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The bridge to possible

DCI and Subsea Trends

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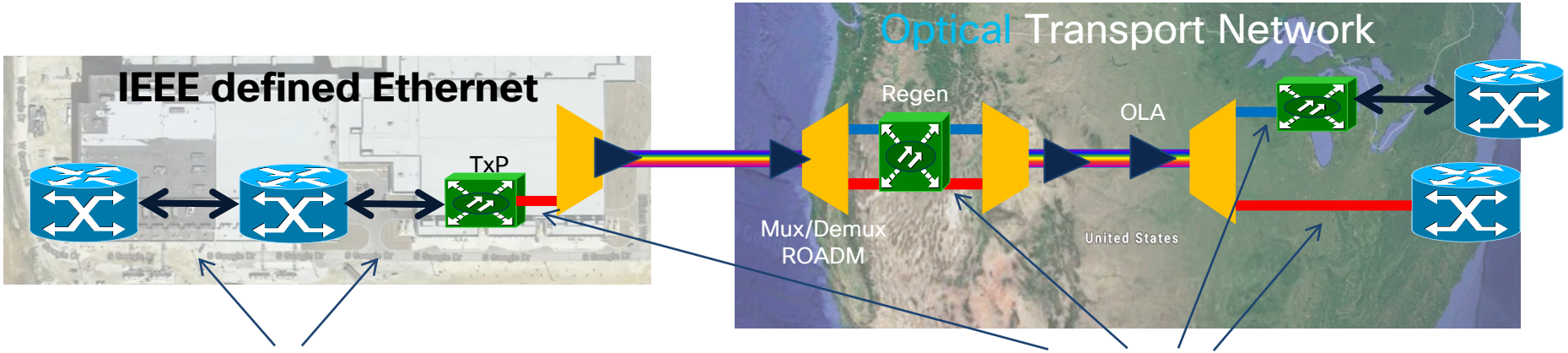
Agenda

- Introduction
- Technology direction
- 400G Digital Coherent Optics
- Compact Modular aka DCI
- Subsea Optical Transmission
- Software
- Conclusion

Optical & Optics Domains



DC & Client Optics

- Grey optics
- Within a building or campus or city
- Ethernet
- Optimize for Cost, Power, Density

Line Optics

- Multiple channels / DWDM (Colored)/ Fiber
- Across country/Ocean (100's to 10,000 km +)
- Forward Error Correction (FEC)
- Optimize for Performances, Spectral Efficiency, Cost, Density

Technology Direction

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What is important for different applications ?

Subsea

2-10 SLTE sites

Fiber very scarce

Repairs days-months and expensive

LH

100-1000s of sites, 10,000s kms of fiber

Power and space a concern at ILA huts

Fiber scarce

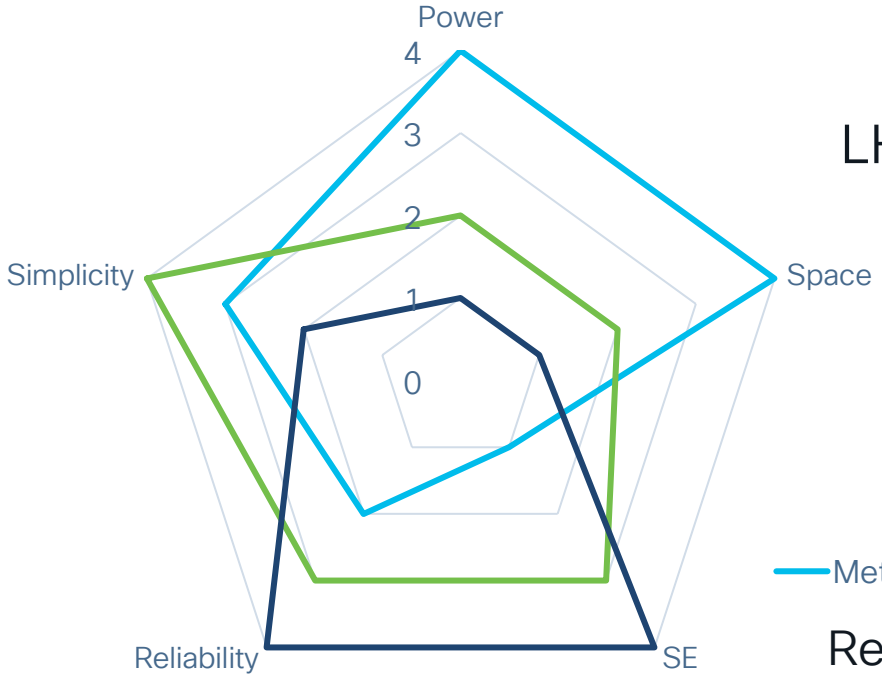
Repairs in days

Metro

Expensive real estate

Fiber readily available

Repairs in hrs-days



Relative importance of different factors

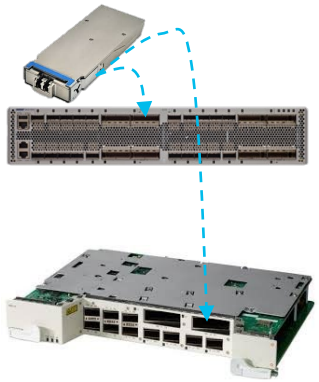
Enabling technologies

	2010	2013	2015	2017	2020	2022
Metro	10G DWDM	100G QPSK				
Long Haul	40G SC/DC coherent					
Subsea	40G SC/DC coherent	100G coherent with extended CD compensation				

- 100G coherent introduced to operator networks
- Capacity increases in network 10x
- Simpler to use for long haul and metro networks
- 100G coherent used for upgrading existing subsea cables that were compensated.

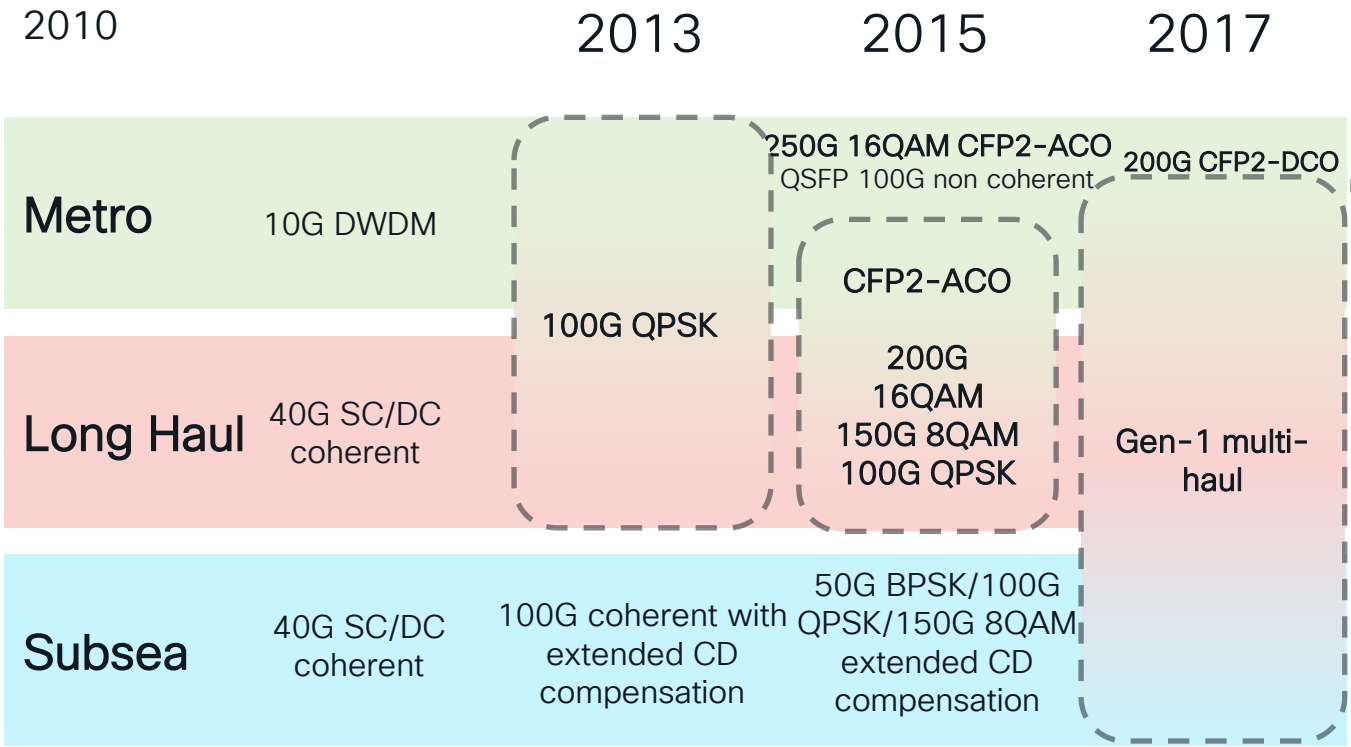
Enabling technologies

	2010	2013	2015	2017	2020	2022
Metro	10G DWDM	100G QPSK	250G 16QAM CFP2-ACO QSFP 100G non coherent CFP2-ACO 200G 16QAM 150G 8QAM 100G QPSK			
Long Haul	40G SC/DC coherent					
Subsea	40G SC/DC coherent	100G coherent with extended CD compensation	50G BPSK/100G QPSK/150G 8QAM extended CD compensation			



- CFP2-ACO introduced with DSP on host.
- 250G 16QAM introduced – 2.5x capacity in metro.
- 8QAM used to get 50-100% increase in long haul.
- Specialized transponders for subsea cables.

Enabling technologies



Gen1 Multi-Haul pizza-box

- CFP2-DCO introduced with DSP on pluggable – valuable in low capacity metro applications. 200G DCOs on router – IP + optical.
- Gen-1 multi-haul – <10 options on trunk. No significant improvement in SNR

Enabling technologies

2010 2013 2015 2017 2020 2022

Metro

Long Hau

Subsea 2

- 400G DCO introduced with QSFP-DD pluggable – valuable in metro and long haul. Fits into router line card ports. Low power and space.
- Gen-2 multi-haul – 6000+ options on trunk from constellation shaping and flexible baud-rates. 70-100 Gbd. Significant improvement in SNR. 30-40% improvement in capacity in LH.

QSFP-DD
400G 16QAM
300G 8QAM
200G QPSK

Gen-2
multi-haul

Enabling technologies

2010 2013 2015 2017 2020 2022

Metro

Long Hau

Subsea 2

- 800G/2x400G DCO planned with QSFP-DD pluggable – valuable in metro and long haul. Fits into router line card ports. Low power and space.
- Gen-3 multi-haul – Further improvement in SNR and power/100G. 120-150 Gbd.

QSFP-DD

Gen-3 multi-haul

400G Digital Coherent Optics

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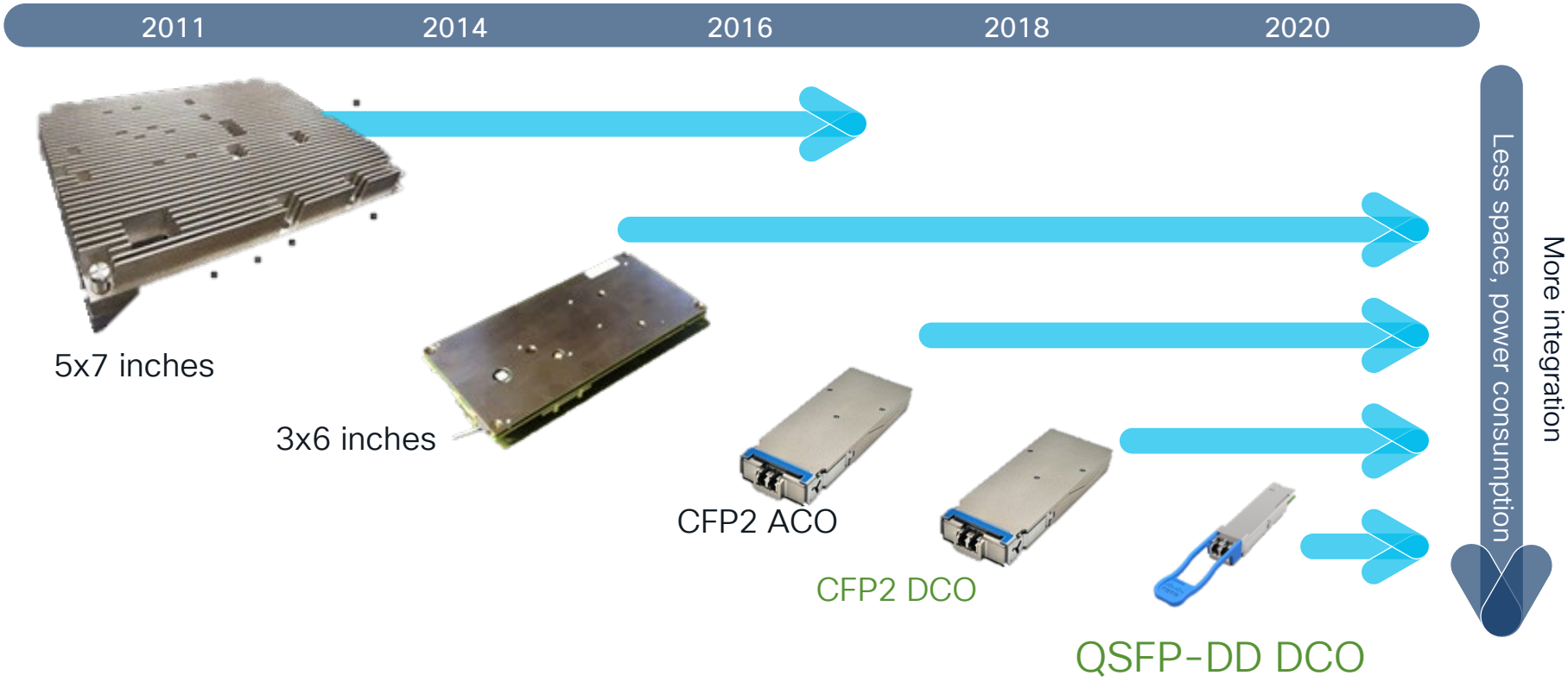
The benefits of coherent optics integration



400G DWDM DCO Variants

- OIF standardized QSFP-DD **ZR** aiming a P2P connectivity of 120km (Metro)
- AT&T **OpenROADM MSA** defines a standard for WDM Interoperable Interfaces operating at 400G, 300G and 200G for **Regional and Long-Haul** applications *(~0 dBm launch power)*
- Acacia and NEL agreed to support an interoperable mode called **OpenZR+** leveraging oFEC to extend the interoperability among Vendors using QSFP-DD form factor (~ *-10dBm launch power*)
- *Cisco QSFP-DD supports OIF ZR, Open ROADM FEC and OpenZR+ on the same pluggable*

Model	Line Rate	Mode	Modulation Format	FEC	OTN OH	Baud Rate (GB)	Target OSNR
OIF 400G ZR	400G	ZR	16QAM	CFEC	NO	59.84	26dB
OpenROADM MSA	400G	OR	16QAM	OFEC	YES	63.14	24dB (in DRAFT)
Open ZR+	400G	OZR+	16QAM	OFEC	NO	60.14	24dB
Cisco QDD ZR+ Version	400G	OZR+	16QAM	OFEC	NO	60.14	22 dB

OpenZR+ MSA

OIF 400ZR
Edge DCI

Client: *400GE*

Line: *400ZR*

Simplified functionality
Edge optimized FEC (C-FEC)

OpenROADM
SP Metro, Regional, LH

100G
200G
300G
400G
Ethernet
OTN
FlexO

Client

Line: *100G* *200G* *300G* *400G* *OpenROADM*

Flexible Client Mapping +
High Performance FEC (oFEC)

OpenZR+ MULTI-SOURCE AGREEMENT

OpenZR+
Metro and Regional

100GE
200GE
400GE

Client

Line: *100G* *200G* *300G* *400G*

Simplified functionality +
High performance FEC (oFEC)

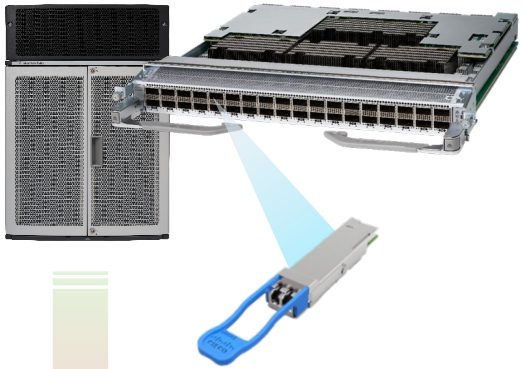
Open ROADM

Combines two standardization efforts to enable high performance pluggable modules that provide multi-vendor interoperability.

For more information : http://openzrplus.org/

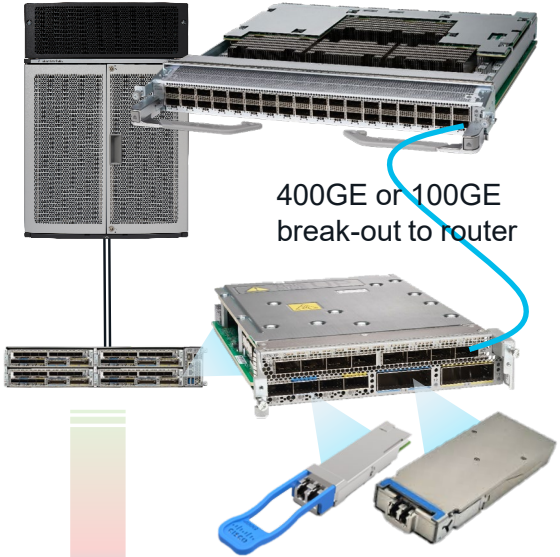
Coherent Optics Models for the router

Direct on Router



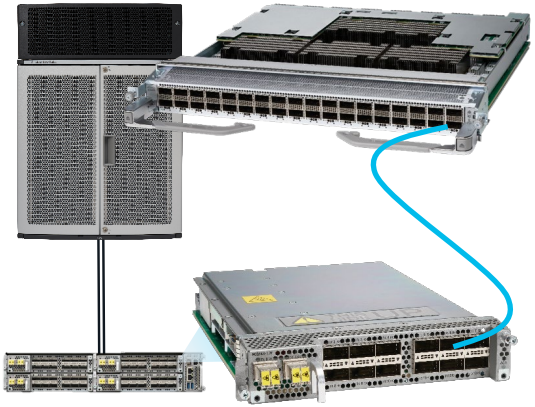
120km with ZR
4000km+ with openZR+

Router and TXP with DCOs



120km with ZR
4000km+ with openZR+
4000km+ with openROADM
over CDC-FS ROADM

Router and TXP



20,000km reach
Max performance

Future Coherent DSP Evolution

- Lower Power Consumption and Increase Processing Power → 5nm
  - Improved Optical Performances for Subsea & ULH applications
  - Double Pluggable capacity (from 400G to 800G) QSFP-DD800
- Optimized DSP Capacity around **400GE Clients**
  - Multi-carrier support to drive Subsea & ULH applications
  - Up to 1.2Tbps per carrier for DCI and Metro applications
- **Flex Spectrum** WDM Layer to enable all applications
  - Even 100GHz Channel Grid is too small at this point!

Compact Modular aka DCI

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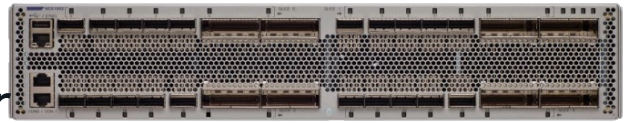
Cisco NCS 1000 *compact modular* Product Suite

"DCI" form-factor
IOS-XR
Automation first

NCS 1004



NCS 1002

Passive MUX-DMX

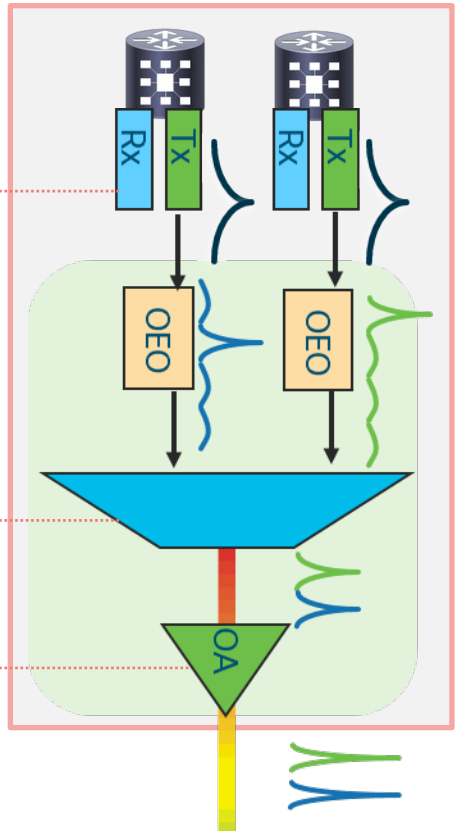
P2P

NCS 1001

ROADM and Raman supported

Future platform

Transponder



Gen-2 multi-Haul with NCS 1004

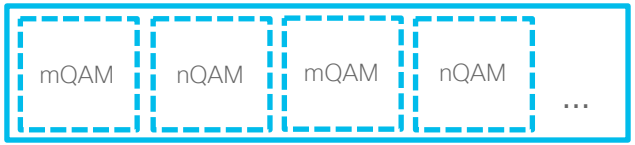
FEC

15%
27%

Baud Rate

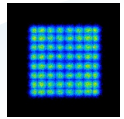
24 - 72
GBd/S

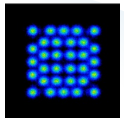
Constellation Shaping

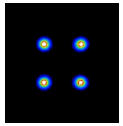


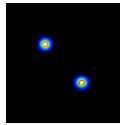
8x DWDM ports in 2RU
100G to 600G in 50G increments
Optimized using 6000+ available combinations

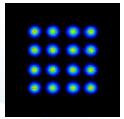
Hybrid combinations- Granularity of 0.008 bits/symbol control

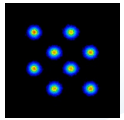

64QAM


32QAM


QPSK

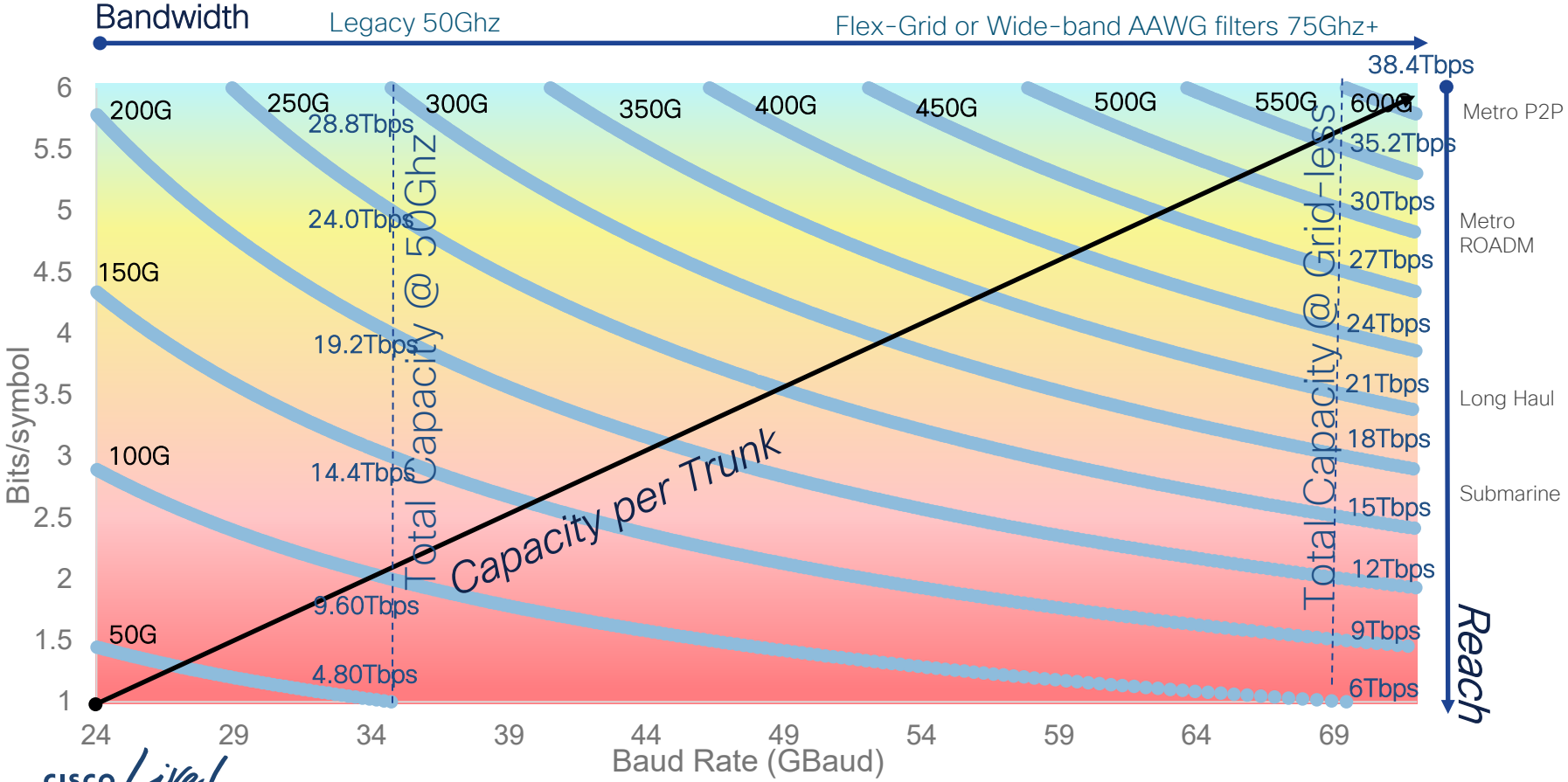

BPSK


16QAM

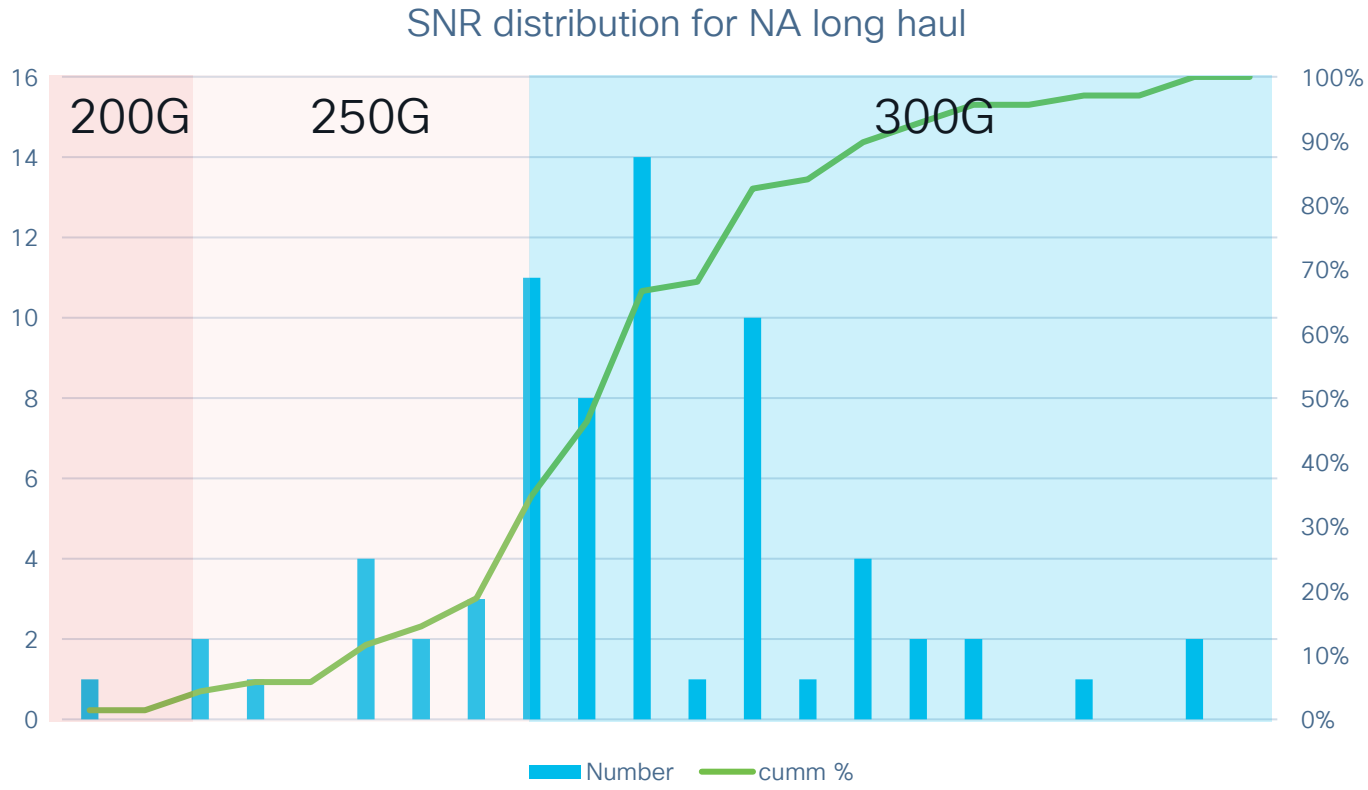

8QAM

6484 unique modes on the NCS 1004 Turbo Coherent DSP
Most industry solutions offer <10 modes today

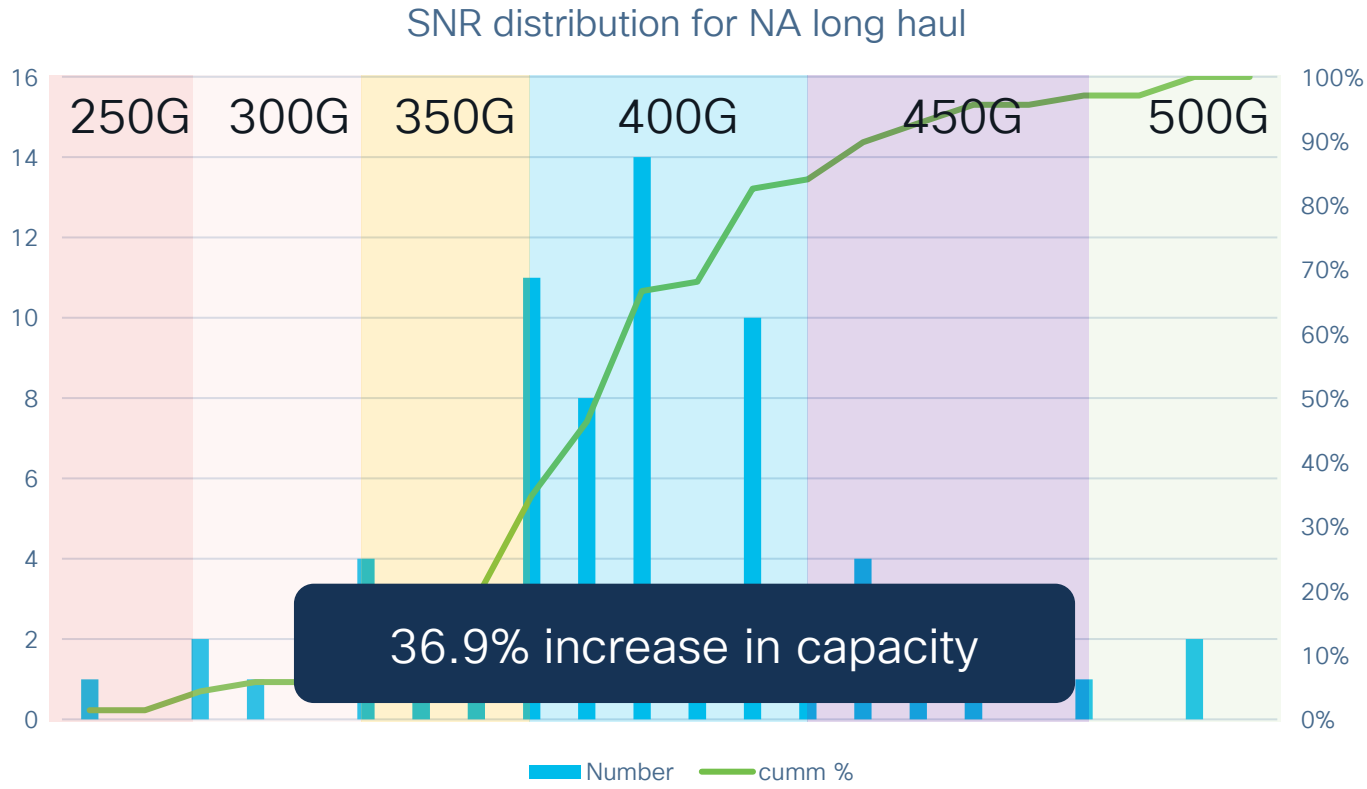
Turbo Coherent with NCS 1004 – 6484 options



North America Back Bone Upgrade with Gen-1 Multi-Haul n x 100G view



North America Back Bone Upgrade with Gen2 Multi-Haul n x 50G view



Subsea Optical Transmission

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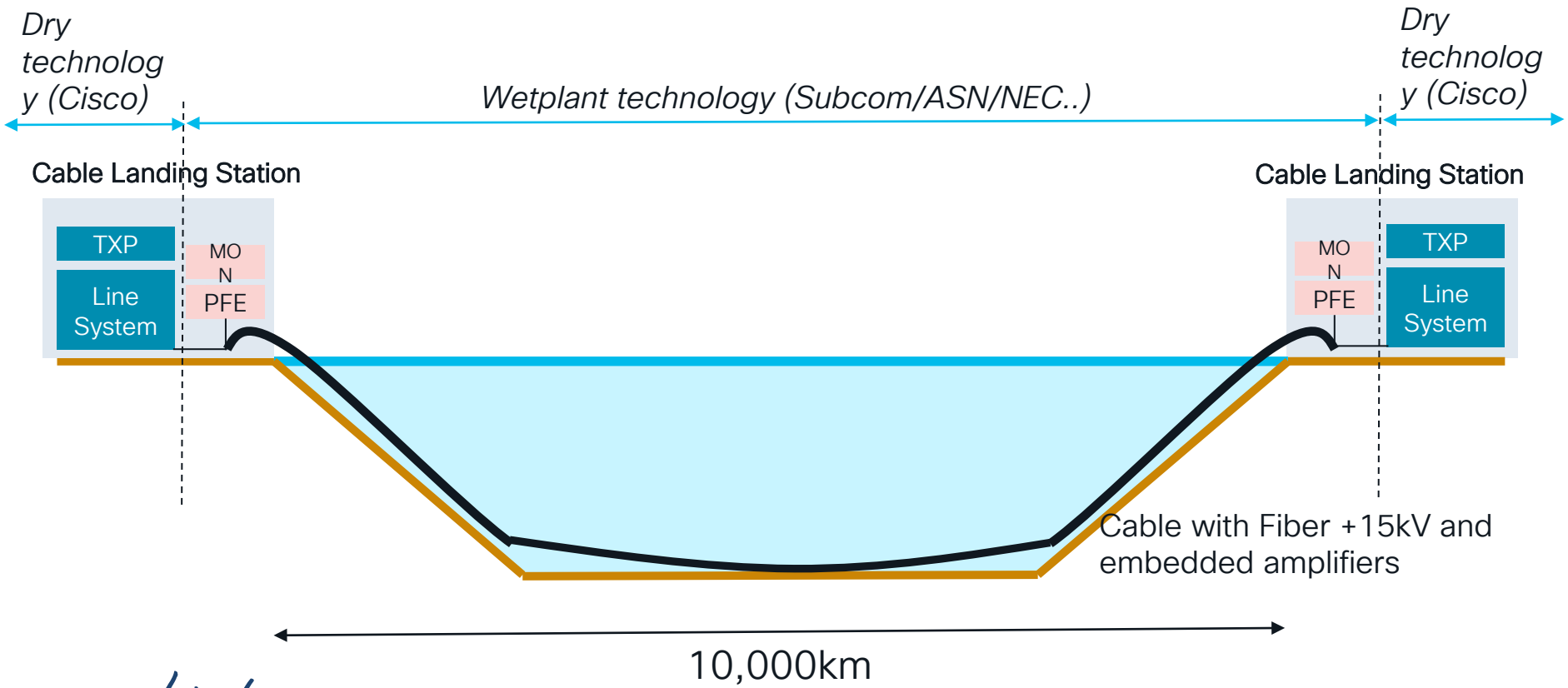
Cisco in Subsea/undersea?

*Subsea, undersea will be used interchangeably



How is Subsea different from Terrestrial?

- More expensive fiber – pure silica core, higher effective area fiber
  - Eg: EX3000 150micron, 0.16db/km
- EDFA amplifiers with symmetrically spacing and operated at Fixed Output Power
- Power management – Noise Loading to maintain Total Power in fiber and CW Idlers on older compensated Systems
- Newer Uncompensated cables are very similar to Terrestrial coherent networks

Where is Cisco in subsea today ?

Completed 6 Deployments

- 1x 10000km+ => 3.7+ b/s/Hz
- 1x 5000-10000km => 4.2+ b/s/Hz
- 4x 4000-5000km => 5.33+ b/s/Hz

Public Announcements

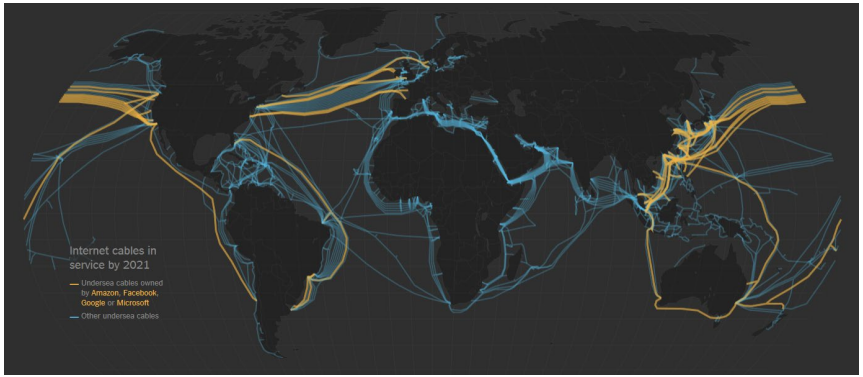
- MAREA
- INDIGO-WEST
- INDIGO-CENTRAL

NCS 1004 Multi-Haul Transponder

- NCS 1004 shipping since April 2019
- Flexible baud-rate and constellations, NLEQ
- L-Band shipping, 400GE to ship in February 2021
- Deployed over 3rd party OLS + Open cable, over Cisco OLS

Subsea Market Trends

- Market driven by Web/OTT: deploying new cables to improve connectivity across the globe (50%+ of total capacity)
- Open cables from sub-com, NEC, ASN
- Space Division Multiplexing (SDM) starting to appear in Subsea

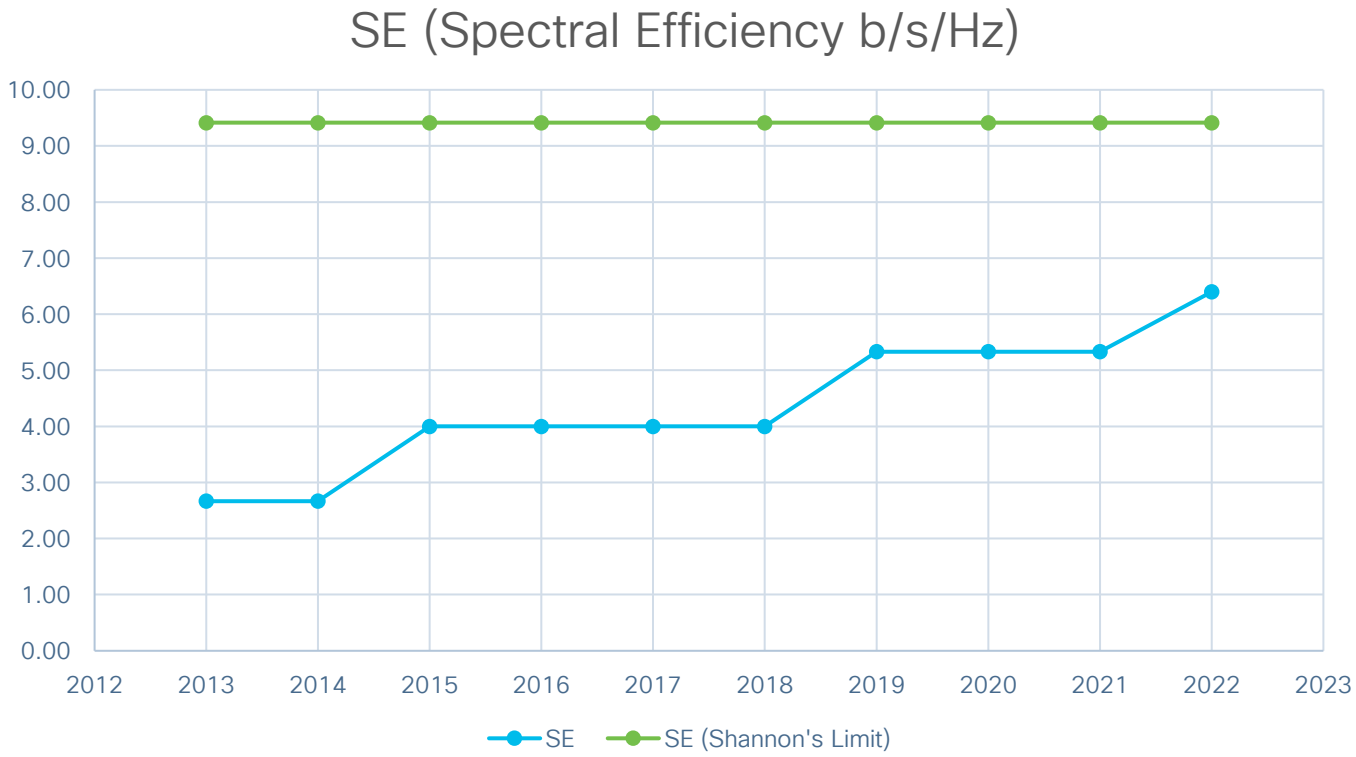


- New uncompensated cables driving unique value:
  - New Routes toward areas not sufficiently covered today
  - Low latency routes bypassing Europe through “Southern Routes”
  - Increased resiliency – 90% of Japan cables impacted by 2011 Tsunami as all terminated in the same area
- More Details on OTT Players and undersea here

Upgrading older cables from 2000

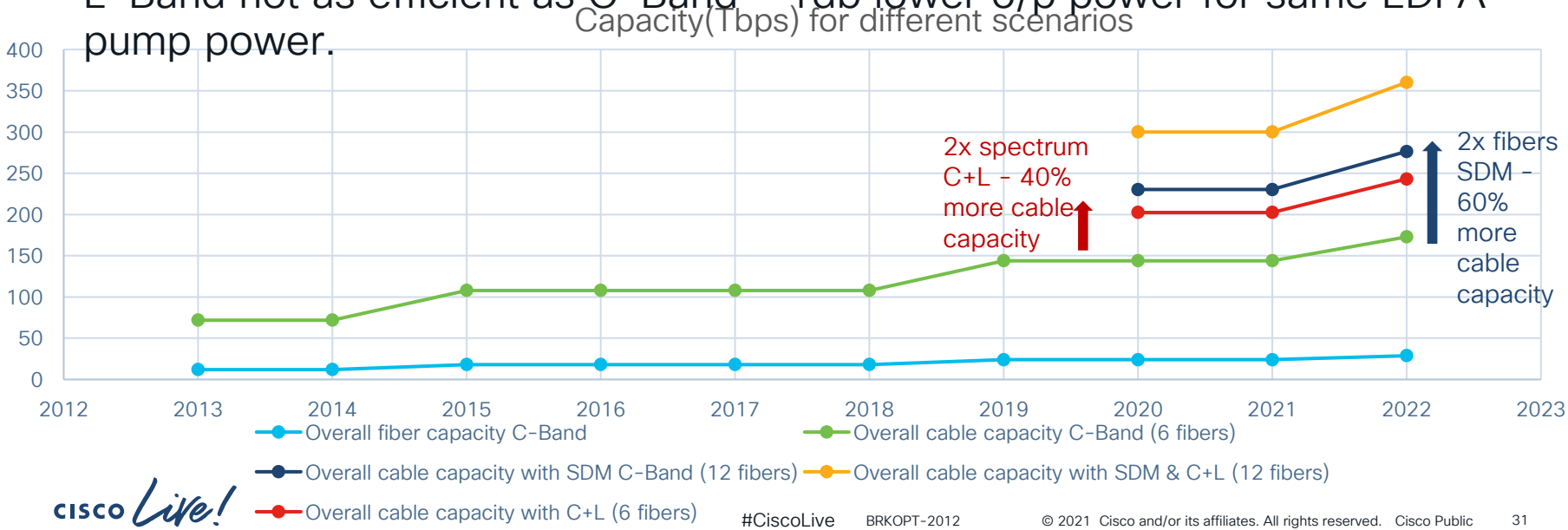
- Between 1997 and 2001, there were 97 subsea cable systems built.
- With a 25 year life approaching and high O&M costs, what is the path forward ?
  - Build new cables ? *More capacity, Better economics*
  - Lease capacity/spectrum ? *DC players driving lower costs*
  - Upgrade and extend life of cables ? *Strategic cable assets, Slower deployments due to regulatory and other issues.*

SE improvements for subsea – trans-Atlantic cable



SDM approach for trans-Atlantic cable

- Map same set of EDFA pumps to more fibers. Lower EDFA launch power and therefore, lower SNR (OSNR = 58 + Pin – NF – 10x log10 N) but, lower impact to SE.
- SE = 2 x $\log_2$ (1+SNR) so, 3dB lower SNR -> 20% lower SE
- L-Band not as efficient as C-Band – 1db lower o/p power for same EDFA pump power.



As we move the network to multi-haul, how can we make things better?

Software

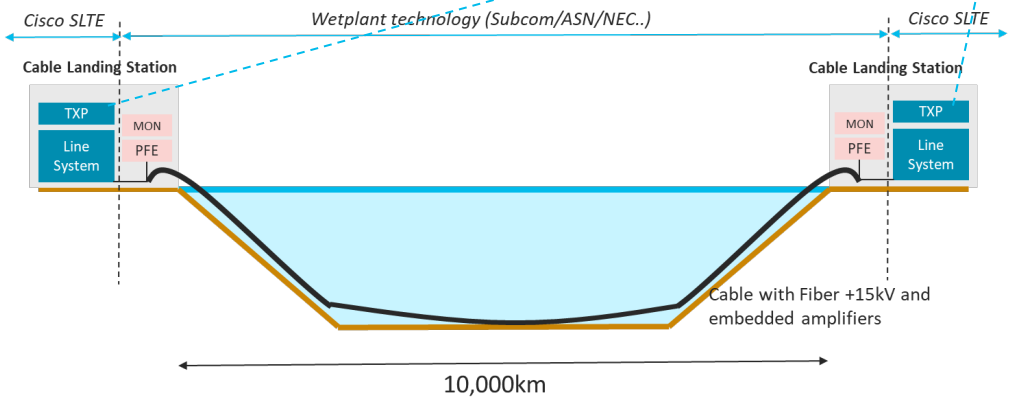
Present Mode of Operation

Planning Tool

Considers worst case transponder performance, optical component losses and aging, margins

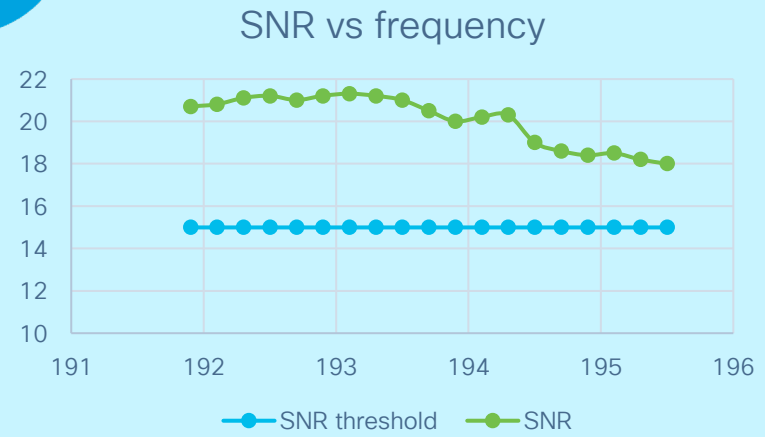
BOM

Installation parameters



Manual tuning to optimize this – can take days

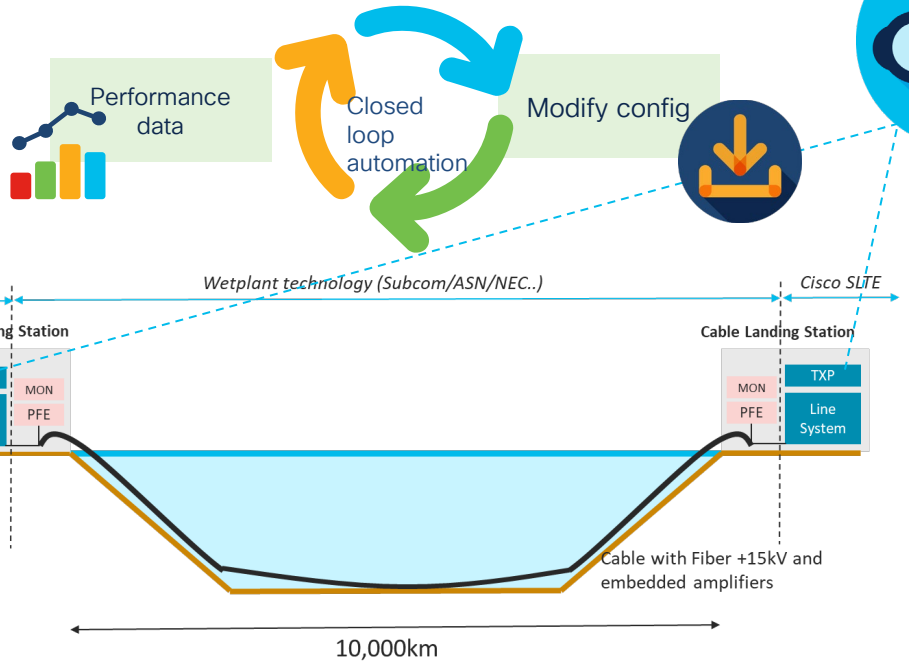
Excess margin in the network



With Cisco Automated Subsea Tuning

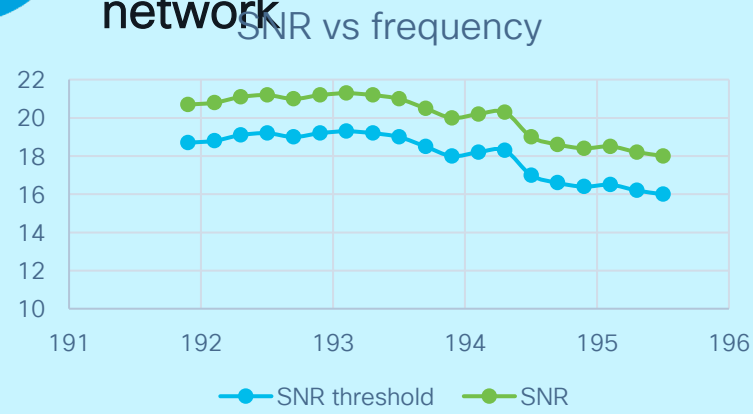
CAST

Considers real time performance to optimize network for maximum capacity.

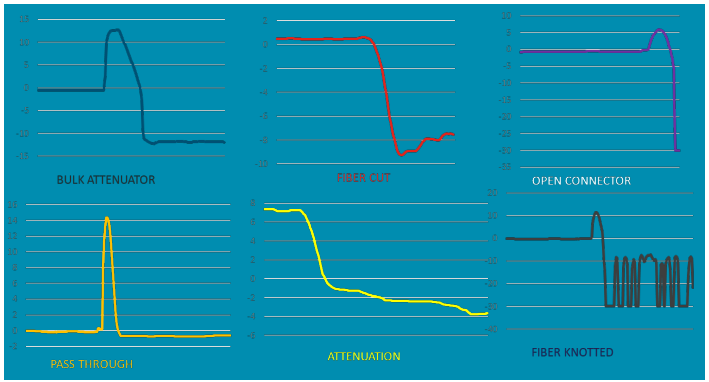


Automated optimization completed in an hour

No Excess margin in the network



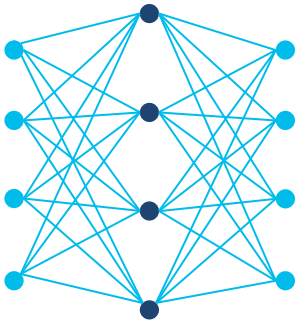
Using Machine Learning to do what a human expert can do?



Reference OTDR trace data

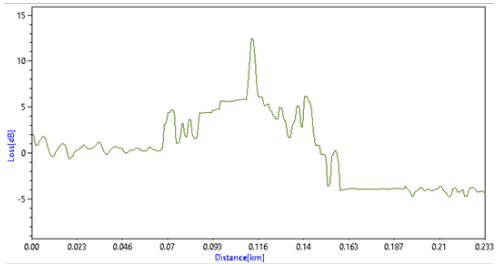
Machine Learning

Train ML classifier neural network to identify Fiber Events

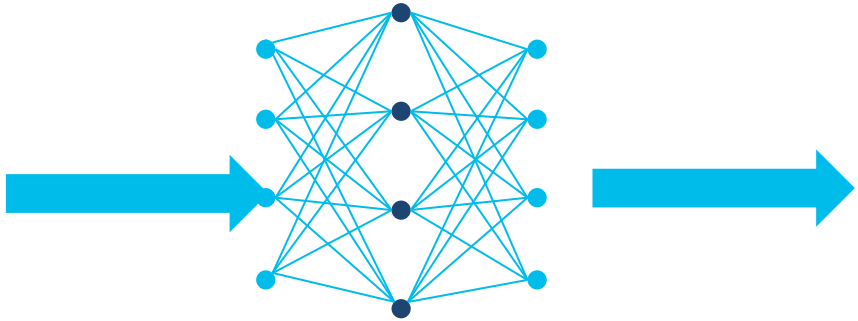


Neural Network

Using Machine Learning to do what a human expert can do?



Network OTDR trace data



"Trained"
Neural Network

Event classified as 55% fiber pass through and 45% knotted fiber i.e. combination of two event types

ML classifier neural network identified fiber event from OTDR data

Conclusion

DCI and Subsea Applications

- Innovation pace in DCI and Subsea is nothing but accelerating
- Simplification and Automation are key drivers for the Innovation in Optical and Networking in general
- Coherent Multi-Haul Transmission is driving major innovation across networks in LH Terrestrial and Submarine applications
- New QSFP-DD Coherent form factors are emerging for DCI applications

The bridge to possible

Thank you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