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High Value Wavelength / Private Line Services

Understanding the Customer and Provider Perspective

Christian Schmutzer, Distinguished Engineer

BRKOPT-1005

Cisco Webex App

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- 4 Enter messages/questions in the Webex space

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<https://ciscolive.ciscoevents.com/ciscolivebot/#BRKOPT-1005>

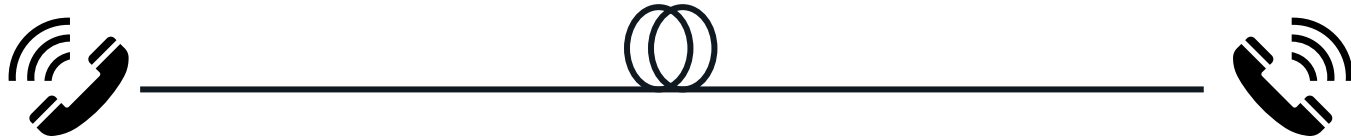


Christian Schmutzer

- Joined Cisco in 1998
- Learned MPLS when it was still called Tag switching
- Bilingual in IP and optical
- Atypical trajectory
 - Sales > marketing > engineering

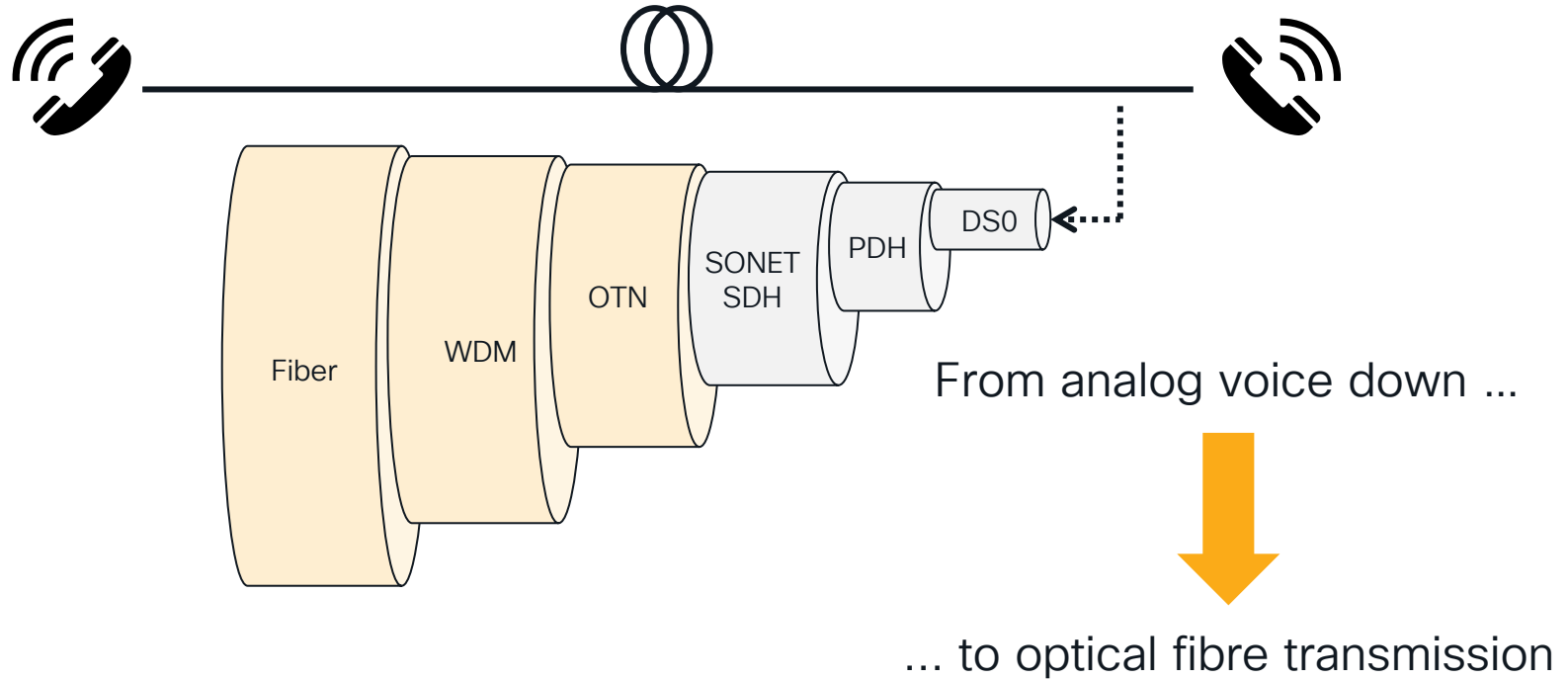


The “Russian Dolls” of the Telecom Industry

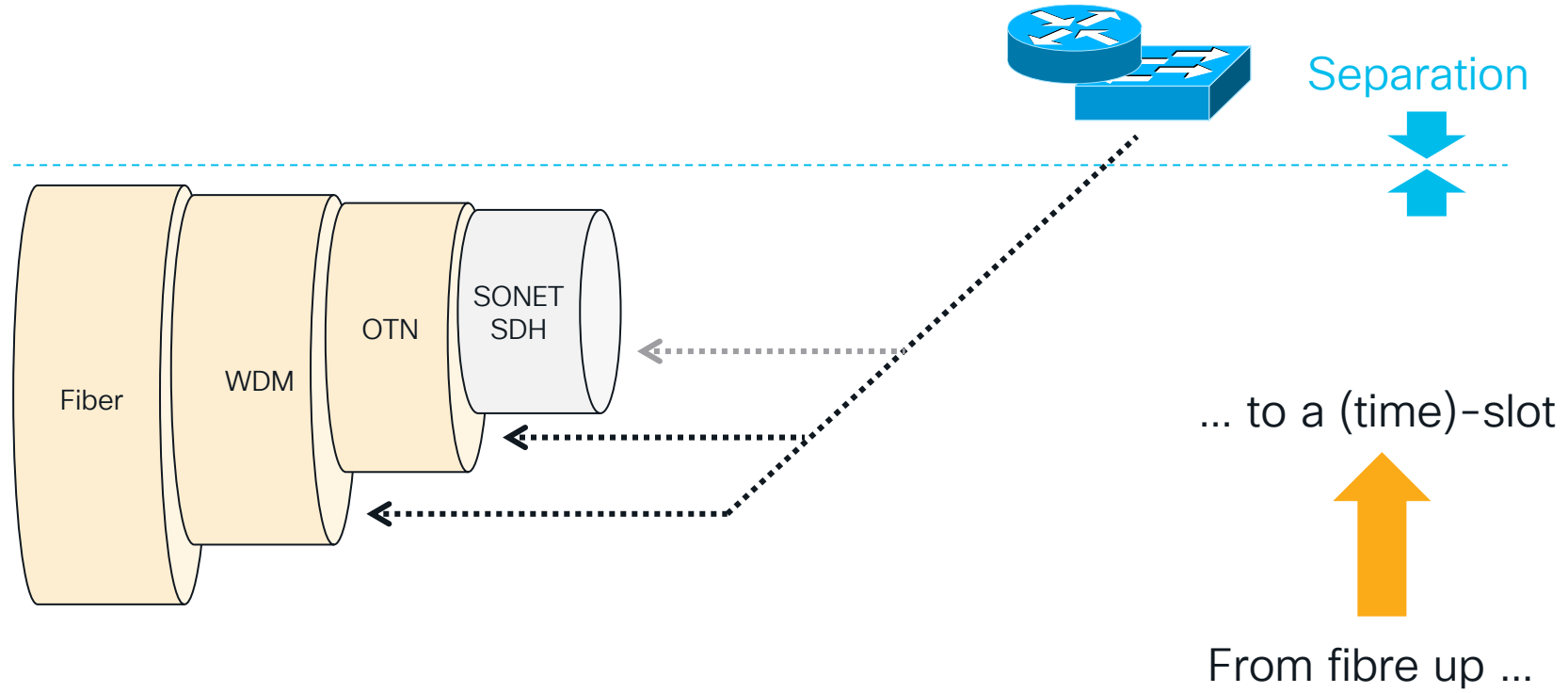


From analog voice down ...

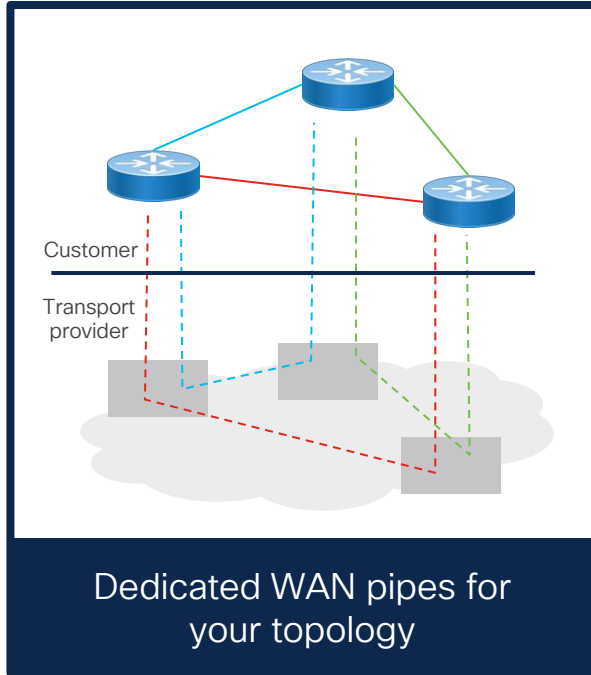
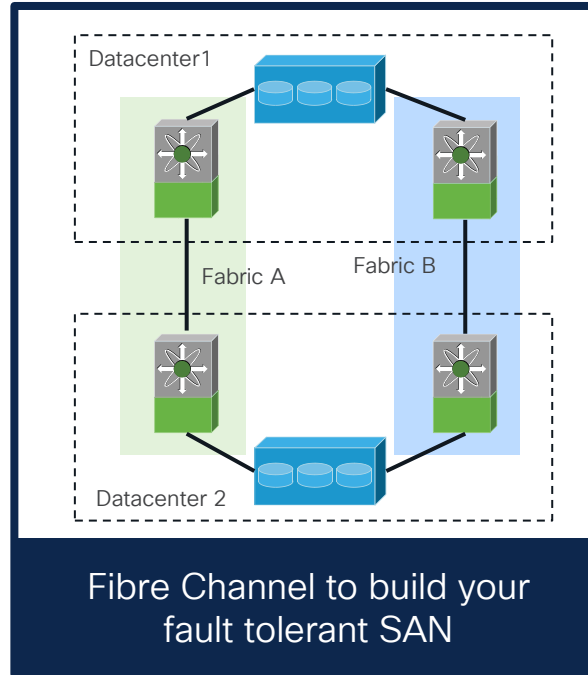
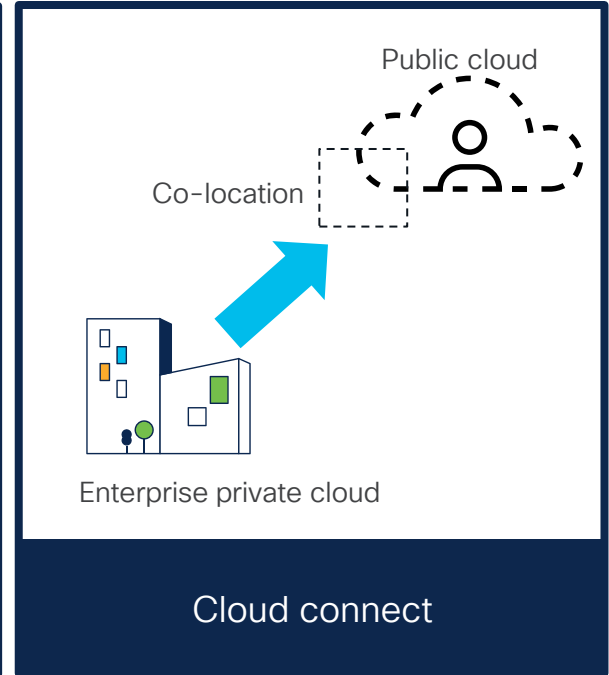
The “Russian Dolls” of the Telecom Industry



Everyone wants fiber, but you don't easily get it



Private Lines are typically used for

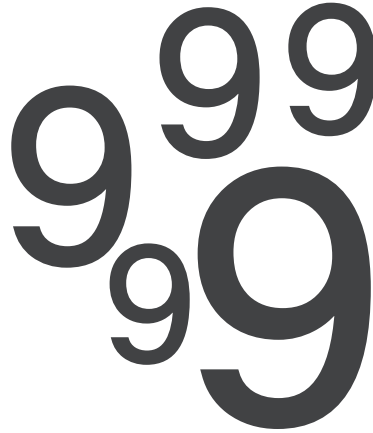


SAN ... Storage Area Network

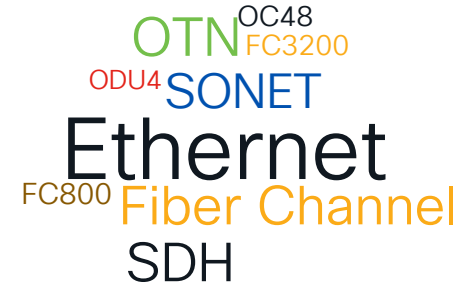
Private Lines are Premium Services



High bandwidth

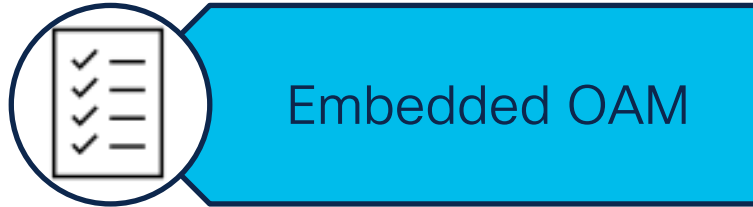


High availability

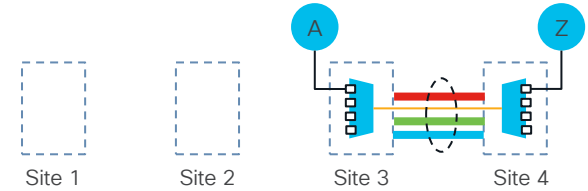


Diverse payloads

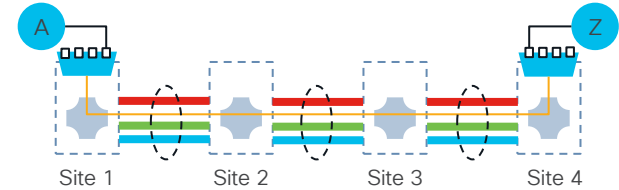
Wavelengths, TDM have been the Gold Standard



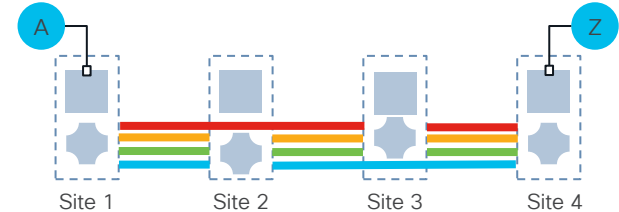
Point to point



ROADM



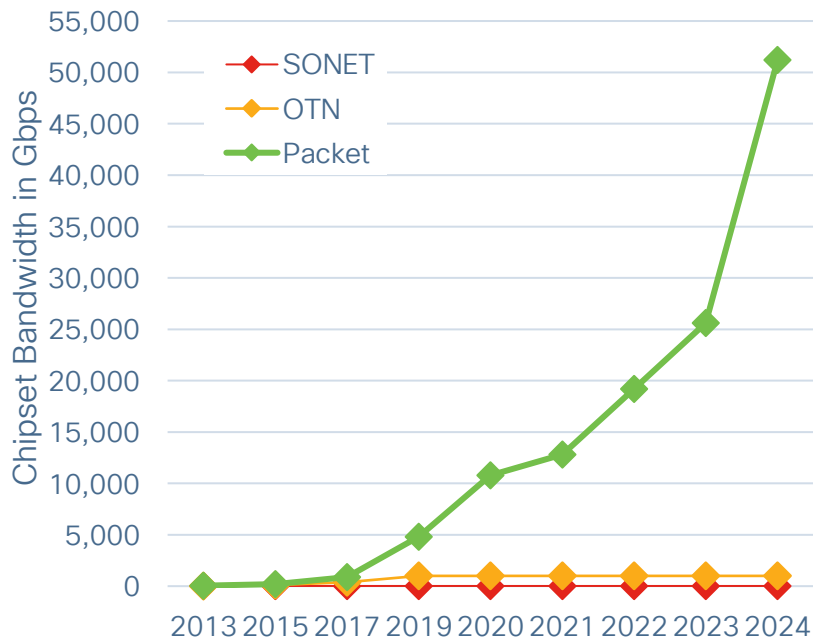
OTN



 Trans- or muxponder  ROADM  OTN switch

1 Massive Shifts in Economics of Routing

Advances in silicon



Coherent transceivers eliminate the need for DWDM transponders



No density penalty



interoperable

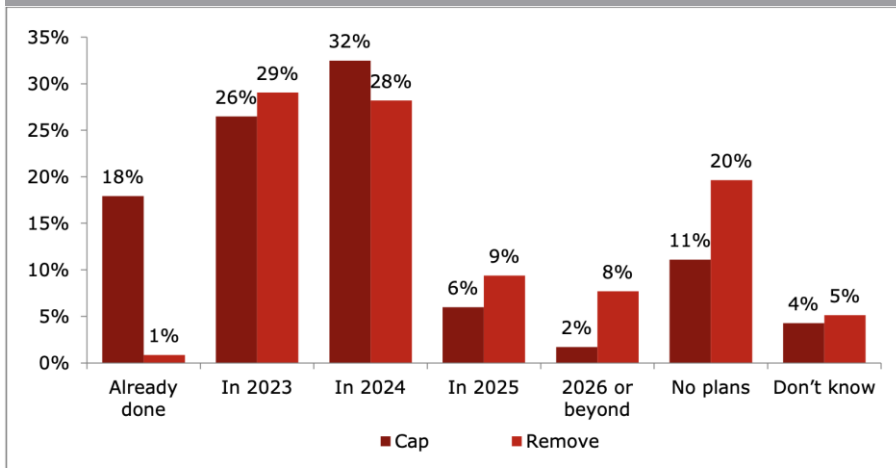


OpenZR+
MULTI-SOURCE AGREEMENT



2 OTN goes out of Fashion

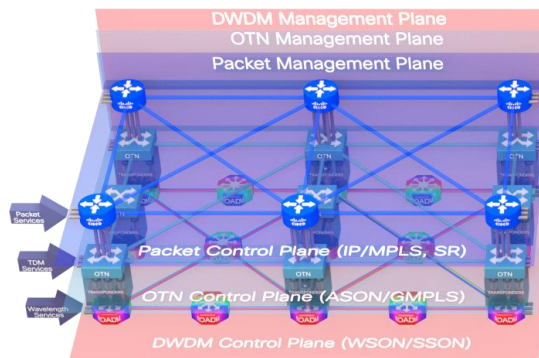
Plans for investment cap or removing OTN switching



n=117
Source: Heavy Reading

Full Heavy Reading report available on <https://www.infinera.com/white-paper/beyond-otn-core-switching/>

This led to Routed Optical Networking



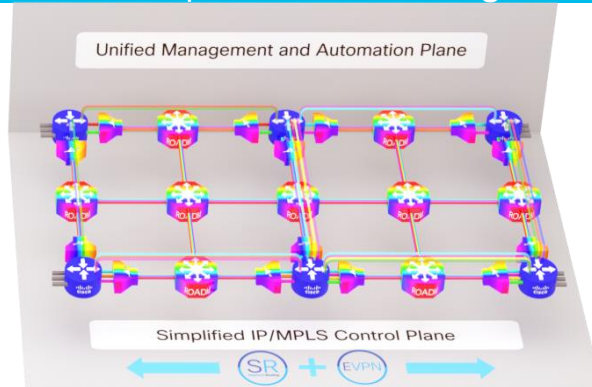
Today's network
Layered architecture

**Collapses 3 layers
into 1**

- A switching element
- Control plane
- Services layer

Single pane of glass

Internet for the Future Routed Optical Networking

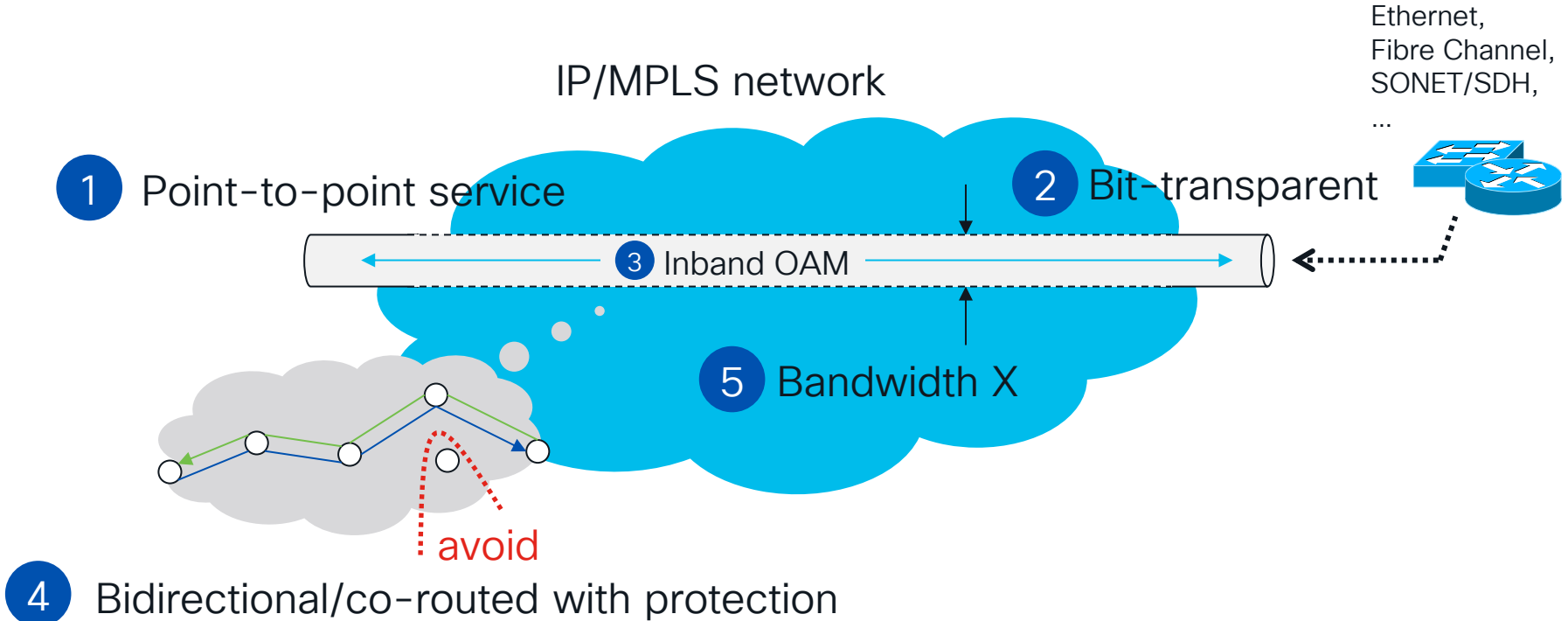


*Route when you can and
ROADM when you need to!*

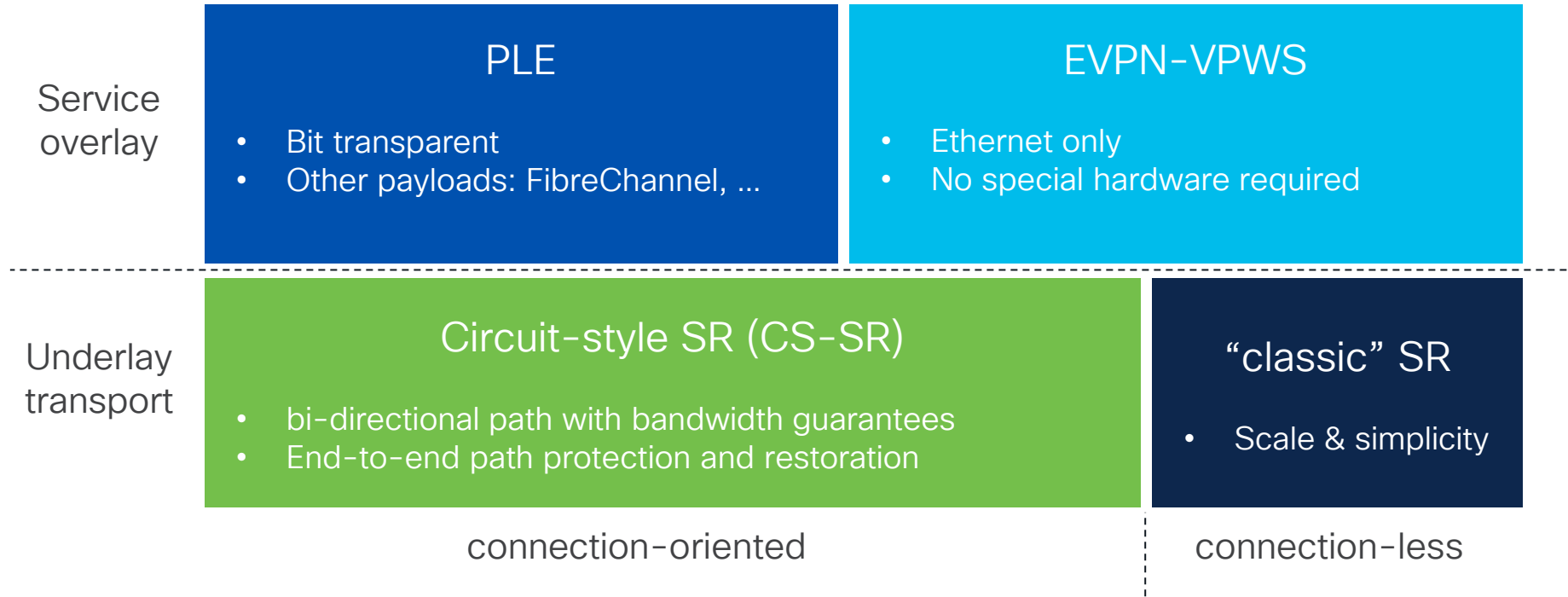
3 S' of RON :

Simplification, **S**avings and **S**ustainability

But how to deliver a "true" Circuit over Packet?



Enabling a “true Circuit” through the Packet Cloud



Bit-transparent, Point-to-point
& in-band OAM (PLE)

Private Line Emulation (PLE) = Bits over Packets

- Encapsulation of bit-stream into packets
- Extends the idea of RFC 4553 (SATOP)
 - beyond T1/E1
 - to Ethernet, Fibre Channel, OCn/STMn, anything

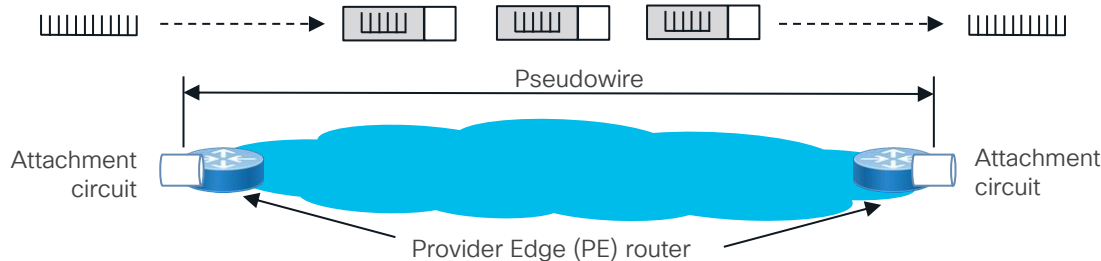
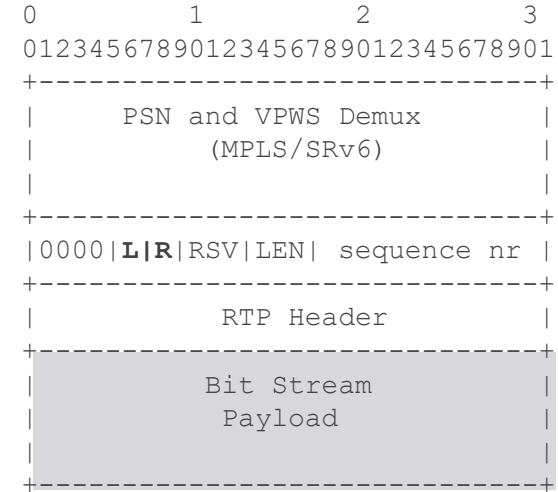
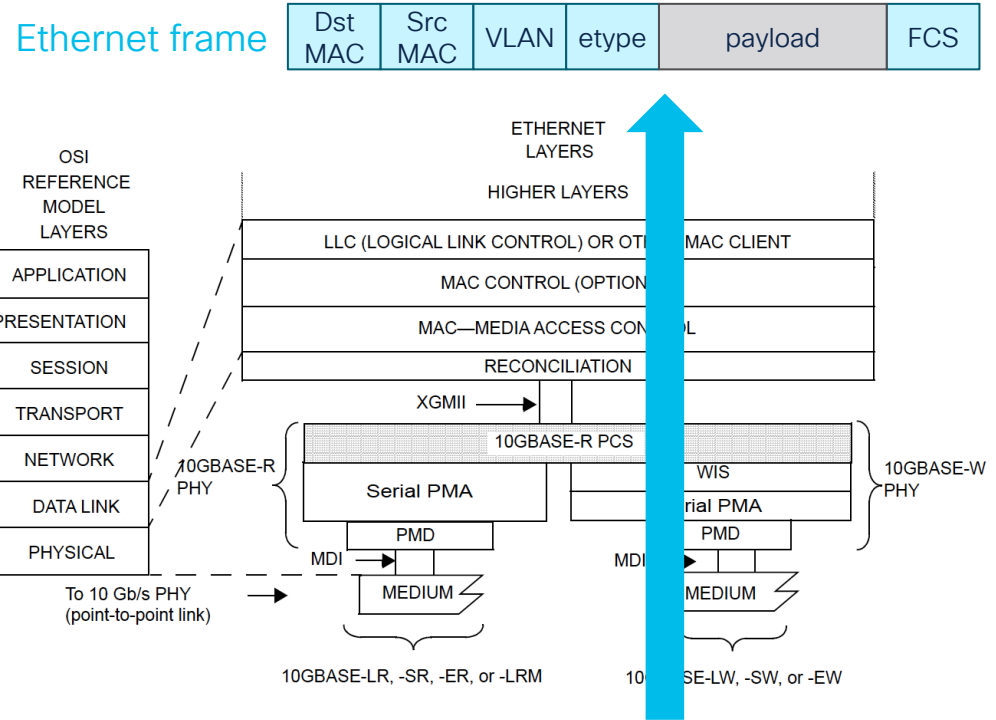


Figure 3: PLE Encapsulation Layer

Source: draft-ietf-pals-ple

Routers do look for Frames on an Ethernet Port

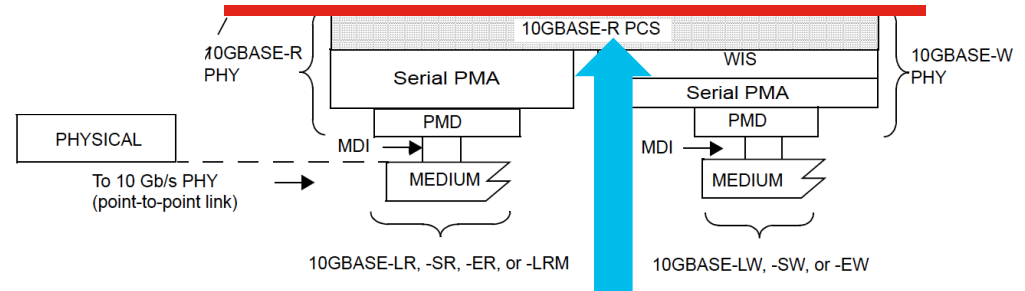
- Incoming bit stream is de-serialized
- Clock is recovered
- Align to PCS stream
 - 8B10B, 64B/66B or 256B/257B
- Identify MAC frames



Bits on the wire 0101010111010101

With PLE we stop processing at lowest level

- We just process bits
- We are unaware of ethernet frames and their boundaries
- We can carry what we want
- (However) we need special hardware to do that



Bits on the wire 0101010111010101

What can be carried by PLE

	SONET/SDH	OTN	Ethernet	Fibre Channel
1Gbps		ODU0	1GE	1GFC
	OC48/STM16	ODU1		2GFC
				4GFC
				8GFC
	OC192/STM64	ODU2/ODU2e	10GE	
				16GFC
			25GE	
				32GFC
			50GE	
				64GFC
		ODU4	100GE	
				128GFC
			200GE	
			400GE	
+100Gbps				

Standardization is well underway at



Workgroup: Network Working Group
Internet-Draft: draft-ietf-pals-ple-10
Published: 5 November 2024
Intended Status: Standards Track
Expires: 9 May 2025

S. Gringeri
Verizon
J. Whittaker
Verizon
N. Leymann
Deutsche Telekom
C. Schmutzer, Ed.
Cisco Systems, Inc.
C. Brown
Ciena Corporation

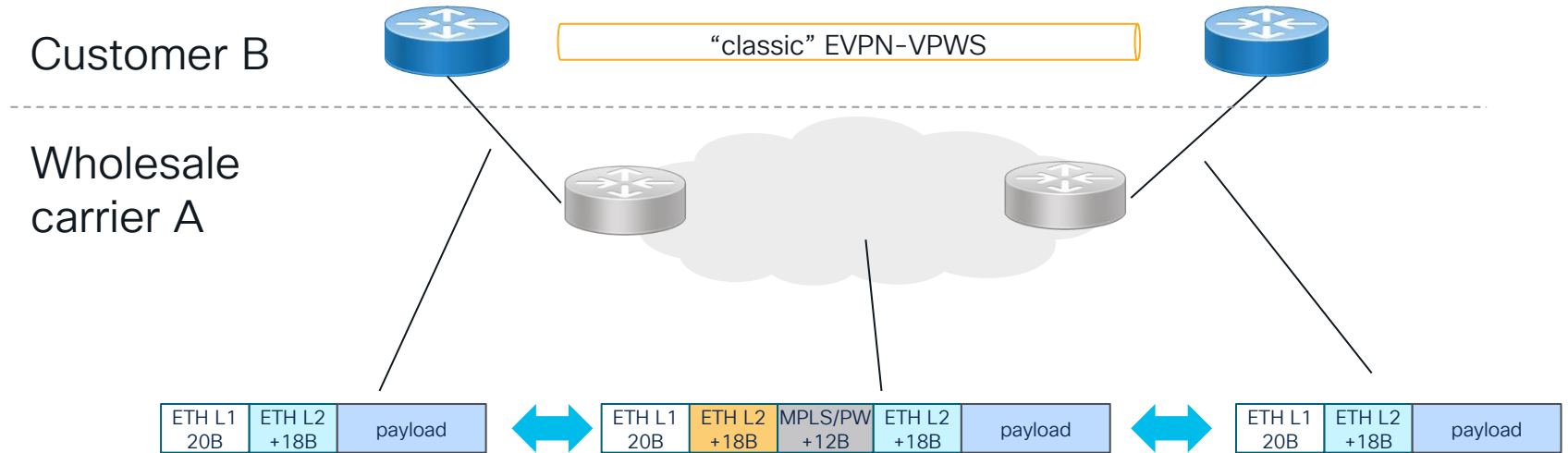
Private Line Emulation over Packet Switched Networks

Abstract

This document describes methods and requirements for implementing the encapsulation of high-speed bit-streams into virtual private wire services (VPWS) over packet switched networks (PSN) providing complete signal transport transparency.

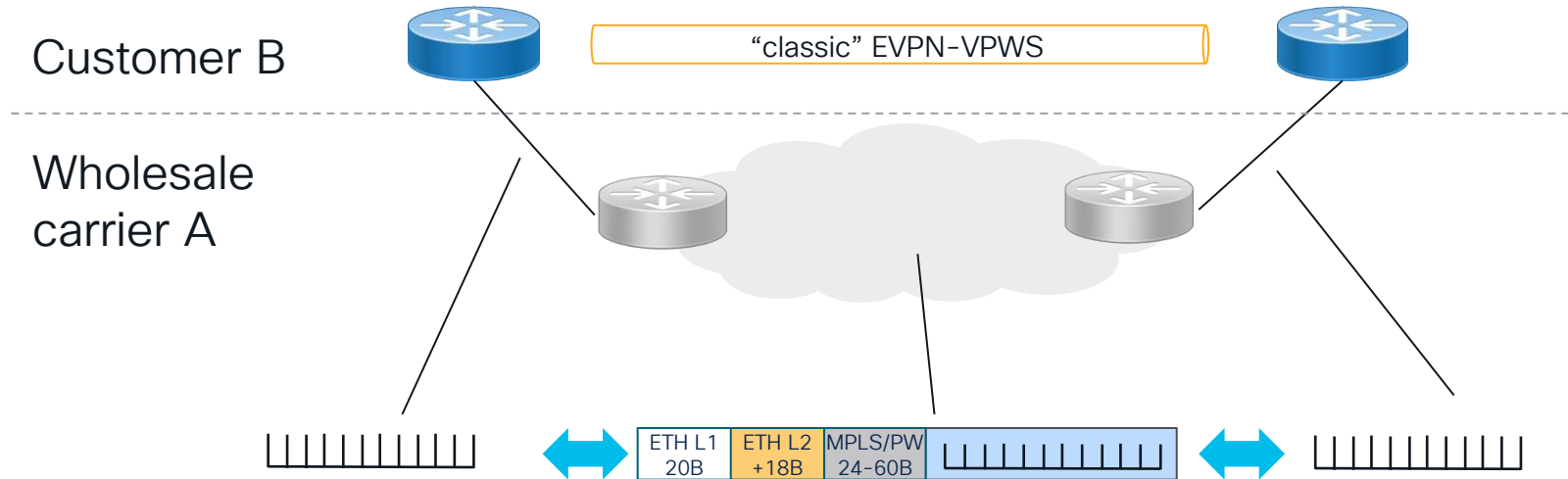
<https://datatracker.ietf.org/doc/html/draft-ietf-pals-ple>

Ethernet PW Overhead reduces Customer MTU



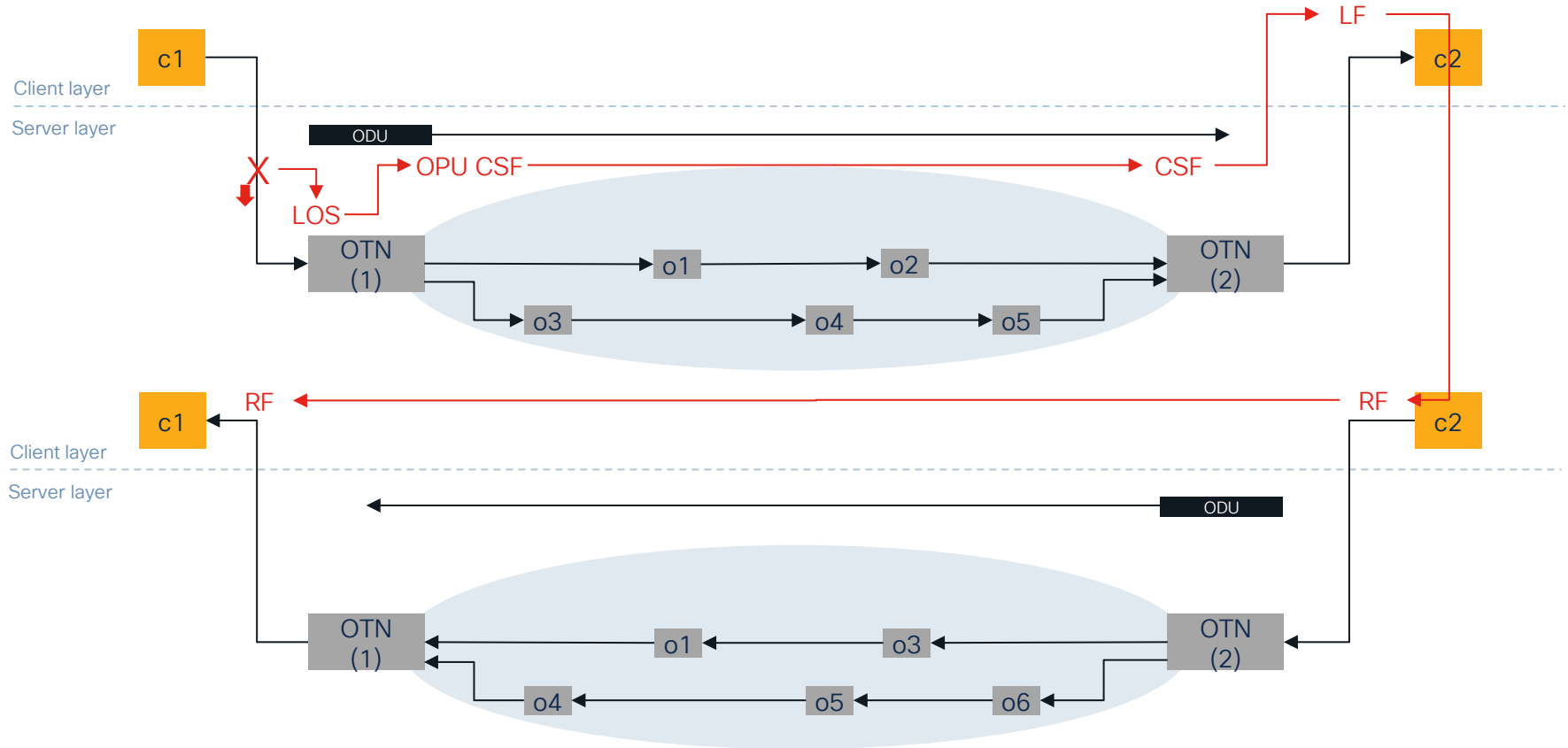
- For a carrier MTU of 9216B, customer MTU must be 9186B or less

PLE VPWS Overhead is just Overhead



- Customer MTU can still be 9216B (actually anything)
- Just ~10% more data is sent (less with PLE payload size >1024B)

What does OTN do in Case of a Client Failure?



OAM during Encapsulation (Ingress)

- Embedded OAM via PW control word
 - Client faults → L bit set
 - Rx pseudowire network fault → R bit set

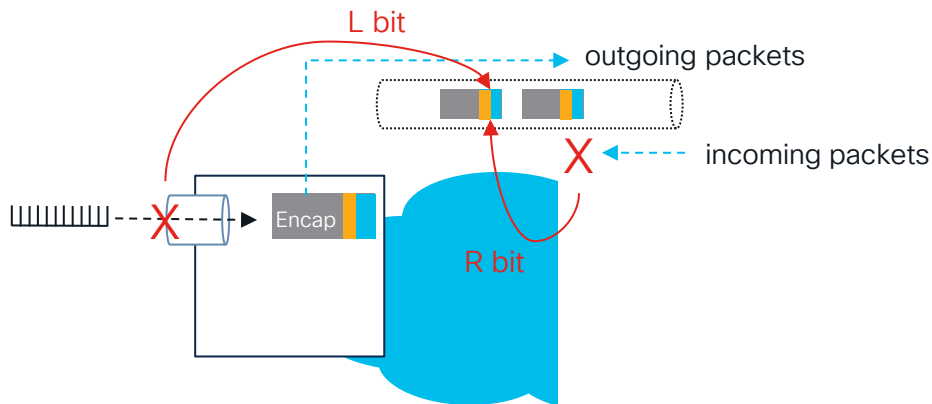
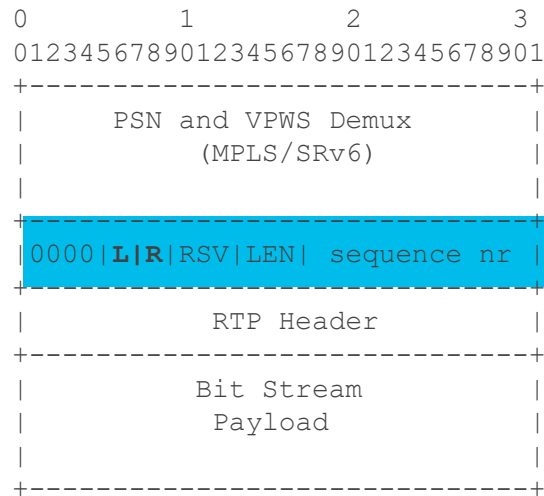
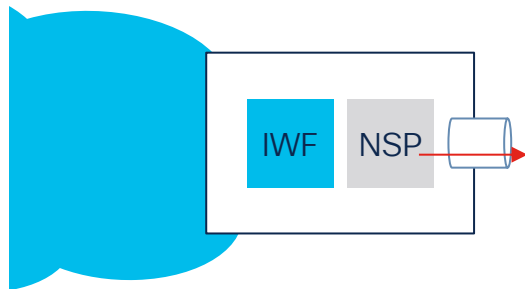
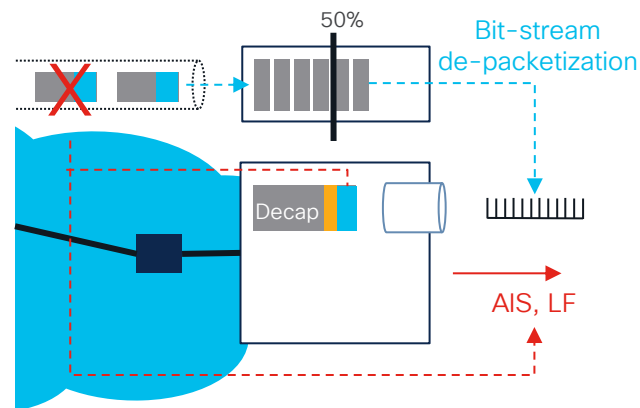


Figure 3: PLE Encapsulation Layer

Source: draft-ietf-pals-ple

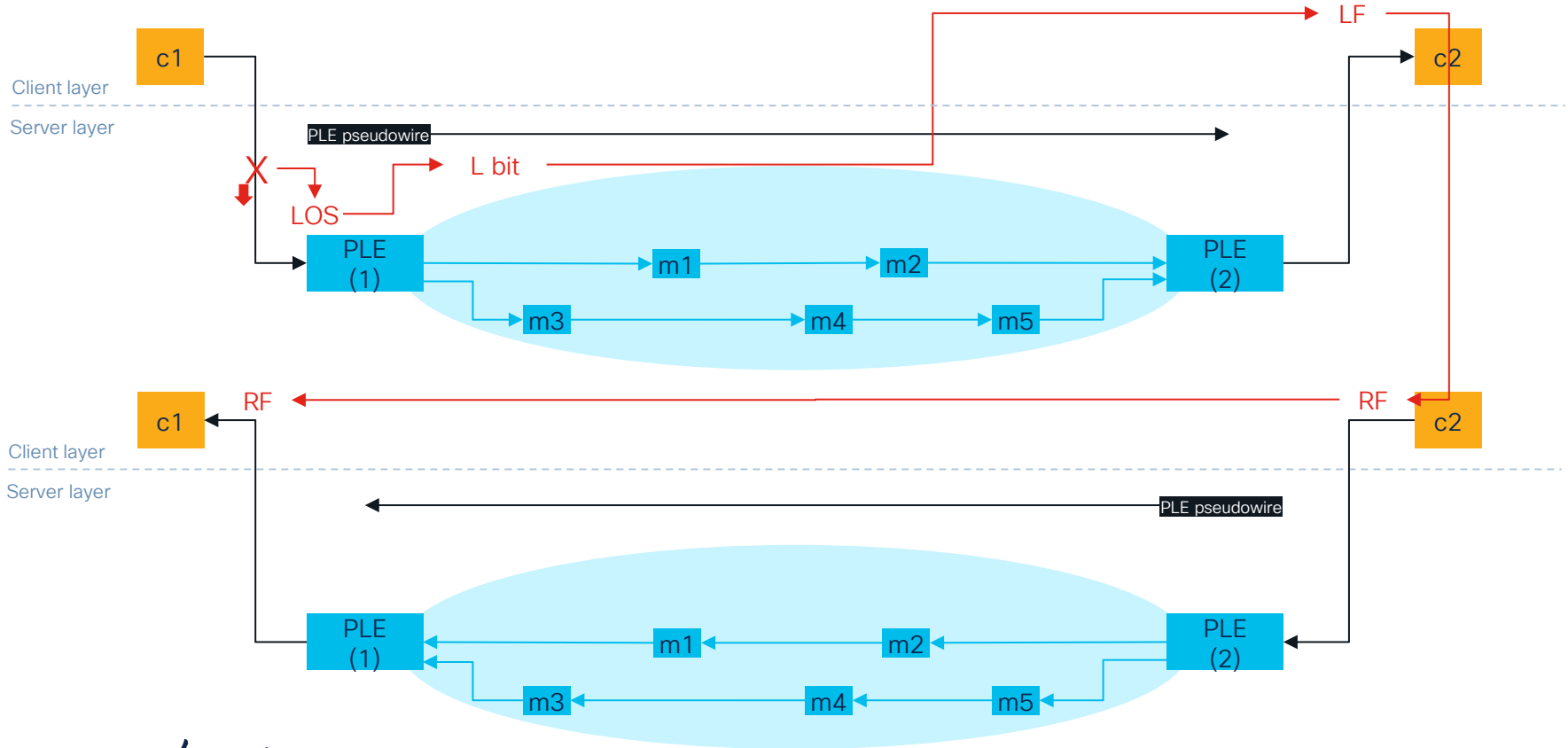
OAM during Decapsulation (Egress)

- Client fault indication
 - Too many packets lost
 - If L bit is set in PW Control word
 - Service specific by structure aware NSP
 - see section 4 of draft-ietf-pals-ple



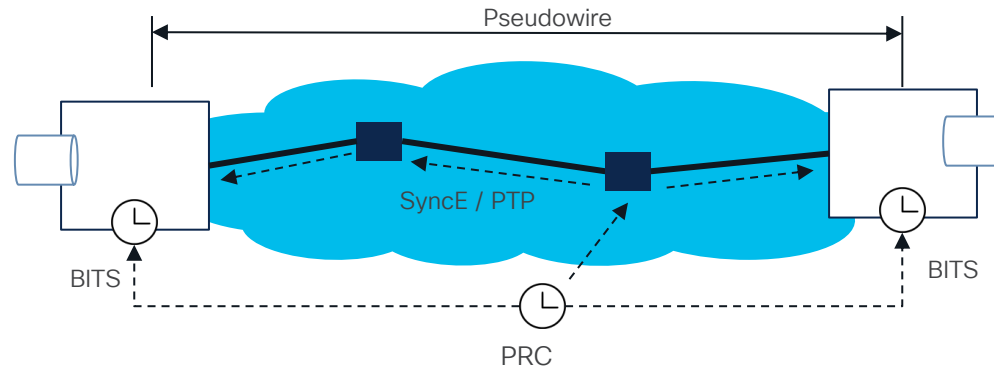
AIS ... Alarm Indication Signal
LF ... Local Fault
NSP ... Native Service Processing

PLE OAM for a Client Failure



The Foundation is a Common Clock

- The two PLE endpoint routers must have synchronous system clocks
- Can be achieved by SyncE or BITS (or PTP)



Indicating Client Clock to the Egress

- Insert RTP timestamps (counter)
- Counter frequency = common clock
- Counter values = how long it takes to fill a packet (depends on client clock)

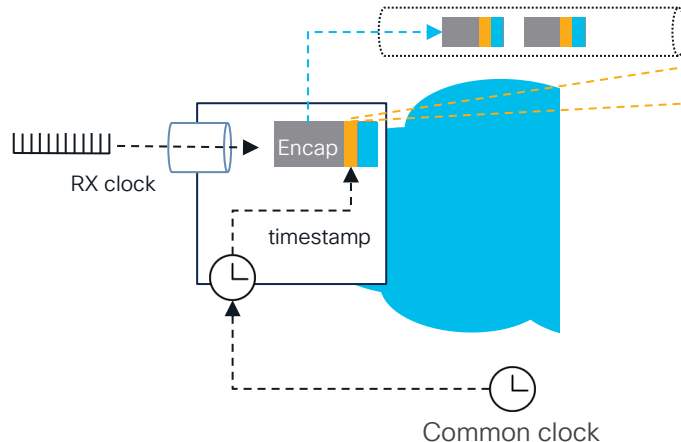
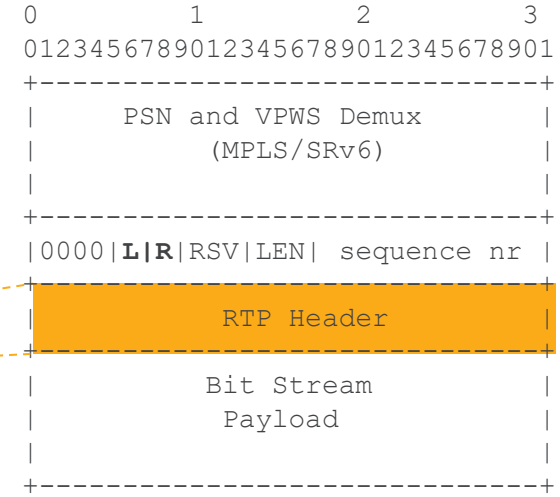


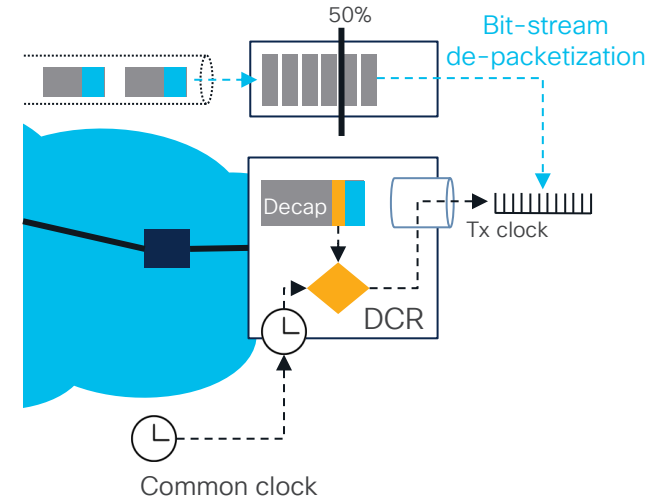
Figure 3: PLE Encapsulation Layer

Source: draft-ietf-pals-ple

PSN ... Packet Switched Network

Converting Packets back to Bits

- Differential clock recovery (DCR)
 - Leveraging RTP timestamps and the common clock
- Transmit PLE payloads
 - Using the recovered clock
- Store packets in a de-jitter buffer
 - Packet Delay Variation (PDV)
 - Packet reordering

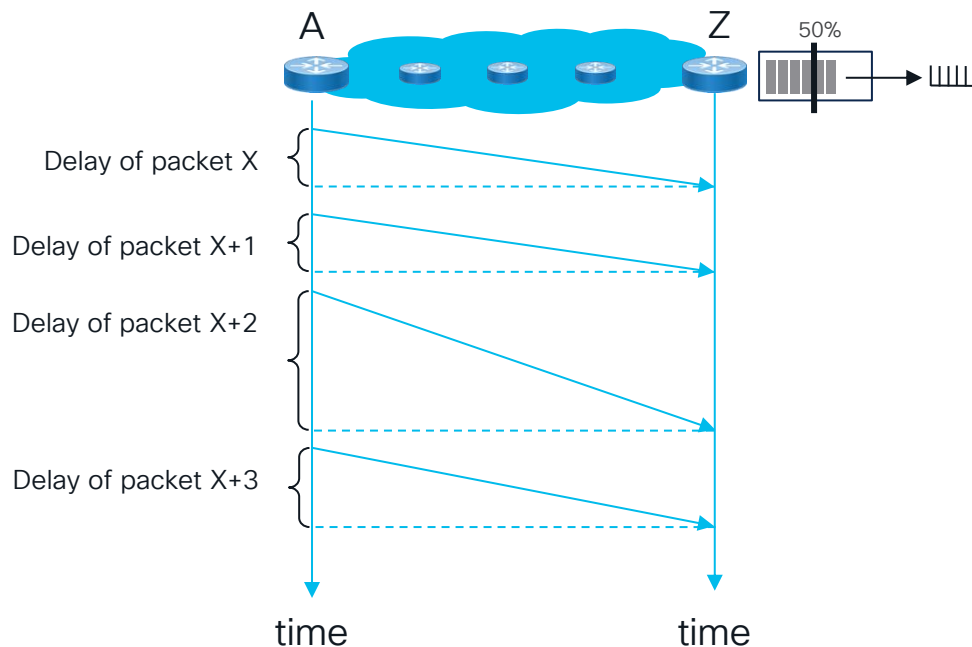


The Packet Network creates Jitter (variable Delay)

- Per router hop jitter $\pm 10 \mu\text{s}$
- Maximum 30 hops
- $30 * \pm 10 = \pm 300 \mu\text{s}$ PDV

Requires 100s of μs
of dejitter buffer !

Network Packet Delay Variation (PDV)





Configuring a PLE Pseudowire

- Define client interface

```
controller Optics0/0/2/2  
port-mode FC framing cem-packetize rate FC8
```

- Enable L2VPN on the emulation interface

```
interface CEM0/0/2/2  
l2transport
```

- Configure EVPN-VPWS

```
l2vpn  
xconnect group PLE  
p2p ple_fc8  
interface CEM0/0/2/2  
neighbor evpn evi 103 target 16022 source 11022  
pw-class unprotected_circuit
```

```
pw-class unprotected_circuit  
encapsulation mpls  
preferred-path sr-te policy srte_c_1_ep_1.0.0.6
```



See later slides

Verifying PLE OAM Statistics

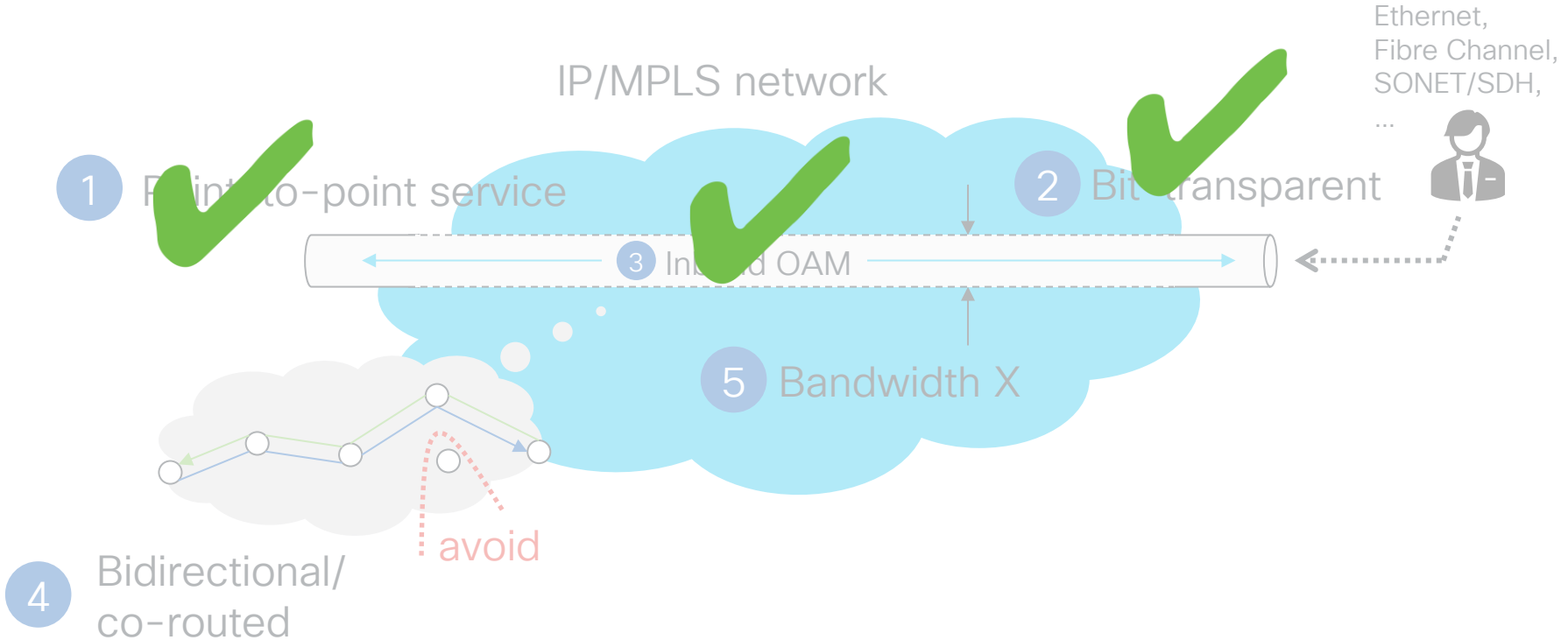
```
RP/0/RP0/CPU0:peyto#show controllers cem 0/0/2/2
.
.
.
Detected Alarms                : None

Statistics Info
-----
Ingress packets                : 569295050, Ingress packets drop      : 0
Egress packets                 : 409658267, Egress packets drop      : 0
Total error                    : 0
    Missing packets            : 0, Malformed packets                : 0
    Jitter buffer underrun     : 0, Jitter buffer overrun           : 0
    Misorder drops             : 0
Reordered packets              : 0, Frames fragmented                : 0
Error seconds                  : 0, Severely error seconds           : 0
Unavailable seconds            : 0, Failure counts                  : 0

Generated L bits                : 409658183, Received L bits         : 409658267
Generated R bits                : 0, Received R bits                : 2541
```

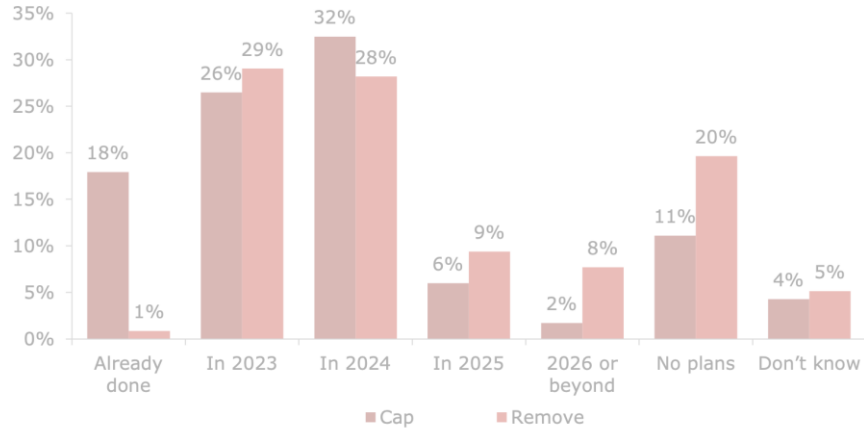
We also have “ITU-style”
Performance Monitoring

But how to deliver a "true" Circuit over Packet?



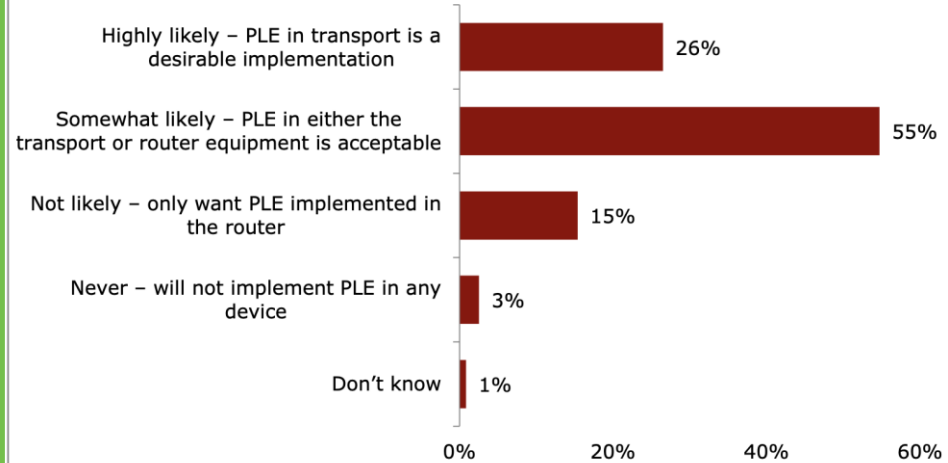
PLE is discussed Publicly as a Viable Solution !

Plans for investment cap or removing OTN switching



n=117
Source: Heavy Reading

Considering PLE deployment

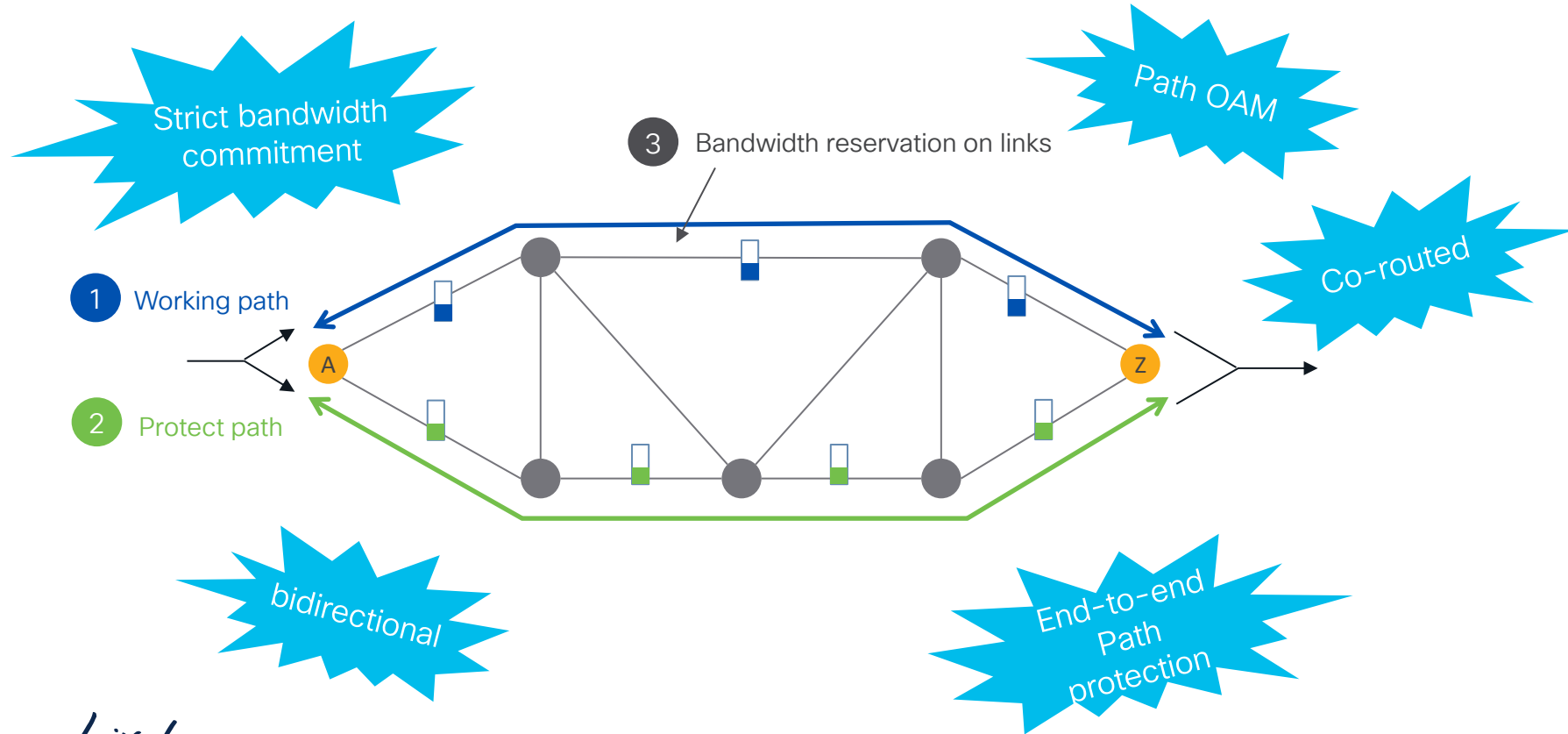


n=117
Source: Heavy Reading

Full Heavy Reading report available on <https://www.infinera.com/white-paper/beyond-otn-core-switching/>

Co-routed, bidirectional Paths & Dedicated Bandwidth (CS-SR)

Premium Transport for Premium Services



Circuit-Style Segment Routing (CS-SR)

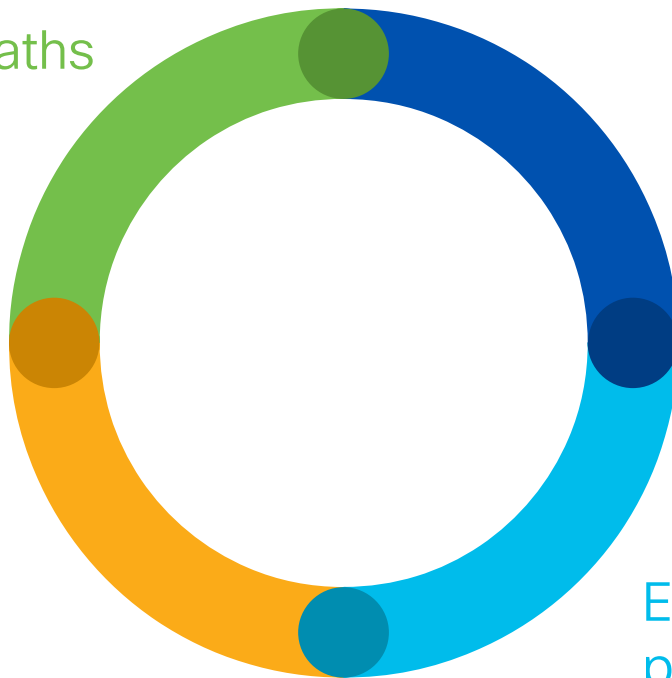
Traffic engineered paths

- bidirectional
- co-routed
- persistent

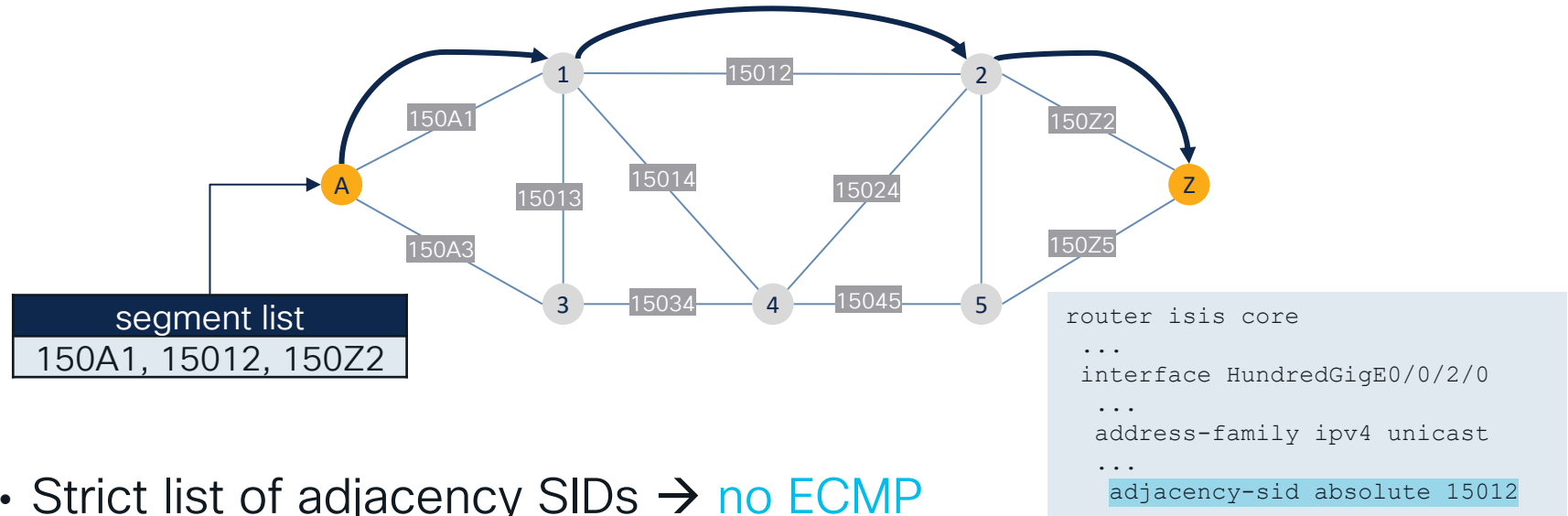
Bandwidth
management

Path OAM

End-to-end path
protection & restoration

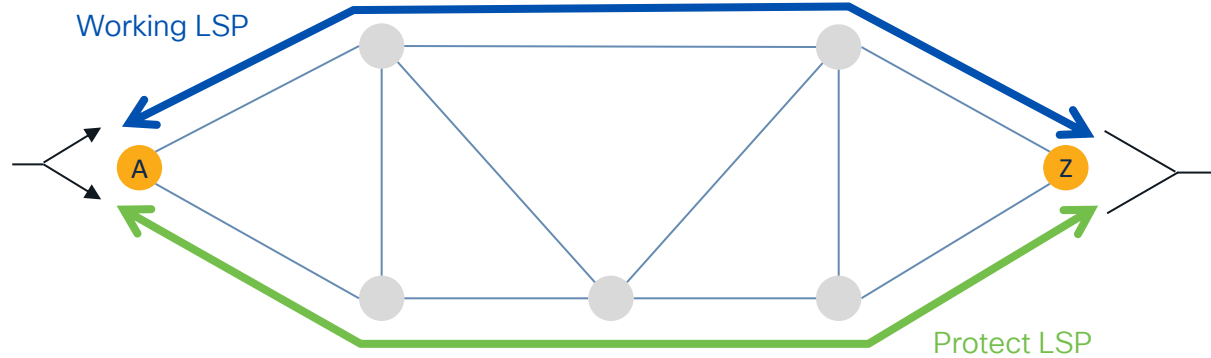
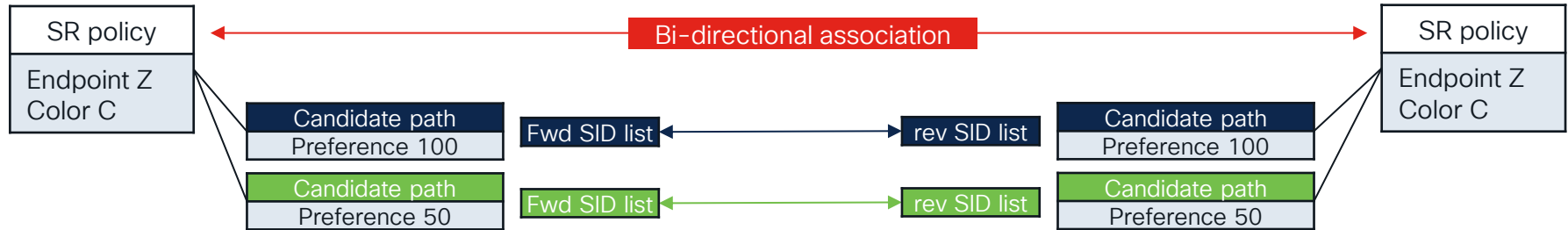


Deterministic and persistent SR paths



- Strict list of adjacency SIDs → no ECMP
- Manual adjacency SIDs → persistent across node reloads
- Unprotected adjacency SIDs → no traffic rerouting due to TI-LFA

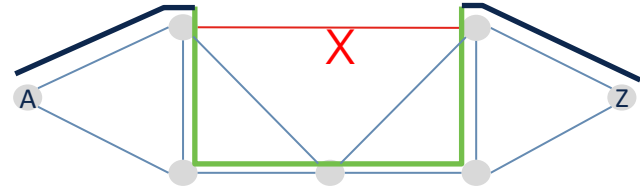
Path protected, co-routed, bi-directional SR policy



Why do protection schemes matter?

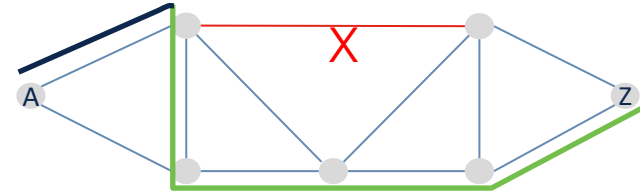
MPLS-TE FRR

Local bypass protection, **without bandwidth allocated**



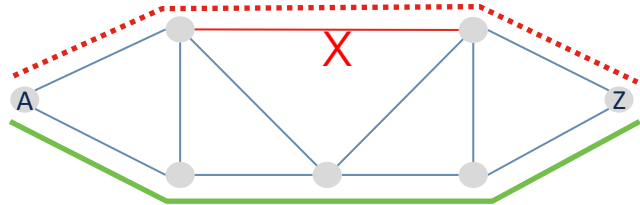
Loop Free Alternate (LFA)

Post convergence path, **without bandwidth allocated**



Path Protection

pre-allocated bandwidth end2end



Only with path protection you know “a priori” that there won’t be congestion

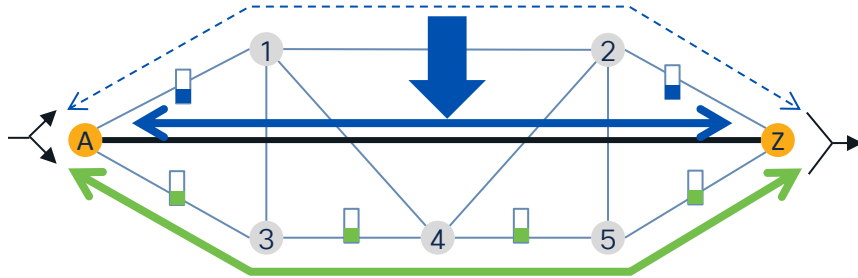
Persistency – ignore newly added Resources

Classic TE behavior



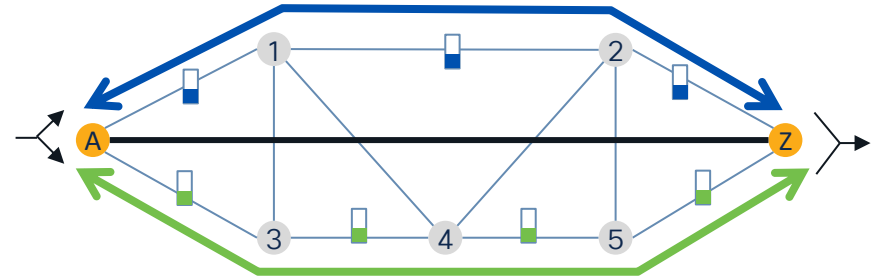
Transport expectation

1' NEW Working LSP



2 Protect LSP

1 Working LSP (stays where it was)



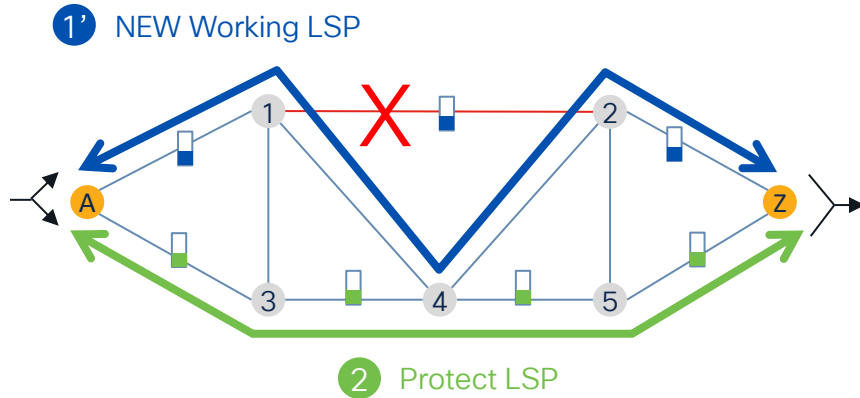
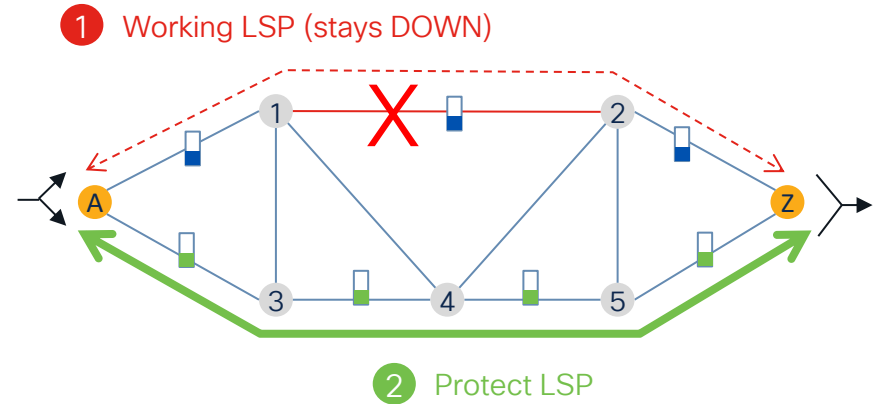
2 Protect LSP

Persistency – don't adjust to failed Resources

Classic TE behavior



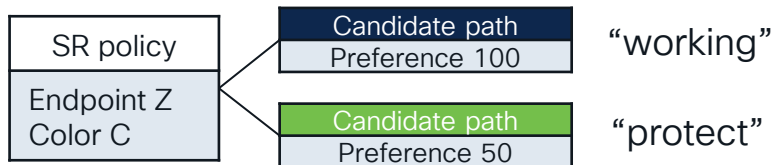
Transport expectation



Configuring a “static” CS-SR Policy

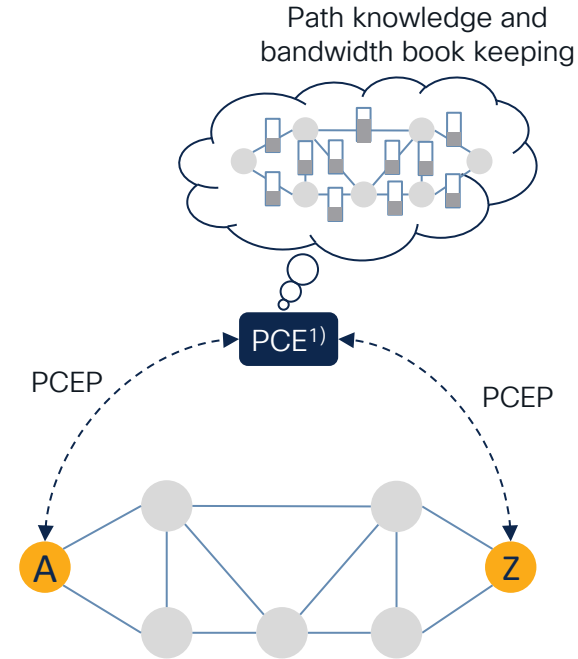
```
segment-routing
traffic-eng
policy protected_manual
color 2 end-point ipv4 1.0.0.6
path-protection
!
candidate-paths
preference 50
explicit segment-list via_three_eight
reverse-path segment-list via_eight_three
!
preference 100
explicit segment-list via_two_four
reverse-path segment-list via_four_two
```

```
segment-list via_four_two
index 10 mpls label 15004
index 20 mpls label 15002
index 30 mpls label 15001
!
segment-list via_two_four
index 10 mpls label 15002
index 20 mpls label 15004
index 30 mpls label 15006
!
segment-list via_eight_three
index 10 mpls label 15008
index 20 mpls label 15003
index 30 mpls label 15001
!
segment-list via_three_eight
index 10 mpls label 15003
index 20 mpls label 15008
index 30 mpls label 15006
```



Finding Suitable Paths in an Automated Way

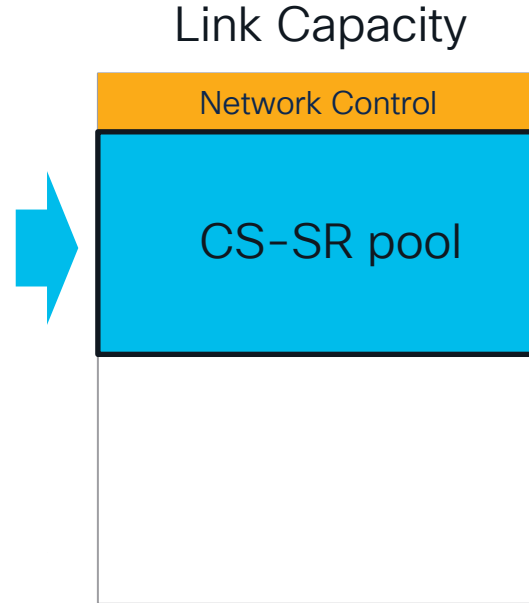
- A **SR policy** is configured **on both endpoints**
- Each endpoint requests a path via PCEP from a central PCE (PCC init)
 - Common bi-directional **association**
 - Required **bandwidth**
 - Path **constraints**
- The central PCE maintains a real time view of
 - The network **topology** (**BGP-LS**)
 - All **path**/bandwidth requests (**PCEP**)



1) Cisco Crosswork Optimization Engine (COE)

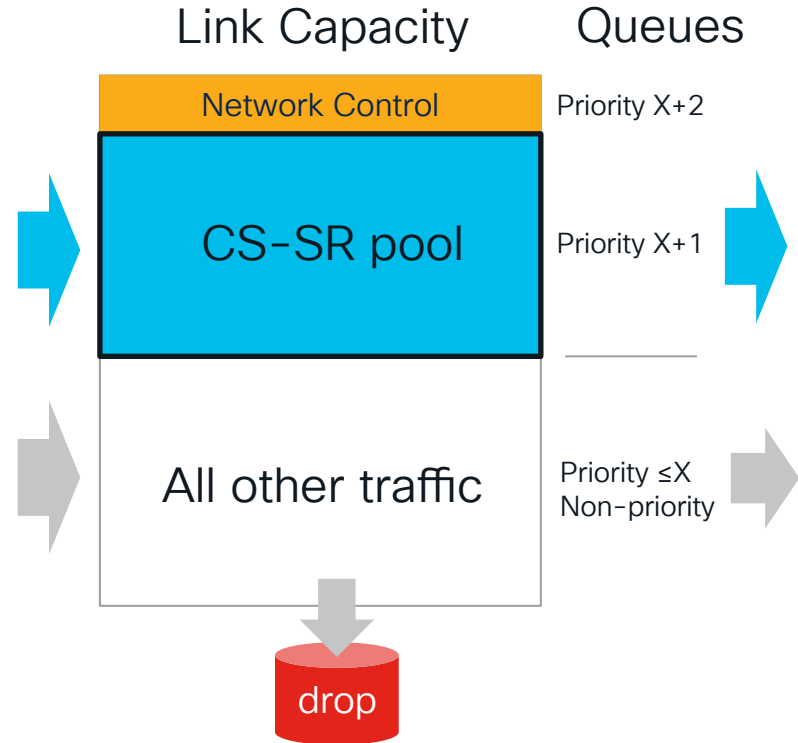
How to manage Bandwidth?

- Two simple rules
 1. Traffic of CS-SR is limited (policed) to requested bandwidth
 2. During congestion only other traffic is dropped, not CS-SR
- To adhere to 2)
 - Don't commit what you don't have

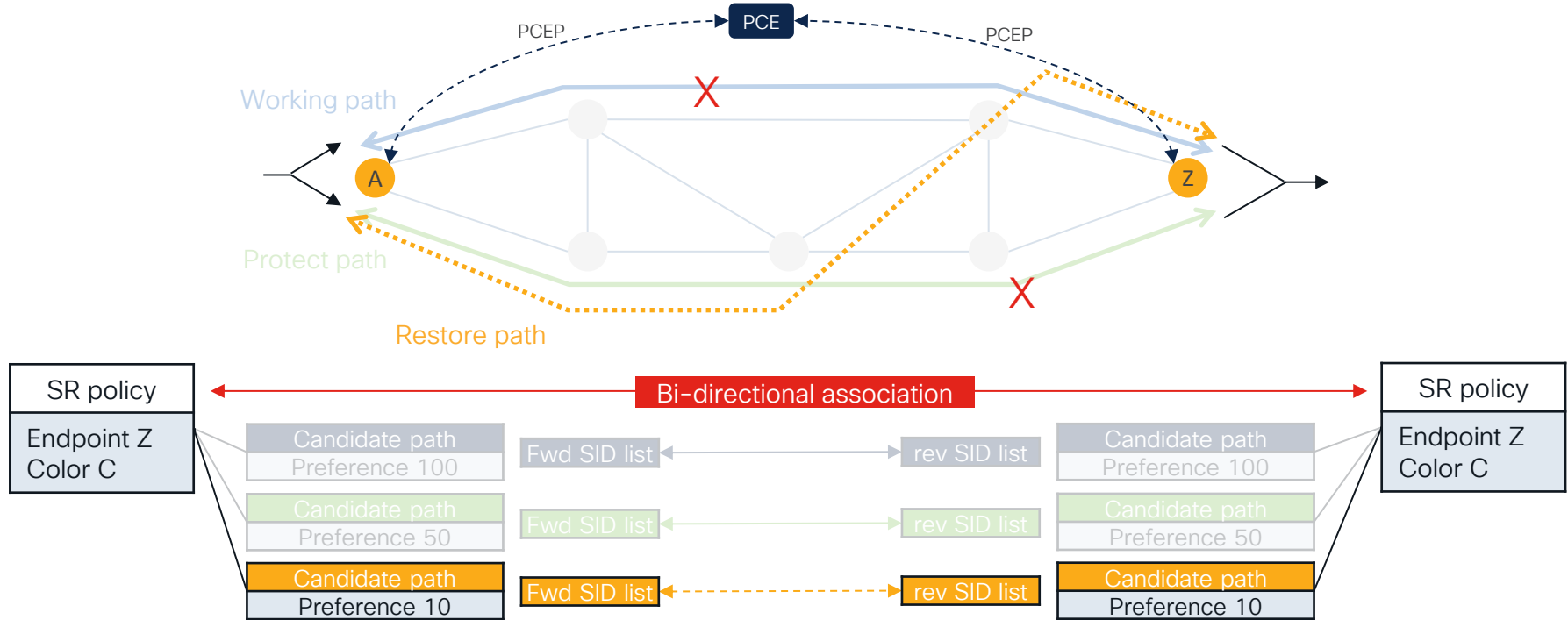


How to manage Bandwidth?

- Two simple rules
 1. Traffic of CS-SR is limited (policed) to requested bandwidth
 2. During congestion only other traffic is dropped, not CS-SR
- To adhere to 2)
 - Don't commit what you don't have
 - Treat CS-SR at highest data priority



CS-SR, Dynamic Recovery from Double Failures



Configuring a “dynamic” CS-SR Policy

```
segment-routing
traffic-eng
policy protected_dynamic
bandwidth 8000000
color 3 end-point ipv4 1.0.0.6
path-protection
!
candidate-paths
preference 100
dynamic
pcep
!
metric
type latency
!
!
constraints
segments
protection unprotected-only
adjacency-sid-only
!
disjoint-path group-id 16 type link
!
bidirectional
co-routed
association-id 10
```

```
preference 50
dynamic
pcep
!
metric
type latency
!
!
lock
duration 60
!
constraints
segments
protection unprotected-only
adjacency-sid-only
!
disjoint-path group-id 16 type link
!
bidirectional
co-routed
association-id 11
!
!
```

```
preference 10
dynamic
pcep
!
metric
type igp
!
!
lock
duration 60
!
backup-ineligible
!
constraints
segments
protection unprotected-only
adjacency-sid-only
!
!
bidirectional
co-routed
association-id 12
```

CISCO *Live!*



For more see [draft-ietf-spring-stamp-srpm](#)

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- Bidirectional Liveness and performance measurement via a single protocol (STAMP)
- Loopback probes with exact reverse path encoded providing bidirectional detection

Enabling Candidate Path Liveness

```
performance-measurement
liveness-profile name cs_protect
liveness-detection
  multiplier 3
!
probe
  tx-interval 100000
!
!
liveness-profile name cs_working
liveness-detection
  multiplier 3
!
probe
  tx-interval 3300
!
npu-offload
  enable
```

```
segment-routing
traffic-eng
  policy protected_manual
  ...
  performance-measurement
  liveness-detection
    liveness-profile backup name cs_protect
    liveness-profile name cs_working
```

Standardization is also well underway at



Workgroup: Network Working Group
Internet-Draft:
draft-ietf-spring-cs-sr-policy-03
Published: 18 October 2024
Intended Status: Informational
Expires: 21 April 2025

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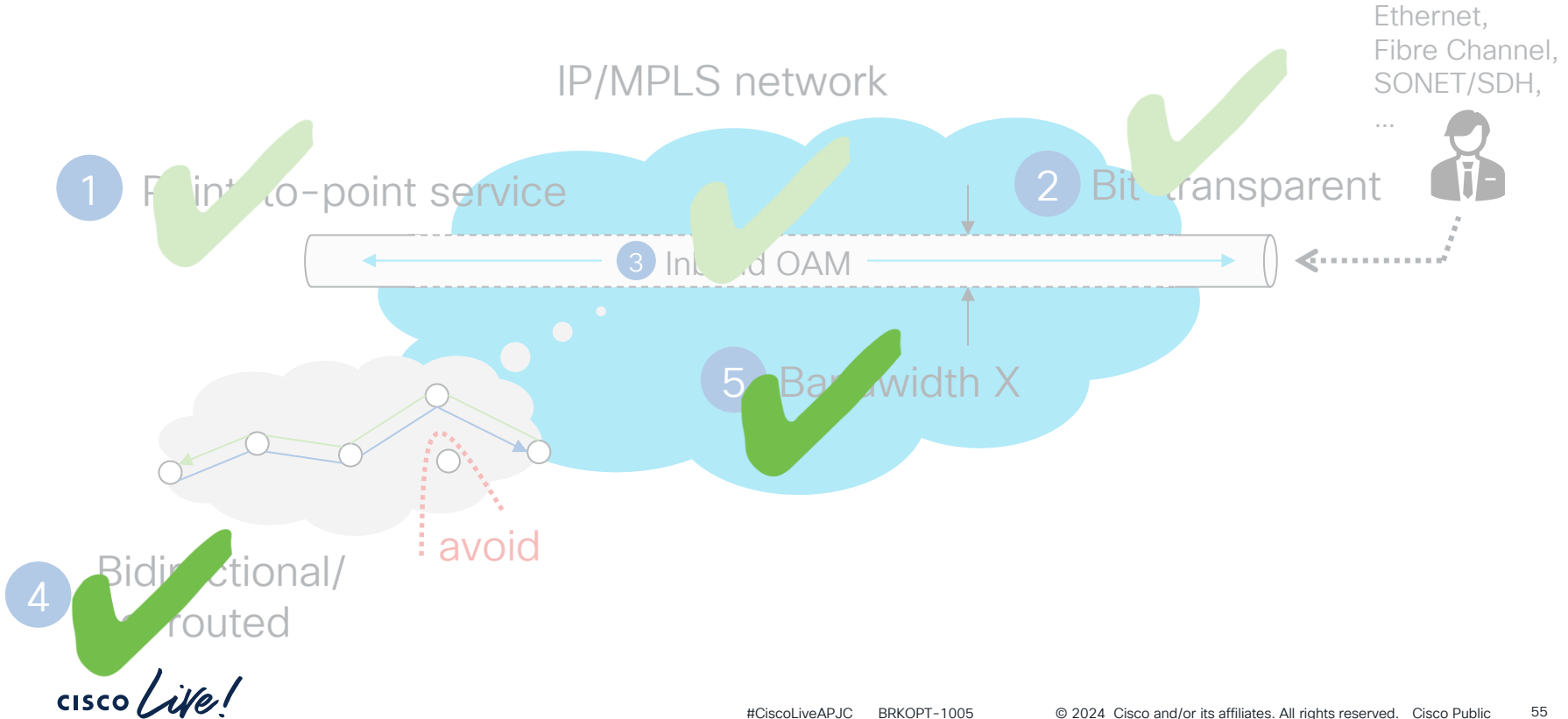
Circuit Style Segment Routing Policies

Abstract

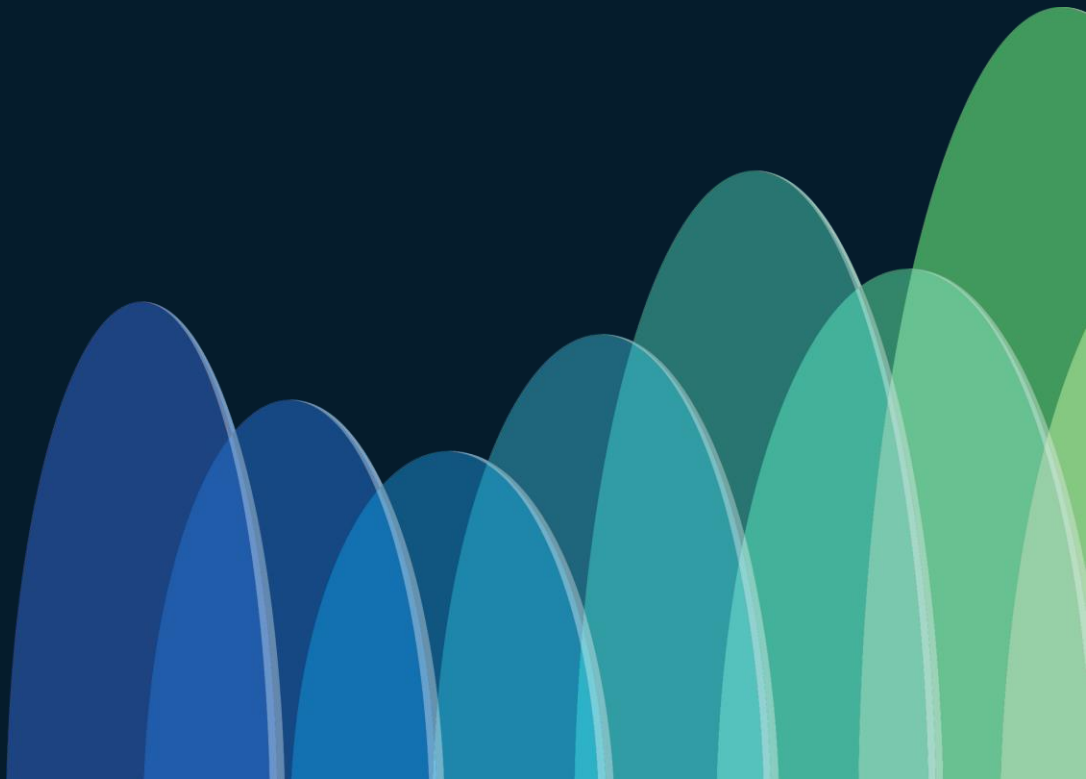
This document describes how Segment Routing (SR) policies can be used to satisfy the requirements for bandwidth, end-to-end recovery and persistent paths within a segment routing network. SR policies satisfying these requirements are called "circuit-style" SR policies (CS-SR policies).

<https://datatracker.ietf.org/doc/html/draft-ietf-spring-cs-sr-policy>

But how to deliver a "true" Circuit over Packet?



Wrapping up ...



PLE is real since XR 7.7.1 (July 2022) !

- Supported client types
 - 1GE, 10GE
 - OC48/STM16, OC192/STM64
 - Fibre channel (1, 2, 4, 8 ,10 ,16 and 32G)
 - OTU2, OTU2e
- Any mix of client types supported
- Supported in NCS-55A2 (peyto) and NCS-57C3 (Eryie)



NC55-OIP-02

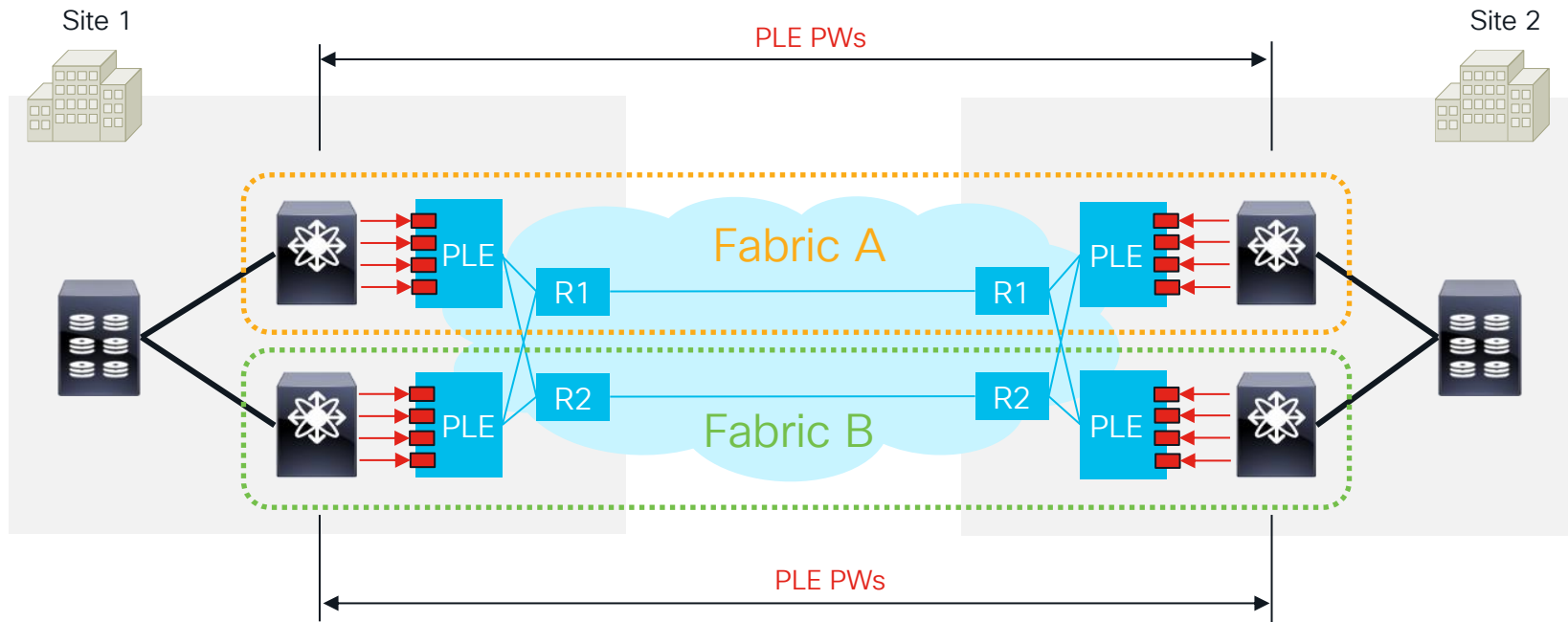


NCS-55A2



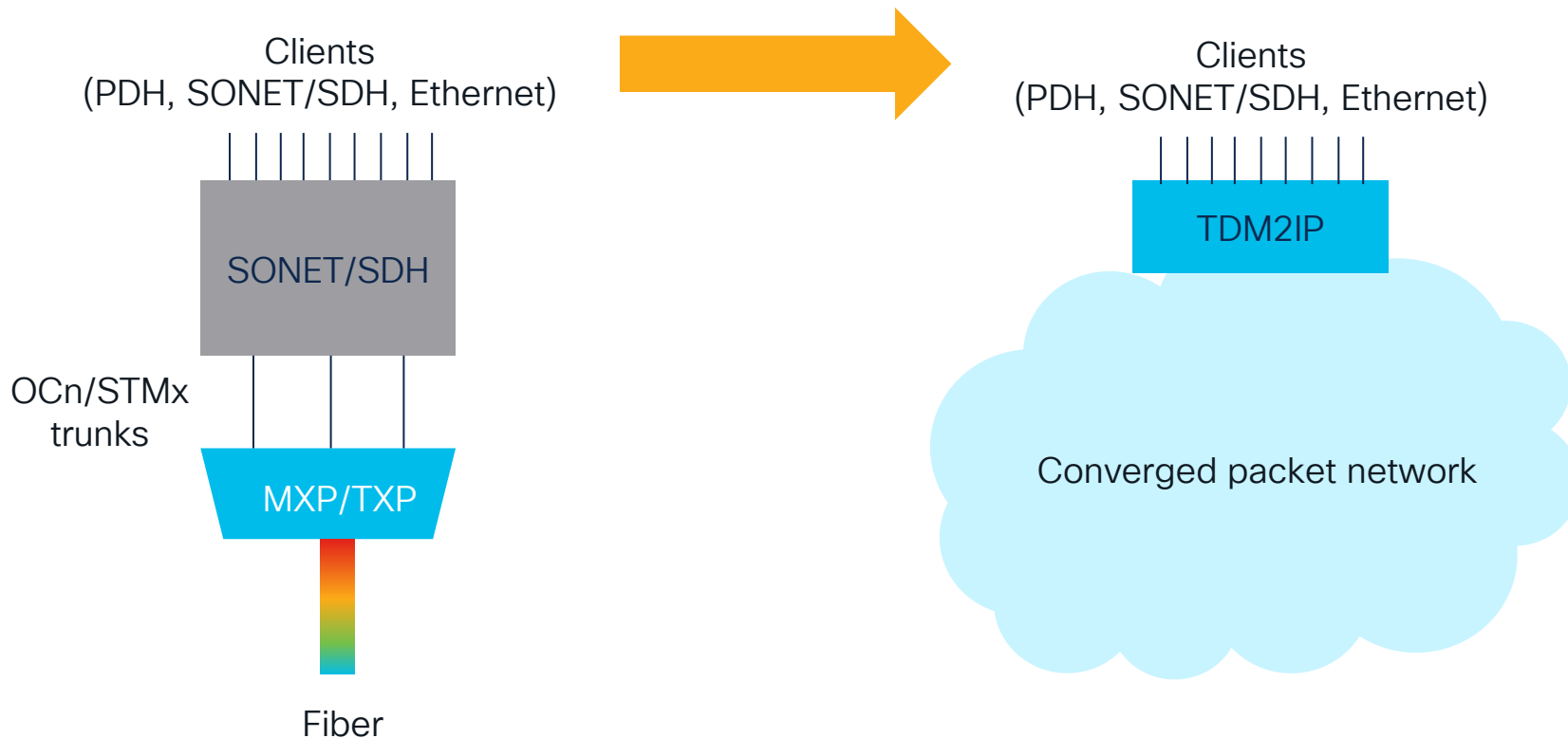
NCS-57C3

Applying PLE to Storage Area Networks (SANs)

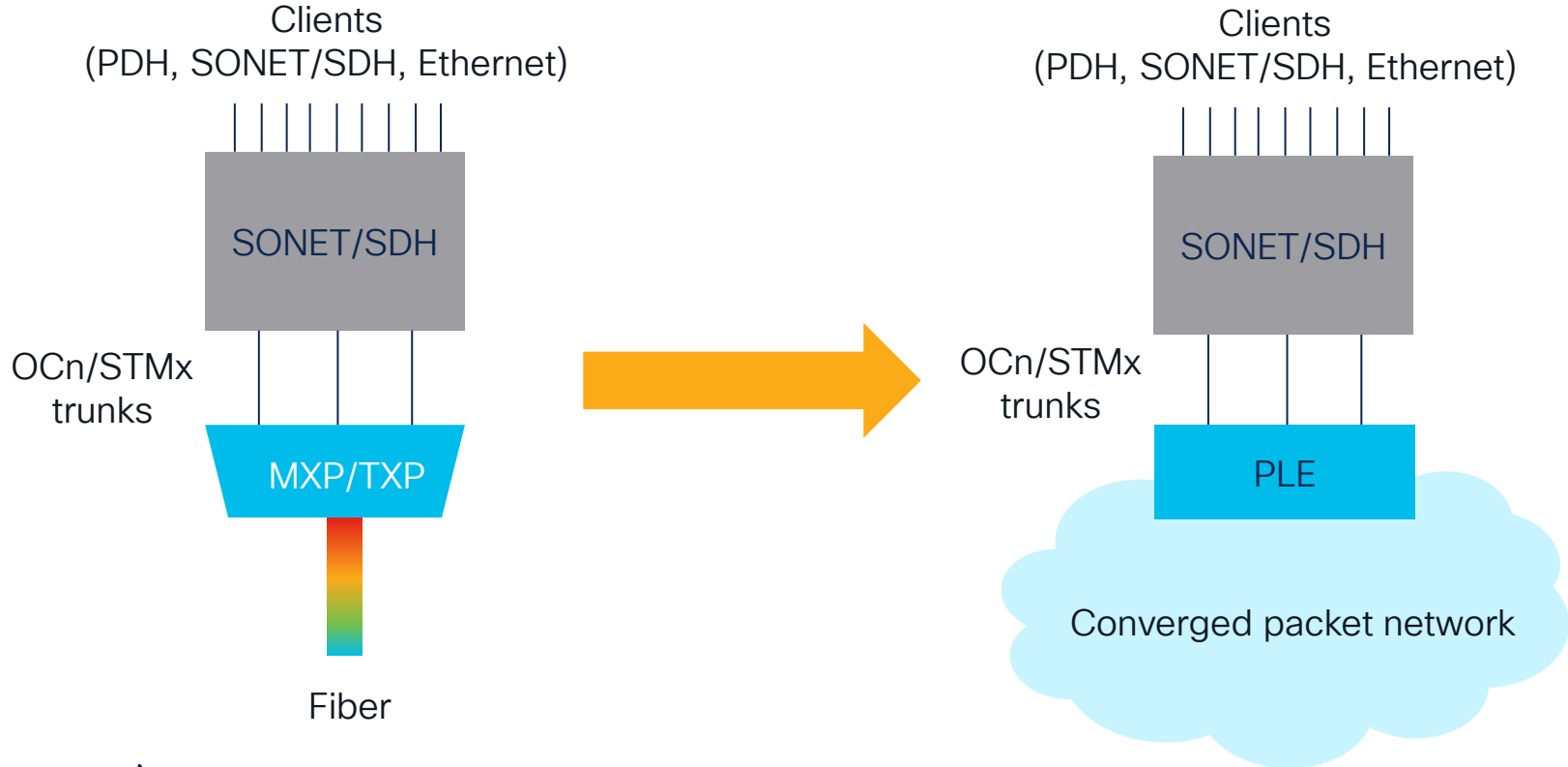


Customer deployments with Storage vendor certification via RPQ

Emulate TDM to replace it (aka TDM2IP)



PLE doesn't replace TDM, but legacy DWDM



CS-SR PCE since CNC5.0

 Crosswork Network Controller

Home

Topology

Network Automation

Performance Alerts

Services & Traffic Engineering

Device Management

Alerts

Administration

Services & Traffic Engineering / VPN Services

Last Refresh: 03-Jun-2023 02:57:09 PM

Show VPN Services

Device Groups Location

Saved Views Select a saved view Save View

Show: ☐ Participating Only ☐ IGP Path ☒ Bi-Dir Path

Circuit Style Policy Details

Current History

Admin State Up

Oper State Up

Binding SID 24054

Policy Type Circuit-Style

Profile ID -

Description -

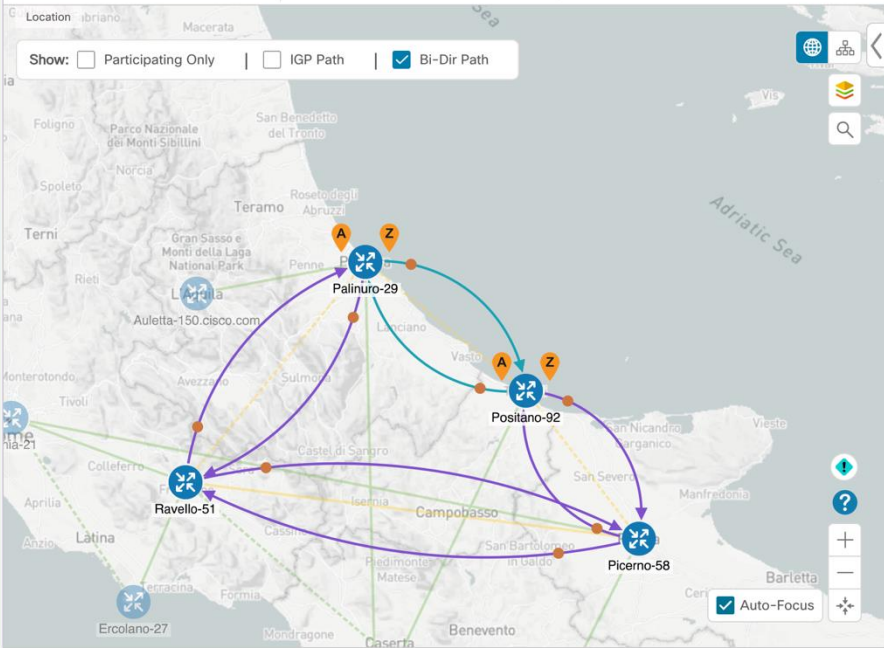
Traffic Rate 9747.47 Mbps

Unused False

See more

Candidate Path

Path Name	Pref	State
☒ > cfg_srte_c_501_ep_29.29.29.29...	100	Up A
☒ > cfg_srte_c_501_ep_29.29.29.29...	50	Up

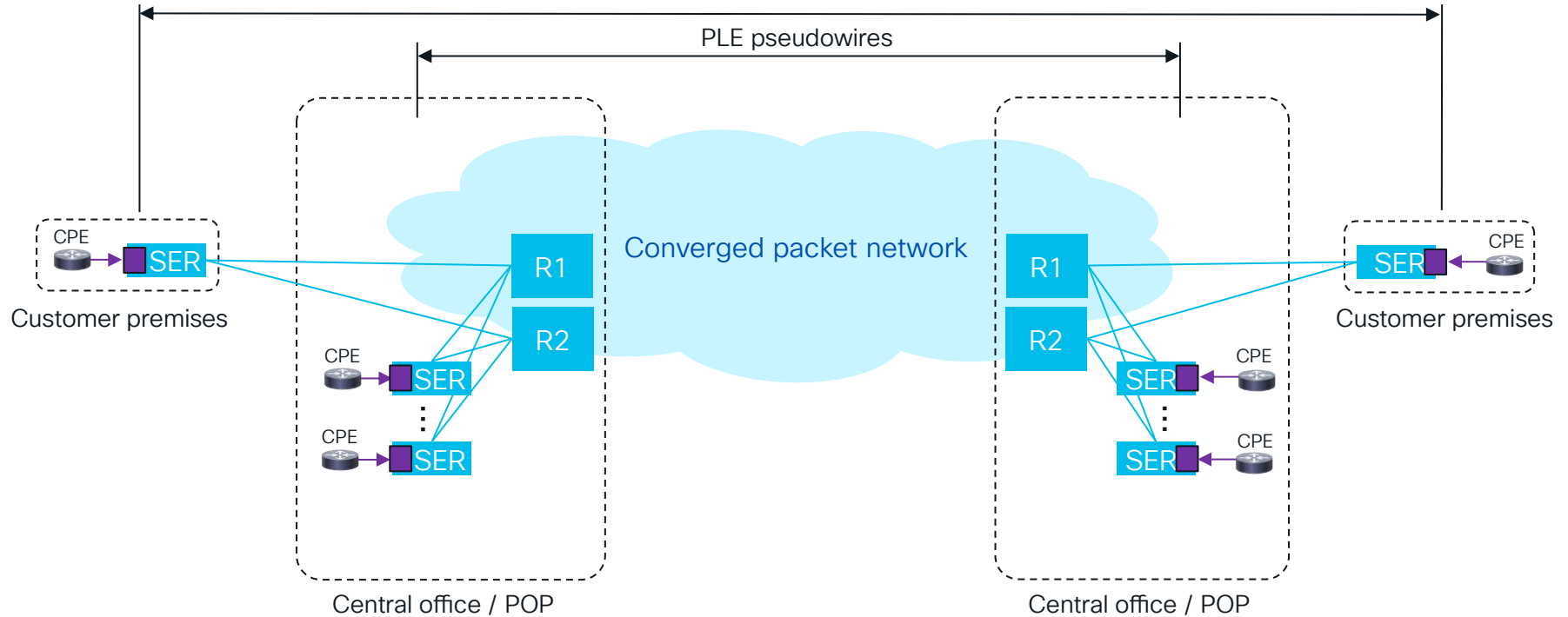


Cisco 8011 PLE SER – In Trials / Limited Availability



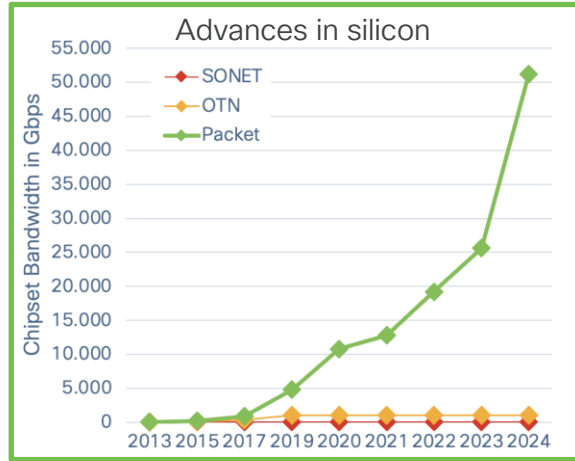
- 1RU system optimized for customer premise deployment
- 2x PLE client ports (same client types as MPA)
- 2x native ethernet client ports
- 4x 10/25/50GE uplink ports
- Redundant, replaceable AC or DC power supplies

PLE in Service Provider Networks

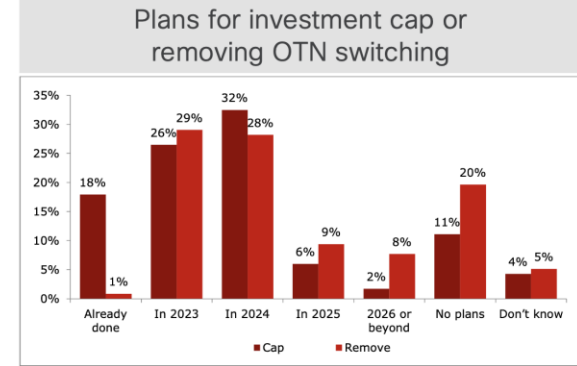


Key take aways

Things are changing !



Time for
something
new !



n=117
Source: Heavy Reading



CS-SR ... providing a new Transport Behavior

Service
overlay

EVPN-VPWS

- Ethernet only
- No special hardware required

Underlay
transport

Circuit-style SR (CS-SR)

- bi-directional path with bandwidth guarantees
- End-to-end path protection and restoration

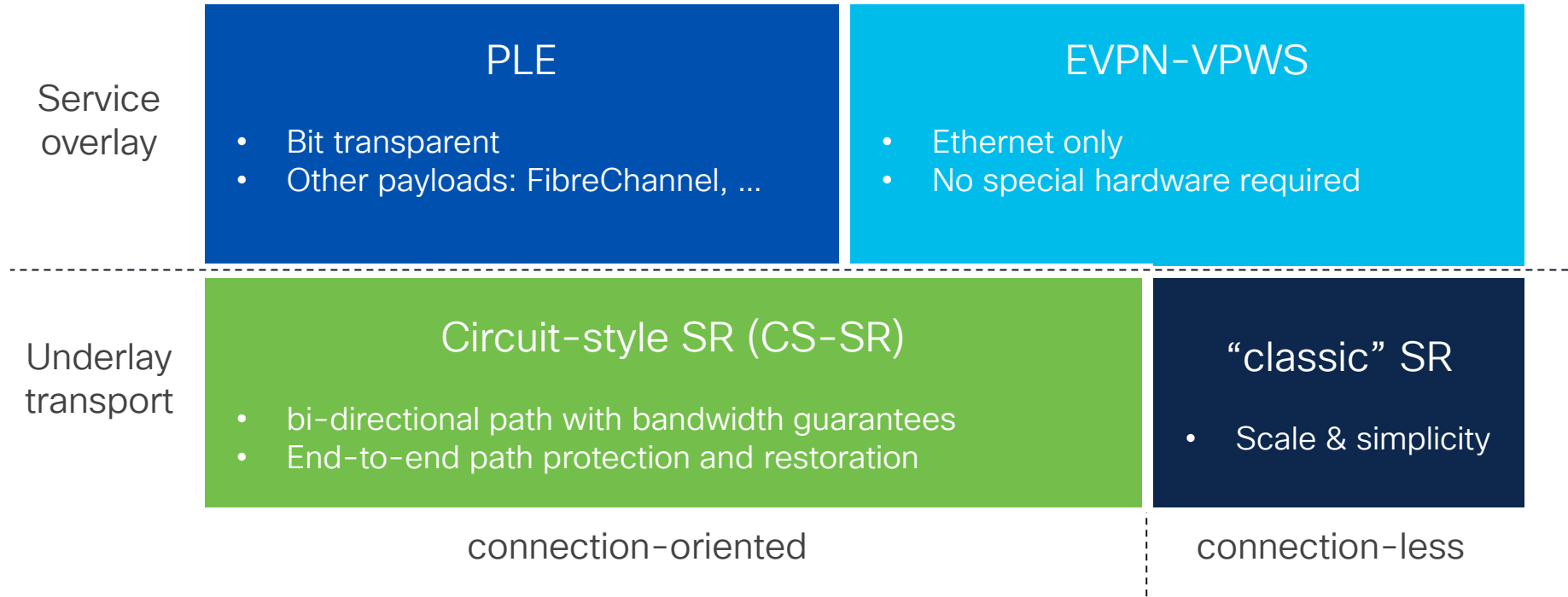
“classic” SR

- Scale & simplicity

connection-oriented

connection-less

... and PLE completing the Service Portfolio



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Thank you

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