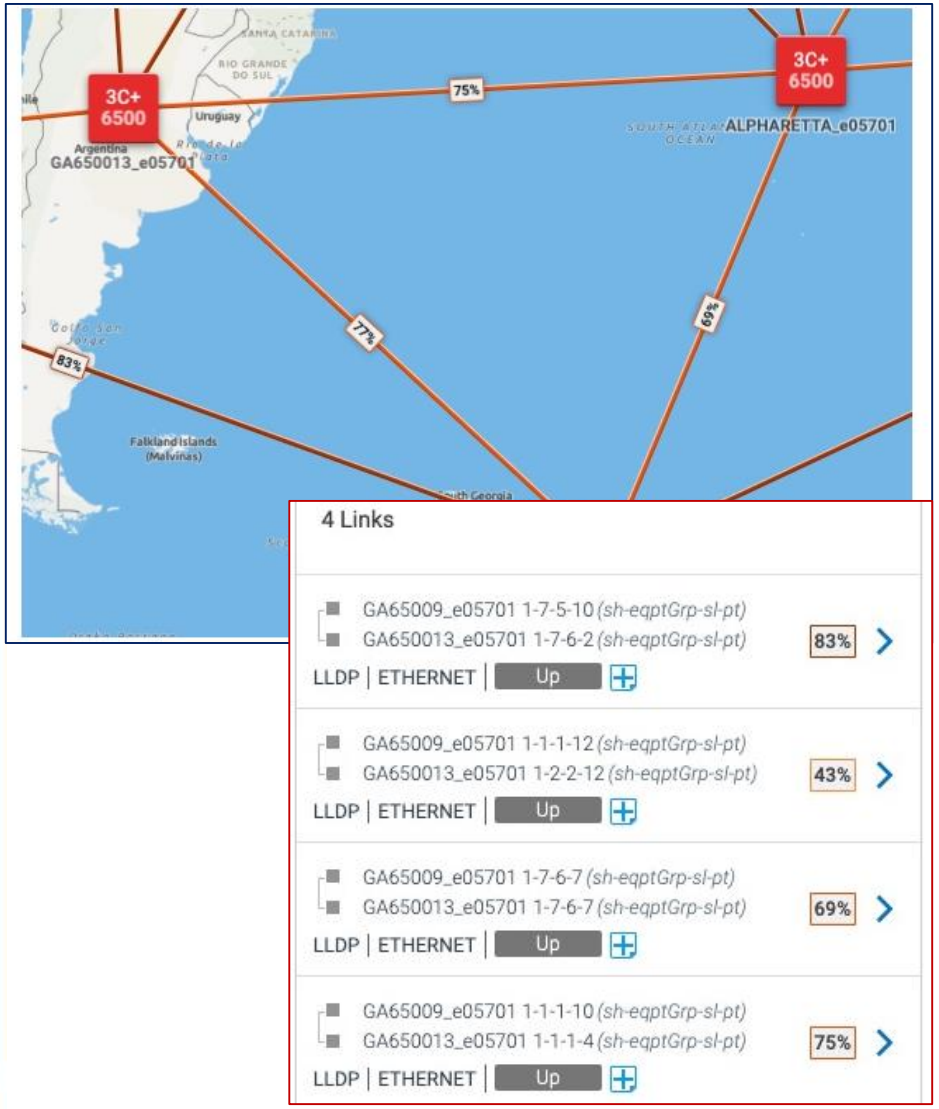
- Ethernet over DWDM multi-layer support
- Supports/Depends tabs on L2 to L0
- 3D multi-layer trace visual (MCP Plus)
- Supports/Depends tabs on L3 to L0 (w/AIPA)

Network Utilization – Geographic map view

Functionality:

- Capacity and utilization overlays are available in the network map sidebar – visible `as heat map or highest usage interval display styles`
- `Visualize provisioned capacity on network map links (Fiber, ROADMLine, OTU, OTN OSRP line)`
- `Visualize 24h and 7d utilization metrics on client ports`
- Link-based heat map shows the utilization percentage on each link
- Supported on specific releases of 6500, Waveserver and RLS devices





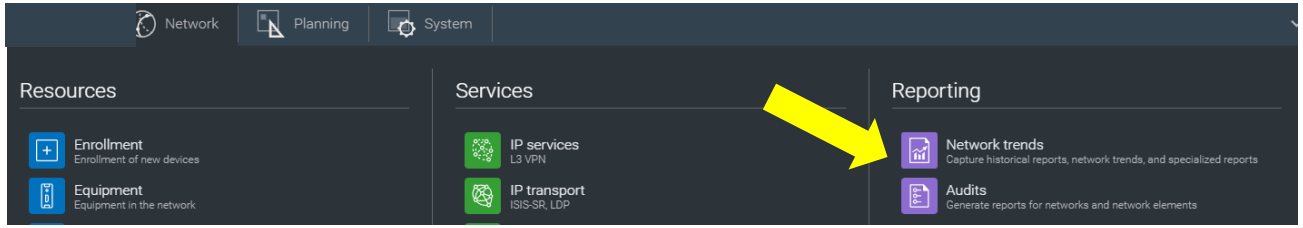
Network Trends – Proactively manage network performance

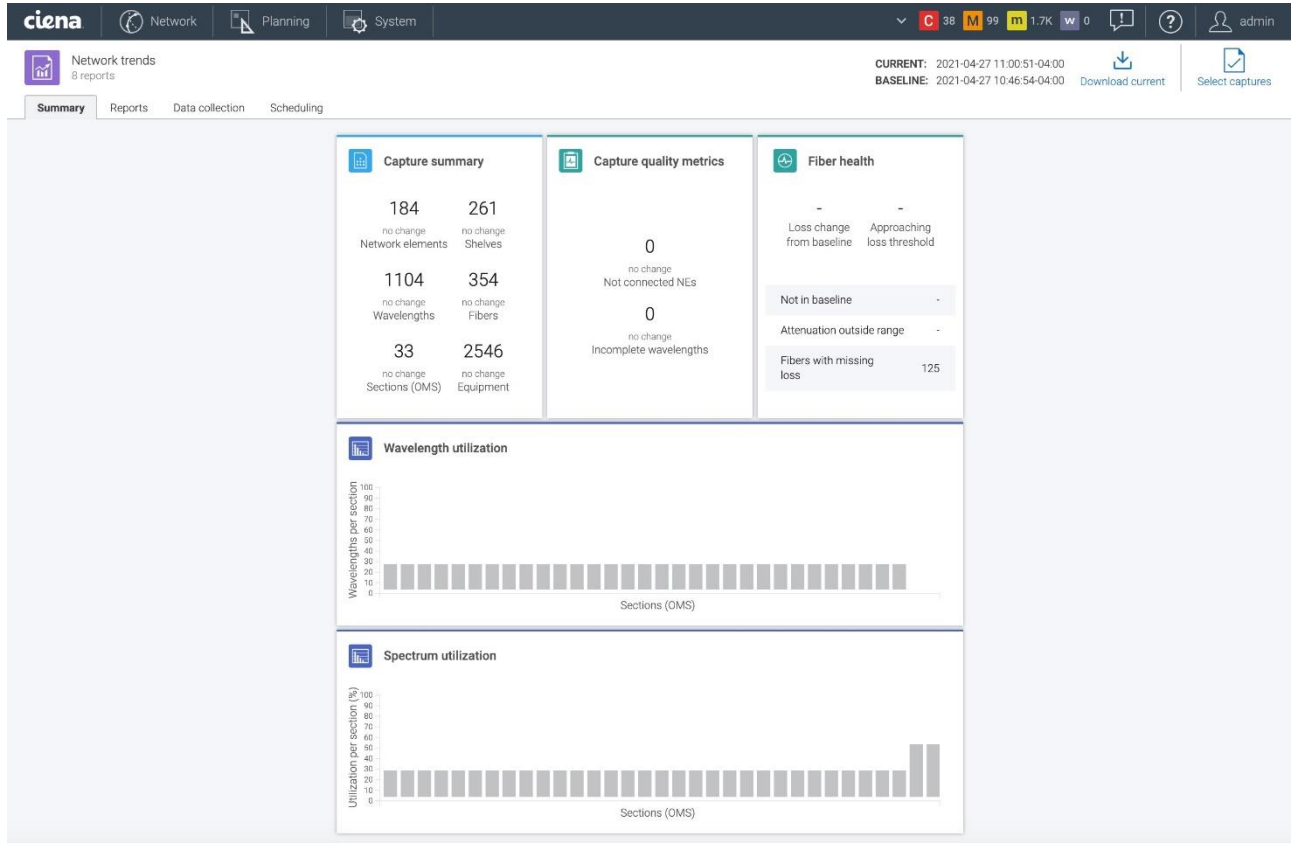
Benefits:

- Visualize historical trends & reports across services, equipment, and performance measurements (PMs)
- Mitigate optical service performance degradation by proactively monitoring fiber health

Functionality:

- Generate historical graphs and reports based on captured network data
- User can schedule network capture daily or weekly, and manage captures
- Retrieve and look at a trend graph for a particular attribute over time, to find predictive patterns
- Compare snapshots from two different points in time
- Trend key PM data points such as SNR with Liquid Spectrum Channel Margin Gauge (CMG), Photonic Performance Gauge (PPG), and Tx/Rx optical power levels to mitigate service issues and fiber degradation
- Supported for all device types



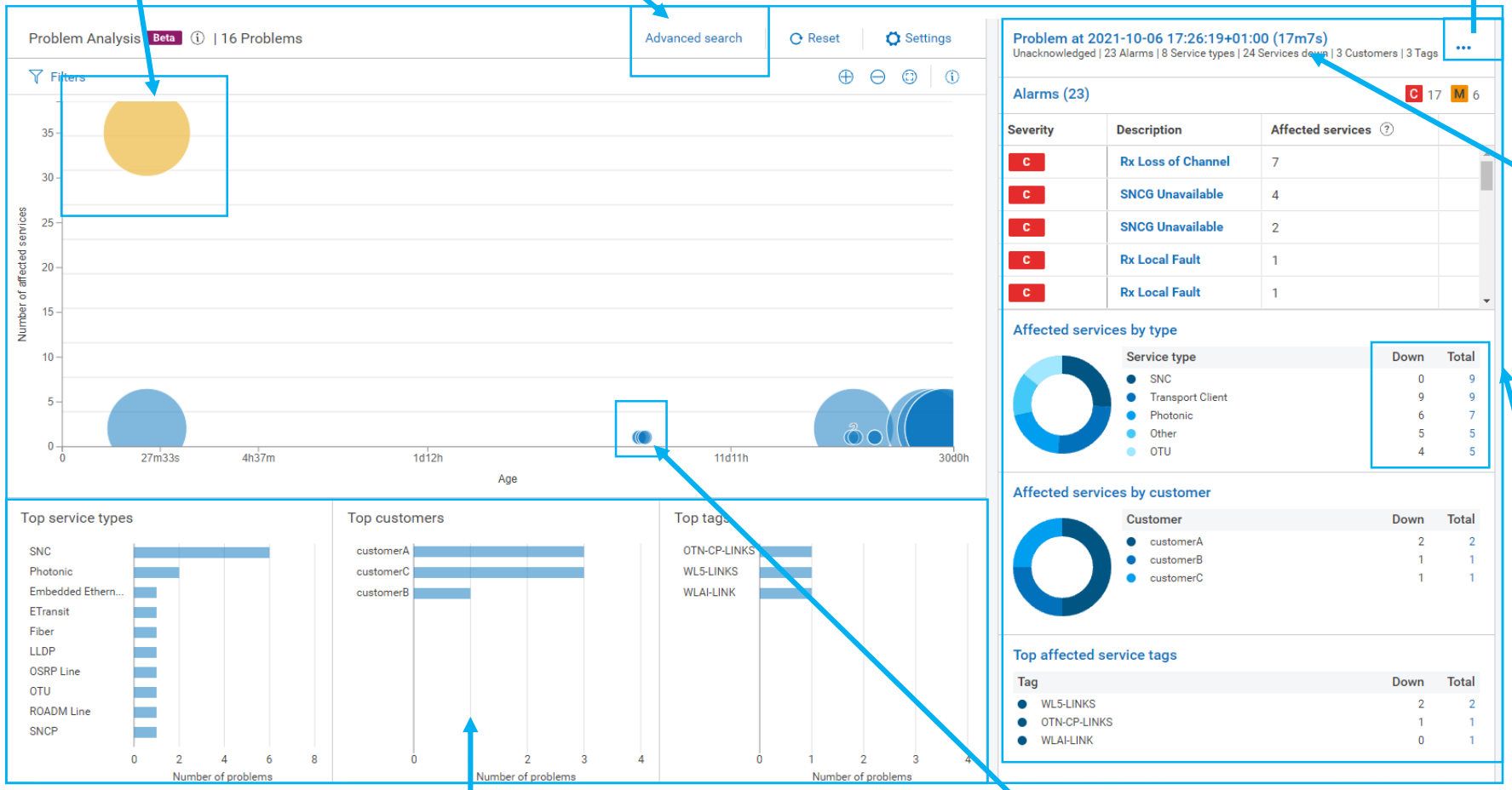


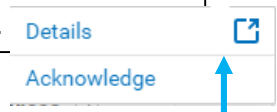
Problem Analyzer

Biggest problem in last 30 days

Advanced Search to filter out less important problems

Acknowledge problem, or show more details for that problem….





Benefits

- Alarms for all related infrastructure and services (Fiber/OTS, ROADM line, Photonic services) grouped together
- Helps identify customer impacts of network alarms quickly
- Dashboard filtering to narrow down focus area

Selected problem high level data:

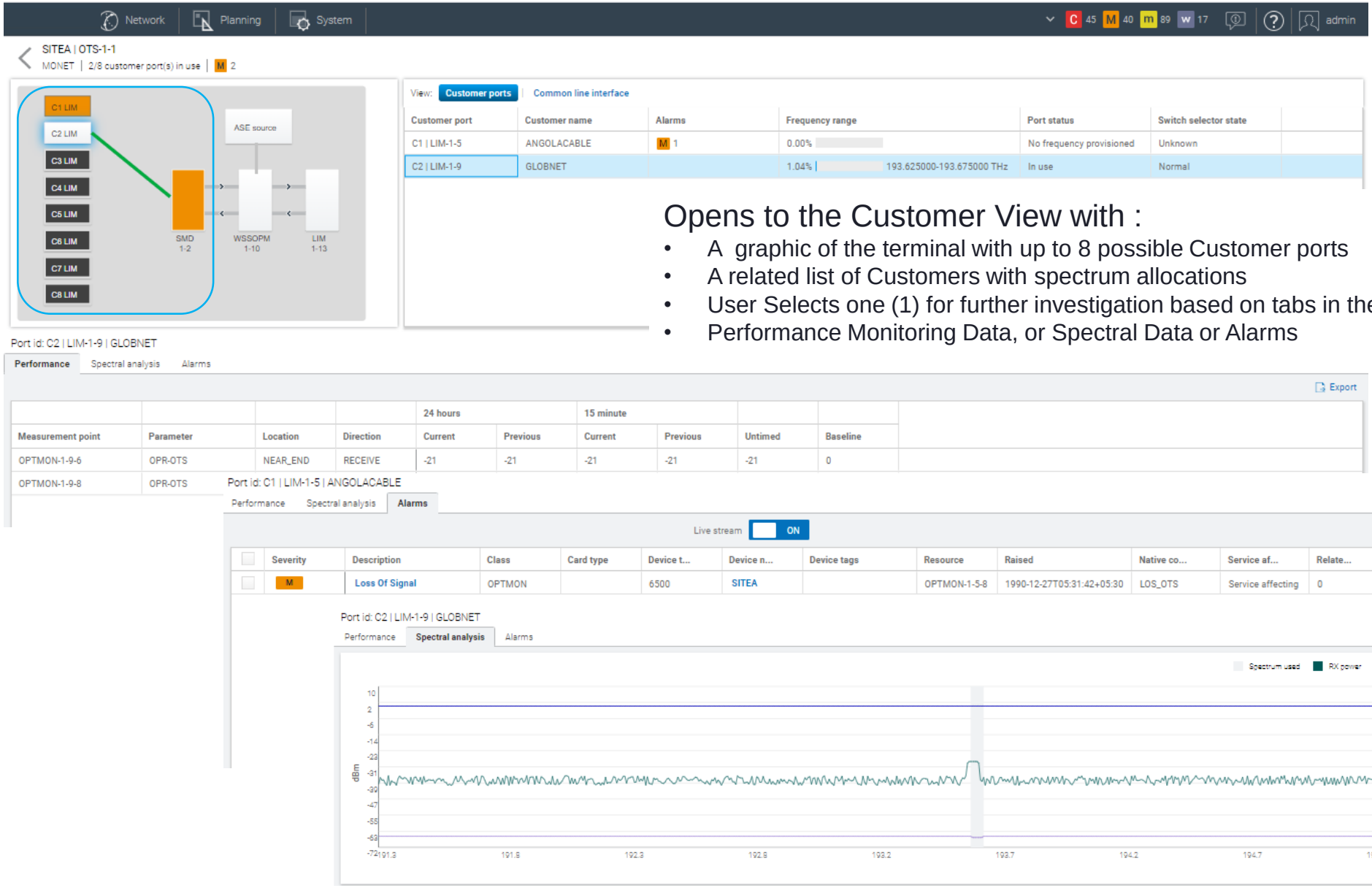
- When did it start?
- How many and what alarms have been correlated?
- How many links / services impacted by
  - Service types
  - Customers
  - Tags

Further breakdown of how many of these services are actually DOWN (could be protected)

High Level problem filters by service type/customer/tags

Low impact active problems that happened in the past

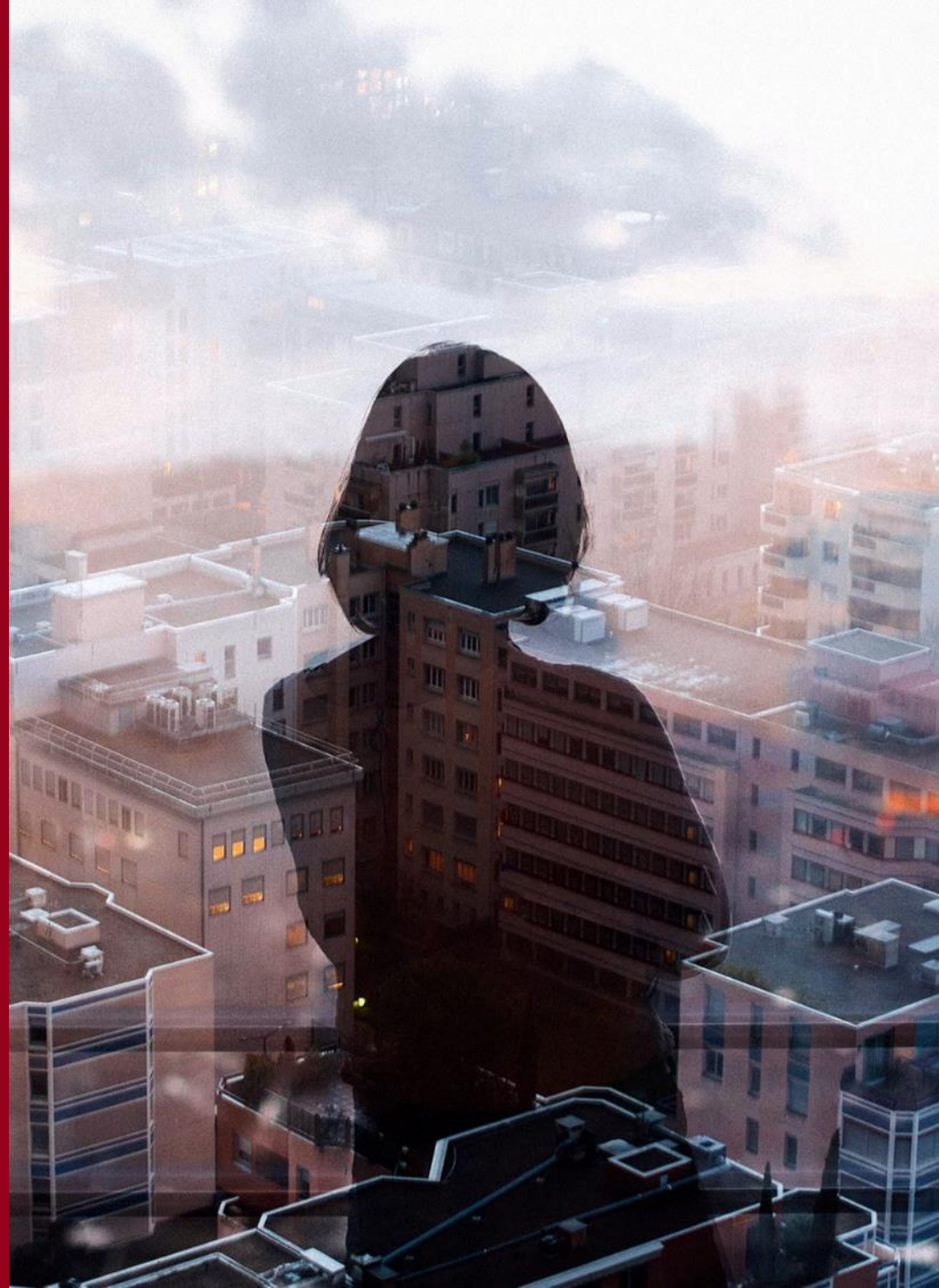
Spectrum Sharing Application



Opens to the Customer View with :

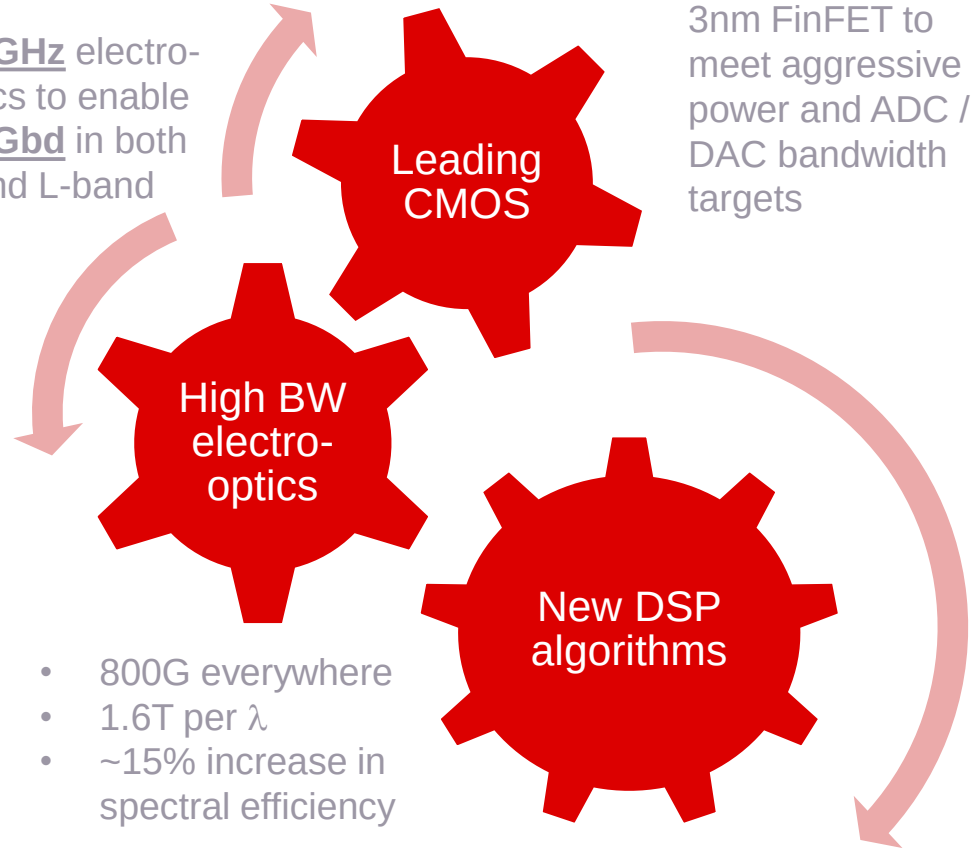
- A graphic of the terminal with up to 8 possible Customer ports
- A related list of Customers with spectrum allocations
- User Selects one (1) for further investigation based on tabs in the lower screen
- Performance Monitoring Data, or Spectral Data or Alarms

CMOS Technology, Modem and Photonic Evolution



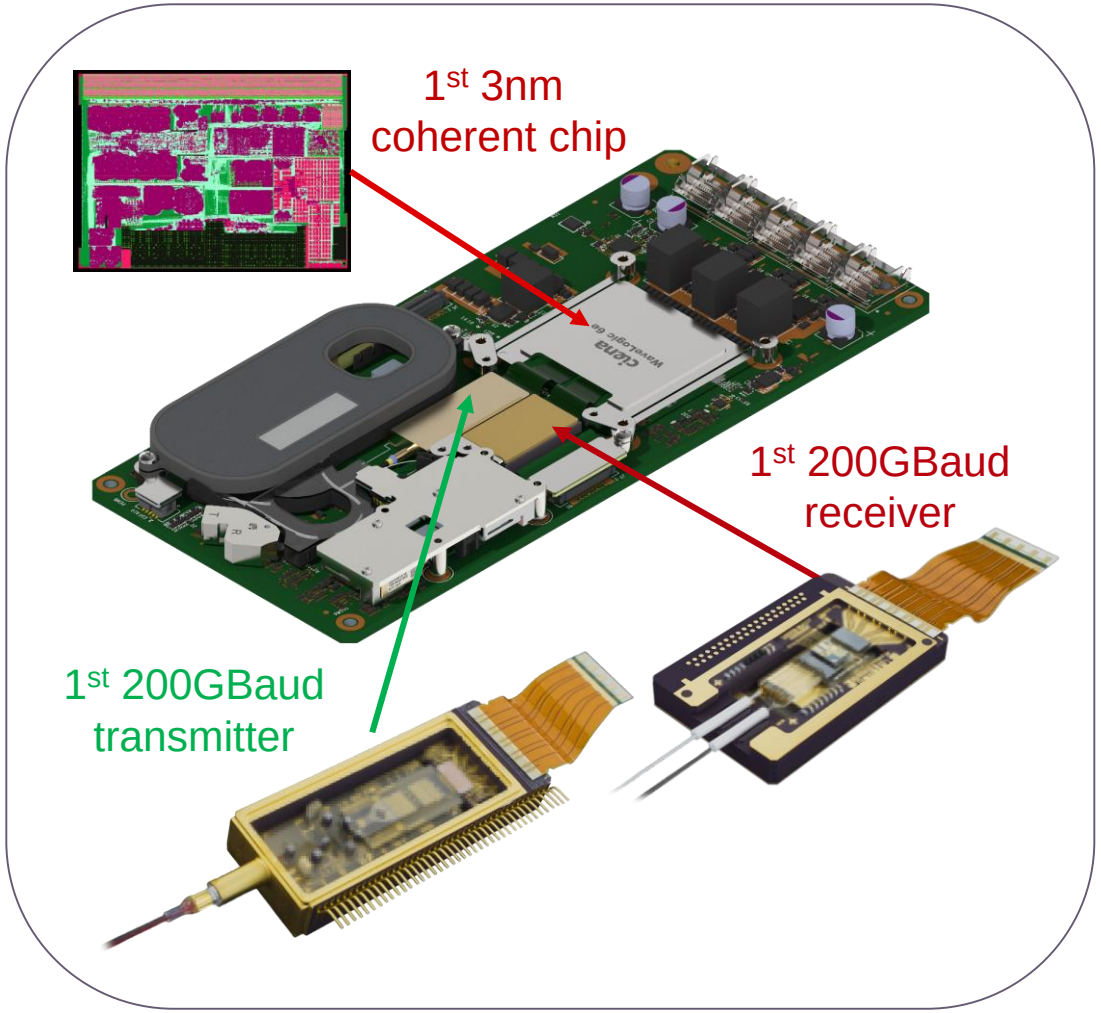
New CMOS engine design addresses the next generation of networking requirements

100GHz electro-optics to enable **200Gbd** in both C and L-band



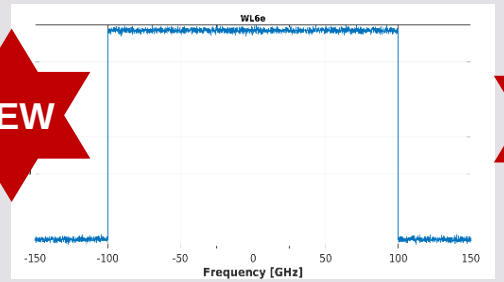
3nm FinFET to meet aggressive power and ADC / DAC bandwidth targets

- 800G everywhere
- 1.6T per λ
- ~15% increase in spectral efficiency

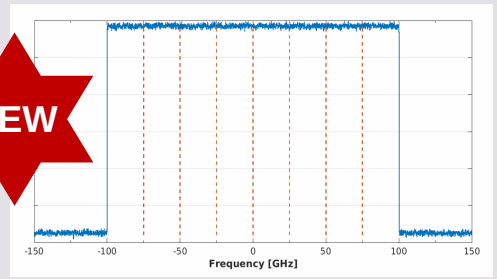


Co-optimized design achieved via vertical integration and real-time optimization

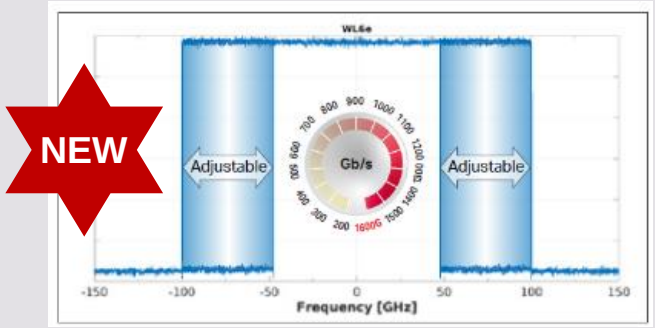
DSP enhancements deliver capacity optimization in all environments



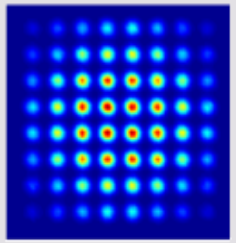
Edgeless clock recovery



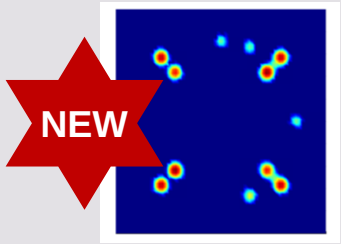
Variable FDM (from 1 to 8)



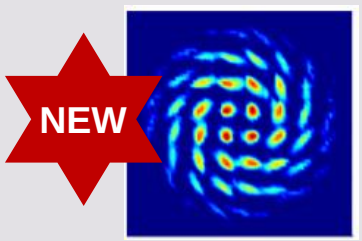
Variable Line Rate and Baud



PCS



Multi-dimensional constellations



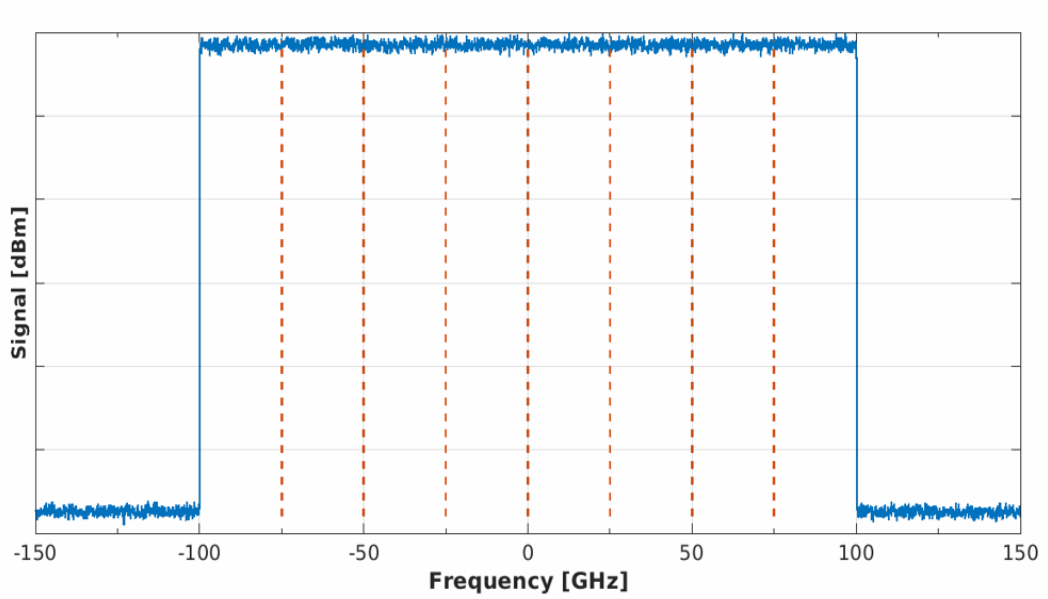
Non-linear compensation

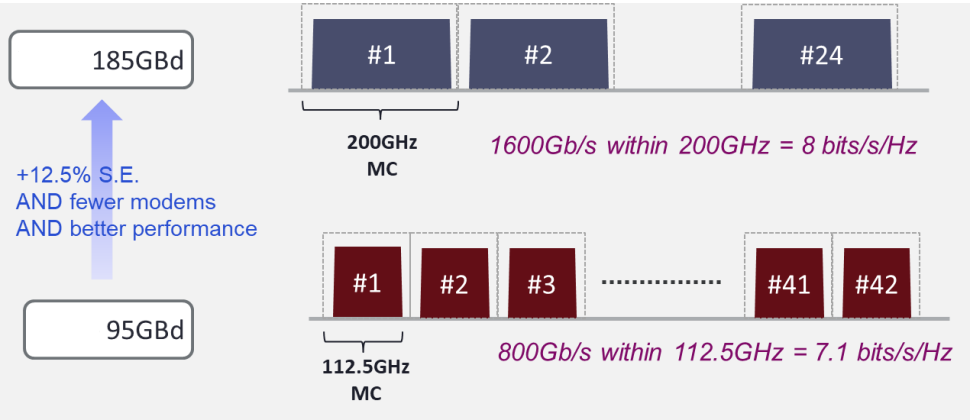
Single technology for optimal capacity over any fiber,
for terrestrial multi-haul applications
and over new and legacy submarine cables

Edgeless Clock Recovery

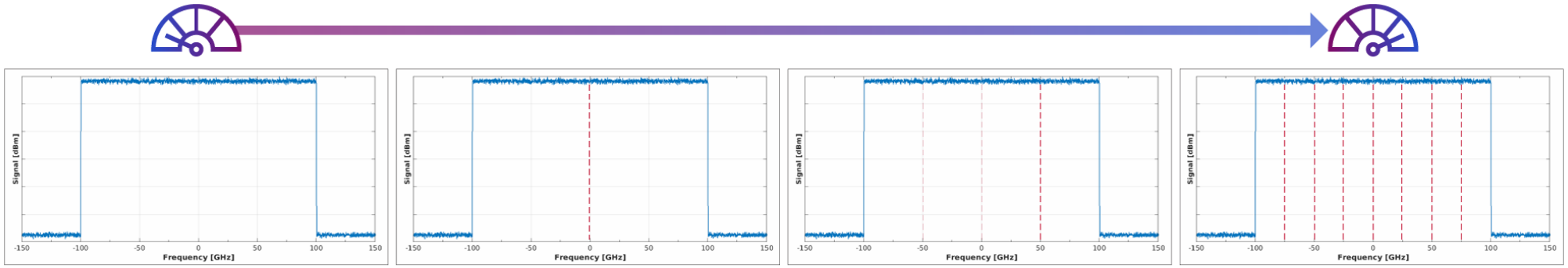
Near-perfect rectangular shaping, for greater throughput within the same amount of spectrum

- New DSP feature
- Improved tolerance to cascaded filters for better performance
- Tightest wavelength spacing, providing ~13% improvement in spectral efficiency
- No notches or dead space between subcarriers





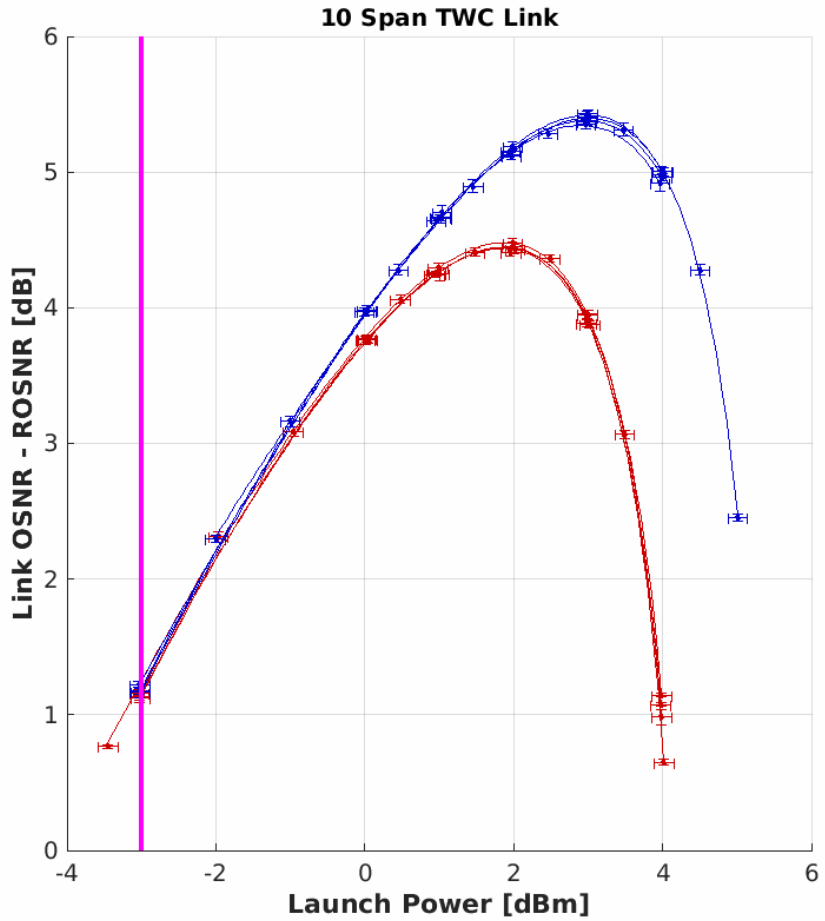
Variable FDM

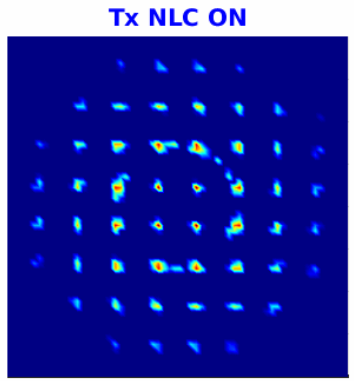


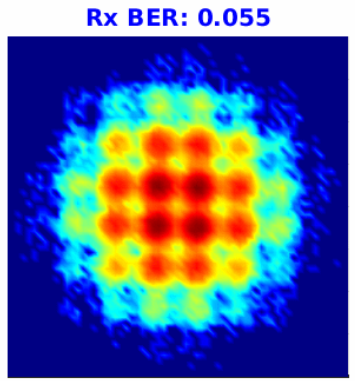
Optimal performance for non-linear applications, reducing intra-FWM, improving capacity or reach

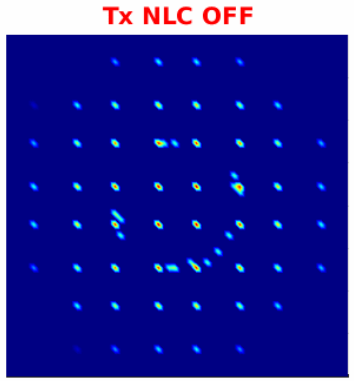
- System automatically implements number of FDM subcarriers
- High dispersion links (uncompensated cables, D+) → high FDM
- Very low dispersion links (compensated cables, Legacy) → single subcarrier

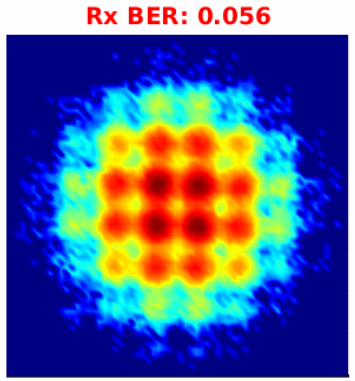
DSP Nonlinear Compensation









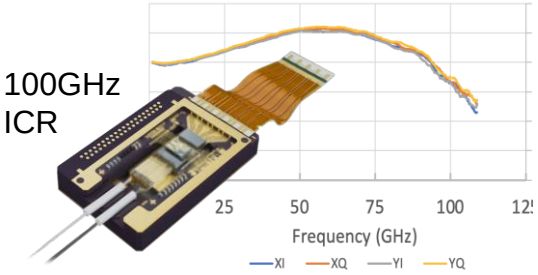


Nonlinear compensation feature provides ability to launch at higher power, and gain significant improvement in SNR margin in nonlinear environments

Industry's first 3nm CMOS and 200GBaud in the lab!

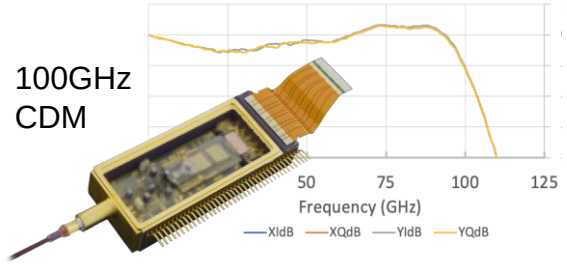
OE S21 RF Response

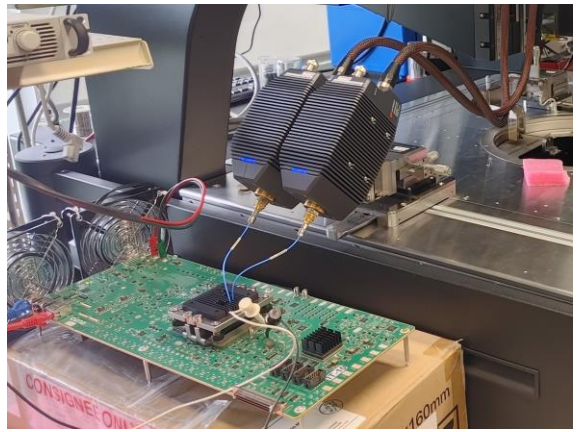
100GHz ICR

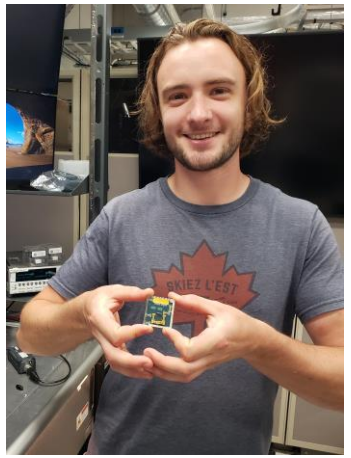


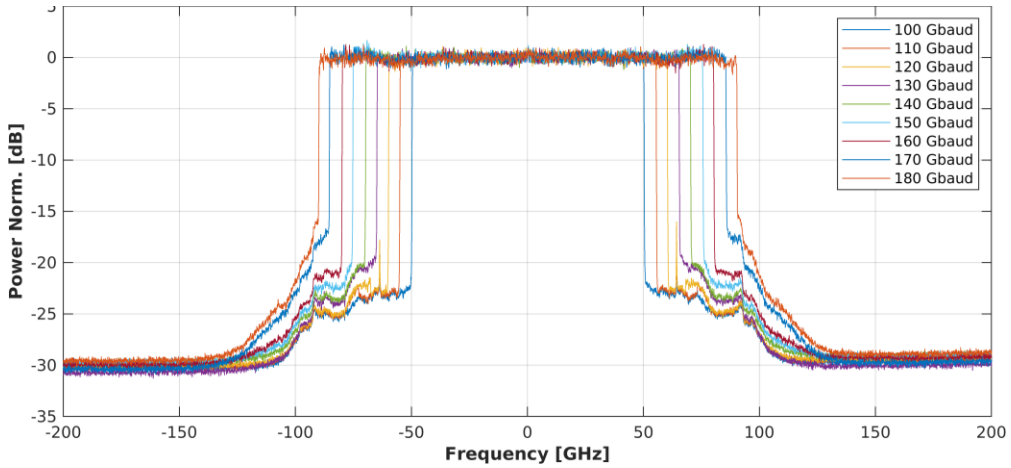
EO S21 RF Response

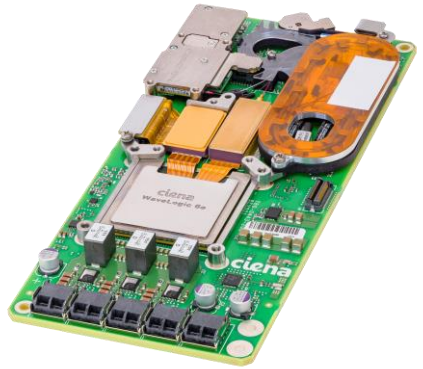
100GHz CDM



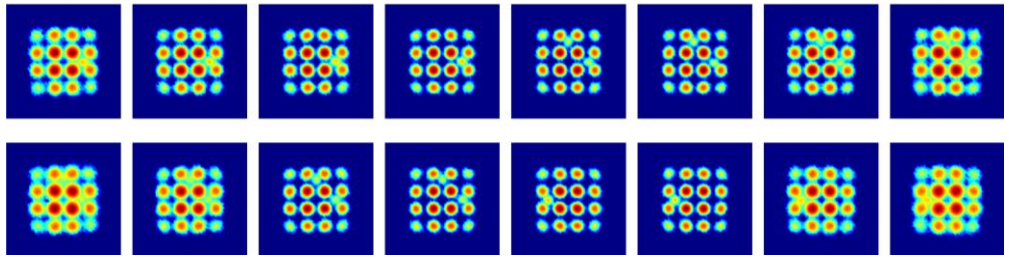


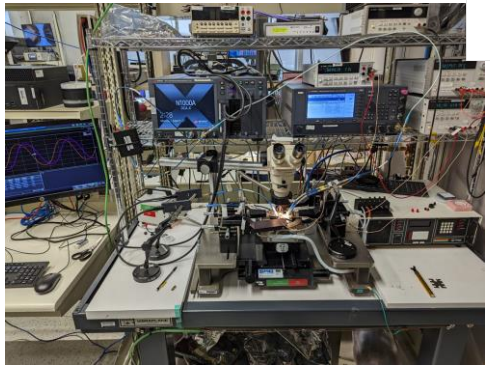


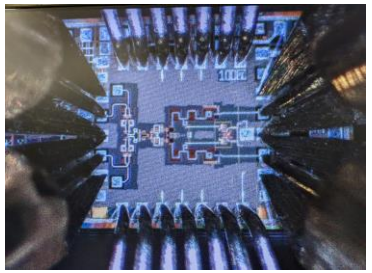


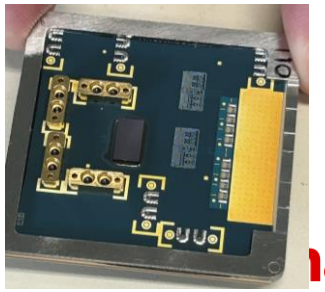


N3E ADC bandwidth testing results





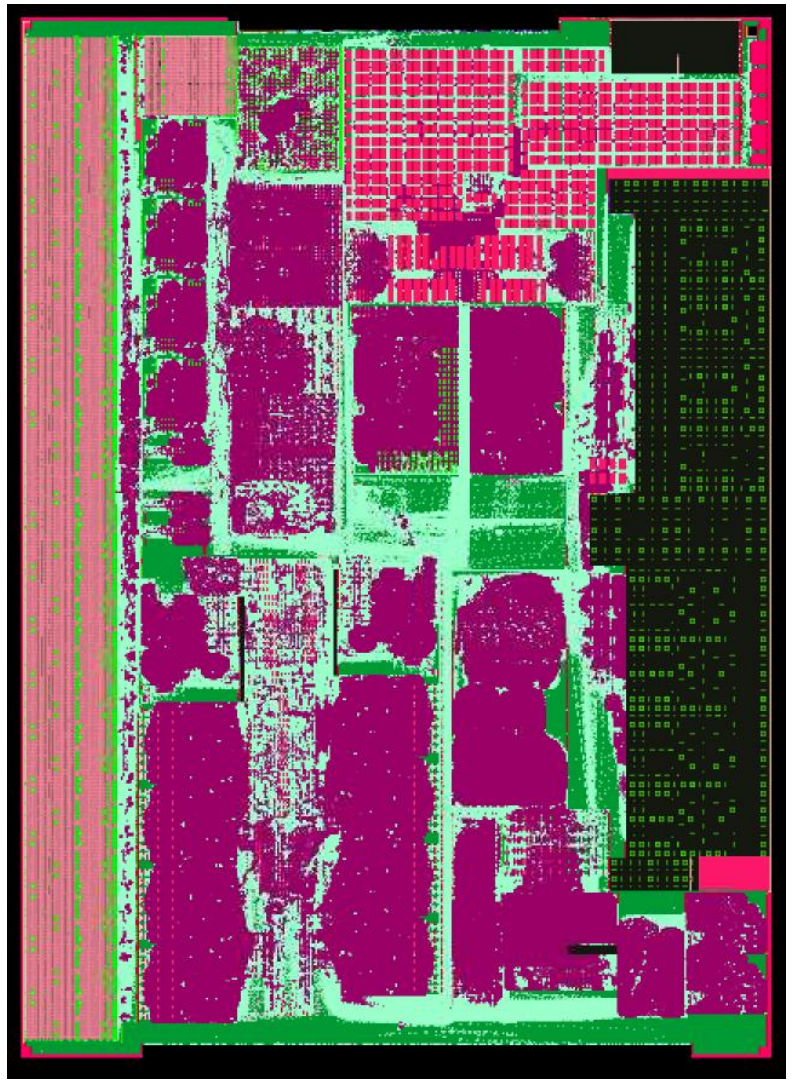




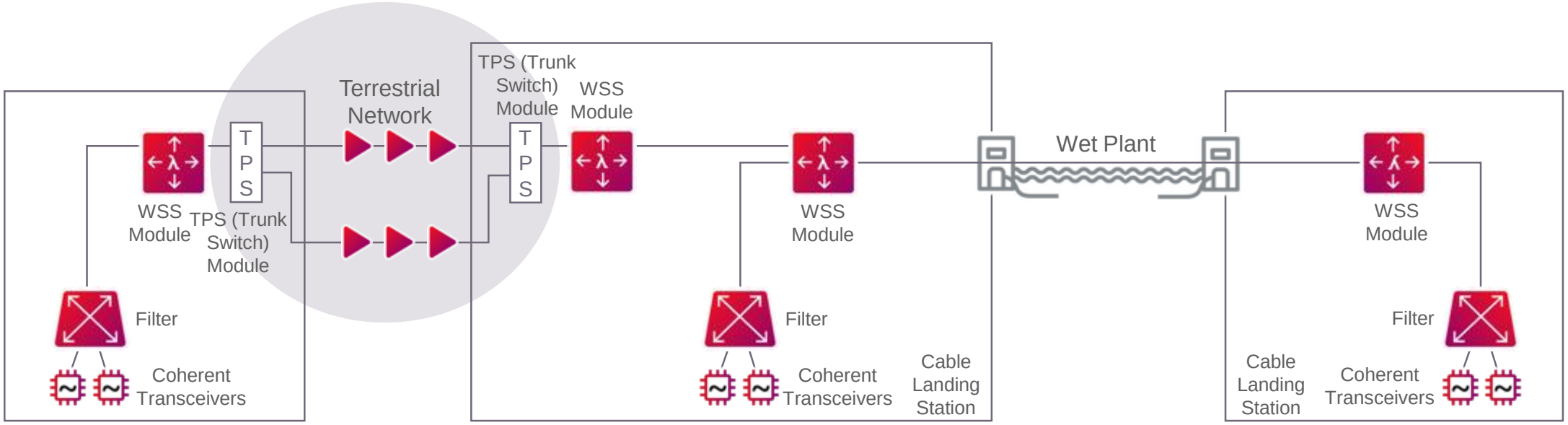
DSP ASIC

- 3nm FinFET CMOS
- 4.2 km of copper wire
- 1600T operations/sec

3nm
0.20X



Increase resiliency for terrestrial backhaul in GeoMesh applications

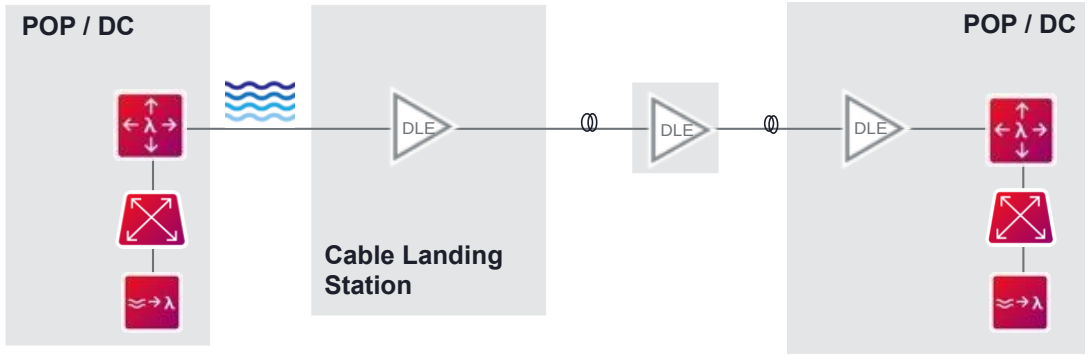


- RLS can provide trunk switch protection of C-band or C&L-band terrestrial backhaul segments of optical bypass networks
  - Two Path or multiple path protection with the TPS module
    - Provides solutions for single or multi-span networks
    - Supports EFDA and Raman amplification
    - Supports cascading of trunk switches to enable three optical paths

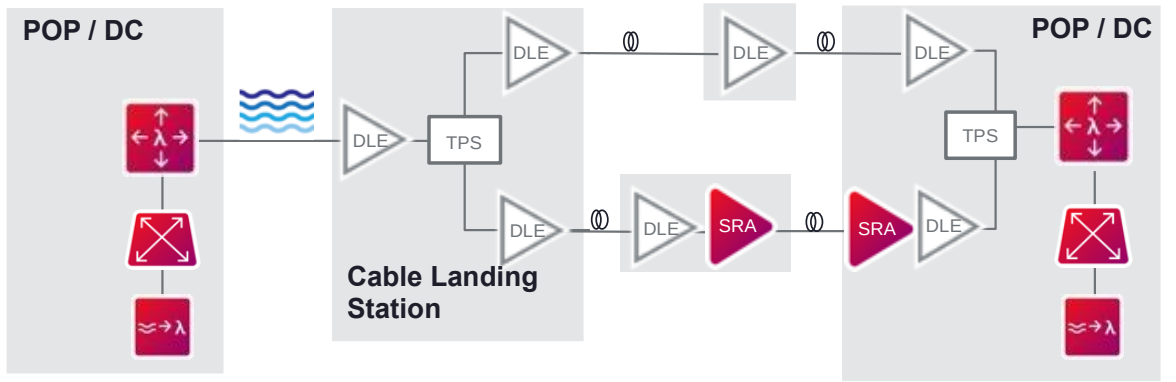
Next Gen Photonics increases network resiliency and improves service reliability for terrestrial backhaul segments with optional trunk protection

Cable Landing Station Bypass to reduce space, cost, and power at the landing station

Cable Landing Station Bypass



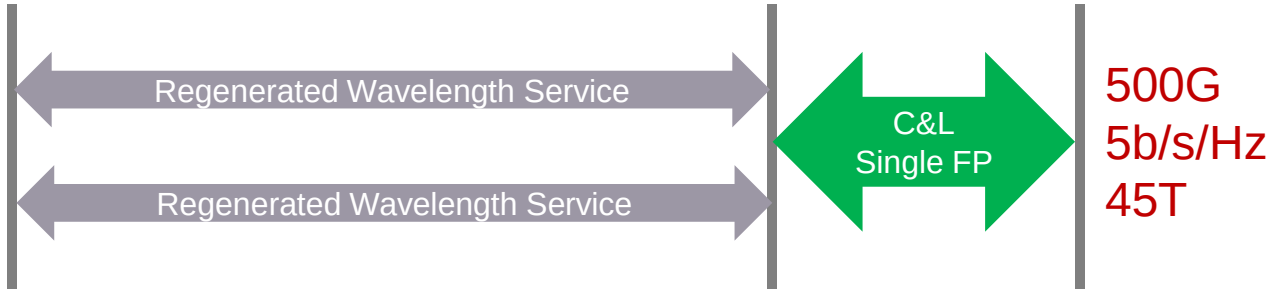
Cable Landing Station Bypass with Trunk Protected Line Amps



- Use a DLE instead of a ROADM to save space, cost, and power at the Cable Landing Station (CLS)
- Move the SLTE to a remote POP / Data Center
- TPS can be used at the CLS to provide trunk protection for the line amps on the terrestrial link between the landing station and the POP or DC

Use of C&L Band – Terrestrial Backhaul Consolidation

C&L on the terrestrial link can double capacity on single fibre pair
Allows consolidation of multiple submarine segments

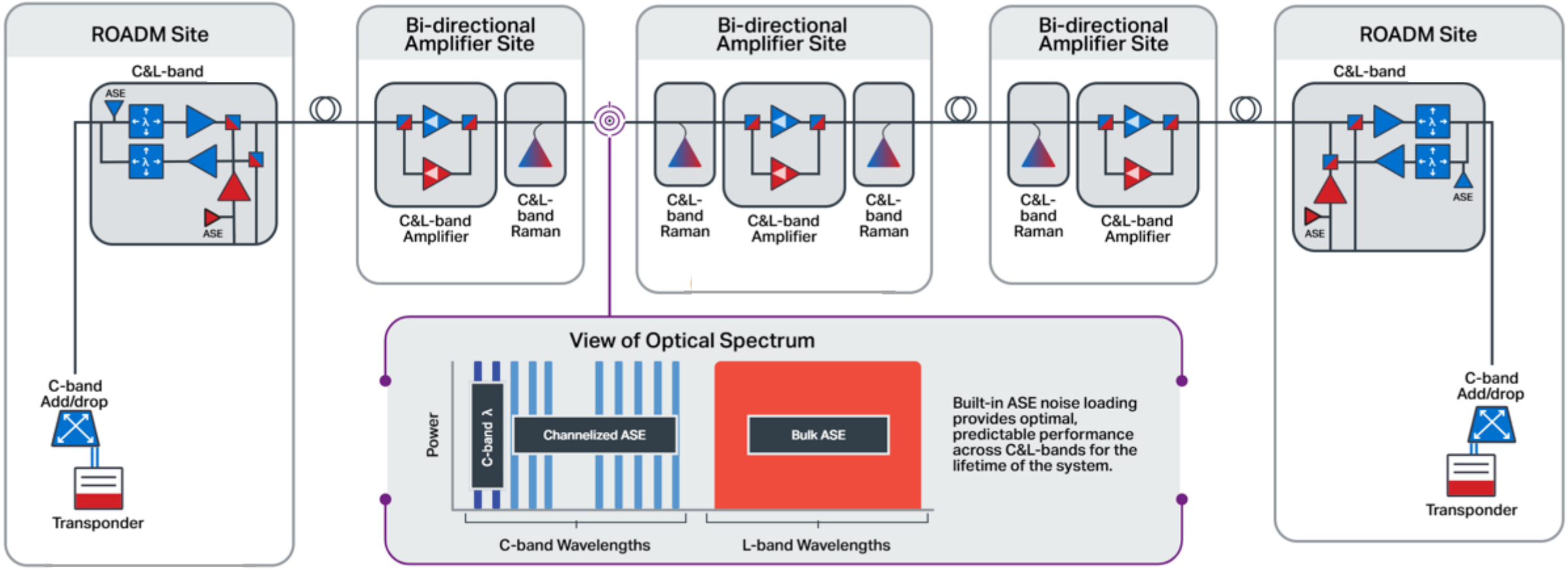


Two regenerated 7,000km DLS over 6,000km submarine segment plus single C&L 1,000km terrestrial = **500G** channels with spectral efficiency of ~ **5b/s/Hz**
Total 2 x DLS capacity = **45T**

Terrestrial C&L halves the fibre requirement

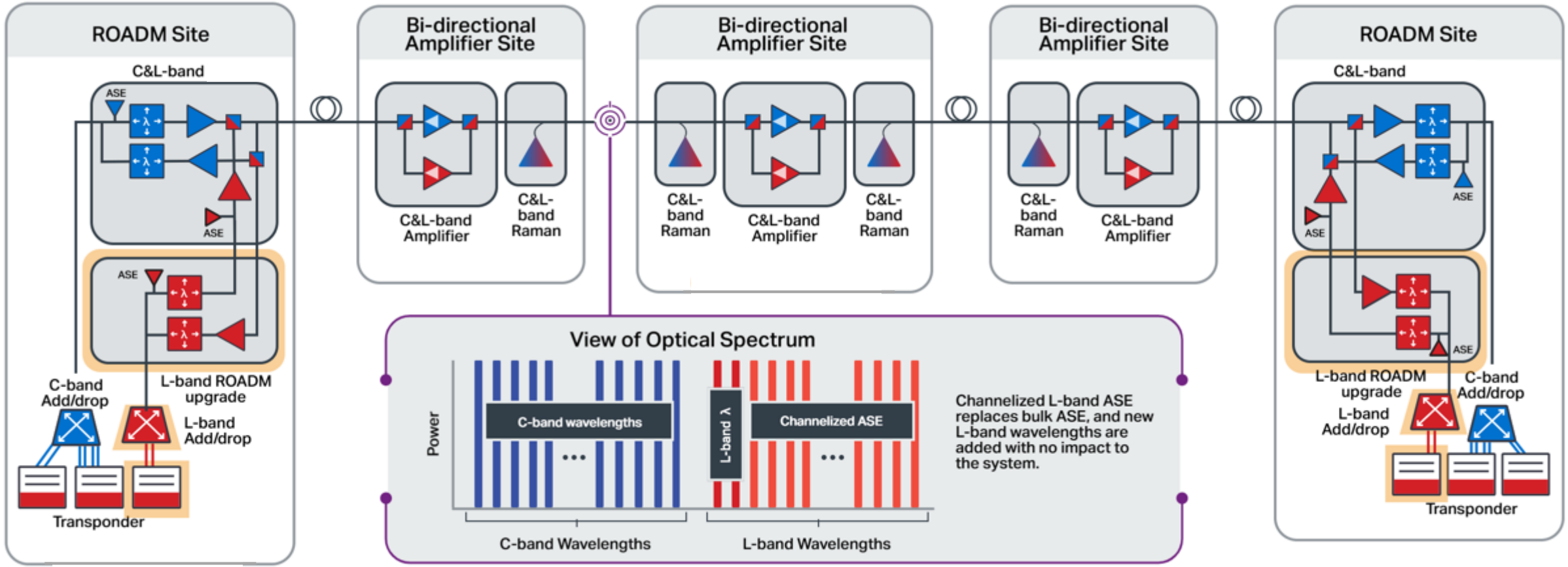
Note: capacities based on typical submarine cable & terrestrial key parameters and current generation of transmission equipment

C&L-band Initial deployment



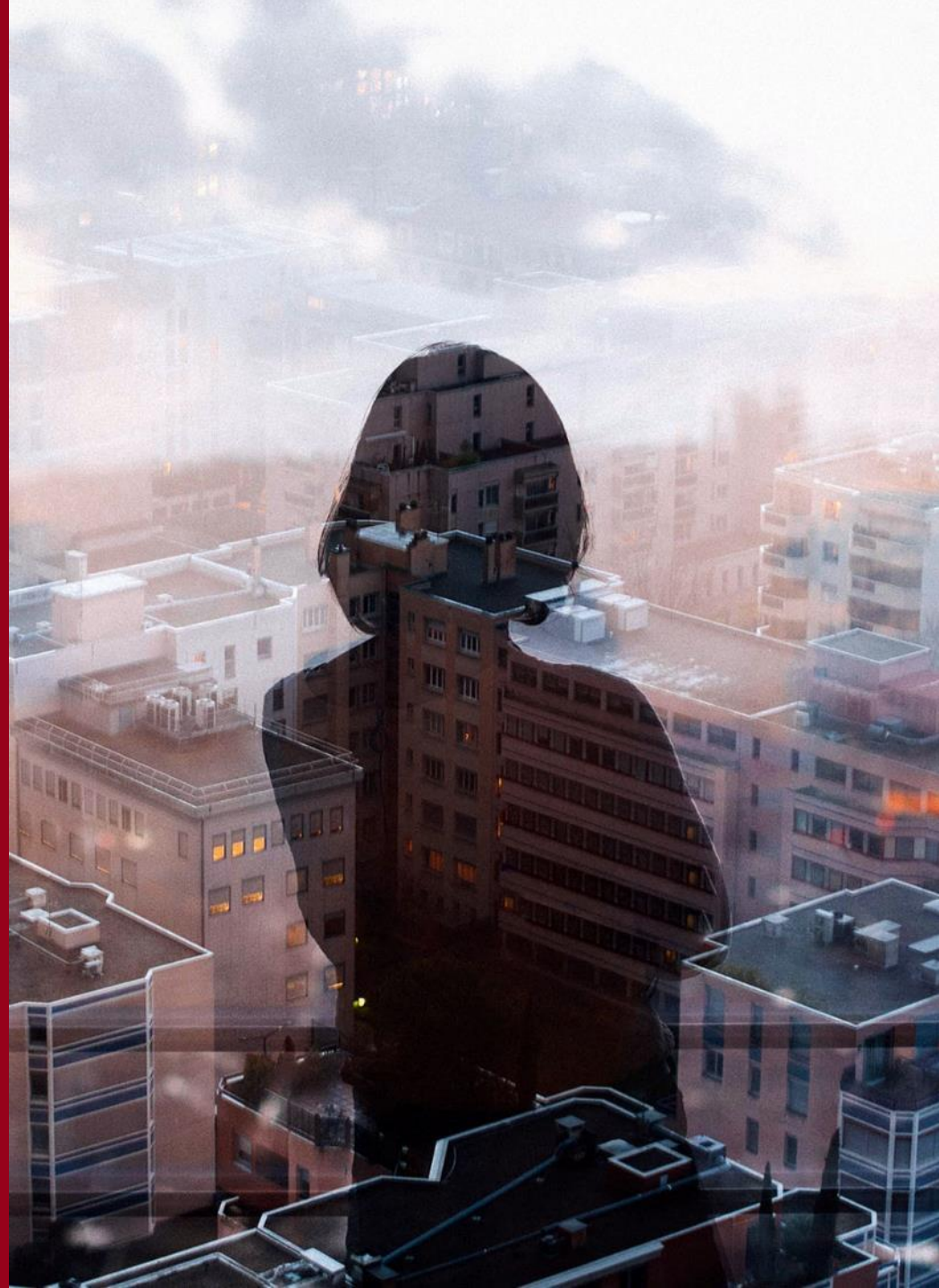
- Integrated C&L-band amps are installed at all in-line amplifier sites, so the system is ready for L-band from day-one
- Built-in ASE noise loading ensures stable, optimal performance from day-one until the system is fully-filled
- L-band ROADM and add/drop can be deferred to lower the initial cost

RLS expansion to the L-band

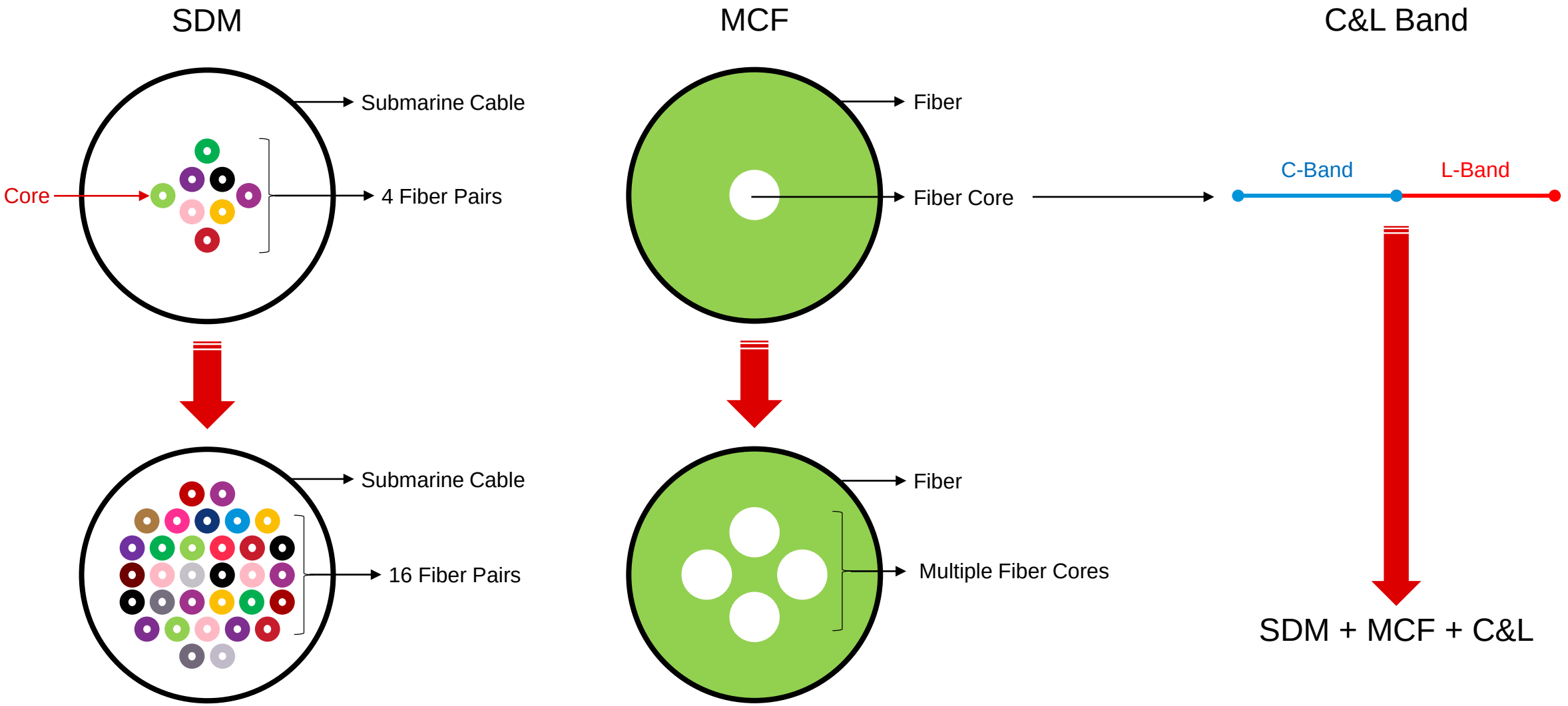


- Double fiber capacity with simple, hitless L-band expansion
- No additional planning/engineering required for L-band
- No amplifier site visits or impact to existing in-service C-band traffic

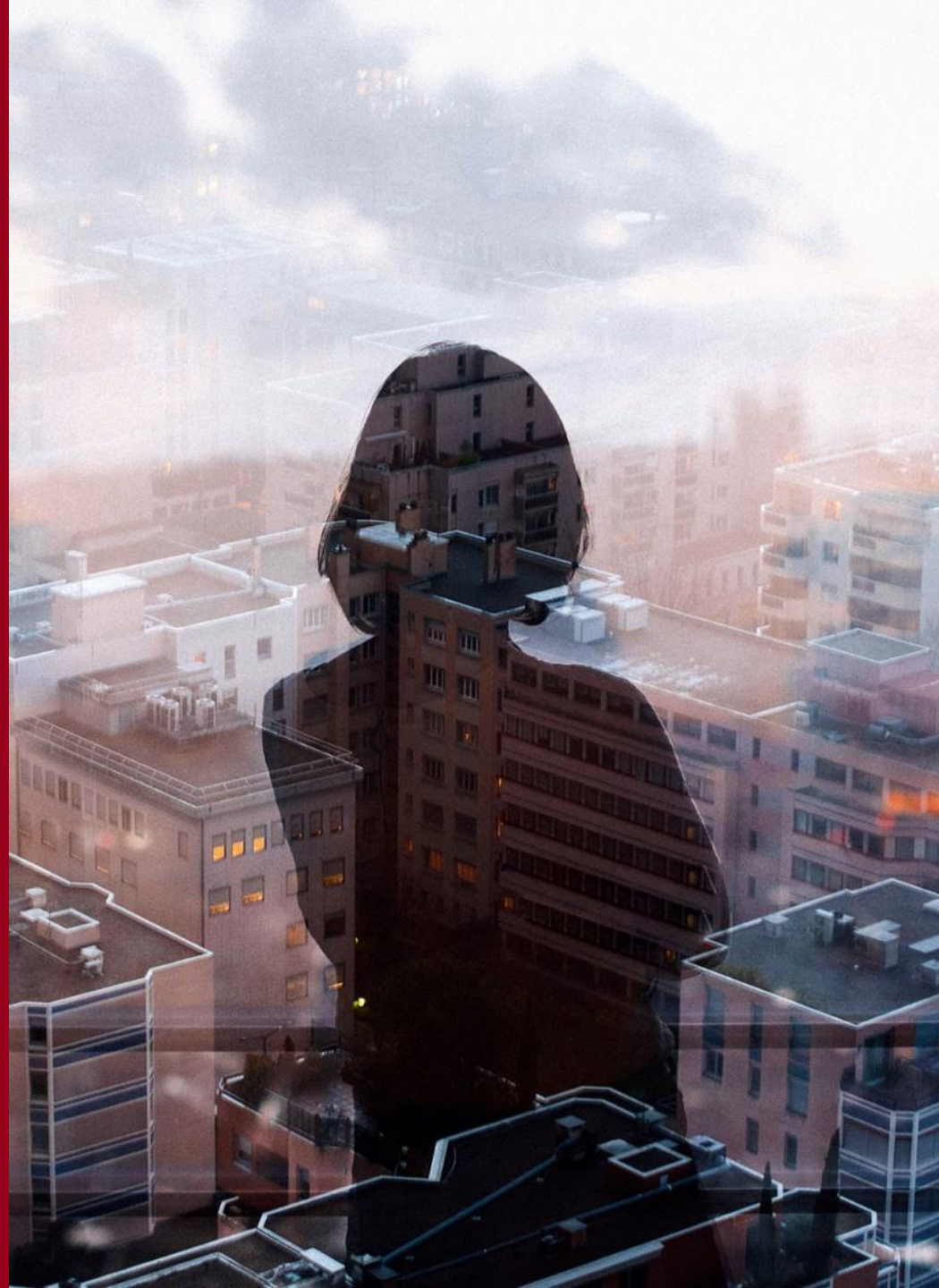
Evolution of the Submarine Network Wet Plant



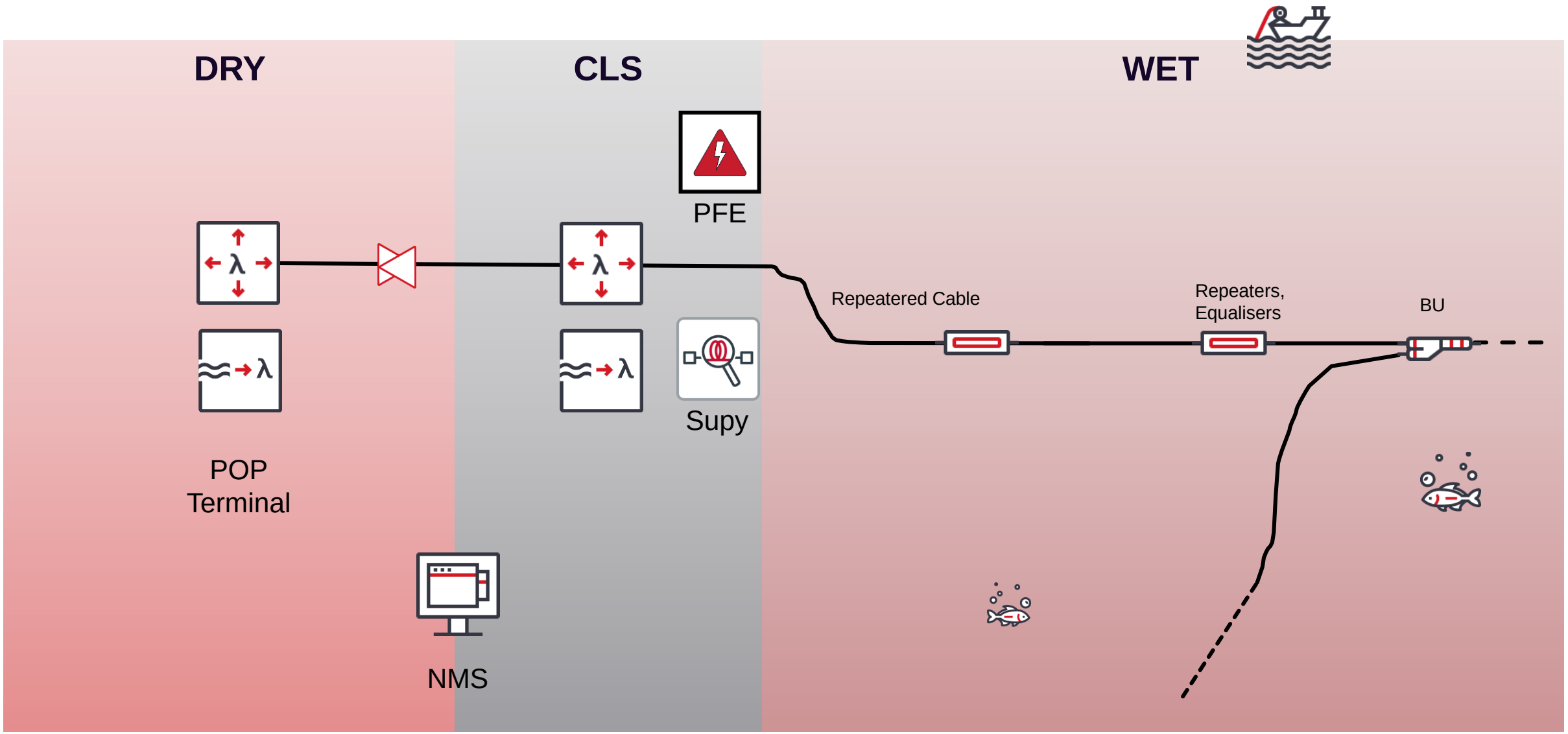
Evolution of the Submarine Network Wet Plant



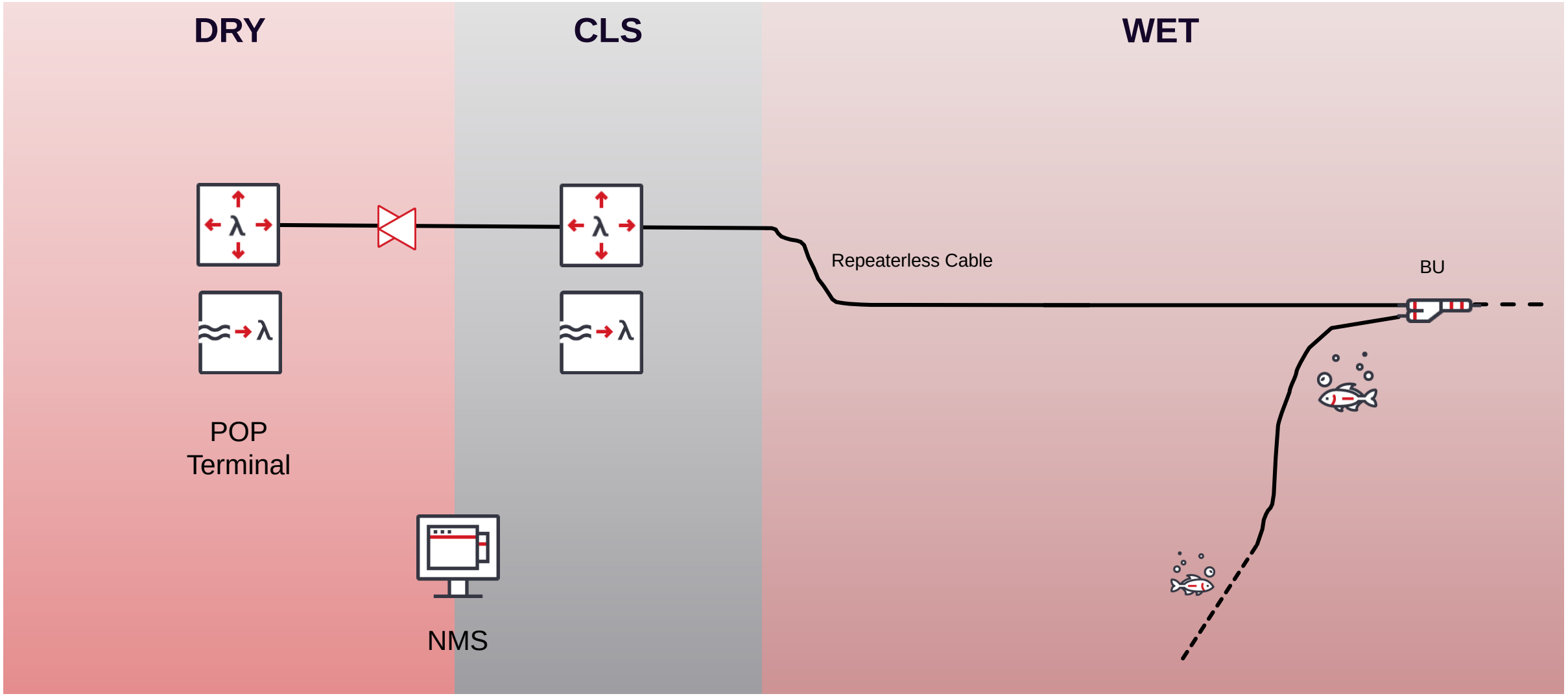
Repeaterless system



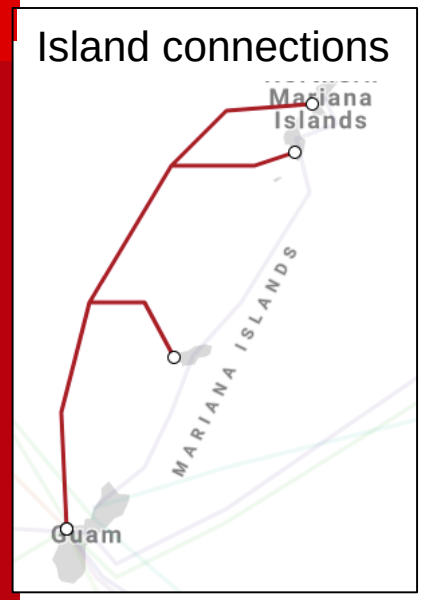
Repeatered system elements

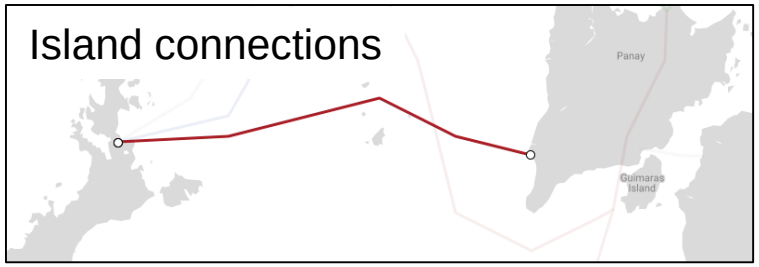


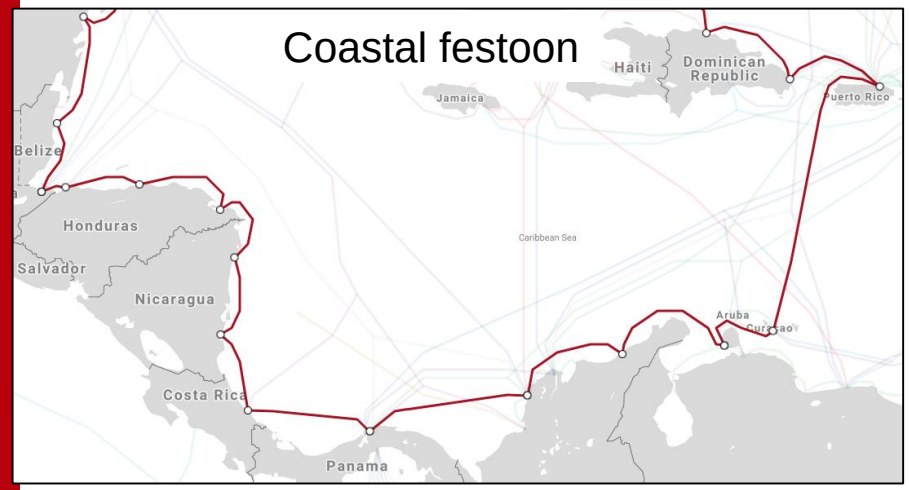
Repeaterless system elements

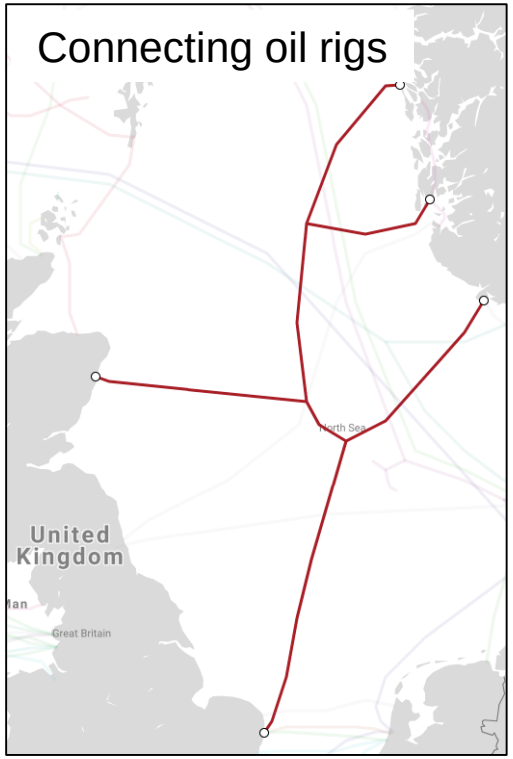


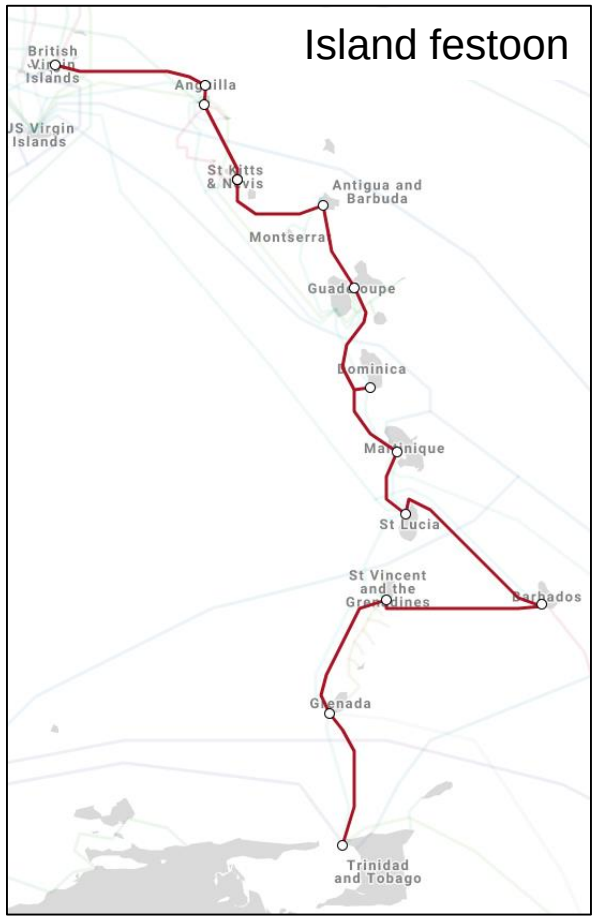
Repeaterless System Types

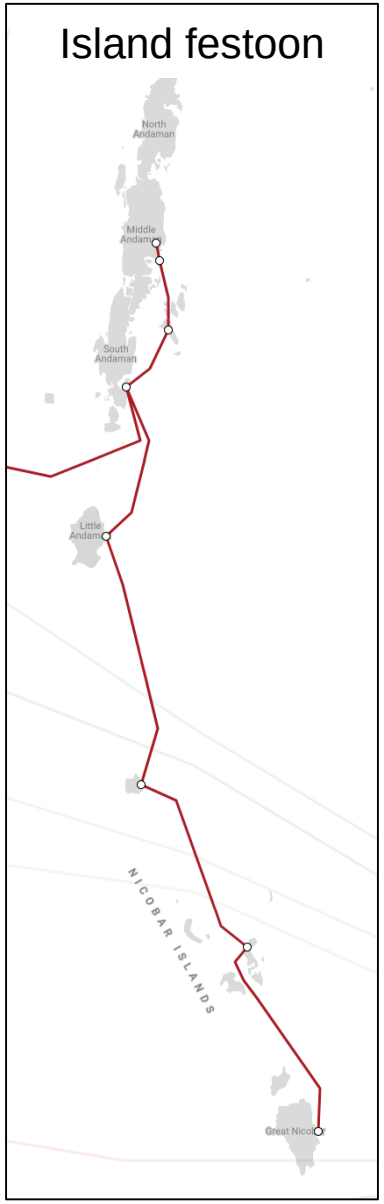












Technology also used on terrestrial systems

- To increase reach
- Hut skipping

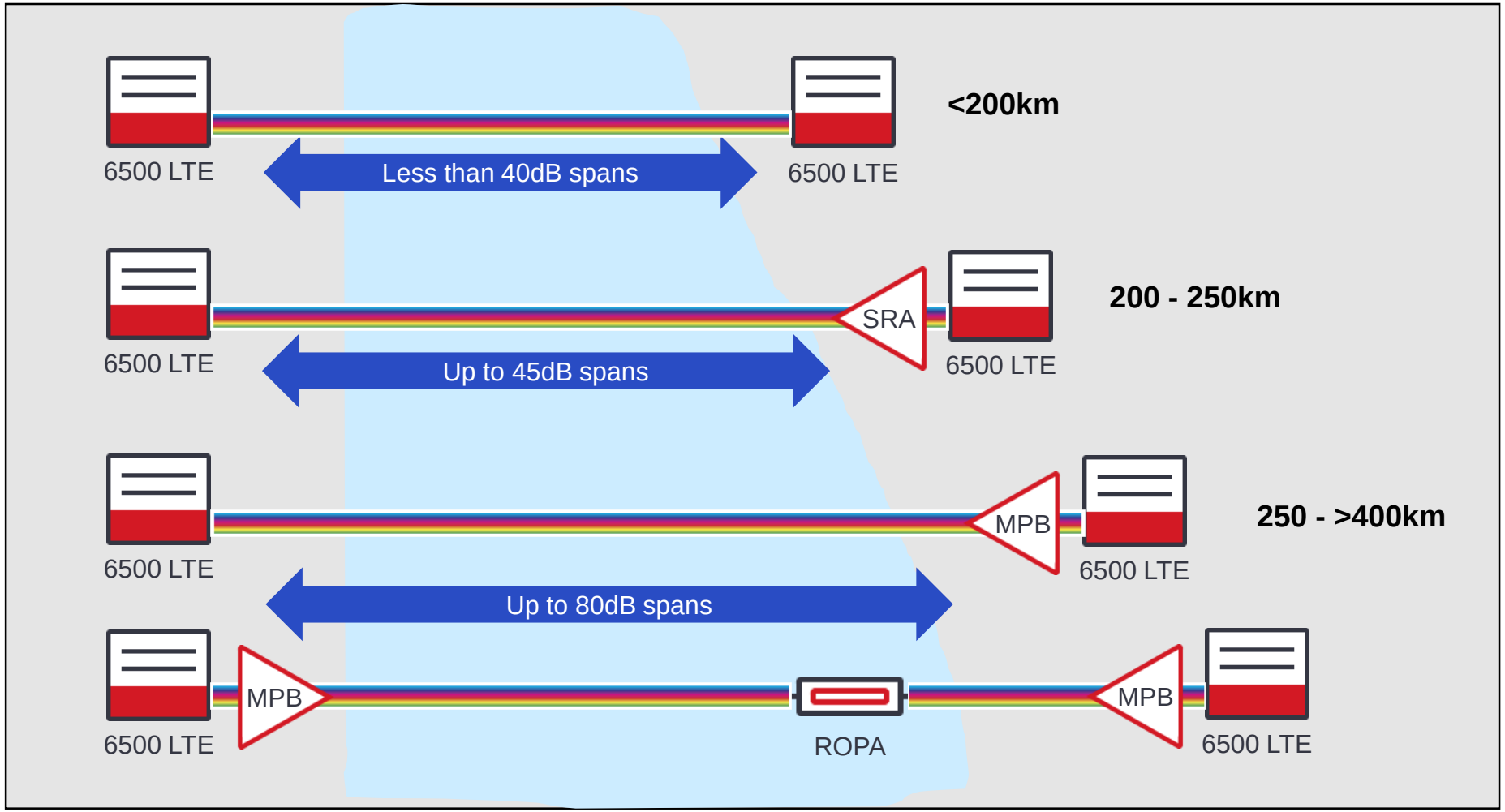
ciena

System Design and Equipment Configuration

Baseline

In house
Raman Amplifier (SRA)

External Raman
(multiple configurations)



Distances dependant on fibre type, modulation format and number of channels

Thank You