TURN IT UP

#CiscoLive

The bridge to possible

5G Packet Based Fronthaul

Waris Sagheer, Principal Product Manager
@mwaris

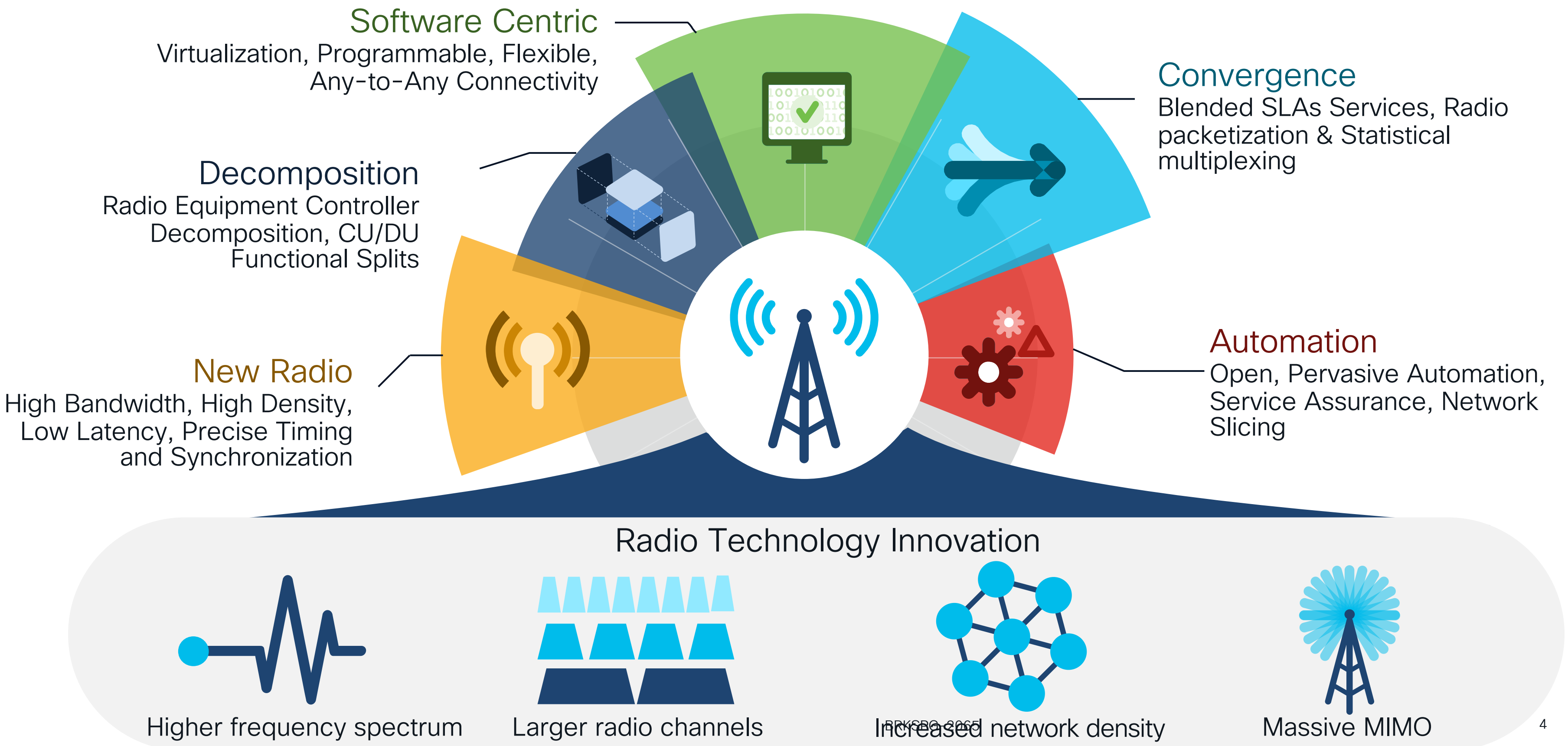
BRKSPG-2065

Agenda

- RAN Architecture
- Centralized RAN Transport Requirement
- Fronthaul Overview
- Packet based Fronthaul
- Customer Case Study
- Conclusion

5G RAN Transformation

Architectural shifts impacting the evolution of RAN transport



RAN Decomposition and Virtualization

Functional Decomposition
Functions Separated to Allow Flexible Placement and Optimization

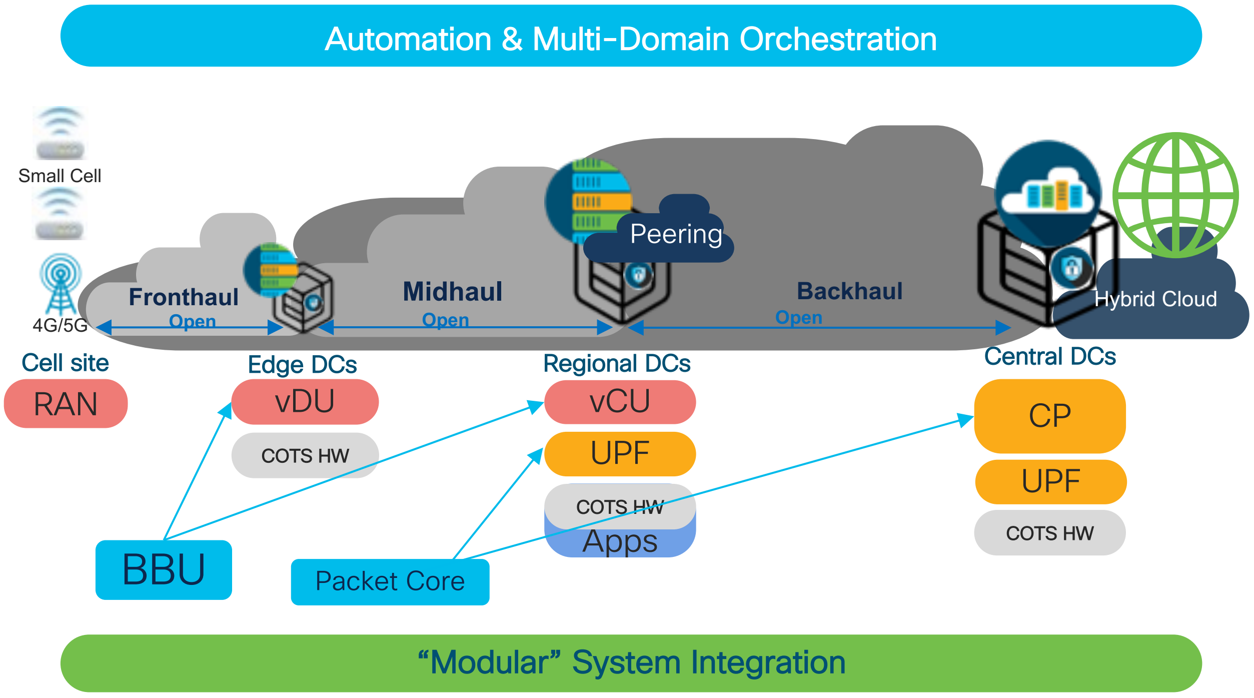
Disaggregation into SW + HW
Software-Centric Solutions Leveraging COTS Hardware

Open
Modular, ORAN, Open, Multi-vendor, More Options = Flexibility and Lower Cost

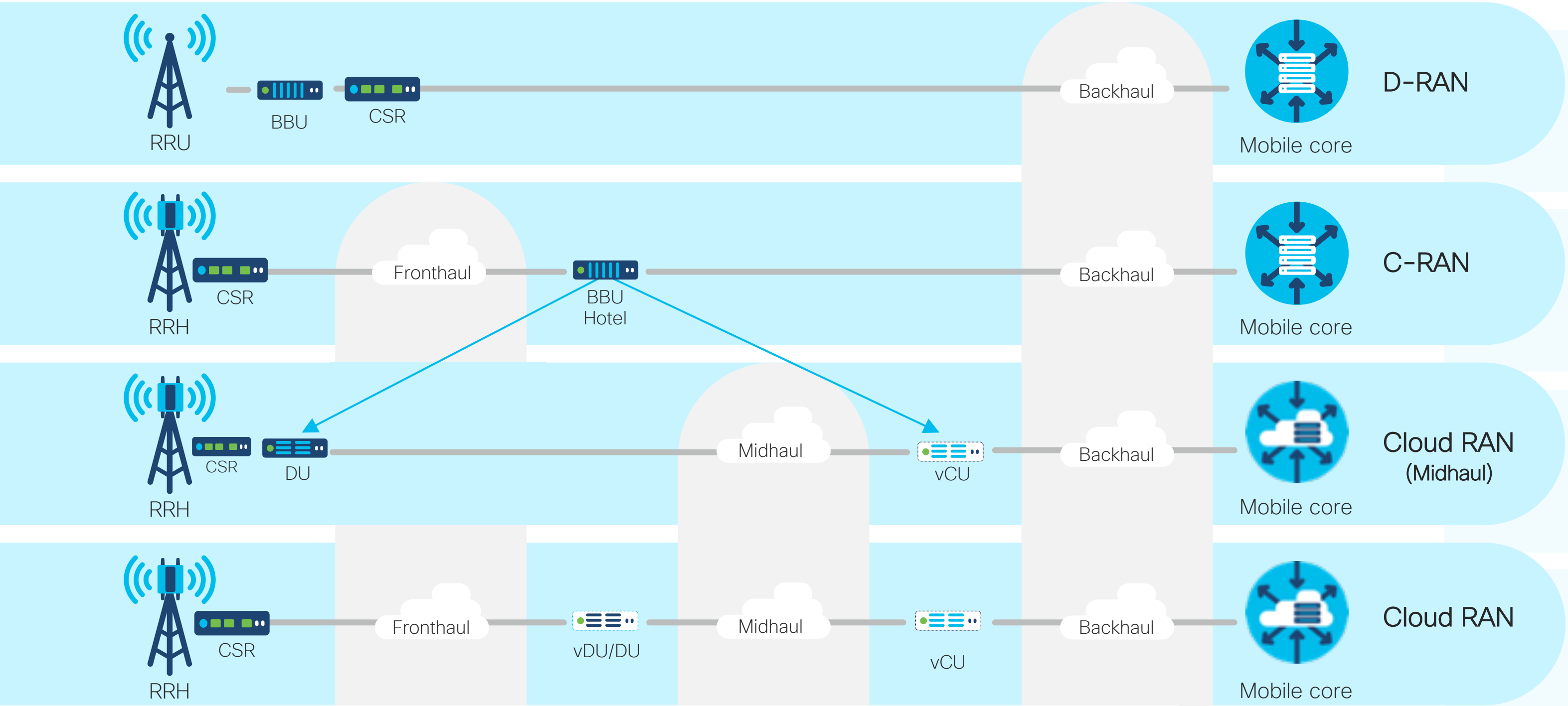
Multi-Use Case
5GNR, LTE, Small Cell, Indoor/Outdoor, mMIMO, Multi-band, mmWave, Private/Public, Enterprise/Consumer, etc.

Optimize for Lower Cost Operations
Agility, Lower TCO, Increased Automation

Enable New Services
Increased Service Flexibility, Velocity



RAN Transport Architecture Options

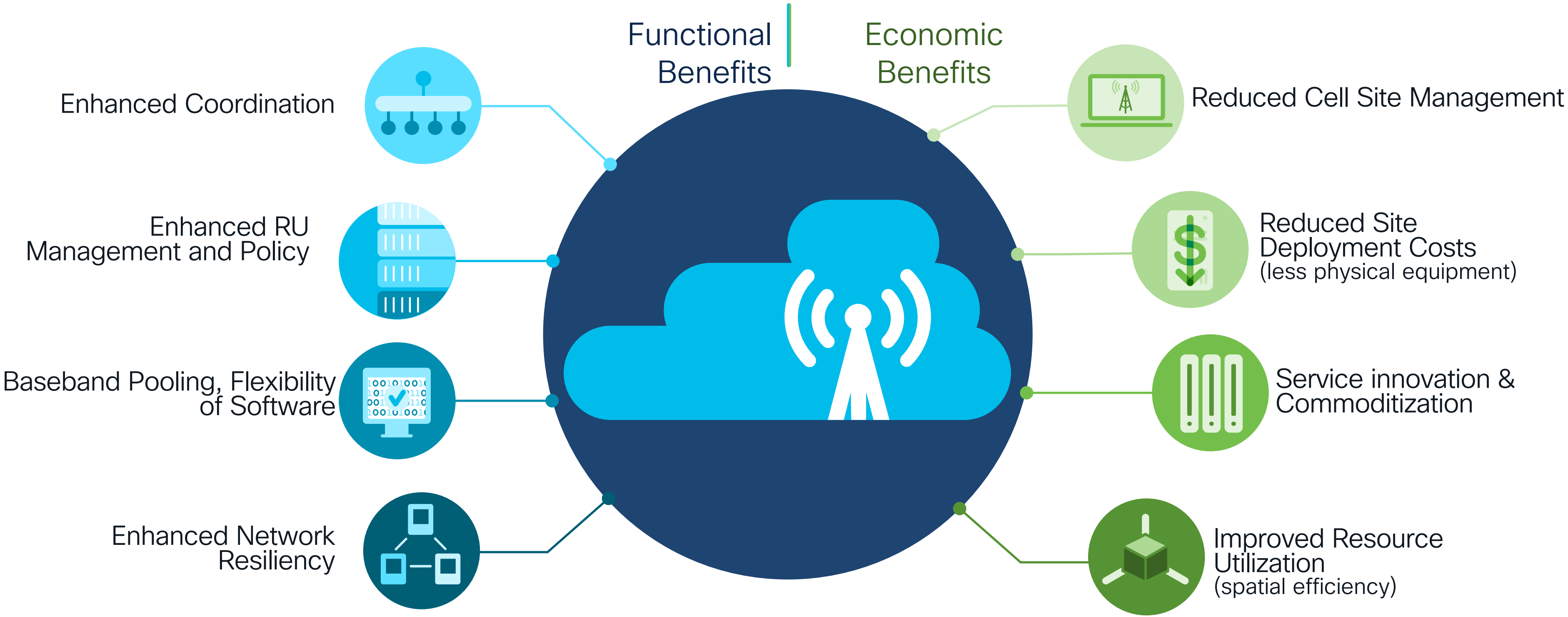


	Fronthaul		Midhaul		Backhaul
1-way latency:	75us/100 us (LTE) 160us (5G NR)	1-way latency:	1-25ms	1-way latency:	10ms
Typical distance:	<15KM	Typical distance:	>10KM	Typical distance:	>10KM
Interface(s):	10G/25G/100G/200G	Interface(s):	10G/25G/100G	Interfaces:	10G/25G/100G/200G

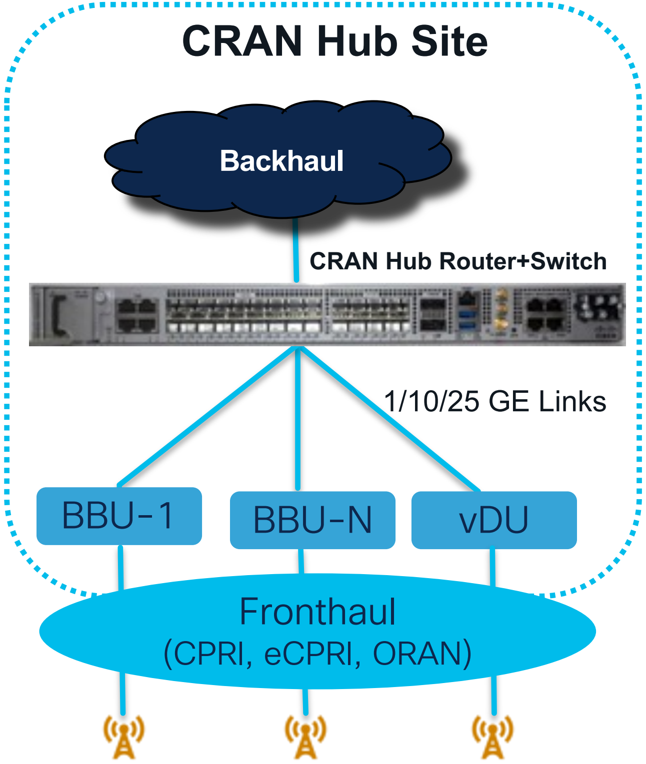
- Higher Speed Interfaces
- Lower Latency
- More Precise Timing & Synchronization
- Any-to-Any Connectivity

Benefits of Centralized & Cloud RAN Architectures

Functional & economic advantages



C-RAN Transport Architecture Components



- Baseband Hotel Router depending on the size of BBU Hotel
    - Fixed
    - Modular
- Low latency L2 switch in case of solution like Ericsson's Elastic RAN
    - Cisco solution combines above two functionalities into single node (NCS portfolio) – cost saving
    - Tested and validated in multiple customer engagements
- 1588/SyncE – Phase & Frequency clocking support
- Scalable Cloud-RAN Fabric Architecture
    - Interface Flexibility – 1/10/25G/100G
    - Horizontal Scaling for large sites
    - Redundancy
- Platforms:NCS5700/NCS5500/NCS540

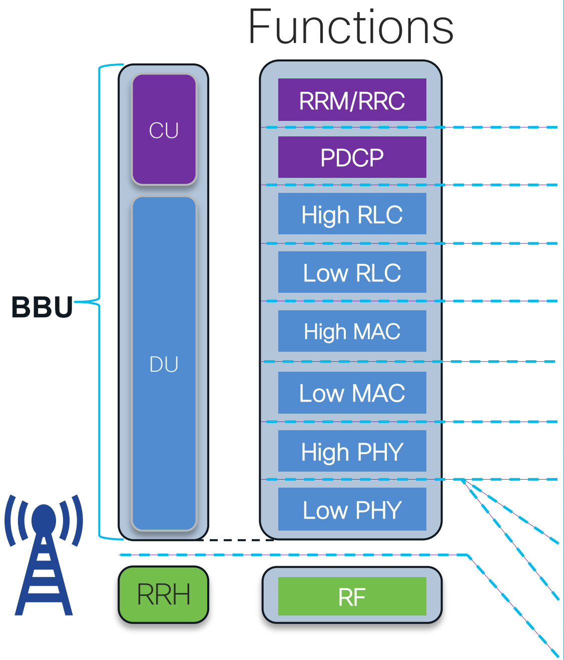
Fronthaul

Radio Standards

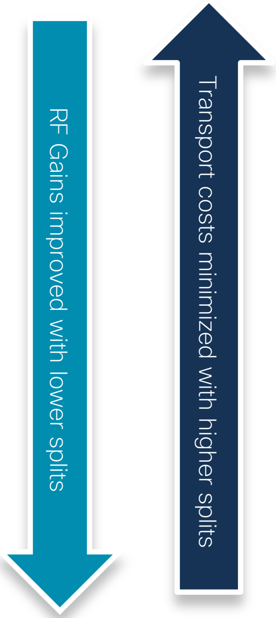
Proprietary	**CPRI** Common Public Radio Interface (ERICSSON, HUAWEI, NOKIA, NEC)	Internal interface of radio base stations between the **Radio Equipment Control (REC) and the Radio Equipment (RE)** http://www.cpri.info/spec.html	**CPRI Specification version 7.0** – October 9, 2015 (in addition to 1.4, 2.1, 3.0 , 4.0, 4.1, 4.2, 5.0, 6.0, 6.1)
	eCPRI Evolution of CPRI	To enable efficient and flexible radio data transmission via a **packet based fronthaul transport network like IP or Ethernet** http://www.cpri.info/spec.html	**eCPRI 2.0 [CPRI and eCPRI interworking] – May 10, 2019** eCPRI 1.2 – June 25, 2018 eCPRI 1.1 – January 31, 2018 eCPRI 1.0 – August 31, 2017
Standard	IEEE Advancing Technology for Humanity **1914.3-2018** **1914.1-2019** Standard for Radio over Ethernet Encapsulations and Mappings	Encapsulation and mapping of radio protocols for transport over Ethernet frames, using **radio over Ethernet (RoE)** https://standards.ieee.org/standard/1914_3-2018.html	Structure-agnostic – any digitized radio data Structure-aware – CPRI Native mode – digitized radio in-phase and quadrature (I/Q) payload
	3GPP **TSG Radio Access Network (TSG RAN)** https://www.3gpp.org/specifications-groups/ran-plenary	TSG RAN WG1 Radio Layer 1 specification TSG RAN WG2 Radio Layer 2 and Radio Layer 3 specification TSG RAN WG3 O&M requirements TSG RAN WG4 Radio performance and protocol aspects (system) TSG RAN WG5 Mobile terminal conformance testing TSG RAN WG6 Legacy RAN radio and protocol	
Open RAN	O-RAN **O-RAN Alliance** leading the industry towards open, interoperable interfaces and RAN virtualization https://www.o-ran.org/	**WG4: The Open Fronthaul Interfaces Workgroup** O-RAN Fronthaul Interoperability Test (IOT) Version 1.0 – October 2019 O-RAN Fronthaul Control, User and Synchronization Plane Version 2.0 – July 2019 O-RAN Fronthaul Management Plane Version 2.0 – July 2019 O-RAN Fronthaul Yang Models Version 2.0 – July 2019	WG1: Use Cases and Overall Architecture Workgroup WG2: The Non-real-time RAN Intelligent Controller and A1 Interface Workgroup WG5: The Open F1/W1/E1/X2/Xn Interface Workgroup WG6: The Cloudification and Orchestration Workgroup WG8: Stack Reference Design Workgroup, WG7 & WG9
Miscellaneous	**IEEE Std 802.1CM™-2018** Time-Sensitive Networking for Fronthaul https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8376066	OPEN **The OCP Telco Project** https://www.opencompute.org/projects/telco	**Telecom Infra Project (TIP)** Accelerate the pace of innovation in the telecom industry by designing, building, and deploying technologies that are more flexible and efficient

RAN Functional Split Consideration

CU Centralized Unit
DU Distributed Unit
BBU Baseband Unit
RRH Remote Radio Head



Split Option	Fronthaul Interfaces
Option 1	
Option 2	F1 (3GPP)
Option 3	
Option 4	
Option 5	
Option 6	
Option 7a	eCPRI ORAN (7-2x) ROE
Option 7b	
Option 7c	
Option 8	CPRI



Packet-Based Fronthaul

Stat-muxing opportunity

Optical Multiplexing (Passive or Active DWDM)

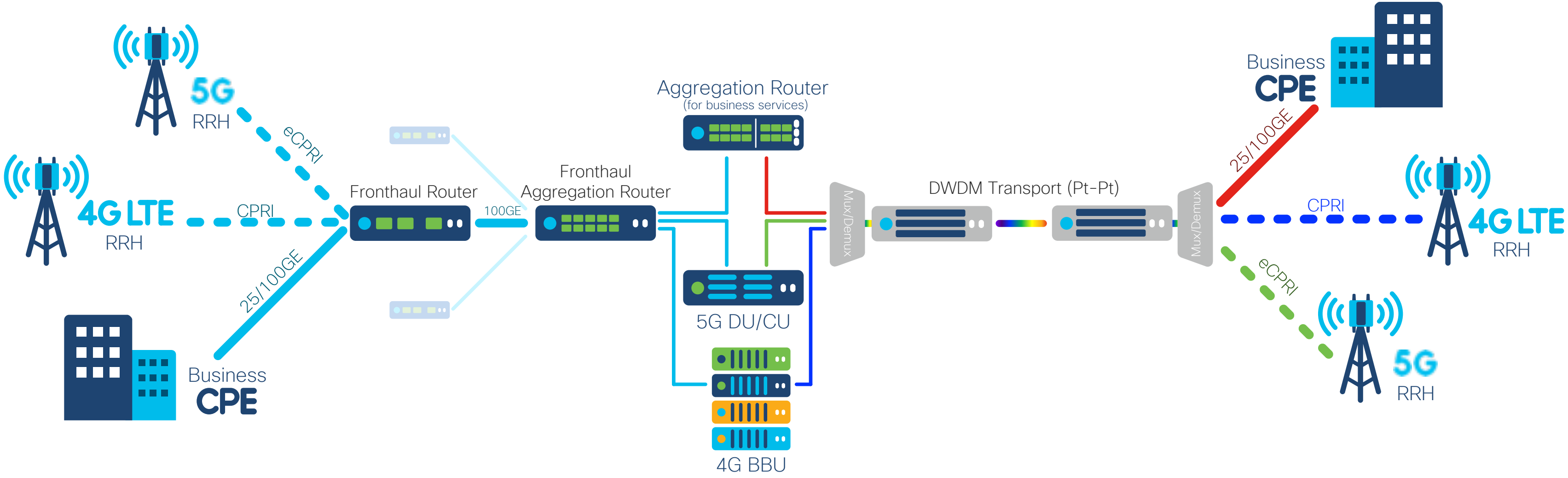
Packet | **Optical**

- ✔ 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

Comparing TCO for fronthaul

Packet vs optical fronthaul solutions



Packet-based fronthaul

Up to **65%** TCO Savings

Optical-based fronthaul

Savings: +65% ROADM | +46% P2P Active DWDM | +40% P2P Passive DWDM | +13% P2P Passive CWDM

Source: ACG – An Economic Comparison of Fronthaul Architectures for 5G Networks

Cisco Fronthaul Strategy

Fronthaul Optimal Transport

- Enable optimal transport for converged packet-based fronthaul supporting resilient and programmable architecture to support RAN innovation

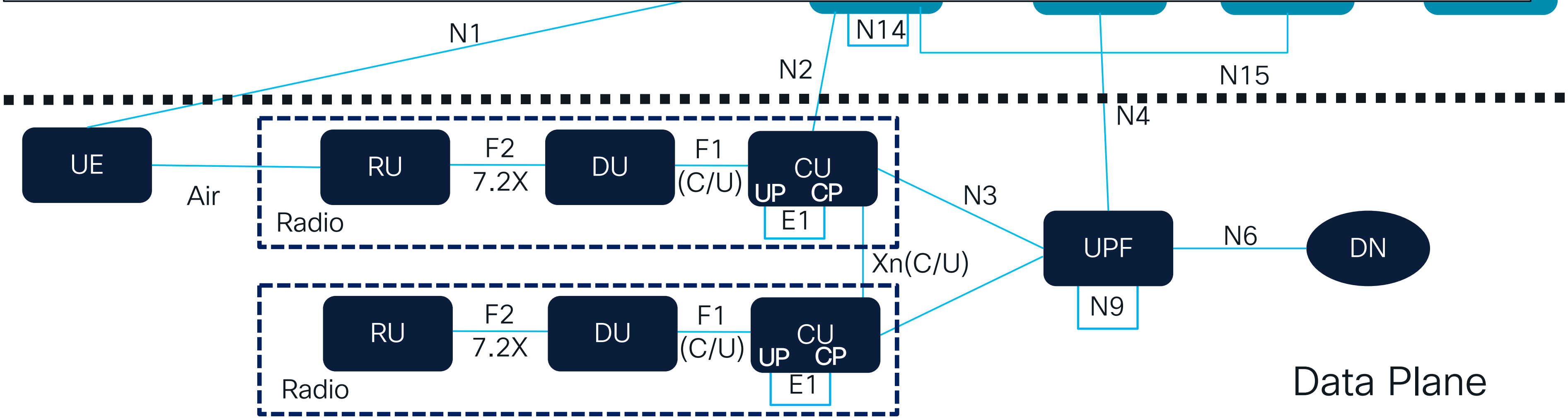
Open vRAN Ecosystem

- Accelerate the viability and adoption of open virtualized RAN (vRAN) solutions

eCPRI/ORAN Fronthaul

RAN and Mobile Core Interfaces

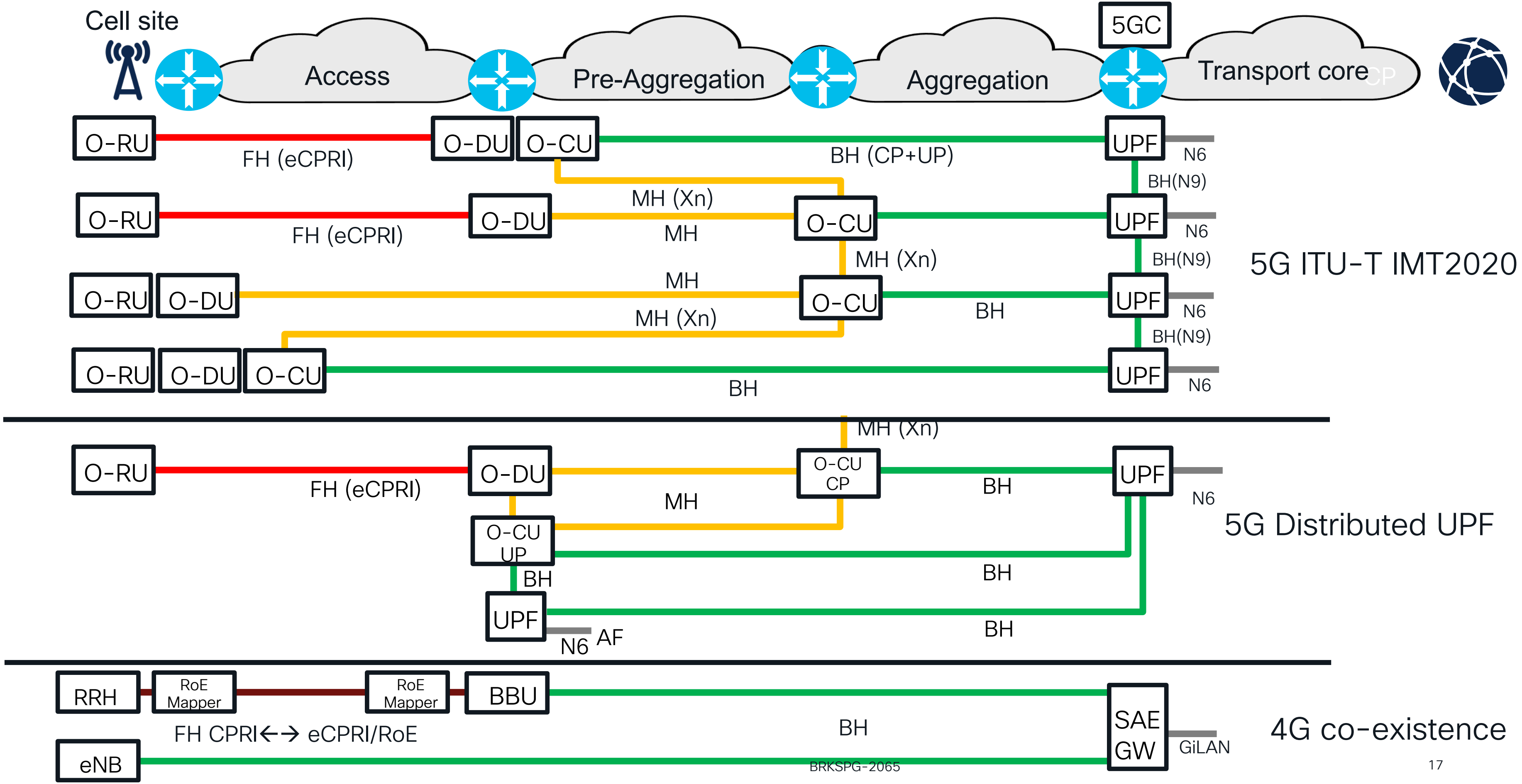
All interfaces are mandatory IP based (except F2 where its optional)
There is a complex set of networking requirements between different 5G components
1 to 1, 1 to many, many to many
Same component may need to support all models concurrently!



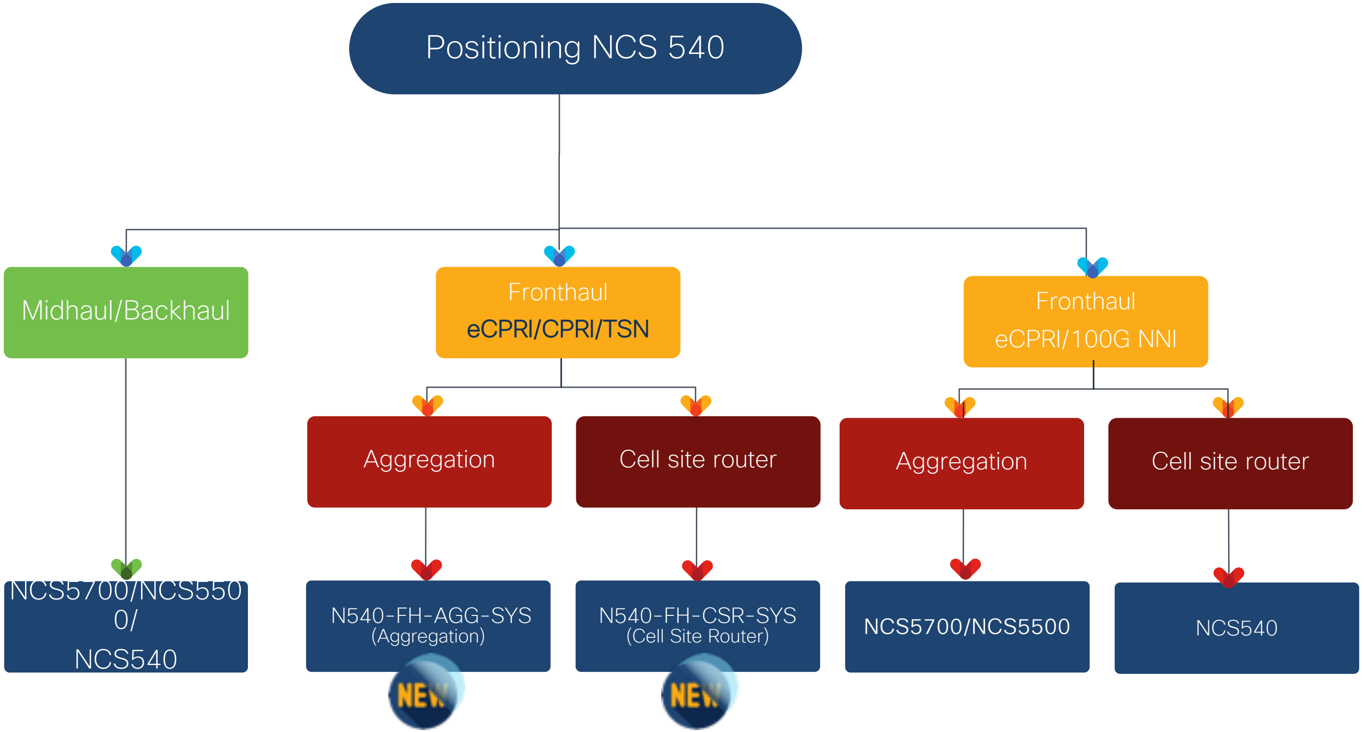
F2/7.2X : RU to DU – 1 to 1 relationship
F1 : DU to CU – many to 1 relationship

5G and 4G mobile use cases – O-RAN WG-9

Adapted from O-RAN WG-9 Packet Switched Xhaul architecture and solutions



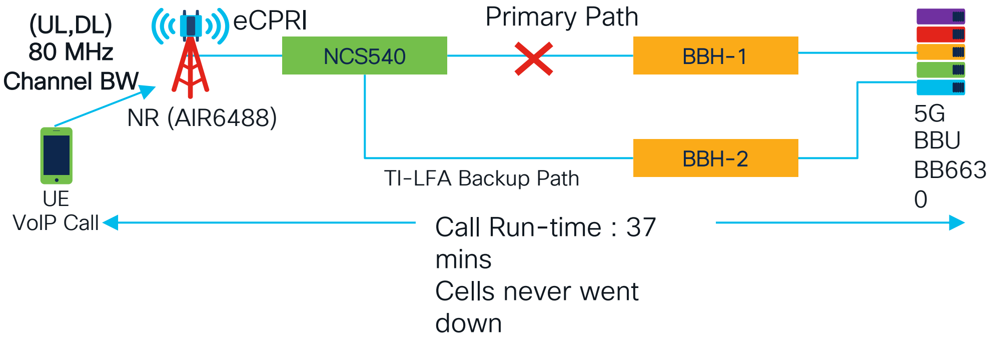
Packet Based Fronthaul



eCPRI/ORAN is fully supported on shipping NCS540 portfolio

eCPRI Trials with NCS540

NOW in PRODUCTION



Speed Test Results

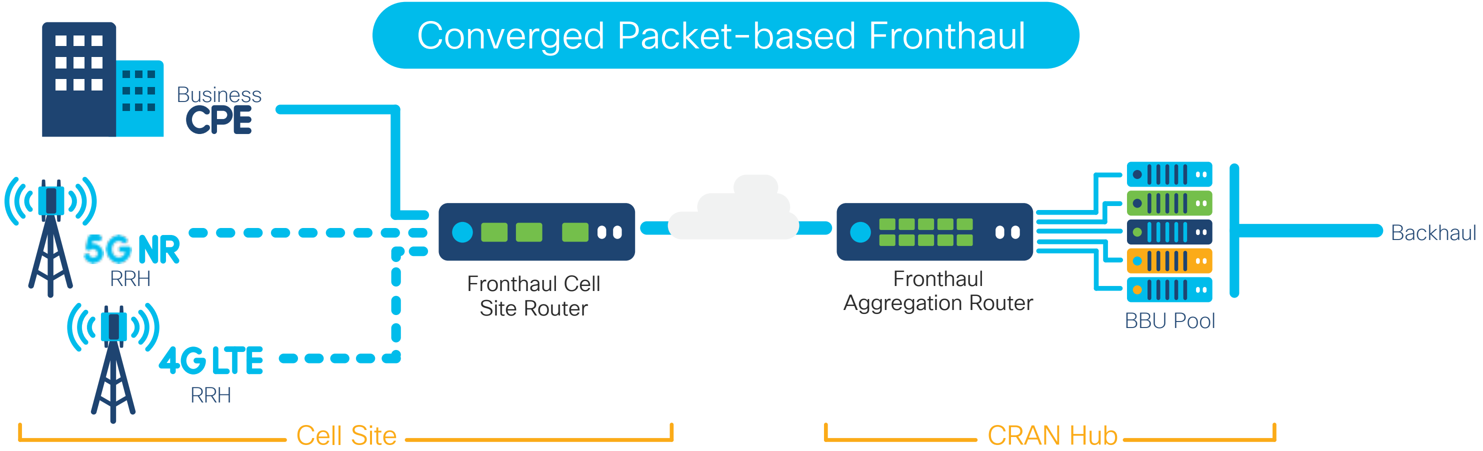
80 MHz : Channel BW
686 Mbps : Download Speed

- Supported radio: Samsung, Ericsson, Nokia, Huawei and all ORAN vendors
- eCPRI Trials with NCS540
- Stat-mux
- TI LFA Failover tests performed
- No cells went down/No call drops during failover tests / VoIP Call ran for 37 mins
- With 80 MHz Channel Bandwidth, 686 Mbps Download Speed was achieved
- Fiber path between NCS540 and BBH is approx. 14 km

Converged Packet based Fronthaul

Cisco Converged Packet-based Fronthaul

Extending to meet the needs of Fronthaul, Midhaul, & Backhaul



BENEFITS

Service Convergence

- Wireless (4G,5G) and Wireline
- Fronthaul, midhaul & backhaul

Monetization

- Enterprise Services

- High-Speed and Ultra-Low Latency
- Forwarding Precise timing and synchronization

End to end IP/MPLS based network for a simplified architecture

Open and automated management

Converged Fronthaul Router Highlights

1 — Converged System
Converged (Wireline + Wireless), Low power & Optimal Form Factor

2 — LTE & 5G Radio
FPGA:CPRI (option 3-8), RoE, eCPRI, ORAN

3 — Low latency
802.1Qbu - Frame Preemption (TSN) support on 10G/25G interfaces

4 — Synchronization
Class C, eEEC, PRTC-A, Better Oscillator

5 — Flexible Transport
SR MPLS/SRv6, BGP VPN, SR PM

6 — Silicon
DNX, 2.5 us ASIC Latency

7 — FPGA (Field Upgradeable)
Radio over Ethernet (RoE) Type 0/Type 1 , L1 PHY Offload (FHG) & TSN

8 — Quality of Service
H-QOS & QOS Enhancements

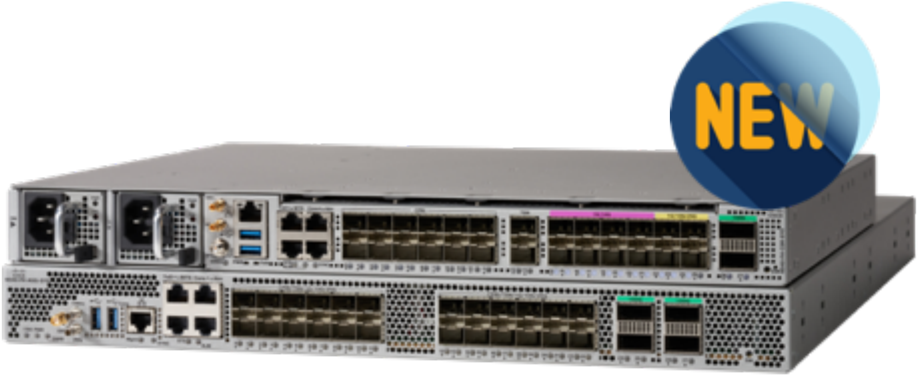
9 — Security
PTP over Macsec, Trust Anchor

10 — Automation
Open & Automated management, NSO & Cisco Crosswork Portfolio

Cisco FrontHaul Router Models
NCS 540 family

N540-FH-CSR-SYS
(Cell Site Router)

N540-FH-AGG-SYS
(Aggregation)



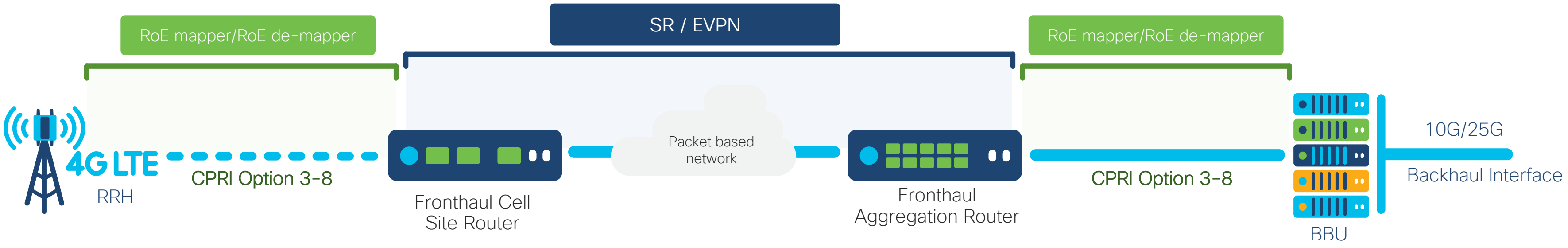
Fronthaul Router	Use Case	Port Config	RU	Capacity	Software
N540-FH-CSR-SYS (Cell Site Router) 	Cell Site Router [Packet + CPRI +TSN]	• 8xCPRI (Option 3-8) • +*4x1/10G/CPRI (Option 3-8) • 8x1/10G • 4x10/25G • 2x10/25G (802.1Qbu) • 2x100G	1 RU	300Gbps	IOS XR
N540-FH-AGG-SYS (Aggregation) 	Aggregate Site Router [Packet + CPRI + TSN]	• 24x10G/25G* • (802.1Qbu, CPRI 3-8) • 4x100G	1 RU	900Gbps	IOS XR

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

CPRI over Radio over Ethernet (RoE)

Optimized for CPRI Transport Over Ethernet

Fronthaul RoE Structure Agnostic Modes (Type 0 & Type 1)



Optimized to enable CPRI "RoE Structure-Agnostic Tunneling Mode (Type 0)"

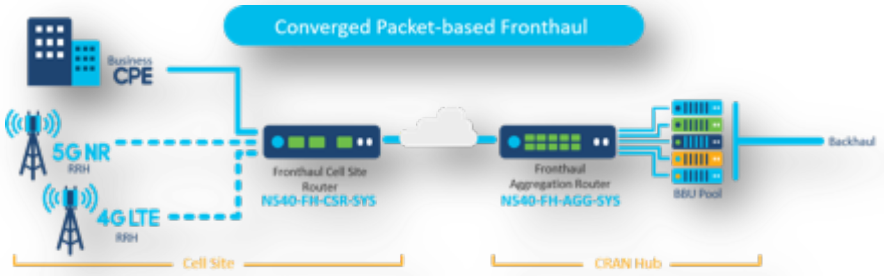
- Compatible with all RAN suppliers' equipment
- RAN vendor CPRI protocol implementation awareness is NOT required
- RoE Tunneling mode does not provide any fronthaul bandwidth reduction (Tested with Ericsson & Huawei)

Extensible to support CPRI "RoE Structure-Agnostic Line Code Aware Mode (Type 1)"

- Solution MUST be tested with every RAN vendor to validate the functionality
- Requires some awareness of CPRI protocol at mapper/demapper
- Fronthaul bandwidth of reduction of 20% by removing 8b10b line coding (Tested with Huawei)

NCS540-FH

Radio Interop



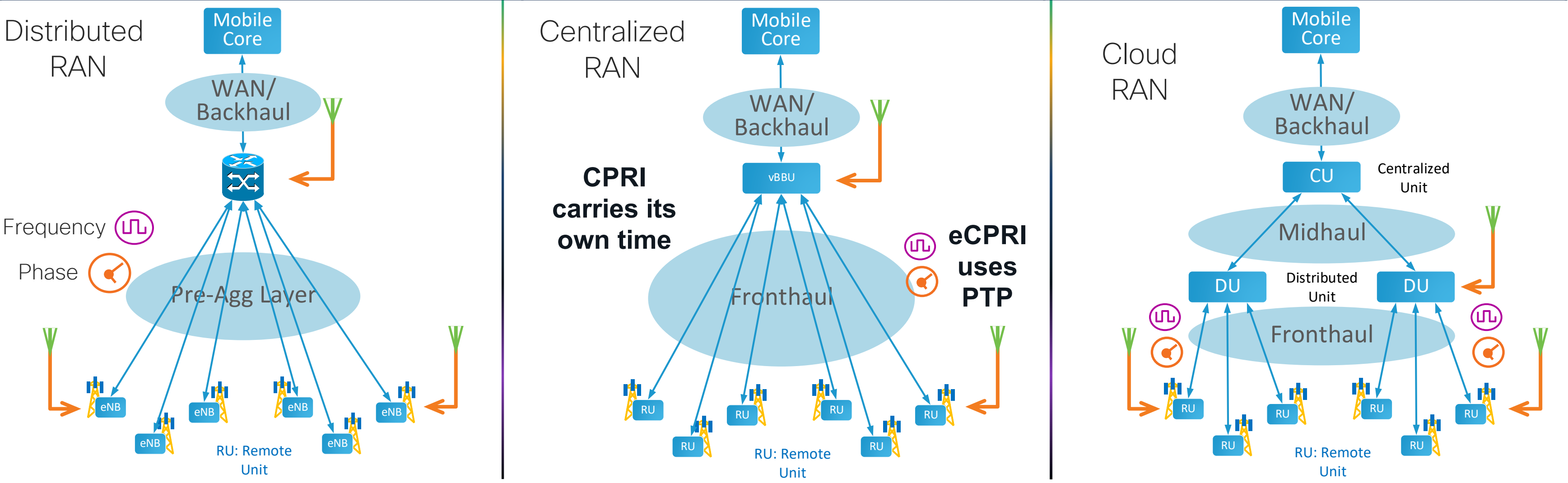
- ✓ Packet Fronthaul Router operates seamlessly with:
  - Ericsson Radio Units, 4G and 5G BBUs
  - Huawei Radio Units, 4G BBUs
- ✓ With Ericsson RU and BBU, Packet Fronthaul Router successfully implements:
  - RoE Structure Agnostic Mapper Type-0
- ✓ With Huawei RU and BBU, Packet Fronthaul Router successfully implements:
  - RoE Structure Agnostic Mapper Type-0 between Huawei RU and BBU
  - RoE Structure Agnostic Mapper Type-1 between Huawei RU and BBU
  - Operates seamlessly with RU Chain Implementation (with Huawei RUs)
  - Operates seamlessly with RU-BBU Load-Balancing Implementation (with Huawei BBUs)

Cisco Packetized Fronthaul Demo

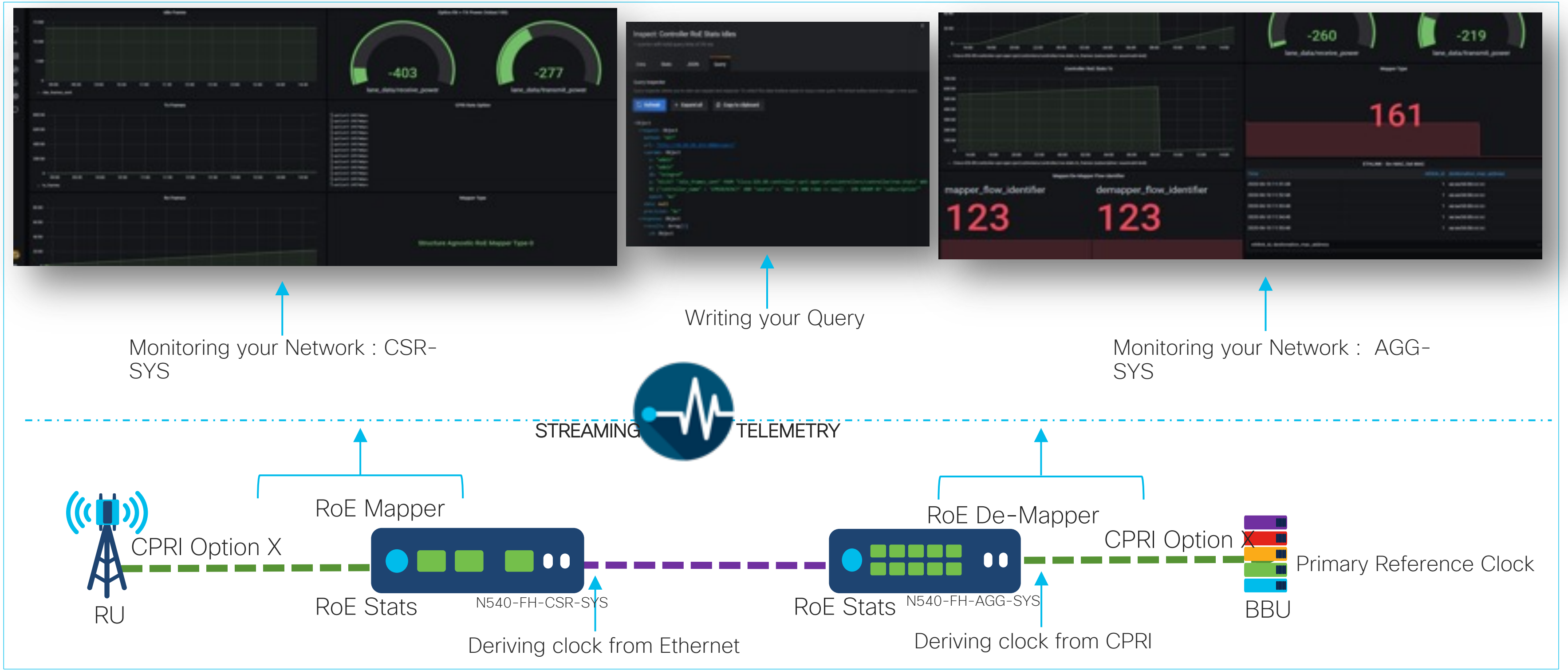
https://www.ciscolive.com/global/on-demand-library.html?search.event=ciscoliveus2020&showMyInterest=true#/video/1592347697861001FJMB

Timing and Synch – Fronthaul Options

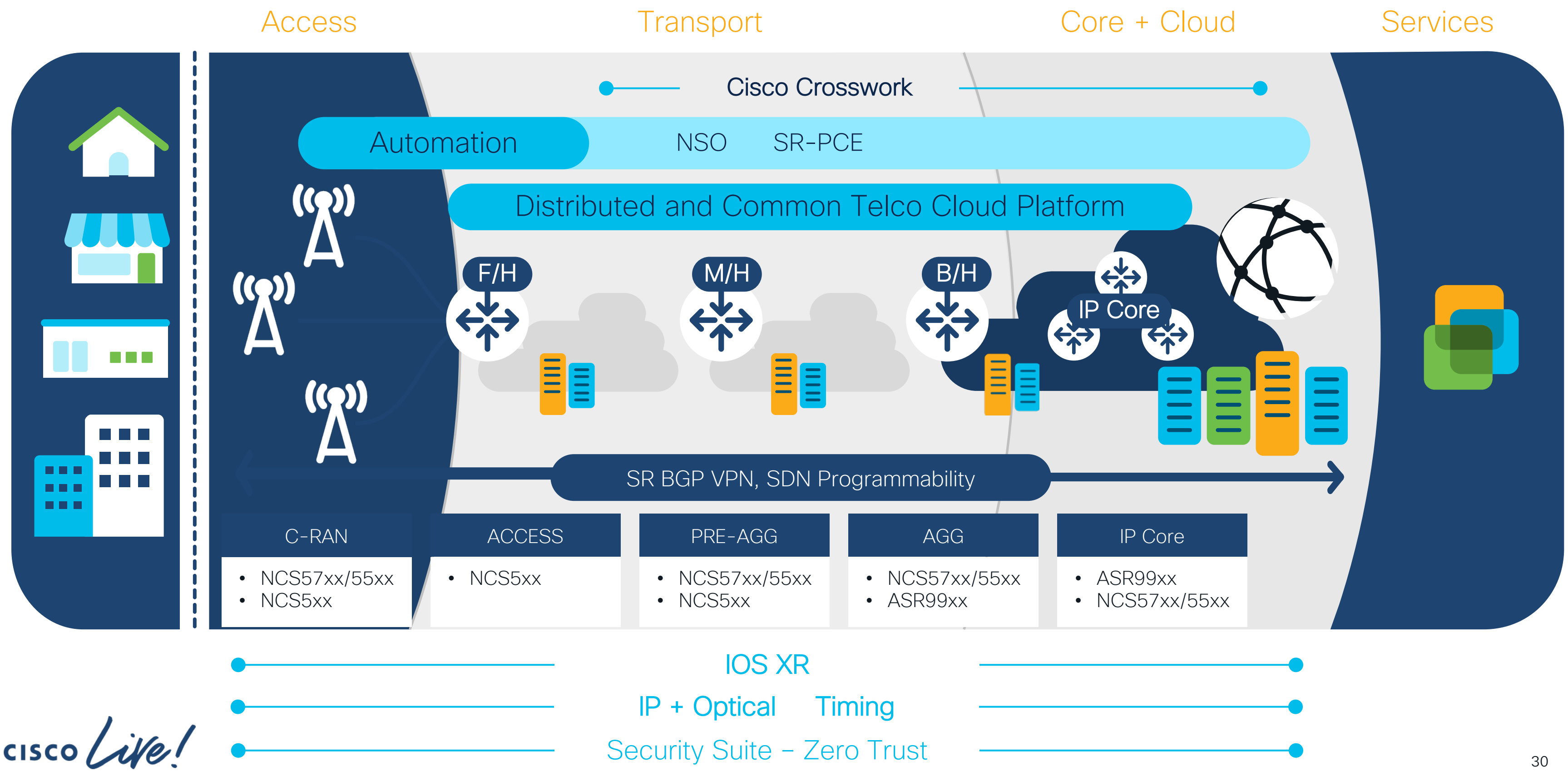
Distributed RAN	Centralized RAN	Cloud/Midhaul RAN
• ±1.5uS phase between radios • Backhaul carries sync from pre-aggregation layer; or • GPS at every cell site	• < ±1.1uS between BBU's • Backhaul carries sync or place GPS at every BBU hotel • CPRI is synchronous; but eCPRI requires PTP or GPS	• ~±130nS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



Streaming Telemetry from Router

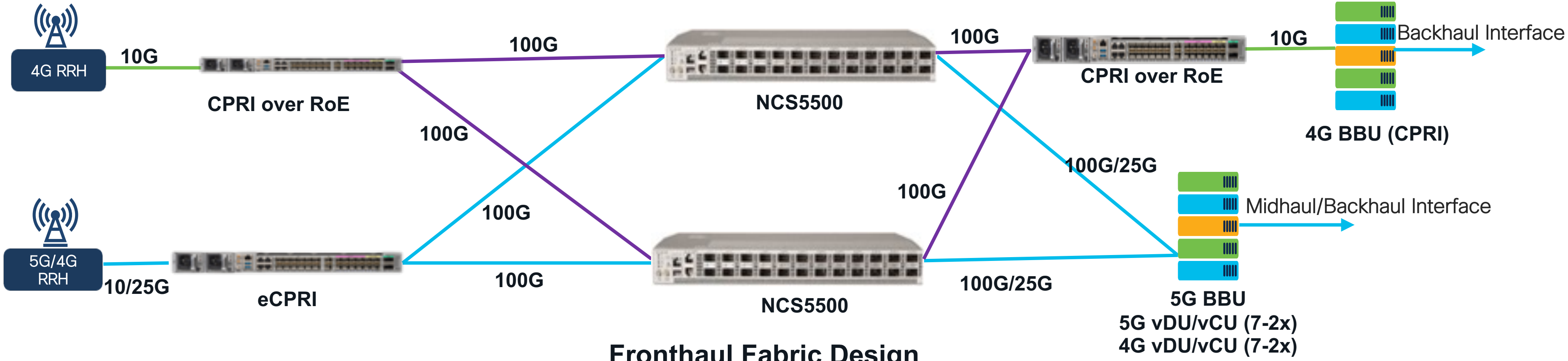


Converged SDN Transport Solution

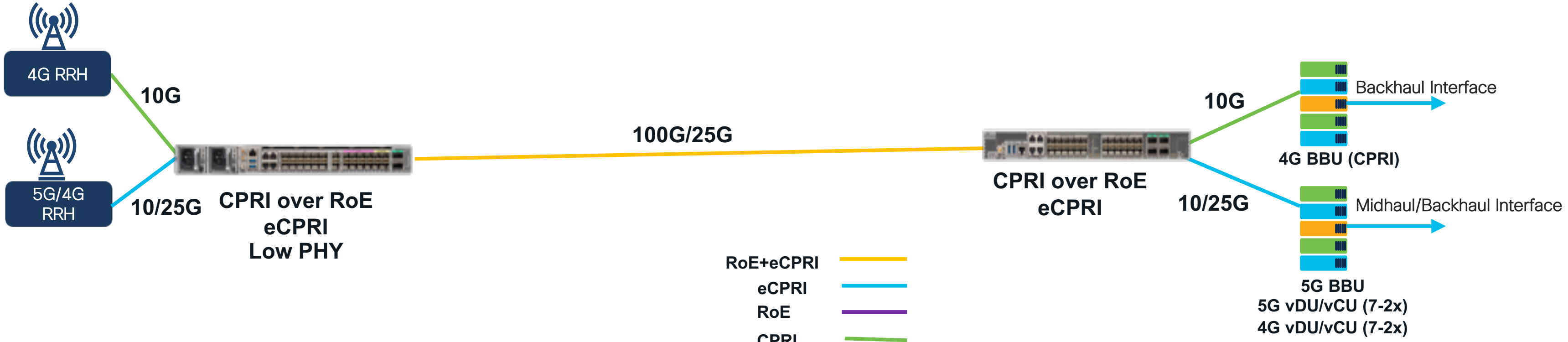


Fronthaul Design

Frontthaul Network Design Options



Frontthaul Fabric Design



Fronthaul/Midhaul/Backhaul Calculation

Single Cell Site/3 Sector 6 Carriers

PRB=Physical Resource Block

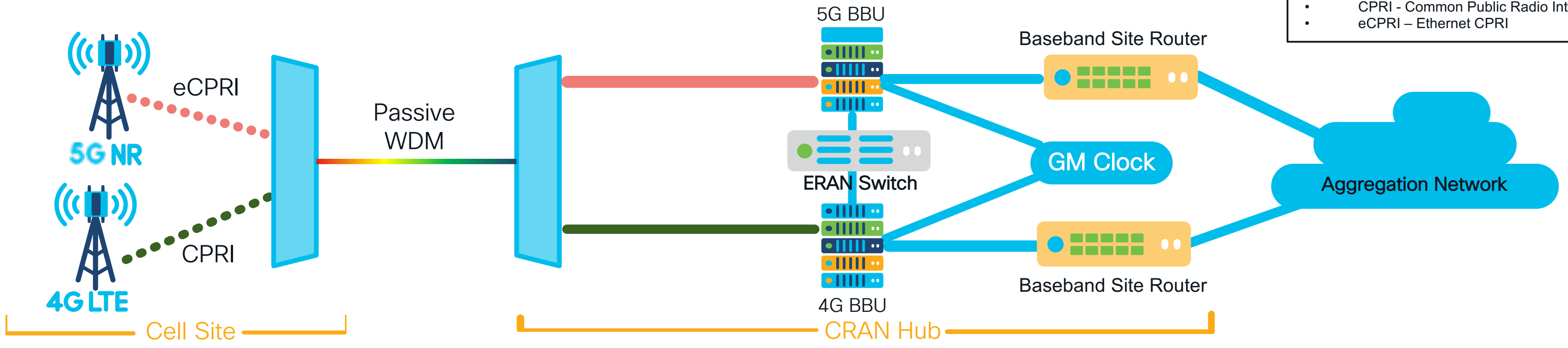
Statistical Multiplexing (Statmux)=1Max+2 Average

Band Number	Band	Bandwidth [MHz]	MIMO/MIMO Layers	Fronthaul Data Rate (Single Sector Peak) CPRI/ORAN Gbps	FH Data Rate ("3" Sectors) CPRI/ORAN Gbps	Midhaul Gbps	Backhaul Gbps
5	850 MHz	10	4T4R	2.45 (CPRI option 3)/0.70	7.35/1.40	0.30	0.25
8	900 MHz	10	4T4R	2.45 (CPRI option 3)/0.70	7.35/1.40	0.30	0.25
9	1.8GHz	20	4T4R	4.9 (CPRI option 5)/1.40	14.7/2.80	0.59	0.50
41	2.6GHz	20	4T4R	9.8 (CPRI option 7)/1.40	29.4/2.80	0.59	0.50
n78	3.5GHz	100	64T64R/8 layers	15.29	30.59	4.44	3.78
n257 (Split 2)	28GHz	400	128T128R/4 layers		NA	6.14	5.22
Total					**FH=LTE CPRI+NR=89.39 Gbps FH=LTE ORAN+NR=39 Gbps**	**12.36 Gbps**	**10.5 Gbps**

Fronthaul Interface Required=100G/50
Midhaul Interface Required=25G
Backhaul Interface Required=25G

Customer Case Study

Customer existing CRAN Topology



- BBU – Baseband Unit
- GM – Grandmaster
- CPRI - Common Public Radio Interface
- eCPRI – Ethernet CPRI

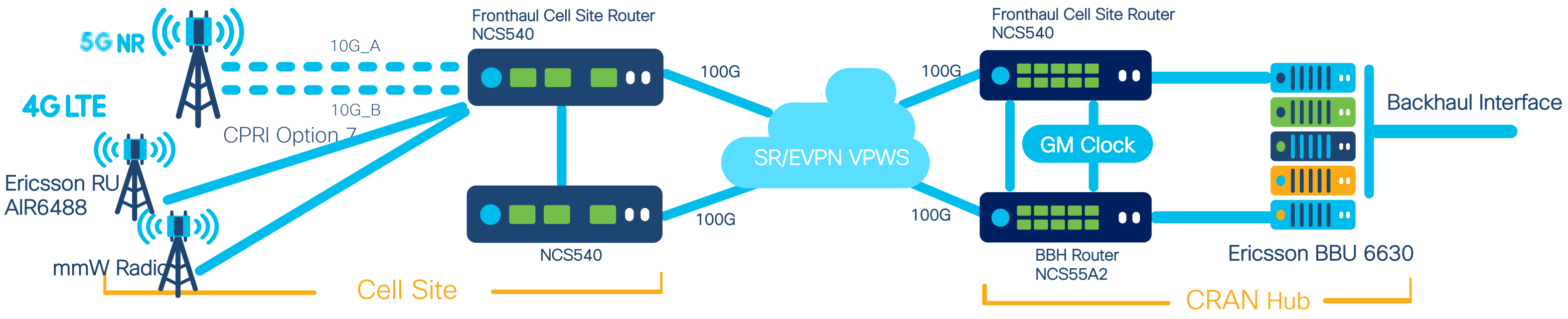
- Complete Ericsson RAN network
- C-RAN & ERAN in production using passive DWDM solution
- Drawbacks of existing CRAN fronthaul
  - Passive infrastructure static
    - No dynamic fault recovery
    - Limited topology options (hub spoke today)
  - Coloured optics
    - operationally challenging (if not using tuneable)
  - Little to no OAM of fronthaul links
  - Dedicated E-RAN switch

Motivation for Packetized Fronthaul

- Packetized fronthaul enables Flexible and programmable architecture to support RAN innovation e.g. Stats-mux, converged services (45/5G/Enterprise)
- Leverage IP protection mechanisms (Segment Routing) for improved resiliency and failover in fronthaul network
  - Ring/mesh FH topologies
  - N+1 BBU use case using NSO
  - Cell management with reduced capacity
- Operational simplicity - visibility of fronthaul network with Telemetry, ZTP, topology visualization and automation

NOW in PRODUCTION

Converged Fronthaul



- 5G NR Split 7 , eCPRI Ethernet
- NCS540 validated with **Ericsson 5G NR**
  - Ericsson BBU 6630
  - Ericsson RU 5G AIR6488
- Phase 1 Lab Trials
  - EVPN-VPWS over SR (MPLS) + TI-LFA
  - Dynamic latency measurement of fronthaul link with SR-PM
  - Telemetry for OAM of fronthaul links
- Completed with 100% Success

- 4G Split 8, CPRI “RoE Structure Agnostic Type 0”
- NCS540-FH CSR validated with **Ericsson 4G radio**
  - Ericsson BBU 6630
  - Ericsson RU 4415
- Phase 1 Lab Trials
  - EVPN VPWS for CPRI over SR (MPLS) + TI-LFA
- Baseline Testing Completed with 100% Success
  - 4G Cell is up and running. MBB and VoLTE tests were successful

Convergence of backhaul & fronthaul traffic

Why Cisco for Fronthaul?

- Packet-based solution with high-speed, Ultra-Low Latency Forwarding to meet and exceed fronthaul requirements
- Converges services while optimizing fronthaul resources
- Flexible and programmable architecture to support RAN innovation
- Simplifies and improves reliability of network operations by extending IP through RAN transport

Supporting Sessions

BRKSPM-2001 5G Converged SDN Transport
BRKSPM-2000 5G Access and DC Edge
BRKSPG-2060 5G Transport: Design Strategies

Resources

- Cisco NCS 540 Fronthaul Router Portfolio Collateral:
  - At-A-Glance: https://www.cisco.com/c/en/us/products/collateral/routers/network-convergence-system-540-series-routers/at-a-glance-c45-743315.html
  - Data Sheet: https://www.cisco.com/c/en/us/products/collateral/routers/network-convergence-system-500-series-routers/datasheet-c78-740296.html
  - ACG Research: An Economic Comparison of Fronthaul Architectures: https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/mobile-internet/acg-fronthaul-architectures-for-5g-networks.pdf?dtid=osscdc000283
- The Deep Edge Podcast "Segment Routing and 5G with Simon Spraggs from Cisco"
  - https://www.buzzsprout.com/1010419/3956699
- 5G transport page
  - www.cisco.com/go/5g-transport

Additional Resources contd..

- ”5G Transport” session Cisco Live Barcelona 2020
  - https://www.ciscolive.com/global/on-demand-library.html?search=waris&search.event=ciscoliveemea2020#/session/1564528251037001eg4o
- ”Clocking” sessions Cisco Live Barcelona 2020
  - https://www.ciscolive.com/global/on-demand-library.html?search=Shahid&search.event=ciscoliveemea2020#/session/1564610726804001cUPp
  - https://www.ciscolive.com/global/on-demand-library.html?search=Dennis&search.event=ciscoliveemea2020#/session/15632796220300016AGl
- Radio and Band info
  - https://www.sharetechnote.com/ (Radio tutorial)
  - Simple lookup for LTE bands
  - https://www.sqimway.com/lte_band.php(Simple lookup for LTE bands)
  - Simple lookup for 5G (new radio) bands
  - https://www.sqimway.com/nr_band.php (Simple lookup for 5G (new radio) bands)

Cisco Validated Design Document

Converged SDN Transport High Level Design

- https://xrdocs.io/design/blogs/latest-converged-sdn-transport-hld
- https://xrdocs.io/design/blogs/latest-converged-sdn-transport-ig

5G Features covered:

- Clocking & Synchronization
- 5G Transport SR MPLS/BGP VPN
- Fronthaul will be covered in future release

The bridge to possible

Thank you

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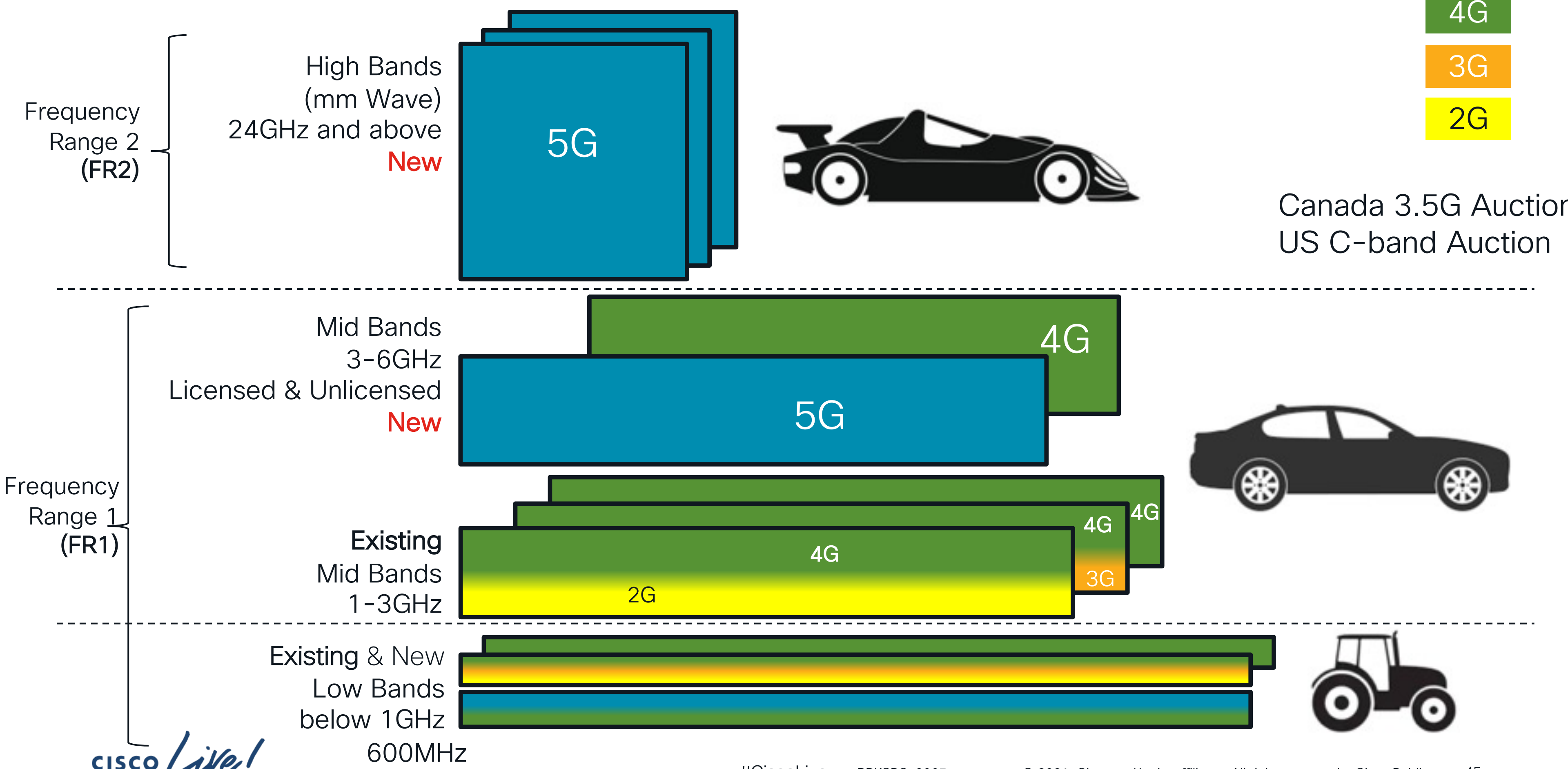
Bonus Material

Mobile Network Spectrum



5G NR Channel Capacity (& Throughput)

Labs, Showcases

Spectral efficiency	bps/Hz (Downlink)	LTE	example 20MHz FDD	LTE-A 3x20MHz FDD	5G NR	example Sub 6GHz 100MHz BW	mmWave 800MHz
Peak/Max Rate	*Theoretical max coded rate*	*15*	*300Mbps*	*900Mbps*	*23*	*2.3Gbps*	*18.4Gbps*
Cell Centre	Minimum rate achieved by top 5% of users	9	180Mbps	540Mbps	13	1.3Gbps	10.4Gbps
Typical	Typical median rate	2.0	40Mbps	120Mbps	2.9	290Mbps	2.32Gbps
Edge	Minimum rate achieved by 95% of users	0.1	2Mbps	6Mbps	0.12	120Mbps	96Mbps
Aggregate cell (multi-user) capacity	Average rate plus multi-user scheduling gain	2.2	44Mbps	132Mbps	3.3	330Mbps	2.64Gbps

* Design caveat: RF Channel capacity depends on many factors, like MIMO schedule deployed, UE capabilities, network loading, mobility, etc. Always consult customer for RAN design guidelines

Network Planning

Access Transport Bandwidth: 1G→10G→25G

Edge/IP Core Transport Bandwidth: 10G→100G→400G

RAN Decomposition and Virtualization

Functional Decomposition
Functions Separated to Allow Flexible Placement and Optimization

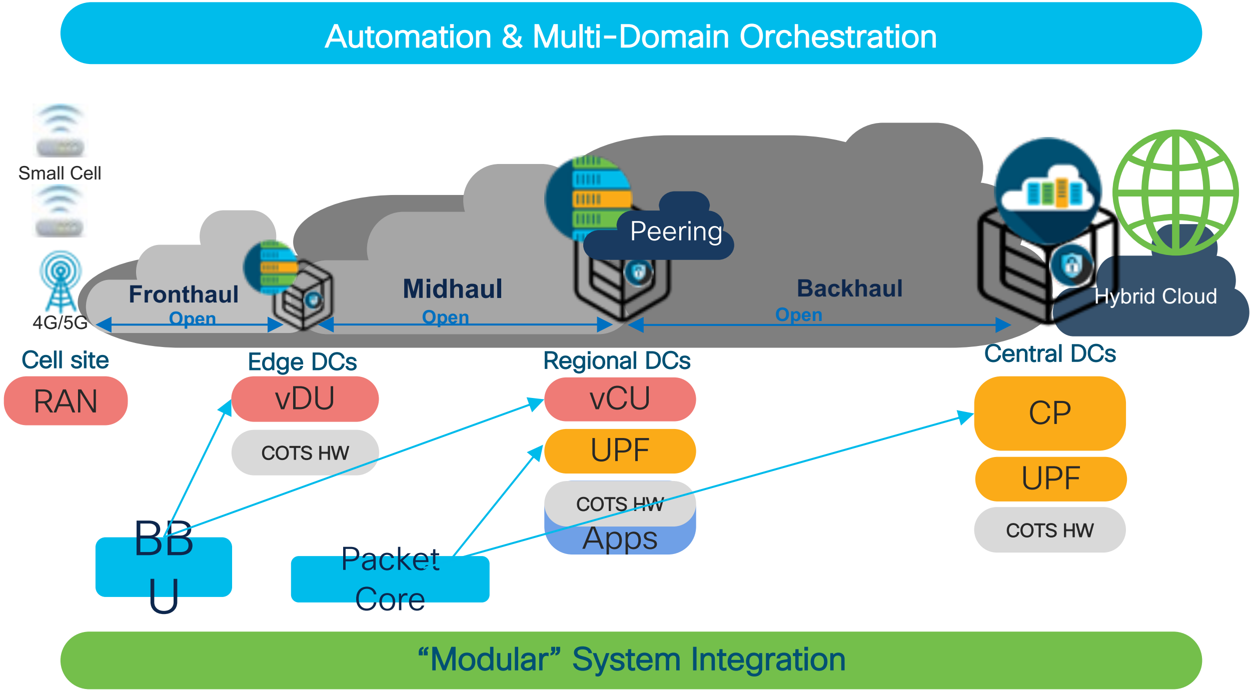
Disaggregation into SW + HW
Software-Centric Solutions Leveraging COTS Hardware

Open
Modular, ORAN, Open, Multi-vendor, More Options = Flexibility and Lower Cost

Multi-Use Case
5GNR, LTE, Small Cell, Indoor/Outdoor, mMIMO, Multi-band, mmWave, Private/Public, Enterprise/Consumer, etc.

Optimize for Lower Cost Operations
Agility, Lower TCO, Increased Automation

Enable New Services
Increased Service Flexibility, Velocity



O-RAN Alliance – Transforming the RAN

- Driving the RAN towards being:

  Open

  Intelligent

  Virtualized

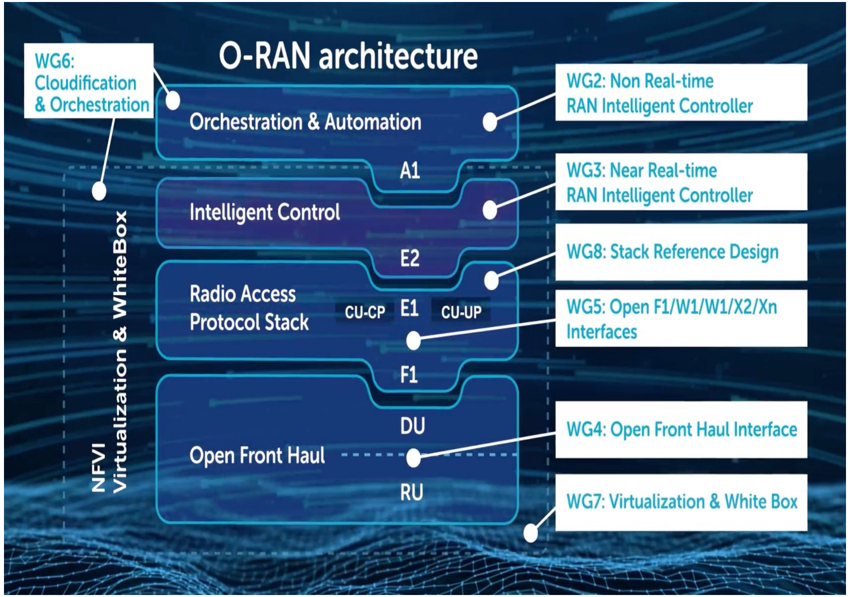
  Fully Interoperable

- WG9→ Open Xhaul transport architecture

  Fronthaul, Midhaul and backhaul

  Working on transport requirements, WDM FH and packet switched xhaul and timing and sync

  Cisco is editor of packet switched xhaul architecture

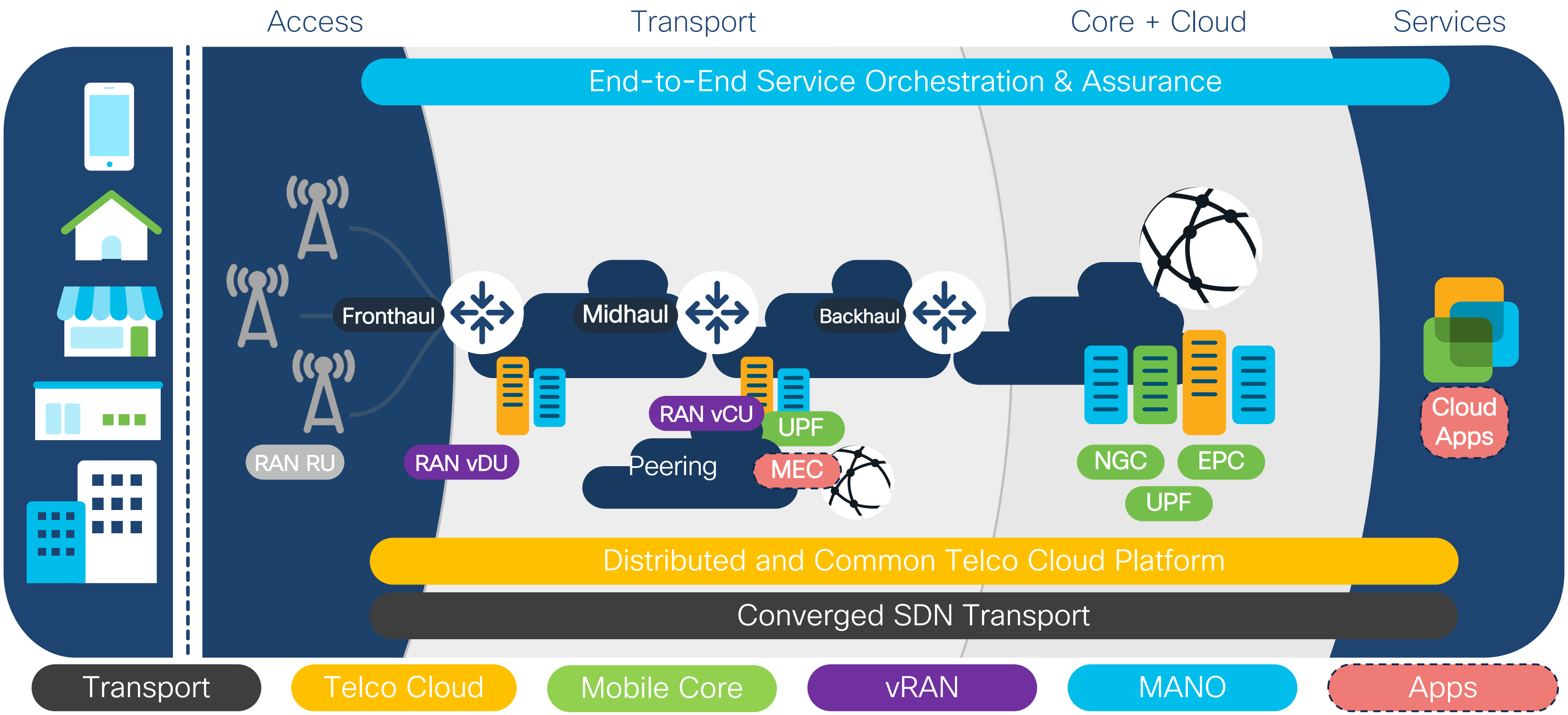


Filling today's functional and interface gap

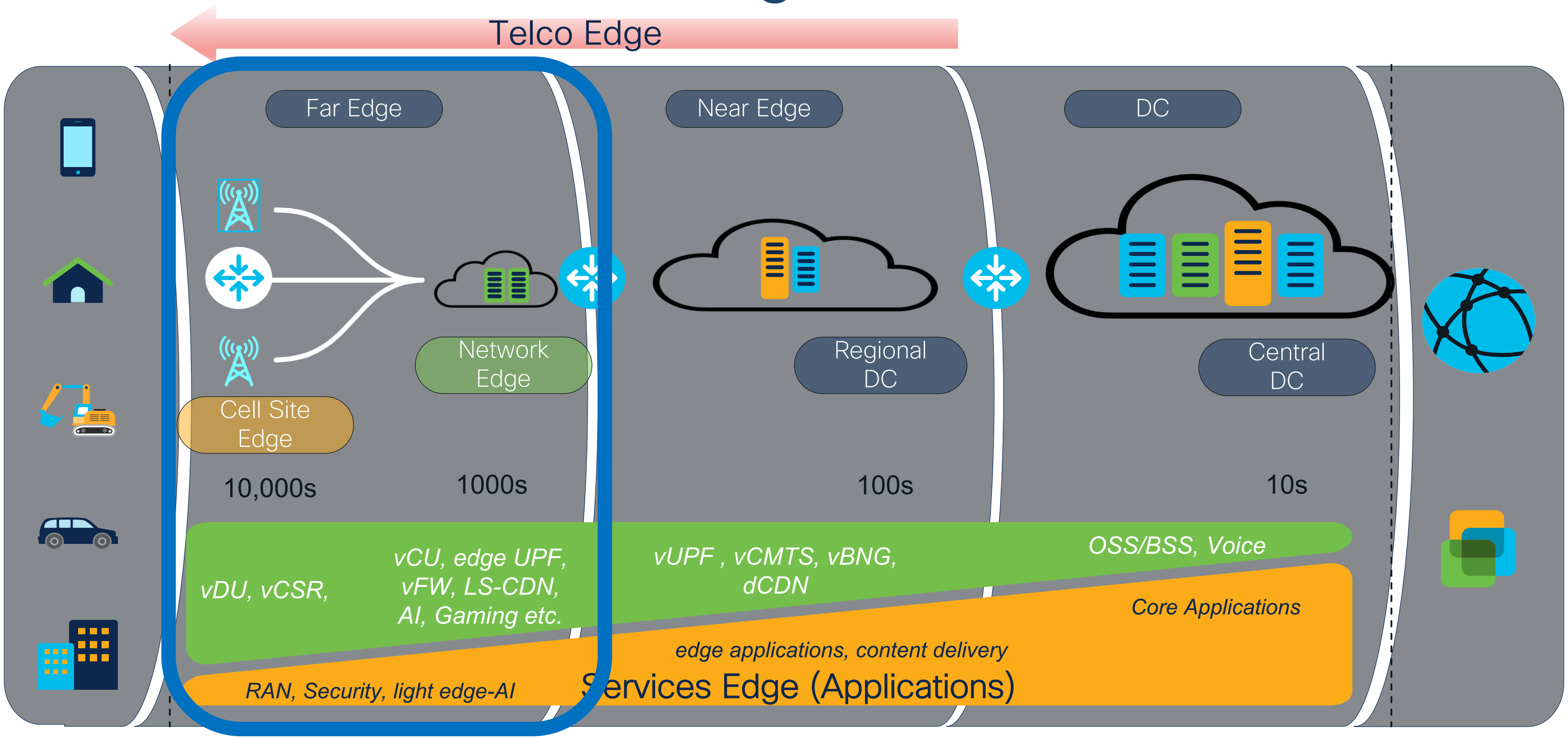
ORAN & IEEE 1914.3 Contribution

- WG4 - Open Fronthaul Interfaces Workgroup
- WG9 - Open X-haul Transport Workgroup
- WG7 - White-box Hardware Workgroup
- IEEE1914.3a: RoE Enhancements

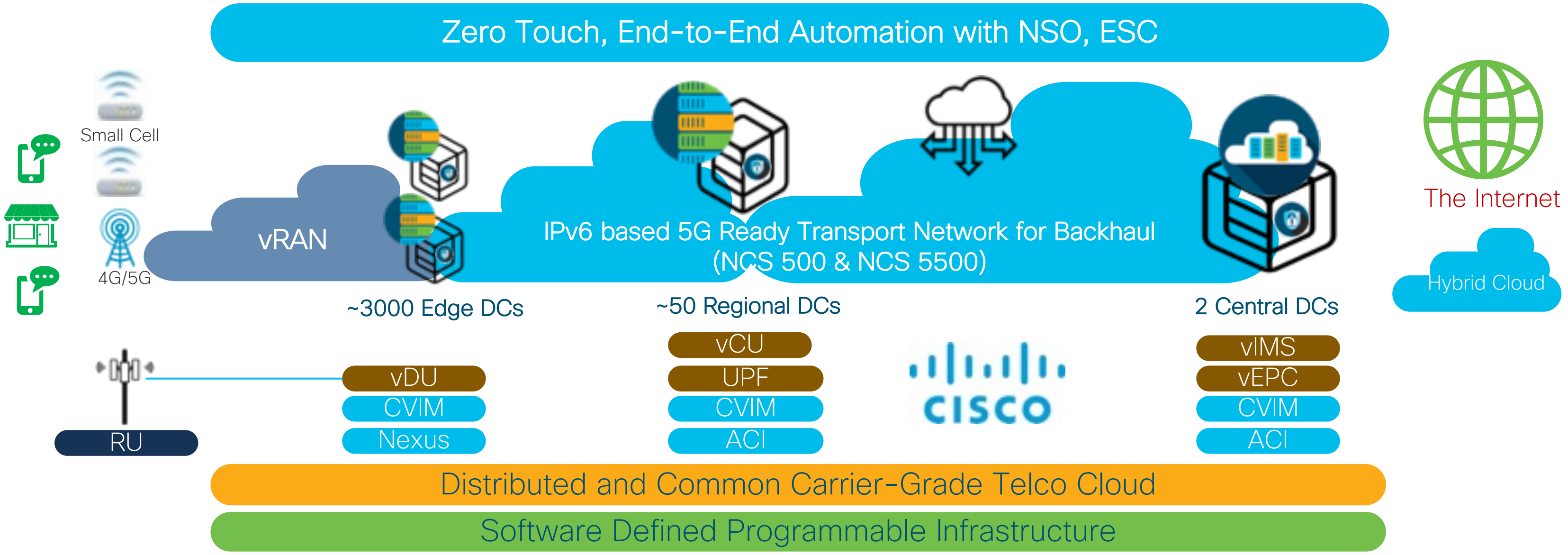
5G Network Transport Evolution



Transition to the Telco Edge



Customer Disruption
Software Defined 5G: O-RAN/vRAN Architecture



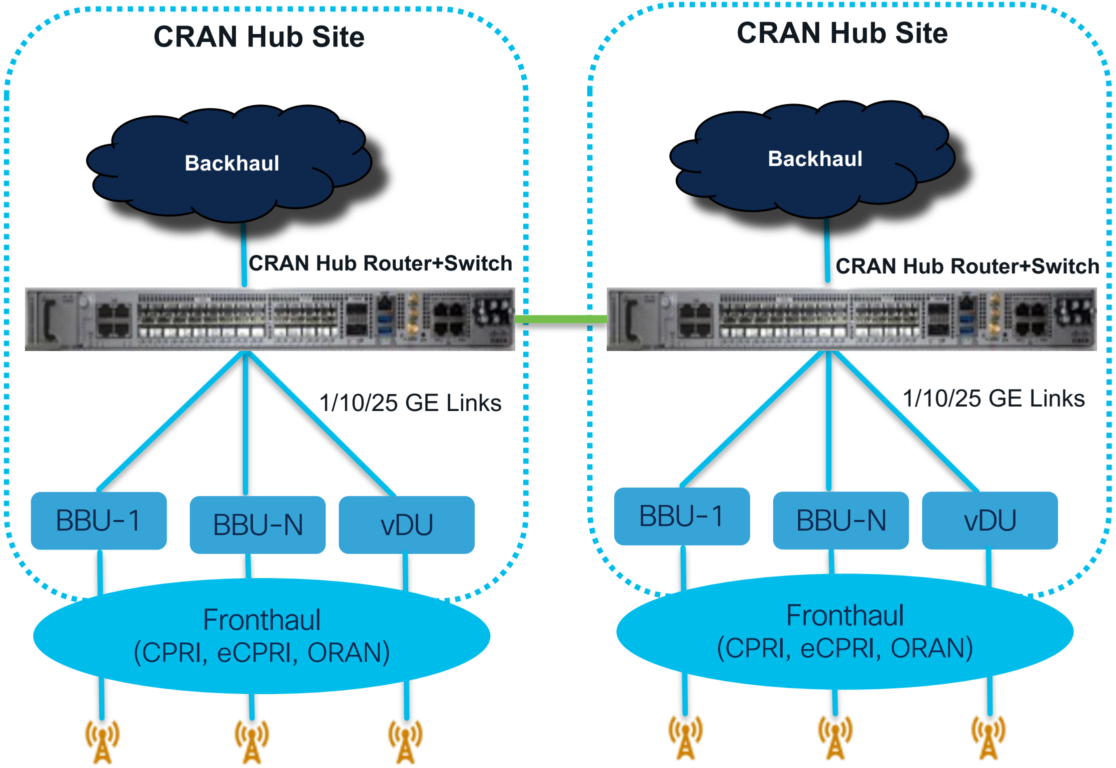
Open, Decomposed, and Virtualized RAN

Edge Computing for Enhanced Experience

New Business Models Including B2B Monetization

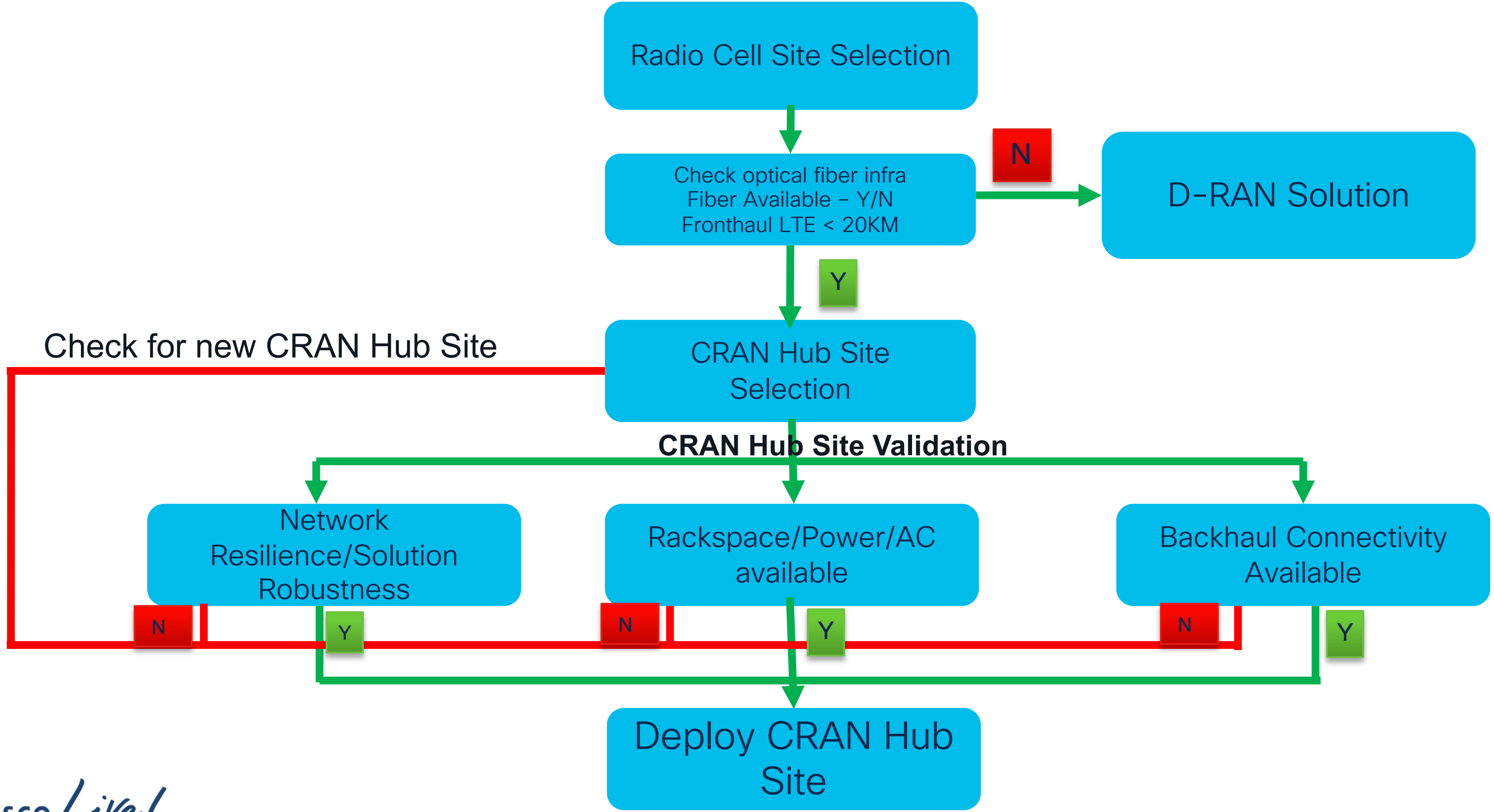
End-to-end Closed-Loop Automation

Elastic RAN Transport Requirement



- ERAN is being used to connect BBUs
- ERAN requires L2 connectivity using Ericsson proprietary Inter Digital Link Ethernet (IDLe) cable
- Strict low latency transport requirement
- ERAN can be used in CRAN & D-RAN

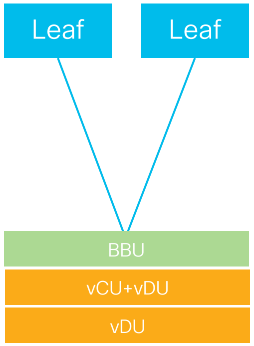
CRAN Hub Site Selection Flow Chart



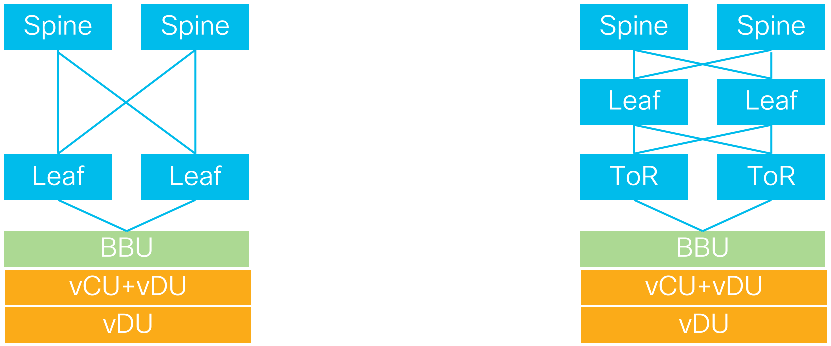
Scalable Cloud-RAN Fabric Architecture

- Deployment Flexibility
- Network Scale
- Horizontal Scalability
- Smaller Failure Domain
- Traffic Patterns (east and west)

Smaller CRAN Hub Sites



Large CRAN Hub Sites



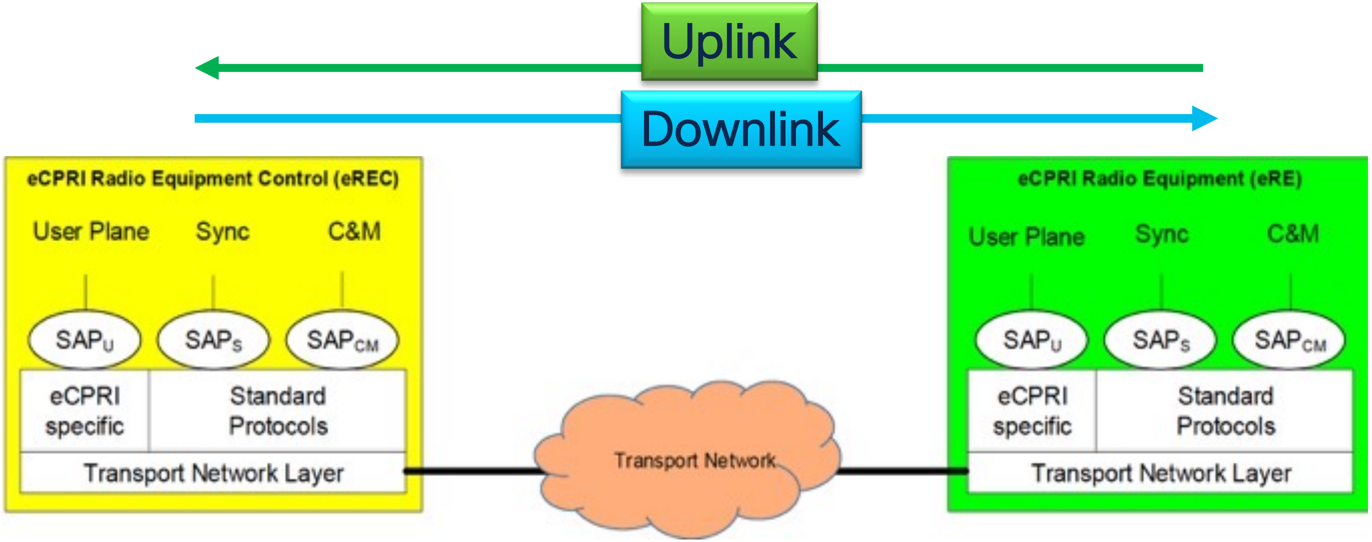
C-RAN Fabric Portfolio

Fixed Platform	Space (RU)	Capacity	Port Density	Timing 1588/Sync-E
 NCS 5501 (SE)	1	800 Gbps	Base: 48x 1/10G + 6x 100G Scale: 40x 1/10G + 4x 100G	Scale only
 NCS-55A1-36H-S/SE	1	3.6 Tbps	36 x QSFP28 or QSFP+	Y
 NCS-55A1-24H	1	1.8 Tbps	24 x QSFP28	Y
 NCS-55A1-48Q6H NCS-55A1-24Q6H-S	1	1.8 Tbps 900 G	48 x SFP28 + 6x100G QSFP28 24x1G/10G SFP+ +24x1G/10G/25G SFP28 & 6x100G	Y
 NCS 540	1	300 Gbps	24x 10GE SFP+ + 8x 25GE SFP28 + 2x 100GE QSFP28	Y
 NCS-55A2-MOD (SE)	2	900 Gbps	Fixed Ports: 24 x 1/10G & 16 x 1/10/25G 2 x MPAs of 400 Gbps each:	Y
Modular Platform				
 NCS560	7 slot	800 Gbps	Modular. 4 x 100G QSFP28, 40 x 10G SFP+, 96 x 1G CSFP	Y
	4 slot	800 Gbps	Modular. 4 x 100G QSFP28, 32 x 10G SFP+ or 72 x 1G CSFP	Y

eCPRI Standard Overview

eCPRI 2.0

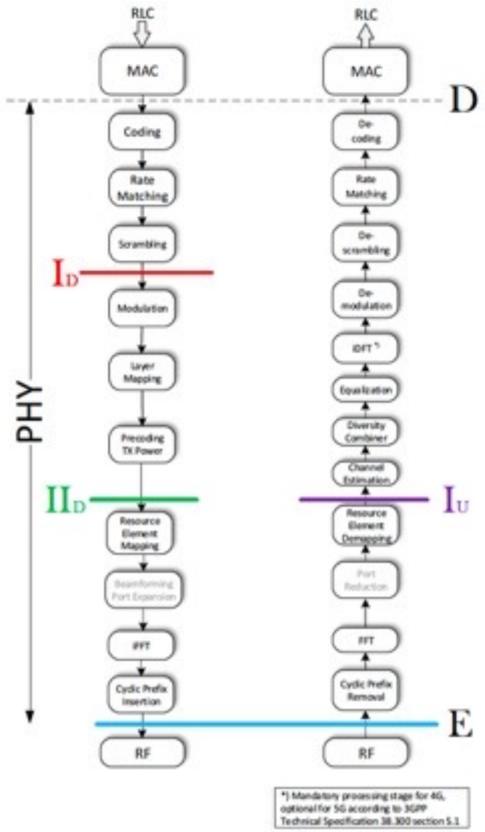
Source: eCPRI 2.0



- The internal radio base station interface establishing a connection between "eCPRI Radio Equipment Control" (eREC) and "eCPRI Radio Equipment" (eRE) via a **packet based transport network** is specified.
- eCPRI Ethertype ($AEFE_{16}$)
- eCPRI can be transported using standard IP/Ethernet routers and switches & it supports Stat-mux
- eCPRI radio may have 10G/25G interfaces
- The specification defines a new eCPRI Layer above the Transport Network Layer. Existing standards are used for the transport network layer, C&M and Synchronization.

eCPRI 2.0 contd..

Source: eCPRI 2.0



The major difference between Split ID and IID is that the data in Split ID is bit oriented and the data in split IID and IU is IQ oriented.

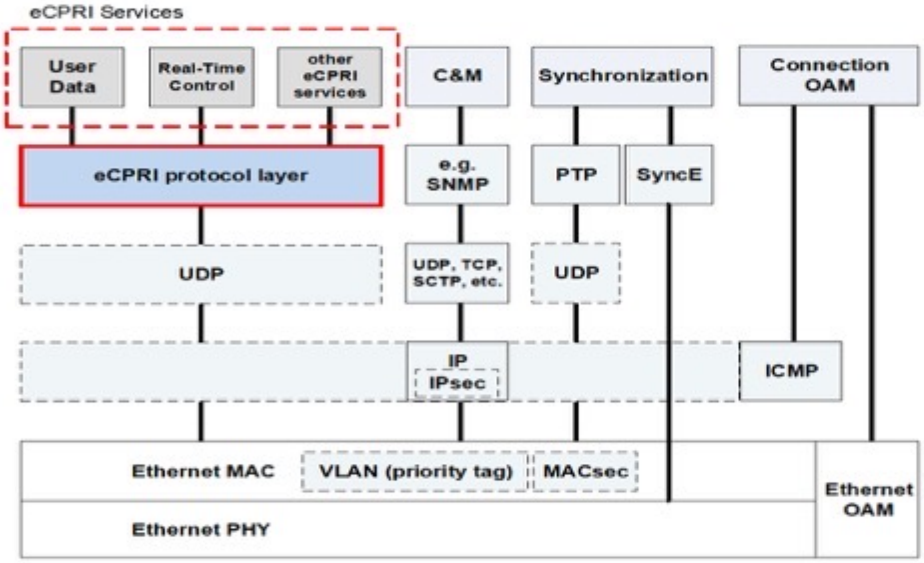


Figure 6: eCPRI protocol stack over IP / Ethernet

eCPRI 2.0 contd..

Source: eCPRI 2.0

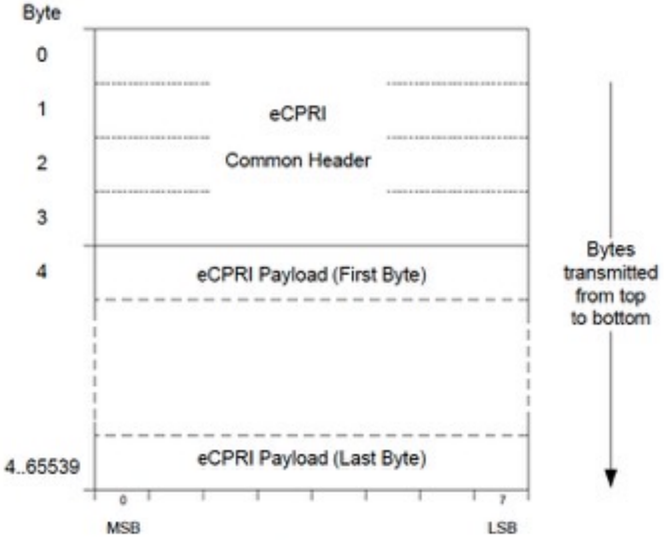


Figure 7: eCPRI message format

Table 4: eCPRI Message Types

Message Type #	Name	Section
0	IQ Data	3.2.4.1
1	Bit Sequence	3.2.4.2
2	Real-Time Control Data	3.2.4.3
3	Generic Data Transfer	3.2.4.4
4	Remote Memory Access	3.2.4.5
5	One-way Delay Measurement	3.2.4.6
6	Remote Reset	3.2.4.7
7	Event Indication	3.2.4.8
8	IWF Start-Up	3.2.4.9
9	IWF Operation	3.2.4.10
10	IWF Mapping	3.2.4.11
11	IWF Delay Control	3.2.4.12
12 - 63	Reserved	3.2.4.13
64 - 255	Vendor Specific	3.2.4.14

Source: eCPRI 2.0

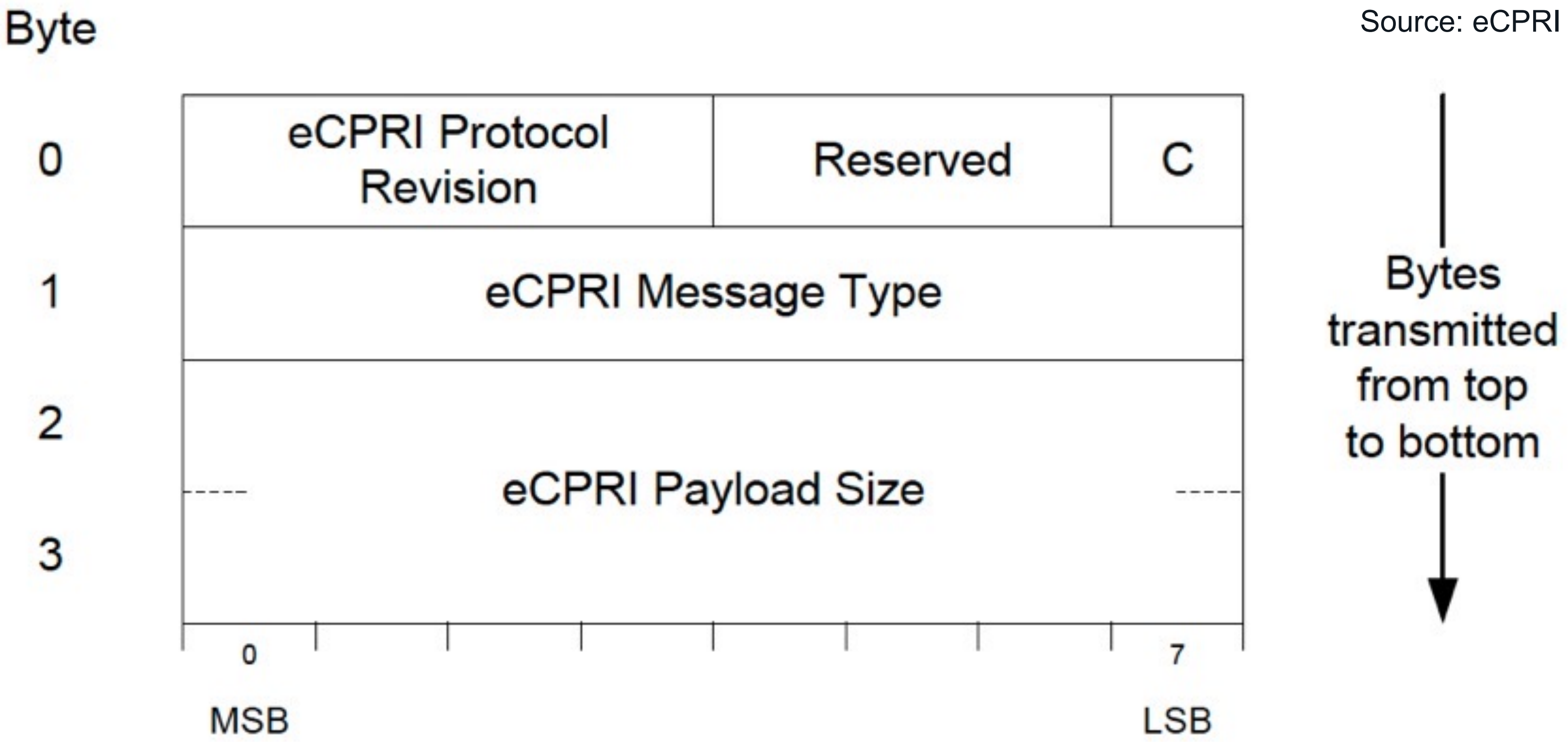


Figure 8: eCPRI Common Header format

eCPRI Protocol Revision

Source: eCPRI 2.0

Table 15: Specification release version and protocol revision numbering

Specification release version	Available eCPRI protocol revision values	Comment
1.0, 1.1, 1.2, 2.0	0001b	The interpretation of the eCPRI message shall follow eCPRI specification versions up to 2.0.
	0010b-1111b; 0000b	Reserved for future eCPRI protocol revisions. Unallocated values can temporarily be used for vendor specific extensions until allocated.

eCPRI Transport

eCPRI Fronthaul Packet Capture

Wireshark · Packet 1 · FHR to Radio port

```
▾ Frame 1: 1286 bytes on wire (10288 bits), 1286 bytes captured (10288 bits)
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 25, 2019 04:38:58.504291357 PST
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1574685538.504291357 seconds
    [Time delta from previous captured frame: 0.000000000 seconds]
    [Time delta from previous displayed frame: 0.000000000 seconds]
    [Time since reference or first frame: 0.000000000 seconds]
    Frame Number: 1
    Frame Length: 1286 bytes (10288 bits)
    Capture Length: 1286 bytes (10288 bits)
    [Frame is marked: False]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:vlan:ethertype:vlan:ethertype:data]
▾ Ethernet II, Src: Ericsson_8a:e0:1b (74:c9:9a:8a:e0:1b), Dst: 98:c5:db:f2:66:28 (98:c5:db:f2:66:28)
  ▸ Destination: 98:c5:db:f2:66:28 (98:c5:db:f2:66:28)
  ▸ Source: Ericsson_8a:e0:1b (74:c9:9a:8a:e0:1b)
    Type: 802.1Q Virtual LAN (0x8100)
▾ 802.1Q Virtual LAN, PRI: 6, CFI: 0, ID: 10
    110. .... .... .... = Priority: Voice, < 10ms latency and jitter (6)
    ...0 .... .... .... = CFI: Canonical (0)
    .... 0000 0000 1010 = ID: 10
    Type: 802.1Q Virtual LAN (0x8100)
▾ 802.1Q Virtual LAN, PRI: 6, CFI: 0, ID: 1024
    110. .... .... .... = Priority: Voice, < 10ms latency and jitter (6)
    ...0 .... .... .... = CFI: Canonical (0)
    .... 0100 0000 0000 = ID: 1024
    Type: Unknown (0xebc0)
▾ Da... (1264 bytes)
    Data: 014004ec000000000000000000002c80000060605c0f0d80...
    [Length: 1264]
```

eCPRI QinQ User plane

Propriety eCPRI Ethertype since eCPRI standard Ethertype is (AEFE16)

0x01=eCPRI **Protocol revision 2.0**

0x40=eCPRI Message type=**Reserved**

Does eCPRI support Statistical Multiplexing?

- Based on eCPRI radio testing, **eCPRI does support stat-mux**
- Stat-mux enables optimal transport bandwidth utilization

Idle state

Channel Width	BBU to Radio (Mb/s)	Radio to BBU (Mb/s)
20Mhz	109.2	4.0032
40Mhz	197.68	5.2696
60Mhz	287.76	6.5520
80Mhz	376.24	7.8192
100Mhz	466.24	9.1040

Single UE downloading 10G file

Channel Width	BBU to Radio (Mb/s)	Radio to BBU (Mb/s)
20Mhz	224.8	144.88

NCS 540 Family

Cell Site Router

NCS 540 Family	Interfaces	Throughput	Timing
N540-24Z8Q2C-SYS N540(X)-ACC-SYS 	2x 100/40GE 8x 25/10/1GE 24x 10/1GE	300G Max Interfaces: 640G	GNSS Class B 1pps/10MHz/ToD
N540X-16Z4G8Q2C-A/D 	2x 100/40GE 8x 25/10/1GE 16x 10/1GE 4x 1GE Copper	300G Max Interfaces: 564G	GNSS Class C 1pps/10MHz/ToD BITS
N540-28Z4C-SYS-A/D 	4x 100/40GE 28x 10/1GE	300G Max Interfaces: 680G	Class B 1pps/10MHz/ToD BITS
N540X-12Z16G-SYS-A/D 	12x 10/1GE 12x 1GE 4x 1GE Copper	140G Max Interfaces: 136G	GNSS Class C 1pps/10MHz/ToD BITS
N540-12Z20G-SYS-A/D 	12x 10/1GE 20x 1GE	140G Max Interfaces: 140G	Class B 1pps/10MHz/ToD BITS

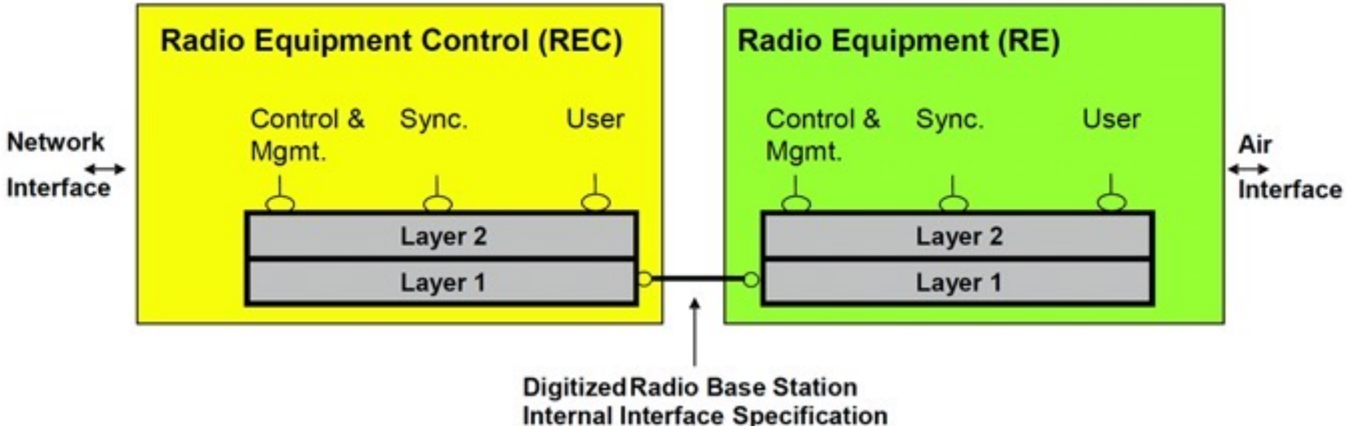
Cisco and Telstra Complete World’s First 5G Call over Packetized Fronthaul Network

https://newsroom.cisco.com/press-release-content?type=webcontent&articleId=2058724&dtid=osscdc000283

CPRI Tutorial

Source: CPRI 7.0

CPRI v7.0



- A digitized and serial internal radio base station interface that establishes a connection between 'Radio Equipment Control' (REC) and 'Radio Equipment' (RE)
- Three different information flows (User Plane data, Control and Management Plane data, and Synchronization Plane data) are multiplexed over the interface.
- The specification covers layers 1 and 2
- The user plane data is transported in the form of IQ data
- Each IQ data flow reflects the data of one antenna for one carrier, the so-called antenna-carrier (AxC)

CPRI v7.0 contd..

Source: CPRI 7.0

- The radio base station system is composed of two basic subsystems, the radio equipment control and the radio equipment
- The subsystems REC and RE are also called nodes
- Several IQ data flows are sent via one physical CPRI link.
- Antenna-carrier (AxC):
    - One antenna-carrier is the amount of digital baseband (IQ) U-plane data necessary for either reception or transmission of only one carrier at one independent antenna element

Source: CPRI 7.0

CPRI v7.0 contd..

- Between REC and RE, working link consists of a master port, a bidirectional cable, and a slave port.
  - The master port in the REC and the slave port in the RE.
- Downlink:
  - Direction from REC to RE for a logical connection.
- Uplink:
  - Direction from RE to REC for a logical connection.

Source: CPRI 7.0

CPRI v7.0 contd..

- Layer 1 defines:
  - Electrical characteristics
  - Optical characteristics
  - Time division multiplexing of the different data flows
  - Low level signaling
- Layer 2 defines:
  - Media access control
  - Flow control
  - Data protection of the control and management information flow

Source: CPRI 7.0

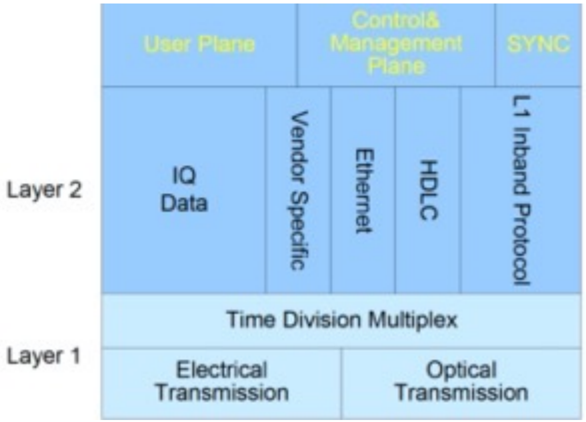
Table 1AA: Functional decomposition between REC and RE (valid for the GSM standard)

Functions of REC		Functions of RE	
Downlink	Uplink	Downlink	Uplink
Radio base station control & management			
Channel Filtering		Channel Filtering	
Abis transport		D/A conversion	A/D conversion
Abis Frame protocols		Up Conversion	Down Conversion
Channel Coding	Channel De-Coding	ON/OFF control for each carrier	Automatic Gain Control
Interleaving	De-Interleaving	Carrier Multiplexing	Carrier De-multiplexing
Modulation	De-Modulation	Power amplification	Low Noise Amplification
Frequency hopping control		Frequency hopping	
Signal aggregation from signal processing units	Signal distribution to signal processing units	Antenna supervision	
Transmit Power Control of each physical channel	Transmit Power Control & Feedback Information detection	RF filtering	RF filtering
Frame and slot signal generation (including clock stabilization)			
Measurements		Measurements	

Source: CPRI 7.0

CPRI v7.0 contd..

- IQ Data
  - User plane information in the form of in-phase and quadrature modulation data (digital baseband signals).
- Synchronization
  - Synchronization data used for frame and time alignment.
- L1 Inband Protocol
  - Signaling information that is related to the link and is directly transported by the physical layer. This information is required, e.g. for system start-up, layer 1 link maintenance and the transfer of time critical information that has a direct time relationship to layer 1 user data.
- C&M data
  - Control and management information exchanged between the control and management entities within the REC and the RE. This information flow is given to the higher protocol layers.
- Protocol Extensions
  - This information flow is reserved for future protocol extensions. It may be used to support, e.g., more complex interconnection topologies or other radio standards.
- • Vendor Specific Information
  - This information flow is reserved for vendor specific information.

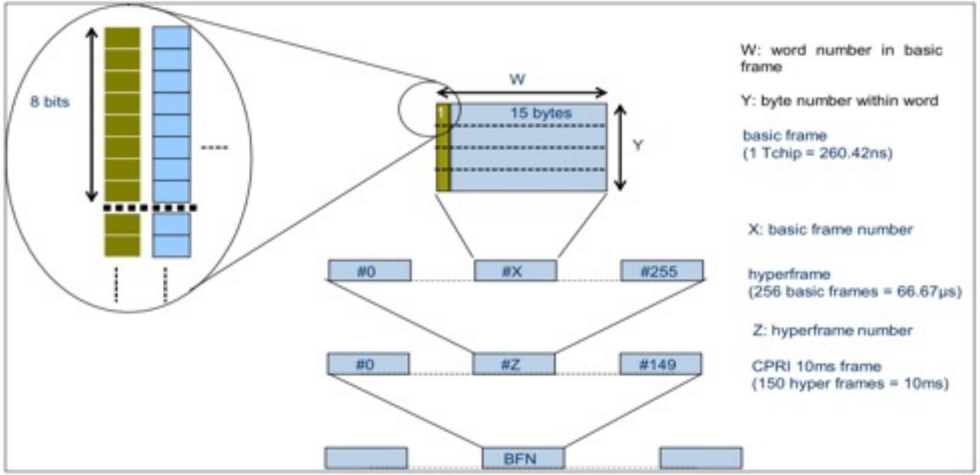


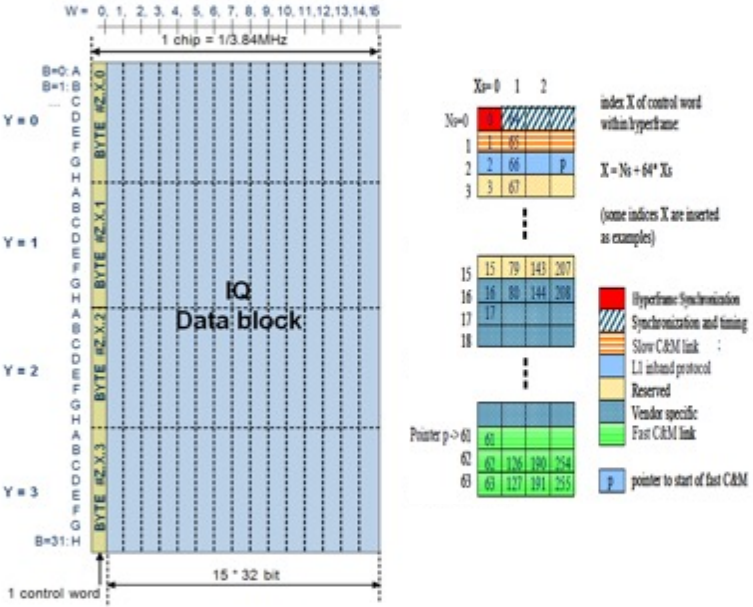
CPRI Frame Structure

Source: CPRI 7.0

- Frame structure
  - 1 Basic Frame (BF) = 16 words (W) = 256 bytes ; BF=260.42ns; X= BF Number
  - W = word number in Basic Frame
  - Y = byte number within a word
  - In each BF, word 0 is used as control word (CW)
  - 1 Hyperframe (HF) = 256 BF (basic frame); 1HF=66.67us; Z=HF Number
  - BFN (Node B Frame Number) = 150 HF =10ms
  - BFN is Synchronization Signal every 10msec
  - 256BF/HF*150HF/0.01s=3.84M BF/s
  - 16W/BF*3.84M BF/s=61.44M W/s. So a word width is ½ BBCLK cycle.
  - BBCLK = 30.74 MHZ SYSCLK, Link Speed multiple of BBCLK

Line rate (Gbps)	Line code	Byte per word	Bit per word
1.2288	8b10b	2	16
2.4576	8b10b	4	32
4.9152	8b10b	8	64
9.8304	8b10b	16	128
10.1376	64b66b	20	160





Frame Structure of 2.4576Gbps

CPRI Line Bit Rate Options

TDM Traffic

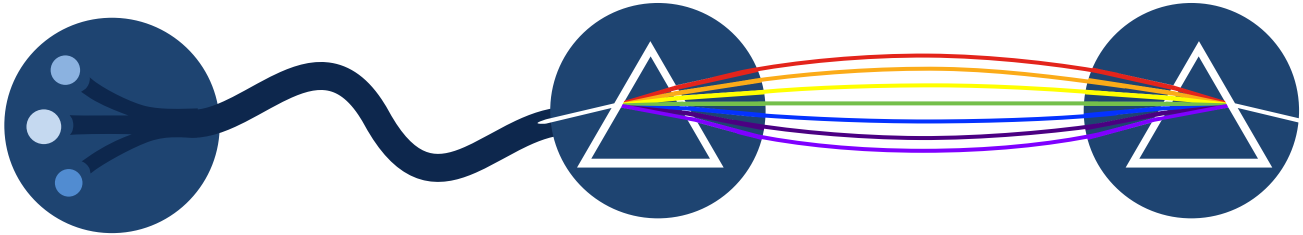
Source: CPRI 7.0

CPRI line bit rate option 1	614.4 Mbit/s	8B/10B line coding (1 x 491.52 x 10/8 Mbit/s)
CPRI line bit rate option 2	1228.8 Mbit/s	8B/10B line coding (2 x 491.52 x 10/8 Mbit/s)
CPRI line bit rate option 3	2457.6 Mbit/s	8B/10B line coding (4 x 491.52 x 10/8 Mbit/s)
CPRI line bit rate option 4	3072.0 Mbit/s	8B/10B line coding (5 x 491.52 x 10/8 Mbit/s)
CPRI line bit rate option 5	4915.2 Mbit/s	8B/10B line coding (8 x 491.52 x 10/8 Mbit/s)
CPRI line bit rate option 6	6144.0 Mbit/s	8B/10B line coding (10 x 491.52 x 10/8 Mbit/s)
CPRI line bit rate option 7	9830.4 Mbit/s	8B/10B line coding (16 x 491.52 x 10/8 Mbit/s)
CPRI line bit rate option 7A	8110.08 Mbit/s	64B/66B line coding (16 x 491.52 x 66/64 Mbit/s)
CPRI line bit rate option 8	10137.6 Mbit/s	64B/66B line coding (20 x 491.52 x 66/64 Mbit/s)
CPRI line bit rate option 9	12165.12 Mbit/s	64B/66B line coding (24 x 491.52 x 66/64 Mbit/s)
CPRI line bit rate option 10	24330.24 Mbit/s	64B/66B line coding (48 x 491.52 x 66/64 Mbit/s)

Converged Fronthaul

cisco Live!

Traditional Fronthaul Deployment Options are Sub-Optimal for 5G



Dark Fiber

- Very expensive solution
- Difficult to scale
- Fiber may not be available everywhere

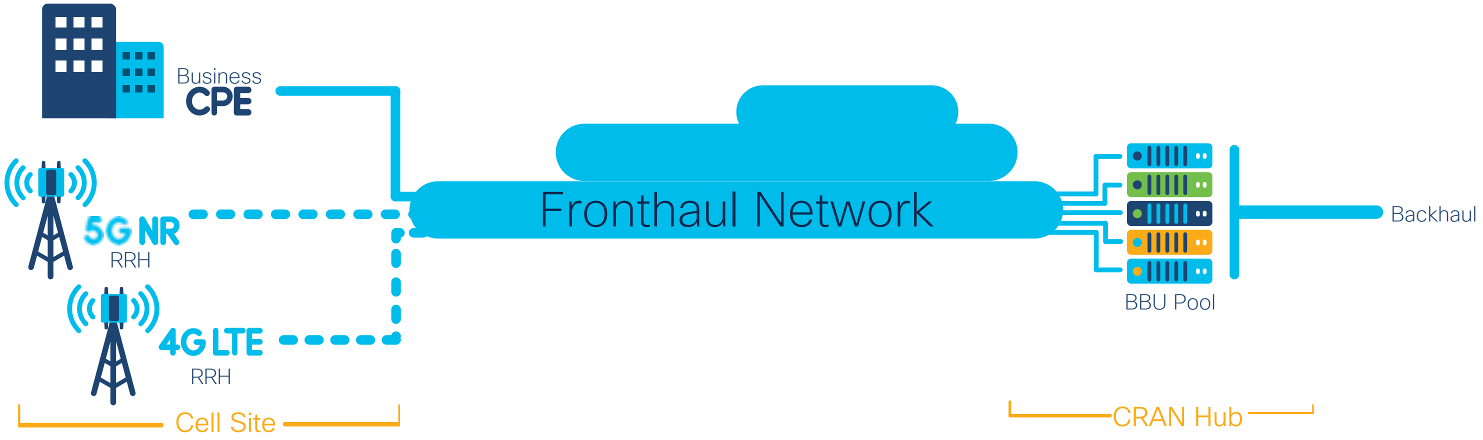
Passive Optical

- Limited lambda (λ) scale
- Manual deployments that are time consuming and error prone
- No visibility of the service making it difficult to troubleshoot
- No redundancy

Active WDM

- Expensive due to colored optics
- Active tunable optics have challenge with I-TEMP
- No Statistical Mux
- Topology dependent (Requires ROADM for ring architecture)

What is Converged Fronthaul?



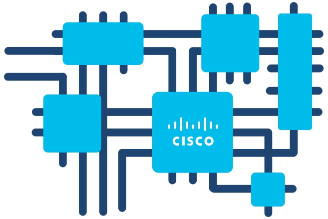
- Converged fronthaul implies transporting radio traffic, CPRI, eCPRI and enterprise traffic at the same time
- Major challenge: Radio traffic requires low latency and enterprise traffic can induce additional latency impacting mobile user experience
- Existing optical fronthaul technologies cannot deliver cost-effective solution

Universal Port Configuration

PID	Port Configuration
N540-FH-CSR-SYS	8xCPRI (Option 3-8) + 4x1/10G Eth/CPRI (Option 3-8) + 2x10/25G TSN + 8x1/10G Eth + 4x1/10/25G + 2x100G
N540-FH-AGG-SYS	Port Configuration • 24xCPRI (Option 3-8) + 4x100G • 24x1/10/25G Eth (TSN) + 4x100G • 18xCPRI (Option 3-8) + 6x1/10/25G Eth (TSN) + 4x100G • 12xCPRI (Option 3-8) + 12x1/10/25G Eth (TSN) + 4x100G • 6xCPRI (Option 3-8) + 18x1/10/25G Eth (TSN) + 4x100G

Flexible & Fully Programmable Architecture

To support evolving radio standards



Field Programmable Gate Array (FPGA) for evolving RAN

- **Flexible platform** to address both short term and long-term requirement for CPRI, eCPRI and RoE
- **Optimized for RoE** type 0 and type 1
- **Future proofed** to allow operators to add new RAN functions and interworking scenarios

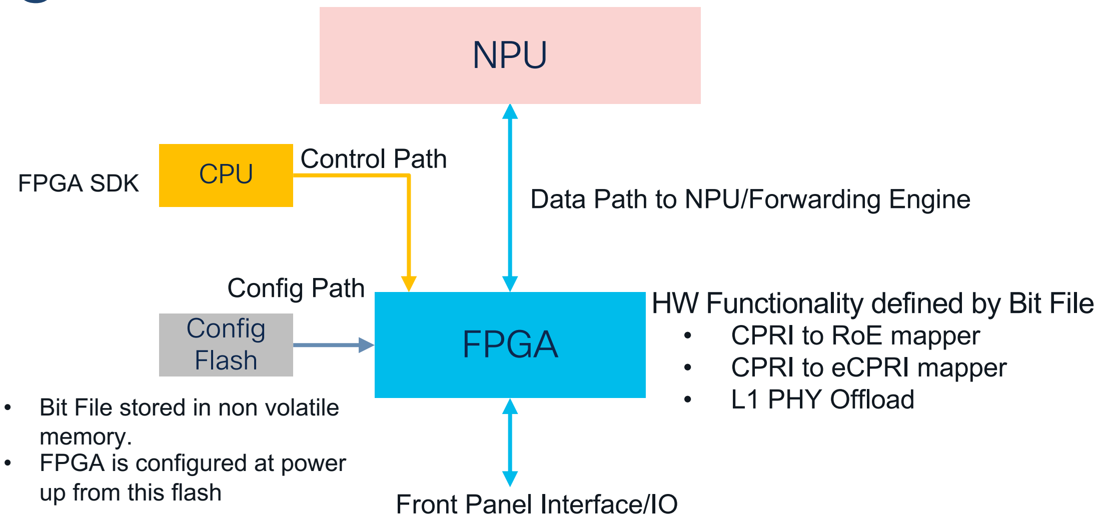
IOS XR

IOS-XR Based - Open APIs

- **Common operating system software** across the physical and virtual platforms
- **Optimized performance** for advanced features: SR, EVPN, security
- **Improved service visibility** with telemetry

Adaptable platform to address emerging requirements

Field Upgradeable FPGA



- FPGA is a programmable Phy/Optical front end in Cisco fronthaul router. Hence the same part can be reprogrammed into one of the following modes
- **To change the personality of the device, router software will load the appropriate bit file to the config flash and perform a reload of the product**

Radio over Ethernet (RoE)

RoE Mappers – To carry Radio Traffic over Packet Network

Structure Agnostic RoE Mapper

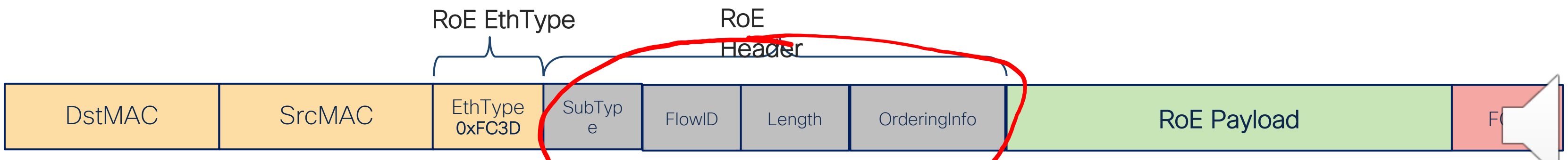
Function that converts other transport framing formats to a RoE framing format, and a RoE De-Mapper performs the opposite function. This mapper captures bits from one end of a constant bit rate link, packetizes the bits into Ethernet frames, sends the packets across the network, and then recreates the bit stream at far end of the link.

Type-0

- ✓ Works as a simple Ethernet Tunnel.
- ✓ Does not remove any Line Coding bits, doesn't interpret any special characters
- ✓ If source-data is 8B/10B encoded, the 10-bit symbols present on the line will be tunneled by the Mapper as 10 bits data

Type-1

- ✓ Works as Line Coding Aware Mode
- ✓ Removes Line Codes and Adds them back
- ✓ If Source Data is 8B/10B encoded, after decoding process, the 8-bit symbols present on the line will be tunneled by the Mapper as 8-bits
- ✓ On the other side, the 8-Bit will be encoded back to 10-Bits using standard Coding-scheme.



Source: IEEE 1914.3

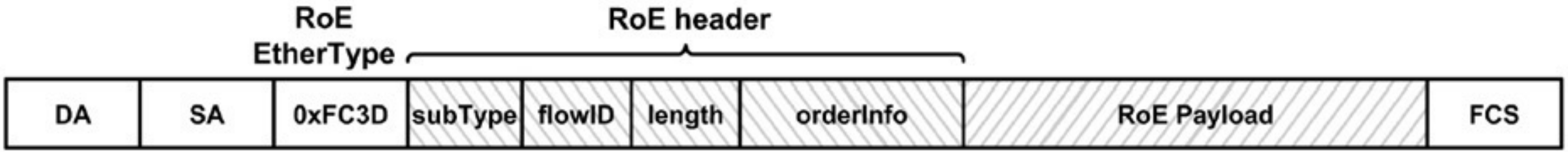
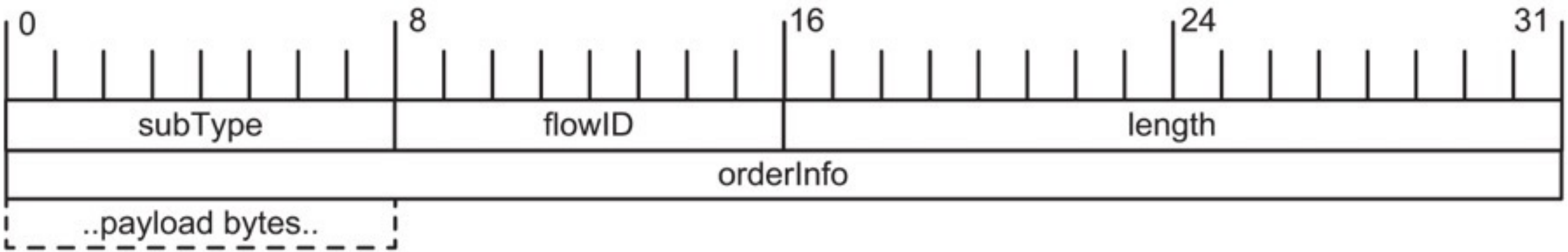


Figure 7—RoE encapsulation in Ethernet frames



Source: IEEE 1914.3

Table 3—RoE subType values

Binary value	Function	Description
0000 0000b	RoE control subtype	RoE message that contains control or management information.
0000 0001b	Reserved1	Reserved for future use by IEEE Std 1914.3. Reserved subType values shall not be transmitted. RoE messages with Reserved subTypes shall be ignored on receipt.
0000 0010b	RoE structure-agnostic data subtype	Data payload packet with RoE common frame header and structure-agnostic payload.
0000 0011b	RoE structure-aware CPRI data subtype	Data payload packet with RoE common frame header and structure-aware CPRI I/Q data.

CPRI RoE Type 0 Capture

Source: IEEE 1914.3

```
24 0.000085133   Cisco_43:b4:19   Cisco_ff:be:1c   MPLS   2604 MPLS Label Switched Packet
25 0.000087244   Cisco_ff:be:1c   Cisco_43:b4:19   MPLS   2608 MPLS Label Switched Packet

> Frame 24: 2604 bytes on wire (20832 bits), 2604 bytes captured (20832 bits) on interface ens192, id 0
> Ethernet II, Src: Cisco_43:b4:19 (d4:6a:35:43:b4:19), Dst: Cisco_ff:be:1c (4c:71:0d:ff:be:1c)
v MultiProtocol Label Switching Header, Label: 24003, Exp: 0, S: 1, TTL: 255
    0000 0101 1101 1100 0011 .... .... .... = MPLS Label: 24003
    .... .... .... .... .... 000. .... .... = MPLS Experimental Bits: 0
    .... .... .... .... .... ...1 .... .... = MPLS Bottom Of Label Stack: 1
    .... .... .... .... .... .... 1111 1111 = MPLS TTL: 255
v PW Associated Channel Header
    .... 0010 = Channel Version: 2
  > Reserved: 0x34
    Channel Type: Unknown (0x5678)
v Data (2582 bytes)
    Data: abcdaaaabbbbccccfc3d027b0a0000008395200053ef3667…
    [Length: 2582]
```

VC Label

```
24 0.000085133   Cisco_43:b4:19   Cisco_ff:be:1c   MPLS   2604 MPLS Label Switched Packet
25 0.000087244   Cisco_ff:be:1c   Cisco_43:b4:19   MPLS   2608 MPLS Label Switched Packet

> Frame 25: 2608 bytes on wire (20864 bits), 2608 bytes captured (20864 bits) on interface ens192, id 0
> Ethernet II, Src: Cisco_ff:be:1c (4c:71:0d:ff:be:1c), Dst: Cisco_43:b4:19 (d4:6a:35:43:b4:19)
v MultiProtocol Label Switching Header, Label: 100004, Exp: 0, S: 0, TTL: 255
    0001 1000 0110 1010 0100 .... .... .... = MPLS Label: 100004
    .... .... .... .... .... 000. .... .... = MPLS Experimental Bits: 0
    .... .... .... .... .... ...0 .... .... = MPLS Bottom Of Label Stack: 0
    .... .... .... .... .... .... 1111 1111 = MPLS TTL: 255
v MultiProtocol Label Switching Header, Label: 24006, Exp: 0, S: 1, TTL: 255
    0000 0101 1101 1100 0110 .... .... .... = MPLS Label: 24006
    .... .... .... .... .... 000. .... .... = MPLS Experimental Bits: 0
    .... .... .... .... .... ...1 .... .... = MPLS Bottom Of Label Stack: 1
    .... .... .... .... .... .... 1111 1111 = MPLS TTL: 255
v Data (2586 bytes)
    Data: aaaabbbbcccc12345678abcdfc3d027b0a000000c3062000…
    [Length: 2586]
```

IGP+VC Label

RoE Header & Payload

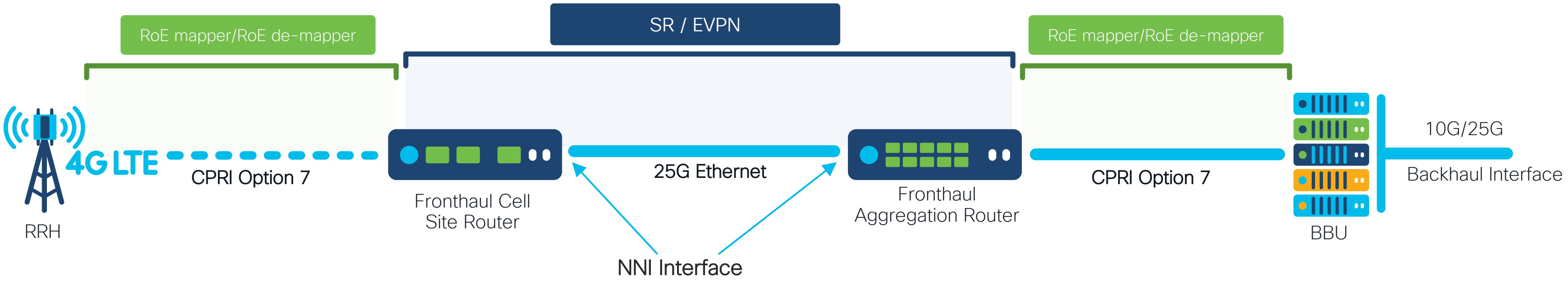
RoE Ethertype OxFC3D

0x02 RoE structure-agnostic

Type0/Type1 RoE Packetization Overhead Comparison

	Type-0	Type-1
Real CPRI data (CPRI data+linecoding) from RU or BBU	2560	2560
Packet size after CPRI frame at Ingress FH Router	2560 B	2048 (8b10b Line coding removed)
RoE Ethernet Header	14B	14B
RoE Header	8B	8B
Cisco Custom Header	4B	4B
MPLS+PW label + CW	4B+4B +4B	4B +4B+48
Outer Ethernet Header	18B	18B
Total Ethernet Packet Size at NNI	56B+2560=2616 B	56B+2048B=2104 B
RoE Packetization Overhead	(2616-2560)*100/2560=2.2%	(2104 – 2048)*100/2048= 2.73%
RoE packetization overhead is SAME regardless of Type 0 and Type 1		

Type0/Type1 NNI egress Interface Traffic Rate Comparison



	Type-0 NNI Interface Bandwidth	Type-1 NNI Interface Bandwidth
CPRI Option 7 = 9.83 Gbps RoE Packet size =1024 bytes	10.32 Gbps	8.26 Gbps
Type1 enables 20% Fronthaul Bandwidth Reduction		

CPRI RoE Structure Type 0 Enhancements

- Auto negotiation feature
  - Detection of CPRI stream, then enable RoE Transmission
- LOS/LOF propagation to remote packet based fronthaul router
  - Packet transport situation awareness
- Delay measurement and Windowing Function
  - Retiming
  - Packet impairment
- Cisco 1914.3 a contribution (planned to be published later this year)
- RoE Yang models

Cisco 5G Converged SDN Transport

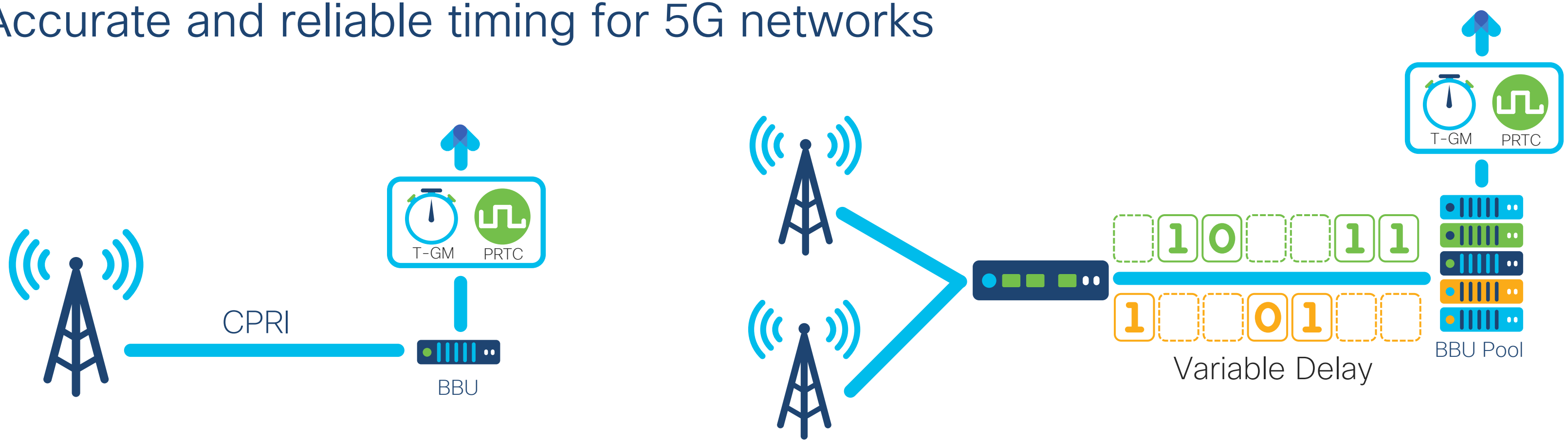
5G Services	Enhanced Mobile Broadband (eMBB) / Massive Machine Types Communications (mMTC) / Ultra-Reliable and Low Latency Communications (URLLC)
Service Orchestration & Programmability	Cisco Crosswork Portfolio
Service	Ethernet VPN (EVPN) and L3VPN
Transport	SR MPLS/SRv6, H-QOS & SR PM Clocking (1588/SyncE – Phase and Frequency, G8275.1, Class C)

L3 and L2 Network Efficiencies Are Almost Same!

Data	Packet Overhead	1500 Bytes Packet	2000 Bytes Packet	9000 Bytes Packet
L2 Only	42	1542	2042	9042
(IFG+Preamble+Ethernet+Dot1Q+CRC)				
L2VPN	64	1564	2064	9064
IFG+Preamble+Ethernet+MPLS 2 Labels+Ethernet				
L3VPN	66	1566	2066	9066
IFG+Preamble+Ethernet+MPLS 2 Labels+IP				
Network Efficiency				
L2 Only		97.28	97.94	99.53
L2VPN		95.91	96.89	99.29
L3VPN		95.79	96.80	99.27

Precise Timing and Synchronization

Accurate and reliable timing for 5G networks



CPRI protocol delivers Sync

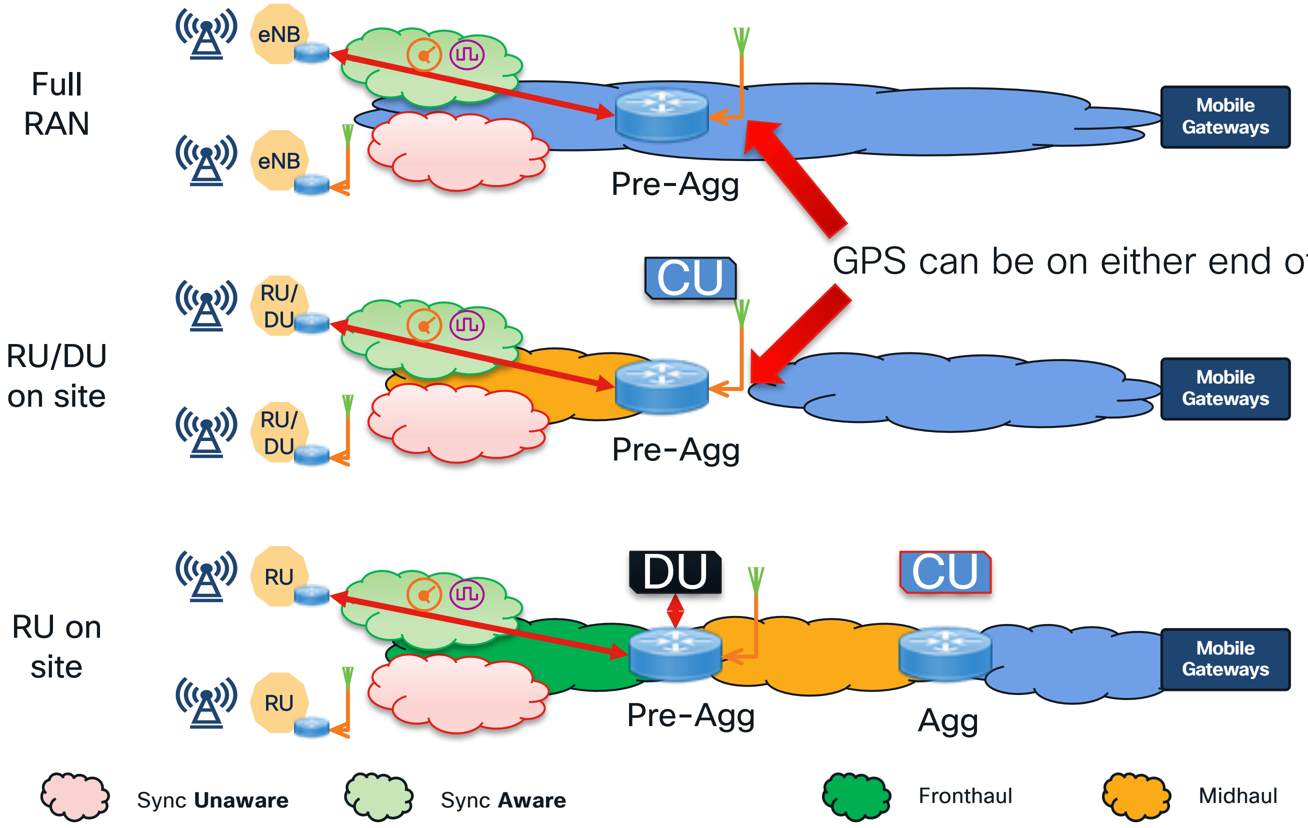
How do we deliver Sync for 5G networks?

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

- CPRI protocol delivers synchronization natively, eCPRI/RoE does not.
- eCPRI use cases require RAN transport to provide accurate phase and frequency synchronization

Cisco Fronthaul Routers support **stringent phase and frequency synchronization** requirements with **up to Class C timing** capabilities

Timing and Synch – Fronthaul Options contd..

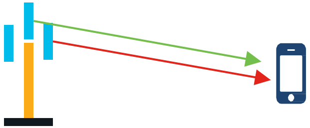


Aware transport carries time
Also delivers redundancy
GPS at time-isolated sites

Aware transport carries time
Also delivers redundancy
CU doesn't need phase

Aware transport carries time
Also delivers redundancy
CU doesn't need phase

Time Synchronization for RAN Use Cases



Transmission Diversity
±32.5ns Phase Accuracy
Improves error performance
Data Rate or Capacity

Carrier Aggregation
±65ns Phase Accuracy
Higher Pick Date Rate
Better Load Balancing

Coordinated Multi Point
±130ns Phase Accuracy
Higher Pick Date Rate
Better Load Balancing

Category	Time Error Requirements at UNI |TE|			3GPP TAE requirements at antenna ports
	Case 1		Case 2	
	Case 1.1	Case 1.2		
A+	N.A.	N.A.	20 ns Relative	65 ns
A	N.A.	60 ns Relative	70 ns Relative	130 ns
B	100 ns Relative	190 ns Relative	200 ns Relative	260 ns
C	1100 ns Absolute		1100 ns Absolute	3 μs

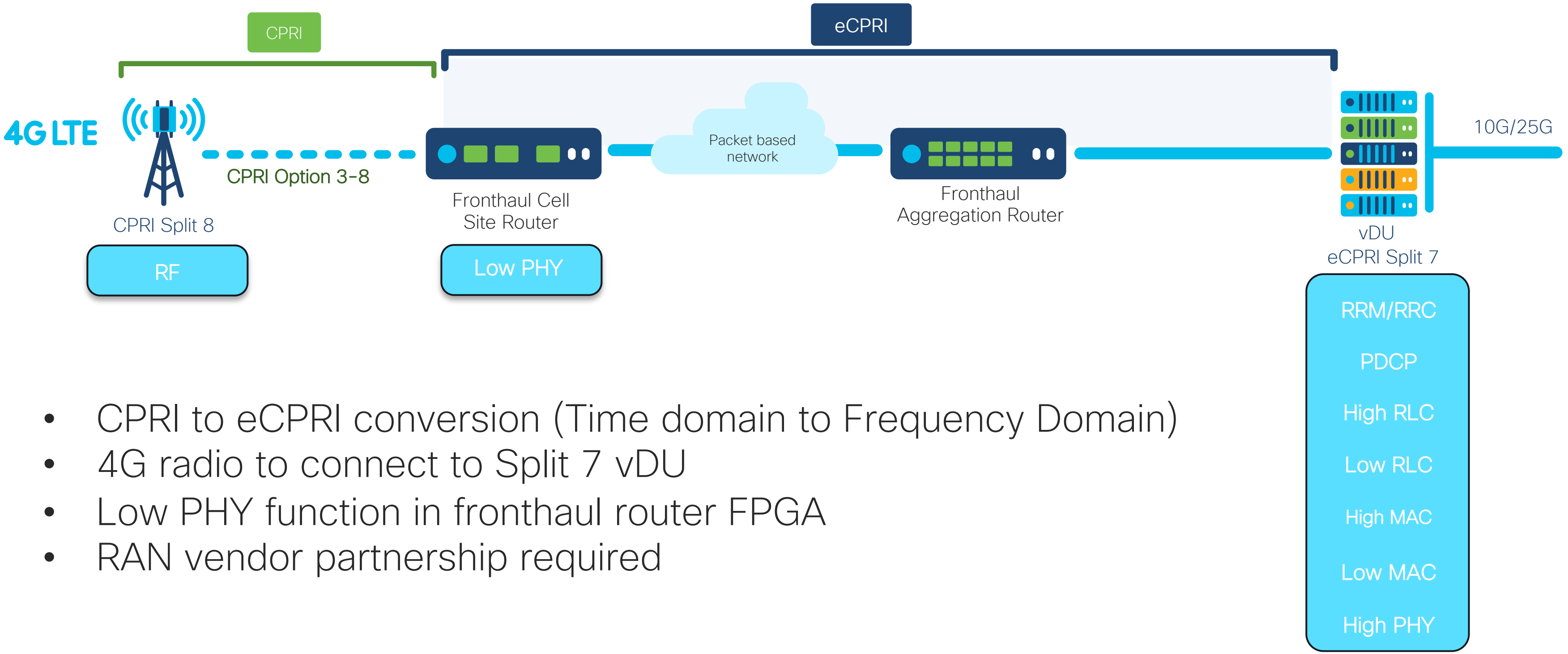
Case 1 = T-TSC is integrated in eRE

- Case 1.1 = integrated T-TSC requirements to T-TSC Class B
- Case 1.2 = enhanced integrated T-TSC requirement is total max |TE| is 15 ns

Case 2 = T-TSC is not integrated in eREs

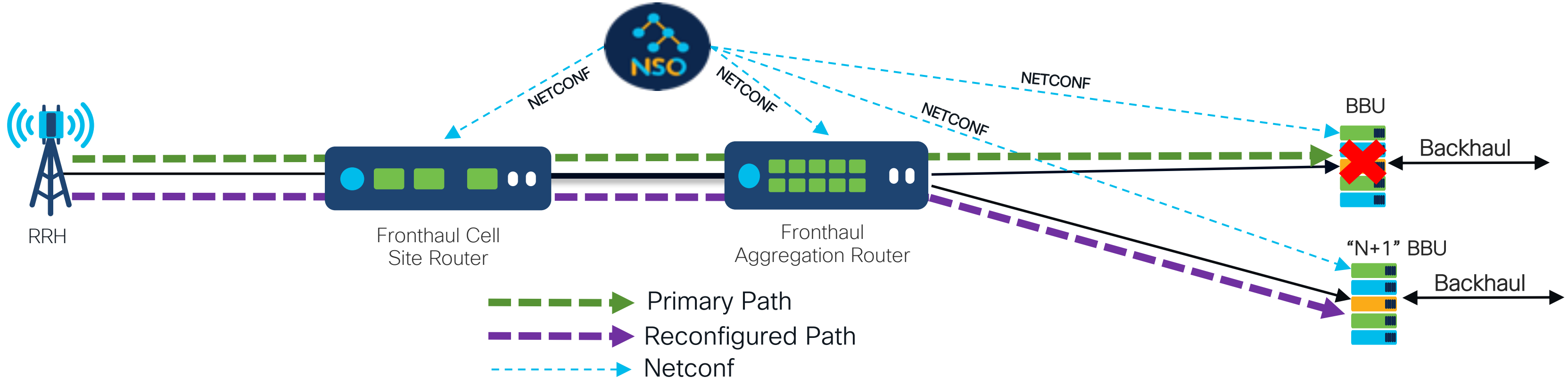
* 3GPP TS 38.104, 38.133

Low PHY Function in Cisco Fronthaul router



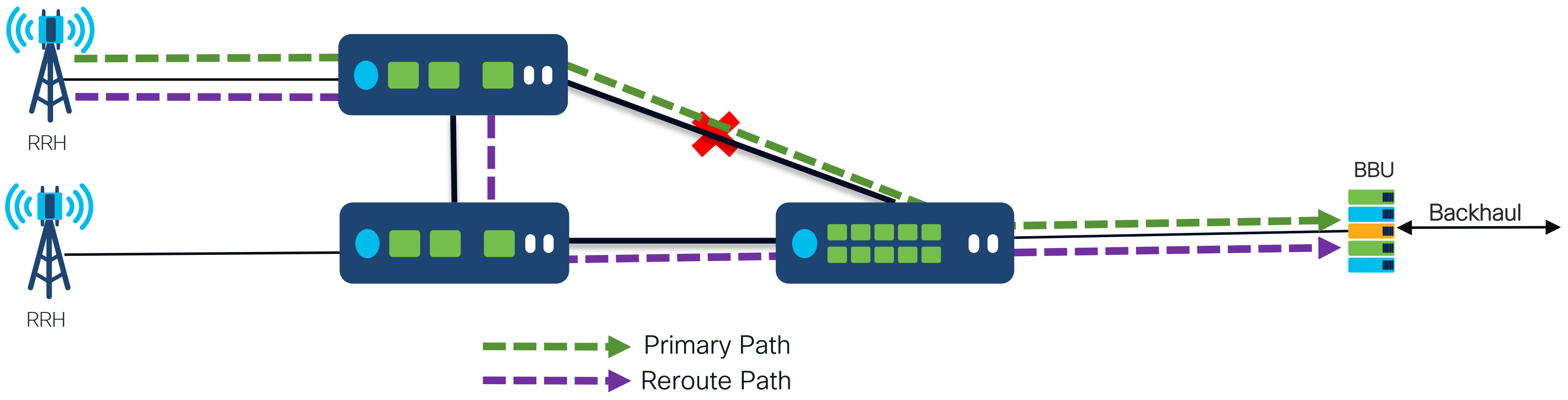
- CPRI to eCPRI conversion (Time domain to Frequency Domain)
- 4G radio to connect to Split 7 vDU
- Low PHY function in fronthaul router FPGA
- RAN vendor partnership required

RAN Programmability



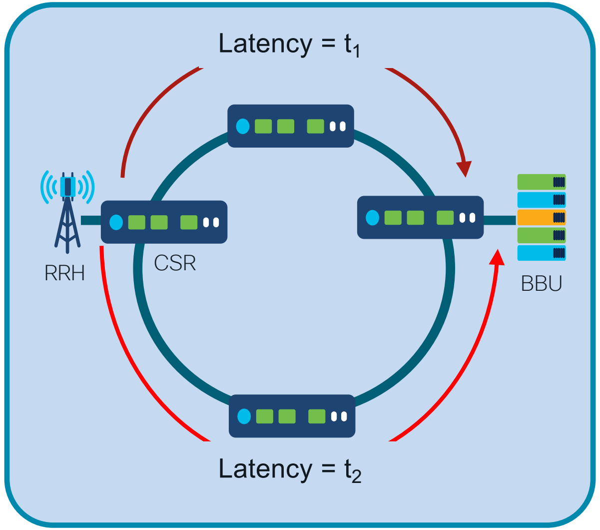
- Passive DWDM topology is static, failure of a baseband unit requires a site visit to recover the cell
- Using NSO customer can dynamically reconfigure a redundant BBU at the hotel site and rehome the VPWS to recover cell if primary BBU fails
- N+1 BBU deployed at BBH site, with only management config (IP, credentials etc.)
- NSO models and syncs the config of all the baseband units
- In the event of BBU failure, NSO will push failed BBU config at N+1 BBU and migrate VPWS to N+1 BBU

Ring/Partial Ring CRAN topologies



- Enable redundant routed path for fronthaul sites for TI-LFA when Fronthaul link fails
- Use SR-TE + SR-PM to ensure latency constraint met over redundant path
- Enable Capacity management if insufficient fronthaul bandwidth to support both sites, option to disable a band (i.e., disable VPWS) at non-failed site to free up capacity for that same band at failed site

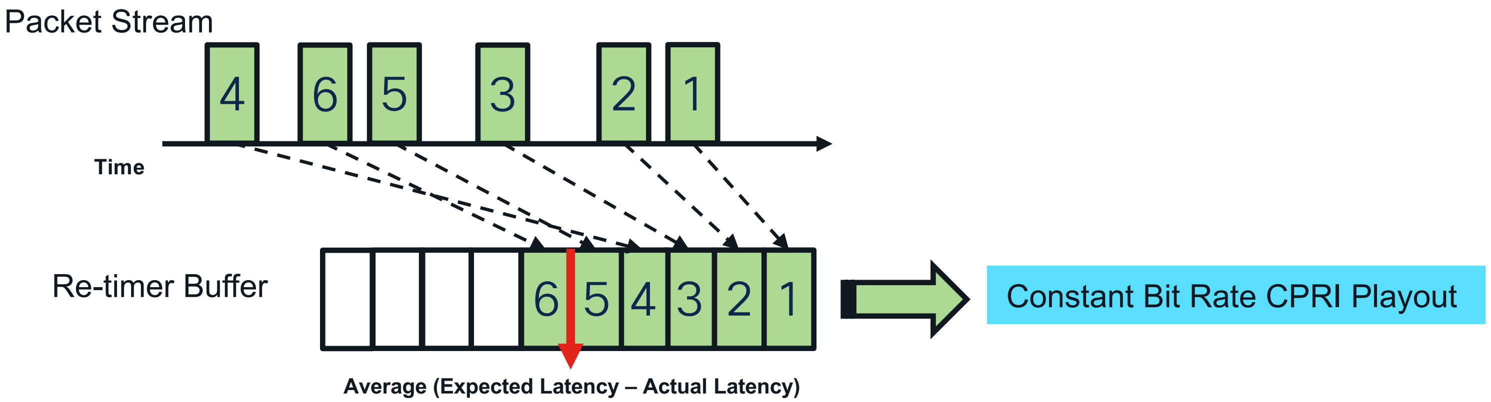
Transport redundancy



- Primary and backup paths might have different transport latencies
- During a failure there will be traffic outage up to 50ms
- Idle CPRI frames are sent during packet outage
- If backup path's latency within +/- 5usec of primary path's latency, CPRI stream can be gracefully restarted
- If the backup path's latency is outside that window, in this case the HFN/BFN order can not be maintained and CPRI reset needs to be asserted
- CPRI will undergo reset and re-establish with updated parameters.

Retimer Buffer

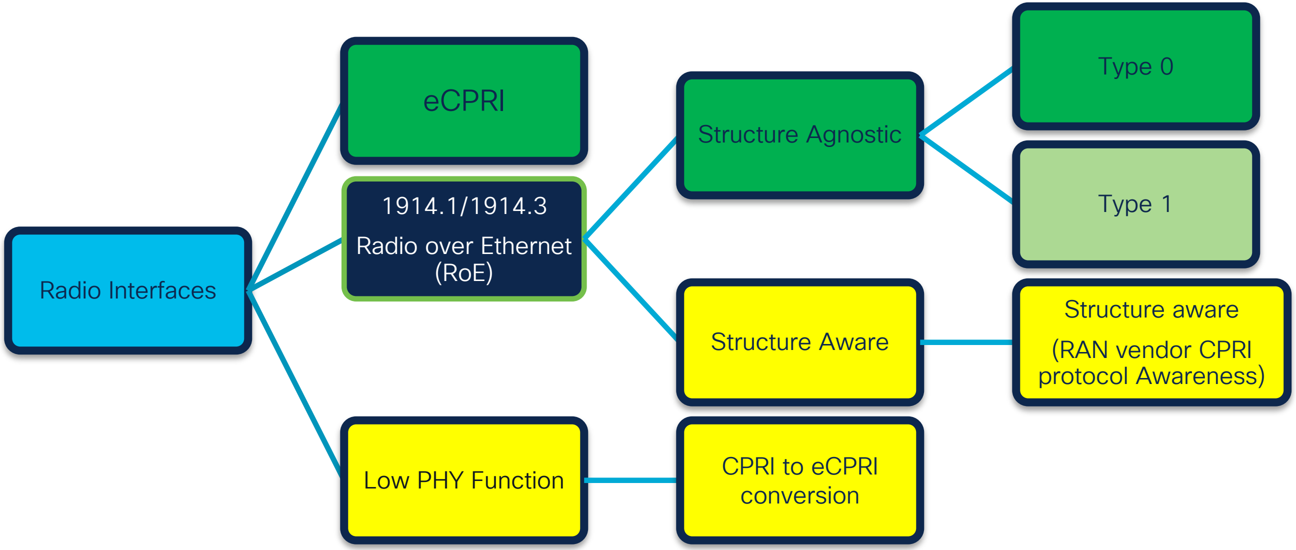
- RoE to CPRI demapper in Cisco fronthaul router has re-timer buffer to cleanup jitter and reordering in the packet transport network



Frontthaul Technologies Support Summary

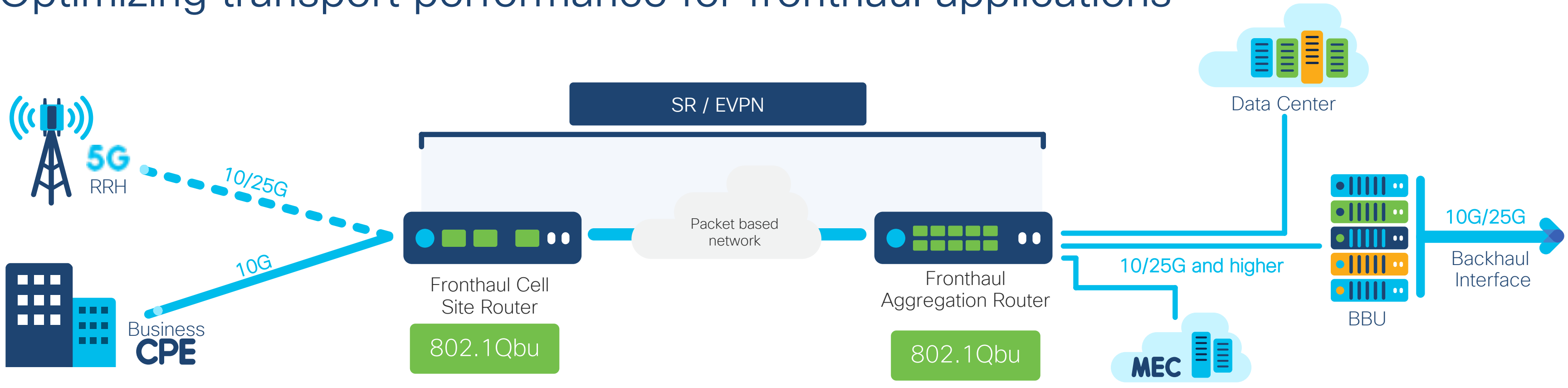
Supported in hardware (FPGA) and Software

Hardware (FPGA) capable of functionality, FPGA firmware & software are in roadmap



Converged Services

Optimizing transport performance for fronthaul applications



- **Converge services** onto a single transport network.
- **Segment Routing** provides traffic steering and policing capabilities to optimize traffic path based on static and/or dynamic computations including latency.
- **Frame preemption** with **802.1Qbu/TSN** assures that Fronthaul and Midhaul traffic can be prioritized over less latency sensitive flows.

Time Sensitive Networking 802.1CM

Ethernet for Fronthaul

- **Profile A**: Strict priority queuing (no frame pre-emption)
  - IQ data traffic belongs to strict priority traffic class - strict priority algorithm
  - C&M data assigned to lower priority than IQ data

- **Profile B**: 802.1Qbu Frame Pre-emption
  - Strict Priority Queuing + Frame Pre-emption
  - IQ data traffic configured (*frame pre-emption status)* as "*express*"
  - C&M data assigned to lower priority than IQ data and set "*pre-emptable*"
  - Frame Preemption up to 25G links

802.1Qbu (TSN)

- Converged platform will have mix of fronthaul and enterprise traffic towards NNI.
  - FH radio traffic can get behind jumbo-packets of enterprise flows (9600 bytes) leading to additional latency
- 802.1Qbu should only be supported on uplink interfaces only and will be supported on 10G/25G interfaces
- Strict Priority + Preemption Offers lowest fronthaul latency and greatest BW utilization
- 802.1Qbu is NOT required on 100G interface
- Frame Preemption is a book-ended solution
- Requires hardware implementation

Port Rate	Without Frame Preemption delay (1500 bytes delay)	Without Frame Preemption delay (9600 bytes delay)	With Frame Preemption (123 bytes delay)	Frame Preemption Advantage (compared to 9600 bytes delay)
1G	12,000 nsec	76,800 nsec	984 nsec	~ 75 usec
10G	1,200 nsec	7,680 nsec	98.4 nsec	~ 7.5 usec
25G	480 nsec	3,072 nsec	39.36 nsec	~3 usec
100G	120 nsec	768 nsec	9.84 nsec	758 nsec

Supported Features (Partial List)

- RoE Structure-Agnostic Tunneling Mode (Type 0)
- RoE Structure-Agnostic Line Code Aware Mode (Type 1)
- TSN 802.1Qbu 10/25G
- Class C Clocking
- SR MPLS/SRv6
- BGP VPN (EVPN/L3VPN)
- Clocking – Class C, G.8275.1
- GTP load balancing
- Y1564 (Service Activation)
- Zero Touch Provisioning
- Microwave Adaptive Bandwidth - "Ethernet bandwidth notification (ETH-BN) / G.8013 Bandwidth Notification Messages"
- Telemetry

Fronthaul Design

CPRI / eCPRI Bandwidth Calculation Factors

- CPRI
  - "Number of antennas" has an impact on the bit rate for split E (Split 8)
- eCPRI (Split 7)
  - Factors that will have an impact on the final needed bit rate of the link between eREC and eRE.
    - Throughput (closely related to the available and used air bandwidth)
    - Number of MIMO-layers
    - MU-MIMO support (y/n)
    - Code rate
    - Modulation scheme
    - Beamforming algorithm
    - Number of antennas

Fronthaul/Midhaul/Backhaul Transport Bandwidth Calculation

LTE CPRI							
Carrier (Band Number)	Number of Sectors	Band	Sub Carrier Spacing (SCS) Numerology	Bandwidth [MHz]	CPRI Option	MIMO (Number of Antennas)	CPRI Mux (if any) CPRI mux configuration details
			15kHz				

- For CPRI fronthaul bandwidth calculation, there is no stat-mux in fronthul since CPRI is TDM traffic.
  - This means if there is CPRI option 7 between REC and RE
    - Packet based fronthaul must support “10G+RoE overhead” bandwidth to carry CPRI option 7 traffic
- Midhaul & backhaul calculation will take into account stat-mux

4G/5G eCPRI/ORAN								
Carrier (Band Number)	Number of Sectors	4G/5G	Band	Sub Carrier Spacing (SCS) Numerology	Bandwidth [MHz]	MIMO Layers	MIMO (Number of Antennas/Antenna Elements in case of Massive MIMO)	Radio Unit Interface Bandwidth
				15kHz or 30kHz (< 6 GHz) 120kHz or 240kHz (> 24 GHz)				

- eCPRI supports stat-mux
  - Stat-mux fronthaul calculation in case of three sectors, 1 Peak + 2 Average (50% of peak)
- Midhaul & backhaul calculation will take into account stat-mux

Fronthaul/Midhaul/Backhaul Calculation

Single Cell Site/3 Sector 6 Carriers

PRB=Physical Resource Block
Statistical Multiplexing (Statmux)=1Max+2 Average

Band Number	Band	Bandwidth [MHz]	MIMO/MIMO Layers	Fronthaul Data Rate (Single Sector Peak) CPRI/ORAN Gbps	FH Data Rate ("3" Sectors) CPRI/ORAN Gbps	Midhaul Gbps	Backhaul Gbps
5	850 MHz	10	4T4R	2.45 (CPRI option 3)/0.70	7.35/1.40	0.30	0.25
8	900 MHz	10	4T4R	2.45 (CPRI option 3)/0.70	7.35/1.40	0.30	0.25
9	1.8GHz	20	4T4R	4.9 (CPRI option 5)/1.40	14.7/2.80	0.59	0.50
41	2.6GHz	20	4T4R	9.8 (CPRI option 7)/1.40	29.4/2.80	0.59	0.50
n78	3.5GHz	100	64T64R/8 layers	15.29	30.59	4.44	3.78
n257 (Split 2)	28GHz	400	128T128R/4 layers		NA	6.14	5.22
Total					**FH=LTE CPRI+NR=89.39 Gbps** **N+NR=39**	**12.36 Gbps**	**10.5 Gbps**

Fronthaul Interface Required=100G/50G
Midhaul Interface Required=25G
Backhaul Interface Required=25G

Maximum transmission bandwidth configuration 38.101 FR1 : below 6 GHz

Sub Carrier Spacing (SCS) Numerology

Channel bandwidth PRB Values

μ	SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
0		25	52	79	106	133	160	216	270					
BW [MHz]	15	4.5	9.4	14.2	19.1	23.9	28.8	38.9	48.6	N/A	N/A	N/A	N/A	N/A
GB [KHz]		242.5	312.5	382.5	452.5	522.5	592.5	552.5	692.5					
1		11	24	38	51	65	78	106	133	162	189	217	245	273
BW [MHz]	30	4	8.6	13.7	18.4	23.4	28.1	38.2	47.9	58.3	68	78.1	88.2	98.3
GB [KHz]		505	665	645	805	785	945	905	1045	825	965	925	885	845
2			11	18	24	31	38	51	65	79	93	107	121	135
BW [MHz]	60	N/A	7.9	13	17.3	22.3	27.4	36.7	46.8	56.9	67	77	87.1	97.2
GB [KHz]			1010	990	1330	1310	1290	1610	1570	1530	1490	1450	1410	1370

N_{RB} max, BW = channel bandwidth, GB = minimum guardband

Source:https://www.sqimway.com/store_nr.php

Maximum transmission bandwidth configuration 38.101 FR2 : above 24 GHz

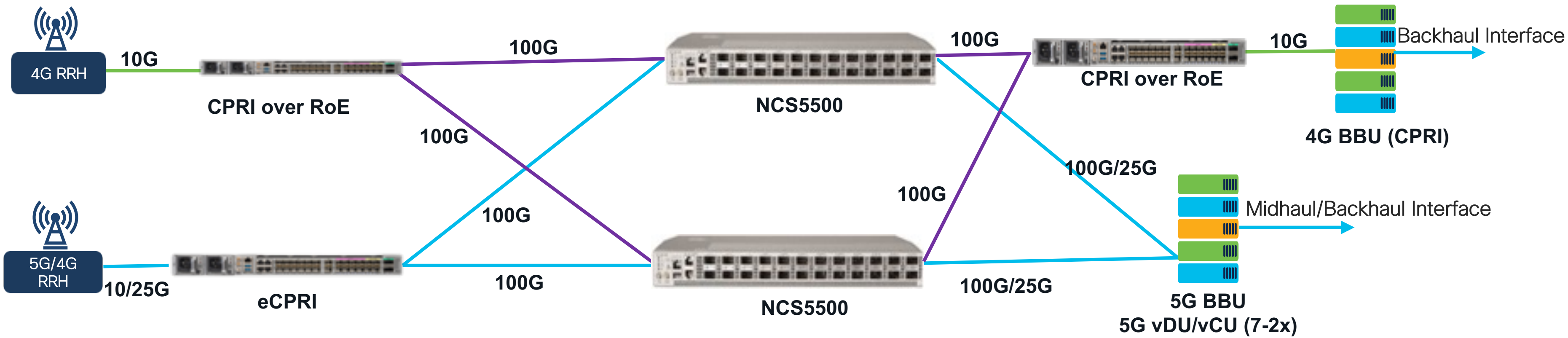
Channel bandwidth PRB Values

μ	SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
2	60	66	132	264	N/A
BW [MHz]		47.5	95	190.1	
GB [KHz]		1210	2450	4930	
3	120	32	66	132	264
BW [MHz]		46.1	95	190.1	380.2
GB [KHz]		1900	2420	4900	9860

N_{RB} max, BW = channel bandwidth, GB = minimum guardband

Source:https://www.sqimway.com/store_nr.php

Frontaul Network Design Options



Fronthaul Fabric Design

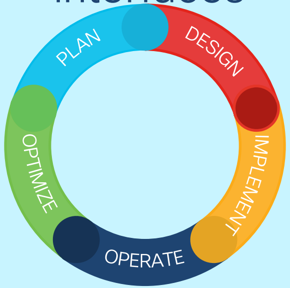
Open & Automated Management

Outcome-driven automation

Flexible NSO function packs

To automate provisioning of multi-vendor domains

Open APIs and management interfaces



To enable full operational lifecycle of the products

Cisco Crosswork Portfolio

Cisco Crosswork

Crosswork Cloud

To provide full suite of FCAPs applications

Closed-loop and outcome-driven automation, on premises and in the cloud.
Simple integration into legacy RAN management domains & other NMS/OSS systems