

The background of the slide is a vibrant, abstract graphic. It features a series of overlapping, wavy bands of color in a rainbow spectrum, transitioning from red and orange on the left to yellow and green on the right. On the right side, there is a bright, multi-colored sunburst or starburst effect that radiates outwards, with colors ranging from blue and purple to yellow and orange. The overall composition is dynamic and energetic.

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The bridge to possible

# Lessons Learned from Designing Routed Optical Networks

... or how to embrace tradeoffs for fun and profit

Dirk Schroetter, Technical Solutions Architect in cooperation with  
Velimir Vujnovic, Principal Architect

BRKOPT-2015

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# Agenda

- Bare minimum of analog domain
- Optical Performance
- Traffic demands vs. capacities
- Topologies & constraints
- Protecting IP on the IP Layer
- Conclusion

*“If you haven’t found the tradeoffs,  
you haven’t looked hard enough.”*

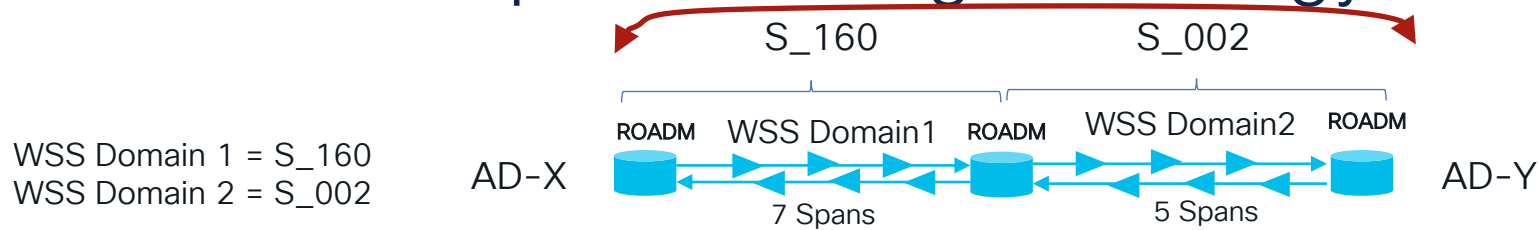
Russ White’s Rule #1

Mr. EIGRP

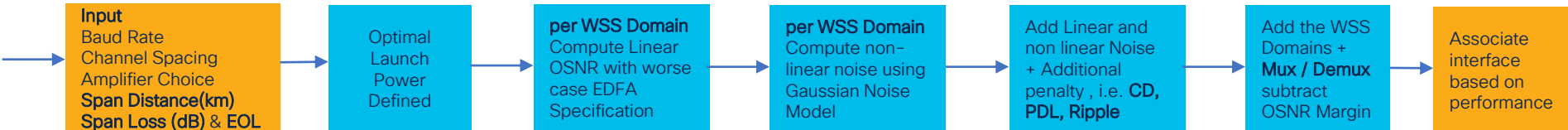
The bare  
minimum on the  
analog domain



# DWDM transport is analog technology



End to End Service is split into smaller WSS Domains:  
ROADM to ROADM -> WSS Domain 1 and WSS Domain 2



Required input:

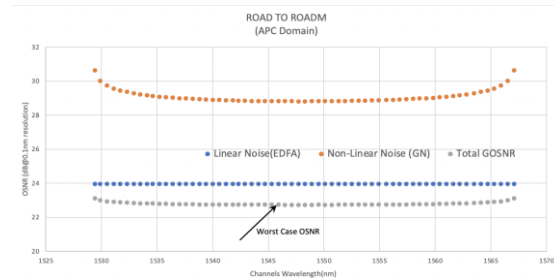
- Topology (span length & attenuation), EOL margins

Method:

- Gaussian Noise simulation

Interesting:

- How we build the Add/Drop structure for the ROADM

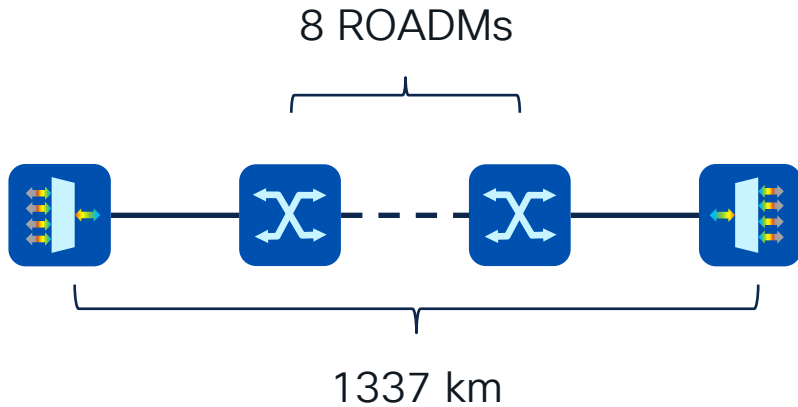


# Lesson 1: Optical Performance





# ZR+ and Transponder performance - comparable



Latest customer ZR+ test over 3<sup>rd</sup>  
party DWDM

400 Gbps



OSNR(dB) @  
0.1 nm RBw

23.1

22.6

Baudrate  
(GBd)

60.14

69

# Channels  
per "Band"

64

54

Modulation

16-QAM

16-QAM

# Lesson 2: Build on IP traffic demands, not capacities



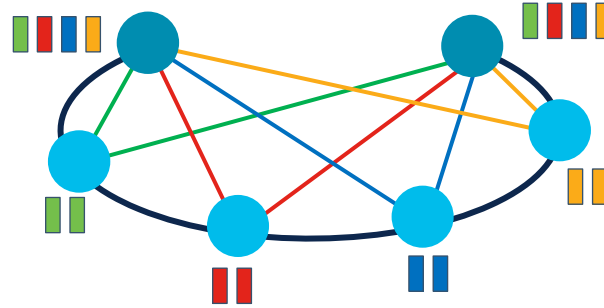
# US operator “metro” simulation results

01 Simulation using P95 of busy hour traffic

02 X Tb/s busy hour traffic.

03 8 X Tb/s installed capacity

04 Single wavelength on aggregation rings



34.1  
Gb/s  
Average site traffic

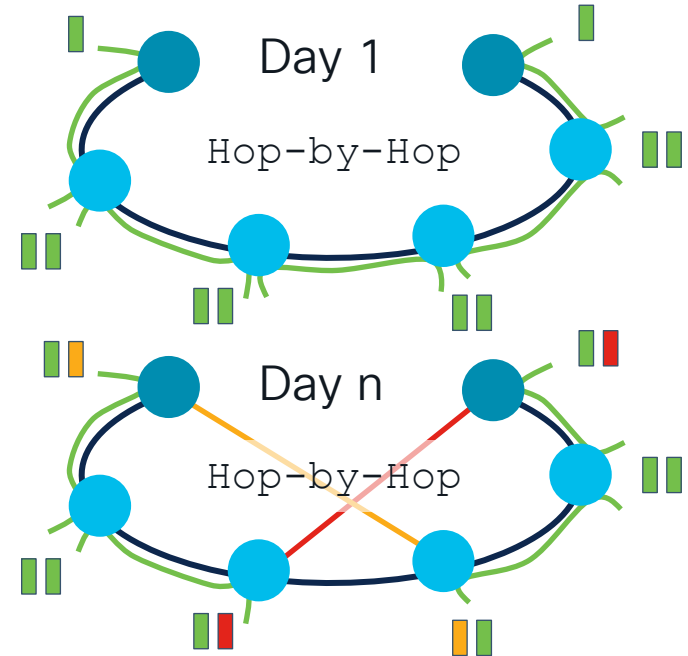
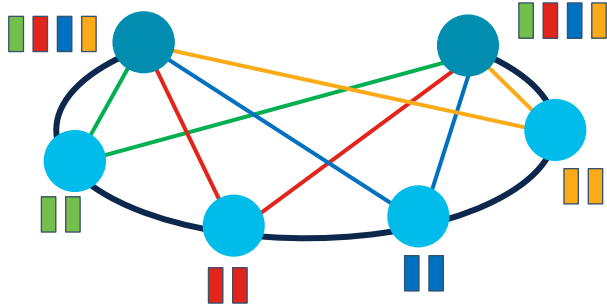
29.3  
Gb/s  
Median site traffic

Wavelength usage

-97%

-95%  
Energy usage

# Transforming Hub & Spoke to Hop-by-Hop



Customer reported being short on wavelengths

# Simulation Results

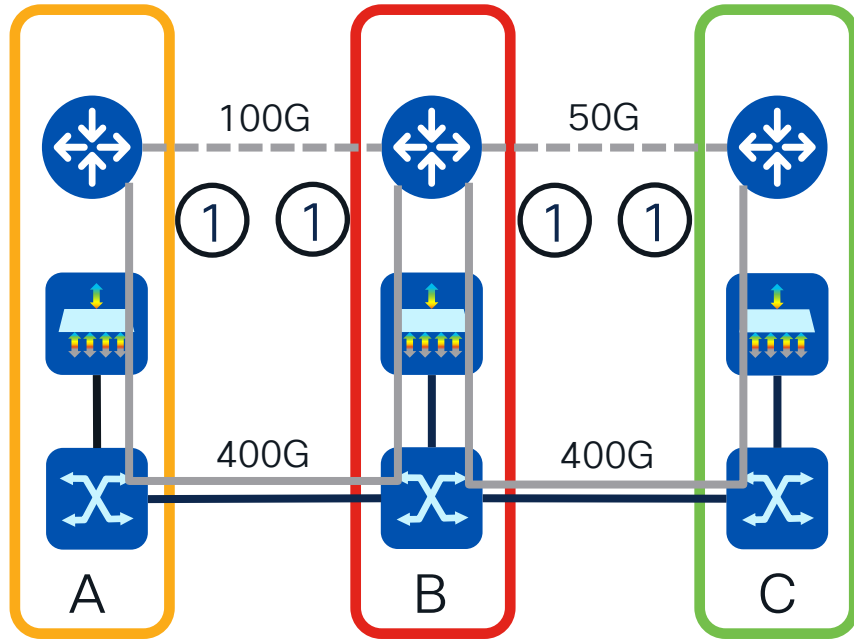
	40% installed PMO capacity	P95 busy hour traffic
Sum inter-site demands	6.408 Tb	1.976 Tb
Inter-site installed capacity	38.7 Tb	30.3 Tb
Intra-site installed capacity	67.26 Tb	62.8 Tb
ZR/ZR+ pluggables	194	152
Grey pluggables	334	314
Maximum $\lambda$ used between hubs	4	2
Maximum $\lambda$ used on rings	2	1
WC link utilization	100 %	70.69 %

Power savings from TXP elimination alone: 55.000 kWh p.a.

# Lesson 3: Topologies & Architectures matter, but Constraints even more so.

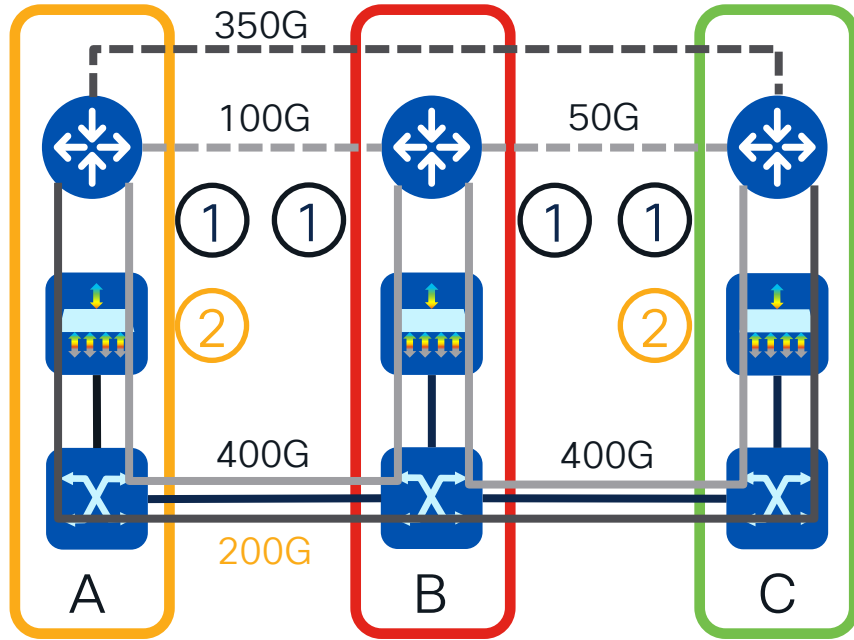


# A toy network showing the concept ...



- Not “one size fits all”
- Consider:
  - Fiber cost / availability
  - Relative importance of sites
  - Achievable bitrates
  - Impact on resiliency
  - Physics
- Both approaches have their place in designs.

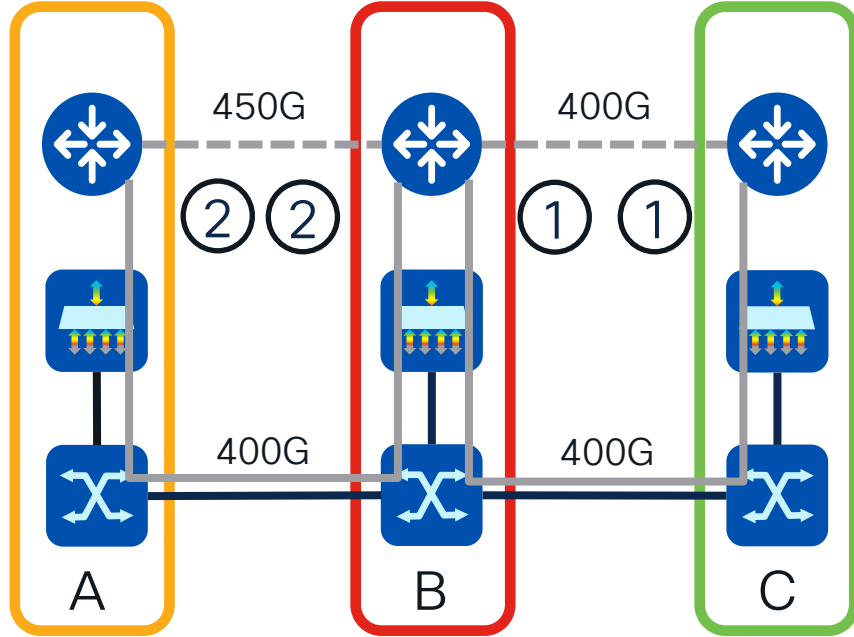
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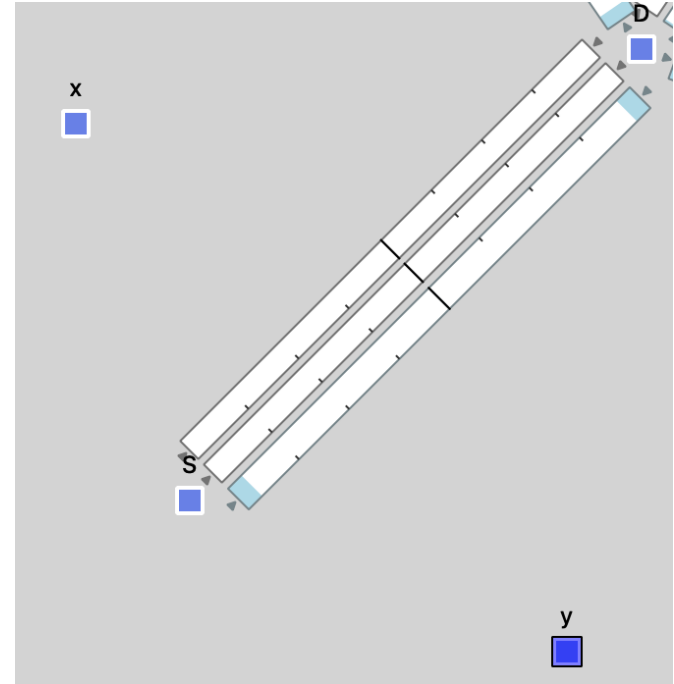
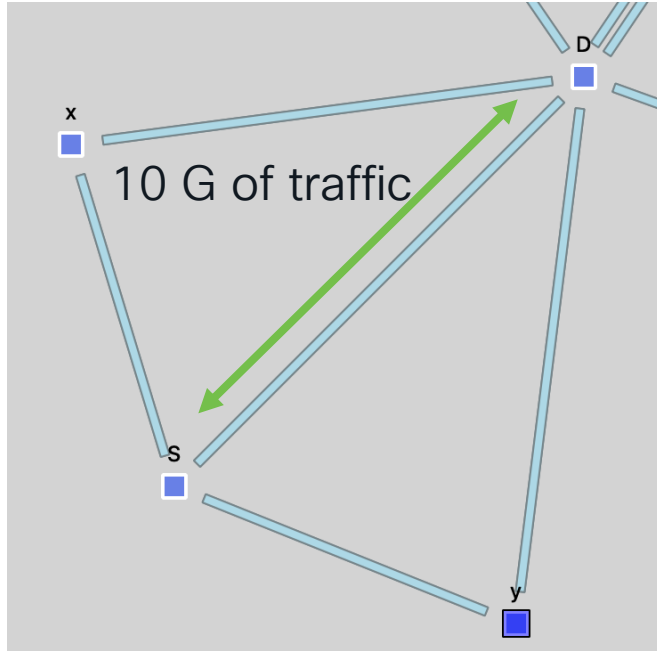


# A toy network showing the concept ...

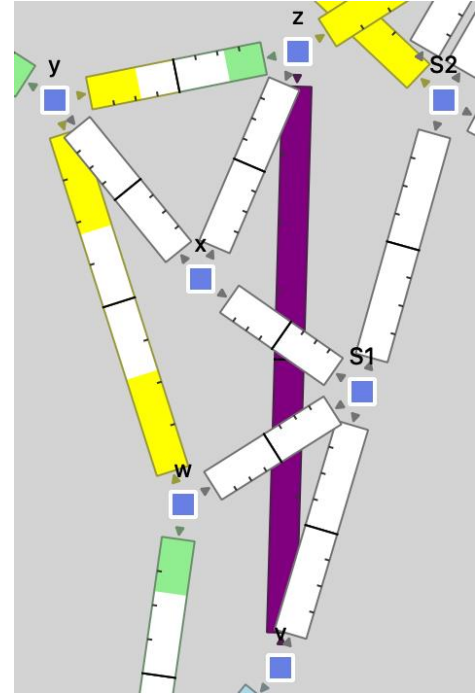
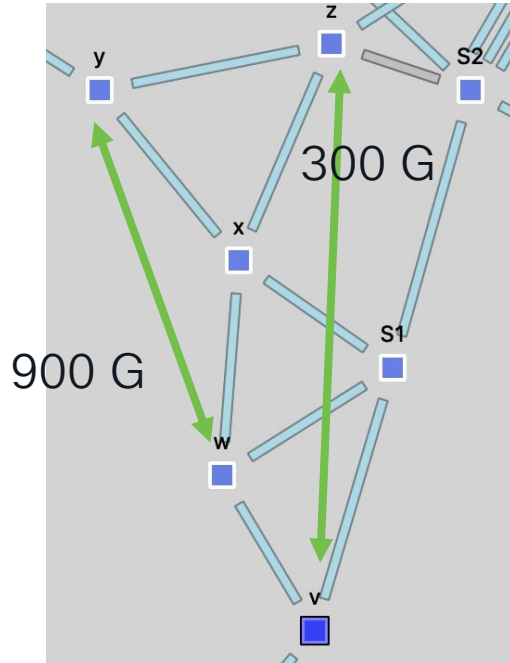


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# Real example 1



# Real example 2



# Physics forcing architectures

Wider channel	Better FEC	Higher modulation	Better spectral efficiency	Use L-Band
"Easily" done	Increased reach	More bits per symbol -> Higher capacity	More b/s/Hz	"Easily" done
Increased capacity per channel	Higher overhead eats into usable capacity	Reach ~ 1/constellation size	Dispersion coefficient $\beta$	Doubles # channels
Fewer channels	Power, real estate, cost	X km @ 16QAM -> X/4 km @ 64QAM	Nonlinear coefficient $\gamma$	Increases attenuation
Increased blocking probability	No "dramatically better" FEC on horizon		Reduce attenuation	Negatively impacts spectral efficiency
			Reduce reach	Requires drastically different fiber to have big effect

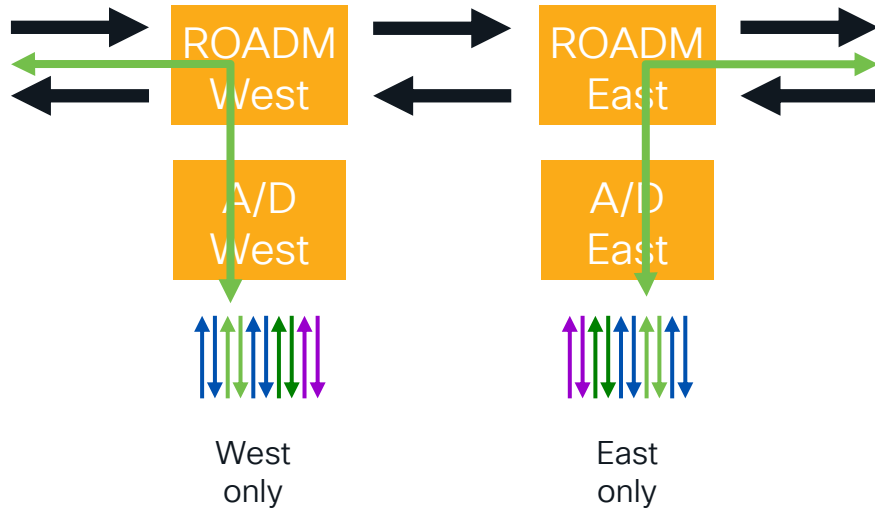
Not a question of "if" but "when" physics mandates shorter paths

# Lesson 4: IP services are protected and restored using IP

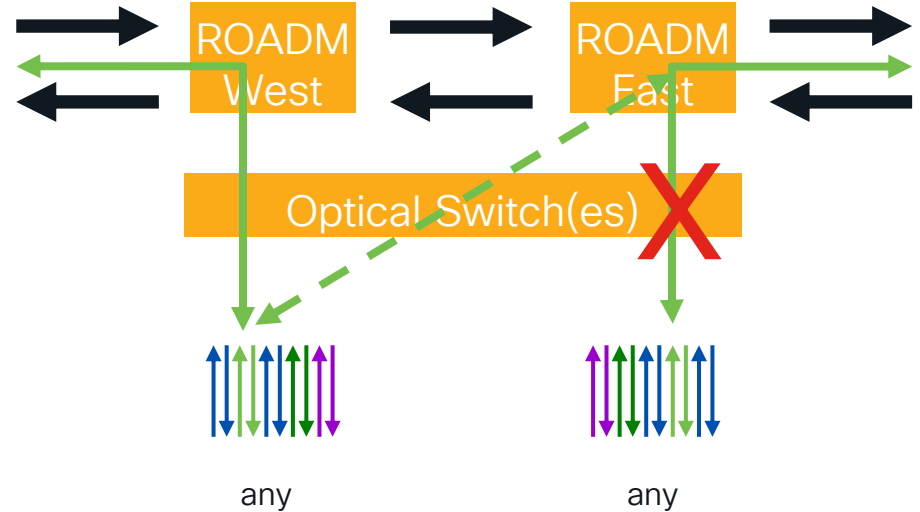


# Omnidirectional Add/Drop

Wiring determines direction



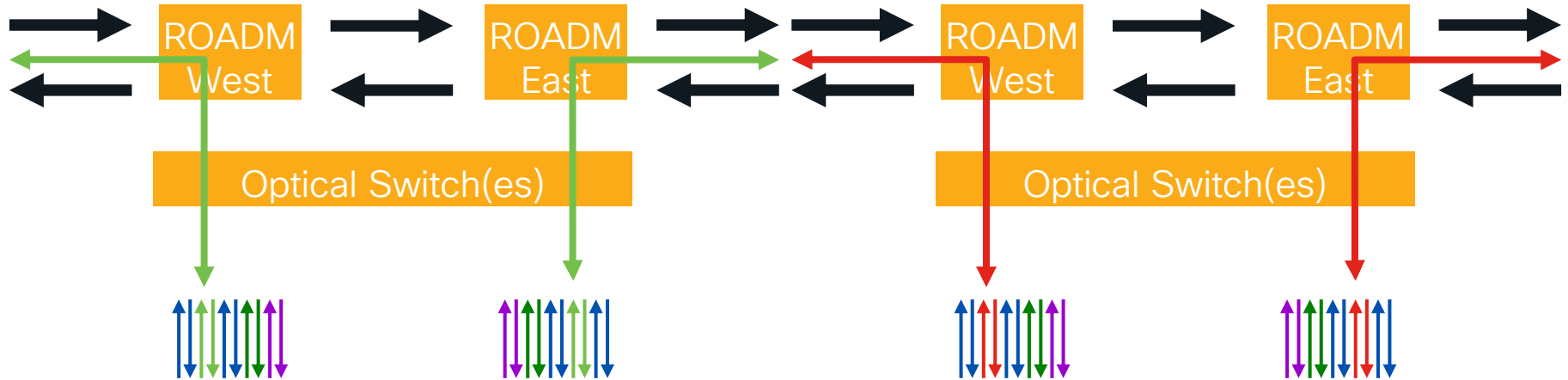
Channel switched to direction



# Colorless Add/Drop

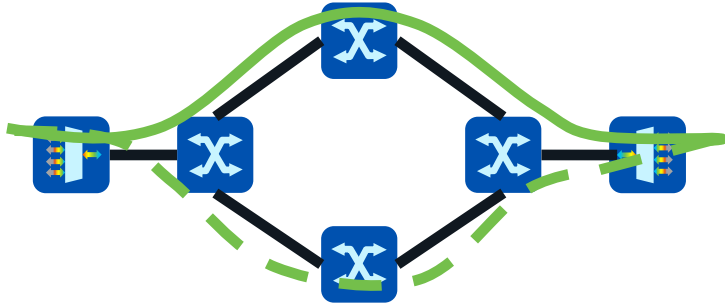
Green  $\lambda$  on port

Red  $\lambda$  on port



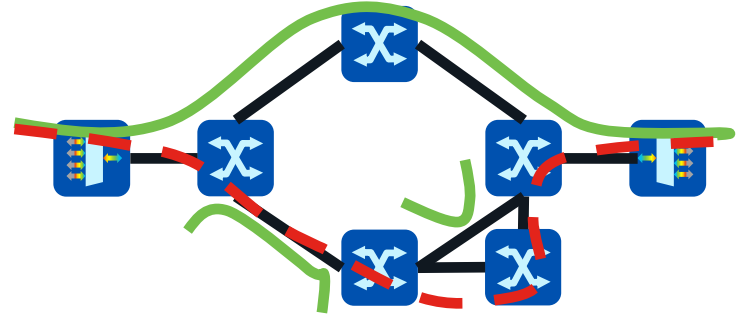
# OK, so what is the use case ?

Optical Protection



Bridge green  $\lambda$  to lower part of network – same patch panel port

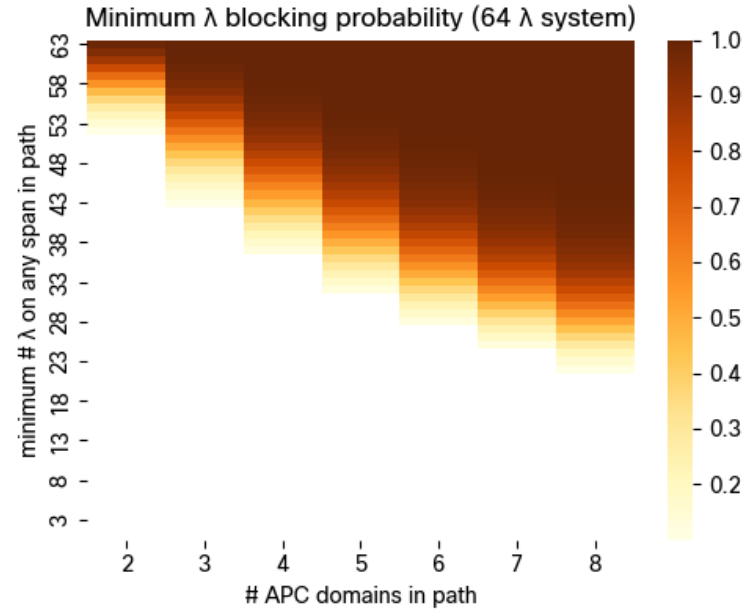
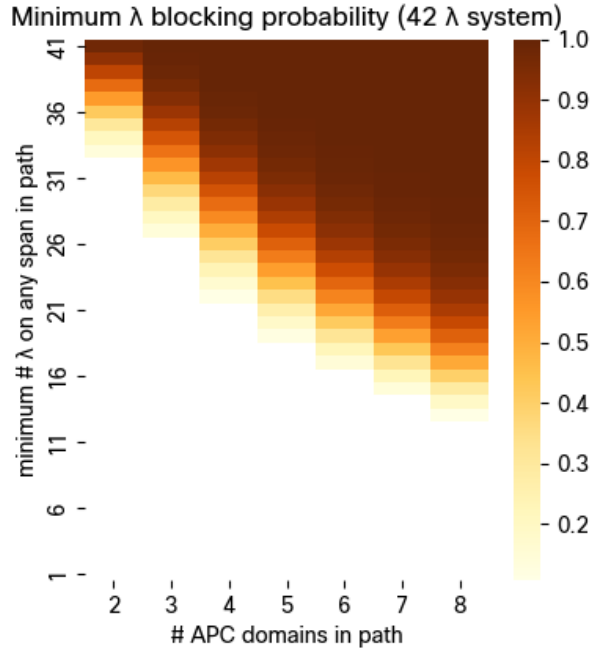
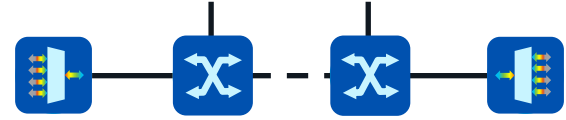
Optical Restoration



Compute new path (optical control plane) and change to red  $\lambda$  – same port

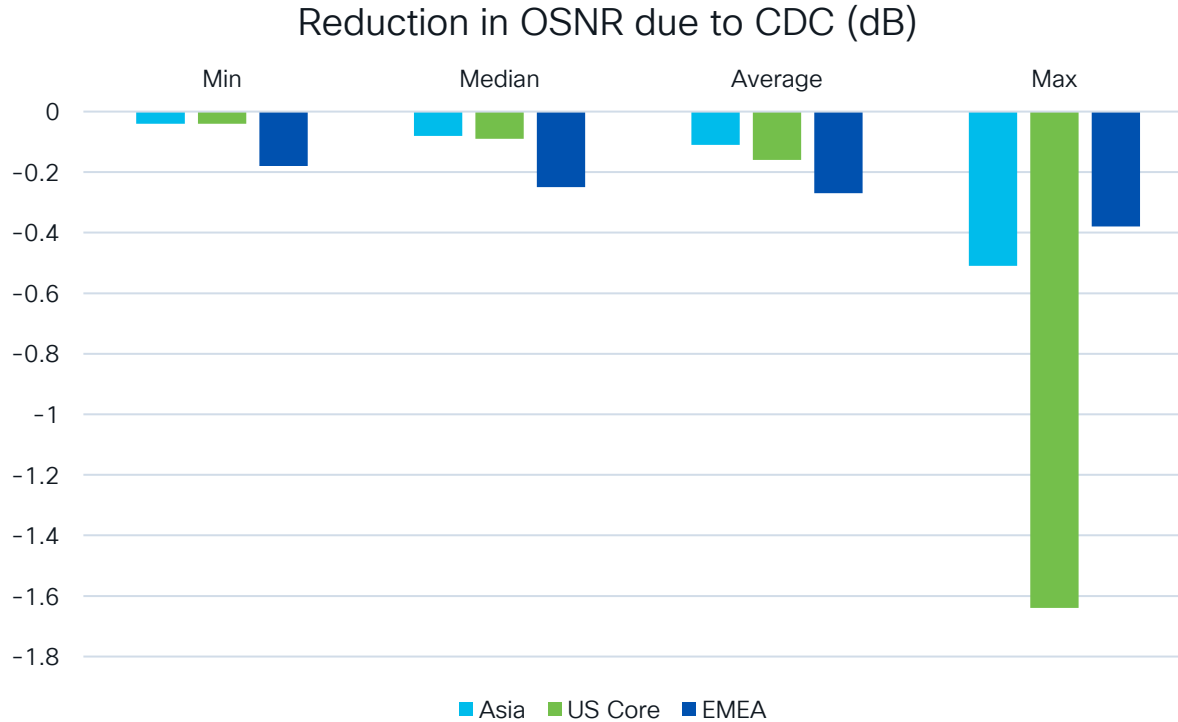


# Is $\lambda$ blocking really an issue ?



It can be – especially in meshed networks ! (Only probabilities  $\geq 10\%$  shown)

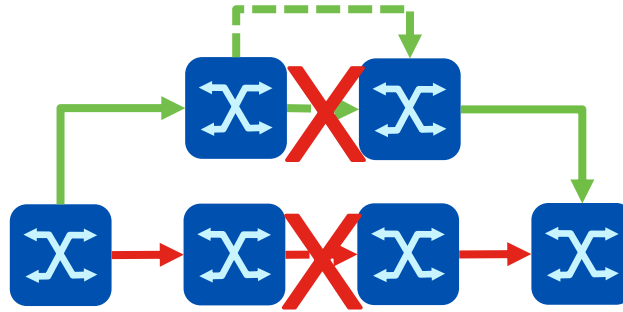
# Negative effect on OSNR & bitrate due to CDC



	Decreased Bitrate (% of non-regen circuits)
Asia	3 %
US Core	4 %
EMEA	0 %

# Does optical restoration work for the Asia net ?

Relations	157
Relations w/o regenerators	121
Relations $\geq 2$ spans	117
Restorable on same bitrate	82
Requires regenerator	35

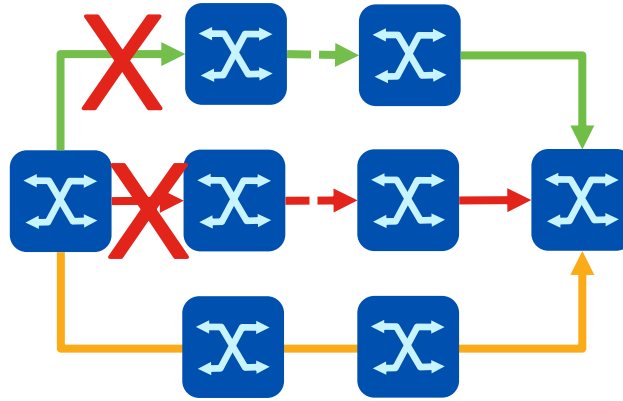


Optical restoration is (by design) not fast – think minute(s)

Of the three networks, Asia network was specifically set up for DWDM restoration

# Does optical restoration work for the Asia net ?

Relations	157
Relations w/o regenerators	121
Relations > 2 spans	117
Restorable on same bitrate	82
Requires regenerator	35



Relations	157
Relations w/o regenerators	121
Relations > 2 spans	N/A
Restorable on same bitrate	72
Requires regenerator	49

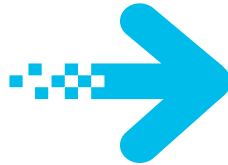
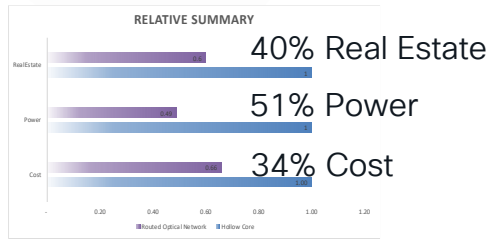
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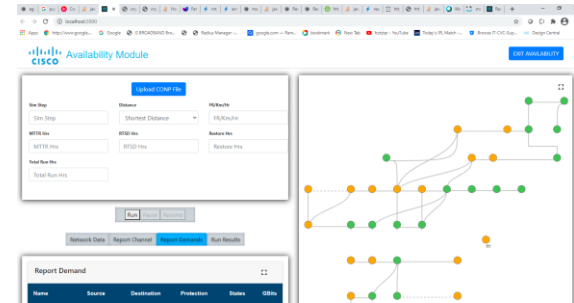
# Actual Network Results

Reduced TCO with enhanced availability vs. Present mode of Operation

>80,000km Long Haul



What about Reliability?



PMO = 50% additional cost for equivalent availability to the Routed Optical Network

## Present Mode of Operation

~ 45 Tbps traffic demands

Optical Restoration used

## Routed Optical Networking

All IP Protection/Restoration

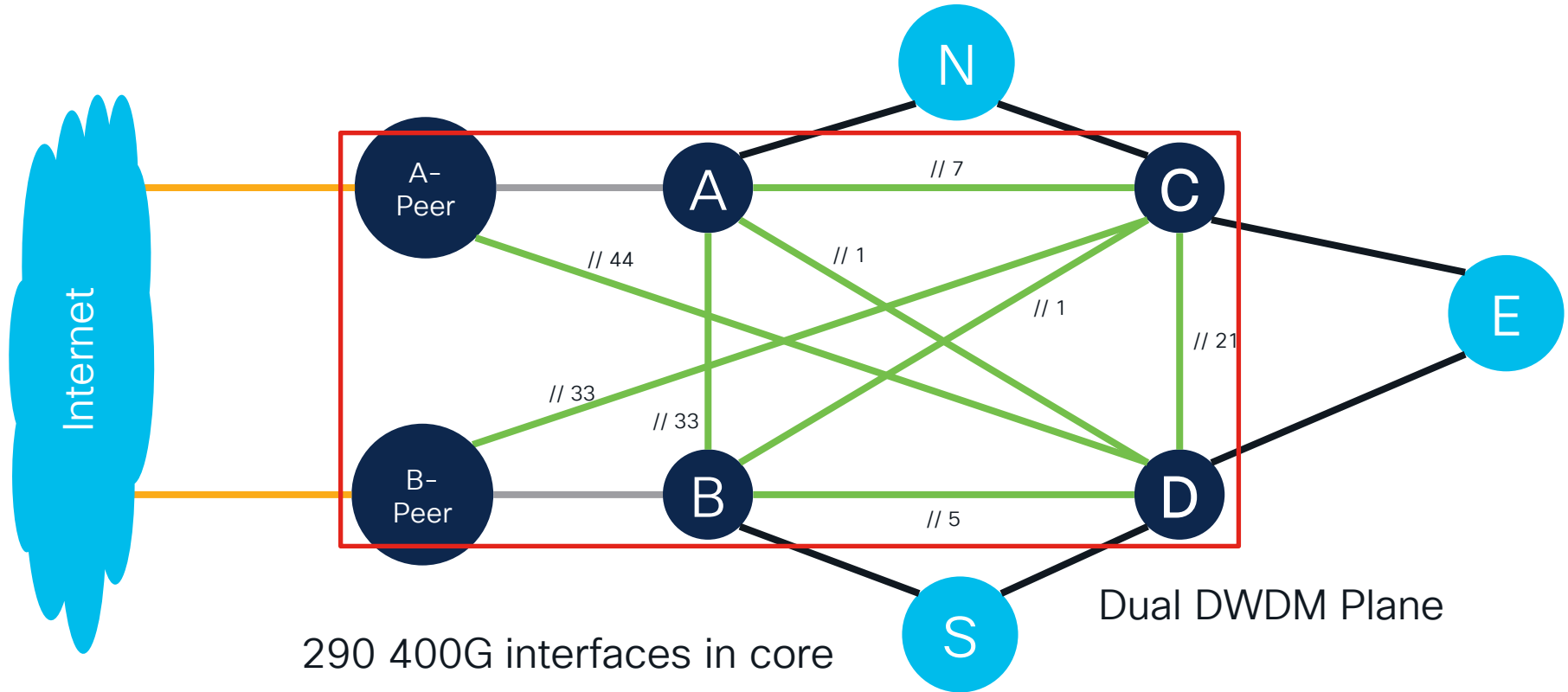
Saved 12000 km of fiber (3 x LA -> NYC)

*“Design is an iterative process. You probably need one more iteration than you’ve done to get it right.”*

Russ White’s Rule #2

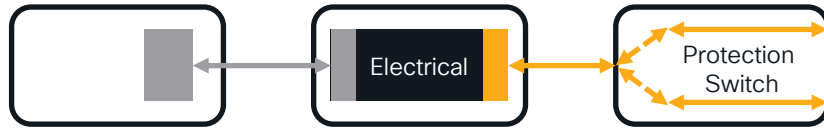
Mr. EIGRP

# That EMEA network – customer view



# Switching to single plane

## Customer Ask



400G IFs 290

Wavelengths 580

# DWDM systems 2

## Final Solution



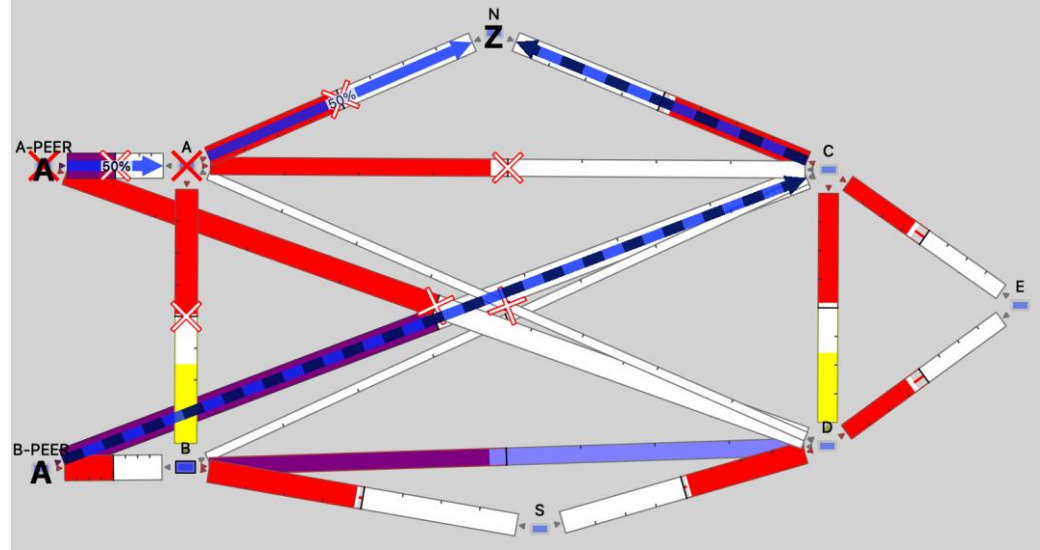
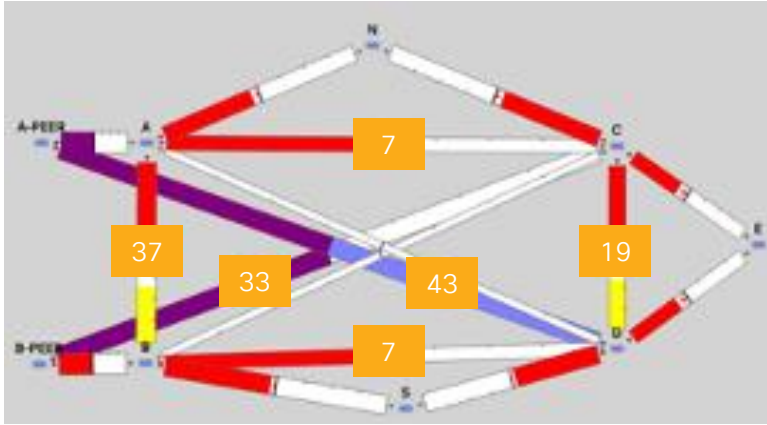
400G IFs 292

Wavelengths 292

# DWDM systems 1



... still survives complete failure at A, B



# Conclusion

- It is all about tradeoffs
- Design from IP layer down
- Physics ...
- Know your IP demands
- Simplify DWDM network
  - Add/Drop structures
  - IP “restoration”
- Design tools

# Fill out your session surveys!



Attendees who fill out a minimum of four session surveys and the overall event survey will get **Cisco Live-branded socks** (while supplies last)!

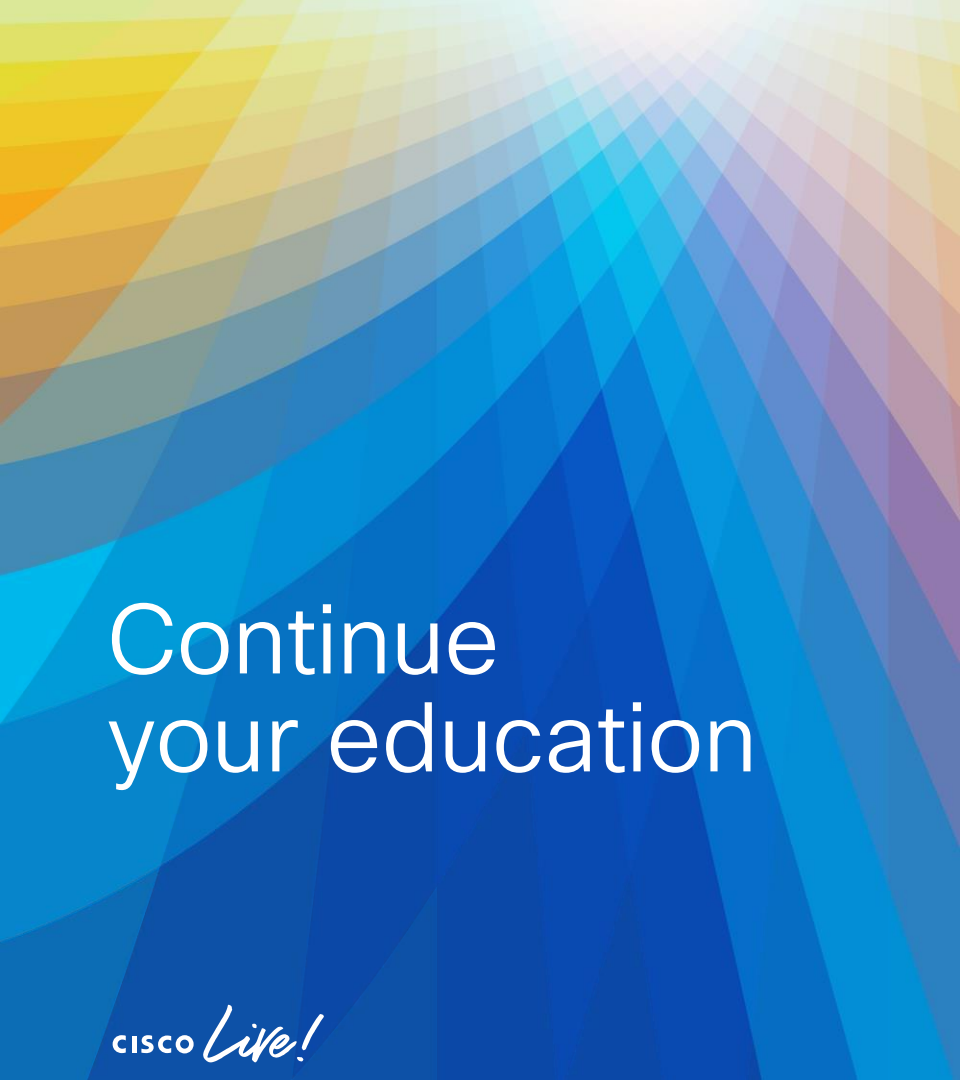
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Attendees will also earn 100 points in the **Cisco Live Challenge** for every survey completed.



**These points** help you get on the leaderboard and increase your chances of winning daily and grand prizes



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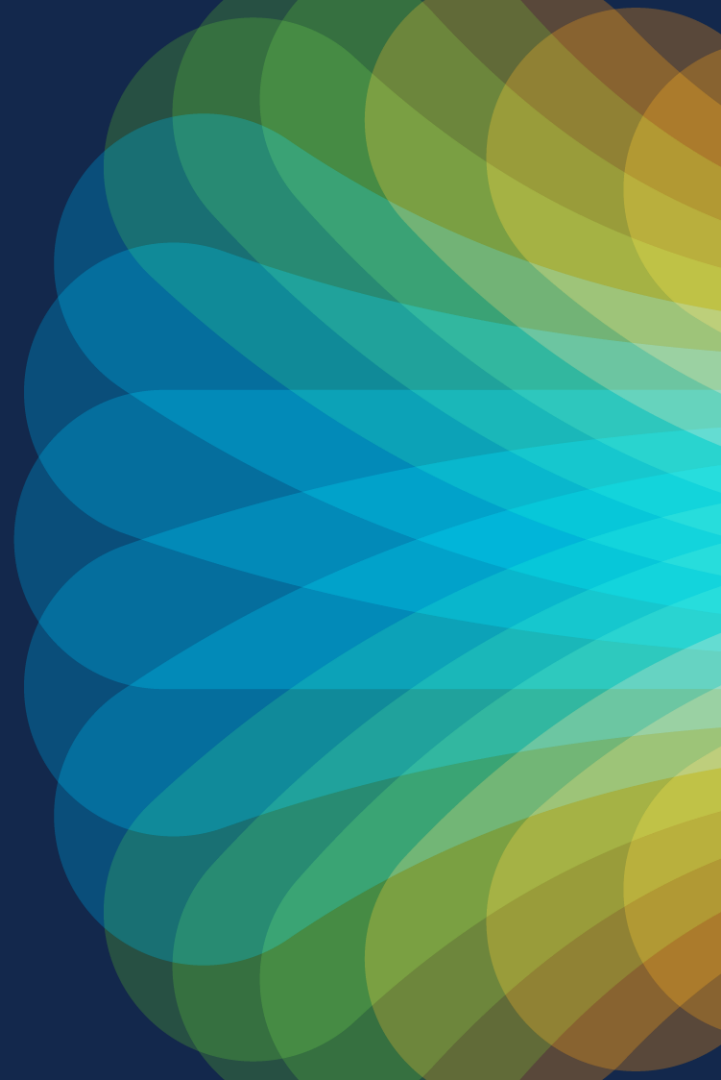


The bridge to possible

# Thank you



#CiscoLive

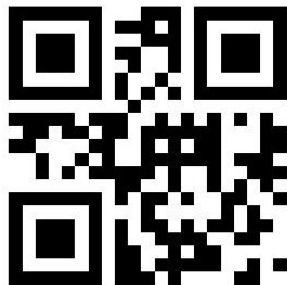


# Cisco Live Challenge

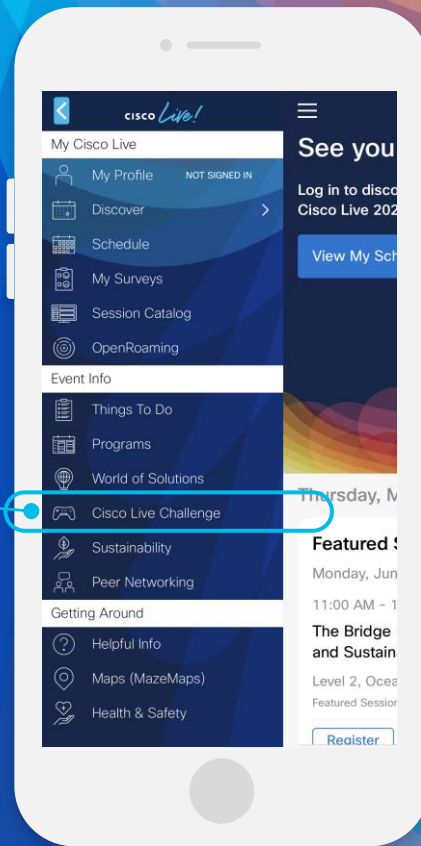
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Get points for attending this session!

## How:

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- 3 Click on View Your Badges at the top.
- 4 Click the + at the bottom of the screen and scan the QR code:



**CISCO** *Live!*



The background is a vibrant, abstract graphic. It features a central bright white light source from which numerous colorful rays emanate, creating a sunburst or starburst effect. The rays transition through a spectrum of colors including yellow, orange, red, and various shades of blue and green. Overlaid on this are several large, semi-transparent, wavy shapes in similar color tones, giving the overall image a sense of motion and energy.

cisco *Live!*

Let's go

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