The bridge to possible

Cloud-Ready Converged SDN Transport

5G Network Evolution to Hybrid / Multi-Cloud

Waris Sagheer, MIG CTO, Cisco Systems Inc.

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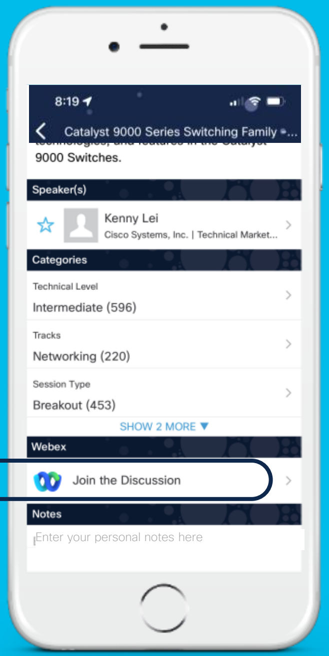


Webex spaces will be moderated until February 24, 2023.

Agenda

- 5G Global Deployment Statistics
- The Changing Landscape of "5G" SP Networks
- CSP Network Architecture Evolution to Hybrid Cloud
- Telco workload and network requirement
- Cisco 5G Telco hybrid/multi-cloud solution
- Hybrid/multi-cloud 5G customer case study
- Conclusion

5G Commercial Networks

Commercial Stand Alone (SA) 5G Services
Operators 33 (August 2022)*

	Lte	5G
Africa	162	14
Asia	139	54
Europe	167	108
Latin America	131	28
Middle East	47	23
Oceania	39	9
U.S. & Canada	17	14
Global Totals	**702**	**250**

Data provided by TeleGeography & 5G Americas as of 12/14/2022

https://www.5gamericas.org/resources/deployments/

*Sources: Industry data, Kagan estimates

Netherlands “Mobile Network Experience Report”
Source: OPENSIGNAL

Mobile Experience Awards

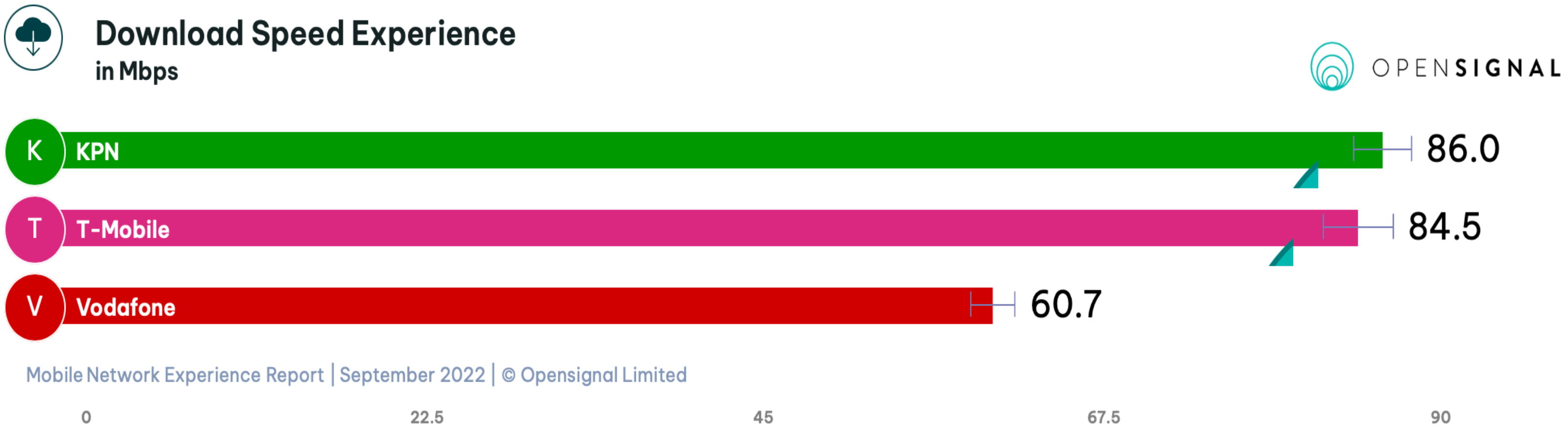
SEPTEMBER 2022, NETHERLANDS REPORT

OPENSIGNAL

	Overall Experience					5G Experience					Coverage		Consistency	
	Video Experience	Games Experience	Voice App Experience	Download Speed Experience	Upload Speed Experience	5G Video Experience	5G Games Experience	5G Voice App Experience	5G Download Speed	5G Upload Speed	Availability	5G Availability	Excellent Consistent Quality	Core Consistent Quality
KPN (K)	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	WINNER	JOINT WINNER			WINNER	
T-Mobile (T)	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER	JOINT WINNER		JOINT WINNER	WINNER	WINNER		WINNER
Vodafone (V)	JOINT WINNER	JOINT WINNER	JOINT WINNER											

Mobile Network Experience Report | September 2022 | © Opensignal Limited

Netherlands "5G Download Speed"
Source: OPENSIGNAL



The Changing Landscape of SP Networks
5G

- Significant investment "100B+ C-band spectrum spending in US"
- Large-scale investments by CSPs, to cater world's appetite for high data consumption
  - +137% "Projected growth in data traffic by 2026 (24% YoY 2022-6), rising to 1.8 million petabytes. [source: Analysys Mason Datahub based on a sample of 27 countries]"
  - -37% "Decline in median ARPU between 2012 and 2021 [source: Analysys Mason Datahub based on a sample of 27 countries]"
  - $1.4T "Cost of capital expenditure to build and upgrade networks between 2022 and 2026. [source Analysys Mason]"
- 70-80% OTT video traffic [Youtube, Netflix etc.] in mobile networks
- Value added services moving to OTT (Over-the-Top) providers
- CSPs are exploring building differentiated solutions with ecosystem partners.

The Changing Landscape of SP Networks
5G

- 5G is driving cloud and Network as a Service (NaaS) strategies within Service Providers
- Fixed Wireless Access (FWA): The first big 5G use case
  - Converged and discounted offers from top wireless and cable players
- Private 5G use cases e.g., Department of Defence
- 5G satellite access -3GPP is working on 5G Non-Terrestrial Networks standardization as part of release 17, for 5G Advanced (R18)

The Changing Landscape of SP Networks
5G

- Connectivity
  - 5G New Radio (NR) “Beamforming, Massive MIMO”
  - High Bandwidth (25G-400G) in fronthaul, midhaul & backhaul
  - Optics: 25G is becoming baseline, 100G ZR, 400G DCO ZR/ZR+
  - Low Latency applications <25ms, requires CSP to rearchitect their network
    - Metaverse networking
- Network Function Virtualization & Decomposition
  - 5GC: Control Plane (CP) & User Plane Function (UPF), 5G Stand alone (SA)
  - ORAN “Centralized Unit (O-CU) & O-DU (Distributed Unit)” & vRAN
  - vRouting
  - Cloud native BNG

The Changing Landscape of SP Networks
5G

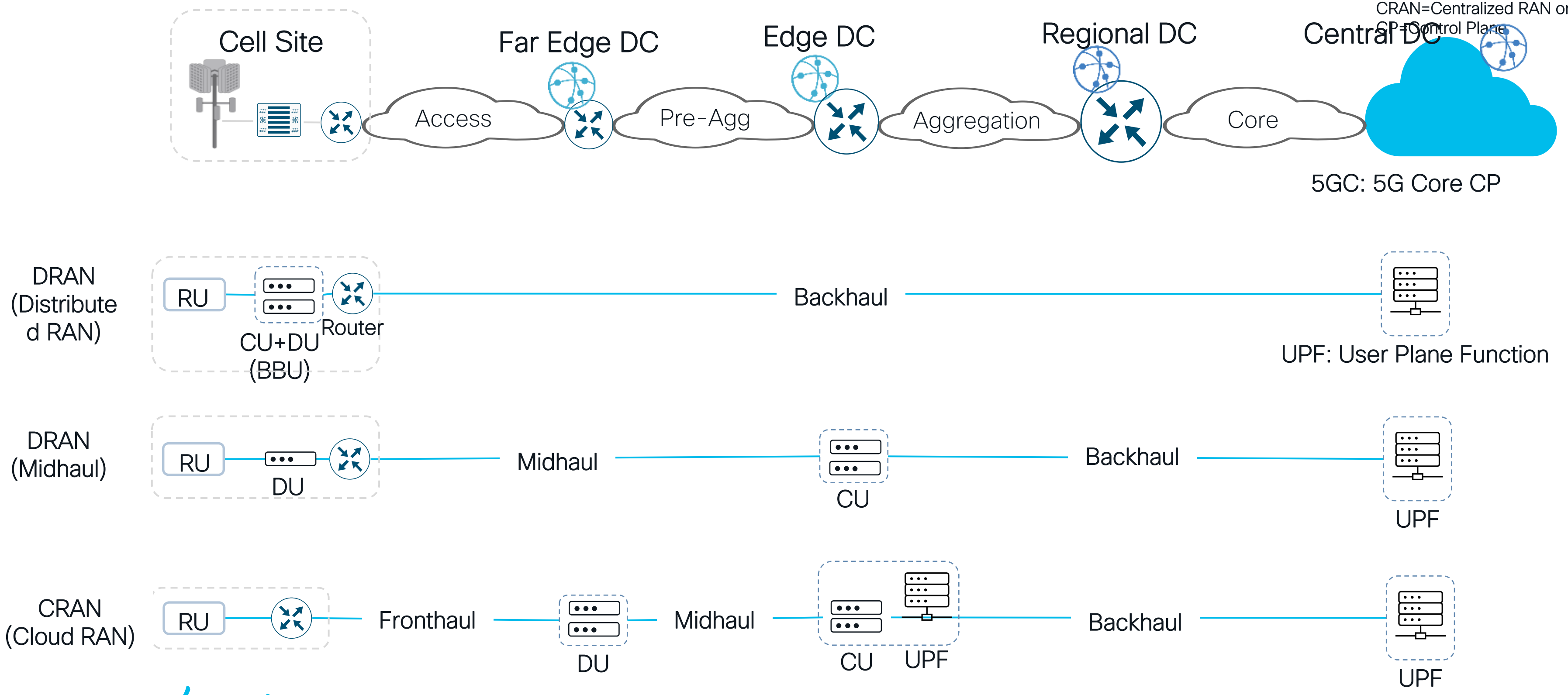
- Convergence
  - Converged Transport ”Wireline + Wireless”
  - IP + Optical convergence
- Operations
  - Simplicity, Lower TCO
  - Programmable (APIs, Cloud Ready)
  - Resiliency & Capacity management
  - Service Assurance, visibility

The Changing Landscape of SP Networks
5G RAN

- 5G driving a reassessment of RAN space (O-RAN, vRAN)
  - ORAN deployment is still in early stages: Dish network, Vodafone, Rakuten,
  - Cost reduction e.g., L1 PHY offload
    - Reduce the number of CPU cores in “Intel FlexRAN” architecture
    - EdgeQ, Marvell, Qualcomm
  - System integration
  - Collaboration (Vodafone & DoCoMo)
  - vRAN is being adopted by Ericsson, Nokia, Samsung
  - There is a strong possibility that the next major global RAN deployment will be "O-RAN."

RAN Transport Architecture

O-RU= Radio Unit aka RRH, TRP
DU= Virtual Distributed Unit
CU=Virtual Centralized Unit
FEDC=Far Edge Data Center aka Pre-Agg
EDC=Edge Data Center aka Aggregation
RDC=Regional Data center
UPF=Packet core user plane function
CRAN=Centralized RAN or Cloud RAN
CP=Control Plane



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 (ORAN)	• 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

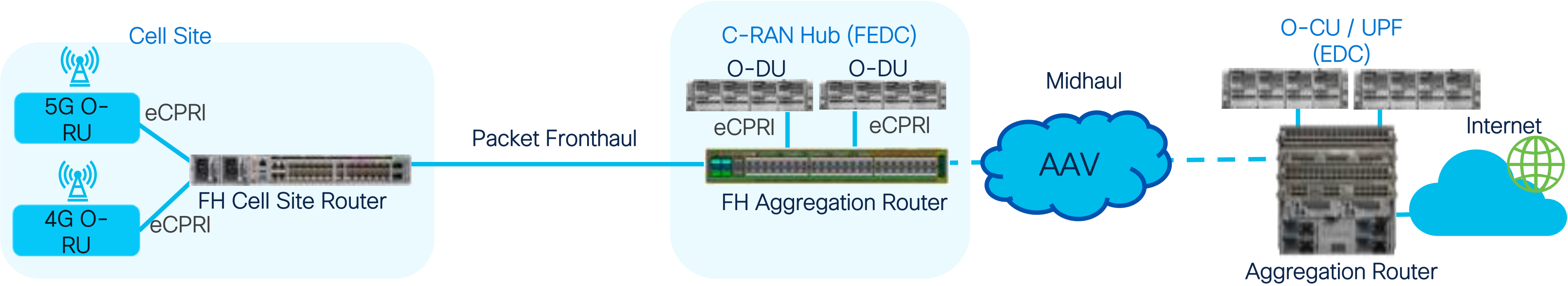
	Latency	
Fiber Latency	5 us / km	20 km = 20 x 5 = 100 us

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

*HENS= Huawei, Ericsson, Nokia & Samsung

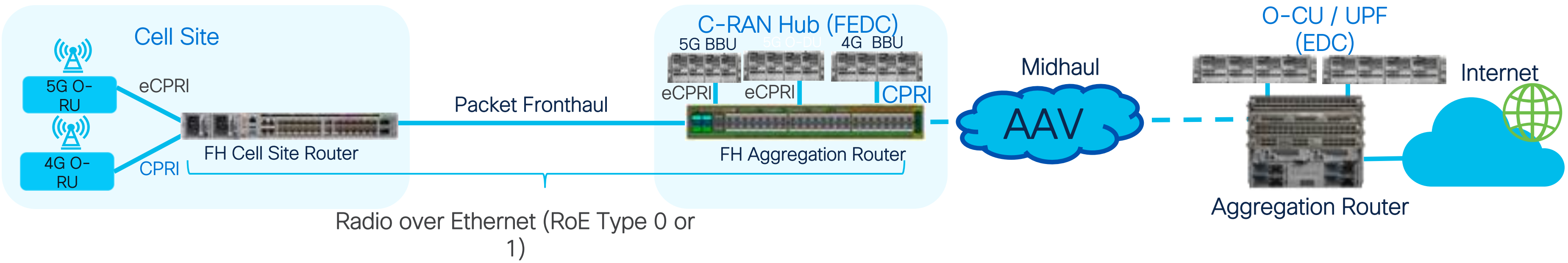
**O-RAN.WG4.IOT.0-v03.00 (NR TDD|NR FDD|LTE TDD|LTE FDD IOT Profile)

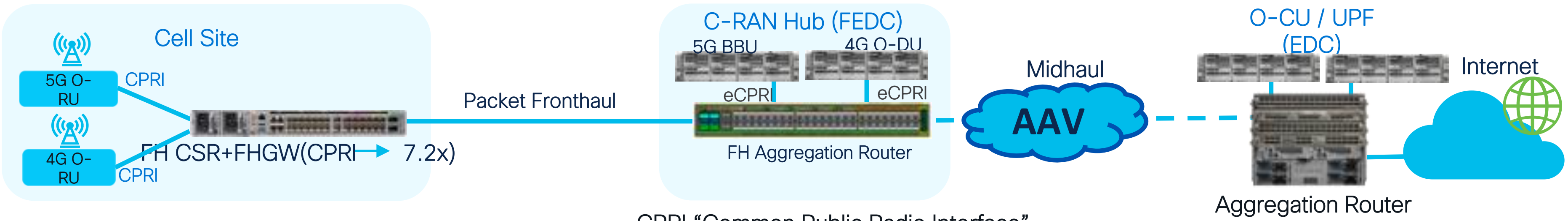
Cloud RAN Transport Solution
vRAN/ORAN Deployment



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

Cloud RAN Transport Solution
Brownfield Deployment HENS* vRAN/ORAN

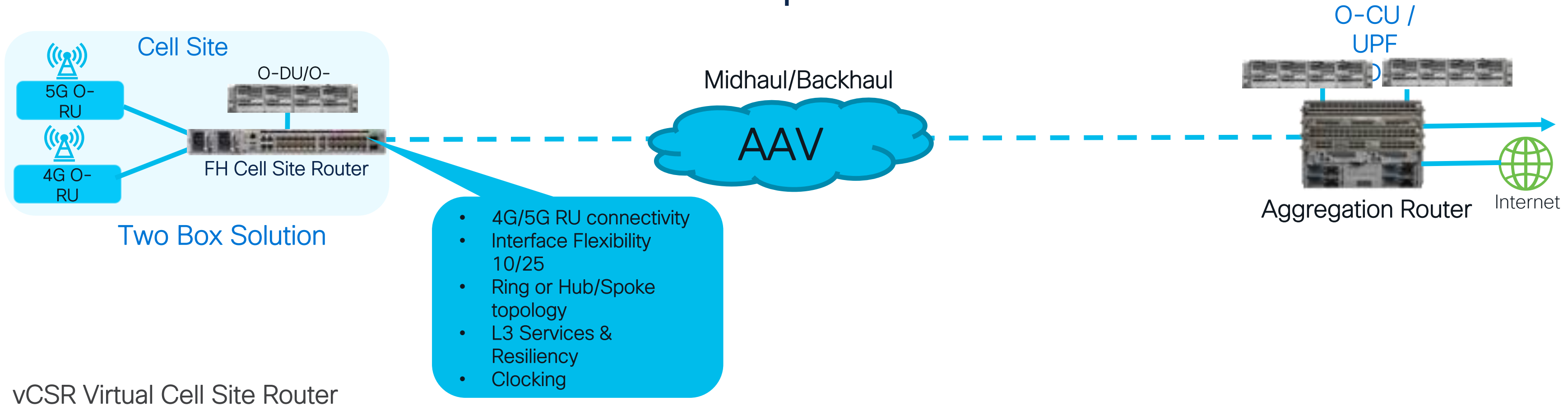




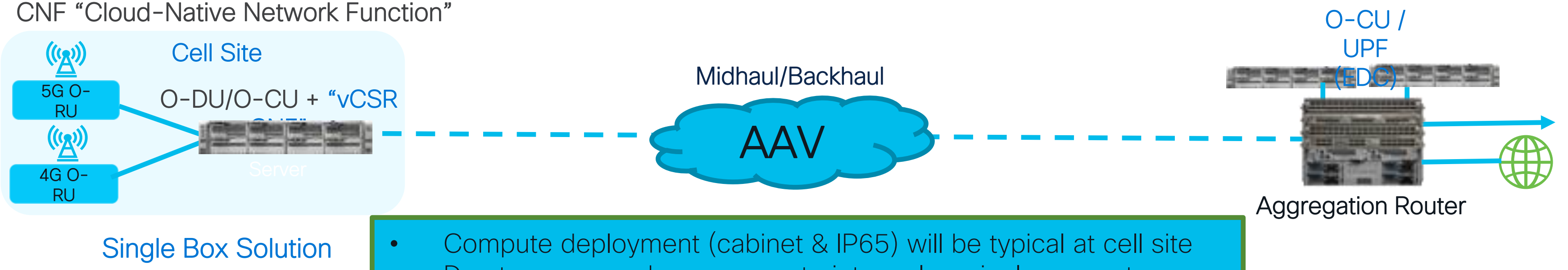
CPRI "Common Public Radio Interface"
eCPRI "Enhanced CPRI"

*HENS= Huawei, Ericsson, Nokia & Samsung

Midhaul/Backhaul Transport Solution



vCSR Virtual Cell Site Router
CNF “Cloud-Native Network Function”

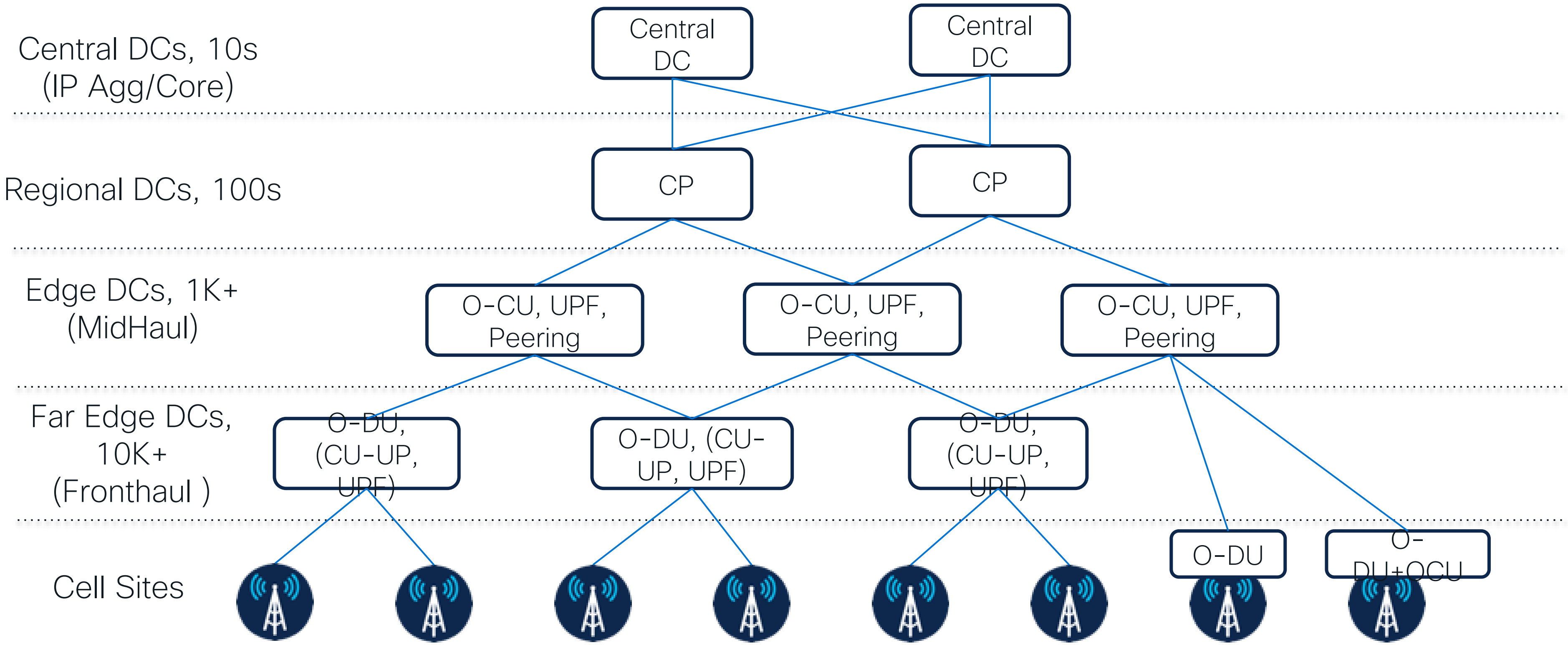


- Compute deployment (cabinet & IP65) will be typical at cell site
- Due to space and power constraints, only a single compute platform

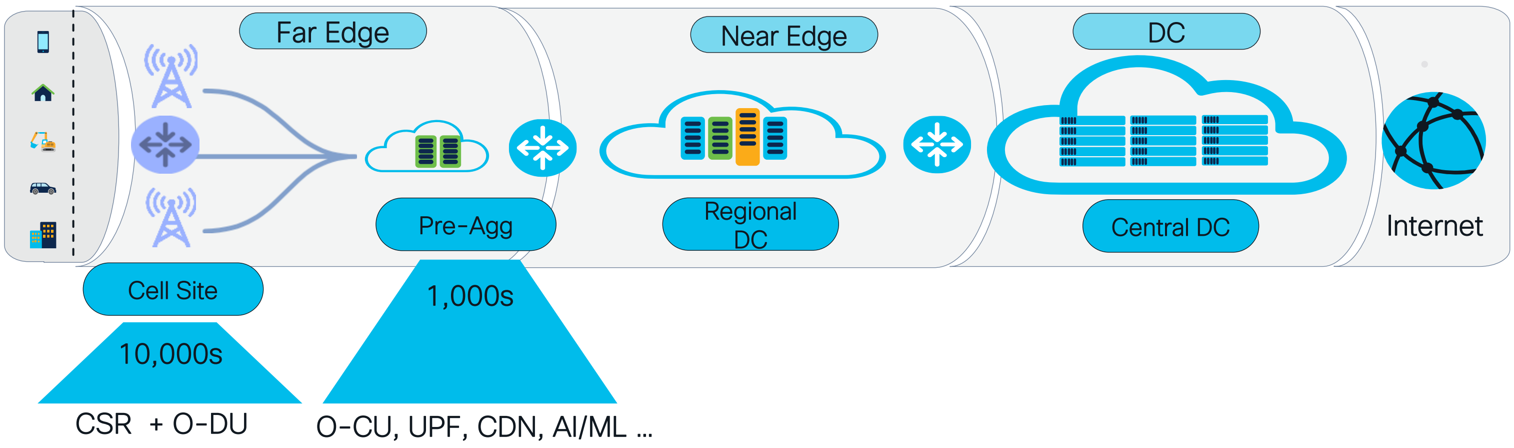
Cisco RAN Transport Solution Benefits

- Unified forwarding & service plane across xhaul
- Flexible and resilient Fronthaul, Midhaul & Backhaul Topology
- Operational Visibility
  - Latency monitoring SR-PM (link and policy)
  - Telemetry
- Extensible
  - Lower cost to serve with single ethernet edge delivering enterprise VPNs over Fronthaul infra

Transition to the Telco Edge



Optimized O-DU/O-CU is needed to address Space, Power, and Cost at the Far Edge

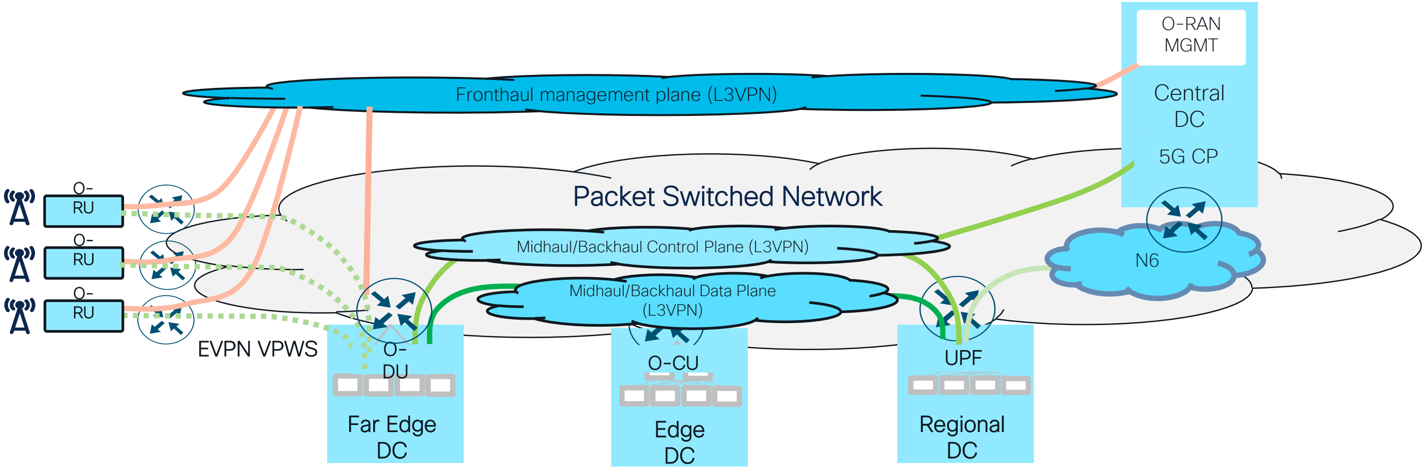


Far Edge constraints limits applicability of generic DC solutions:

- Limited space, and power prevent simply adding more servers to increase compute capacity
- Distributed locations make management more challenging

O-RAN 5G Transport Architecture

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



O-RAN WG-9 “Packet switched architectures and solutions” outlines followings:

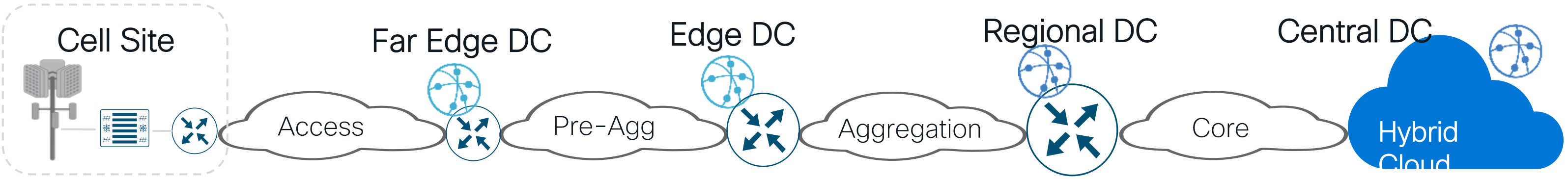
- Segment Routing based on MPLS or IPv6 packet switched network
- Ethernet VPWS services for fronthaul interfaces with priority queuing
- BGP based L3 VPN for O-RAN 7.2X M-Plane
- BGP based L3 VPNs for midhaul / backhaul
- Appropriate packet based QoS and forwarding plane for the 5G service
- The transport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

The Changing Landscape of SP Networks
MEC

- Traffic moving off or being served closer to the edge through remote peering, cloud or caching
- Core routing market moving from transit / worldwide telcos to cloud and content providers

Reference Blog:
https://blogs.cisco.com/sp/inflection-points-of-a-converged-metro

Multi-Access Edge Computing (MEC)



5GC: 5G Core CP

Bandwidth Optimization				Latency	Edge connectivity & 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

The Changing Landscape of SP Networks
Sustainability and Energy costs

- With energy costs rising, the focus is on reducing use and increasing sustainability
  - The global telecommunications industry produced 2.6% of the total world carbon dioxide (CO2) emissions in 2020 – more than the airline industry, according to a European Telecommunications Network Operators Association report.
  - According to GSMA Intelligence, energy consumption accounted for 15-40% of telcos' operating expenditure in 2021, which is expected to rise.
- For mobile network operators, the bulk of this energy consumption (60-75%) is from radio access networks (RAN) [Source: LightReading]

The Changing Landscape of SP Networks
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
- Transport Slicing (for 5G customers) is the same as a complete "Transport Service" for non-5G customers
  - intent/outcome based, simplified, with clear SLAs
- Simplified "intent" (latency, reliability, etc) based slice provisioning

The Changing Landscape of SP Networks
Network Slicing

- Cisco has a powerful and complete toolset for Transport Slicing including Segment Routing, ODN/AS, FlexAlgo, QOS, L2/L3 VPNs…
- 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

The Changing Landscape of SP Networks
Network Slicing

- Use case: Enterprise FWA
- Phase 1: Capacity based slices
  - Pre-configured slices
  - Slices built with particular application types in mind, e.g., eMBB traffic slices.
  - Most related to capacity rather than advanced network capabilities (for example, low latency)
  - Few, static slices
- Phase 2: Service Specific network slices (2-3 years)

The Changing Landscape of SP Networks
Hybrid Cloud

- Hyperscalers (AWS, Azure, GCP, Oracle Cloud)
  - Cloud providers advancing in all other aspects of the Service Provider environment
    - Using cloud/network experience to move to edge, middle mile and into SP marketplace (disrupting)
    - Adapting for regional laws around privacy and sovereignty (e.g., AWS Local Zone)
  - CSPs partnering with Hyperscalers

The Changing Landscape of SP Networks
Hybrid Cloud

- CSPs have launched Multi-access Edge Computing (MEC) solutions with hyperscalers
- CSPs hosting “telco workloads” e.g., UPF, O-CU, on cloud enabling hybrid & multi-cloud
- ”Why are CSPs partnering with hyperscalers?” (Source Heavy Reading)
  - Ease of deployment
  - Accelerated service time-to-market
  - Enhanced cloud-based security
- Enable scalability by building services adjusting to fluctuations in market demands more effectively

The Changing Landscape of SP Networks
Hybrid Cloud

- Partnership is mutually beneficial
  - Value-added services to the enterprise, including private 5G
  - Bring the most innovative & economical solutions to market
  - CSPs have substantial assets, footprint, and telco domain expertise
  - Hyperscalers have developed cloud-scale platforms, operate highly available state-of-the-art data centers, latest generation of hardware & services with global presence and connectivity

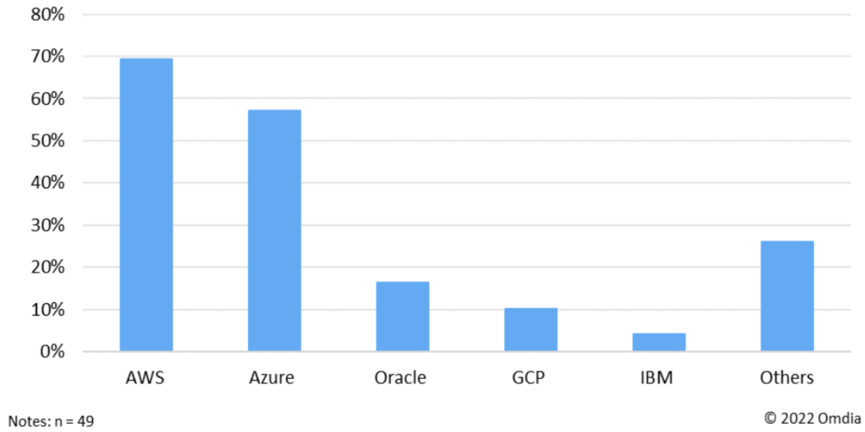
Network Functions in Public Cloud

- AT&T and Dish have been widely cited as among the first to move decisively into the public cloud.
- STL points out that Bell Canada is working with Google Cloud on edge computing.
- Switzerland's Swisscom is putting its network functions into the AWS cloud
- Belgian operator Telenet is preparing its 5G standalone core to run in Google Cloud's Anthos for Telecom platform

Source: LightReading

- https://www.lightreading.com/service-provider-cloud/brace-for-collision-between-telecom-public-cloud/a/d-id/782835

- Omdia asked 49 telecom executives
- List which public cloud or clouds their company is currently using to run any network functions
- Respondents could select all that apply



Omdia asked 49 telecom executives to list which public cloud or clouds their company is currently using to run any network functions, and respondents could select all that apply. Azure is Microsoft's cloud and GCP is Google Cloud Platform. Click here for a larger version of this image.
(Source: Omdia)

The Changing Landscape of SP Networks
Hybrid Cloud Examples

- DISH Wireless
  - Partnering with AWS.
  - Utilizing AWS as a platform to run DISH 5G service infrastructure including some of the Radio Access Network (RAN) components and 5G Packet Core.
  - First operator in the US, potentially worldwide, to leverage the public cloud to deploy and operationalize its network in the cloud.
- Verizon
  - Offering 5G network edge services with Amazon AWS
  - Private mobile edge computing for enterprises with Microsoft Azure
  - 5G edge with Google distributed cloud edge (GDCE) to support real-time enterprise applications

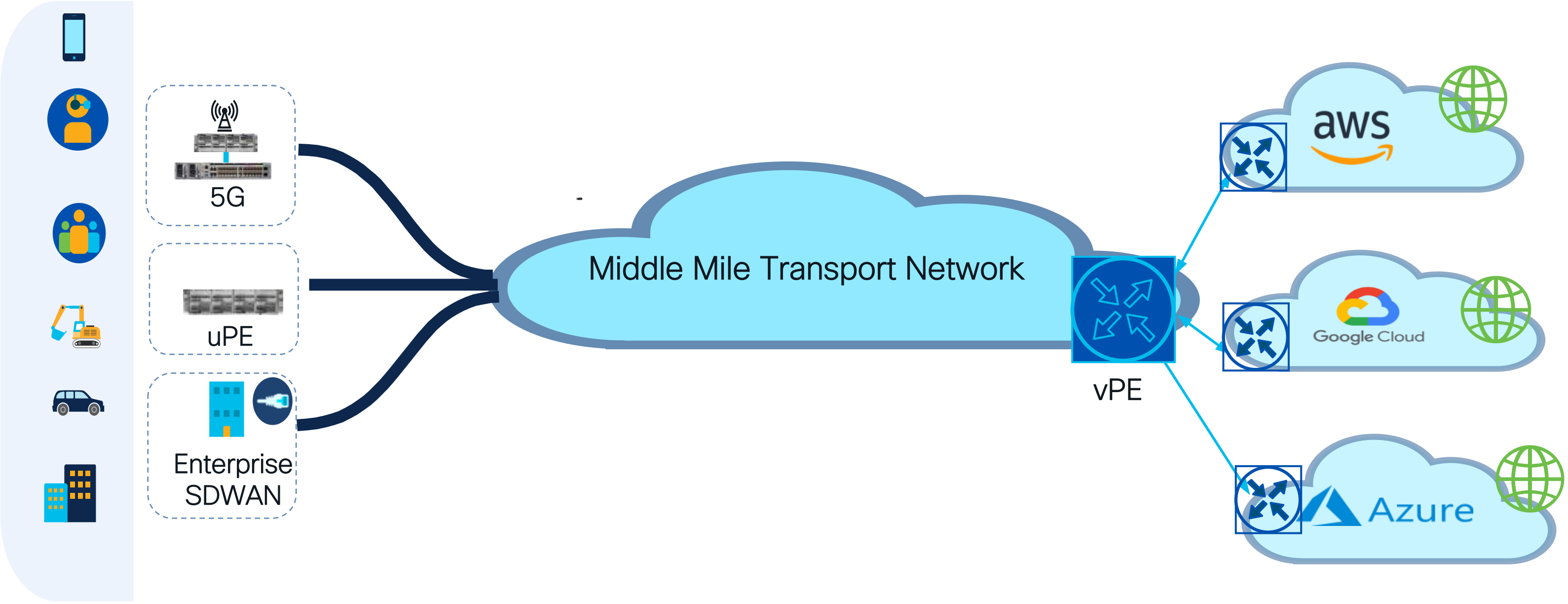
The Changing Landscape of SP Networks
Hybrid Cloud Examples

- AT&T
  - Collaboration with AWS on cloud, security, and IoT
  - Azure for operators and solutions: operator 5G core, private 5G core, public MEC
  - Partnership with Google cloud to offer on-prem MEC & network edge capabilities targeting enterprise customers
- Etisalat, Rogers, Telstra, SK Telecom, Telefonica, Telkomsel & Vodafone partnering with Microsoft Azure
- KDDI, SK Telecom & Vodafone partnering with AWS
- BT, Telecom Italia & Telefonica partnering with Google cloud

The Changing Landscape of SP Networks
Middle Mile Provider

- Middle Mile Provider (Megaport, Packet Fabric, Alkira, Equinix)
  - Global footprint, Hybrid & Multi-cloud connectivity, DC & API skills

Middle Mile Provider



Hybrid Cloud
Telco **Workload** Requirements

- Telco workloads are quite different from typical enterprise and IT applications that the public clouds were built to support
- Telco workloads have strict requirements
  - Latency budgets, jitter
  - Seamless failover to ensure service continuity, and regulatory requirements are mandated by federal and/or state agencies.
- Traffic flows limit and virtual machine templates are not aligned with Telco specific requirements.
- Performance and behavior characterization of telco workloads in hyperscaler infrastructure is crucial

Hybrid Cloud
Telco **Workload** Requirements

- CSPs will have to be able to deploy their workload and integrate them seamlessly across a multitude of target environments
  - public clouds
  - operator edge
  - enterprise private cloud
- The adoption of DevOps for Telco workloads

Hybrid Cloud
Telco **Network** Requirements

- A unified forwarding and service plane, using industry standard routing technologies agnostic to where the workload is located
  - on-premises
  - any PCP
  - any platform be it physical, virtual or containerized
- A cohesive, transparent, and high-performance transport fabric that enables workloads to seamlessly communicate within the tight tolerances and latency budgets required by Telco workloads – critical for URLLC

Hybrid Cloud
Telco **Network** Requirements

- Public cloud providers does not provide the level of control and visibility in their underlay network that Telco requires
  - For example, support for QoS in Public Cloud Provider (PCP) network underlay is not supported universally by the hyperscalers
- Intelligent Network controller that provides the ability to orchestrate, automate and service enablement from a single pane-of-glass in a hybrid-cloud/multi-cloud environment providing end-to-end network visibility.
- Accelerate adoption, remove any cloud-specific requirements
- No public cloud provider / vendor lock-in

Solution: Cloud-Ready Converged Transport

5G

“Ubiquitous Connectivity Enabler” for hyperscalers, middle mile providers and CSPs

Converged Infrastructure

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

Programmable Transport and Services

- ✓ SRv6: Unified Service Aware Forwarding
- ✓ BGP/VPN
- ✓ Network Slicing

Telco workload in hybrid /multi-cloud

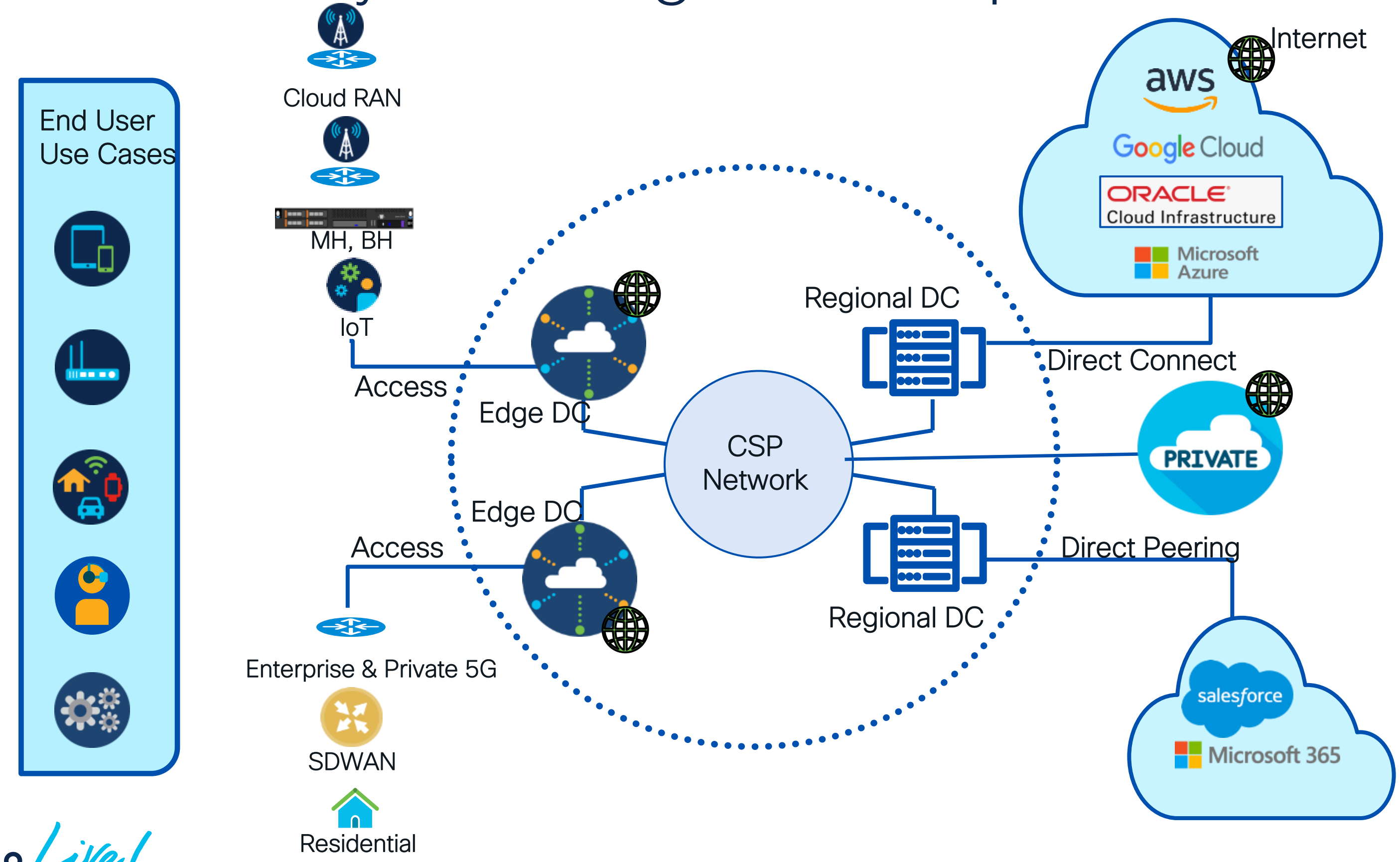
- ✓ Distributed Elements
- ✓ Virtual Routing
- ✓ Flexible service placement
- ✓ Scale-out

Ease of Operations

- ✓ Automation (CNC)
- ✓ Service Assurance & Observability
- ✓ Reliance and Security

Cloud-Ready Converged Transport

5G

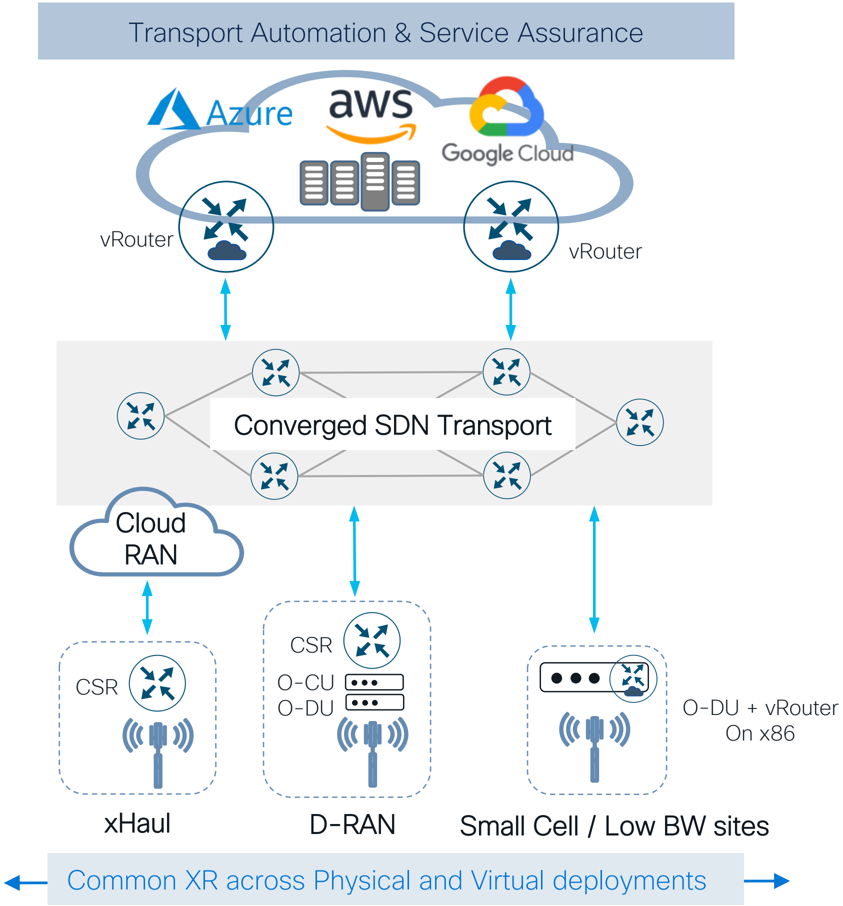


Hybrid Cloud
Cisco Solution

- A key component of Cisco's Cloud-Ready Converged Transport solution is the Cisco Cloud vRouter
  - Enables end-to-end transport connectivity that spans Cisco's routing portfolio on-prem, cloud networking and telco workloads hosted on the cloud
  - Provides hybrid-cloud/multi-cloud transport with service assurance, network segmentation & resiliency.
- As the first in the industry, Cisco has delivered hybrid cloud transport for Telco workloads (User Plane Forwarding & RAN centralized unit) hosted in AWS for the DISH Wireless.

Cloud-Ready Converged Transport

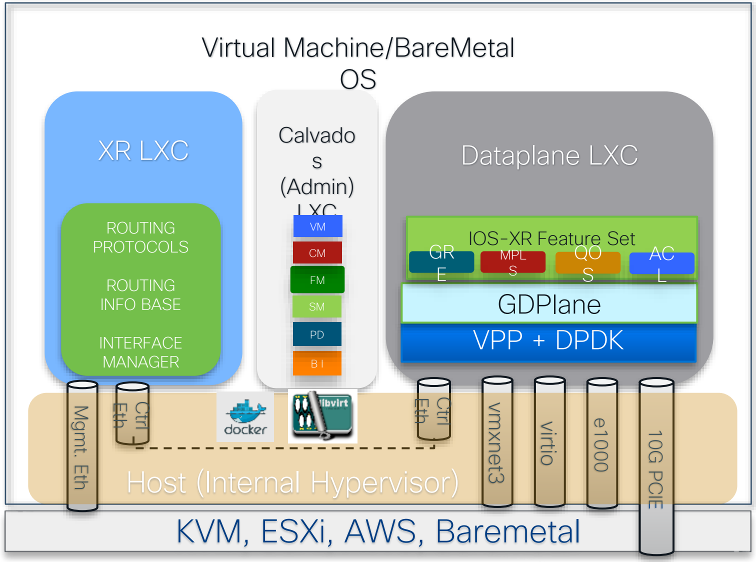
- vRouter:
  - XRv9K as VNF
  - XRd as CNF [NEW]



Cisco's vRouting Portfolio

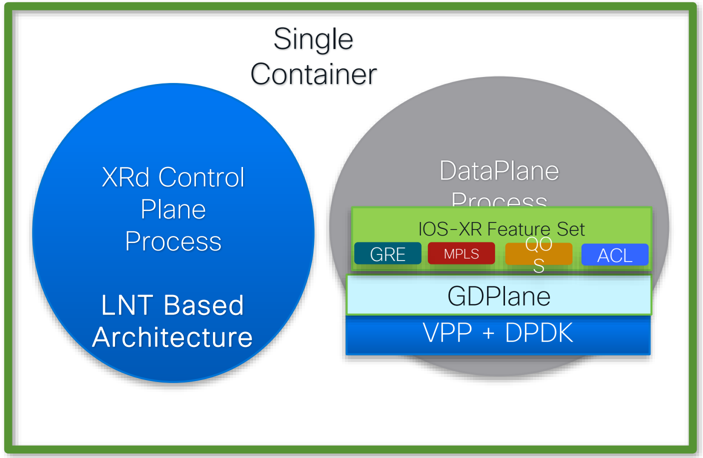
XRv9K

- VM (ESXI, KVM)
- Appliance (Bare Metal), Cloud AWS Instance



XRd

- **Standalone Docker Container**
- Deployable via Standard K8s and VMware Tanzu K8s. Amazon EKS planned for a future Release.
- XRd vCSR: FCS 7.7.1
- XRd Cloud vRouter - FCS November 2022 (7.8.1)



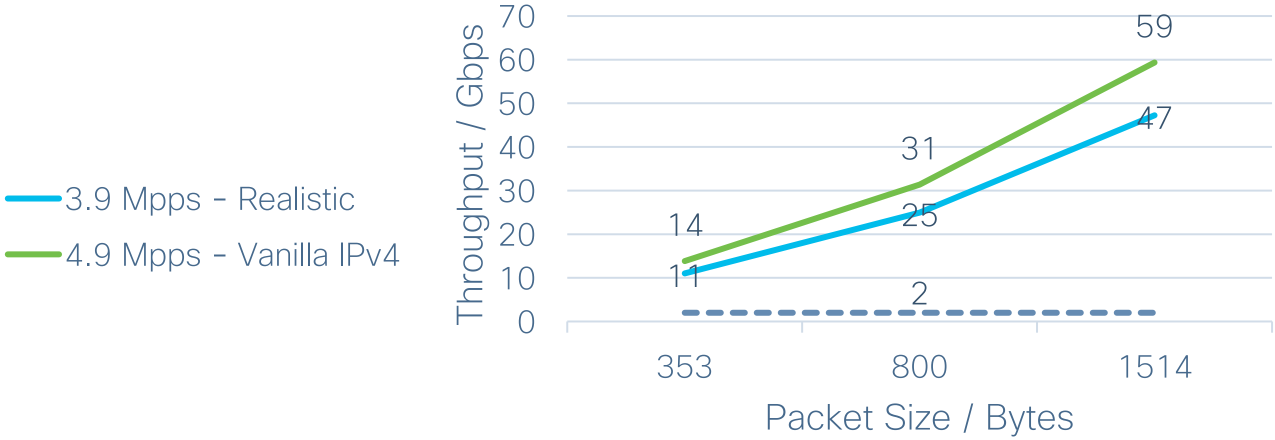
Cisco XRd Use Cases

	Cisco XRd Control Plane	Cisco XRd vRouter	
Use Case Characteristics	vRR/SR-PCE	Cloud vRouter/vPE	vCSR
Deployment Form-Factor	Control Plane Only	Control Plane + Data Plane	Control Plane + Data Plane
Deployment Environment (On-Prem/Cloud)	On-Prem & Cloud	On-Prem & Cloud	On-Prem
Routing Functionality	BGP/IGP	IP/MPLS/SR Transport, BGP/IGP, L3VPN	IP/MPLS/SR Transport, BGP/IGP, Eth Loopback, L3VPN
Scale	Low	Medium	Medium
Bandwidth	1G	20G-100G+	Up to 50G

Footprint “vCSR”

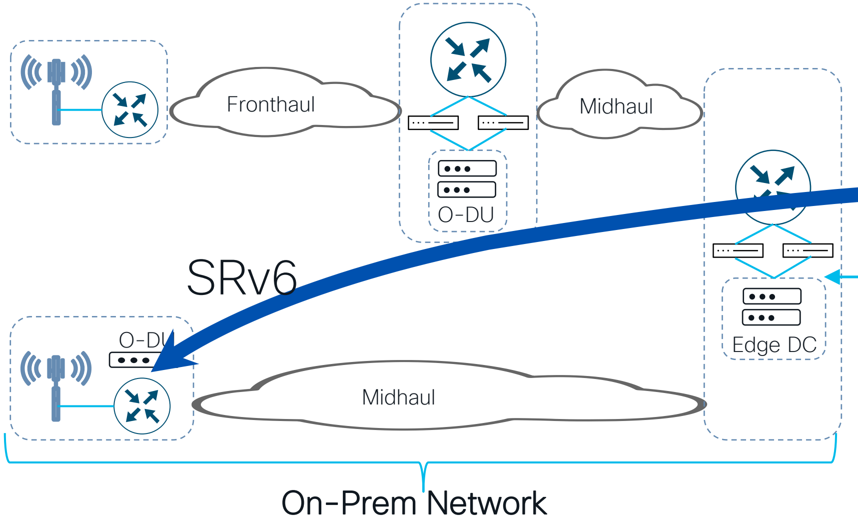
CPU Cores:	2 physical cores: 1 for control plane ; 1 for dataplane
Memory:	11 GiB: 8 GiB regular memory + 3 GiB huge pages (**)
Disk:	7 Gb (**)
Boot time:	~1 min (to EXEC prompt)

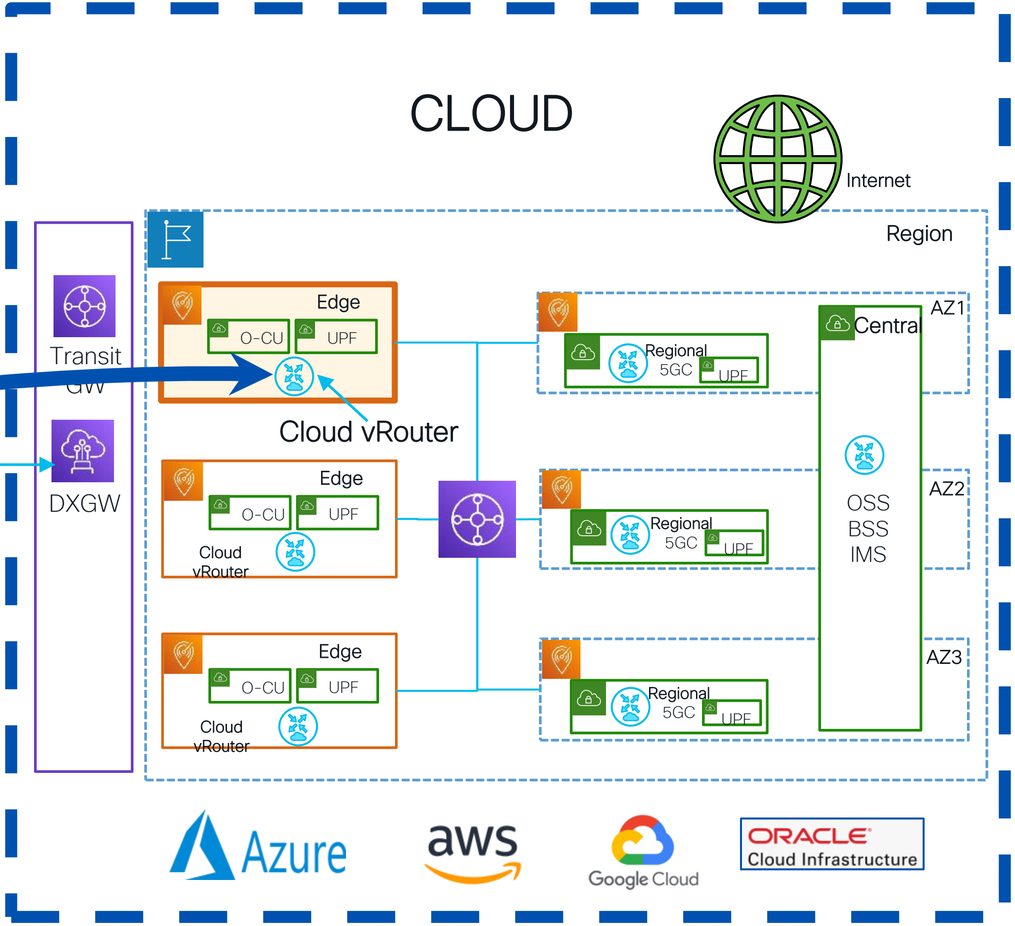
Performance “vCSR”



- Latency: ~50 usec average through Cisco XRd “vCSR”
- Ice Lake CPU @ 3.5 GHz turbo
- ‘Realistic’ configuration uses L3VPN o SR-MPLS o ECMP VLANs with Egress QoS
- **Technology can scale up to 100 Gbps+ throughput for the Cloud vRouter use case**

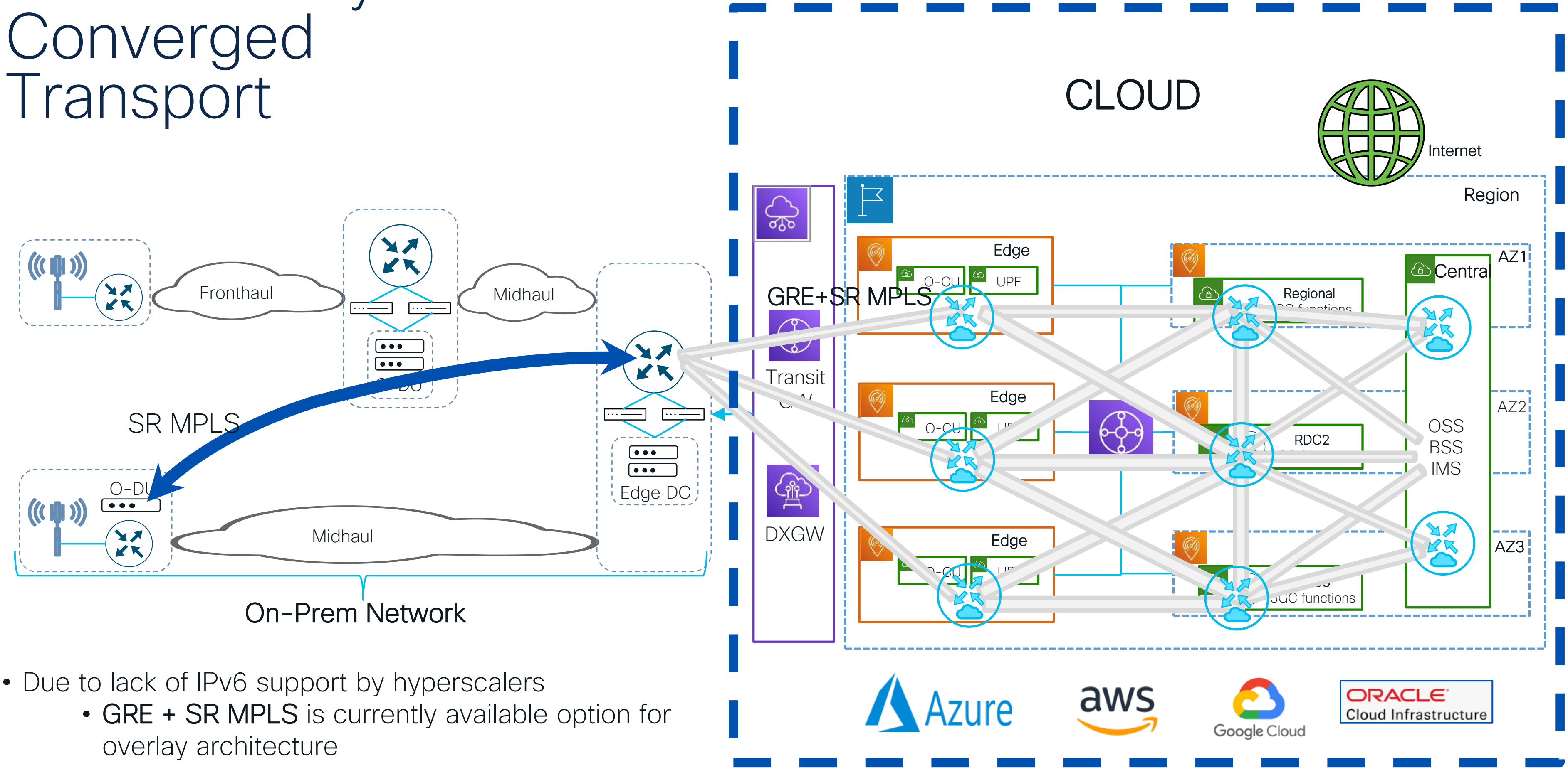
Cloud-Ready Converged Transport





- vRouting for hybrid & multi-cloud
  - IP data plane(Cloud provider agnostic networking) using unified service aware forwarding (SRv6) to enable hybrid & multi-cloud
  - IPv6 & flow label support are required from hyperscalers

Cloud-Ready Converged Transport



- Due to lack of IPv6 support by hyperscalers
  - GRE + SR MPLS is currently available option for overlay architecture

Technology Comparison

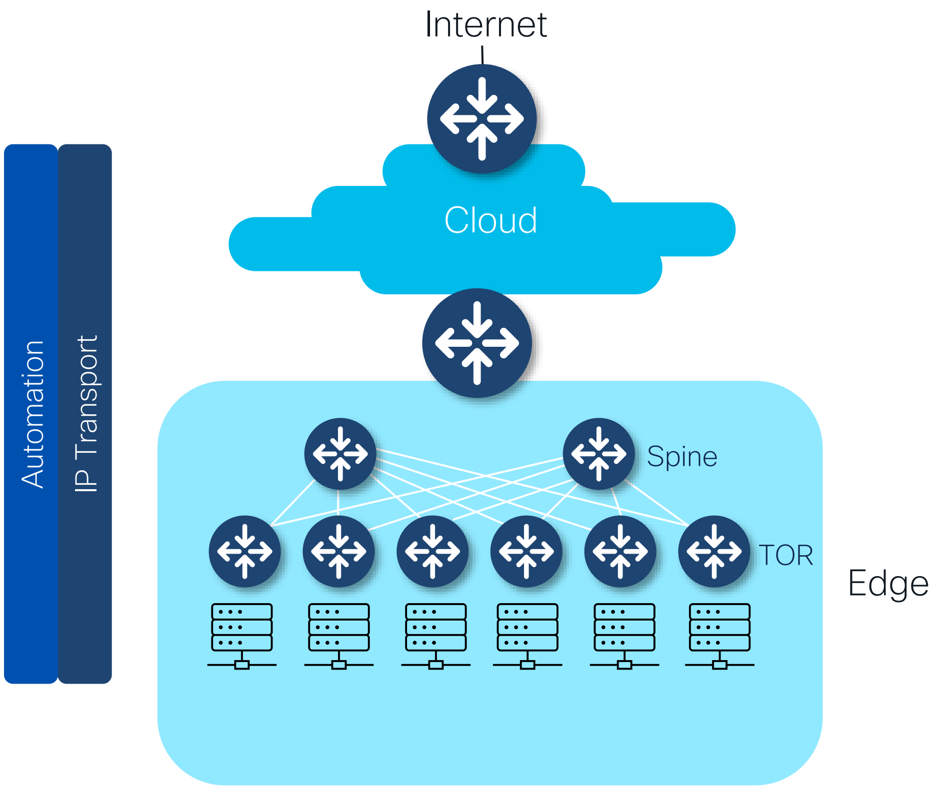
	MPLS+GRE	VXLAN	MPLSoUDP	SRv6
Entropy (Load Balancing)	N/A	UDP port	UDP port	Flow Label
Encapsulation	IPv4/IPv6	IPv4/IPv6	IPv4/IPv6	IPv6
Service Chaining	Not supported	Not supported	Not supported	Supported
End to End	No	No	No	Yes (for SRv6 SP)
SP Edge	Complex	Complex	Medium	Routing Only
Scalability	Limited	Good	Good	Good
Overhead v6	56(40+8+4+4)	68(40+8+8+12)	52(40+8+4)	40

SRv6 is the recommended hybrid cloud transport technology

IPv6 routing & Flow label support required from cloud provider

Single technology - End to End

Cloud-scale Architectures



Cloud Principles

Scale-out for elasticity

Power-optimized performance

Cloud Solutions

High density leaf/spine architectures

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 FCC and DOJ obligations to cover 20% of the US population by June 14th, 2022, and 70% of the US population by June 2023.
- DISH with over $30 Billion worth of 5G spectrum (TDD+FDD) and $1B of CBRS spectrum, is focusing 80%+ of their revenues on Enterprise, with network slicing a key enabler of their network of network approach.
- 5G SA only network.

Who is DISH Wireless?

- DISH is the 1st O-RAN based Greenfield network in US, cloud-native service provider focused on container-based applications and mobility network functions in AWS.
- 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.

DISH xHaul Transport Architecture

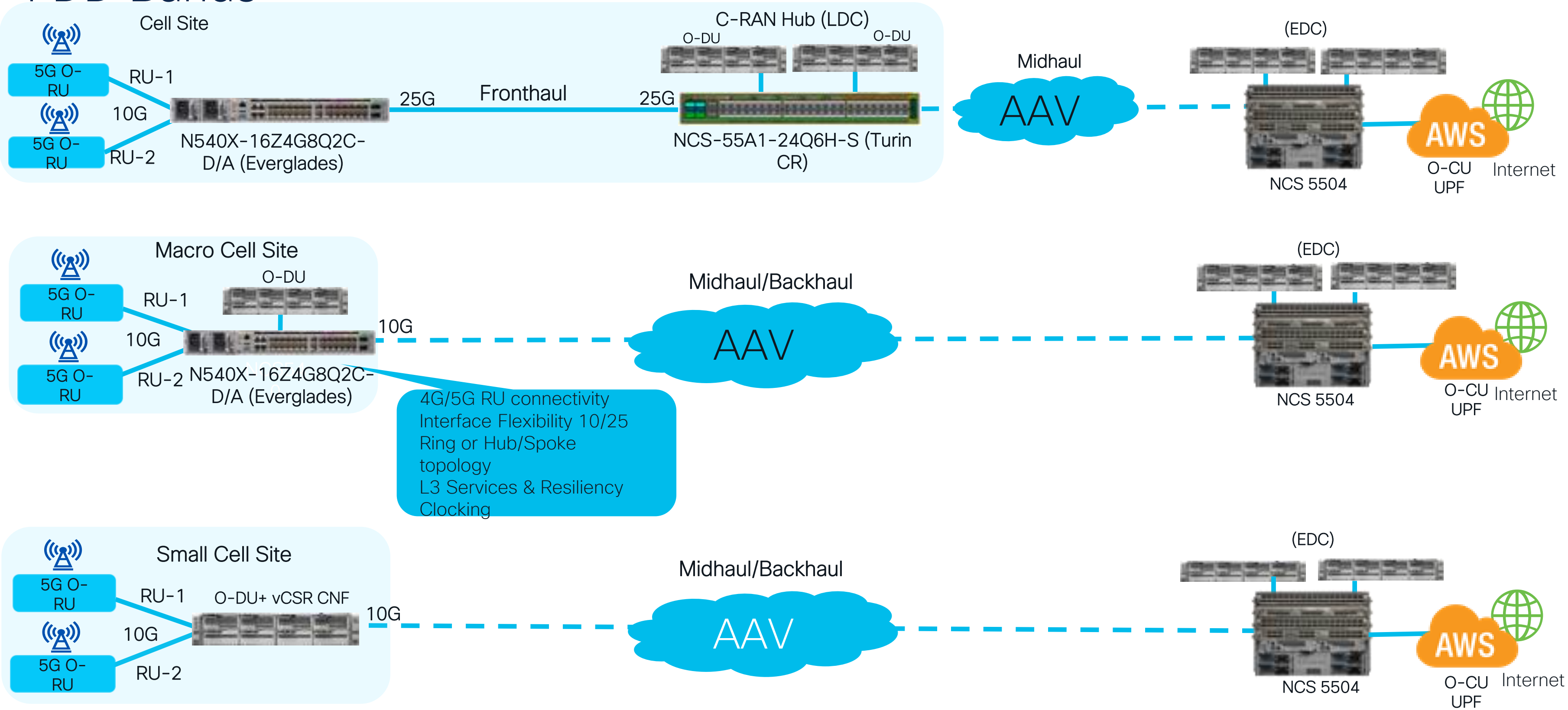
- DISH Transport network utilizes On-Prem and Cloud-based resources
  - IOS XR enables on-prem and virtualized routers to implement a cohesive set of services, including
    - L3 VPN, SR-MPLS, QoS, Automation
- Unified forwarding (SR MPLS) and service plane (BGP VPN) architecture enables flexible location of Network Functions
  - RAN NFs, 5G Core NFs, IMS NFs, etc., can be placed on-prem or on-cloud, according to performance and capacity requirements, availability of facilities, etc.

DISH xHaul Transport Architecture

- DISH Cloud-based network
  - Cisco XRv9K Cloud vRrouters
  - Architecture enables Hybrid + Multi-Cloud
  - Cisco XRd Cloud vRouter CNF evolution from XRv9K Cloud vRouter (under discussion)

Deployed Network Fronthaul & Midhaul Design
FDD Bands

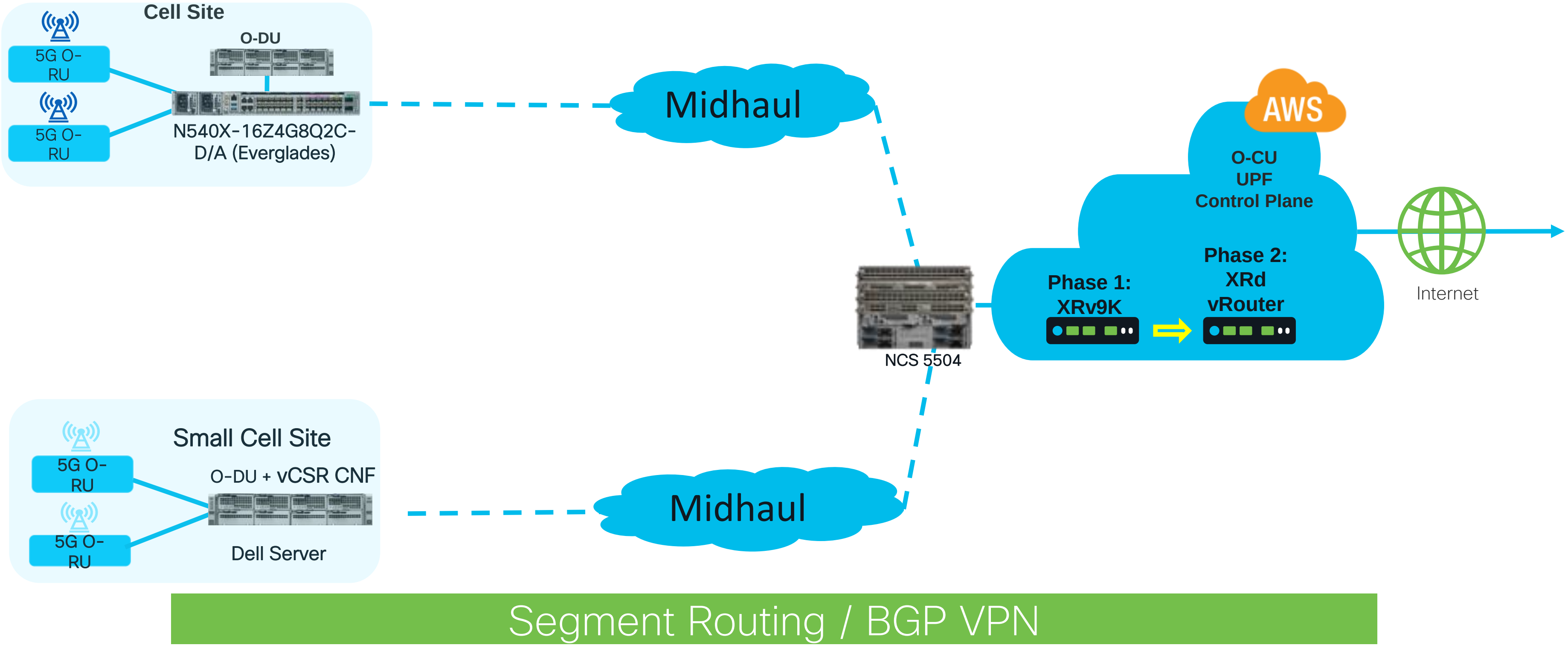
O-RU= Radio Unit aka RRH, TRP
FH = Fronthaul
O-DU= Virtual Distributed Unit
O-CU=Virtual Centralized Unit
AAV= Alternate Access Vendor aka Backhaul provider
LDC=Local Data center
EDC=Edge Data Center aka Aggregation



*For resiliency in dense fronthaul sites , ring topology is considered

Virtual Routing Evolution (Cisco XRd vRouter)

O-RU= Radio Unit
AAS= Active Antenna System
O-DU= Virtual Distributed Unit
O-CU=Virtual Centralized Unit
UPF= User Plane Function



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

Conclusion

- Global 5G deployments
- 5G SP Network Trends
- CSP Network Architecture evolution to Hybrid Cloud
- Telco workload and network requirements
- Cloud-Ready Converged Transport
- Customer Case Study

Cisco Live Sessions

- Introduction to SRv6 uSID Technology - BRKSPG-2203
- Synchronizing 5G Mobile Networks - BRKSPG-3050
- SRv6 Basics - LABMPL-1201
- EVPN IOS-XR Deep Dive for Service Providers and Data Center - BRKSPG-2835
- IOS-XR EVPN Hands-On Lab - LTRSP-2837
- Deploying VPNs Over Segment Routed Networks Made Easy - BRKMPL-2131
- Design, Deploy and Manage Transport Slices using SDN Controller and Assurance - BRKSPG-2263
- Introducing XRd: Lightweight, Programmable and Containerized. - BRKSPG-1552
- Demystify NCS5500/NCS5700 Resources for Effective Network Design and Operations - BRKSPG-2397
- Deep Dive on New Age anyG xHaul Portfolio - BRKSP-2398
- SP Service Creation and Edge Transformation - BRKSP-2133

ORAN PlugFest & Demos

SRv6 uSID based Xhaul validated in ORAN PlugFest 2022.

- https://blogs.cisco.com/sp/why-isnt-your-5g-ran-transport-flexible-and-efficient
- https://youtu.be/JwKUDMoAMug

Cisco, Xilinx and Keysight Packet Fronthaul Demo

- Innovating the future of Open RAN

Cisco FHGW solution demo at O-RAN Global PlugFest 2021.

- Making 5G adoption cost effective for brownfield providers
- O-RAN Global Plugfest 2021

5G Tutorials

- 5G Transport Overview (Tech Field Day)
  - Cisco 5G Packet and RAN Transport Architecture
- 5G xHaul Transport - DGTL-BRKSPM-2012
- 5G Packet Based Fronthaul - DGTL-BRKSPG-2065
- 5G Timing & Synchronization architectures – BRKSPM-3295
- 5G Synchronization - Design, Testing and Deploying Timing to support 5G rollouts - BRKSPG-2557
- Cisco Press Book: Synchronizing 5G Mobile Networks

Continue Your Education

- Visit the Cisco Showcase for related demos.
- Book your one-on-one Meet the Engineer meeting.
- Attend any of the related sessions at the DevNet, Capture the Flag, and Walk-in Labs zones.
- Visit the On-Demand Library for more sessions at ciscolive.com/on-demand.

Complete your Session Survey

- Please complete your session survey after each session. Your feedback is very important.
- Complete a minimum of 4 session surveys and the Overall Conference survey (open from Thursday) to receive your Cisco Live t-shirt.
- All surveys can be taken in the Cisco Events Mobile App or by logging in to the Session Catalog and clicking the "Attendee Dashboard" at https://www.ciscolive.com/emea/learn/sessions/session-catalog.html

The bridge to possible

Thank you

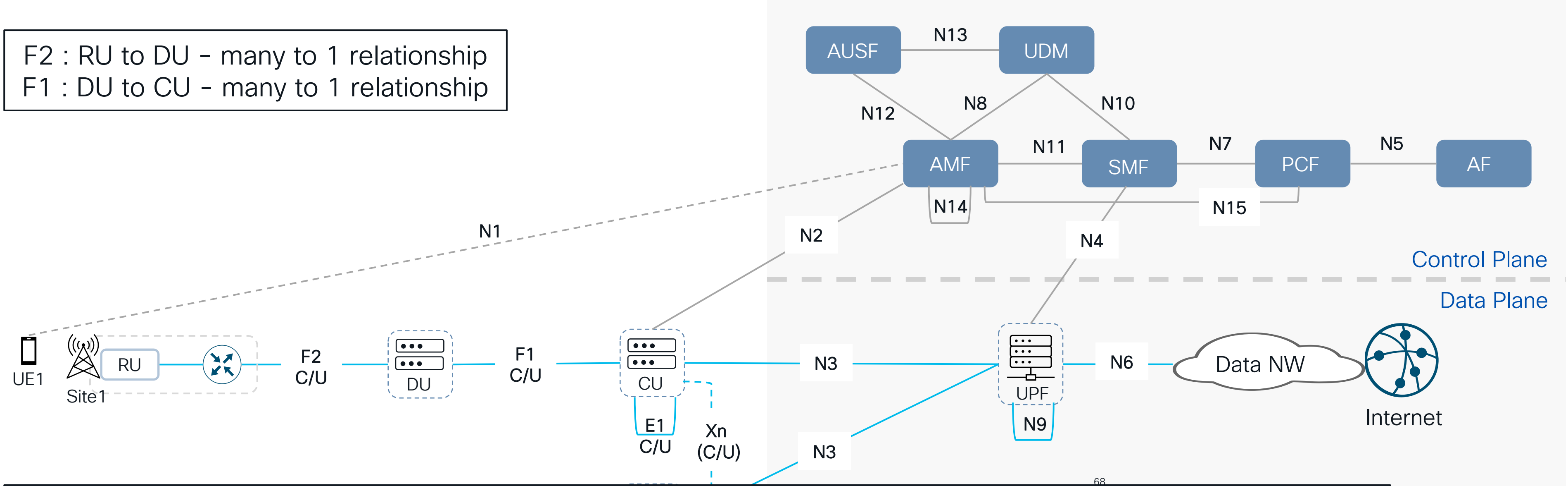
cisco Live!

ALL IN

Backup

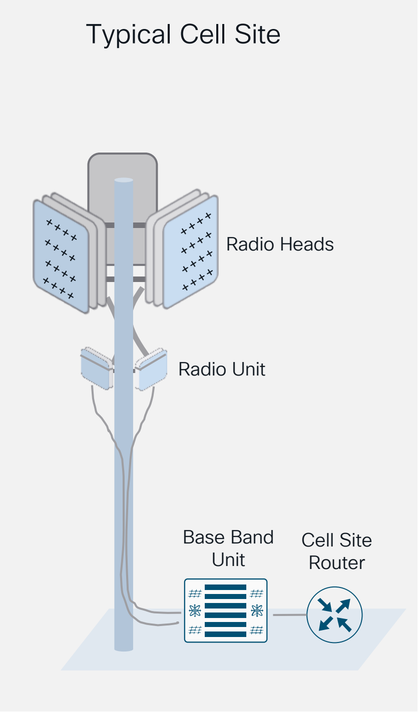
RAN and 5GC Interfaces

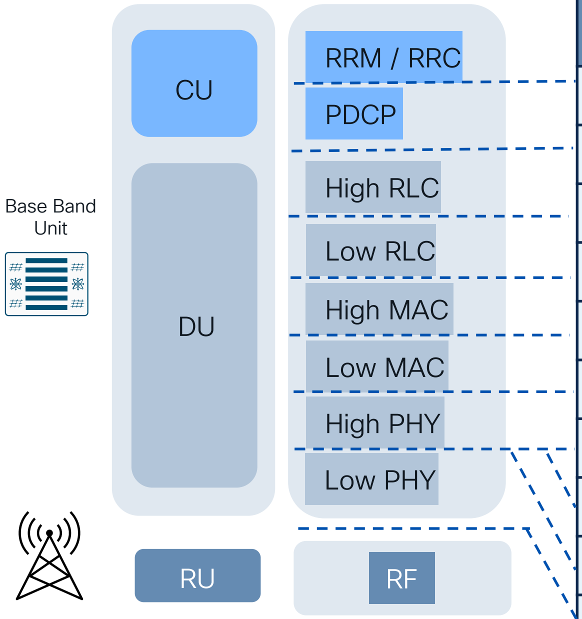
F2 : RU to DU – many to 1 relationship
F1 : DU to CU – many to 1 relationship



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!

RAN Virtualization



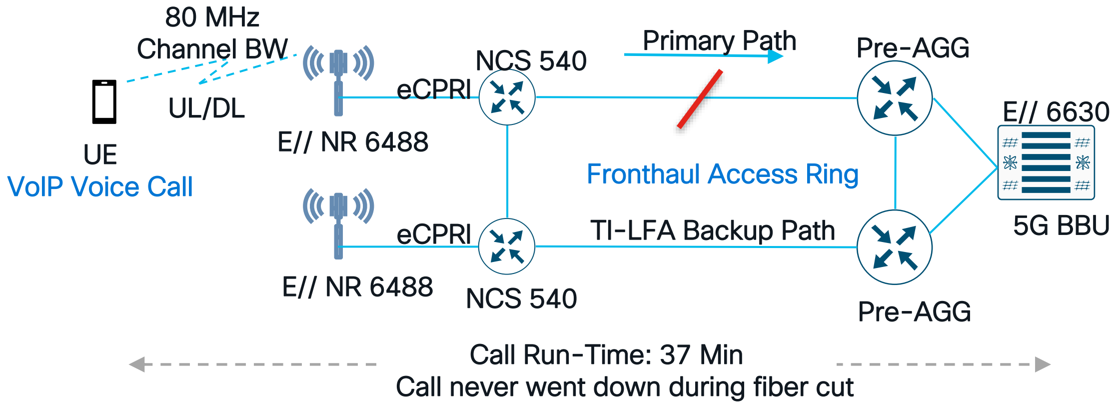


Split Option	Interfaces
Option 1	
Option 2	F1 (3GPP)
Option 3	
Option 4	
Option 5	
Option 6	
Option 7a	F2 (3GPP) eCPRI, ORAN (7.2x) IEEE RoE
Option 7b	
Option 7c	
Option 8	CPRI

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

5G RAN Resiliency with Segment Routing (SR)

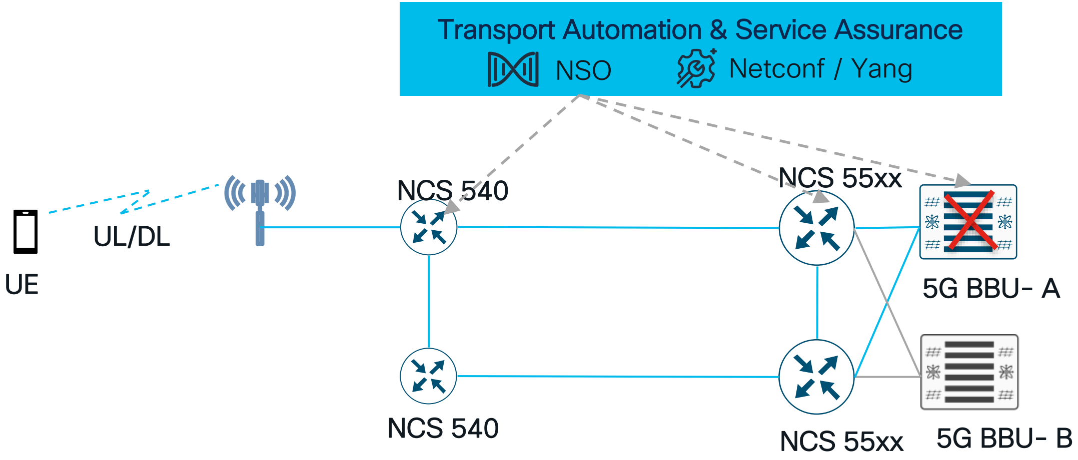
Case Study: Packet fronthaul network



- 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

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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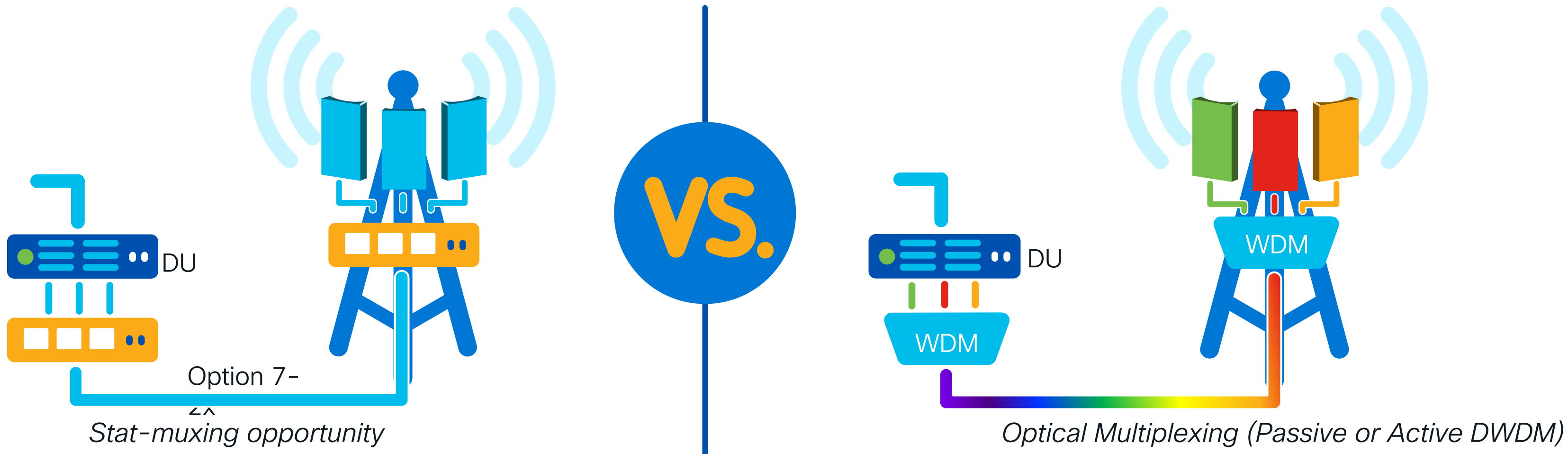
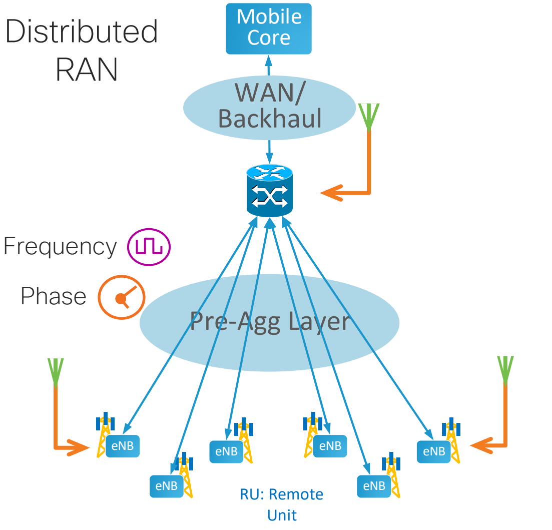
Packet-based Fronthaul

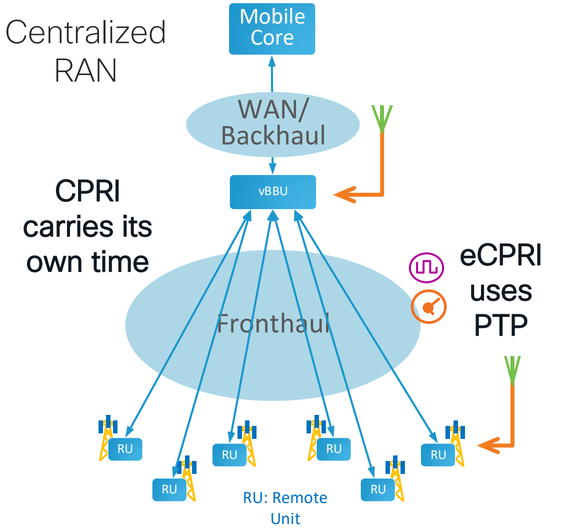


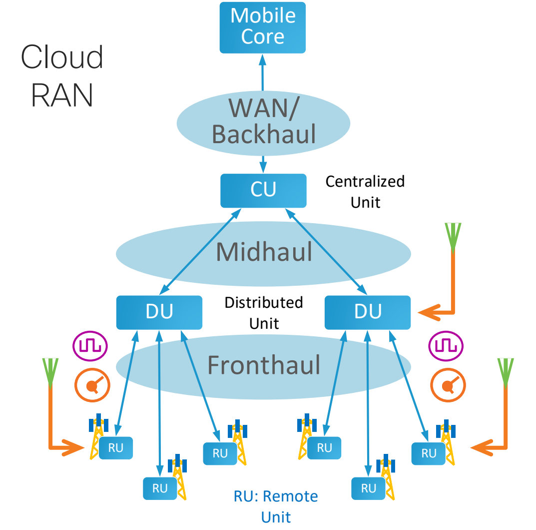
Packet	Optical
✔ Stat Mux Advantages	✖ Optical multiplexing
✔ Cost Effective	✖ Non-scalable, architecturally rigid
✔ Topology Independent	✖ Point-to-point, topology dependent
✔ Service Visibility & Transparency	✖ Limited-service visibility
✔ Scalable E2E Converged IP	✖ Capex dependent scale
✔ Resiliency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

Timing and Synch – Fronthaul Options

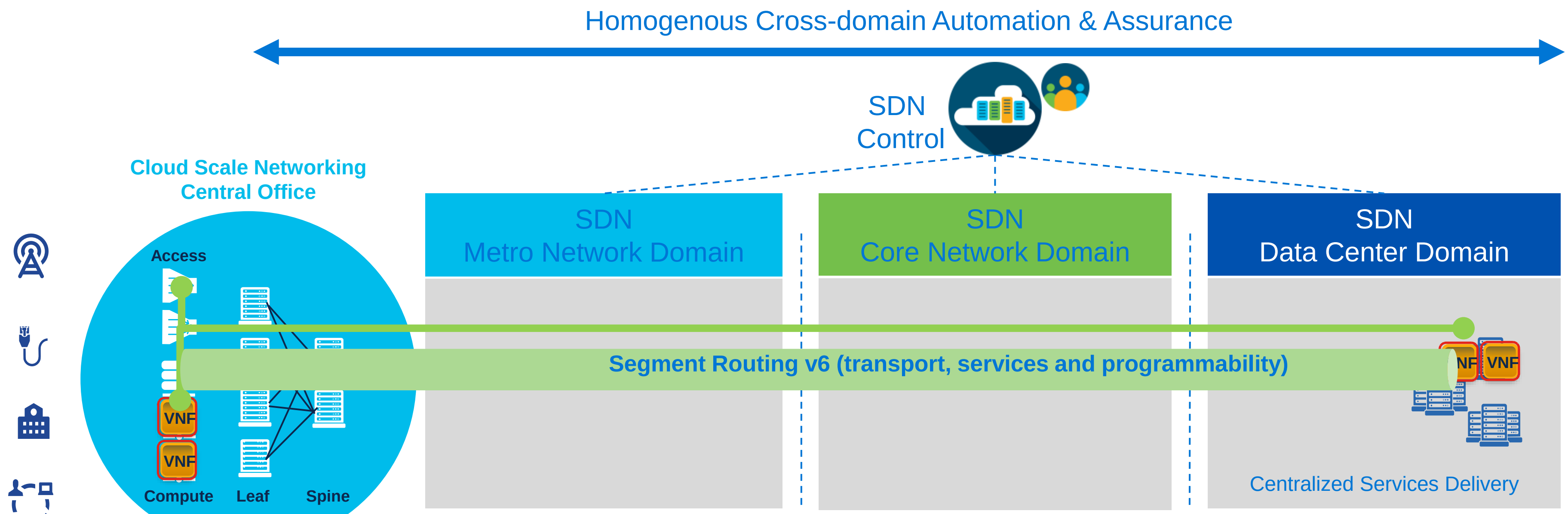
Distributed RAN	Centralized RAN	Cloud/Midhaul RAN
• ±1.5uS phase between radios • Backhaul carries sync from pre-aggregation layer; or • GPS at every cell site	• < ±1.1uS between BBU's • Backhaul carries sync or place GPS at every BBU hotel • CPRI is synchronous; but eCPRI requires PTP or GPS	• ~±130nS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







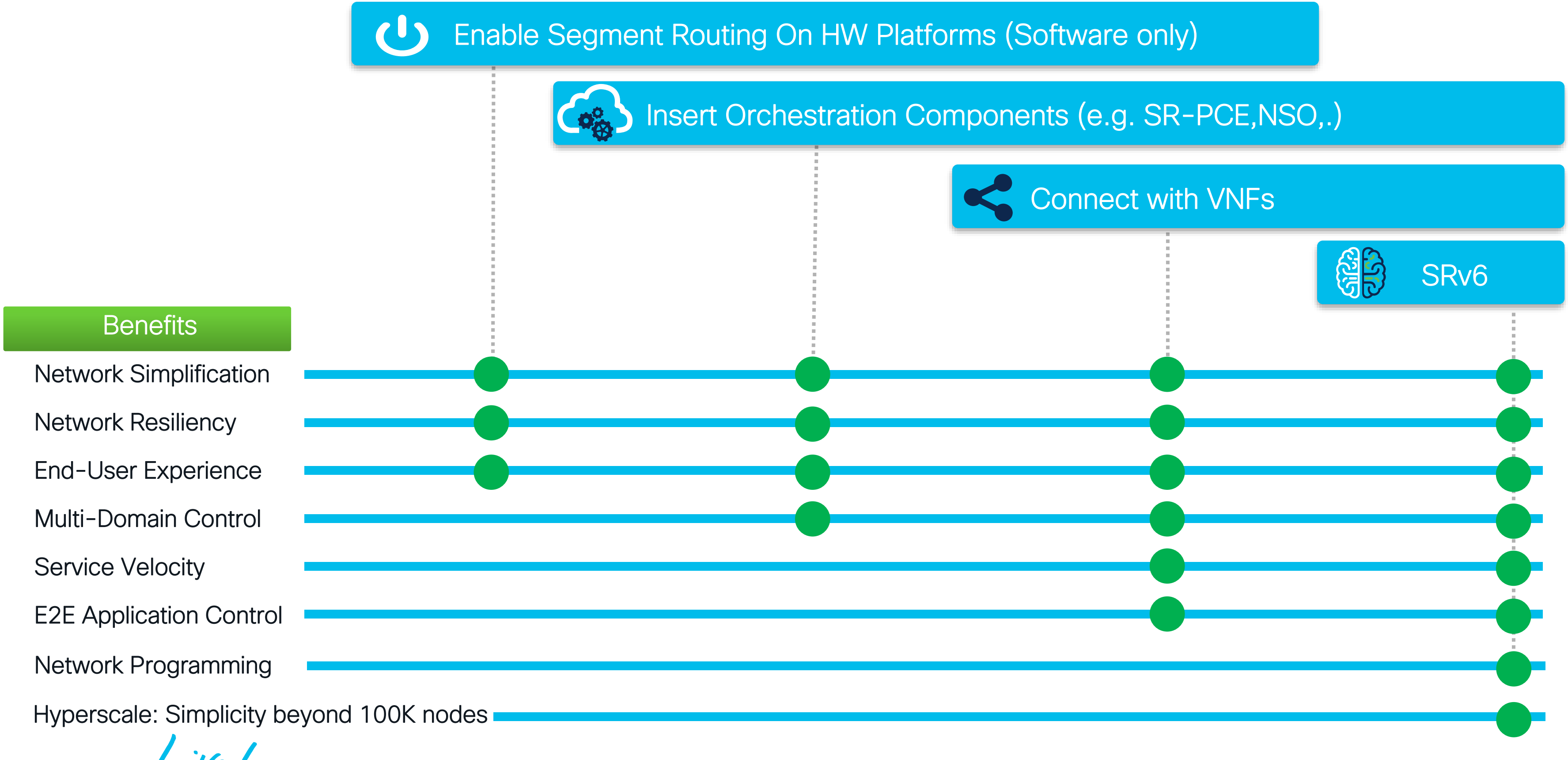
SRv6: SDN, NfV, 5G ready
“Network as an API” for Service Creation



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)

Segment Routing Journey
Adding value at your own pace



Slicing Overview

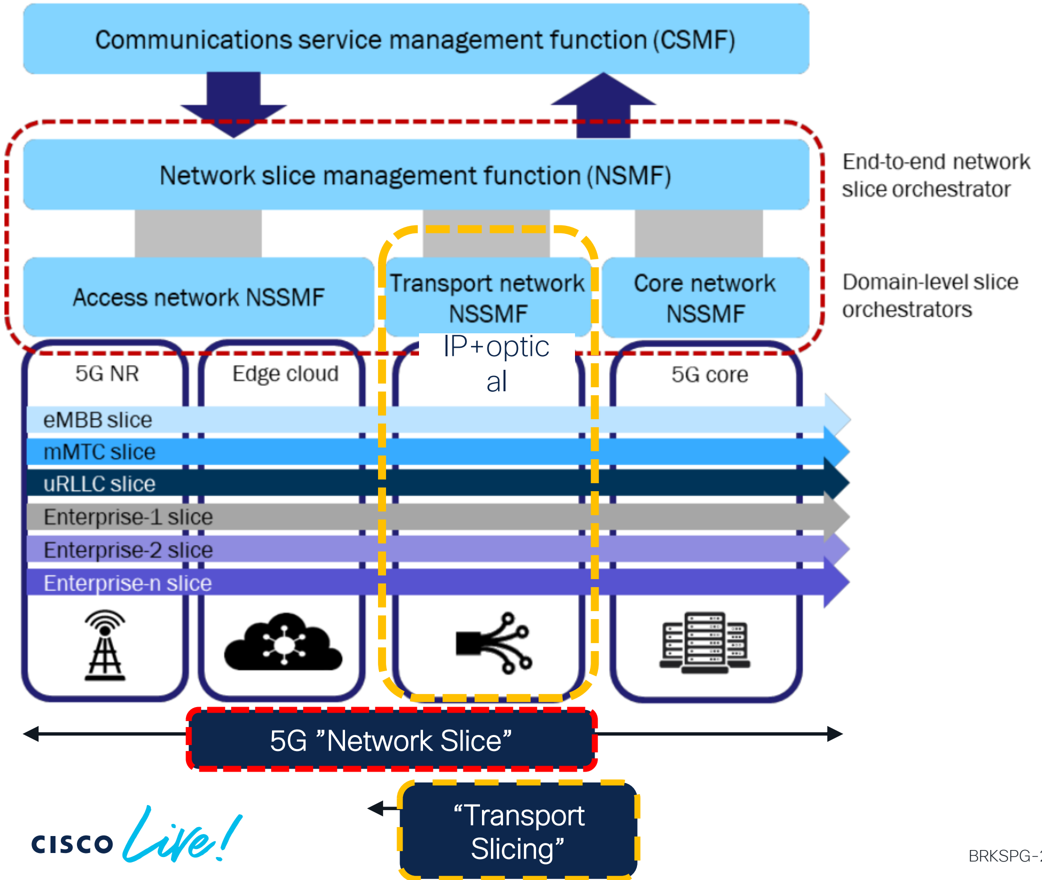
Intent with Transport Network Slicing : A Definition

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

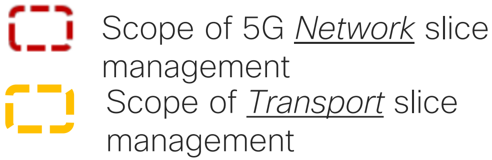
Its about offering:

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.

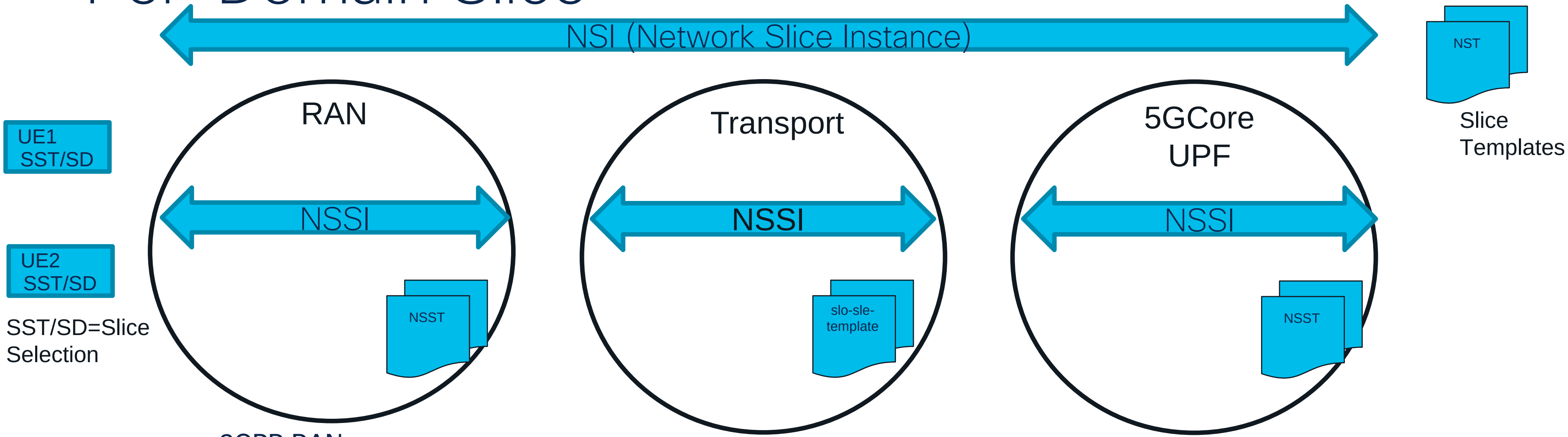
Defining Transport Slicing Scope: 3GPP reference architecture for 5G network slicing



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



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

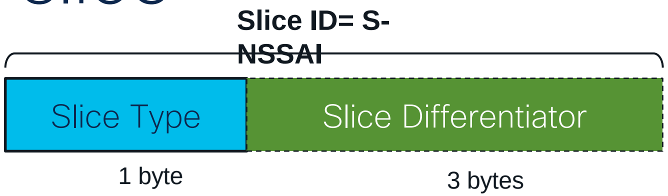
How is a user/UE placed into a “slice” 3GPP- 5G Slice ID= ST/SD

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.



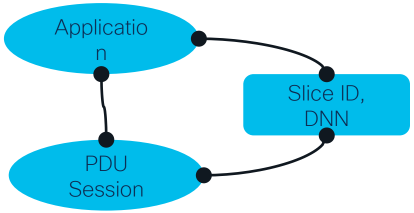
S-NSSAI: Single Network Slice Selection Information

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

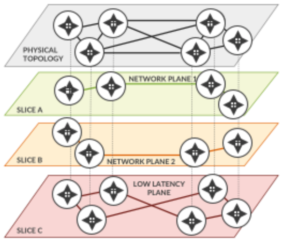
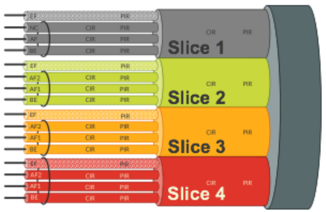
Example: Custom slices SP defined



O-RAN 5G Transport Architecture

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

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

	Isolation	Topology	Resources
	VPN1 VPN2 VPN3 VPN4 VPN5		
PURPOSE	▪ Traffic isolation between slices	▪ Subset of physical topology Low Latency slice High Capacity slice Plane A, Plane B slices	▪ Resources Links Bandwidth Queues/buffers
TOOLSET	▪ L3VPN ▪ EVPN L2 Services ▪ VLANs	▪ Intra-domain slicing architectures SR Flexible Algorithms SR Traffic Engineering RSVP Traffic Engineering ▪ Inter-domain slicing architectures Seamless / redistribution Controller based	▪ Bandwidth Management with Call Admission Control ▪ Dedicated components ▪ Per-link slicing Hierarchical QoS Hierarchical Policers

Source: O-RAN Xhaul Packet Switched Architectures and Solutions

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

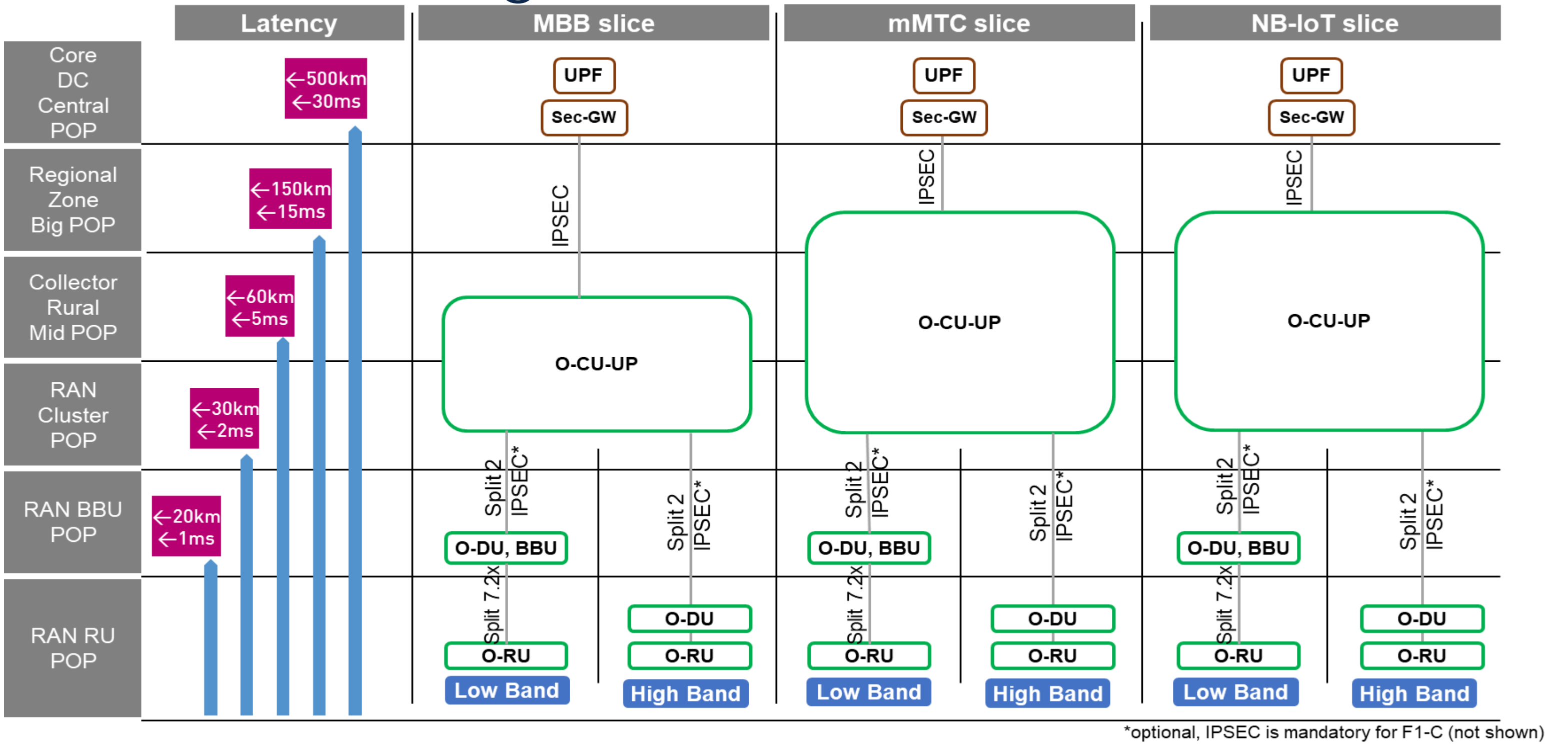
Combining these offer different levels of transport slice separation (ie soft or hard slice solutions)

- 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.

5G O-RAN Slicing: Phase 1

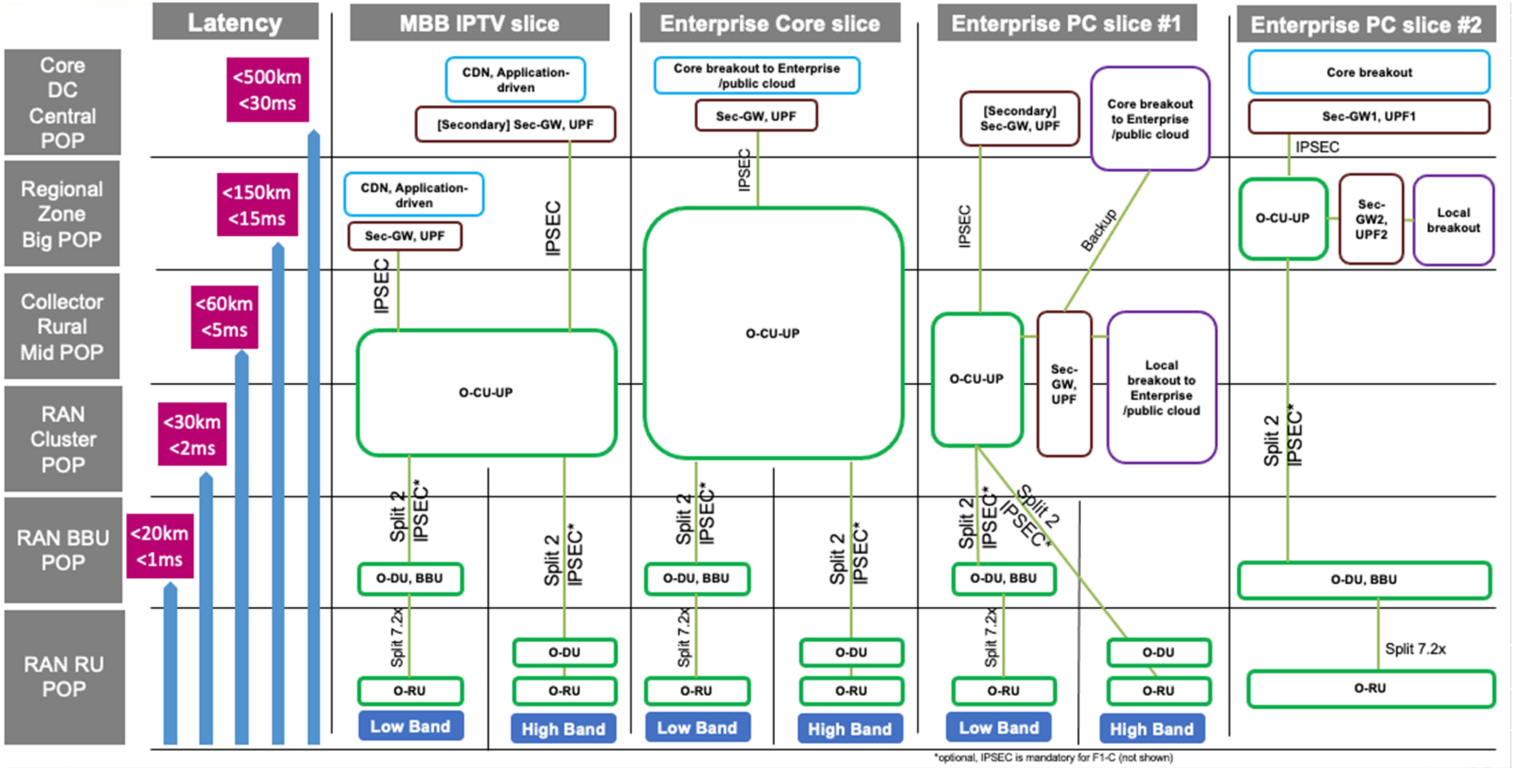
- Only Backhaul slicing
- No Midhaul and Fronthaul slicing
- Centralized UPF



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

5G O-RAN Slicing: Phase 2

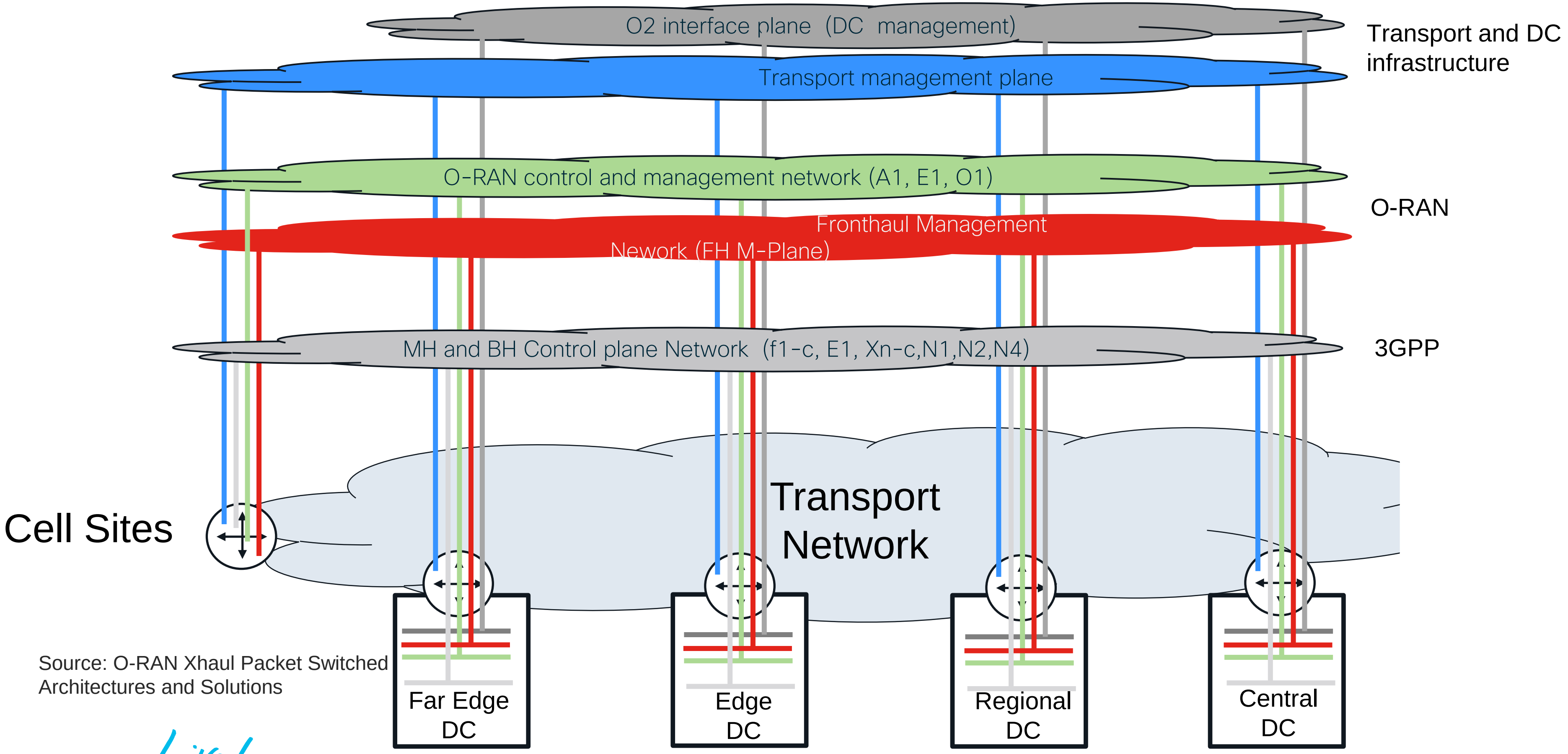
- **Backhaul & Midhaul slicing**
- **No Fronthaul slicing**
- **Distributed UPF**



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

Control and Management Plane VPNs architecture

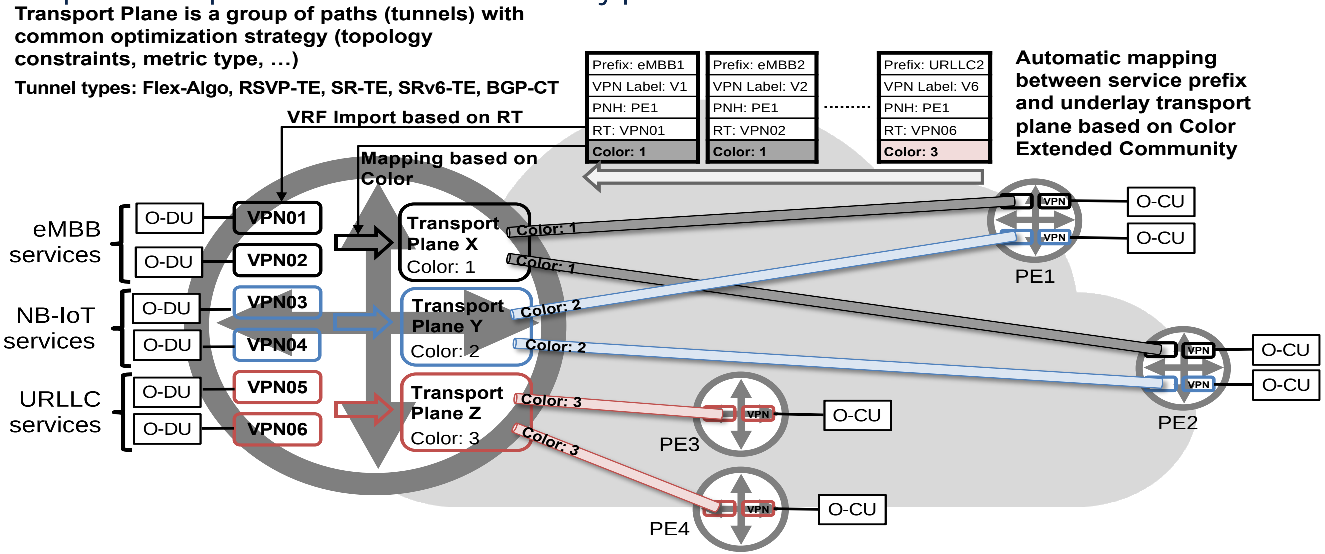
Applicable to both phase 1, phase 2 & phase 3



Source: O-RAN Xhaul Packet Switched Architectures and Solutions

Packet-switched underlay network

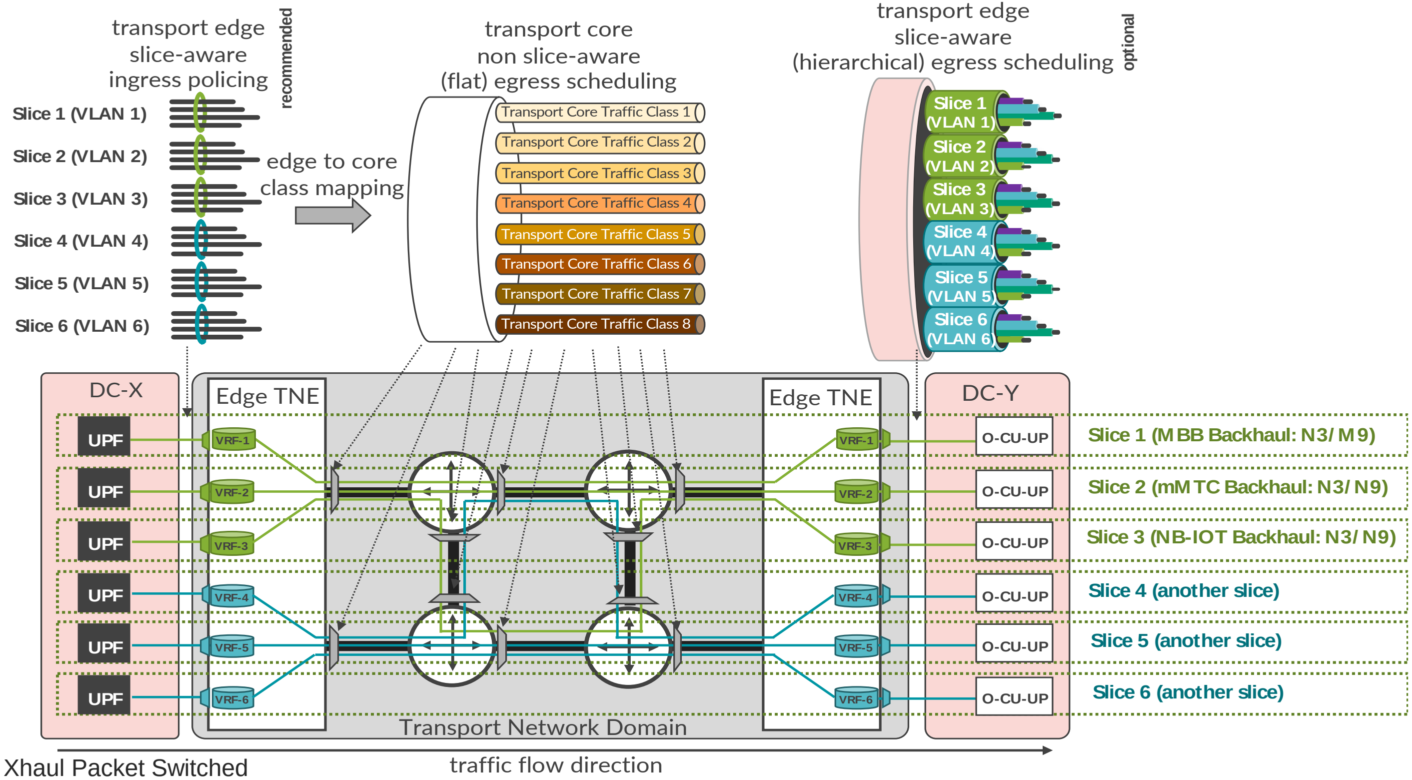
Transport plane per 5G service type



- 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

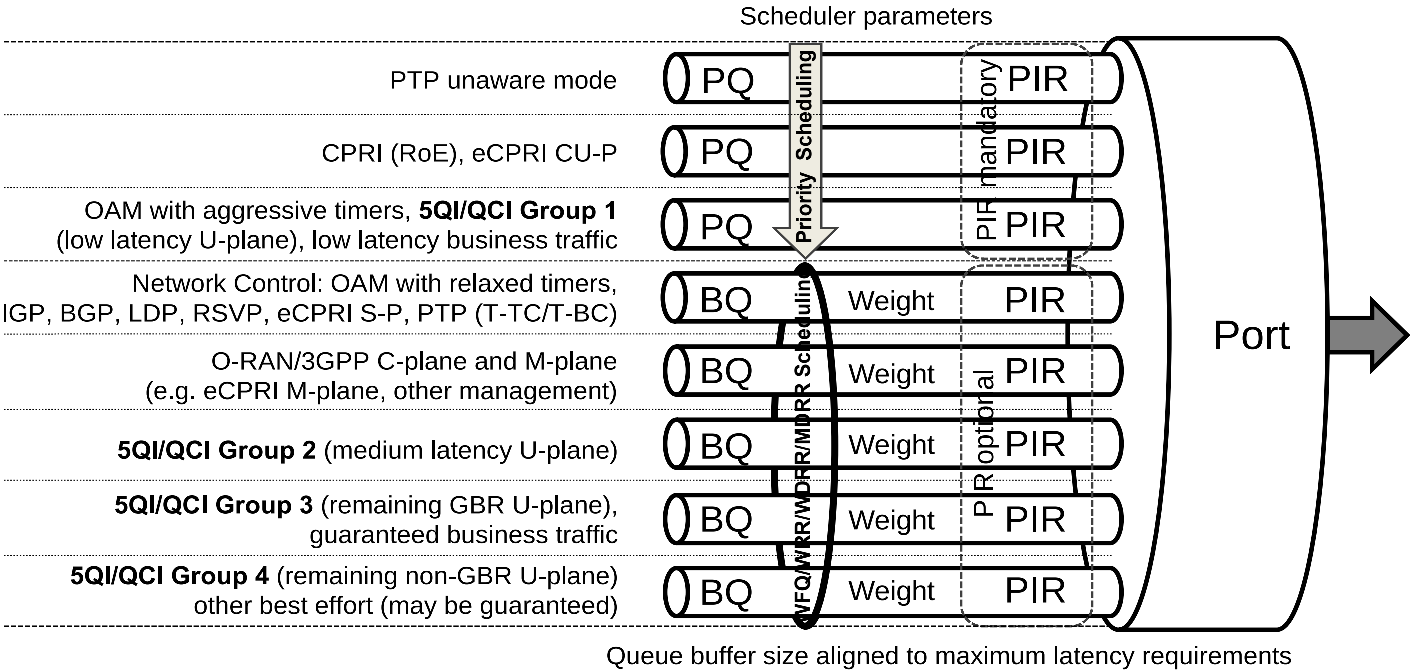
Source: O-RAN Xhaul Packet Switched Architectures and Solutions 3.0 (O-RAN.WG9.XPSAAS-v03.00)

High-level QoS model for transport slices



Source: O-RAN Xhaul Packet Switched Architectures and Solutions

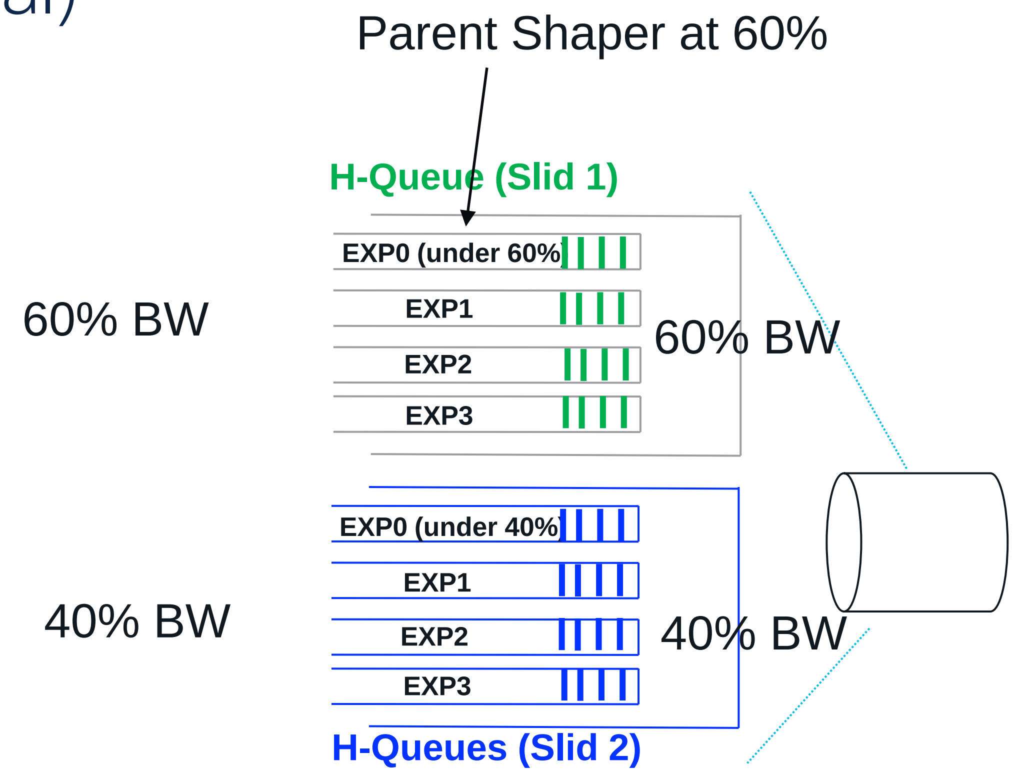
Example of QoS model with multiple priority queues



Source: O-RAN Xhaul Packet Switched Architectures and Solutions

SLID Attributes (Proposal)

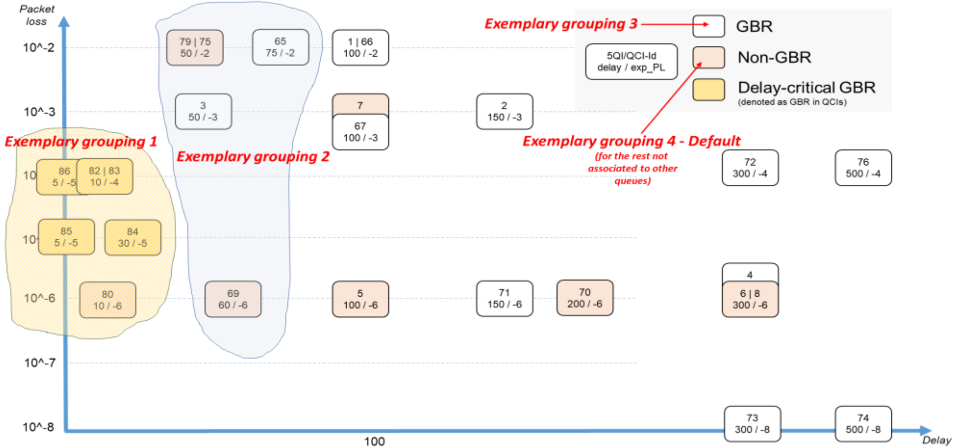
- **draft-filsfils-spring-srv6-stateless-slice-id**
- SLID is a differentiated behavior at a node
- SLID enables the differentiate treatment
  - QoS/ DiffServ policy on a per SLID
- SLID construct is like QoS
  - Independent of Routing and Topology
- Stateless
- Backward compatible
  - Incremental deployments



Terminology is still being worked out. It may be called Resource partition ID. Not to be confused with Network Slicing “Slice ID” NSSAI.

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

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

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

SR QoS VPN → Traditional Transport Orchestrators

SLA → SLA

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

Slice YANG Model

Next-Gen Transport Service Orchestrator

SR QoS SLA VPN

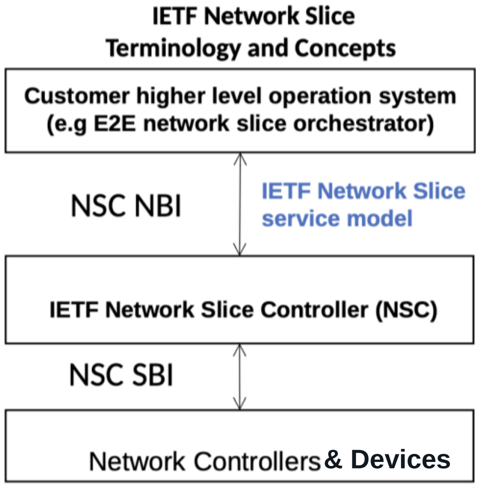
Transport Device Provisioning

SLA Engine

Telemetry collection

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



ATT DISH hosted Spring ORAN Plugfest, 2022

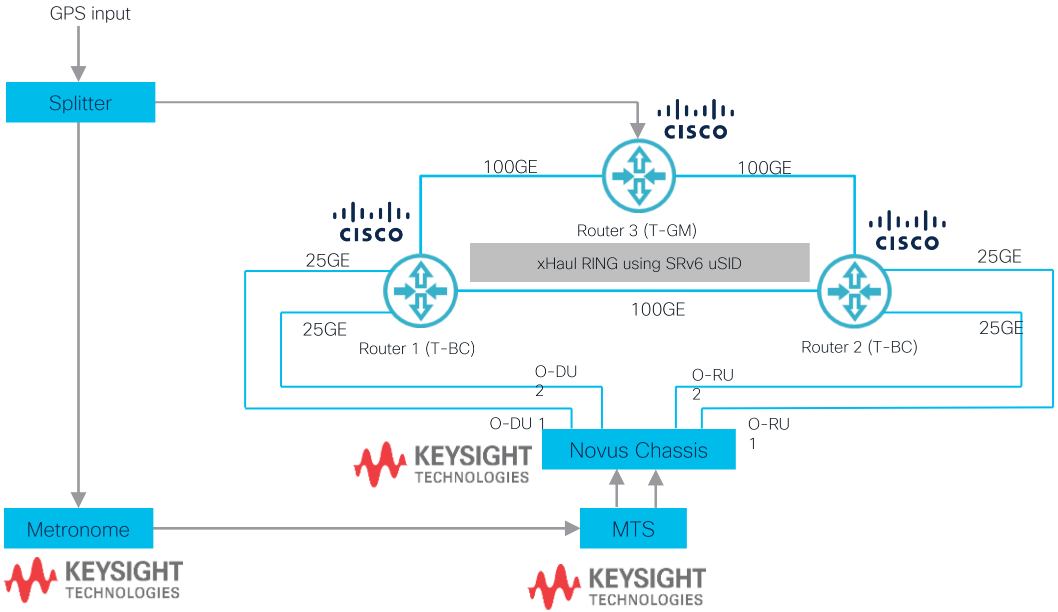
cisco Live!

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

4th Global O-RAN PoCFest

June 2022 Closing Calls

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.

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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