Let's go

The bridge to possible

Understanding Cloud-Ready Converged Transport

5G Advanced & Beyond Network Evolution

Waris Sagheer, CTO Routing Architecture, Cisco Systems Inc.

BRKSPG-2782

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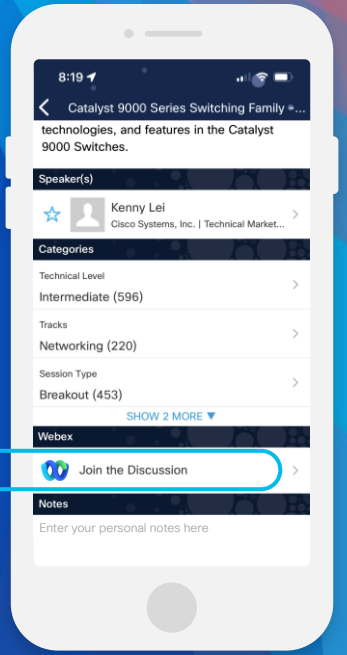

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Agenda

- State of 5G MNO
- 5G MNO Strategic and Network Priorities
- SP Network Architecture Transformation
- SP & Hyperscalers Partnership
- Cisco 5G Cloud-Ready Transport solution
- DISH Wireless, USA case study
- Conclusion

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Glossary

O-RU - Radio Unit aka RRH, TRP

O-DU - Distributed Unit

O-CU - Centralized Unit

FEDC - Far Edge Data Center

EDC - Edge Data Center

RDC - Regional Data center

UPF - Packet core user plane function

CRAN - Centralized RAN or Cloud RAN

CP - Control Plane

CSR - Cell Site Router

5G SA - 5G Stand Alone

FH - Fronthaul

AAV - Alternate Access Vendor aka Backhaul provider

LDC - Local Data center

vRAN - virtual Radio access network

MNO - mobile network operator

CSP - communication service provider

UPFv - User Plane Function for Voice

UPFd - User Plane Function for data

Mgmt. - Management & Orchestration

CNF - Cloud-Native Network Function

GD plane - Generalized data plane

OTT - over-the-top

D2D- Direct to Device

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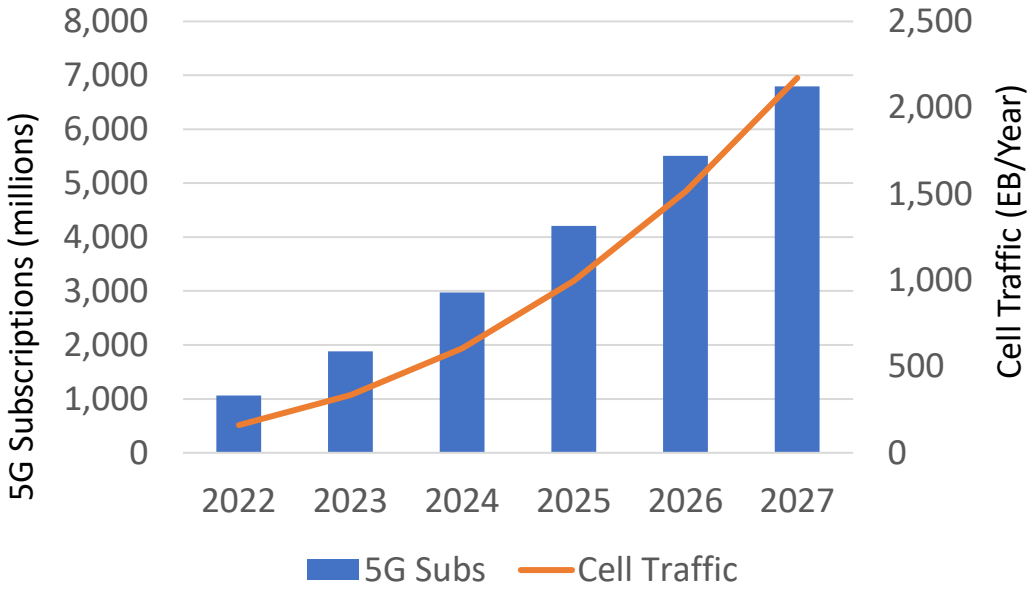
Explosive Growth in Mobility Driven by 5G and Edge

Global 5G Subscriptions and Cellular Data Traffic Forecasts, 2022–2027



- 5G growth metrics:
  - Forecasted subscriptions: 45% CAGR
  - Forecasted data traffic: 68% CAGR
- Edge cloud strategies tightly coupled with 5G plans

Sources: Omdia Mobile Subscriptions and Revenue Forecast, July 2023 and Omdia Cellular Data Traffic Forecast, July 2023
LightReading

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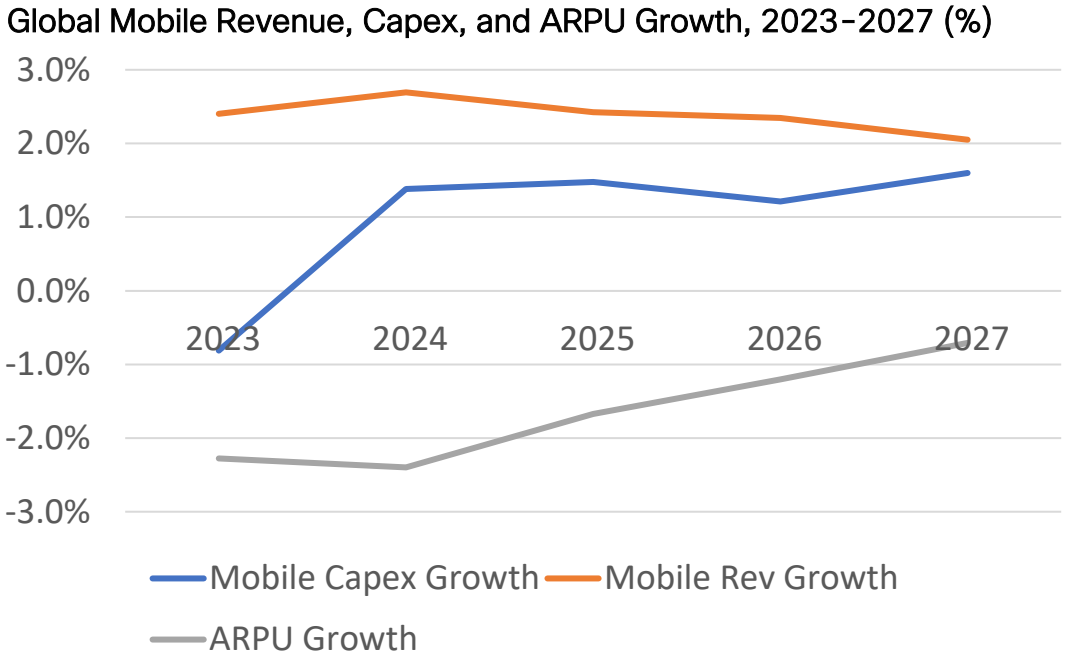
State of Mobile Operators



Sources: Omdia Mobile Subscriptions and Revenue Forecast, July 2023 and Omdia Cellular Data Traffic Forecast, July 2023
LightReading

- CSP realities …
  - Requirement to build infra to support 5G drives capital spend
  - New services and networks must co-exist with large legacy installed bases
  - Overall global revenue growth constrained, despite growth areas
- Drive network mandates:
  - Scale to meet bandwidth demands
  - Build to support revenue growth
  - Lower TCO (including capex and opex)
  - Deliver efficiency/agility
  - Protect the infrastructure

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Mobile Operator 5G Strategic Priorities

- Monetize the 5G investments for consumer services
  - Fixed Wireless Access (FWA) has emerged as the first big 5G use case
  - 77% of SPs are now offering 5G FWA solutions
  - Worldwide FWA SPs revenues: $27 billion in 2022; $67 billion by 2028.
  - Network Challenges
- Monetize 5G investments for enterprise services
  - Private 5G use cases are near-term priority
  - Network slicing planned for enterprise longer term
- Form strategic partnerships to monetize and differentiate 5G services
  - With hyperscalers for ease of deployment, accelerated service time-to-market, enhanced cloud-based security, and other benefits
    - MEC* & SP workload (Packet core, RAN functions) hosting in public cloud; SP workload are different from IT
  - With satellite providers for non-terrestrial network opportunities e.g., Backhaul, 5G NTN, disaster recovery
- Operational Savings
  - Operational cost reduction
  - Decreasing energy use and promoting sustainability

Source: Light Reading
*Multi-Access Edge Compute

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Mobile Operator 5G Network Priorities

- Migrate from Non-standalone (NSA) to Standalone (SA) 5G core
  - 116 operators globally investing in public 5G SA networks per GSA
  - 5G SA core will be implemented in cloud native
- Build out edge computing infrastructure
  - Edge computing essential for many emerging enterprise use cases
- Prepare for 5G Advanced (Release 18)
  - Non-terrestrial Networks (5G NTN), Extended Reality (XR), Advanced MIMO, Mobile IAB*, Green networks, Sidelink “Device to Device”, NR-Light (RedCap), AI/ML data-driven designs, Enhanced Mobility
- Adopt RAN decomposition and virtualization (O-RAN/vRAN)
  - To deliver better utilization, scalability, flexibility, cost reductions
  - Enabler for open RANs and breaking RAN vendor lock-in
  - Flexible SP workload placement on-premises, co-location, private & public cloud

Source: LightReading
*Integrated Access and Backhaul

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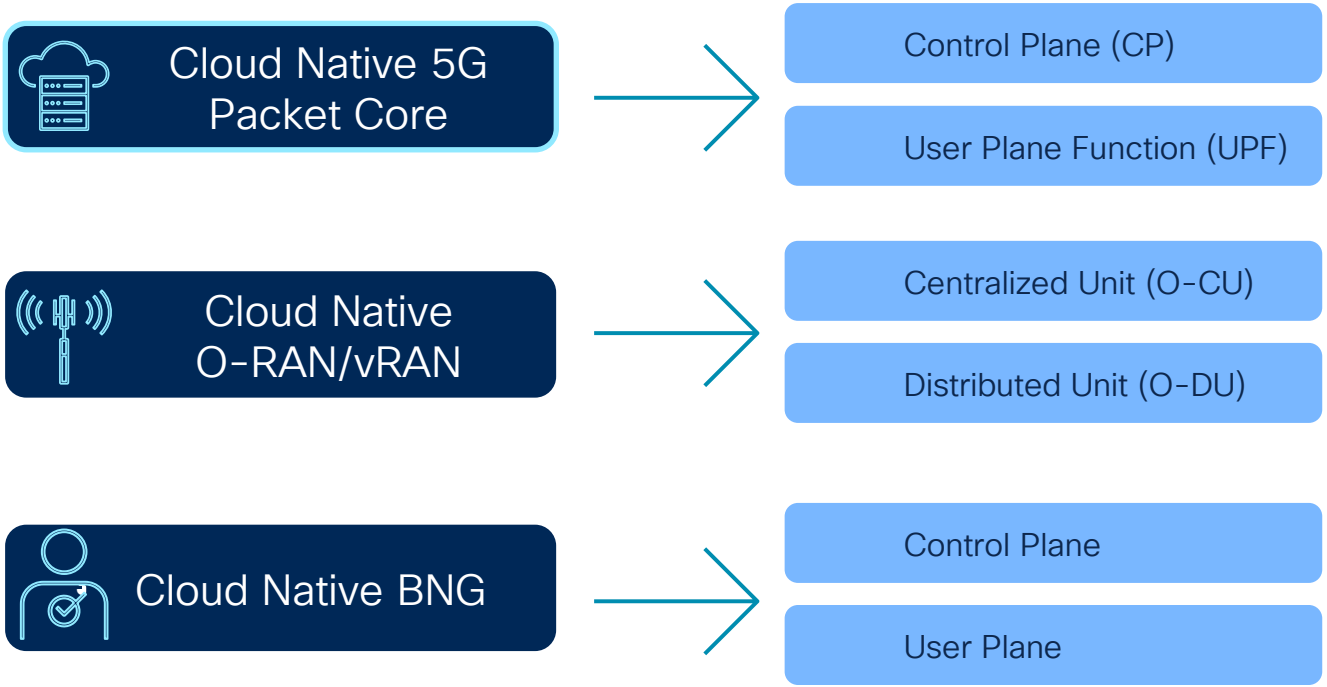
SP Network Function Decomposition & Virtualization



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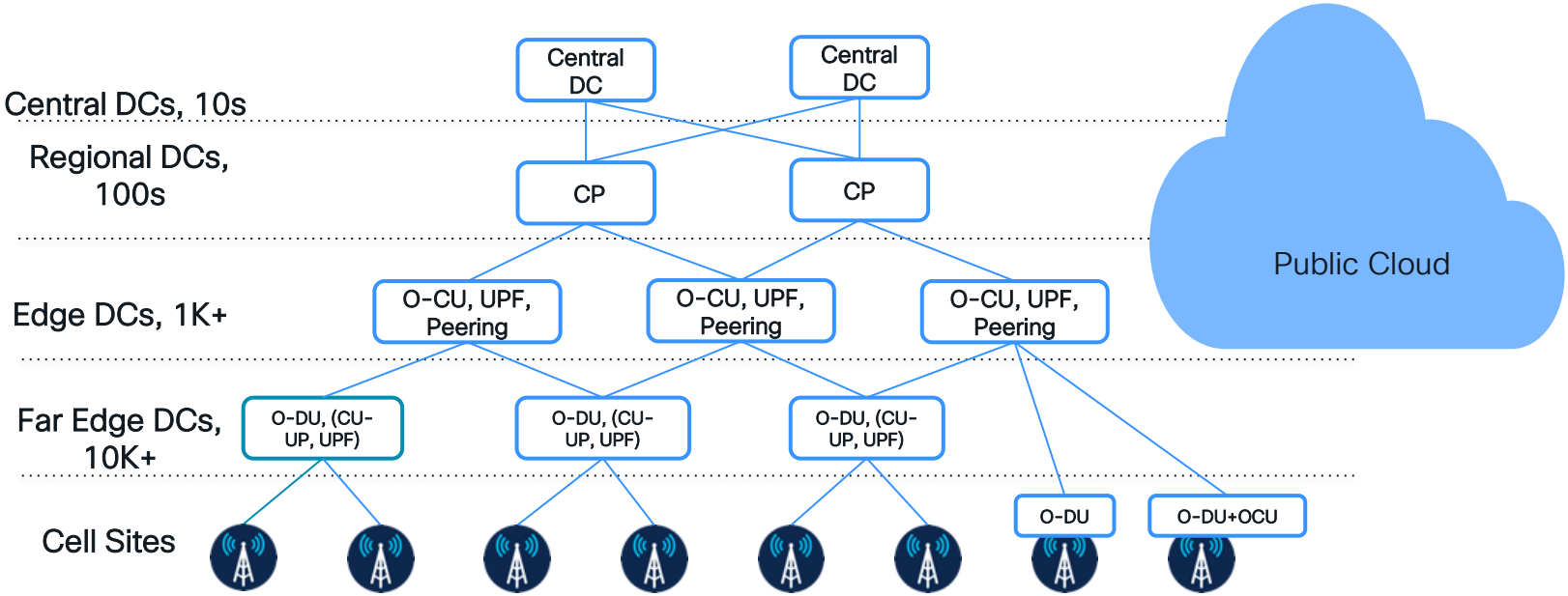
Transition to the Telco Edge



Flexible & Dynamic SP Workload Placement
(on-premises, co-location, private & public cloud)

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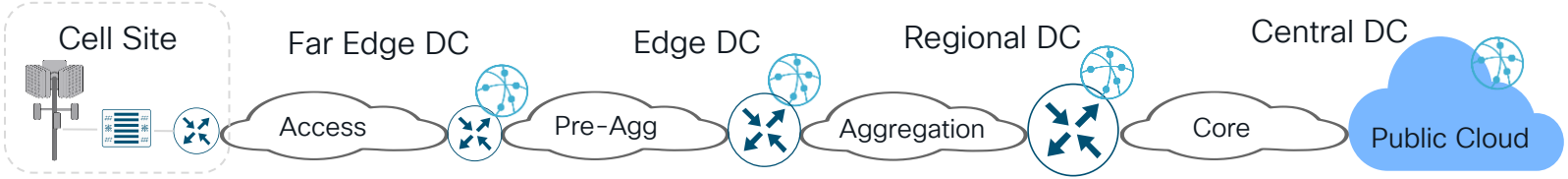
Multi-Access Edge Computing (MEC)



Bandwidth Optimization				Latency	Edge Connectivity & hybrid/multi-cloud	
Content Delivery (downstream)	Data Reduction (upstream)	Mass Customization	Localization	Ultra-low latency/ jitter reduction	Infrastructure Workload Hosting	Hybrid Cloud
Video, Software downloads & updates	Surveillance, IoT, Edge analytics	Live event coverage	Industrial Automation	Virtual and augmented reality	UPF, O-CU, O-DU	Edge Services

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5G RAN

- 5G is driving a reassessment of RAN space (O-RAN, vRAN)
  - O-RAN Benefits
    - Economics: Reduce capex/opex
    - Evolution: Reduce time to deploy new network services or changes
    - Standard & Support: Break vendor lock-in and diversify supply chain
- O-RAN large-scale macro deployments are still in the early stages: DISH Wireless, 1&1, Rakuten
- Potential future brownfield deployments
- Rural, small cell & private 5G deployments use cases
- The next major global RAN deployment, 5G Advanced, may likely be O-RAN
  - Dell'Oro projects open RAN to comprise 15-20% of the total market by 2027.

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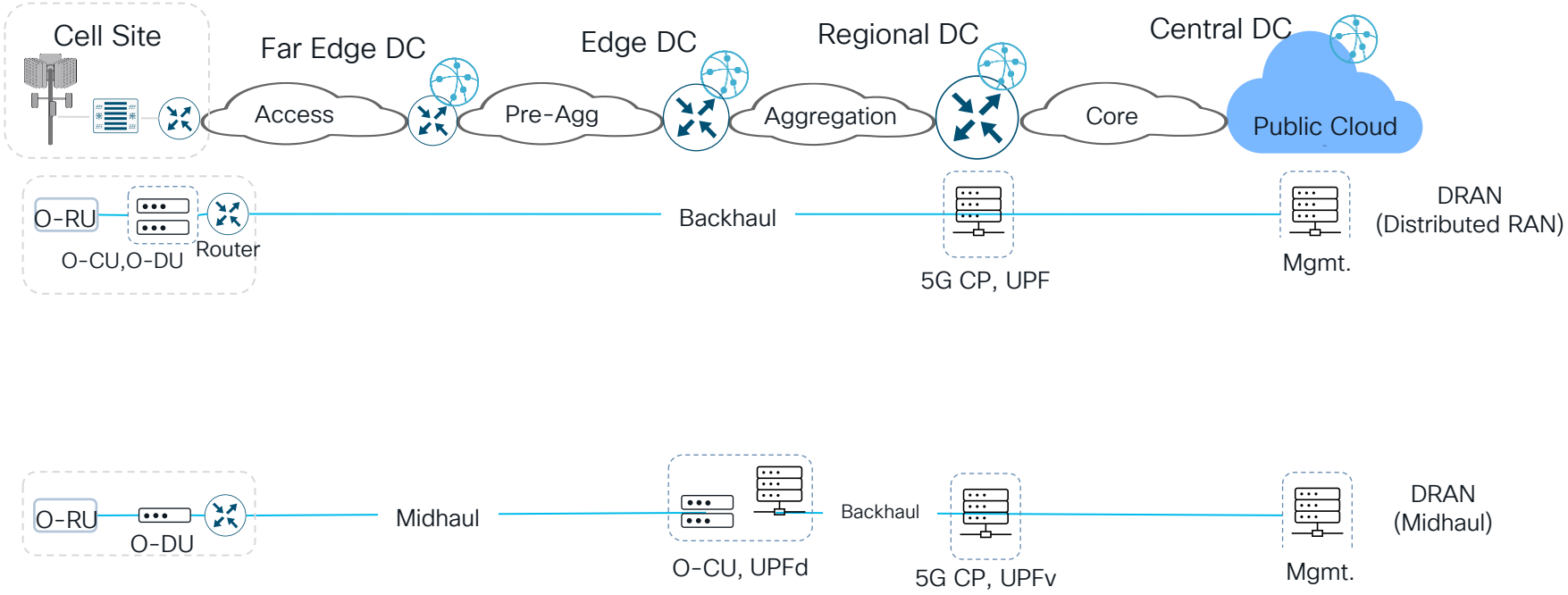
RAN Transport Architecture



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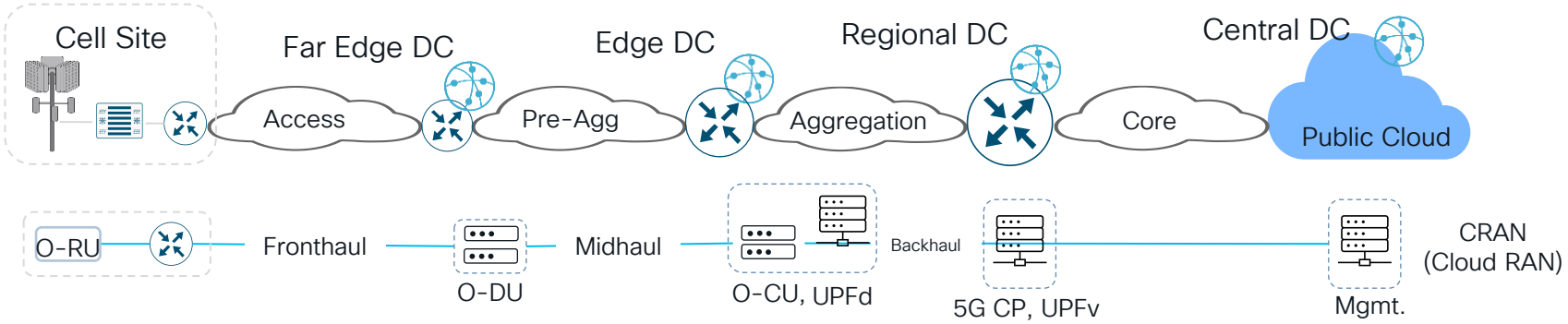
RAN Transport Architecture



- Beamforming and Massive MIMO technologies in 5G New Radio (NR) and Fixed Wireless Access (FWA) require more bandwidth in the transport network
- Backhaul “10G to 25G”; Packet based fronthaul “100G in hub and spoke & 400G in ring topology”
- Leaf & Spine topology in xHaul enabling horizontal scalability with compute
- Low Latency applications <25ms; Flexible workload placement capability “Edge as a Function” (on-premises, co-location, private & public cloud)
- Converged Access “wireless & wireline” requires increased bandwidth & resiliency

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Cisco O-RAN/vRAN Transport Solution Benefits

- Unified forwarding & service plane across packet-based xHaul (fronthaul, midhaul & backhaul)
- Flexible and resilient topologies
- Service assurance & Operational visibility
  - Latency monitoring SR-PM (link and policy)
  - Telemetry
- Monetization
  - Enterprise VPNs over xHaul infrastructure

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Cisco in the Satellite Ecosystem

- Fifteen years experience in Satellite networking; launched first space router in 2009 with Intelsat and engaged with satellite constellations.
- Investment and dramatically reduced launch costs enable deployment of Low Earth Orbit (LEO) constellations
- Satellite transition from proprietary silo towards integration with terrestrial and 5G network

Cisco Ambition

- Simplify and secure the adoption of satellite networking for CSPs, enterprises, the public sector, and consumers for ubiquitous reachability.
- Enable high capacity, low latency use cases, taking full advantage of the value of LEO satellite constellation.
- Satellite networking is a key area of investment and innovation for Cisco.

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Satellite Network Segments & Use Cases

Satellite Service Providers	Communication Service Provider	Hyperscalers	Enterprise
LISL	Mobile Backhaul	Ground Station Service	Site connectivity
5G NTN	Managed Enterprise	5G Telco workload	Cloud Connectivity
Ground Station POP networks	Disaster Recovery		
Connectivity Services	5G NTN		

LISL “Laser Inter-Satellite Links”

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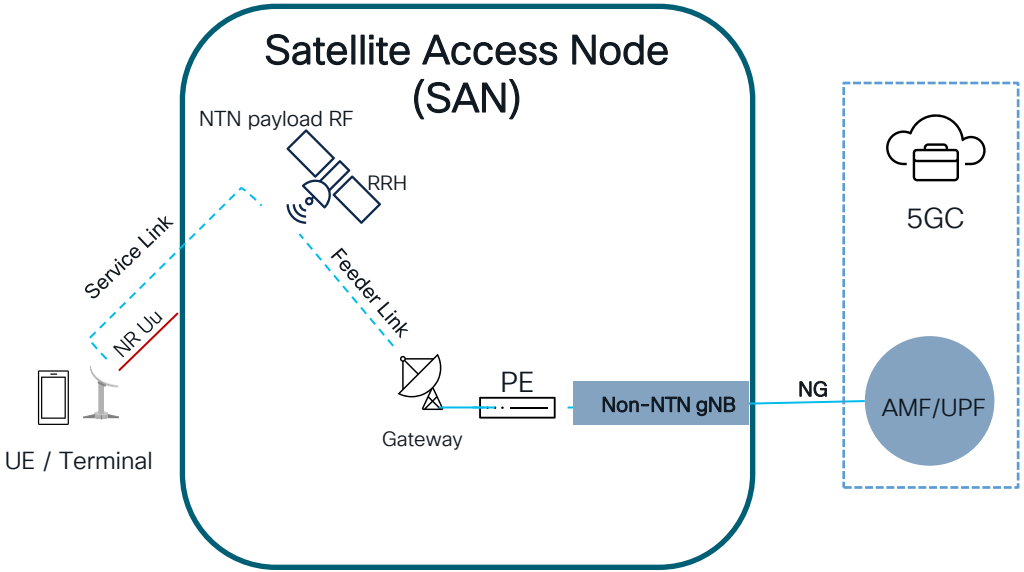
5G NTN

3GPP Release 17



- Satellite NG-RAN
  - New RAN 3GPP access
  - Backhaul
- Direct to Device (D2D)
- Transparent Satellite
  - The NTN payload transparently forwards the radio protocol received from the UE (via the service link) to the NTN Gateway (via the feeder link) and vice-versa.
- Service Link
  - With NGSO satellites, the NTN gNB can provide either quasi-Earth-fixed cell coverage or Earth-moving cell coverage
  - gNB operating with GSO satellite can provide Earth fixed cell coverage

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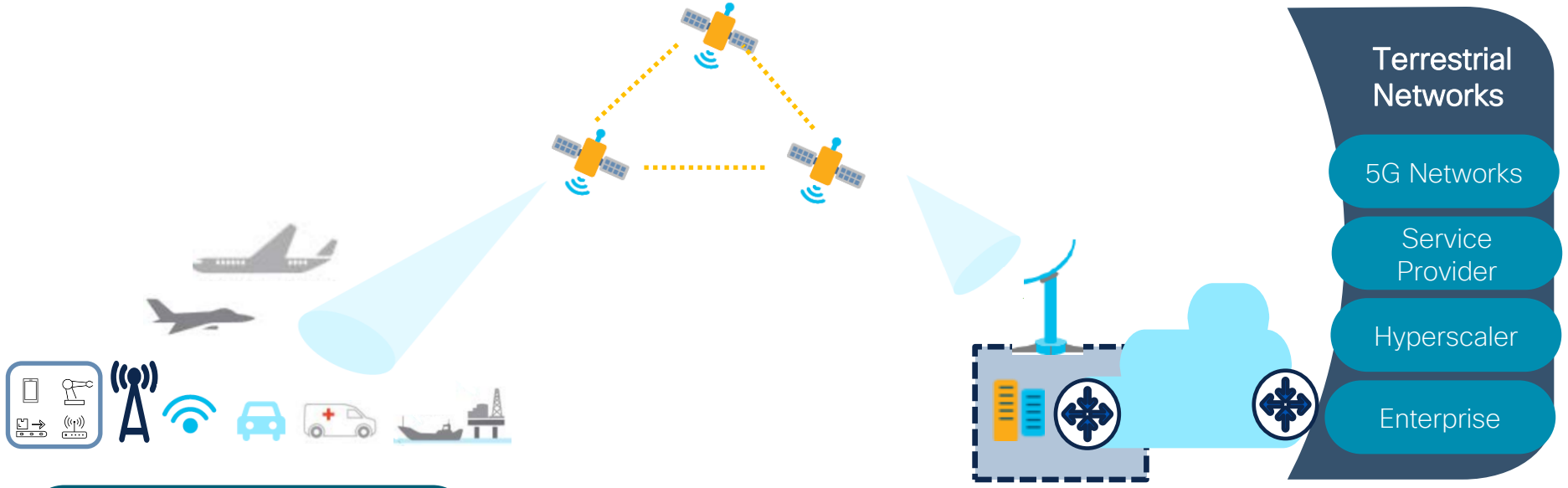
Satellite Packet Transport Network



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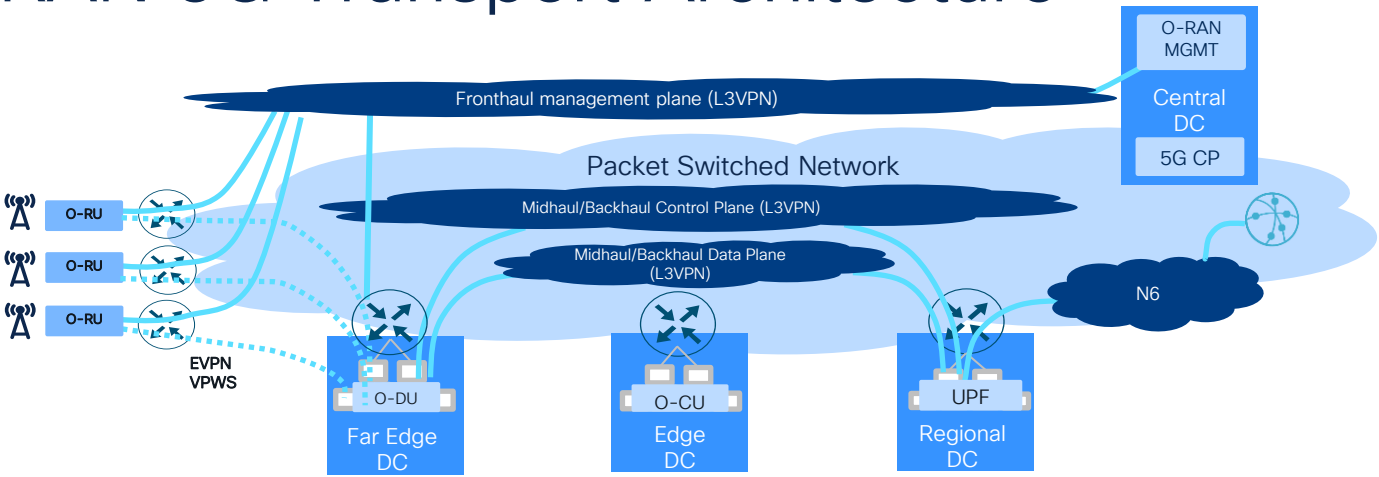
O-RAN 5G Transport Architecture



O-RAN WG-9 “Packet switched architecture and solution” outlines following:

- Segment Routing based on MPLS or IPv6 packet switched network
- Ethernet VPWS services for fronthaul interfaces with priority queuing
- BGP based L3 VPN for O-RAN 7.2X M-Plane
- BGP based L3 VPNs for midhaul / backhaul
- Appropriate packet based QoS and forwarding plane for the 5G service
- The transport architecture is ready to support Network Slicing

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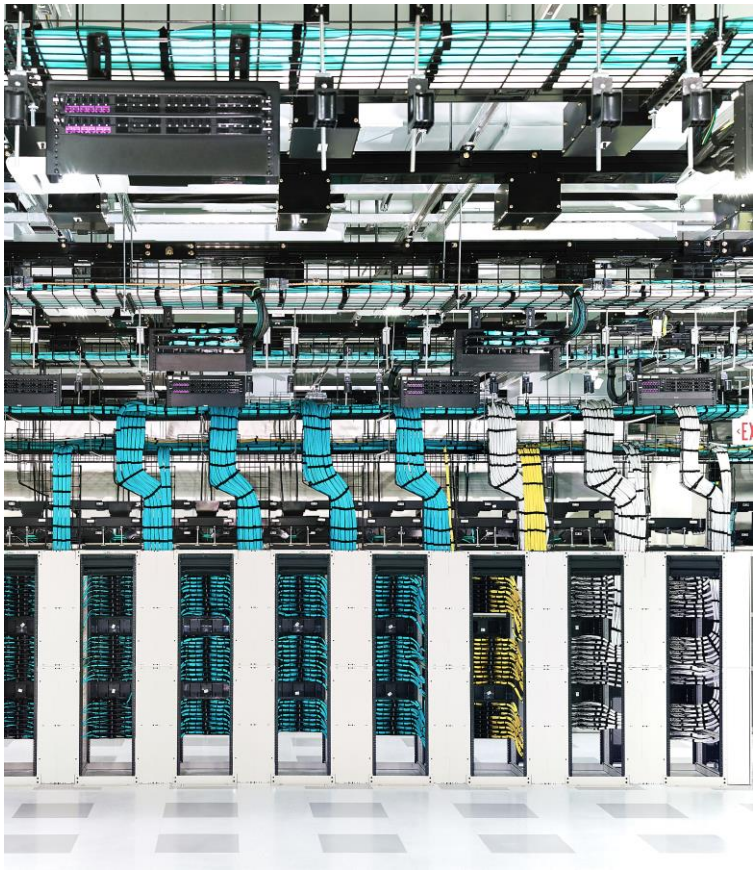
Network Slicing

- Slicing is seen as a key capability for 5G
- In 5G, end-to-end slicing typically covers RAN, Transport, DC and the Mobile Core
  - Different domains covered by different organizations
- Cisco has a powerful and complete toolset for Transport Slicing including Segment Routing, ODN/AS, Flex Algo, QOS, L2/L3 VPNs.



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Network Slicing

- Cisco is taking a lead role in defining IETF Transport Slicing standards and YANG model.
- Crosswork Network Controller is Cisco's SDN solution to orchestrate and automate Transport Network Slicing

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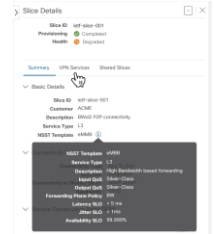
Transport Slicing Automation Made Easy with Crosswork Network Controller (CNC)

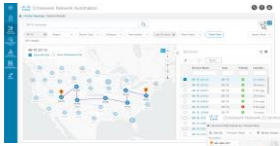
Transport Slice SLA Monitoring

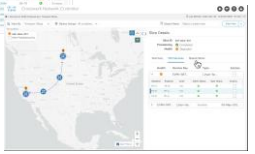
- Proactive SLA monitoring per Slice
- Leveraging Cisco (SR-PM) or Accedian instrumentation
- SLA breach notification
- SLA reporting

Transport Slice Orchestration

- Intent-based slice definition
- Abstracted Slice model based on IETF model
- Slice Template Catalog
- Simplified provisioning User Interface
- Optimizations

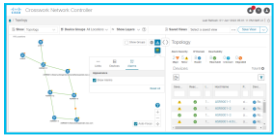






Transport Slice Visualization

- Overlay maps
- Slice details: Type, Template, VPNs, Transport
- Navigation between Slice components
- Infrastructure visibility
- Multi-layer view and analysis of the slice



Transport Slice Health Monitoring

- Service Centric approach to health monitoring
- Dynamically tie Slice Intent to infrastructure telemetry
- Correlate active probing with infrastructure monitoring

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Network Slicing

- Use case: Enterprise FWA
- Phase 1: Capacity based slices
  - Pre-configured eMBB slices
  - Few, static slices
- Phase 2: Service Specific network slices (URLLC, eMBB, mMTC)

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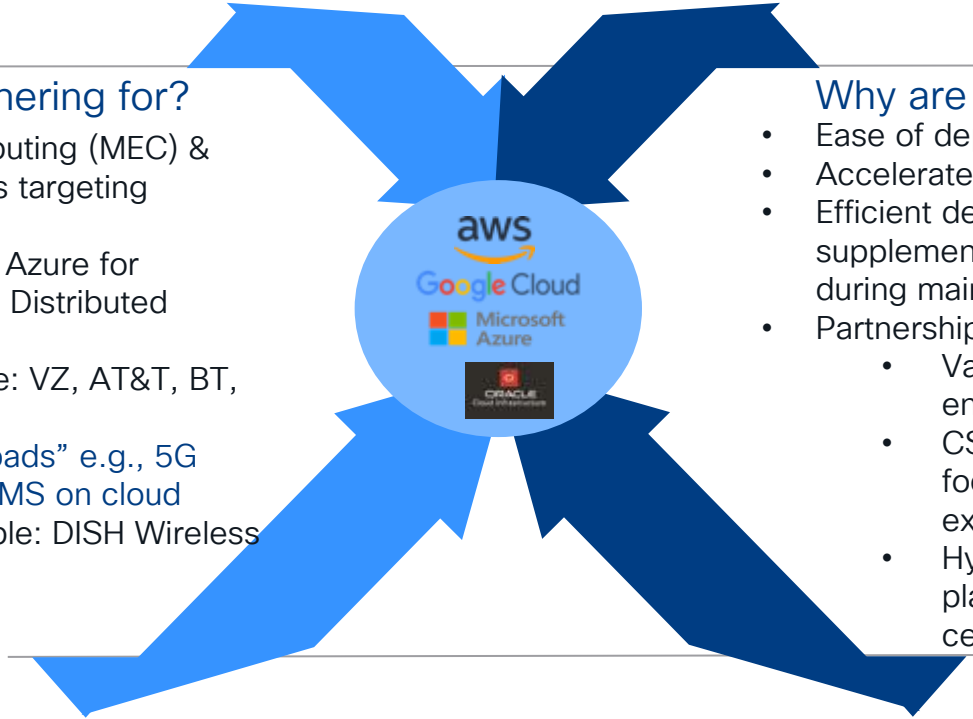
SP & Hyperscalers Partnership

What are they partnering for?

- Multi-access Edge Computing (MEC) & network edge capabilities targeting enterprise customers
  - AWS Wavelength, Azure for Operators, Google Distributed Cloud.
  - Operators Example: VZ, AT&T, BT, VF and others
- Hosting “Network Workloads” e.g., 5G Core (CP & UP), O-CU, IMS on cloud
  - SP Adopter example: DISH Wireless



Why are they partnering?

- Ease of deployment*
- Accelerated service time-to-market*
- Efficient deployment for fluctuating needs, supplementing private cloud with public during maintenance or peak traffic.
- Partnership is mutually beneficial
  - Value-added services to the enterprise
  - CSPs have substantial assets, footprint, and telco domain expertise
  - Hyperscalers offer cloud-scale platforms, state-of-the-art data centers, and global connectivity

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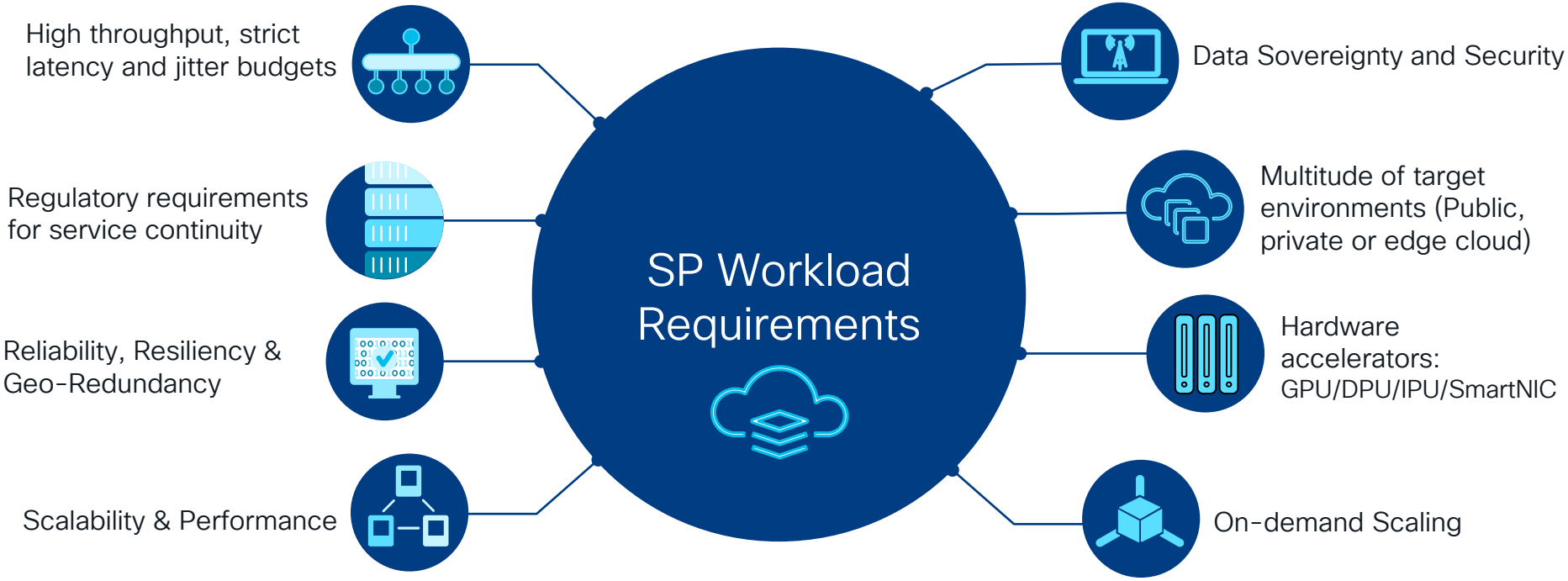
SP Workloads differ from Enterprise/IT Applications

SP Workload Requirements



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SP Workload Network Requirements

- Dynamic routing in the cloud
- Network separation (VRF Inter-DC)
- Traffic isolation e.g., voice aggregators, regulatory entities, etc.
- High Availability, routing it to the standby network function in case of failure
- Geo-Redundancy to enable service continuity during outage
- Link/Network error detection
- Routing features at scale
- Unified forwarding and service plane
- Standard routing technologies
- no cloud lock-in

BGP/MP-BGP, Anycast, L3VPN, BFD & QOS

On-Premises	Cloud
Network Slicing	
BGP VPN	
IGP/BFD/SR	

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Why Hybrid Cloud for Service Providers?

On-Premises Hosted	Public Cloud Hosted
• O-RU (Radio Unit) • O-DU (Distributed Unit) • DNS, DHCP and IP Address Management	• 5G Packet Core, IMS, Voice and Data Plane UPF • Centralized (O-CU), RAN Management and Radio Intelligent Controller (RIC) • Observability, Automation, and Orchestration

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What changes are needed in the architecture to meet SP requirements?

5G Cloud-Ready Converged Transport

Ubiquitous Reachability Enabler

Converged Infrastructure

- ✓ Wireless (eMBB, mMTC, URLLC), wireline, IP+Optical
- ✓ Decomposition & virtualization
- ✓ Rich connectivity
- ✓ O-RAN/vRAN

Programmable Transport and Network Slicing Services

- ✓ Segment Routing (SR): Unified Service Aware Forwarding
- ✓ BGP VPN
- ✓ Network Slicing
- ✓ Terrestrial Timing transport with reduced GNSS dependency

Cloud-Ready

- ✓ Agnostic to workload location
- ✓ SP workload in Public/Private Cloud, co-location or on-premises
- ✓ Cisco vRouter with the same look-and-feel & flexibility as on-premises
- ✓ Addresses all SP workload and network requirements

Simplified Operational Model

- ✓ Automation & Orchestration
- ✓ Service Assurance & Observability
- ✓ Reliance and Security

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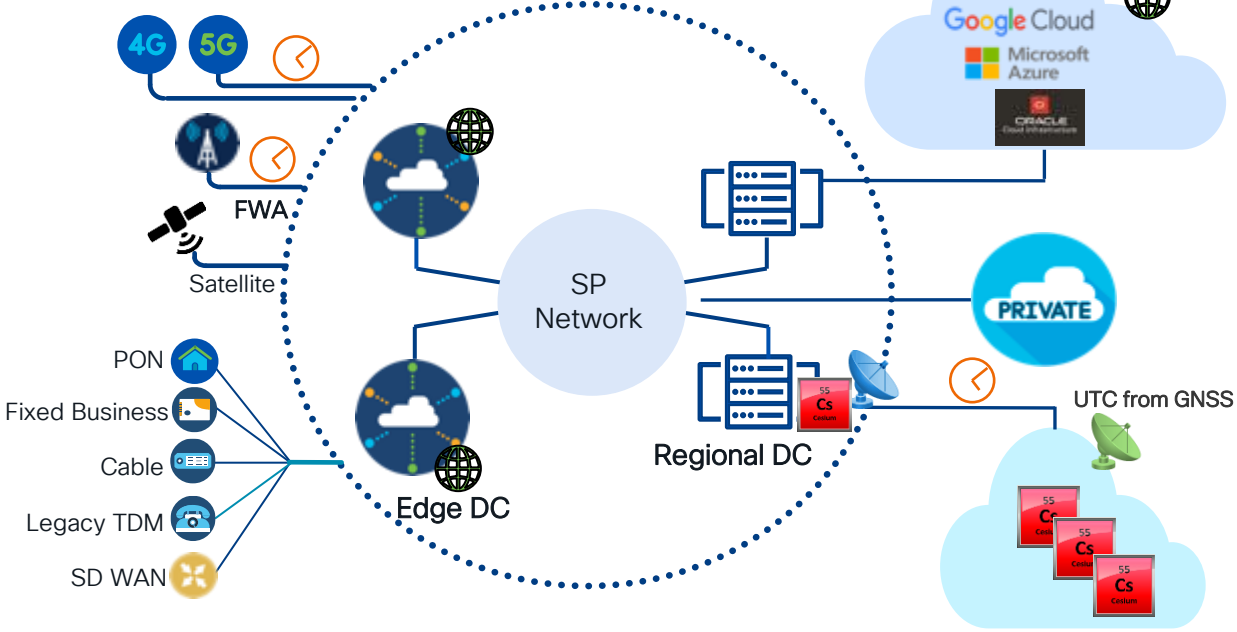
5G Cloud-Ready Converged Transport

Automation, Orchestration & Assurance

SR: Unified Service Aware Forwarding

End User
Use Cases



Converged Infrastructure
Wireline & Wireless

Programmable Transport & Network Slicing Services
SR: Unified Service Aware Forwarding

Cloud-Ready
On-Premises/Private Cloud/ Co-location/Public cloud

Simplified Operational Model

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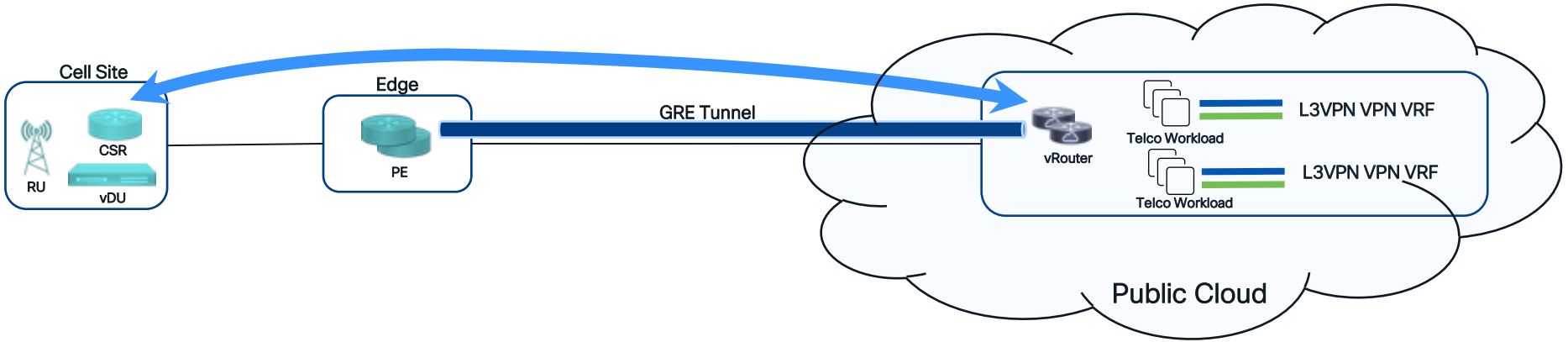
5G Cloud-Ready Converged Transport Architecture



On-Premises	Cloud
Network Slicing	
BGP VPN	
IGP/BFD/SR	

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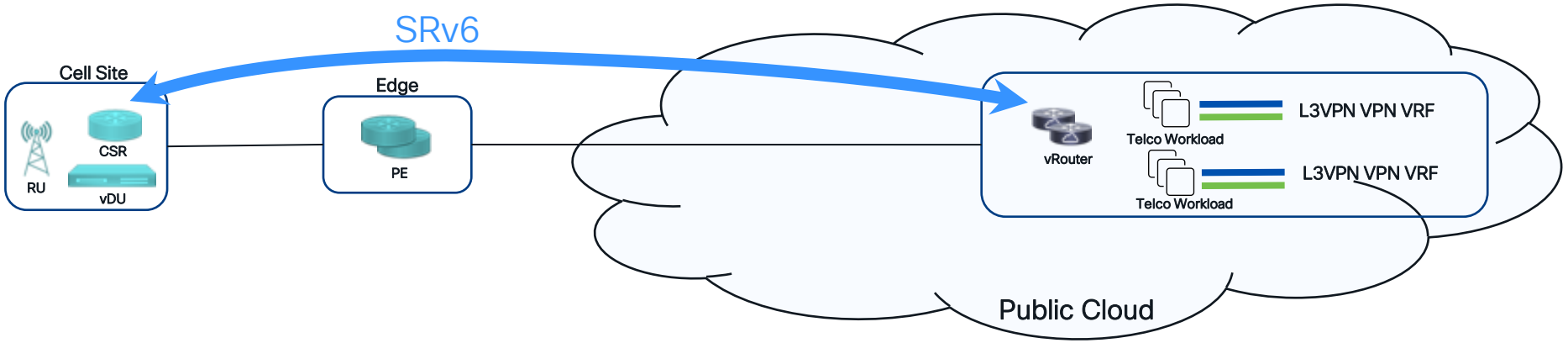
5G Cloud-Ready Transport Architecture Evolution



SRv6

- SRv6 enable scalable hybrid & multi-cloud
- IPv6 with flexible address allocation & flow label support are required from hyperscalers

On-Premises	Cloud
Network Slicing	
BGP VPN	
IGP/BFD/SR	

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Cloud-Ready Converged Transport

Hybrid Cloud Solution

- A key component of Cisco's Cloud-Ready Converged Transport solution is the Cisco vRouter

  - Unified forwarding and service plane across on-premises and cloud environments enabling flexible workload placement
  - Provides hybrid-cloud/multi-cloud transport with service assurance, network segmentation & resiliency

- Cisco pioneered hybrid cloud transport for DISH Wireless by delivering Telco workloads hosted on the public cloud, the first of its kind in the industry

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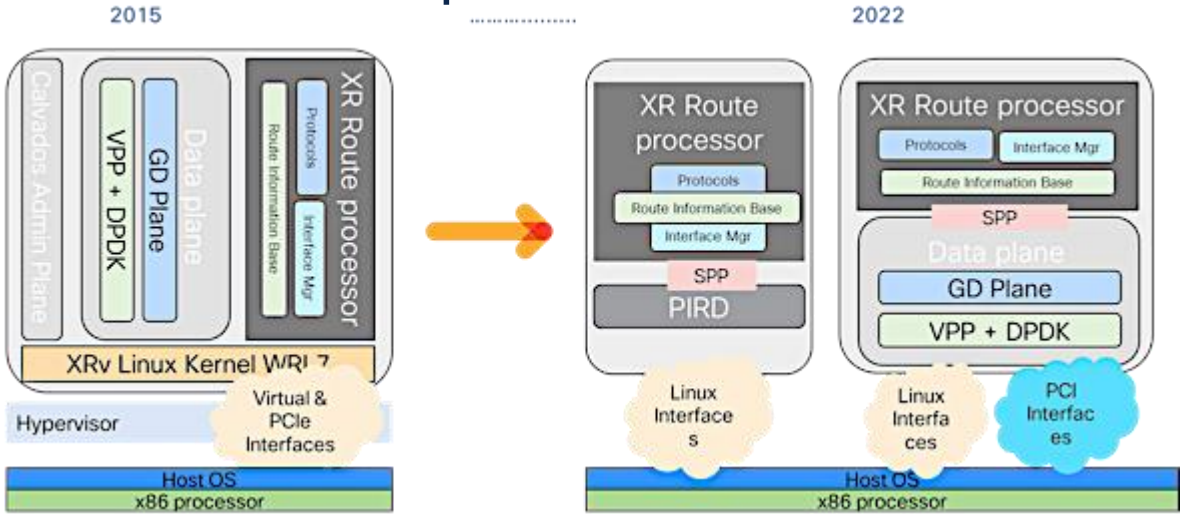
XRd vs XRv9K Comparison



XRv9K:

- LXCs within Virtual Machine, based on eXR
- Generalized Data (GD) plane does the Packet processing
- VPP provides the identification
- Appliance (Bare Metal), Cloud AWS Instance

XRd:

- Standalone Docker Container, based on XR7 & ONELinux
- Deployable via Standard K8s and VMware Tanzu
- Red Hat OpenShift operator certified
- XRd inherits the same GD Plane + VPP Stack
- Optimizations for low footprint core (vCPU) use cases
- Throughput scales up with additional resources (vCPUs)
- Faster boot time (Boot time: About 90 seconds)

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Virtual Routing Use Cases

Virtual Network Edge	Virtual User Edge	Metro Edge*	Control Plane Functions	Digital Twin
Public Cloud	Virtual Cell Site Router	Services Edge (Virtual BNG)	Route Reflector	Network Simulation
Private Cloud	CPE (Network in a box)		SR PCE	
Co-location				

*Roadmap

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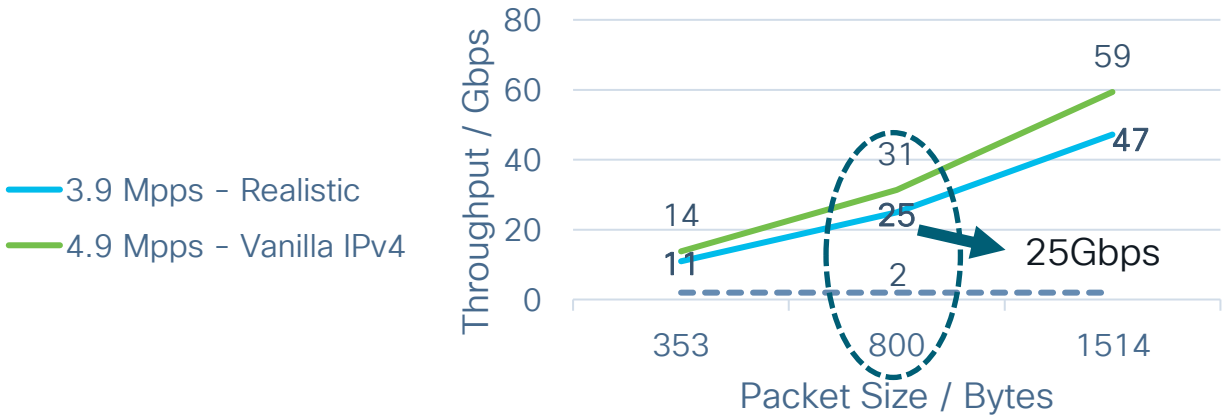
Performance “XRd vCSR”



- Latency: ~50 usec average through Cisco XRd “vCSR”
- Ice Lake CPU @ 3.5 GHz turbo, 2 physical cores: “1 for control plane ; 1 for data plane”
- ‘Realistic’ configuration uses L3VPN o SR-MPLS o ECMP VLANs with Egress QoS

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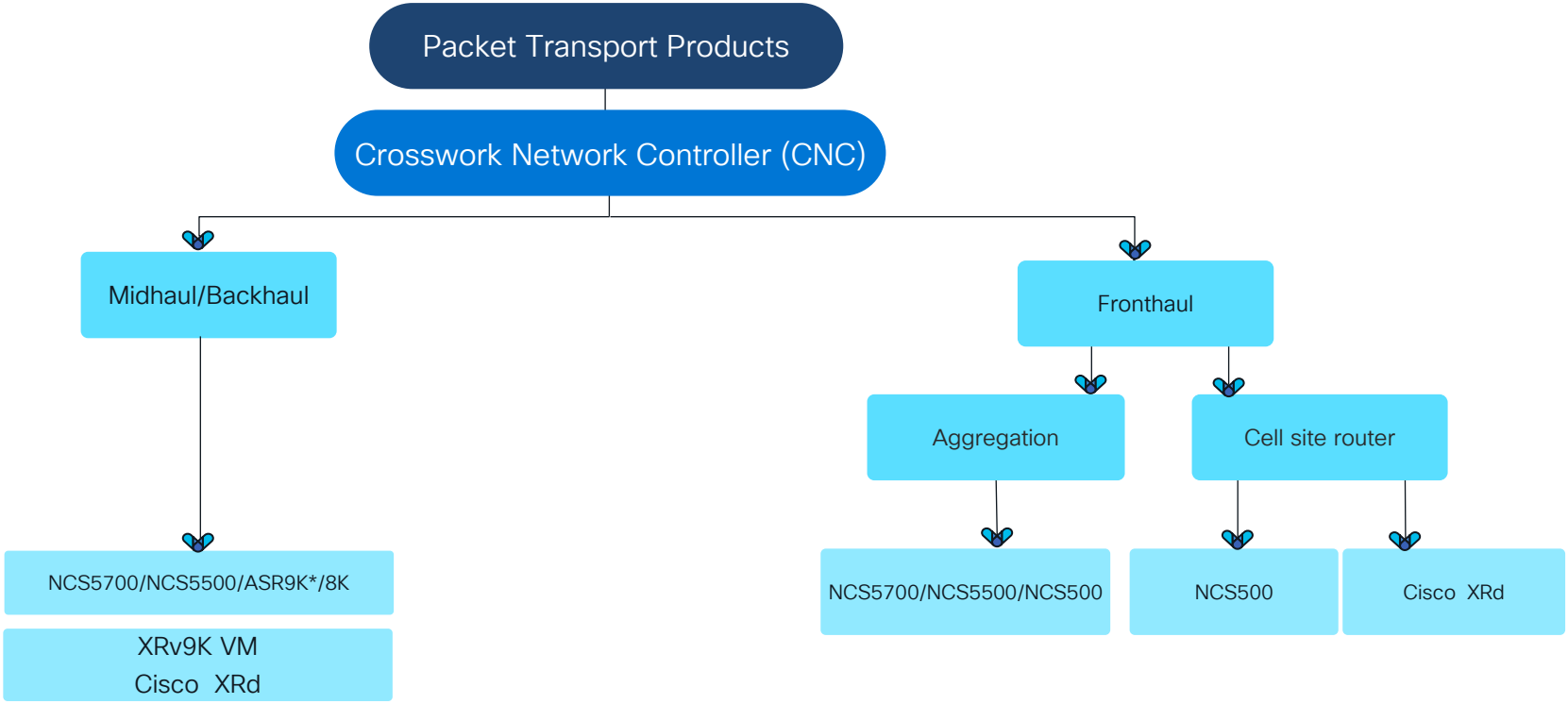
Cloud-Ready Transport Portfolio



*High-scale services requirement

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DISH Wireless

Who is DISH Wireless?

- With the T-Mobile and Sprint merger, DISH Wireless is now the 4th largest national 5G provider in USA as a result of acquiring Boost Mobile and over 9 million consumer subscribers

- DISH has just met FCC and DOJ obligations to cover 20% of the US population on June 14th, 2022, and 70% of the US population on June 2023

- DISH network is a 5G SA only network

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Who is DISH Wireless?

- DISH is the first O-RAN based Greenfield network in US, cloud-native service provider focused on container-based applications and mobility network functions in the cloud
- DISH is the first Telco that deployed both Control-Plane and Data-Plane in a Public Cloud
- Cisco is responsible for packet transport, automation and services
  - https://about.dish.com/news-releases?item=123535#.YZ3v-NpXRrY.linkedin
  - The partnership will help to drive wireless disruption and innovation for enterprises by building the United States' first innovative 5G network

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DISH xHaul Transport Architecture

- DISH Transport network utilizes On-Prem and Cloud-based resources
  - IOS XR enables on-prem and virtualized routers to implement a cohesive set of services including L3VPN, SR-MPLS, QoS leveraging same Automation
- Unified forwarding (SR MPLS) and service plane (BGP VPN) architecture enables flexible location of Network Functions
  - RAN NFs, 5G Core NFs, IMS NFs, etc., can be placed on-premises or in the cloud, according to performance and capacity requirements, availability of facilities, etc.
- DISH Cloud-based network
  - Architecture enables Hybrid + Multi-Cloud
    - Cisco vRouter

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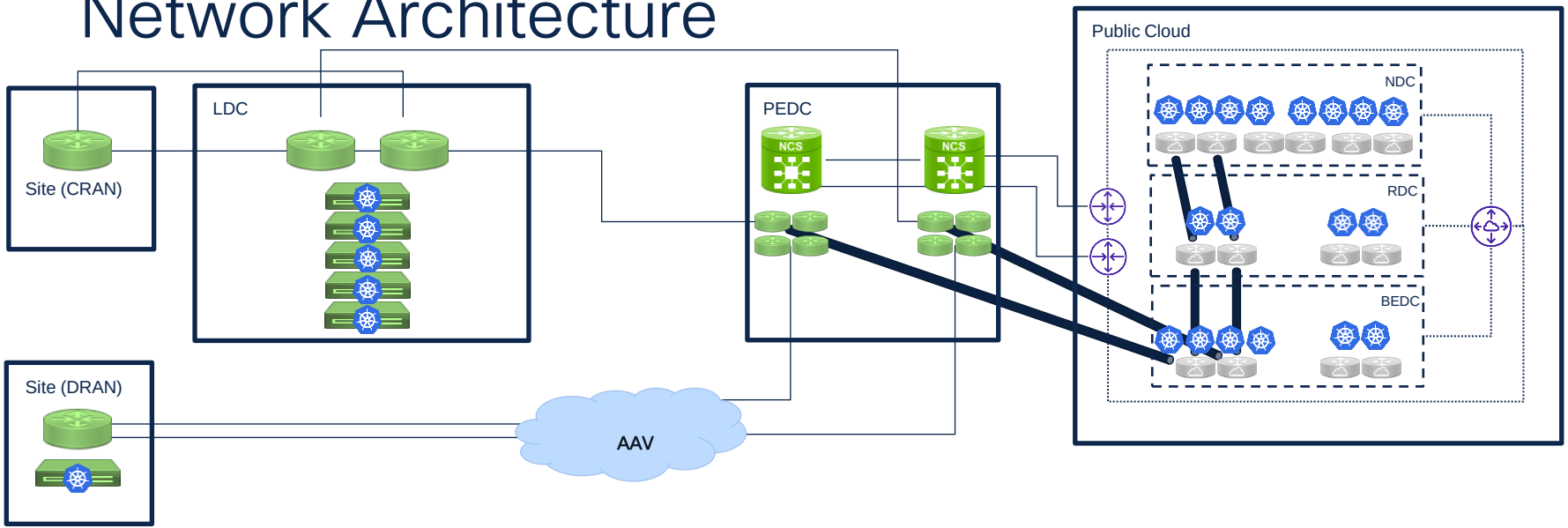
Network Architecture



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SP Hybrid Cloud Deployment Challenges

Challenges

Routing

- **Limited dynamic routing in cloud**
  - BGP and Anycast required for Geo-Redundancy and Active/Standby network functions
  - VRF required for network services segmentation and prioritization (QoS)
- **Limited route scalability**

Performance

- Within the Public cloud, latency is difficult to predict.

Throughput

- **Traffic Limit**
  - Per flow limit at the interface level
  - Packet per second limit based on instance type

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SP Hybrid Cloud Deployment Learnings

	Learning/Recommendation

Overlay Network	• Overlay Service Provider network to supplement cloud routing
	  • Virtual Router with the same look-and-feel as on-premises
	  • Unified forwarding in hybrid/multi-cloud
	  • Route scales independently to cloud network
	  • End-to-End network visibility

Certification	• Establish Baseline, Service delivery and Validation framework for SP network functions: • Feasibility→Onboarding→xNF Baseline→PoC→Integration→Performance→Network Ready for Use • Establish baseline performance for Instances (i.e., Throughput, disk IOPS, etc.)

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DISH Wireless & Cisco Systems

"Industry's first whitepaper on the world's first 5G network deployment with a hybrid cloud"

- https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/converged-sdn-transport/white-paper-sp-5g-network-hybrid-cloud.pdf

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Conclusion

- State of 5G MNO
- 5G MNO Strategic and Network Priorities
- SP Network Architecture Transformation
- SP & Hyperscalers Partnership
- Cisco 5G Cloud-Ready Transport solution
- DISH Wireless, USA case study
- Conclusion

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Resources

- Light Reading Digital Symposium
  - Day 1 Session 1: Scaling and Operating 5G Backhaul
  - https://event.on24.com/wcc/r/4277818/3D78F3385E9D95D489A3D744DDF408AC
- Light Reading “5G Cloud-Ready Converged Transport ” webinar
  - https://event.on24.com/wcc/r/4279056/B332D995F783E2E757F78EBC5EA007C1
- 5G Advanced and beyond whitepaper
  - https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/converged-sdn-transport/white-paper-sp-transform-your-transport-network.pdf

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Resources

- 5G transport page
  - www.cisco.com/go/5g-transport
  - https://www.cisco.com/c/en/us/solutions/service-provider/converged-sdn-transport.html

- 5G Transport Overview (Tech Field Day)
  - Cisco 5G Packet and RAN Transport Architecture

- Cisco Press Book: Synchronizing 5G Mobile Networks

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Resources: Cisco Live Sessions

- 5G Transport
  - **Cloud-Ready Converged SDN Transport** - BRKSPG-2315, Event: Las Vegas, 2023
  - **Introducing XRd: Lightweight, Programmable and Containerized** – BRKSPG-1552, Event: Amsterdam, 2023
  - **Evolution of the Transport Network Architecture in the Context of 5G and Open RAN** - BRKSPG-2133, Event: Las Vegas, 2023
  - **5G RAN Transport Architecture** - BRKSPM-2977, Event: Las Vegas, 2022
  - **5G Packet based Fronthaul** - BRKSPG-2065, Event: Digital 2021
  - **5G xHaul Transport** - BRKSPM-2012, Event: Barcelona, 2020

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Resources: Cisco Live Sessions

- 5G Timing & Synchronization
  - Synchronizing 5G Mobile Networks – BRKSPG-3050, Event: Las Vegas, 2023
  - 5G Timing & Synchronization architectures - BRKSPM-3295, Event: Barcelona, 2020
  - 5G Synchronization - Design, Testing and Deploying Timing to support 5G rollouts - BRKSPG-2557, Event: Barcelona, 2020
- Private 5G
  - 5G Use Cases Flight Line of the Future and Smart Warehouse - BRKSPG-2044, Event: Las Vegas, 2023
- Network Slicing
  - Design, Deploy and Manage Transport Slices using SDN Controller and Assurance - BRKSPG-2263, Event: Las Vegas, 2023

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Resources

- Packet Fronthaul "Cisco's Mobile Fronthaul Solution" (YouTube Channel)
  - https://www.youtube.com/channel/UCi5ofLT2s724jVjs-5QSMUA
- https://xrdocs.io/packet-fronthaul/
- Update on 5G Non-Terrestrial Networks Briefing Paper
  - https://www.5gamericas.org/update-on-5g-non-terrestrial-networks/

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O-RAN PlugFest & Demos

- SRv6 uSID-based Xhaul validated in O-RAN PlugFest 2022. The demo shows Cisco O-RAN/vRAN transport as defined in ORAN working group 9, delivering ultra-low-latency service with fast convergence and resiliency
  - https://youtu.be/JwKUDMoAMug
  - https://blogs.cisco.com/sp/why-isnt-your-5g-ran-transport-flexible-and-efficient
- Cisco, Xilinx and Keysight Packet Fronthaul Demo. The demos show how brownfield operators with legacy interfaces like CPRI can co-exist with the new O-RAN-defined fronthaul network protecting existing investment.
  - Innovating the future of Open RAN
- Cisco FHGW solution demo at O-RAN Global PlugFest 2021. The demos show how brownfield operators with legacy interfaces like CPRI radios are connected to the new O-RAN-defined fronthaul network using fronthaul gateway functioning, translating CPRI to eCPRI, protecting existing radio investment along with significant bandwidth reduction
  - Making 5G adoption cost effective for brownfield providers
  - O-RAN Global Plugfest 2021

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Resources: Cisco Validated Design Document

- Cisco Converged SDN Transport SRv6 Transport High Level Design
- https://xrdocs.io/design/blogs/latest-converged-sdn-transport-srv6
- Converged SDN Transport High Level Design v5.0
- https://xrdocs.io/design/blogs/latest-converged-sdn-transport-hld
- Converged SDN Transport Implementation Guide
- https://xrdocs.io/design/blogs/latest-converged-sdn-transport-ig
- Cisco Routed Optical Networking
- https://xrdocs.io/design/blogs/latest-routed-optical-networking-hld

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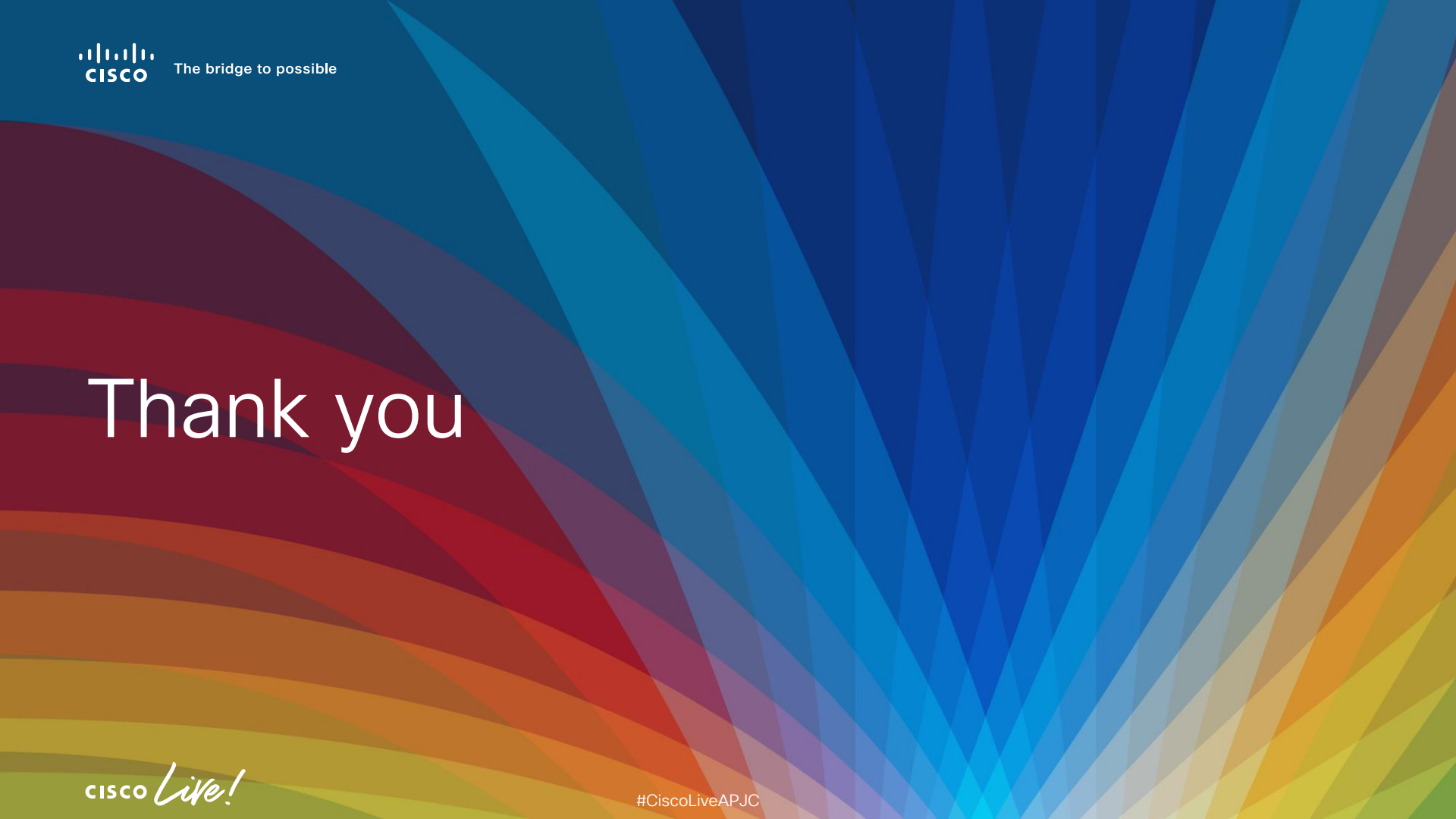

cisco
The bridge to possible
Thank you
cisco Live!
#CiscoLiveAPJC

cisco Live!

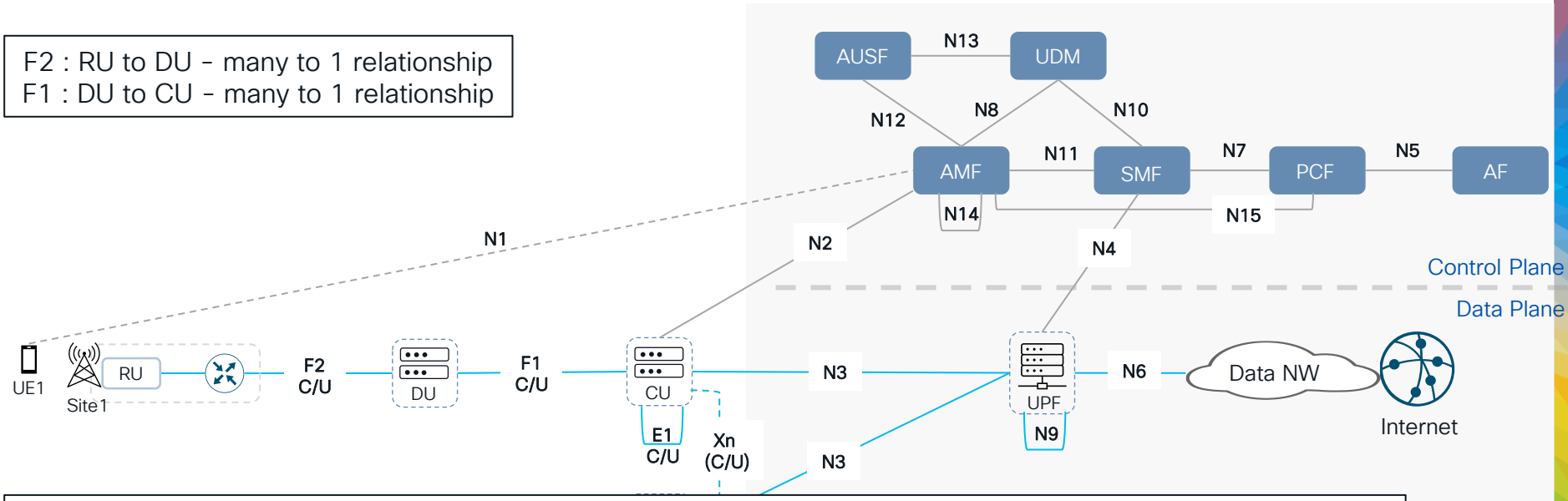
Let's go

#CiscoLiveAPJC

Backup

RAN and 5GC Interfaces

F2 : RU to DU – many to 1 relationship
F1 : DU to CU – many to 1 relationship



All interfaces are mandatory IP based (except F2 where its optional)
There is a complex set of networking requirements between different 5G components
1 to 1, 1 to many, many to many
Same component may need to support all models concurrently!

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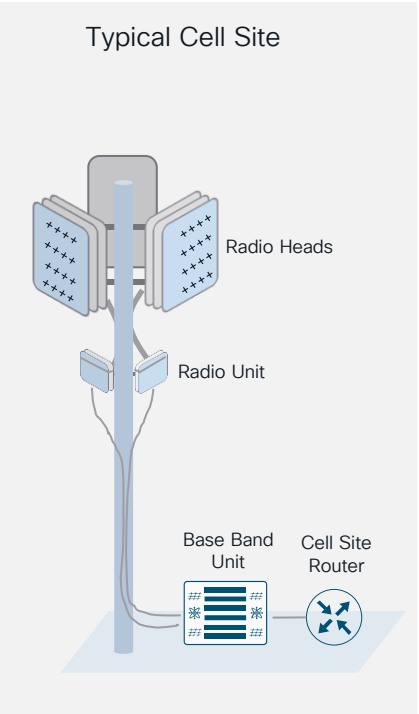
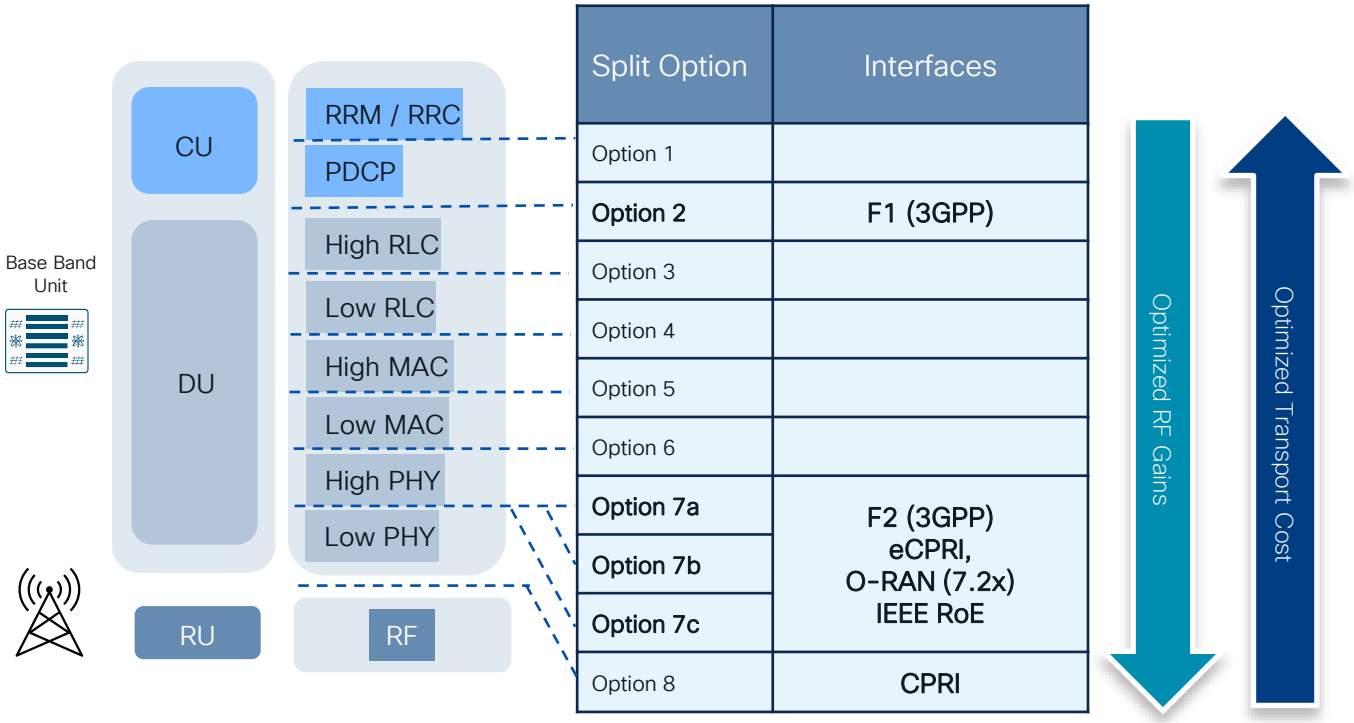
RAN Virtualization





RU: Radio Unit, CU: Centralized Unit, DU: Distributed Unit. BBU: Baseband Unit, CPRI: Common Public Radio Interface, eCPRI: enhance CPRI, RoE: Radio over Ethernet

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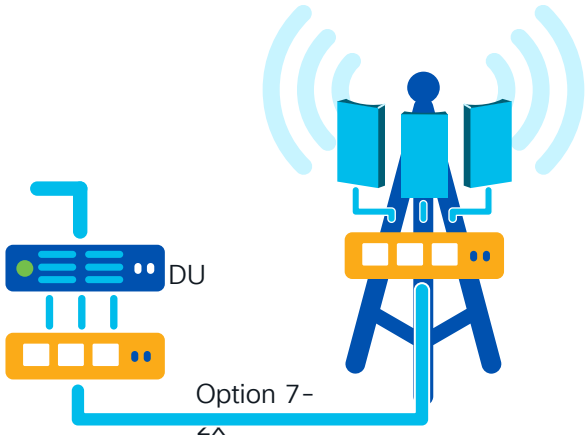
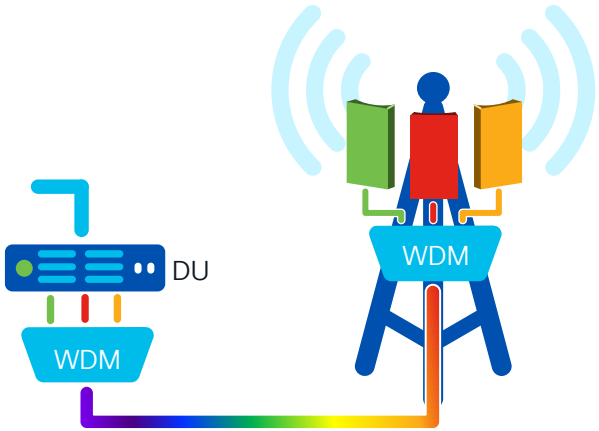
Packet-based Fronthaul



Stat-muxing opportunity

VS.



Optical Multiplexing (Passive or Active DWDM)

Packet	Optical
✔ Stat Mux Advantages	✔ Service Visibility & Transparency
✔ Cost Effective	✔ Scalable E2E Converged IP
✔ Topology Independent	✔ Resiliency (Fast convergence)
✖ Optical multiplexing	✖ Limited-service visibility
✖ Non-scalable, architecturally rigid	✖ Capex dependent scale
✖ Point-to-point, topology dependent	

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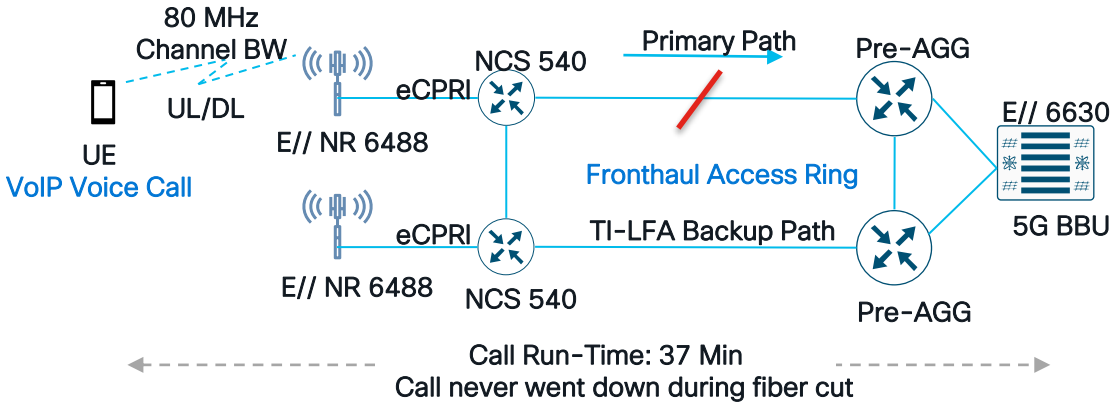
5G RAN Resiliency with Segment Routing (SR)

Case Study: Packet fronthaul network



- Fronthaul network between Cisco NCS 540 and E// BBU is approx. 14km
- The setup was running eCPRI between E// NR Radios and BBU
  TI-LFA is enabled to provider protection against link failures
- No cell went down during the failure and convergence time
- No service issue or call drop observed

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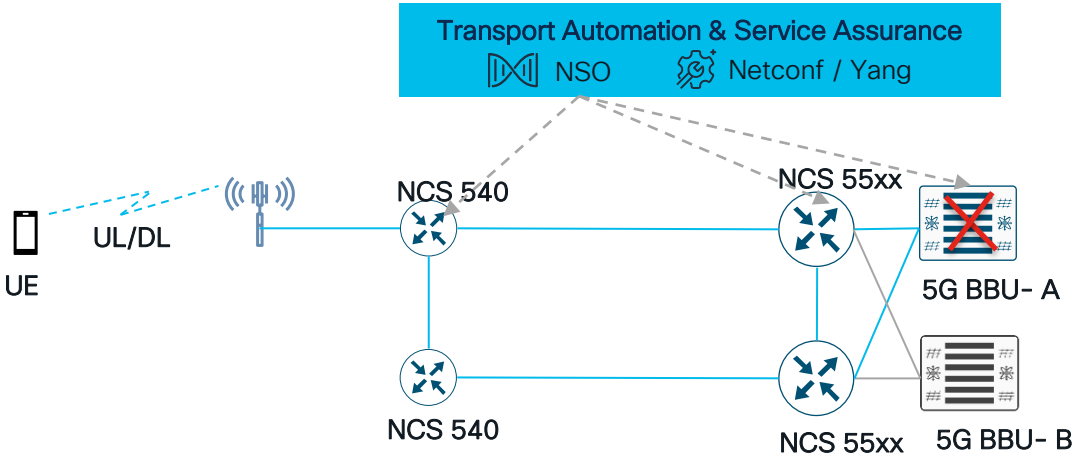
5G RAN Resiliency with Automation

Case Study: Packet fronthaul network



Scenario:

- Radio is connected to BBU-A
- When BBU-A fails, move Radio connections to BBU-B.

- NSO replicated Radio specifics from BBU-A to BBU-B
- NSO updated VPWS service model to move active connections to BBU-B
- Automation improved Service provisioning time to minutes; no manual intervention

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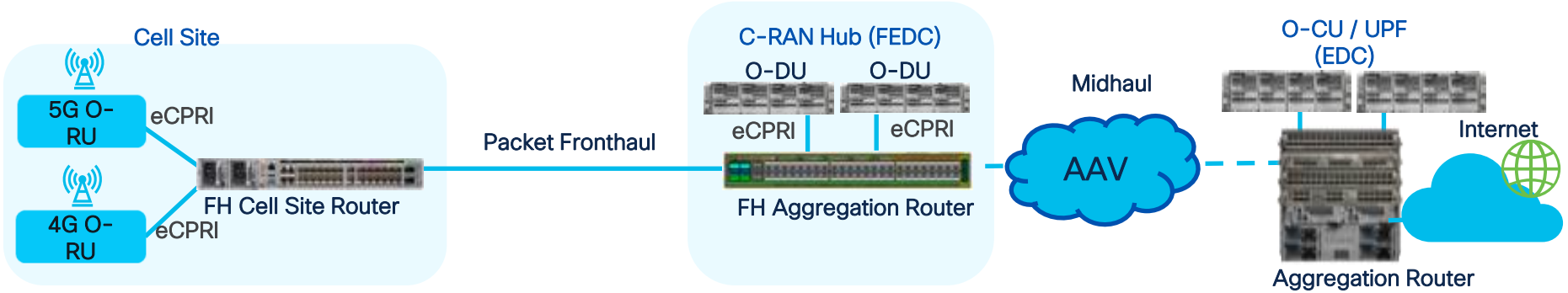
Cloud RAN Transport Solution
vRAN/ORAN Deployment



O-RU= Radio Unit
FH = Fronthaul
O-DU= Virtual Distributed Unit
O-CU=Virtual Centralized Unit
AAV= Alternate Access Vendor aka Backhaul provider
FEDC=Far Edge Data Center aka Pre-Agg
EDC=Edge Data Center aka Aggregation
UPF=Packet core user plane function

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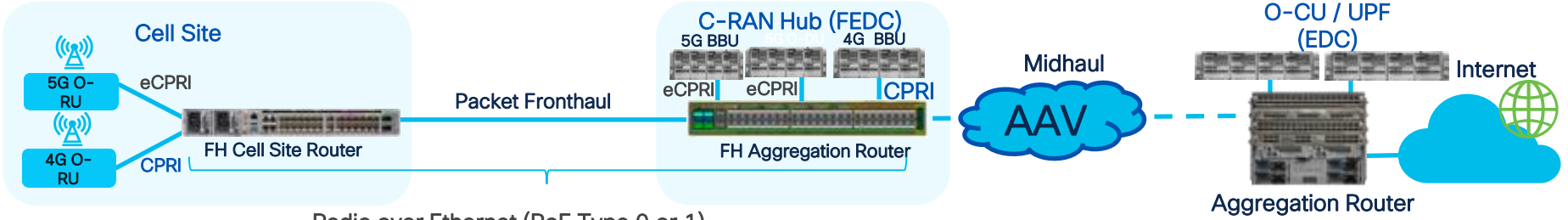
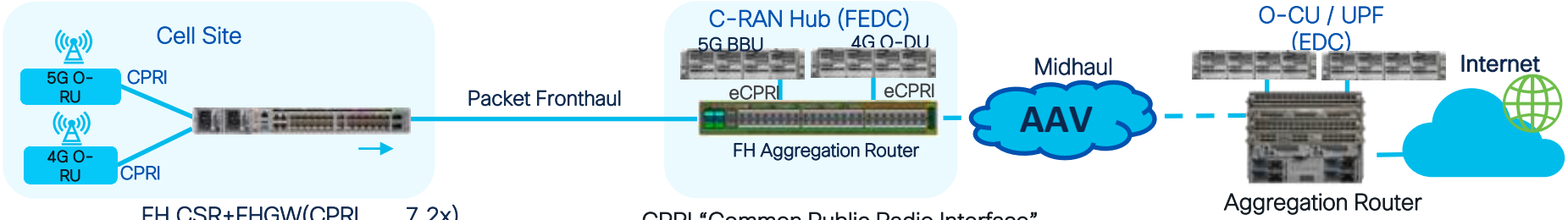
Cloud RAN Transport Solution
Brownfield Deployment HENS* vRAN/O-RAN





*HENS= Huawei, Ericsson, Nokia & Samsung

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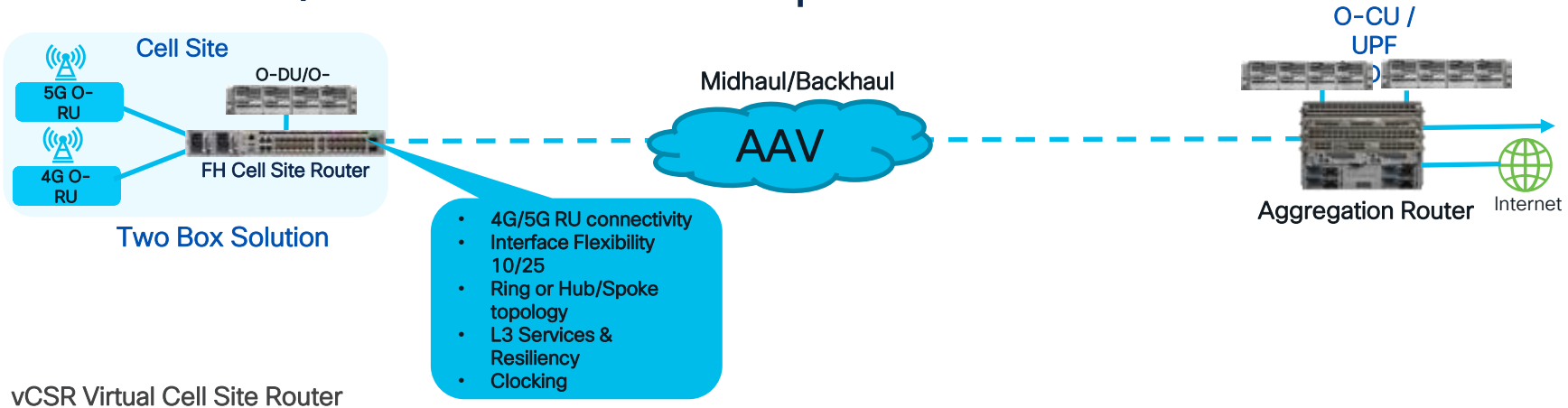
Midhaul/Backhaul Transport Solution



- Compute deployment (cabinet & IP65) will be typical at cell site
- Due to space and power constraints, only a single compute platform

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Fronthaul and Midhaul Transport Latency Requirements

Network	Split Options	Transport Latency (One Way)	Distance	Traffic Types & Packet Size
Midhaul (F1)	Option 2: PDCP-RLC	5 ms – 10 ms	> 20KM	• F1-U & F1-C (IP) | 800-9K bytes
Fronthaul (F2)	Split 7 Split 7.2x (O-RAN)	• 75 us / 100 us (HENS*) • 160 us**	< 40KM	• User Plane & Control Plane - VLAN tagged | 800-9K bytes • Synchronization plane is untagged multicast | <1500 bytes • Management plane is IPv6/IPv4 routed |<1500 bytes

	Latency	
Fiber Latency	5 us / km	20 km = 20 x 5 = 100 us

Latency Number varies with RAN vendor implementation. Check with your RAN vendor.

*HENS= Huawei, Ericsson, Nokia & Samsung
**O-RAN.WG4.IOT.0-v03.00 (NR TDD|NR FDD|LTE TDD|LTE FDD IOT Profile)

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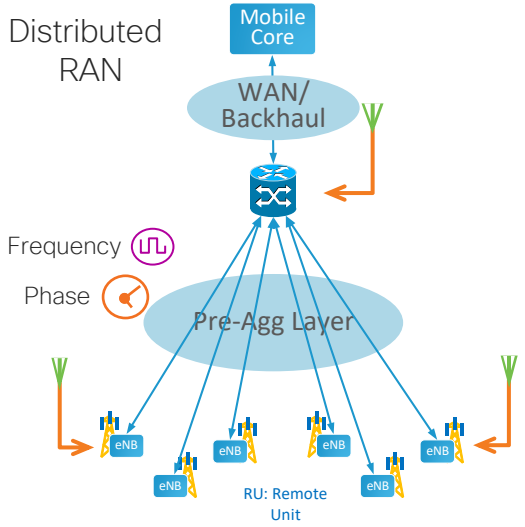
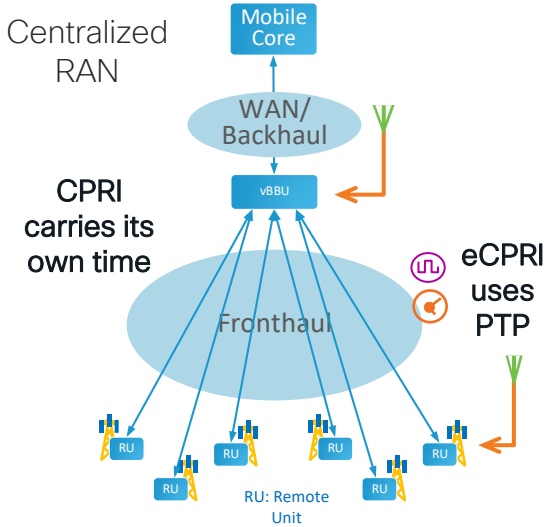
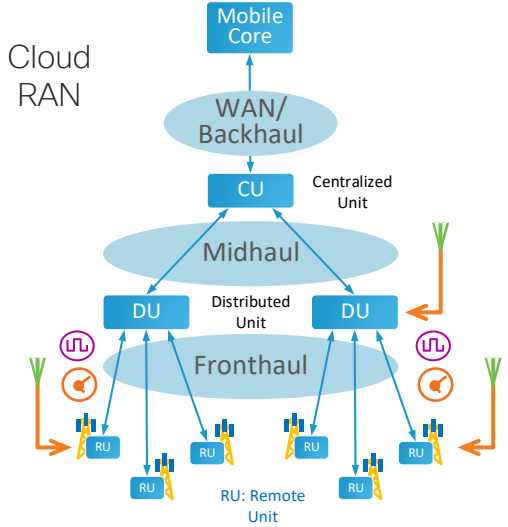
Timing and Synch – Fronthaul Options

Distributed RAN	Centralized RAN	Cloud/Midhaul RAN
• ±1.5uS phase between radios • Backhaul carries sync from pre-aggregation layer; or • GPS at every cell site	• < ±1.1uS between BBU's • Backhaul carries sync or place GPS at every BBU hotel • CPRI is synchronous; but eCPRI requires PTP or GPS	• ~±130nS between RU/DU • Midhaul carries sync or GPS at every DU hotel • eCPRI requires PTP in Fronthaul or GPS at every RU and DU







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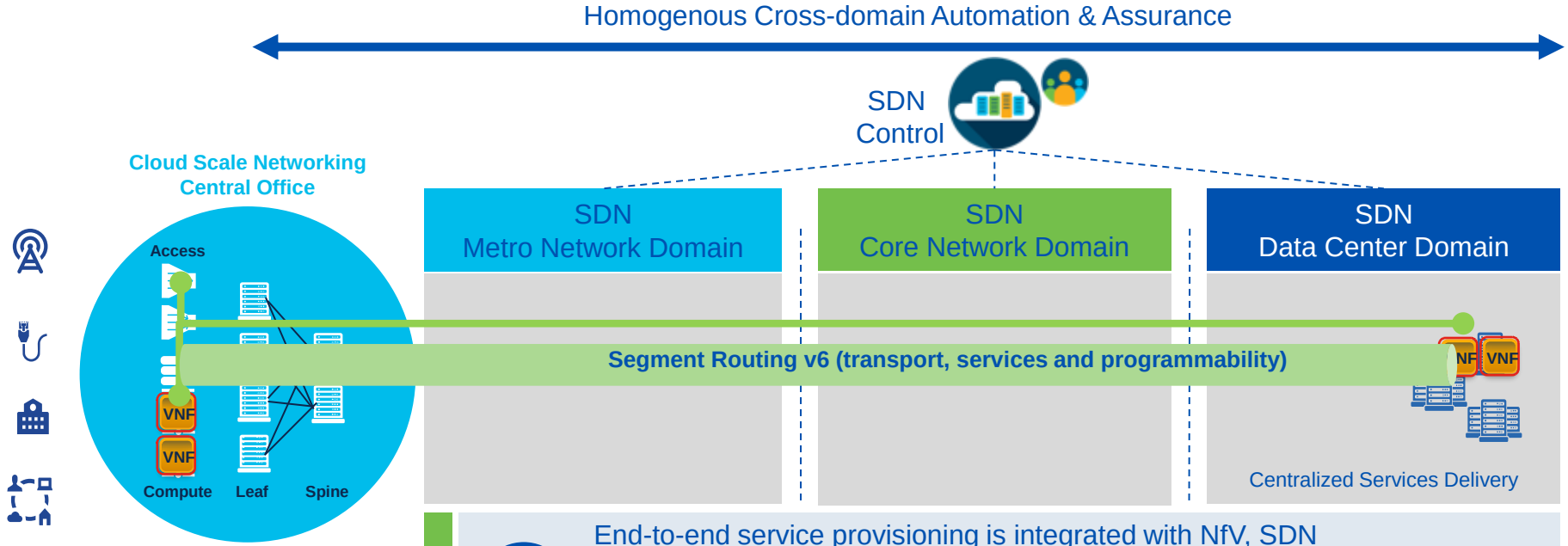
SRv6: SDN, NfV, 5G ready
“Network as an API” for Service Creation



End-to-end service provisioning is integrated with NfV, SDN

- Multiple network domains under same management teams
- Automated operations
- Integrated underlay and overlay networks (NfV)
- Network as API (NfV)
- Hyper Scale (5G)

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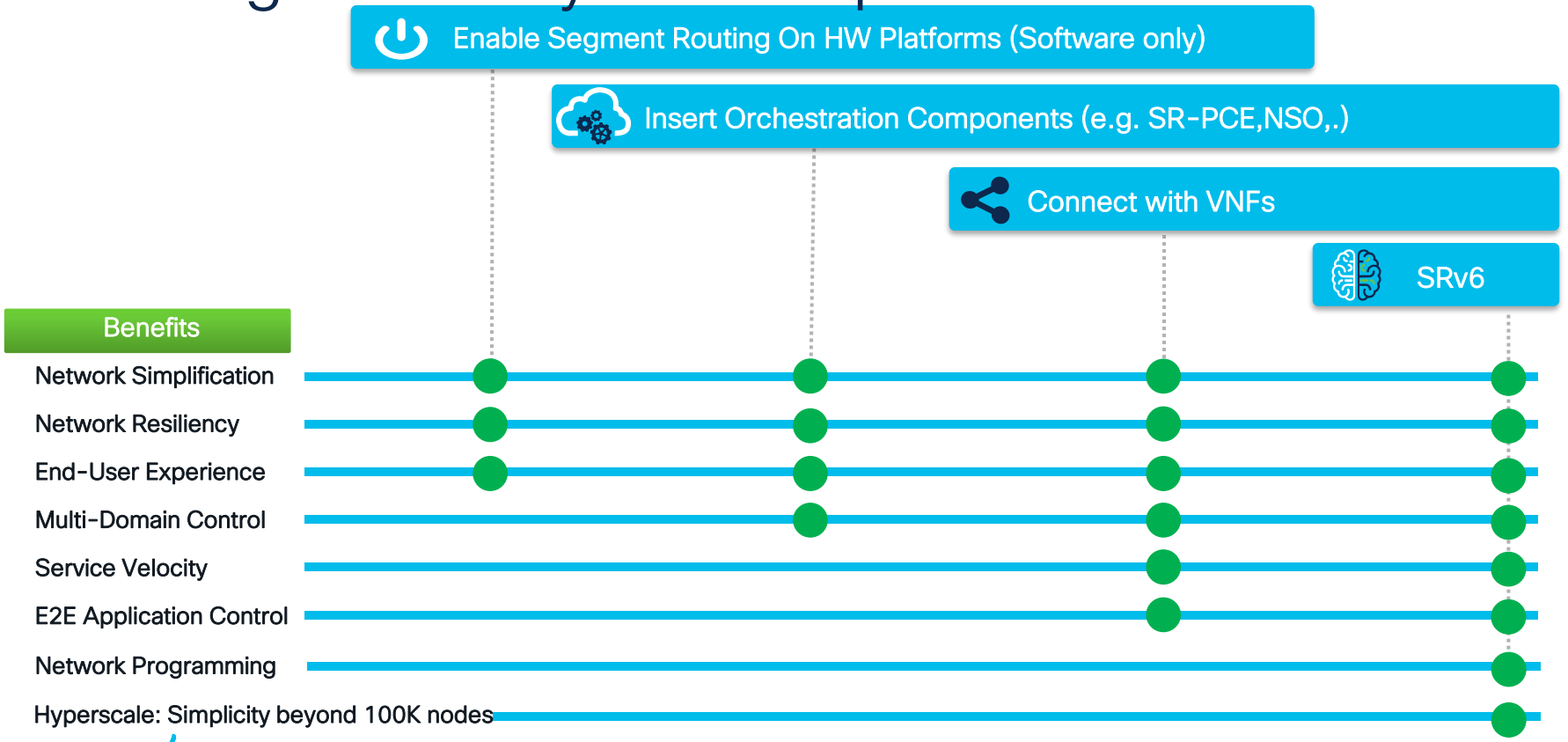
Segment Routing Journey
Adding value at your own pace



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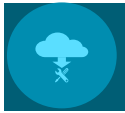
SP Workloads differ from Enterprise/IT Applications



SP Workload Network Requirements

- BGP/MP-BGP, Anycast, L3VPN, BFD & QOS
  - To enable connectivity within cloud and the on-premises network to cloud
    - Dynamic routing in the cloud
    - Network separation (VRF Inter-DC)
    - Traffic isolation across on-premises, public cloud, and third parties (like voice aggregators, regulatory entities, etc.).
    - IP overlapping at peering partner networks (VRF)
  - High Availability, routing it to the standby NF in case of failure
  - Geo-Redundancy to enable service continuity during outage
  - Link/Network error detection
  - Network Slicing
- Routing features at scale
- Unified forwarding and service plane across on-premises and cloud environments enabling flexible workload placement
- Standard routing technologies common across clouds & on-premises enabling hybrid & multi-cloud
- no cloud lock-in

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NCS 5700 – Fixed Portfolio
High Scale Aggregation

NCS5700 Products J2/J2c/J2C+

NCS-57D2-18DD-SYS

- 400G ZR/ZR+
- 2RU; 7.2 Tbps throughput
- 2x400G +16x400G/64x100G
- MACSEC, IPsec*
- Class C Timing

NCS-57B1-6D24

- 400G ZR/ZR+
- 1RU; 4.8 Tbps throughput
- 24x100G + 6x400G
- MACSEC, Timing

NCS-57B1-5DSE

- 400G ZR/ZR+
- 1RU; 4.4 Tbps throughput
- 24x100G + 5x400G
- MACSEC, Timing
- External TCAM

NCS-57C3-MOD-S

- 400G ZR/ZR+
- 3RU; 2.4T throughput
- Fixed: 48x1/10/25G + 8x100G QSFP28
- 3 x MPA: 2x800G + 1x 400G
- MACSEC, Timing

NCS-57C3-MOD-SE

- 400G ZR/ZR+
- 3RU; 2.4T throughput
- Fixed: 48x1/10/25G + 4x100G QSFP28
- 3 x MPA: 2x800G + 1x 400G
- MACSEC, Timing
- External TCAM

NCS-57C1-48Q6D-S

- 400G ZR/ZR+
- 1RU; 2.4T throughput
- 32x1/10/25G + 16x1/10/25/50G + 6x400G
- MACSEC, Timing

Trust · Segment Routing · EVPN · MACSec · Timing · 400G ZR/ZRP

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NCS 540 Medium Density Routers

N540X-16Z4G8Q2C-D/A

N540X-12Z16G-SYS-D/A

	Interfaces	Throughput	Timing	Power
N540X-16Z4G8Q2C-D/A	2x 100/40GE 8x 25/10/1GE 16x 10/1GE 4x 1GE Cu	300G Max Interfaces: 564G	GNSS Class C	Fixed: 1 AC 1+1 DC
N540X-12Z16G-SYS-D/A	12x 10/1GE 12x 1GE 4x 1GE Cu	160G Max Interfaces: 136G	GNSS Class C	Fixed: 1 AC 1+1 DC

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NCS 540 Large Density Router

N540-24Q8L2DD-SYS

Interfaces	Throughput	Timing	Power
2x400GE 8X50/25/10/1GE 24x25/10/1GE	800G Max Interfaces: 1TB	GNSS Class C	Modular: 1+1 AC/DC

QDD-400G-ZR-S

QDD-400G-ZRP-S

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NCS 540 Small Density Routers

N540X-6Z18G-SYS-D/A

N540X-8Z16G-SYS-D/A

N540X-4Z14G2Q-D/A

Interfaces	Throughput	Timing	Power	Release
6x 10/1GE 18x 1GE	64G Max Interfaces: 78G	Class C	Fixed: 1+1 AC 1+1 DC	Feb 2021
8x 10/1GE 4x 1GE SFP 4x 1GE RJ45 8x 1GE SFP or 16x 1GE cSFP	120G Max Interfaces: 104G	Class C	Fixed: 1+1 AC 1+1 DC	Feb 2021
2x 25/10/1GE 4x 10/1GE 10x 1GE 4x 1GE Combo SFP/RJ45	120G Max Interfaces: 104G	Class C	Fixed: 1+1 AC 1+1 DC	Aug 2021

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NCS 540 Fronthaul Routers

N540-FH-CSR-SYS

N540-FH-AGG-SYS

Interfaces	Throughput	Timing	Power	Release
8xCPRI +*4x1/10G/CPRI, 8x1/10G , 4x10/25G 2x10/25G (802.1Qbu) 2x100G	300G Max Interfaces: 550G**	Class C	Modular 1+1 AC 1+1 DC	Feb 2021
24x10G/25G* (802.1Qbu, CPRI 3-8) 4x100G	900G Max Interfaces: 1000G	Class C	Modular 1+1 AC 1+1 DC	Feb 2021

*Universal Port = Port can be used for CPRI or eCPRI or Ethernet (1/10/25GE)

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Slicing Overview

Intent with Transport Network Slicing : A Definition

Network Slicing is fundamentally an end-to-end partitioning of the network resources and network functions on a shared infrastructure so that selected applications/services/connections may run in isolation from each other for a specific business purpose

Its about offering:

1) Service Intent and Abstraction
2) End to End Service Level Agreements (SLAs)
3) SLOs: Delay, jitter, loss, availability
4) SLEs: Disjoint paths, encrypted paths, etc.

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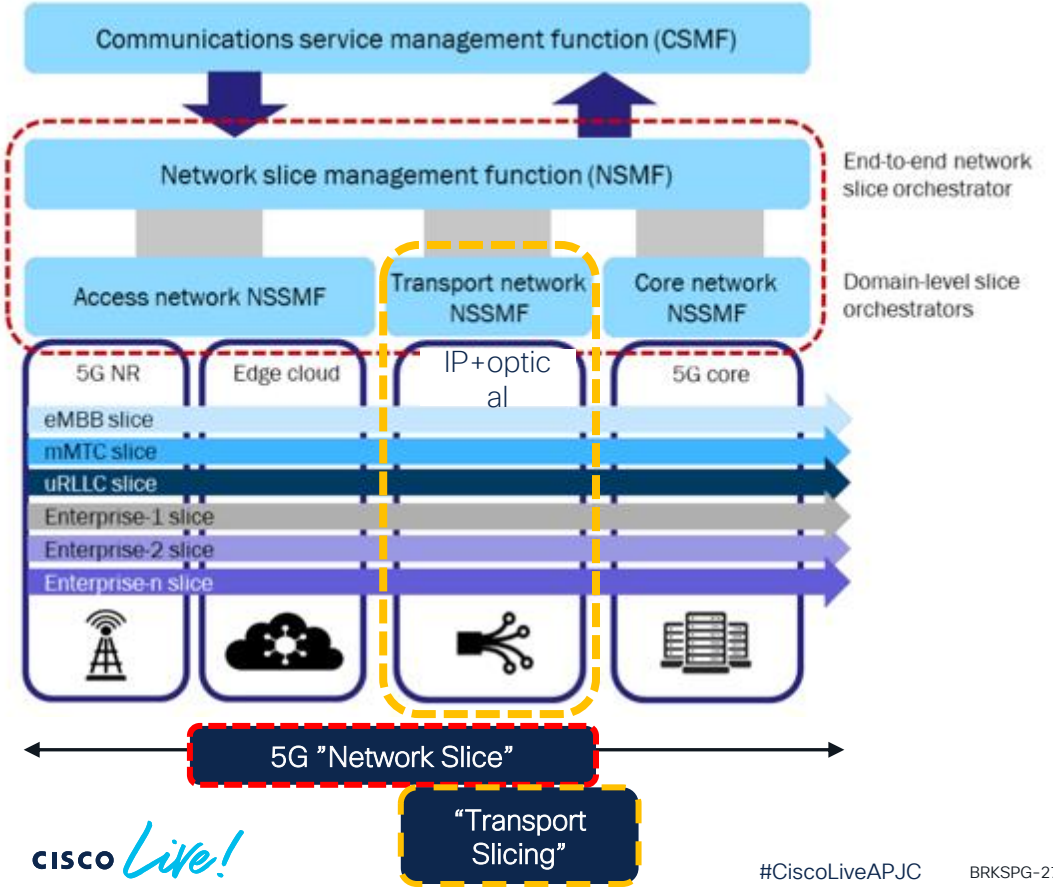
Defining Transport Slicing Scope: 3GPP reference architecture for 5G network slicing



NSMF= Network Slice Mgmt. Function
NSSMF= Network Slice Subnet Mgmt. Function
NST= Network Slice Template
NSST= Network Slice Subnet Template
NSI= Network Slice Instance
NSSI= Network Slice Subnet Instance

Scope of 5G *Network* slice management

Scope of *Transport* slice management

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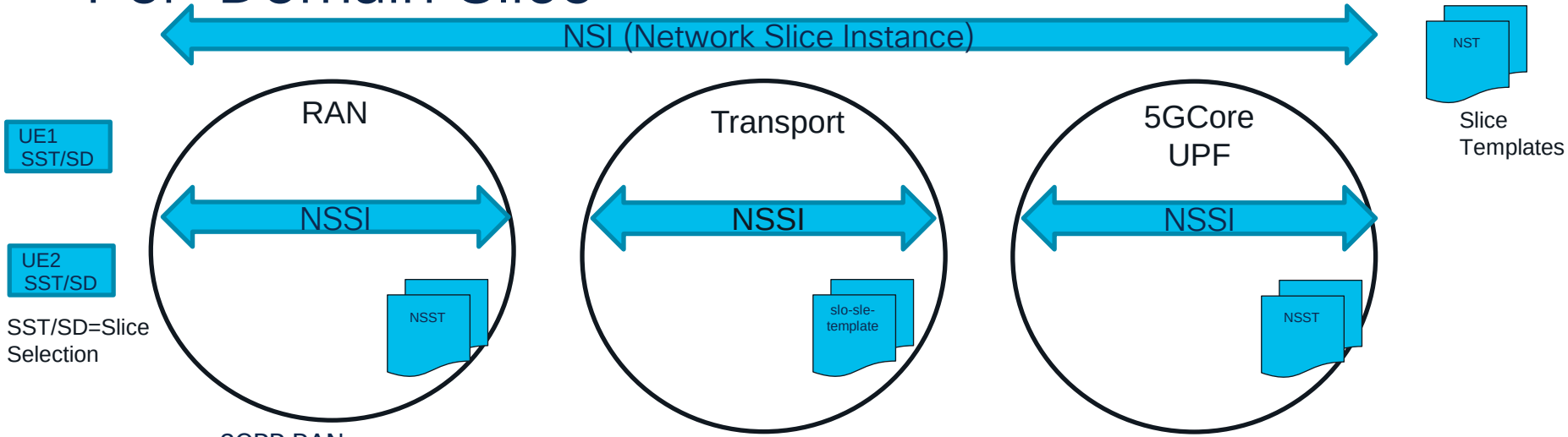
Per-Domain Slice



- 3GPP RAN
- O-RAN
  - O-RAN.WG1.Slicing-Architecture-v08.00 (Oct 2022)
  - O-RAN.WG8-IOT-v05.00 (Oct 2022)
  - O-RAN.WG1.Study-on-O-RAN-Slicing-v02.00 (April 2020)

- O-RAN
  - O-RAN WG9 Xhaul Packet Switched Architectures and Solutions 3.0
- IETF

- 3GPP SA/CT

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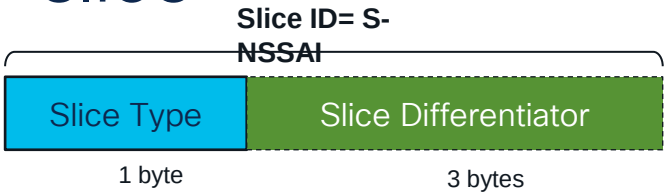
How is a user/UE placed into a “slice” 3GPP- 5G Slice ID= ST/SD

Standard Slice Type (STT) Values

TS 23.501, section 5.15.2.2-1

3GPP 23.501 defines a set of default values for SST as listed in the following table:

Slice/Service type	SST value	Characteristics
eMBB	1	Slice suitable for the handling of 5G enhanced Mobile Broadband.
URLLC	2	Slice suitable for the handling of ultra- reliable low latency communications.
MIoT	3	Slice suitable for the handling of massive IoT.
V2X	4	Slice suitable for the handling of V2X services.



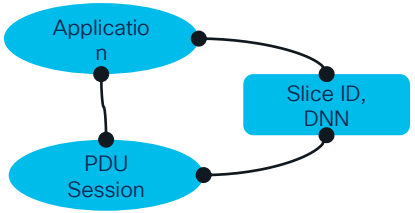
S-NSSAI: Single Network Slice Selection Information

Slide ID Set: NSSAI

- Ultimately, the control plane (AMF) uses the S-NSSAI (sliceID) from the UE to drive selection of a UPF for the user.
- S-NSSAI can also be used by RAN to select a CU-UP.

SP Custom Slice Services??	Slice Type (SST) (examples)
Link Affinity-Blue Links	100
Max Delay 20ms	101
Encrypted Links	102

Example: Custom slices SP defined



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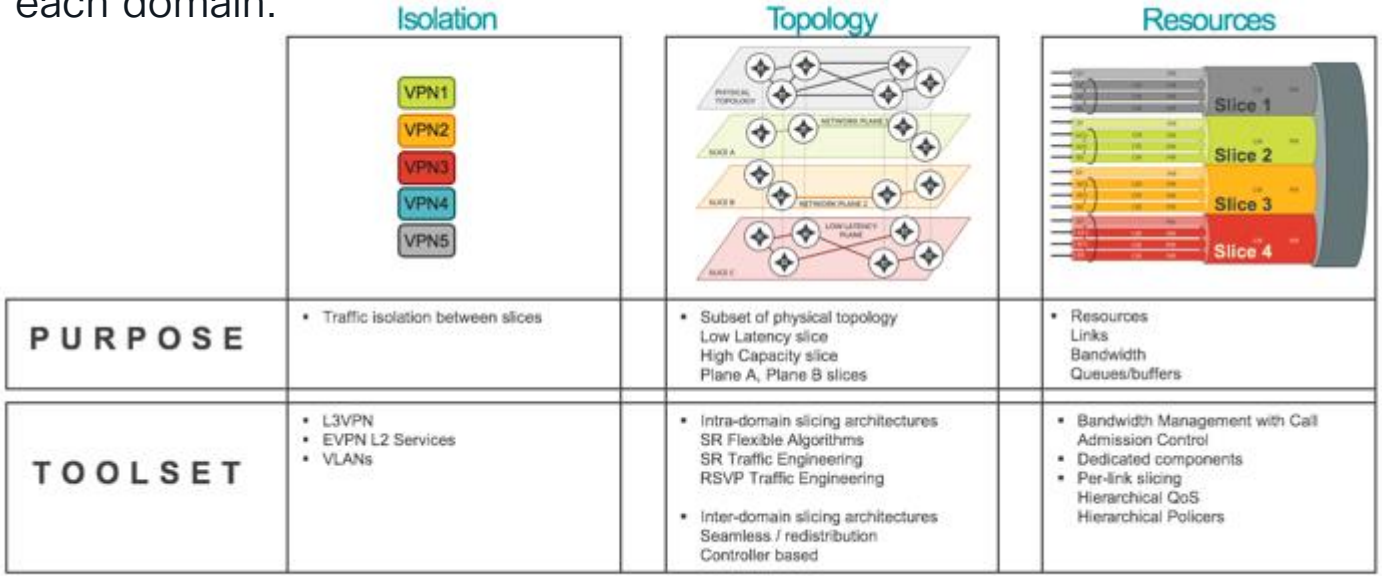
Adapted from O-RAN WG-9 Packet Switched xhaul Architecture and Solutions

O-RAN 5G Transport Architecture

- 5G transport slicing
  - Transport separation between Fronthaul, Midhaul, Backhaul interfaces.
  - Transport separation between Control, management, and user plane interfaces of each domain.



Source: O-RAN Xhaul Packet Switched Architectures and Solutions

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Cisco Toolset for transport level slicing

- QoS and H-QoS: Core and edge
- Forwarding Planes: Shortest Path / SR policies (SRv6 / SR-TE / Flex-algo / Circuit-Style)
- SR underlay performance management tools (SR-PM)

Creating and managing the forwarding plane

Combining these offer different levels of transport slice separation (ie soft or hard slice solutions)

- Virtual Private networks : L2 / L3 VPNs
- ODN and Automated traffic Steering (AS)
- VPN performance management tools (TWAMP, Y1731)

Slice isolation and mapping to slice forwarding planes.

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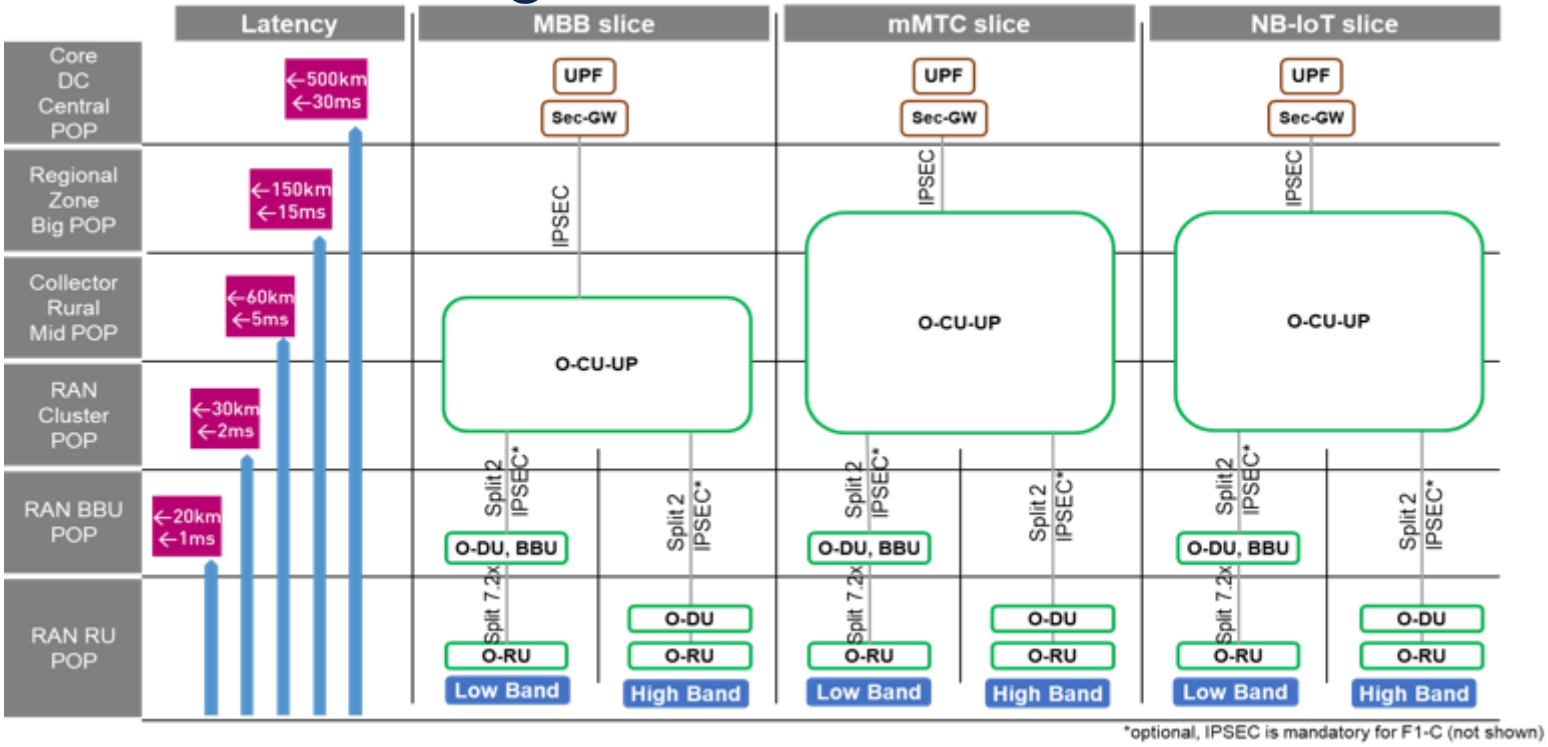
5G O-RAN Slicing: Phase 1

- Only Backhaul slicing
- No Midhaul and Fronthaul slicing
- Centralized UPF



Source: O-RAN Xhaul Packet Switched Architectures and Solutions 3.0 (O-RAN.WG9.XPSAAS-v03.00)

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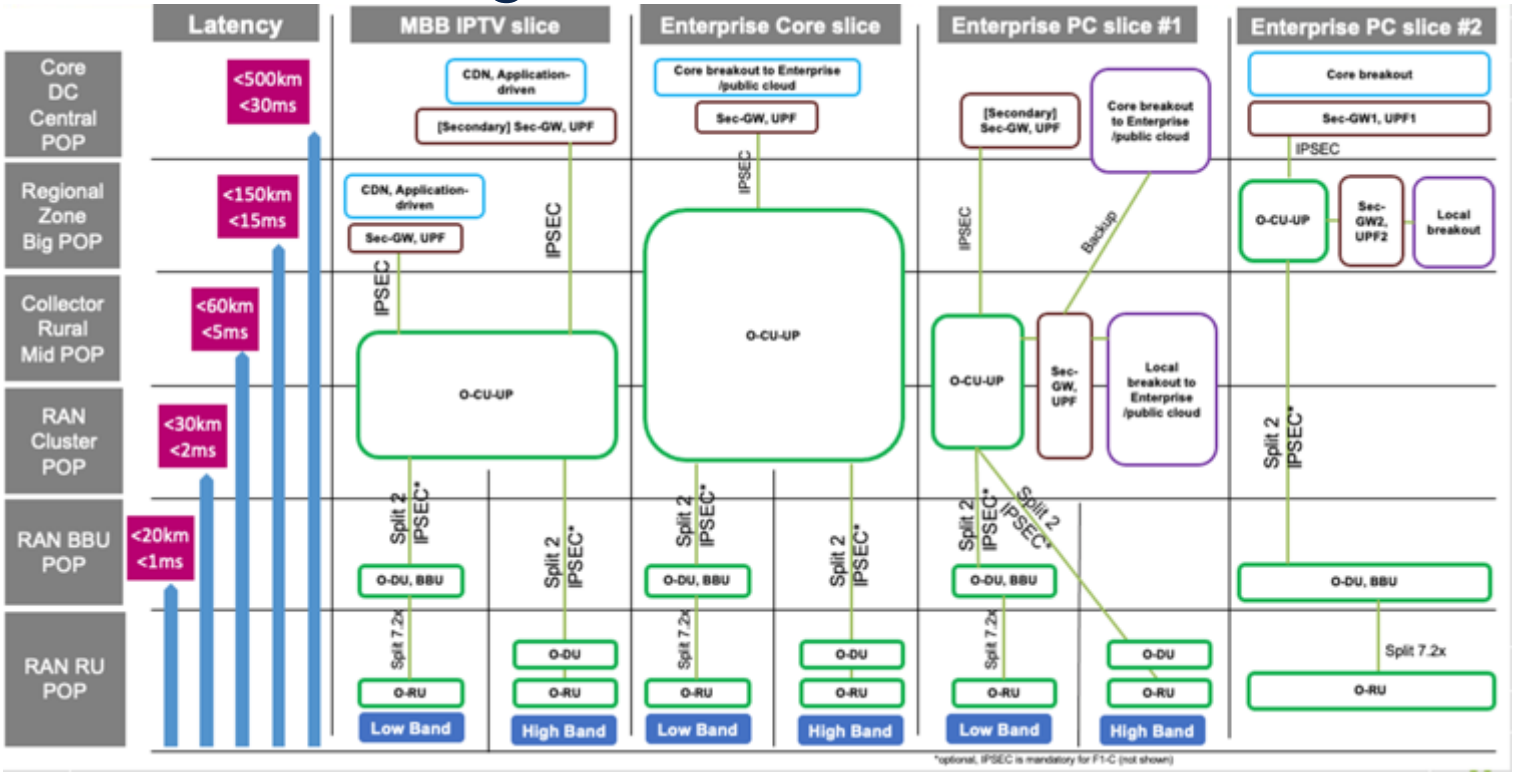
5G O-RAN Slicing: Phase 2

- **Backhaul & Midhaul slicing**
- **No Fronthaul slicing**
- **Distributed UPF**



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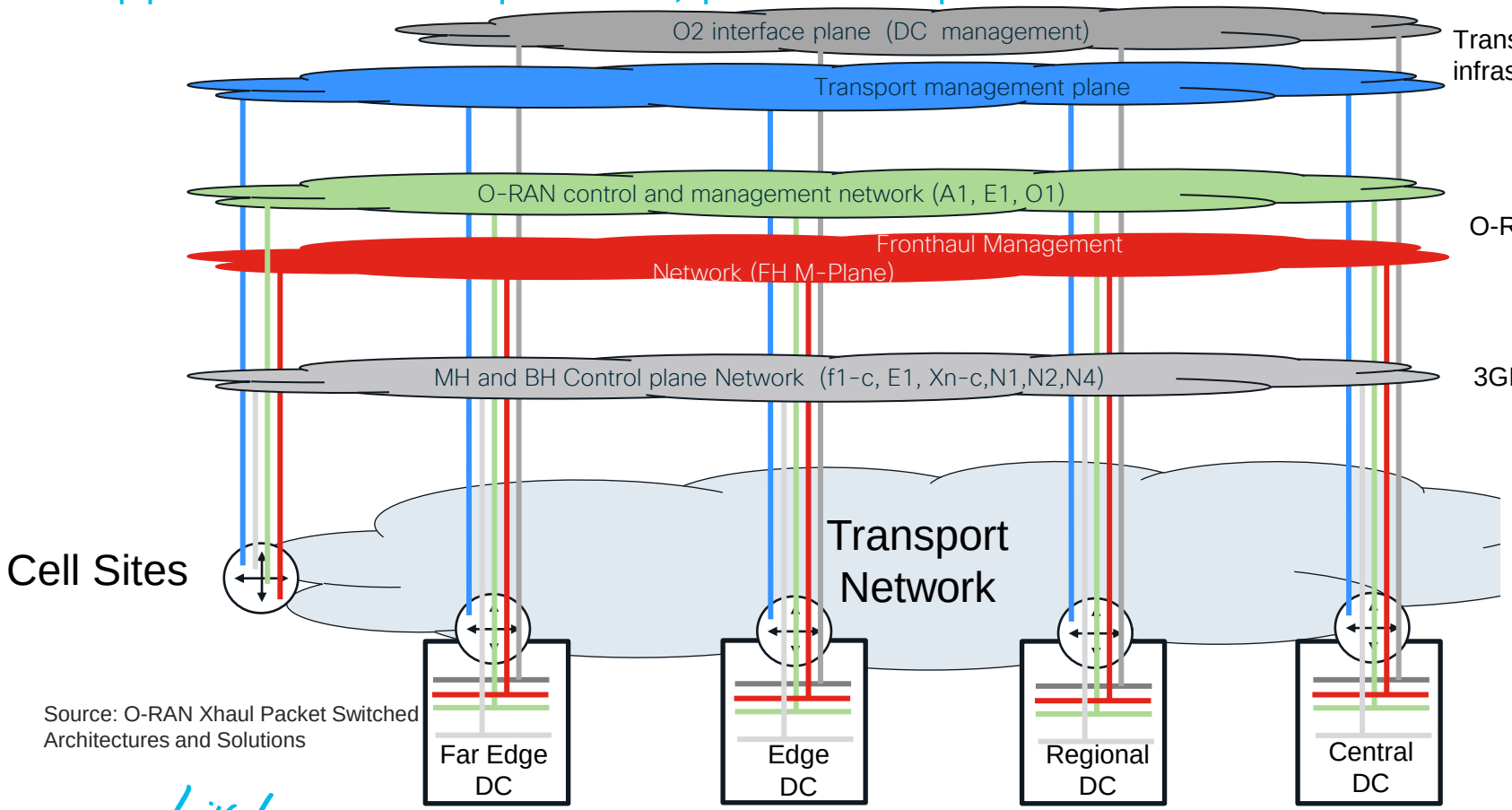
Control and Management Plane VPNs architecture

Applicable to both phase 1, phase 2 & phase 3



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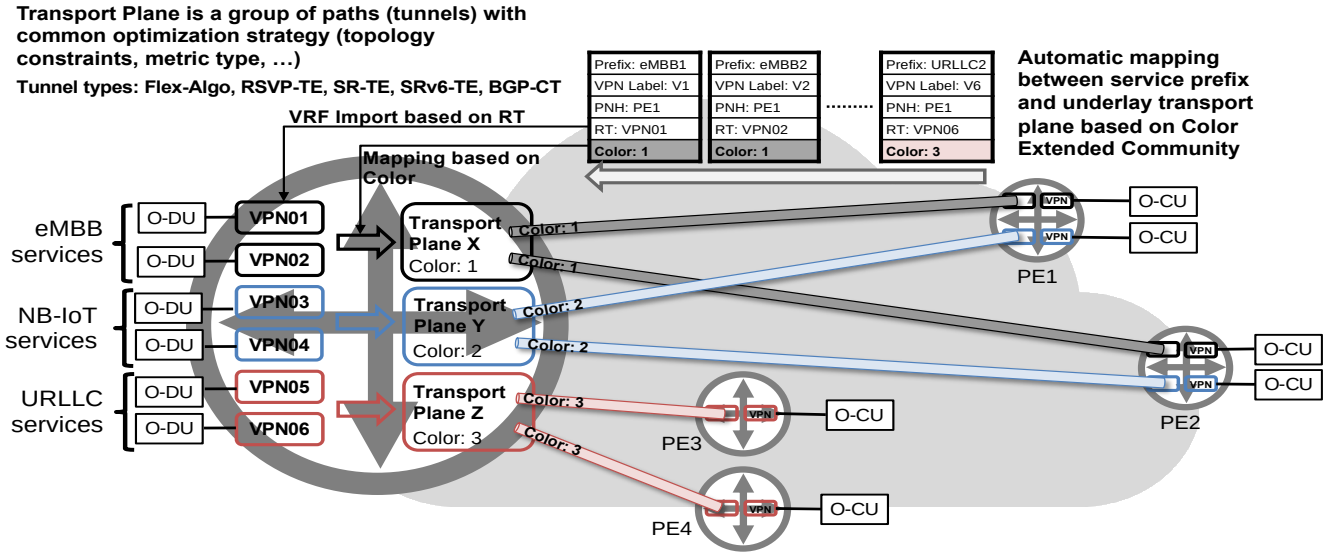
Packet-switched underlay network
Transport plane per 5G service type



- Within the underlay network, multiple transport planes are built to meet the specific forwarding behaviors associated with the different 5G services types.
- VPNs and traffic steering techniques
- The transport planes can utilize different topologies and be optimized based on different criteria

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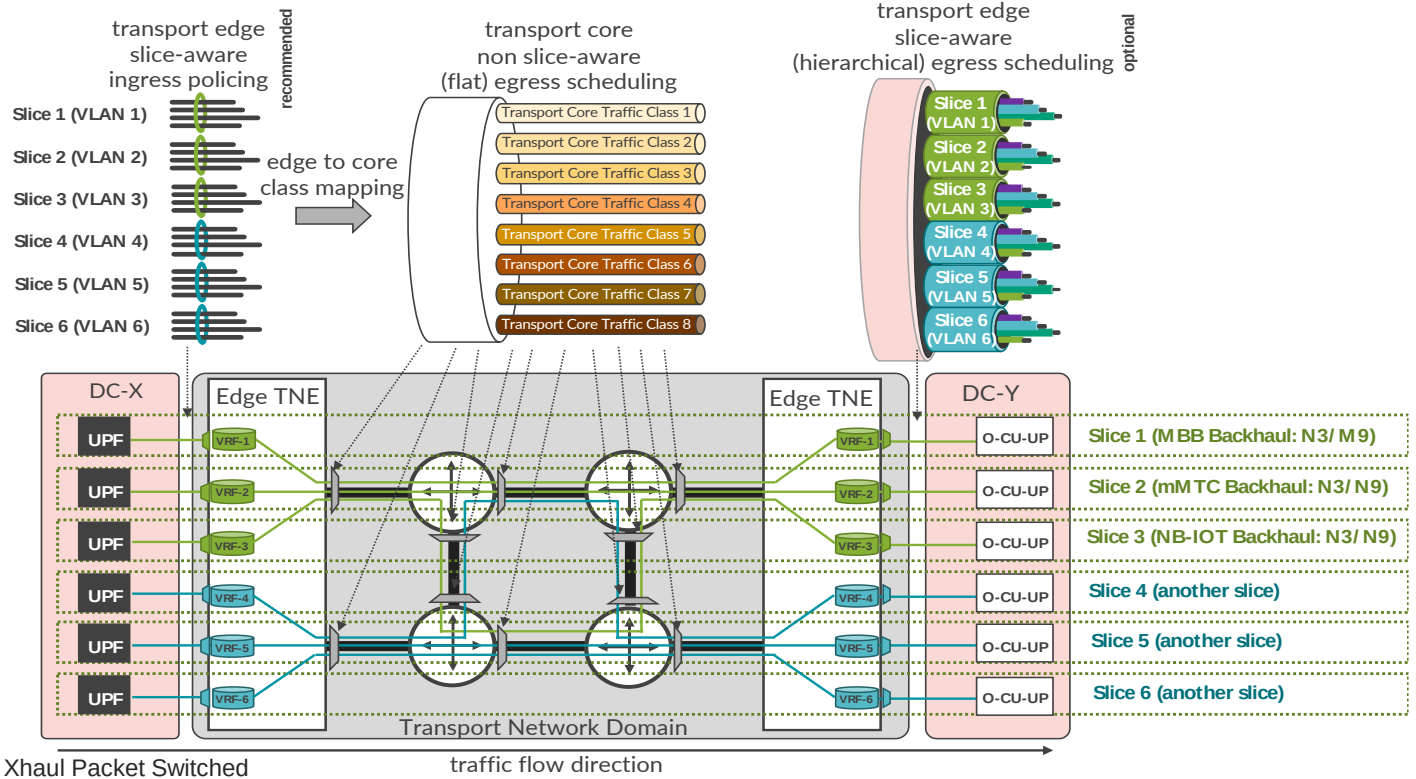
High-level QoS model for transport slices



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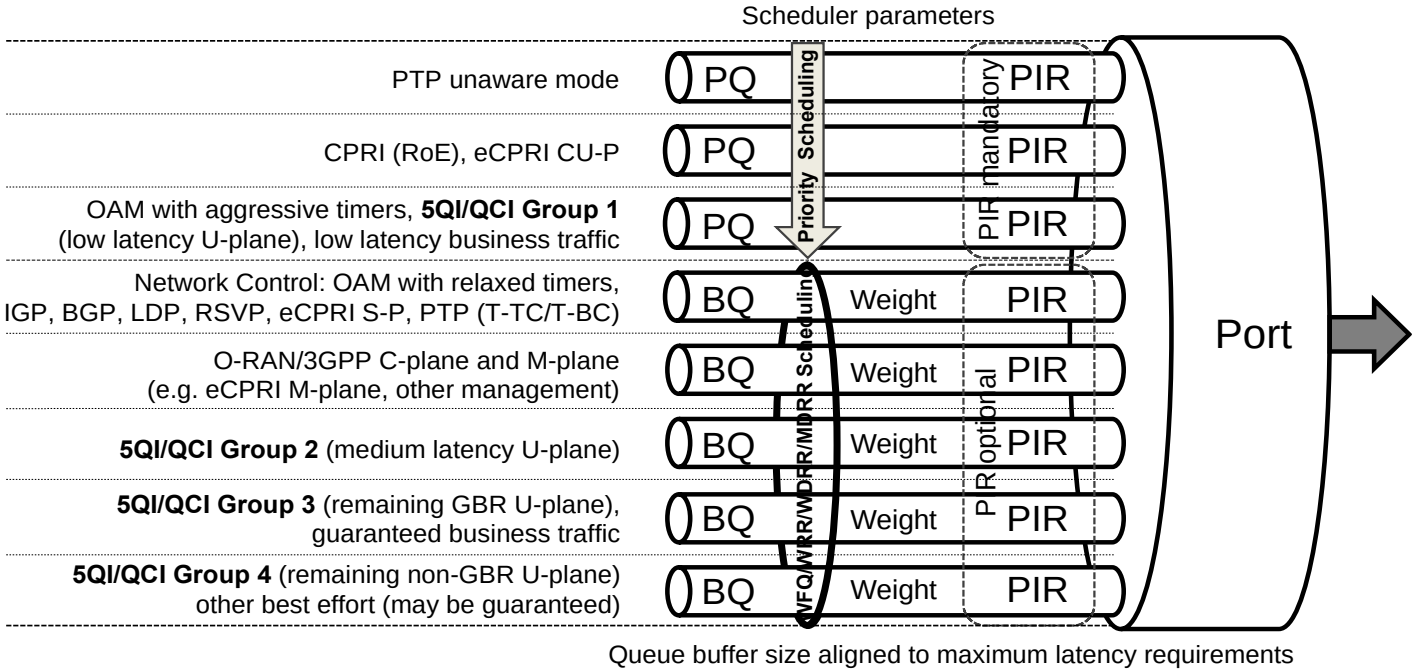
Example of QoS model with multiple priority queues



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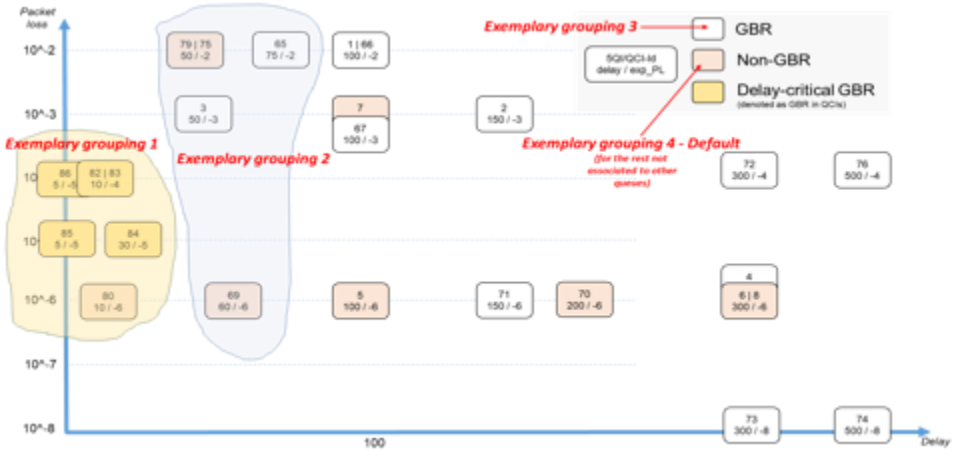
Packet Switched Slicing : Quality of Service
Recommendations for grouping of standard QCI/5QI

*



- Diffserv model
- Fronthaul impacts traditional QoS designs
- 5QI/QCI groupings by behavioural characteristics
- Example core queue design and mapping examples for multi-service environment

Source: O-RAN Xhaul Packet Switched Architectures and Solutions

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Models describe intent

- A service model describes all the things you can do with the service
- Models allow for
  - A common abstraction of intent
  - A standard way of exchanging data (w/protocol)
- YANG Modeling language is becoming the clear leader here

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Abstracting the Service Intent

Before

Imperative, Not intent based, Not tied together

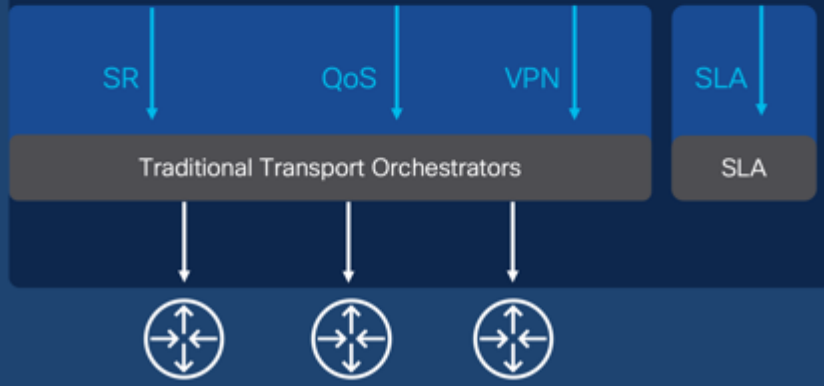
Northbound Workflow/OSS/BSS

Create SR-TE policy
- Head-ends
- BGP colors
- Path preferences
- PCE based
- Constraints
- Etc.

Create QoS policy
- Policy-maps
- Class-maps
- QoS groups
- Etc.

Create route policy
- Color specific prefixes

Create VPN-profile
Create L3VPN
- VPN-id
- Route-targets
- AS#s
- Endpoints
- PE-CE addressing
- Create SA probes/ external SLA tools

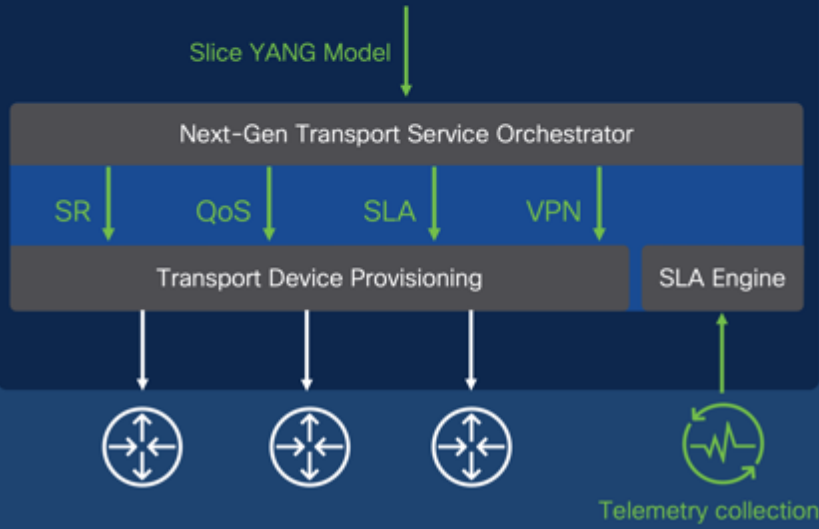


After

Declarative, Intent based, Service oriented

Lite-Weight Workflow/OSS/BSS

Connect endpoints X , Y and Z in an any-to-any topology with:
- SLO of <10ms delay
- <.00009% Loss
- SLE to use only high speed (>100G) links with encryption



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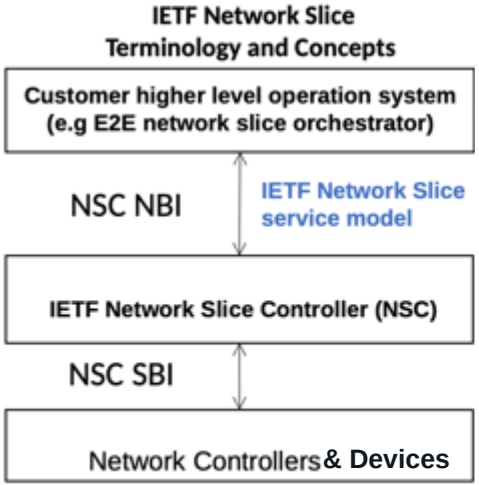
Why IETF Network slide service YANG?

- draft-ietf-teas-ietf-network-slices defines IETF Network Slice Service, and also define IETF NSC NBI as a technology-agnostic interface for creation/modification/deletion of the IETF Network Slices; it expresses requirements of what is required rather than how that is to be achieved (**intent**)!
- Based on RFC8309, IETF NSC NBI is thus classified as **customer service model**. Existing customer service YANG modules are all technology specific, e.g. L3SM, ACTN VN (tight coupling to TE)
- A network slice service YANG module is needed when a SP provides "slicing as a service", so the customer could focus on the service requirements rather than the technical implementation



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ATT DISH hosted Spring O-RAN Plugfest, 2022

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Cisco and Keysight
Demonstration of WG9 XHaul Transport Specifications over SRv6 for FH, MH and BH

4th Global O-RAN PoCFest

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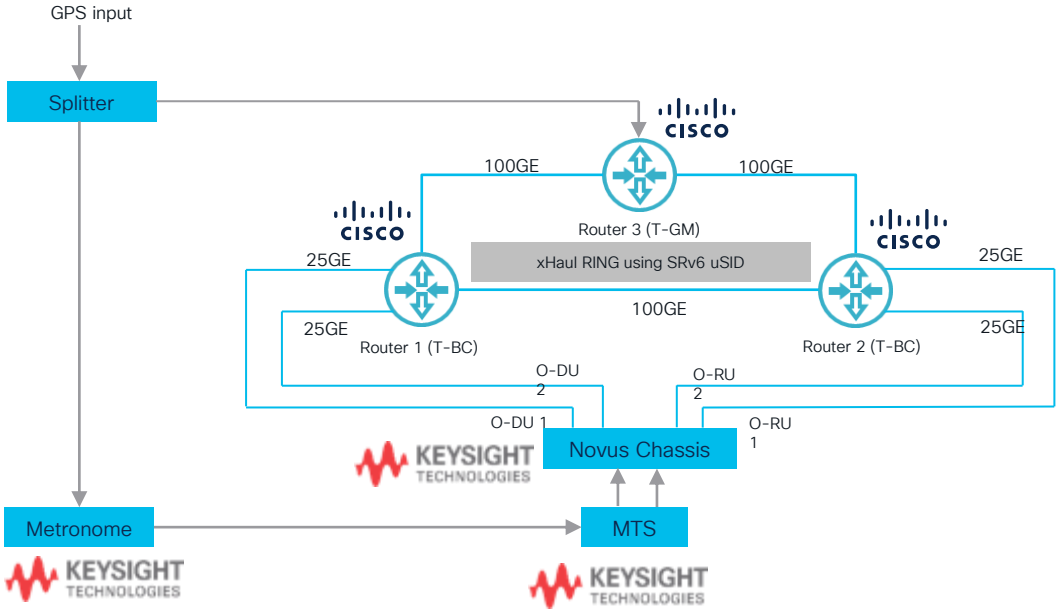
Testbed Setup



- Keysight ORAN Transport Test solution is used to simulate CUSM traffic between RU and DU.
- Keysight's Novus simulated 2 RUs, and 2 DUs on separate interfaces.
- GPS input is given to Cisco Router, which is configured as T-GM to distribute clock across transport to synchronize RUs and DUs simulated by IXIA.
- Metronome Timing System is also provided with GPS input. Metronome used GPS input as a reference to measure time error received from transport on Keysight Novus ports.
- Traffic is sliced in RING topology using SRv6 uSID based topology: FH data plane traffic is carried in low latency L2 EVPN slice, while FH management plane traffic is carried over L3 VPN slice.
- Characteristics of xHaul transport; FH, MH and BH is measured against latency, Jitter, Synchronization and convergence.

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Test Scenario Introduction

ORAN WG9 Test	TEST	DESCRIPTION	Results	Status
8.2.1	eCPRI over SRv6 uSID	• Keysight Novus emulates 2 pairs of O-DUs and O-RUs, • Each configured with 2 X 400 MHz downlink and uplink carriers • The traffic between ODU and ORU carried over SRv6 xHaul transport	• Latency for eCPRI traffic over SRv6 transport: 11 us • For non-eCPRI traffic: 28 us	PASS
8.2.2	Constraints based eCPRI transport over SRv6 uSID	• FA Slice (latency metric) is created in the network • R1 -R3 IGP metric is manually increased • EVPN service is moved to FA slice		PASS
8.2.4	L3VPN Service verification over SRv6 uSID	• L3VPN is created between each pair of O-DU and O-RU to carry M-plane traffic simulated by Keysight Novus		PASS
8.4.2	VLAN manipulation	• eCPRI streams are VLAN tagged by Keysight Novus • VLAN is popped by routers R1 and R3		PASS
8.4.4	jitter verification	• Keysight Novus measures latency and jitter with different frame size transported over EVPN VPWS in the presence of high bandwidth low priority background traffic	• Average Jitter for eCPRI traffic over SRv6 transport: ~ 600ns	PASS
8.5.5	Convergence	• Interface connecting R1-R3 shut down • eCPRI streams and M-plane streams are moved to backup path • Interface connecting R1-R3 restored • eCPRI streams and M-plane streams are moved to primary path	• Convergence time during link failure: 22ms	PASS
9.1.14	Time Synchronization testing	• Router 3 is T-GM. Both Router 3 and Ixia receives same GPS signal • Keysight Novus receives PTP from all the ports emulating O-DU and O-RU • Keysight Novus measures PTP time error against own reference and plot time error graph	• Relative time error: <30ns	PASS
9.1.16	Time Synchronization testing with background traffic	• While sending and receiving eCPRI streams and M-plane streams, Keysight Novus measures PTP time error against own reference and plot time error graph.		PASS

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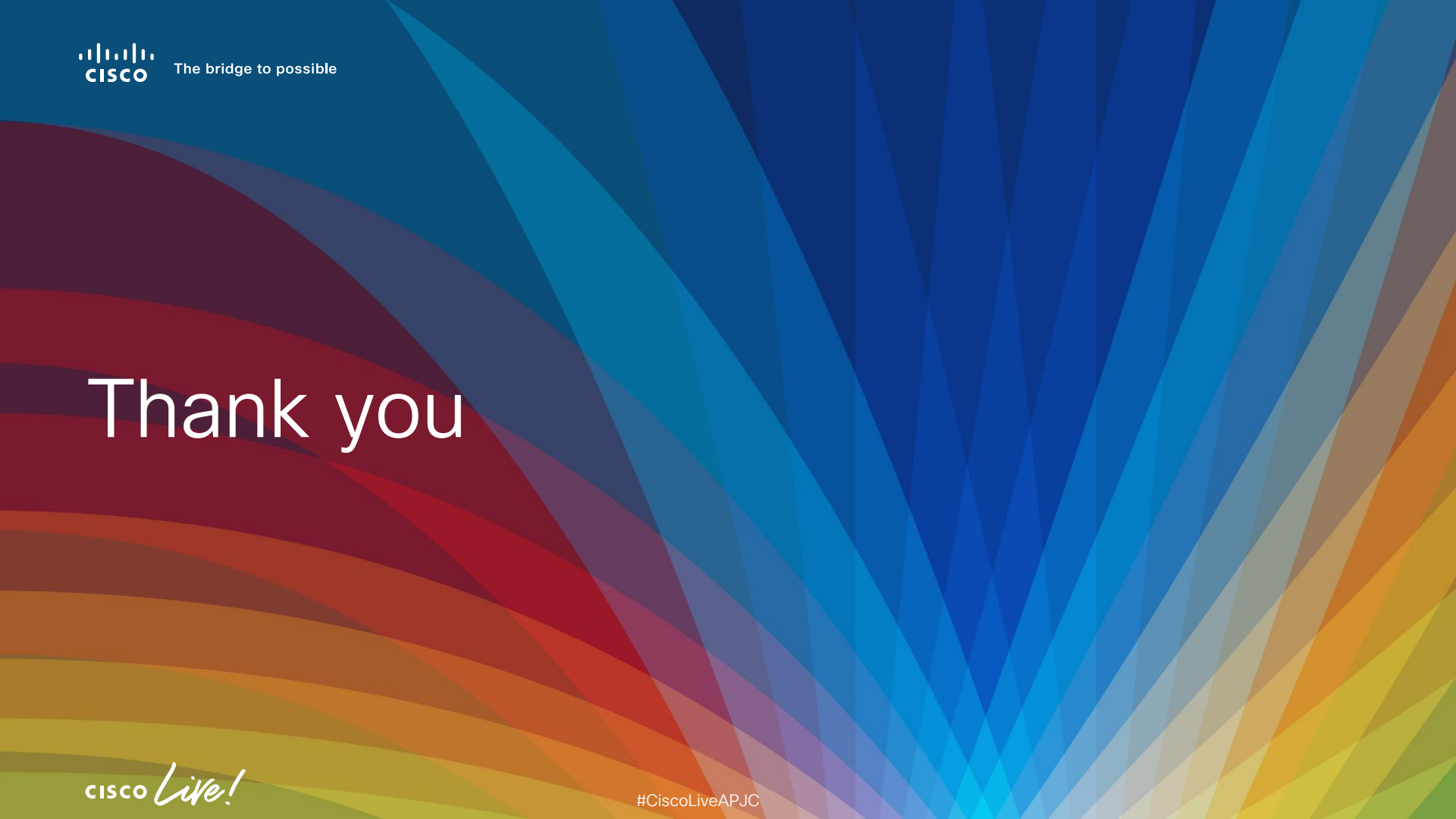
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