The bridge to possible

Evolution of the transport network architecture in the context of 5G and Open RAN

Roberta Maglione, Technical Solutions Architect
Global MIG Architectures Specialists

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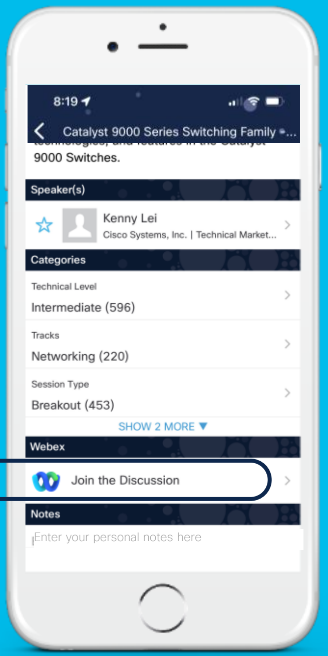

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Agenda

- Introduction
- RAN and Transport Network Evolution
- Cisco 5G Converged SDN Transport
- 5G Transport in Hybrid Cloud Environment
- Conclusion

Introduction

5G Architectural shifts

Impact network evolution

Software Centric
Virtualization
Cloud Native
Edge Computing
Programmable

Disaggregation
Radio Access
Mobile Core
Converged Core
Open, Disaggregated

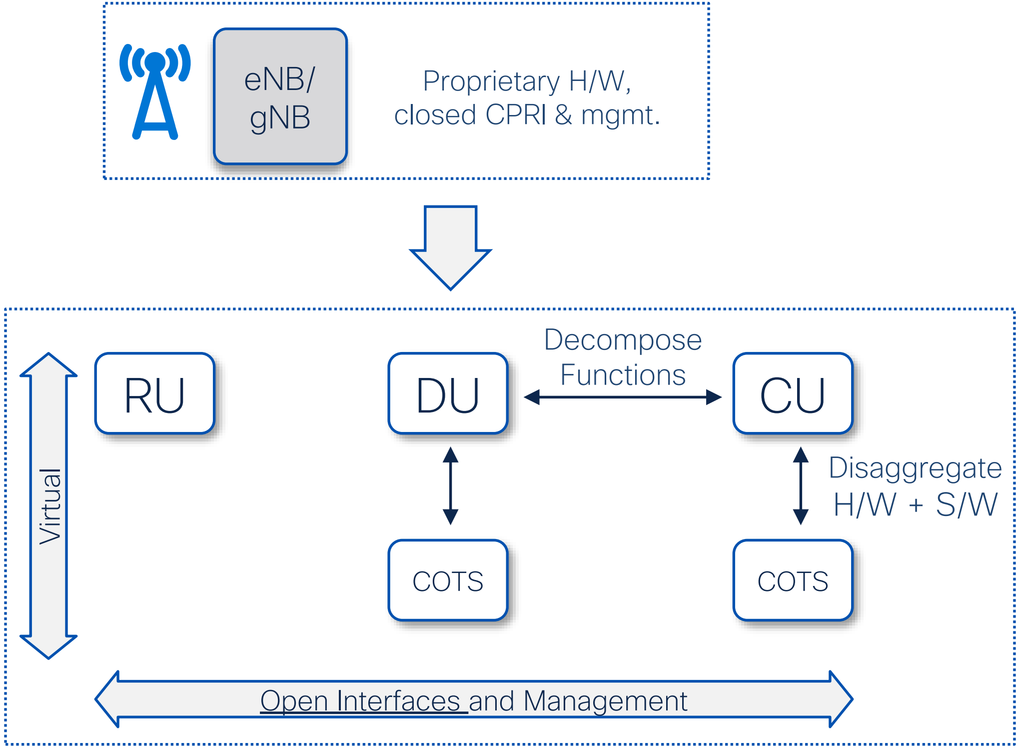
Convergence
Any Access
Common Sub Mgmt.
Converged Transport
Common Policy

New Radio
Higher Flexibility
High BW, low latency
Multiband Connectivity
Massive MIMO

Automation
Closed Loop
Multi Domain
Network Slicing
Service Assurance

RAN and Transport Network Evolution

Open & Virtual RAN

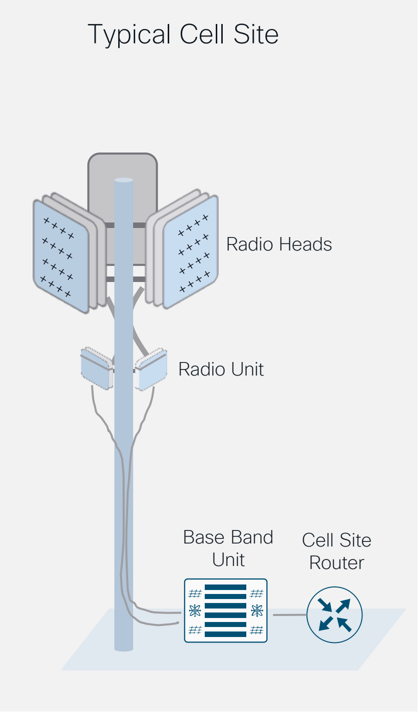


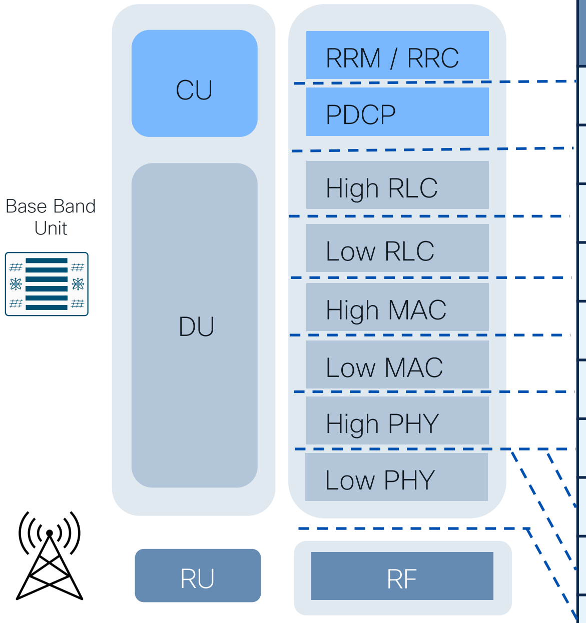
- Open interfaces for **vendor diversity** and a more robust ecosystem with competitive innovation
- Disaggregated software supports cloud-based models for **operational efficiency**

RU: Radio Unit
DU: Distributed Unit
CU: Centralized Unit

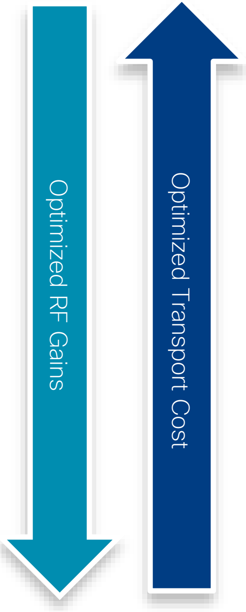
COTS: Commercial Off-The-Shelf

RAN Components





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

RAN Fronthaul Standards

Evolving towards Open RAN

TDM based
Split 8

Ethernet based
Split 7

Ways to carry
Radio over
Ethernet

Standard
Fronthaul interface
Split 7.2x

CPRI

- Common Public Radio Interface

eCPRI

- enhanced Common Public Radio Interface

RoE

- Standard for Radio over Ethernet & NGFI (IEEE 1914.1/3)
- Time Sensitive Networking
  TSN Profiles 802.1CM, Frame Preemption 802.1Qbu

IEEE
Advancing Technology for Humanity

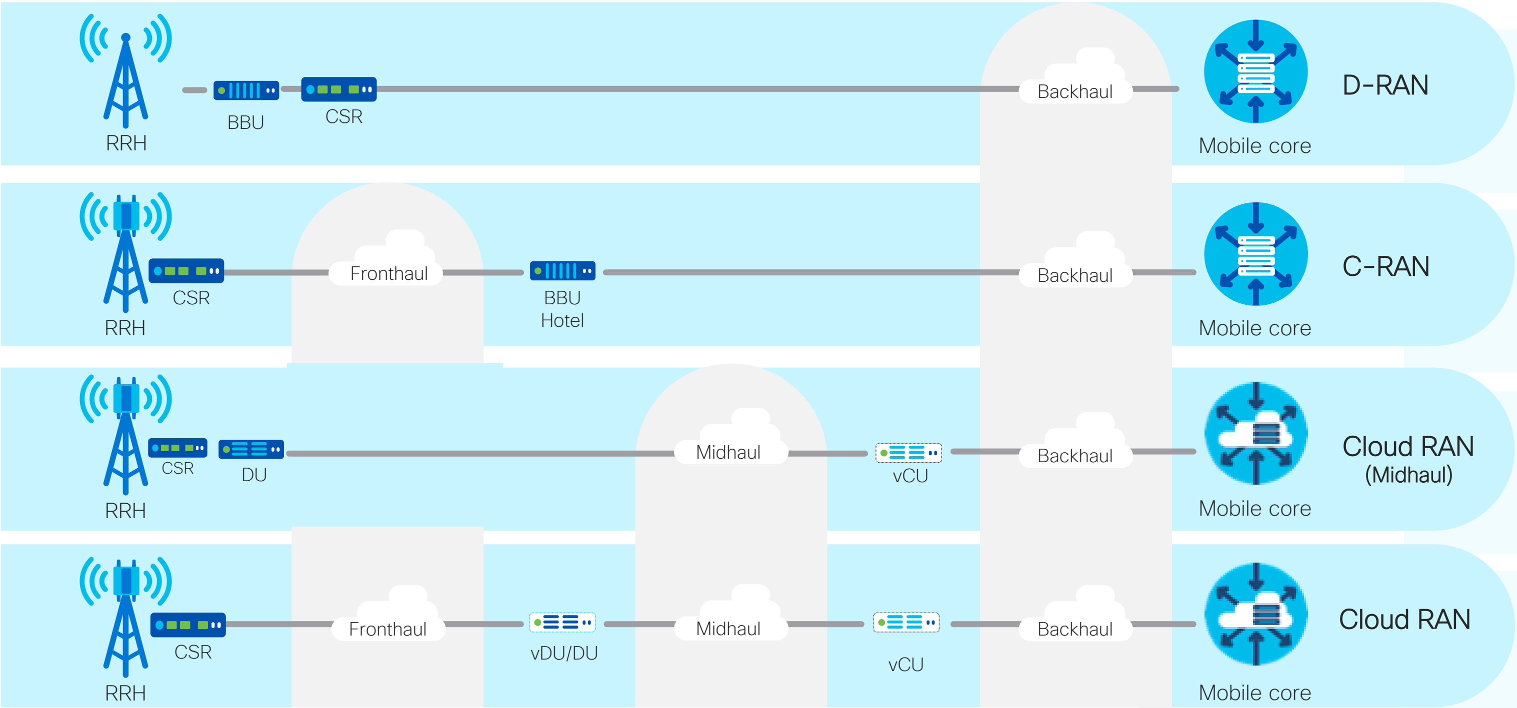
Open RAN

- O-RAN Alliance (Open RAN)
  - ✔ Open feature development
  - ✔ Reduced time-to-market
  - ✔ Incubation of ecosystem innovation

O-RAN ALLIANCE

Driving towards open standards for RAN Interfaces

RAN Transport Architecture Options



	Fronthaul		Midhaul		Backhaul
1-way latency:	75us/100 us (LTE) 160us (5G NR)	1-way latency:	1-25ms	1-way latency:	10ms
Typical distance:	<15KM	Typical distance:	>10KM	Typical distance:	>10KM
Interface(s):	10G/25G/100G/200G	Interface(s):	10G/25G/100G	Interfaces:	10G/25G/100G/200G

1Km of fiber = 5 us

- Higher Speed Interfaces
- Lower Latency
- More Precise Timing & Synchronization
- Any-to-Any Connectivity

Cisco 5G Converged SDN Transport Solution

Requirements and Architecture

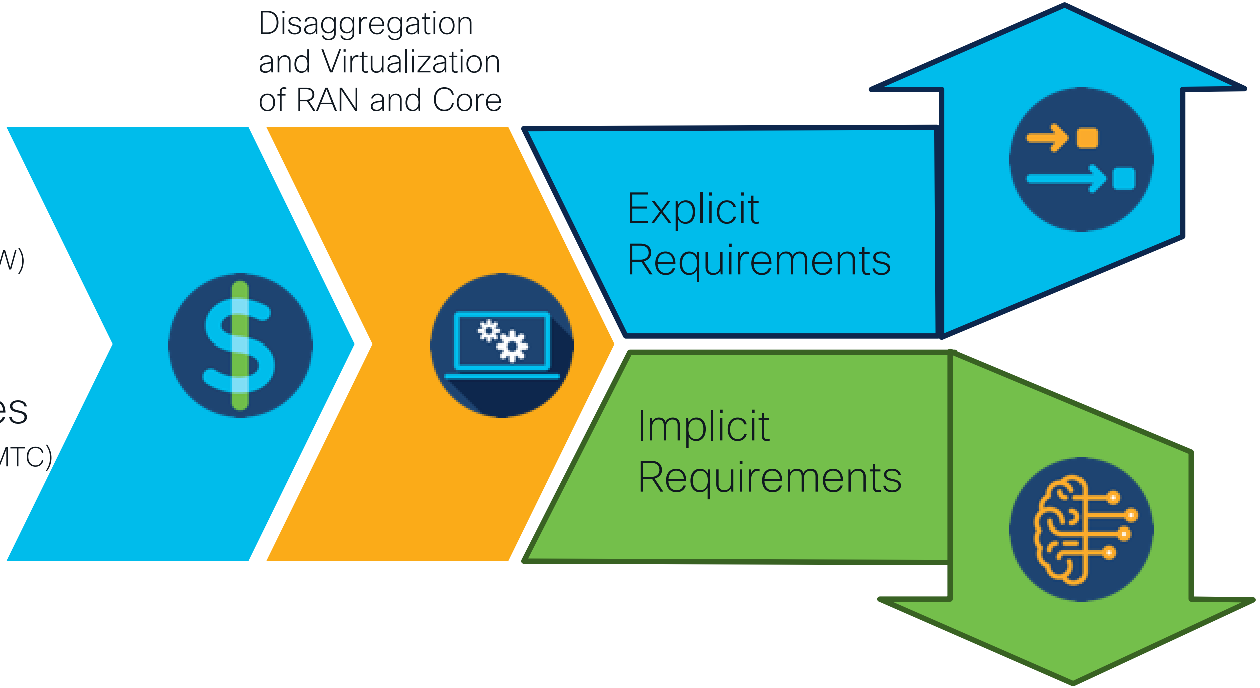
What's Different in 5G?

New requirements on transport network

5G RAN
(Sub-6Ghz, mmW)

+

5G Services
(eMBB, URLLC, mMTC)

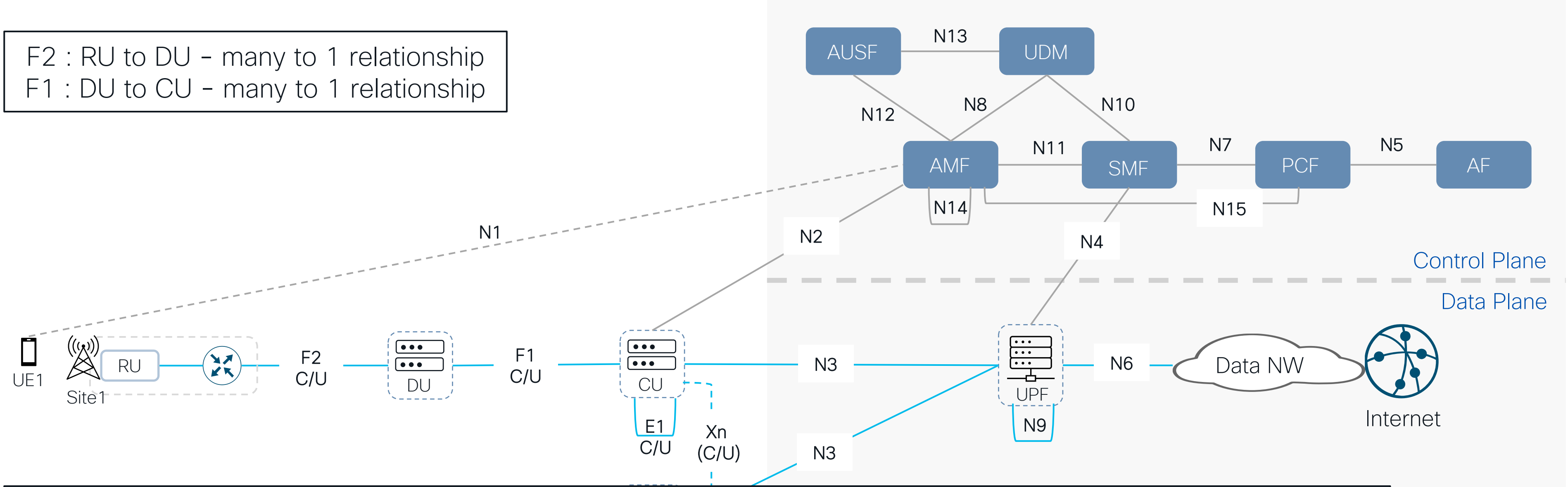


- Bandwidth and scale
- Low latency
- Precise timing and sync
- Flexible service placement
- Network slicing

- Re-architect the network (MEC)
- Operational efficiency
- Simplification
- Any to any connectivity
- Reliability and awareness

RAN and 5G Core Interfaces

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

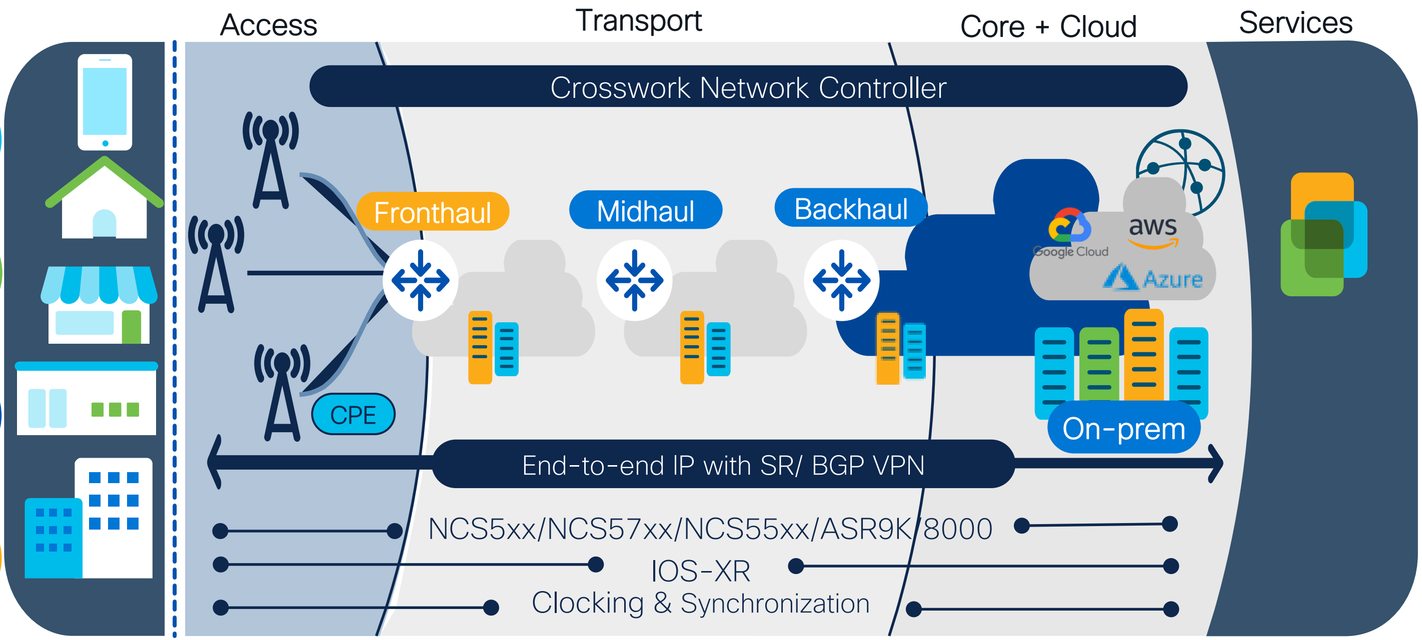


All interfaces are mandatory IP based (except F2 where its optional)
There is a complex set of networking requirements between different 5G components
1 to 1, 1 to many, many to many
Same component may need to support all models concurrently

Cisco’s 5G Converged SDN Transport

Reduce Infrastructure Costs and Simplify Operations

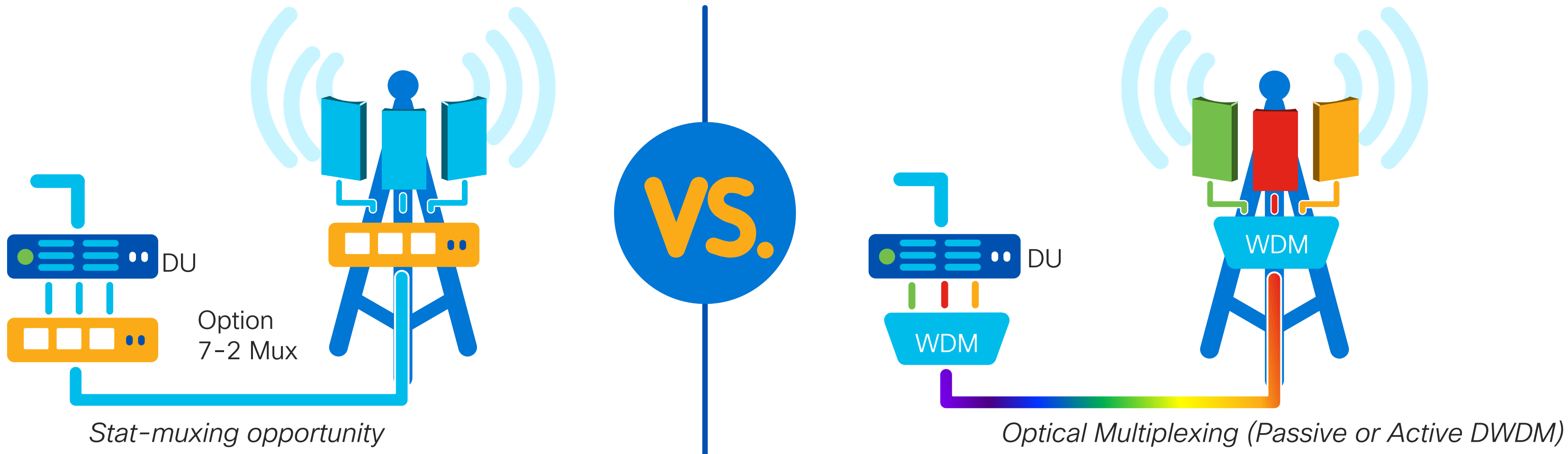
- Converged Infrastructure for all Services
- Common Technology End-to-end: SR and BGP VPN
- Open, Programmable SDN-based
- On-prem & Cloud-based (Hybrid Cloud)



Cisco architecture is validated as per O-RAN WG-9 “*Packet* Switched xHaul architecture and solutions”

Packet-Based Fronthaul

As optimal solution



Packet | Optical

- ✔ Stat Mux Advantages
- ✔ Cost Effective
- ✔ Topology Independent
- ✔ Service Visibility & Transparency
- ✔ Scalable E2E Converged IP

- ✘ Optical multiplexing
- ✘ Non-scalable, architecturally rigid
- ✘ Point-to-point, topology dependent
- ✘ Limited service visibility
- ✘ Capex dependent scale

Different types of fronthaul Interfaces

How do we deal with legacy interfaces in a packet-based network?

Ethernet based

CPRI

- Common Public Radio Interface

Legacy
TDM based

eCPRI

- enhanced Common Public Radio Interface

RoE

- Standard for Radio over Ethernet & NGFI (IEEE 1914.1/3)
- Time Sensitive Networking
  TSN Profiles 802.1CM, Frame Preemption 802.1Qbu

IEEE Advancing Technology for Humanity

Open RAN

- O-RAN Alliance (Open RAN)
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  - ✓ Incubation of ecosystem innovation

O-RAN ALLIANCE

Driving towards open standards for RAN Interfaces

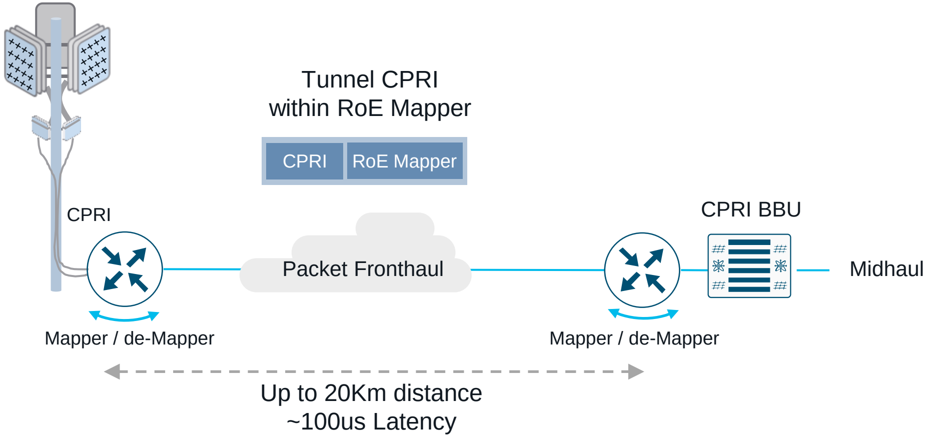
Brownfield C-RAN deployments

Options for CPRI in a packet-based network:

- CPRI over Ethernet
- Fronthaul Gateway Interworking Function

Fronthaul: CPRI over Ethernet

Radio over Ethernet Structure Agnostic Modes (Type 0 & Type 1)



CPRI over Ethernet for CPRI CRAN deployment

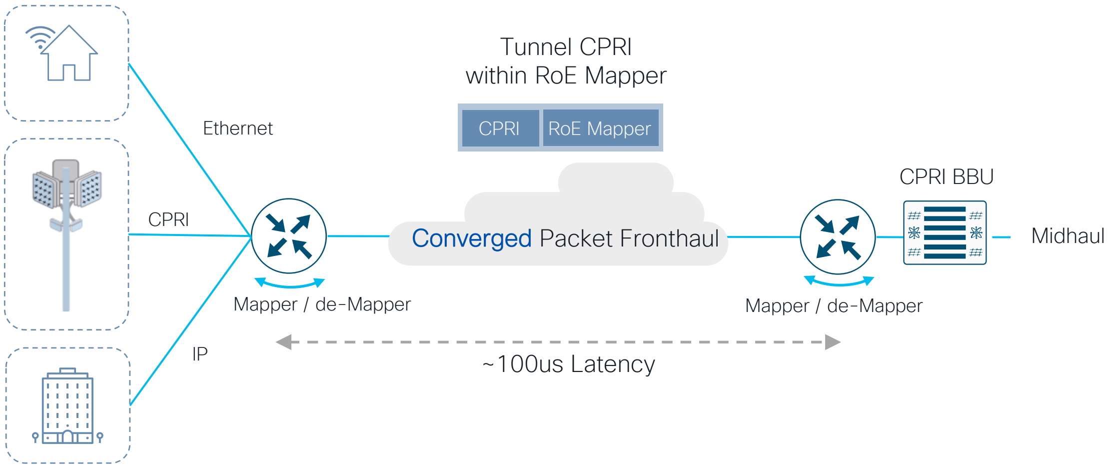
Based on IEEE 1914.3 Standard for Radio over Ethernet Encapsulations and Mappings

Deployment Modes:

- RoE Structure-Agnostic Tunneling Mode (Type 0)
  - Compatible with all RAN suppliers' equipment
  - Tested with Huawei, Ericsson and Samsung radio
- RoE Structure-Agnostic Line Code Aware Mode (Type 1)
  - Tailored with RAN vendor specific CPRI information to reduce fronthaul bandwidth by 20%.
  - Tested with Huawei radio

CPRI over Converged Packet Fronthaul

How can we optimize transport performance for multiple applications?



- Multiple services (Mobile, Residential, Business VPN) on a common transport network
- Different applications may have different packet size
- How can we meet the strict latency requirements for 5G services at the Fronthaul?

Time Sensitive Networking IEEE 802.1CM

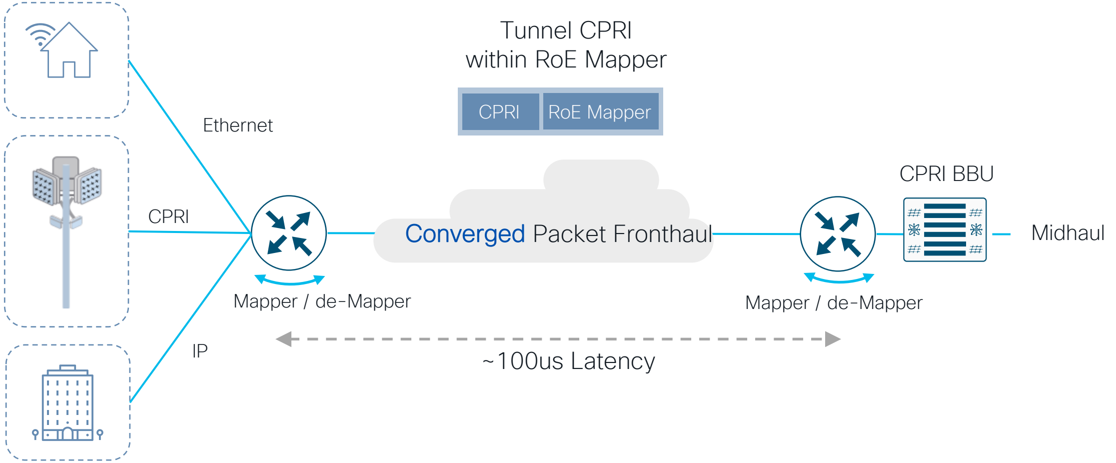
Ethernet for Fronthaul

- **Profile A**: Strict priority queuing (no frame pre-emption)
  - Radio data payload frame size max is 2000, C&M max is 1500 octets
  - IQ data traffic belongs to strict priority traffic class - strict priority algorithm
  - C&M data assigned to lower priority than IQ data

- **Profile B**: IEEE 802.1Qbu Frame Preemption
  - Pre-emption useful to avoid restrictions on the maximum frame size
  - Frame Preemption up to 25G links
  - IQ data traffic configured (*frame pre-emption status*) as "*express*"
  - C&M data assigned to lower priority than IQ data and set "*pre-emptable*"

CPRI over Converged Packet Fronthaul

IEEE TSN: 802.1Qbu, Frame Preemption Technique



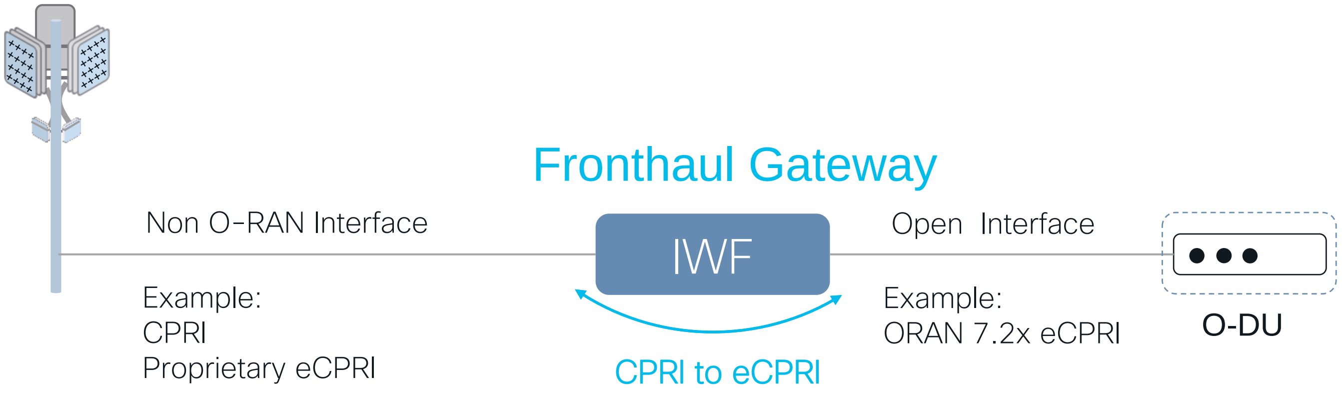
- IEEE 802.1Qbu with Strict Priority + Preemption offers lowest fronthaul latency and greatest BW utilization
- Required on uplink 10G or 25G interfaces
- Its book ended, hardware solution

In -> Out	HP Packet Size	LP Packet Size	802.1bu (w Frame Preemption)		No 802.1bu (wo Frame Preemption)	
			HP Latency (us)	HP Jitter (us)	HP Latency (us)	HP Jitter (us)
10G->25G	1500 (eCPRI)	9K (Enterprise)	17.677 (Saving of 4.34 us)	3.24	22.021	4.54

Saving of 4.34 us = 1Km fiber or 1-Router hop delay

Fronthaul Gateway Interworking Function

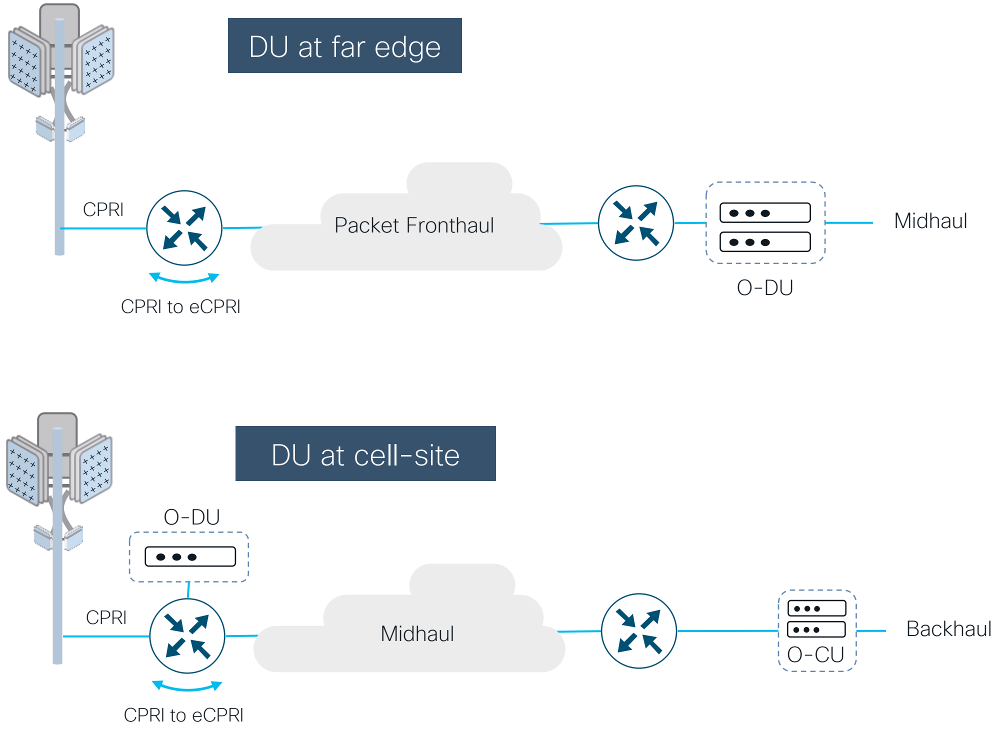
Standard based solution to integrate legacy interfaces

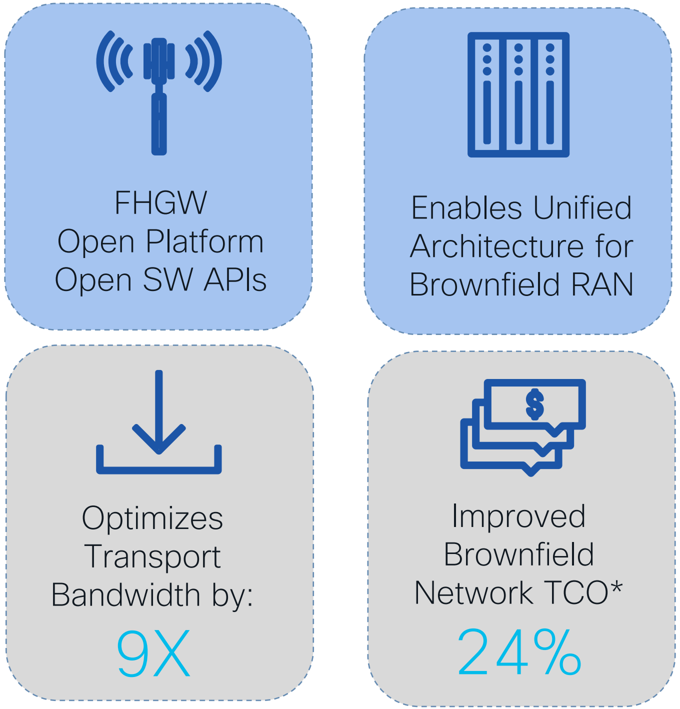


- Fronthaul gateway (FHGW) is a RAN function that converts non-ORAN interface to O-RAN 7.2.x Interface (CPRI to eCPRI conversation)
- ORAN Alliance defined IWF and Open FHGW Hardware Platform specification as part of ORAN Alliance working group 7 ORAN.WG7.HRD.0-v02.00.pdf

Fronthaul Gateway Interworking Function

Deployment models and benefits

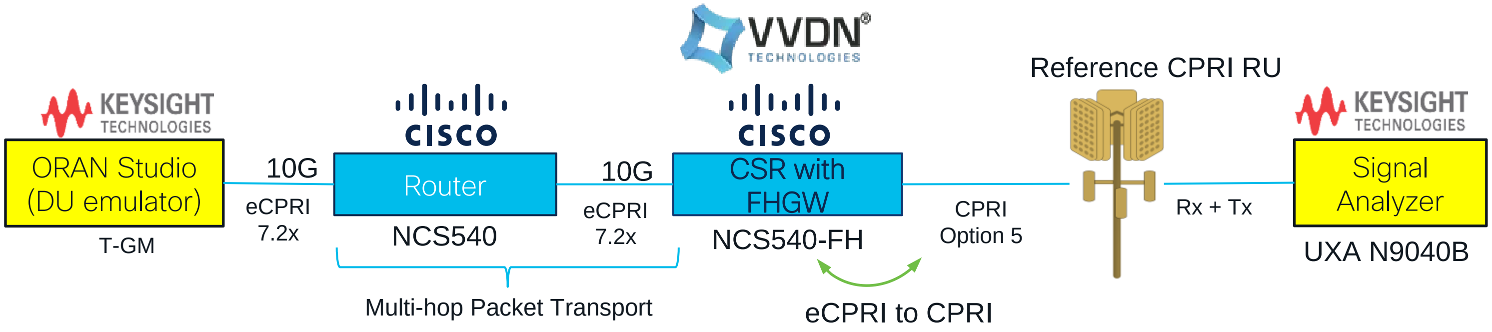




*As per TCO done for an operator

Fronthaul Gateway on Cisco NCS540-FH

Prototype and demonstration



- Fronthaul Gateway: software function running as container on NCS540-FH
- Tested with Barthi Airtel as part of ORAN Plugfest in India Nov 2021 [1]
- Demonstrated at Mobile World Congress Barcelona 2022[2]
- 4.5Gbps of CPRI → 0.5Gbps of eCPRI traffic

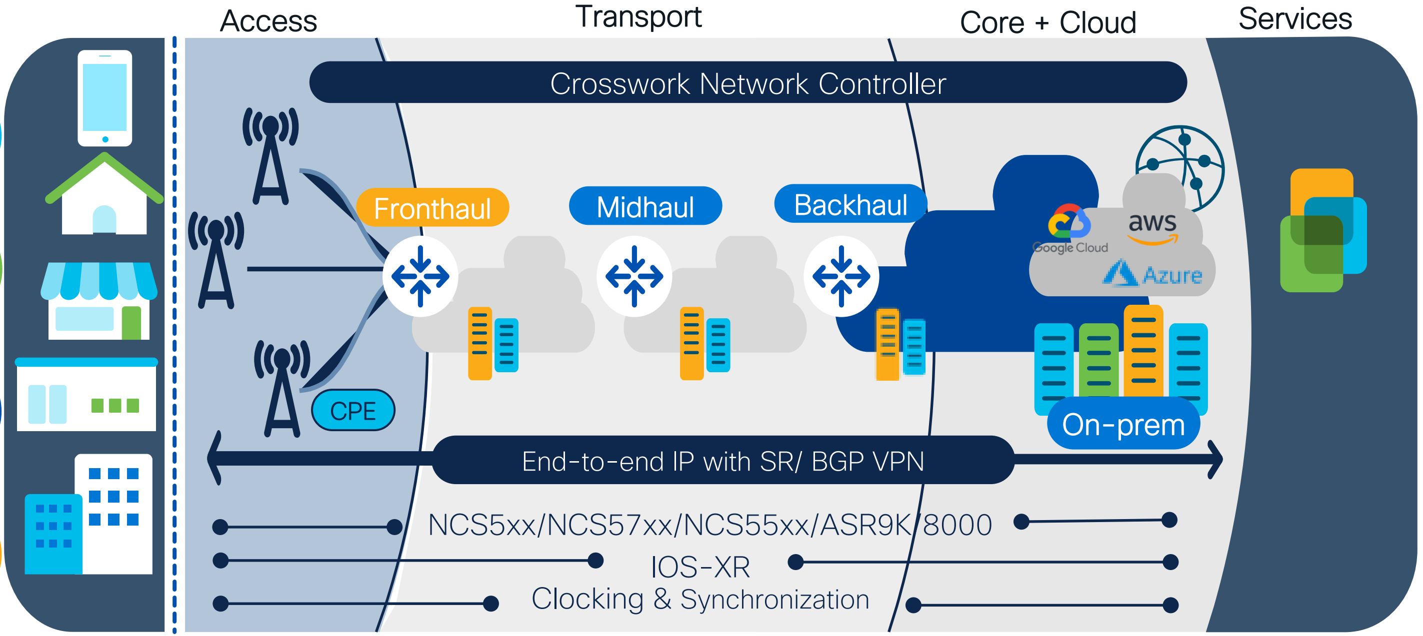
(1) https://www.o-ran.org/blog/o-ran-global-plugfest-2021-demonstrates-stronger-ecosystem-and-maturing-solutions
(2) https://www.linkedin.com/pulse/optimized-architectural-approach-brownfield-scenarios-maglione

Architecture principles and components

Cisco's 5G Converged SDN Transport

Reduce Infrastructure Costs and Simplify Operations

- Converged Infrastructure for all Services
- Common Technology End-to-end: SR and BGP VPN
- Open, Programmable SDN-based
- On-prem & Cloud-based (Hybrid Cloud)



Cisco architecture is validated as per O-RAN WG-9 "*Packet* Switched xHaul architecture and solutions"

Key principle: simplification at all layers

Simplified

Operational Simplification – Ease of Use
IOS-XR end-to-end, Crosswork, NSO, Yang suite

Service Simplification
BGP based VPN for unified service delivery

Transport Simplification
Simplified transport with Segment Routing + SR-PCE

Cisco IOS XR 7: single OS end to end

Redefining software for better operations

Simple

- Optimized to reduce memory, downloads, and boot times
- Streamlined protocols with SR/EVPN, Telemetry
- Secure zero-touch rollout

Modern

- Open APIs
- Customizable software images
- Cloud-enhanced

Trustworthy

- Assess hardware and software authenticity at boot and runtime
- Immutable record of all software and hardware changes
- Real-time visibility of trust posture

50% Less Memory Footprint

50% Faster Boot Times

40% Smaller Image Sizes

40% Faster Download

Why Segment Routing for Transport?

Network Resiliency
TI-LFA and automated 50ms protection

Network Simplification
Eliminate LDP, RSVP and other protocols

Granular and simple TE
Dynamic and efficient provisioning of custom traffic paths

Simplified Service Creation
Easily configure L2VPN and L3VPN services

Any-to-any Connectivity
Flexible any-to-any connectivity

Scalable Network Slicing
Faster creation, adaptation and deletion of slices at scale

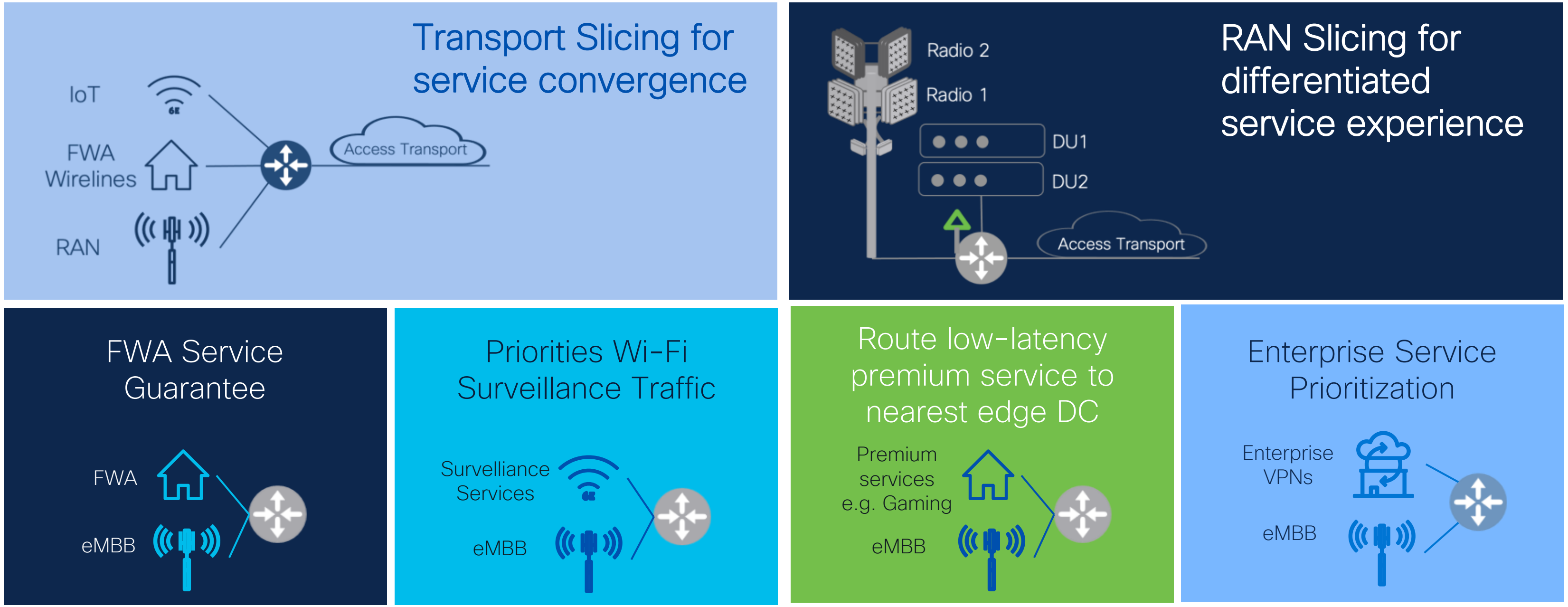
Simplified Operations
Easy to operate the network

Standards Based
No vendor lock-in

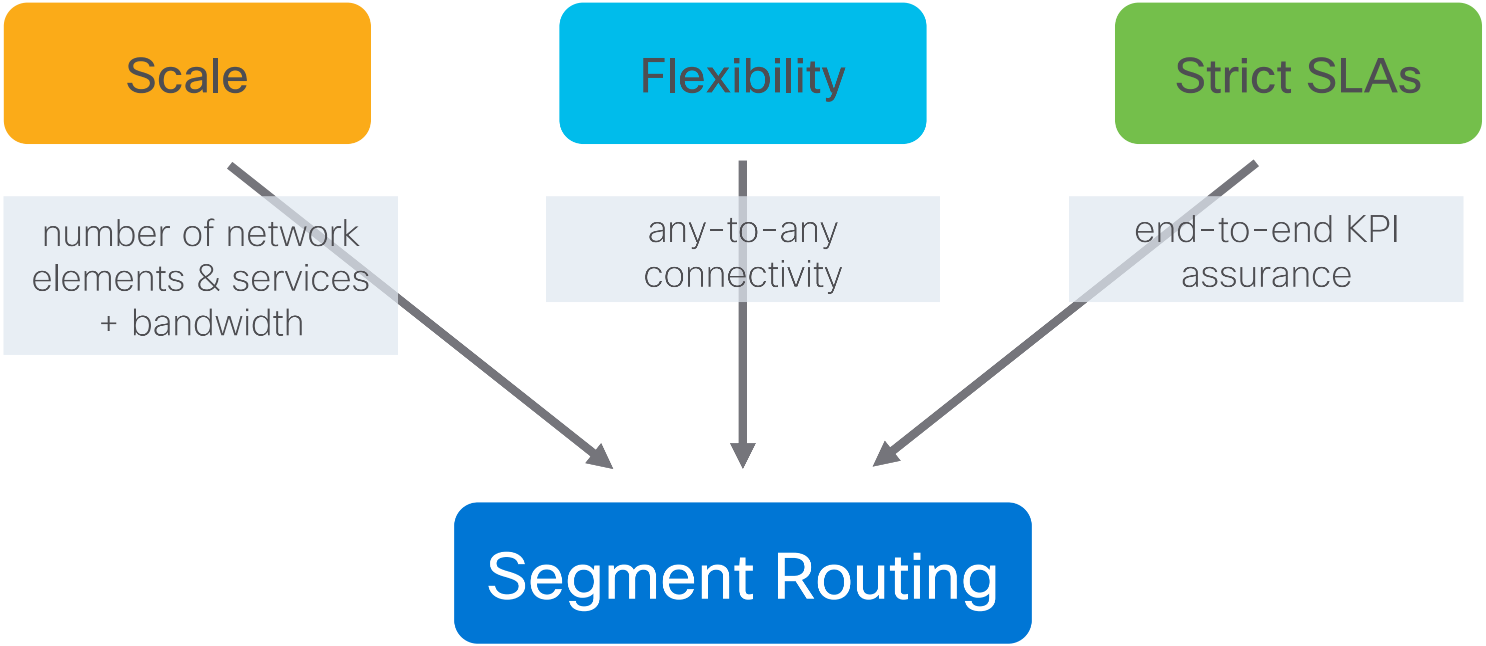
Transport Network Slicing

Transport Slicing for Service Experience

Goal: to enable multi-services support

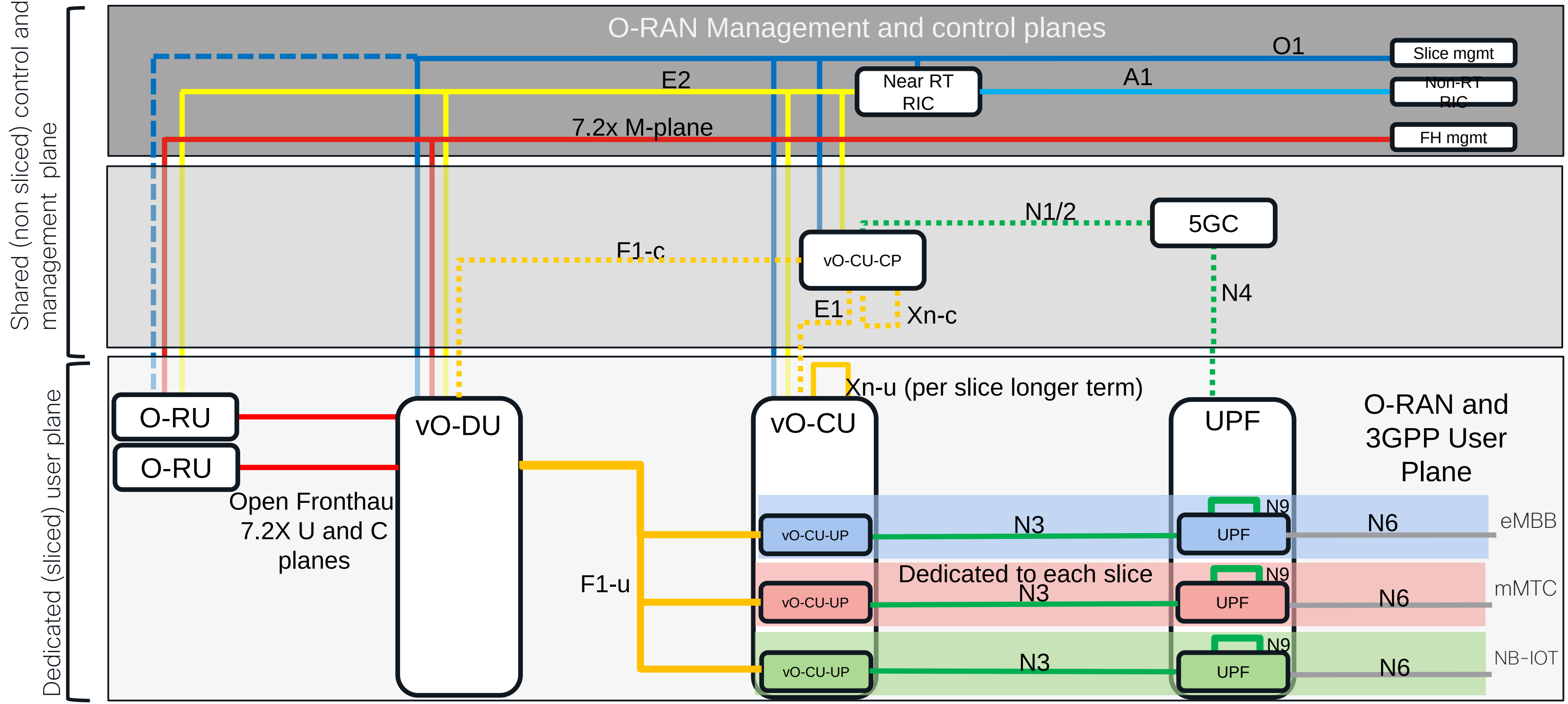


Transport Network Slicing



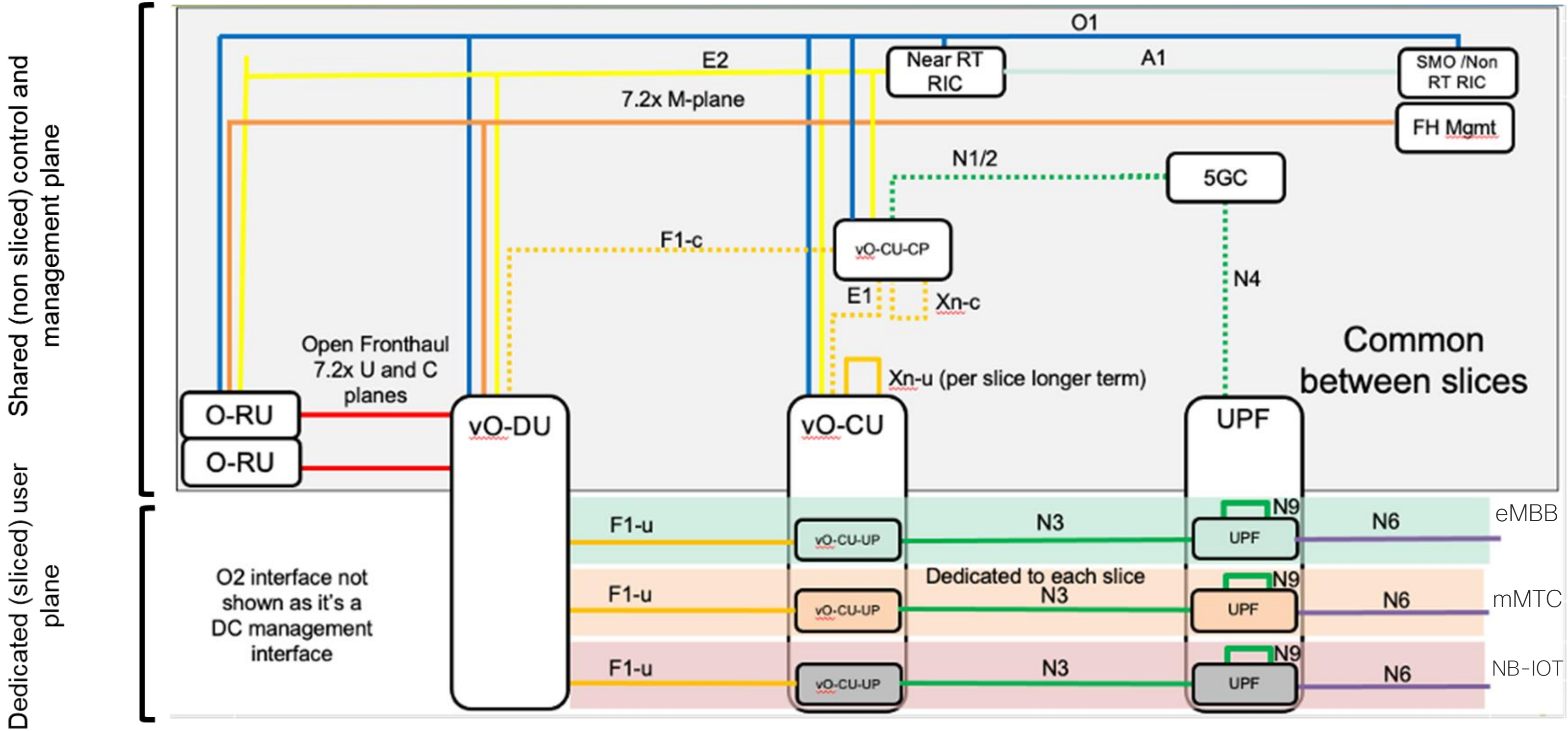
O-RAN WG9: transport network slicing phase 1

- Only Backhaul can be sliced
- Mapping 5QI to DSCP only at backhaul



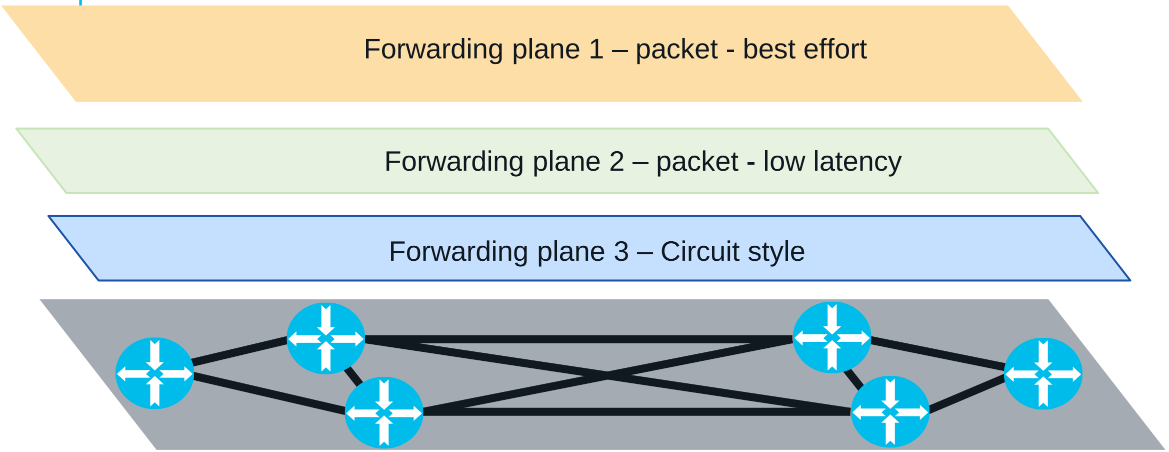
O-RAN WG9: transport network slicing phase 2

- Both Backhaul and Midhaul can be sliced
- Mapping 5QI to DSCP also at Midhaul



Underlay Forwarding planes

Different planes to provide different behaviours

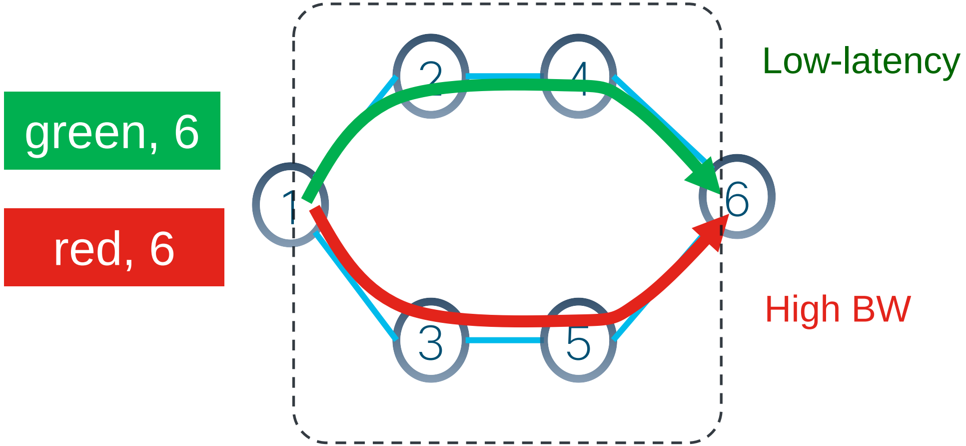


- **Small number** of forwarding planes defined in underlay:
  - Services orientated (eMBB, URLLc, MMTc, circuit style services)
- **Forwarding planes** aims to support a set of **behavioural characteristics**:
  - Delay, loss, topological constraints, subscription ratio, service type and characteristics, admission control
- **Tools** to build forwarding planes:
  - **Segment Routing TE policies, Segment Routing Flex-algo**, QoS and admission control

Segment Routing Traffic Engineering Policies

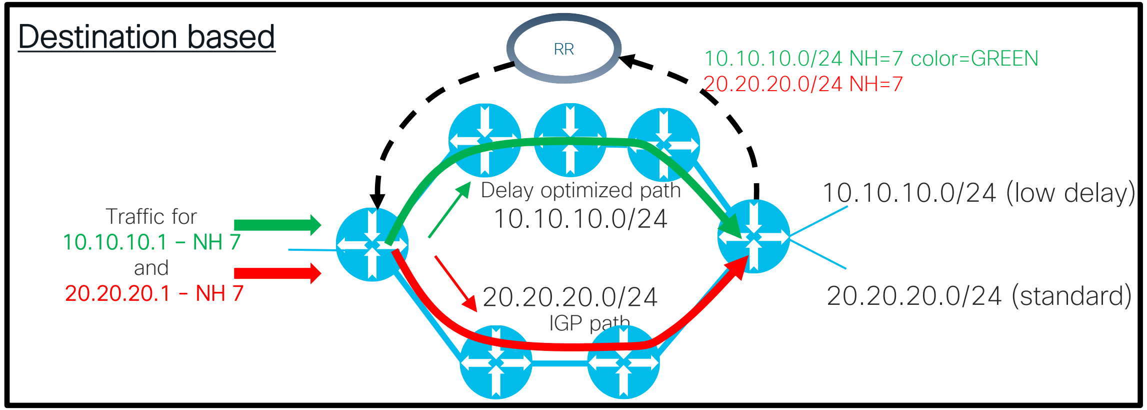
For the same source/end-point different colors for different SLA

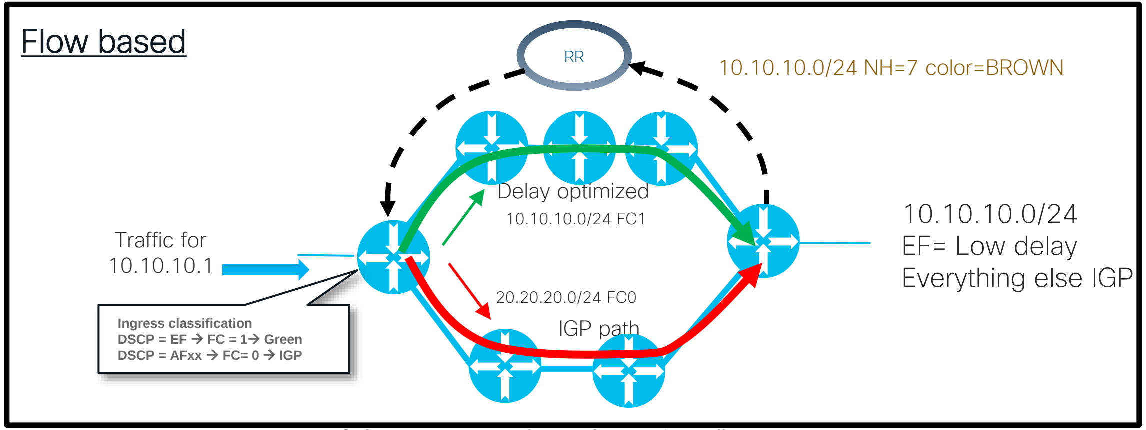
- E.g Green = Low Latency and Red = High Bandwidth
- Policy *Color* designed to match BGP Ext. Community *Color*
- Extended Community Color is specified in RFC 5512



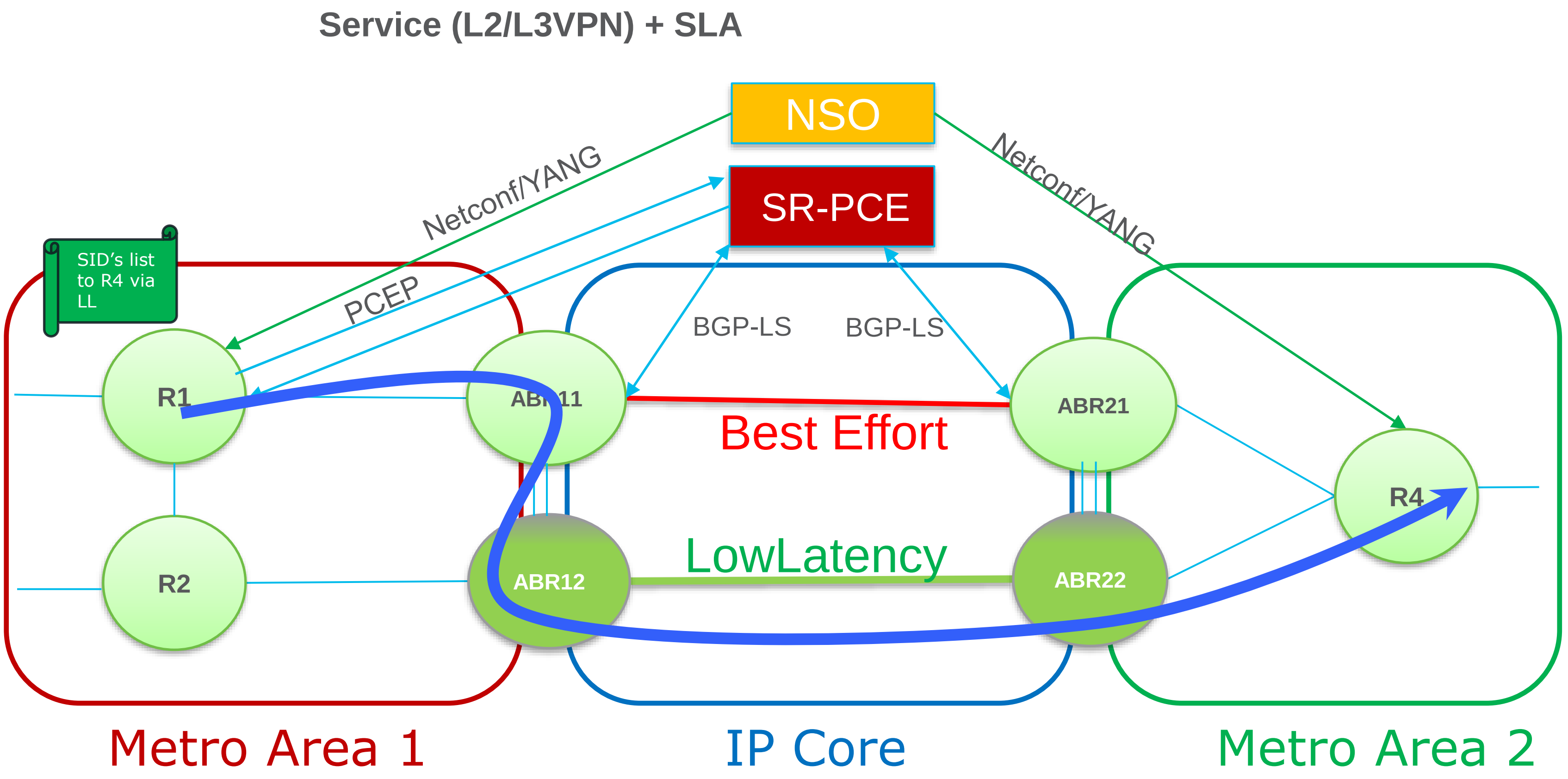
Segment Routing Traffic Steering

- Mechanism on source router to steer traffic
- By default traffic uses IGP path
- Can steer traffic into a SR policy or specific Flex-algos
- Destination based Traffic Steering: destination only
- Flow based Traffic Steering : Destination + QoS criteria





SR On Demand Next Hop for Inter-Domain



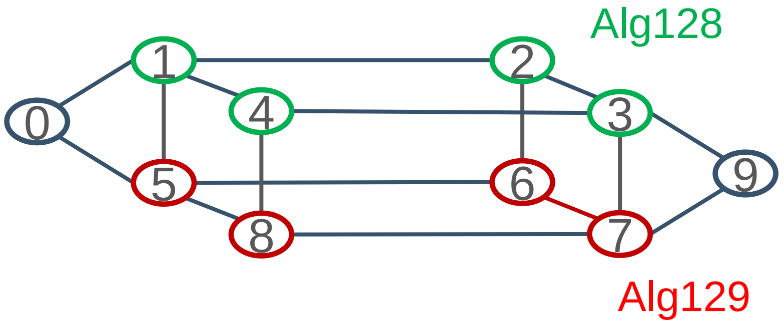
Segment Routing IGP Flexible Algorithm

- New Prefix-Segments with specific optimization objective and constraints
  - minimize igp-metric or delay or te-metric
  - avoid SRLG or affinity
- Each node MUST advertise Flex-Algo(s) that it is participating in
- Each node MUST have the definition of the Flex-Algo(s) that it is participating in
  - e.g. ALGO 128: minimize on IGP metric and avoid TE affinity RED
  - Local configuration

Nodes 0 and 9 participate to Algo 0 and 128 and 129

Nodes 1/2/3/4 participate to Algo 0 and 128

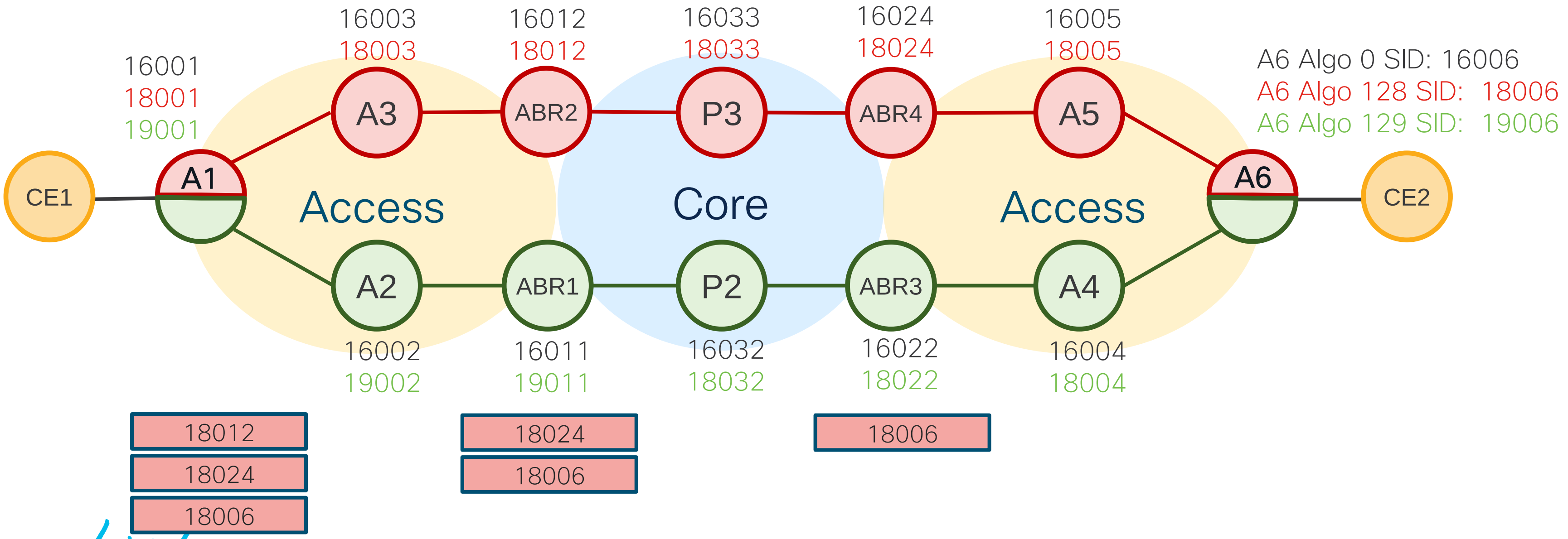
Nodes 5/6/7/8 participate to Algo 0 and 129



For Your Reference

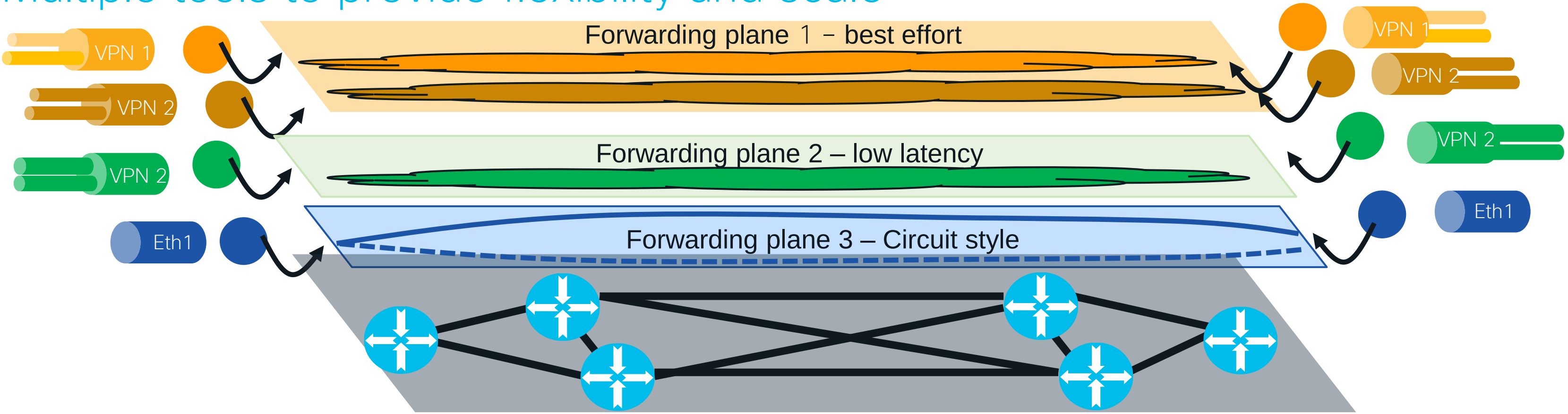
Example of Flex-Algo Dual-Plane

- A1 and A6 belong to both topology algorithms
- Transit nodes belong to a single algorithm
- On A1 / A6 traffic is steered into SR-TE Policy by using algorithm constraint via SR Policy local config or ODN



Mapping services to forwarding planes

Multiple tools to provide flexibility and scale



- **Packet services** (O-RAN WG9)
  - EVPN VPWS services for FH with priority queuing
  - BGP L3 VPN for O-RAN 7.2X M-Plane
  - BGP L3 VPNs for midhaul / backhaul control plane and user plane – 4G and 5G
- Circuit Style services
  - Controller computation with end-to-end b/w admission control and reservation

- **Forwarding behaviours** with SR policies, FlexAlgo, QoS and admission control
- **N:1 Many VPNs to 1 forwarding plane**
- Traffic pushed into correct forwarding plane:
  - **Segment Routing ODN** and Automated Steering
- Monitoring transport and service layers (SR PM, etc.)

Crosswork Network Controller

Simplify operations and speed up the time to market

Crosswork Network Controller

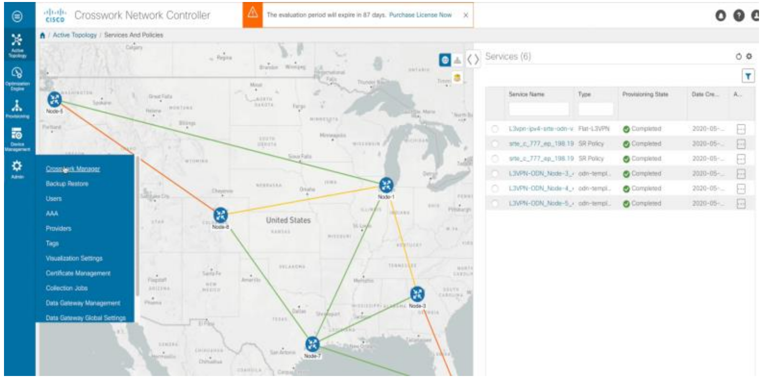
Crosswork Common UI & API

- Crosswork Optimization Engine
  - Real Time Network Optimization
- Active Topology & Inventory
  - Service Inventory
- Cisco NSO + Core Function Packs
  - Model-based Service & Device Provisioning
- SR-PCE
  - Path Computation and Programming
- Crosswork Data Gateway
  - Data Collection

Use Cases

- Service Provisioning for L3VPN and L2VPN
- Service-Oriented Transport Provisioning (SR-TE)
- Topology & Inventory
- Bandwidth Optimization
- Real time network optimization to meet SLA

Multivendor
Multi-domain
Physical and Virtual



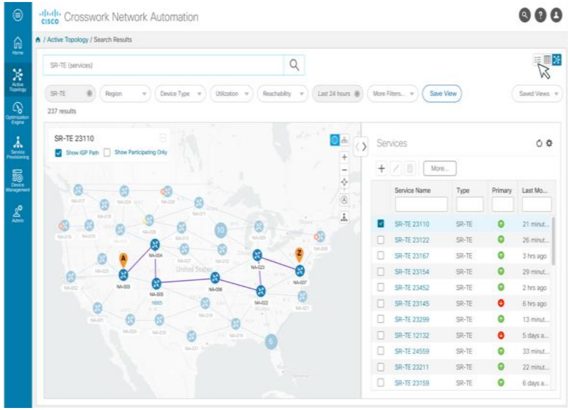
Extended for Network Slicing

CNC 5.0 will support transport network slicing

Designed to simplify network slicing automation

NSST Name	Slice Type Value	Description	QoS Plane Profile	Forwarding Plane Policy
eMBB	1	Use High BW links	Soft-Shared-Queues	IGP
URLLC	2	Use low-delay links	Soft-Shared-Queues	min-delay
mMTC	3	Use low-delay links	Soft-Shared-Queues	min-delay
Encrypted	4	Transit MACsec encrypted links only	Soft-Shared-Queues	encrypt
Disjoint-Path-Top-Rail	5	Only transit links marked top-rail	Soft-Shared-Queues	top-rail
Disjoint-Path-Bottom-Rail	6	Only transit links marked bottom-rail	Soft-Shared-Queues	bottom-rail
20ms-max-delay	7	Delay not to exceed 20ms e2e	Soft-Shared-Queues	NTE-20ms
30ms-max-delay	9	Delay not to exceed 30ms e2e	Soft-Shared-Queues	NTE-30ms

Building Blocks
- FlexAlgo, SR-TE support
- QOS support
- L2VPN/L3VPN enhanced NSO Function Packs



Slice Creation Abstraction
- Simplified UI to abstract the Slice components
- Slice Template Catalog

Slice Lifecycle
- Overlay maps
- KPI collection and Closed-Loop Automation
- Network Optimization

Timing and synchronization

Why do we need timing and synchronization?

Audio / Video Voice Communications

- Audible clicks
- Latency (echo)
- Dropped calls
- Corrupted Video
- Loss of Frame
- Audio Video mis-alignment

Wireless Networks

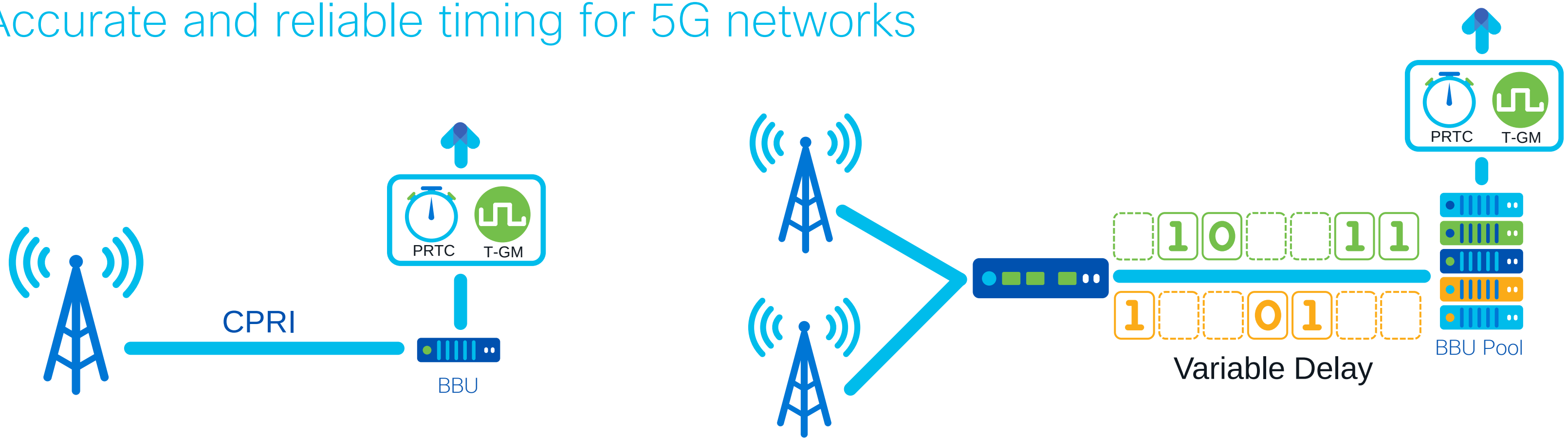
- Seamless Handover
- Interference (eICIC)
- CoMP
- Carrier Aggregation
- Dual Connectivity
- Location Accuracy

Application Impacted

- Location Services
- Industrial Automation
- Smart grid
- IoT
- Network Monitoring

Precise Timing and Synchronization

Accurate and reliable timing for 5G networks



CPRI protocol delivers Sync | **How do we deliver Sync for 5G networks?**

ANSWER Advanced throughput optimization techniques such as Inter-Cell Interference Cancelation, MIMO coordinated multi-point data delivery require precise time synchronization.

- CPRI protocol delivers phase and frequency synchronization, eCPRI/RoE does not.
- eCPRI/RoE Interworking use cases require RAN transport to provide phase and frequency synchronization including diverse delivery of accurate timing

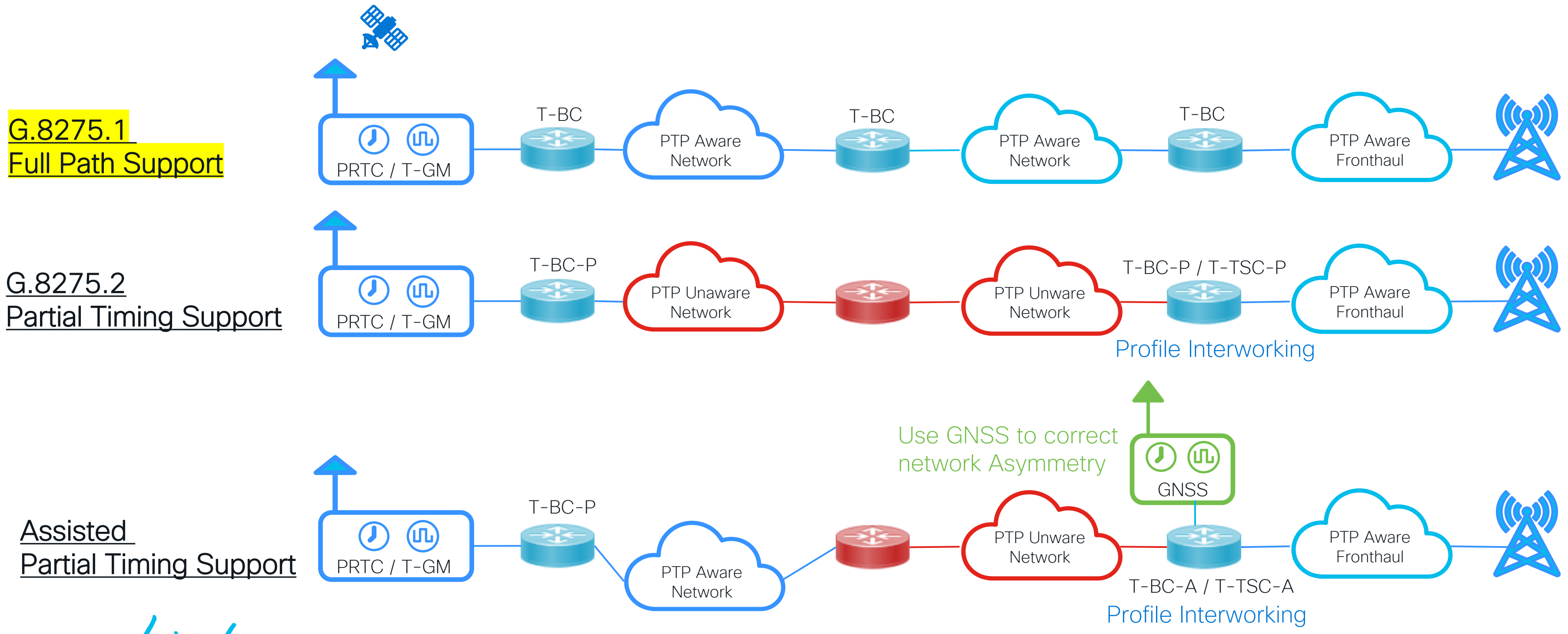
Cisco Fronthaul Routers support **PTP** and **SyncE** protocols to meet **stringent phase** and **frequency synchronization** requirements

Timing solution options

PTP Telecom Profiles

G.8275.1 is the recommended timing solution for 5G services
Supported across all Cisco routing portfolio

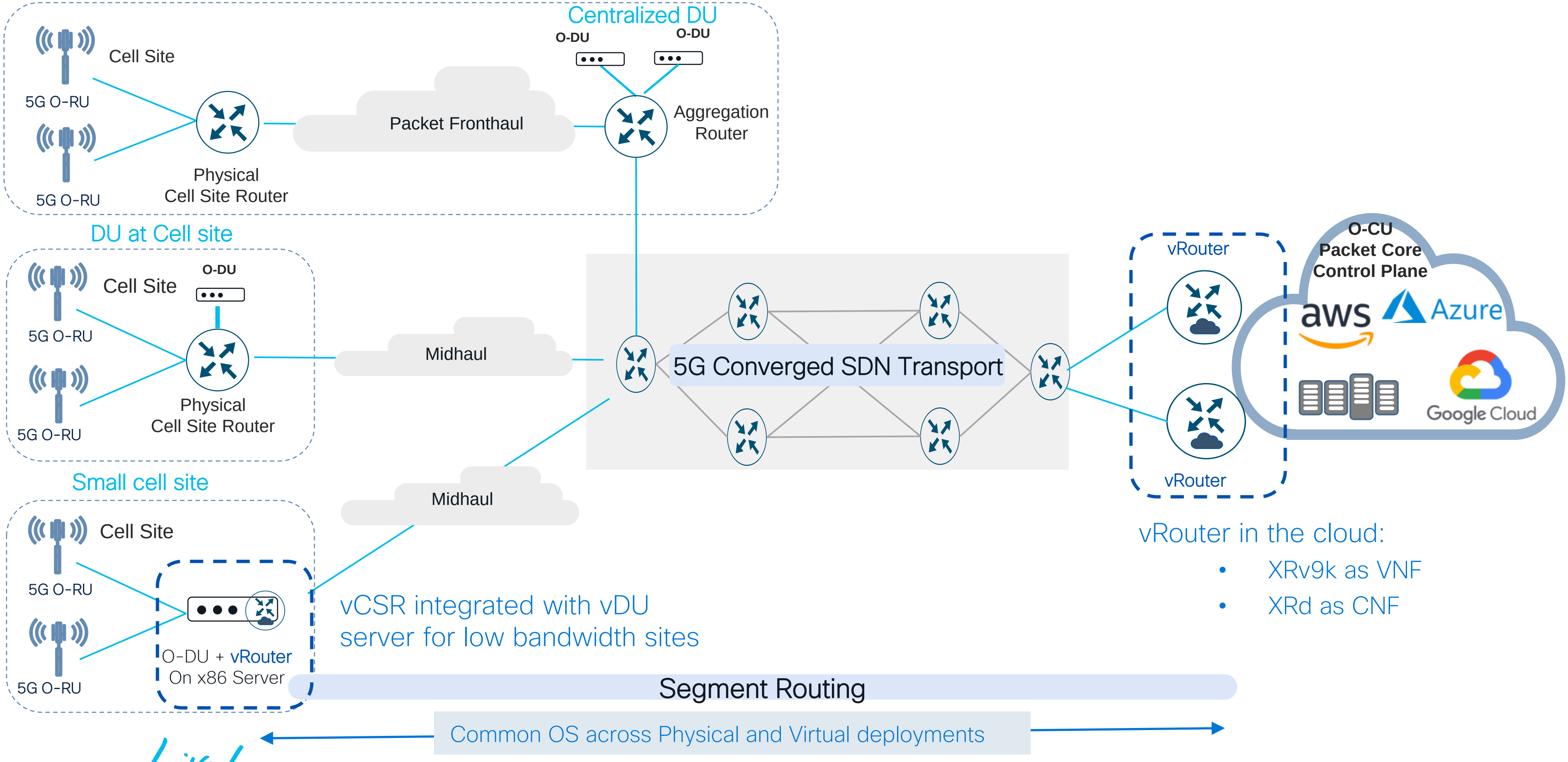
PRTC: Primary Reference Time Clock
T-TSC: Telecom Time Slave Clock
T-GM: Telecom Grandmaster
T-BC: Telecom Boundary Clock
T-BC-P: T-BC with partial support
T-TSC-P:T-TSC with partial support



5G Transport in Hybrid Cloud Environment

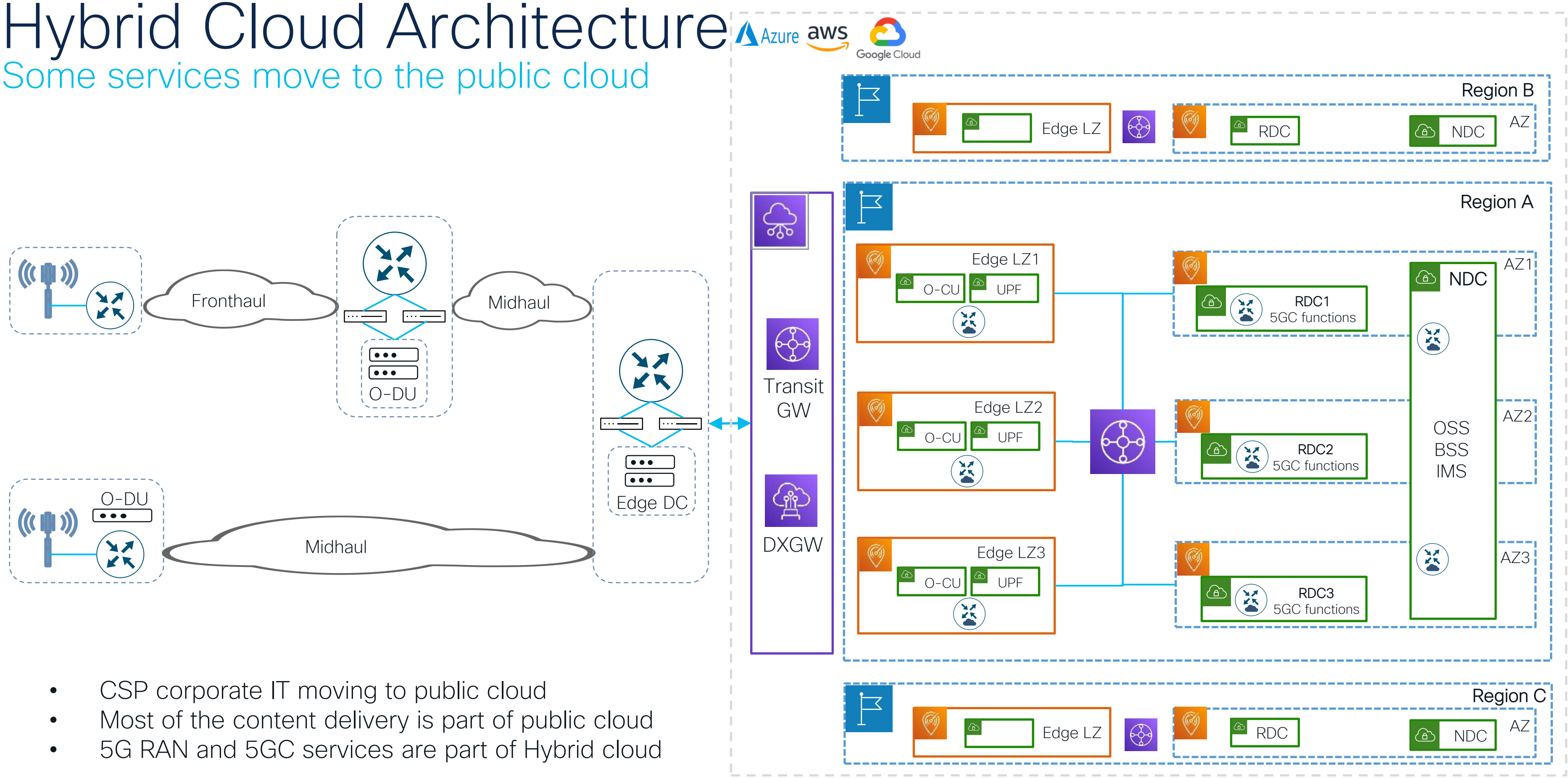
5G Transport in Hybrid Cloud Environment

5G Converged SDN Transport is extended to support public cloud



Hybrid Cloud Architecture

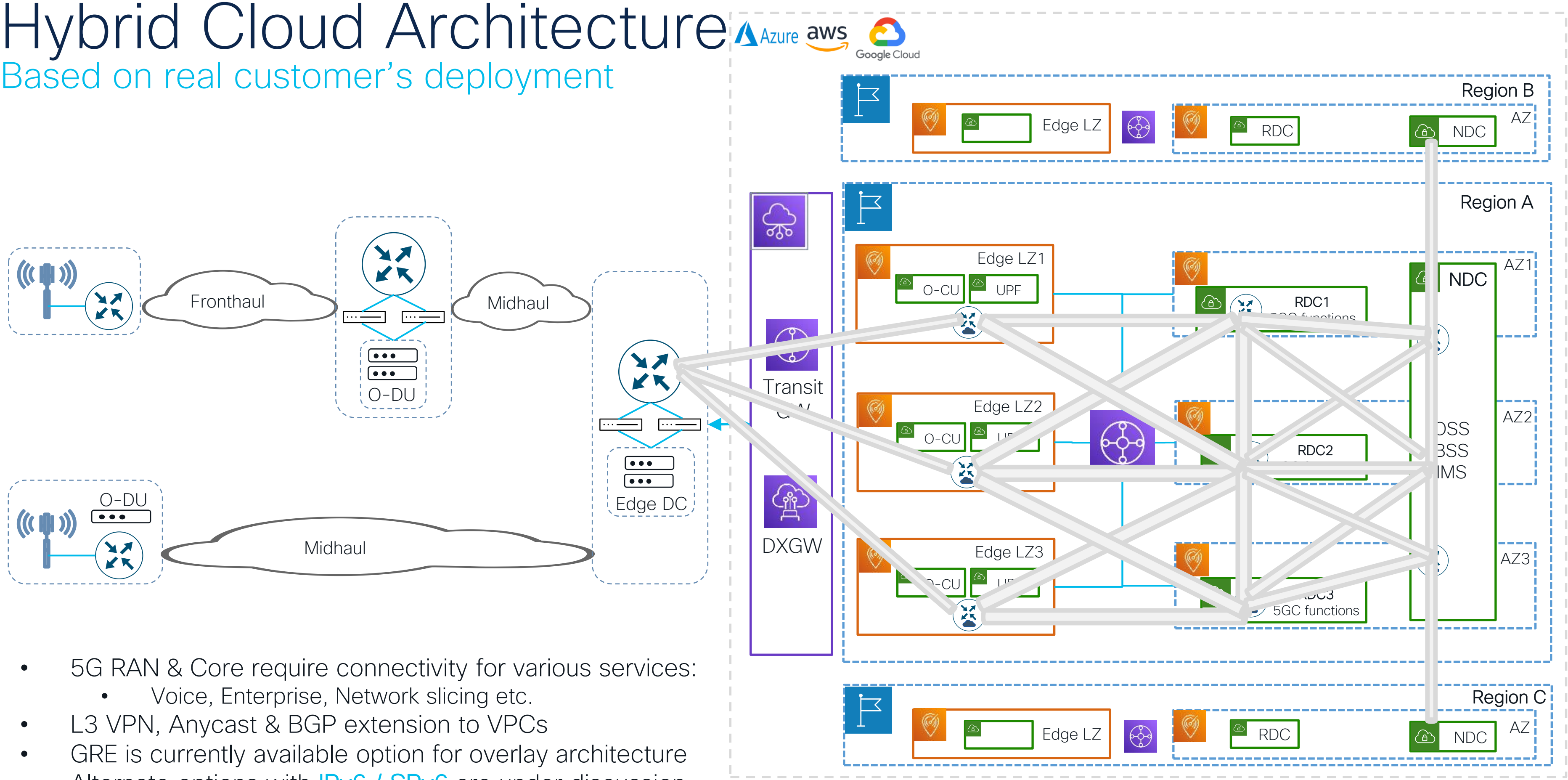
Some services move to the public cloud



- CSP corporate IT moving to public cloud
- Most of the content delivery is part of public cloud
- 5G RAN and 5GC services are part of Hybrid cloud

Hybrid Cloud Architecture

Based on real customer's deployment



- 5G RAN & Core require connectivity for various services:
  - Voice, Enterprise, Network slicing etc.
- L3 VPN, Anycast & BGP extension to VPCs
- GRE is currently available option for overlay architecture
- Alternate options with IPv6 / SRv6 are under discussion

Cisco Cloud Native Router (Xrd)

For Your Reference

Software based router to run on x86

- Cisco IOS-XR and Management
- DPDK/VPP based forwarding
- Kubernetes compliant
- Light footprint on x86 compute

Solution for Cloud native deployments

- Suitable for Cloud native environments
- Routing function at low-bandwidth cell site
- Physical CSR Feature parity

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	~2 mins (to BGP convergence)
Latency	50us via vRouter CNF
Performance	Intel Ice Lake CPU @3.5 GHz turbo, Packet size 1514 bytes ~ 56 Gbps – IPv4 Only ~ 47 Gbps – Customer config (L3 VPN, SR/MPLS, ECMP VLAN with egress QoS)

* CPU may require hyperthreading for control plane stability

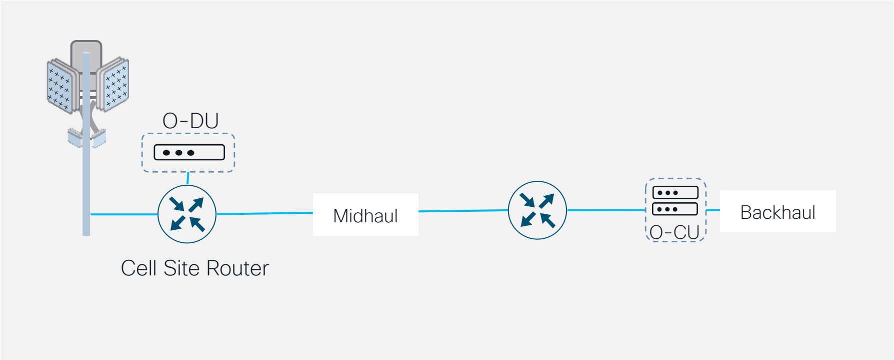
** 11 GiB provides equivalent memory to NCS540
- 8 GiB is minimum to boot
- Real configuration expected to be < 10 GiB

*** Includes provision for logs and other operational data; in most cases usage <= 2Gb

Cell Site with Cloud Native Routing

Alternative model for small cell sites

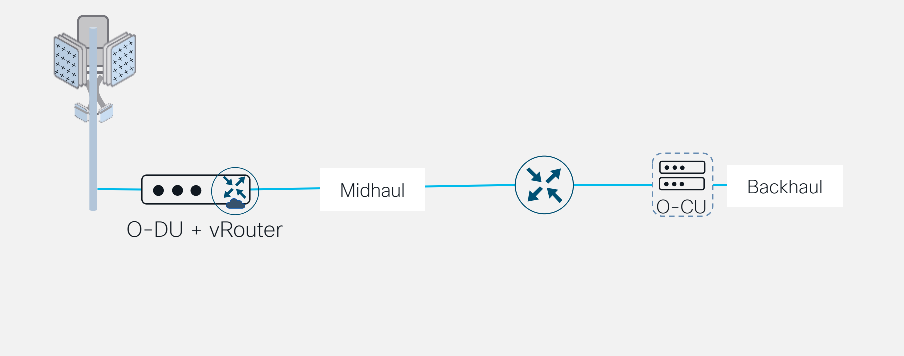
Traditional Cell site



Two boxes solution:

- Physical Cell site Router
- x86 Server hosting O-DU
- Suitable for any size of cell sites

Cloud Native Cell site



Single box solution:

- vCSR (Cisco Xrd) and O-DU hosted on the same x86 server
- Cisco Xrd is a Software based router running into containers
- Cloud native routing helps optimize inventory and power at low-bandwidth cell site
- Suitable for small cell sites requiring low throughput

https://www.cisco.com/c/en/us/td/docs/routers/virtual-routers/xrd-77x/release/notes/b-release-notes-xrd-r771.html

Conclusion

Why Cisco for xHaul transport?

Converges multiple services while optimizing costs and resources

Supports brown-field C-RAN deployments with CPRI over Ethernet and Fronthaul Gateway Interworking function

Provides flexible and scalable transport network slicing with Segment Routing tools

Allows for seamless deployments of cloud-native functions within hybrid cloud environments

References

Cisco 5G Transport page:
www.cisco.com/go/5g-transport

Converged SDN Transport design:
https://xrdocs.io/design/blogs/latest-converged-sdn-transport-hld

Segment Routing:
http://www.segment-routing.net/

O-RAN Alliance Specifications:
https://www.o-ran.org/specifications

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The bridge to possible

Thank you

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