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5G xHaul Transport

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BRKSPM-2012

Barcelona | January 27-31, 2020

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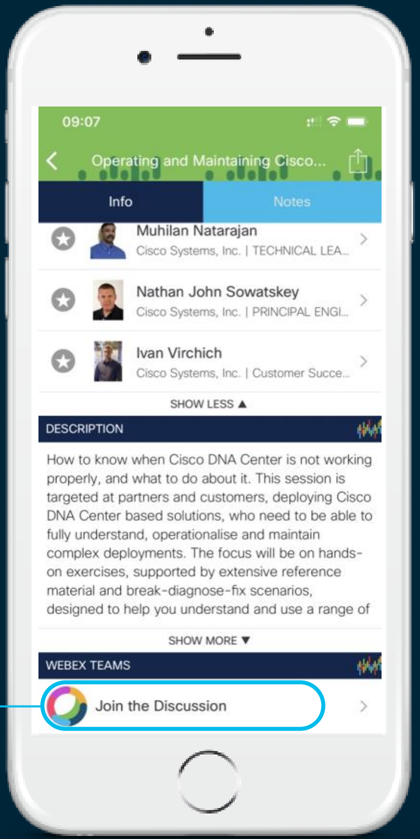


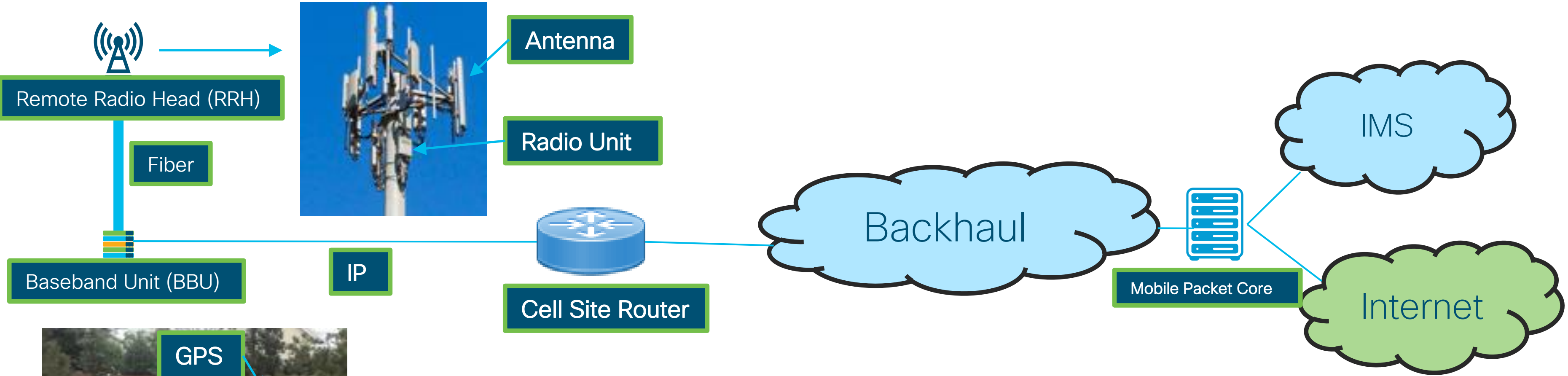
Agenda

- Introduction
- 5G xHaul Transport Requirement
- Cisco 5G xHaul Transport Strategy & Solution
- Customer case studies
- Helpful Links

Glossary

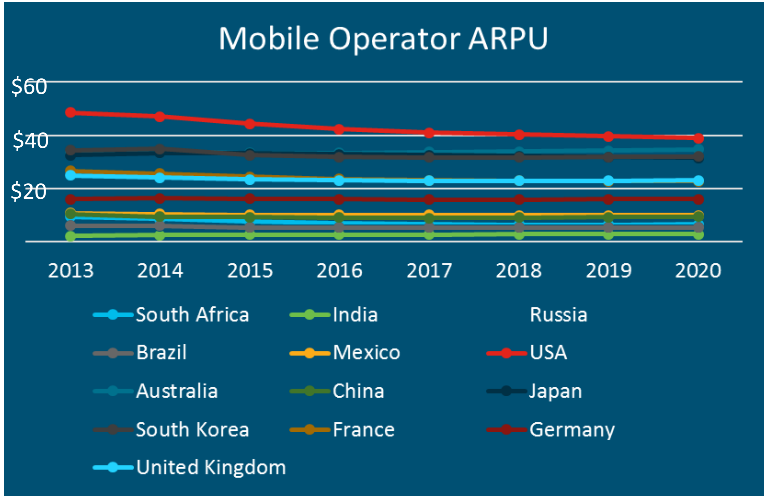
- UE (User Equipment)
- RU (Radio Unit) RAN (Radio Access Network)
- BBU (Baseband Unit)
- EPC (Evolved Packet Core)
- CSR (Cell Site Router)
- C-RAN (Centralized RAN)
- Remote Radio Head (RRH)
- TRxP (Transmit Receive Point)
- vEPC (Virtual EPC)
- CU-CP (Centralized RAN Control Plane)
- CU-UP (Centralized Unit User Plane)
- SR (Segment Routing)
- MEC (Multi-access Edge Compute)
- xHaul (Backhaul + Midhaul + Sidehaul + Fronthaul)
- FH Agg (Fronthaul Aggregation Router)
- FH Access (Fronthaul Access Router)
- D-RAN (Distributed RAN)
- mmW (>24GHz)
- Sub 6Hz (Below 6GHz e.g. 600 MHz, 3.5GHz)

Mobile Network Fundamentals



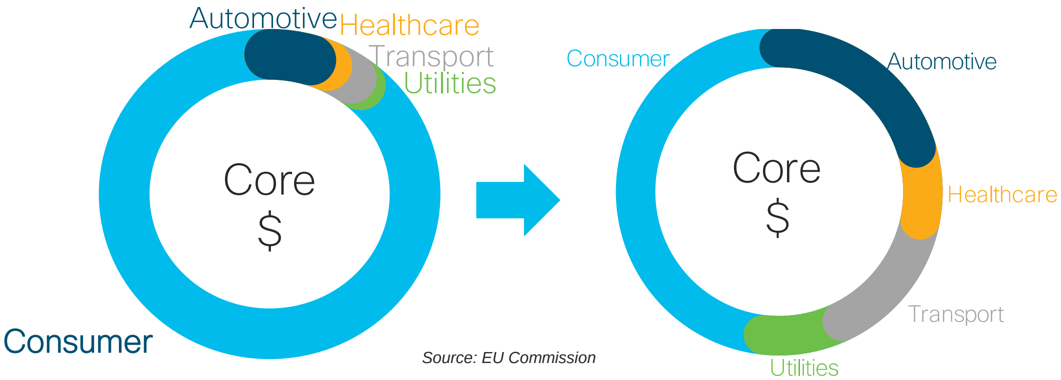
RRH+BBU=eNodeB (LTE) or gNodeB (5G)

Business Landscape



Source: Informa ARPU, March 2017

- Overall mobile ARPUs have been flat or declining:
  - Pressure to drive greatest efficiency in delivering 5G
  - Pressure to expand beyond consumer services



Source: EU Commission

Today
Mobile Video (55%, 75%)
Video drives traffic…
but NOT revenue

2025
Vertically targeted services will accelerate operator business growth

LTE to 5G

Emergence of **Low Latency** Need for immersive experience and to enable New Applications

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5G CSP Service Examples

Secure Remote Car Software Update

10 - 100M lines of code and hundreds of subsystems

Vehicle updates, telematics, and infotainment

CSP hosted Network Slicing for Public Sector Private Networks

Police, fire, hospitals with strict SLAs and Security

Private 5G Network Customized Enterprise Mobile Networks

Mining, factory with private policies

Augmented / Virtual Reality Delivery

Augmented, virtual, and mixed reality for learning, gaming, 4K/8K

Video enablement required

Timeline to 5G @ Scale

New use-cases

Evolved use-cases

Existing use-cases

2017	2018	2019	2020	2021	2022

5G PoCs & Field Trials

5G Trials End-to-end (w/ 5G core)

City-level 5G

Commercial @Scale

Densification & National Coverage

3GPP R15
5G NR NSA anchored on enhanced LTE/EPC

3GPP R15 (con'd)
Final 5G NR SA (inc. FWA)
5G Core Network

3GPP R16
Fixed Mobile Convergence

EURO2020

TOKYO 2020

3GPP
A GLOBAL INITIATIVE

cisco Live!

5G xHaul Transport Requirement

5G - Key Use Case Categories

Enhanced Mobile Broadband (inc. Fixed Wireless Access) → Increased bandwidth and capacity

- Extra capacity delivered through new 5G frequency bands
- Not too concerned with connection density or latency

Massive Machine-type Communication → Scale, Reliability

- Focused on low power wide area NB-IoT with high connection density and energy efficiency

Ultra-reliable, Low Latency Communication → Push data plane to the edge, intelligence in network

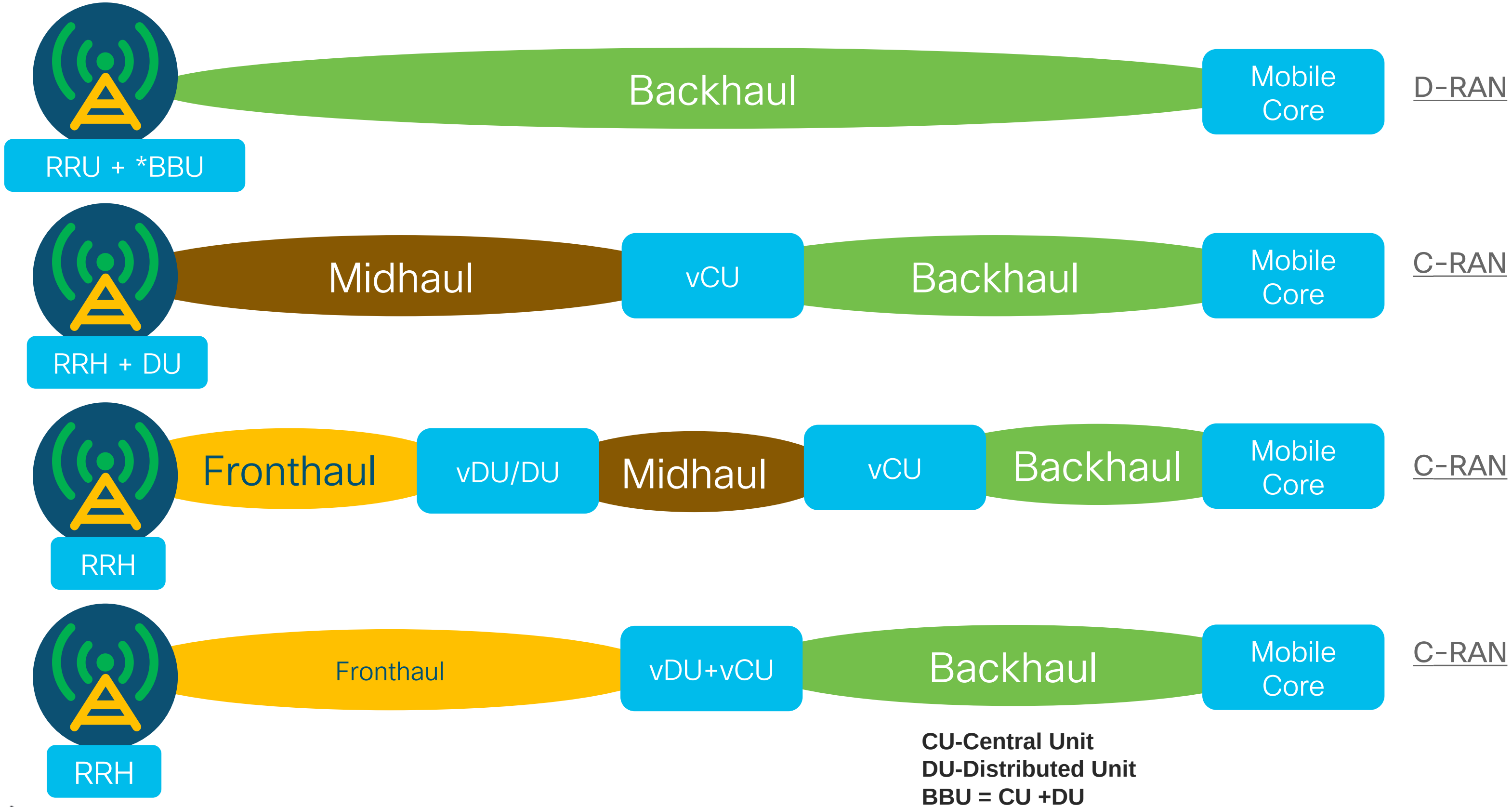
- For mission critical use cases (self driving, Public safety, ...)
- 1-25 msec latency

Source: Recommendation ITU-R M.2083

Emerging - Low Latency → Push data plane to the edge, Intelligence in Network

- Low latency applications, entertainment

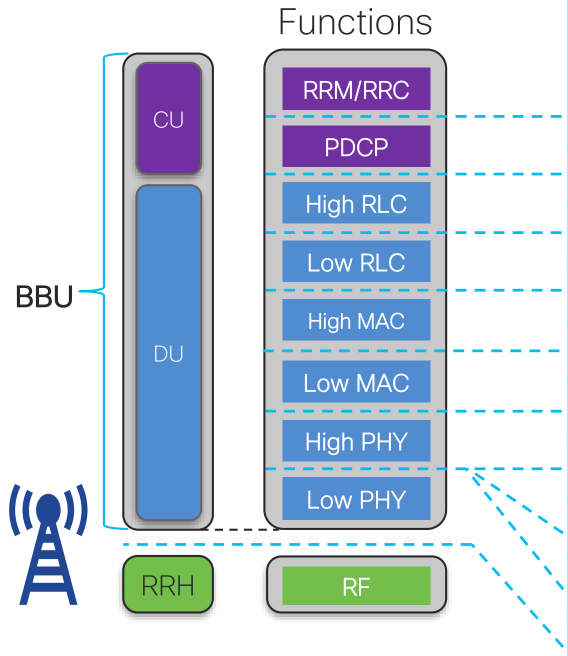
5G RAN Transport



CU-Central Unit
DU-Distributed Unit
BBU = CU +DU
RRH-Remote Radio Head

RAN Functional Split Consideration

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



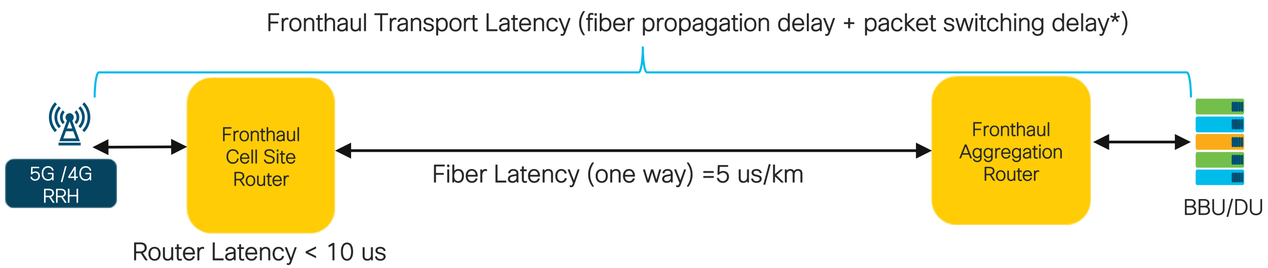
Split Option	Required Bandwidth		Max allowed 1-way Latency	Fronthaul Interfaces
	DL	UL		
Option 1	4Gbps	3Gbps	10ms	
Option 2	4016Mbps	3024Mbps	1ms~5ms	F1 (3GPP)
Option 3	Lower than option 2 for UL/DL		1.5ms~10ms	
Option 4	4000Mbps	3000Mbps	Approx. 100us	
Option 5	4000Mbps	3000Mbps	100's us	
Option 6	4133Mbps	5640Mbps	250us	
Option 7a	10.1~22.2Gbps	16.6~21.6Gbps	250us	eCPRI ORAN ROE
Option 7b	37.8~86.1Gbps	53.8~86.1Gbps	250us	
Option 7c	10.1~22.2Gbps	53.8~86.1Gbps	250us	
Option 8	157.3Gbps	157.3Gbps	250us	CPRI

Transport costs minimized with higher splits

RF Gains improved with lower splits

Note: * Transmission link Requirements per TR 38.801 (100MHz, 256QAM,m 8x8 MIMO)

Transport Network Latency



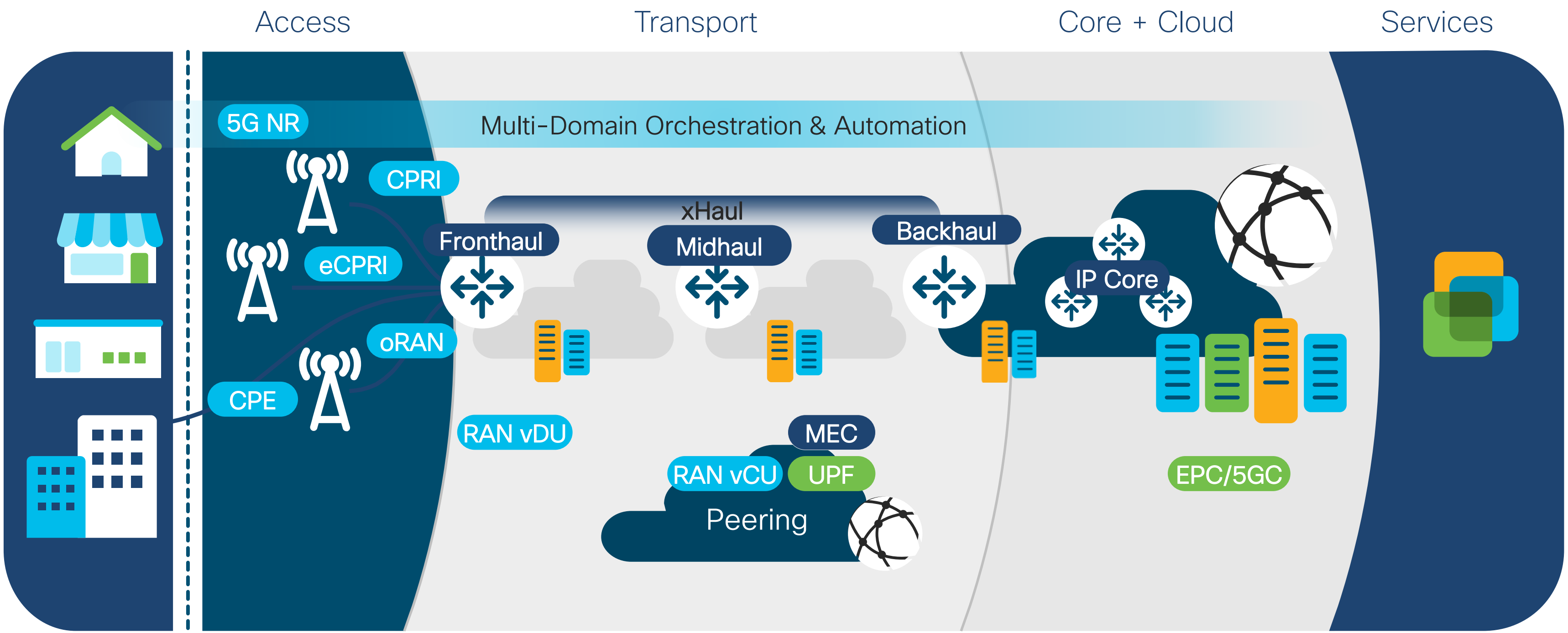
Network	Split Options	Transport Latency One Way	Bandwidth
Backhaul (S1 / Nx)	None	Service Dependent	~User bandwidth
Midhaul (F1)	Option 2: PDCP-RLC	1- 5 milliseconds	~User bandwidth
Fronthaul	Option 8	75us/100 us (LTE)	Very High
Fronthaul	Option 7: PHY Hi- PHY Lo	150us (5G NR uRLLC)	High
Fronthaul	Option 7: PHY Hi- PHY Lo	500 us (5G NR eMBB)	High

Source OCP Telcos Project: AT&T Fronthaul Gateway (FHG) requirements and Use Cases Revision 1

- Fronthaul uRLLC Round trip (RRT) must not exceed **125 microseconds** (62.5 microseconds one way)
  - The maximum fiber distance between the RRU and BBU is 10km
  - This delay budget requirement applies to both CPRI and eCPRI traffic.

*The processing performed by the BBU (DU) or RRH is not included

5G Network Evolution



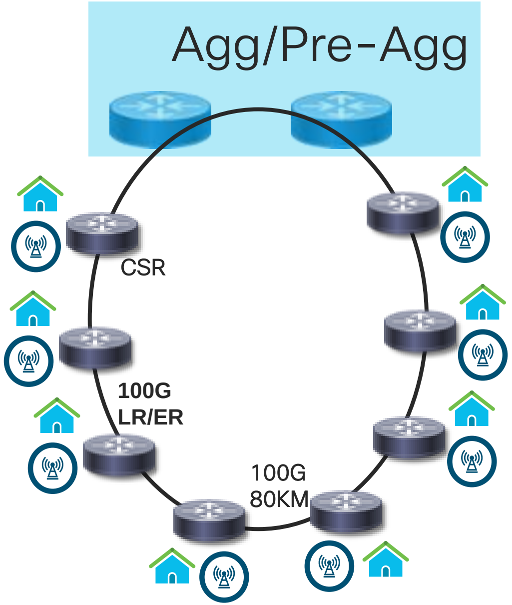
Fronthaul/Midhaul/Backhaul Calculation

Single Cell Site/3 Sector 6 Carriers

Band Number	Band	Bandwidth [MHz]	PRB	MIMO/MIMO Layers	Fronthaul Data Rate [Gbps] per Sector	FH Data Rate 3 sectors [Gbps]	FH Data Rate With Compression (CPRI to eCPRI) Gbps	Midhaul/Backhaul
5	850 MHz	10	52	4T4R	2.45 CPRI option 3	7.35	1.8 Gbps [150 Mbpsx4 (Antennas) x3 sectors]	330 Mbps (110x3) 220 Mbps (statmux)
8	900 MHz	10	52	4T4R	2.45 CPRI option 3	7.35	1.8 Gbps [150 Mbpsx4 (Antennas) x3 sectors]	330 Mbps (110x3) 220 Mbps (statmux)
9	1.8GHz	20	106	4T4R	4.9 CPRI option 5	14.7	3.6 Gbps [300x4 (Antennas) x3 sectors]	660 Mbps (220x3) 440 Mbps (statmux)
41	2.6GHz	20	106	4T4R	4.9 CPRI option 5	14.7	3.6 Gbps [300x4 (Antennas) x3 sectors]	660 Mbps (220x3) 440 Mbps (statmux)
n78	3.5GHz	100	273	64T64R/8 layers	19.29	57.87 38.58 (statmux)	38.58	13.5 Gbps (4.5x3) 9 Gbps (statmux)
n257	28GHz	400	264	64T64R/4 layers	27.44			19.5 Gbps (6.5x3) 13 Gbps
						102 Gbps 83 Gbps (statmux)	49 Gbps	34.3 Gbps 23.3 (statmux)

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

Dimensioning Converged Transport



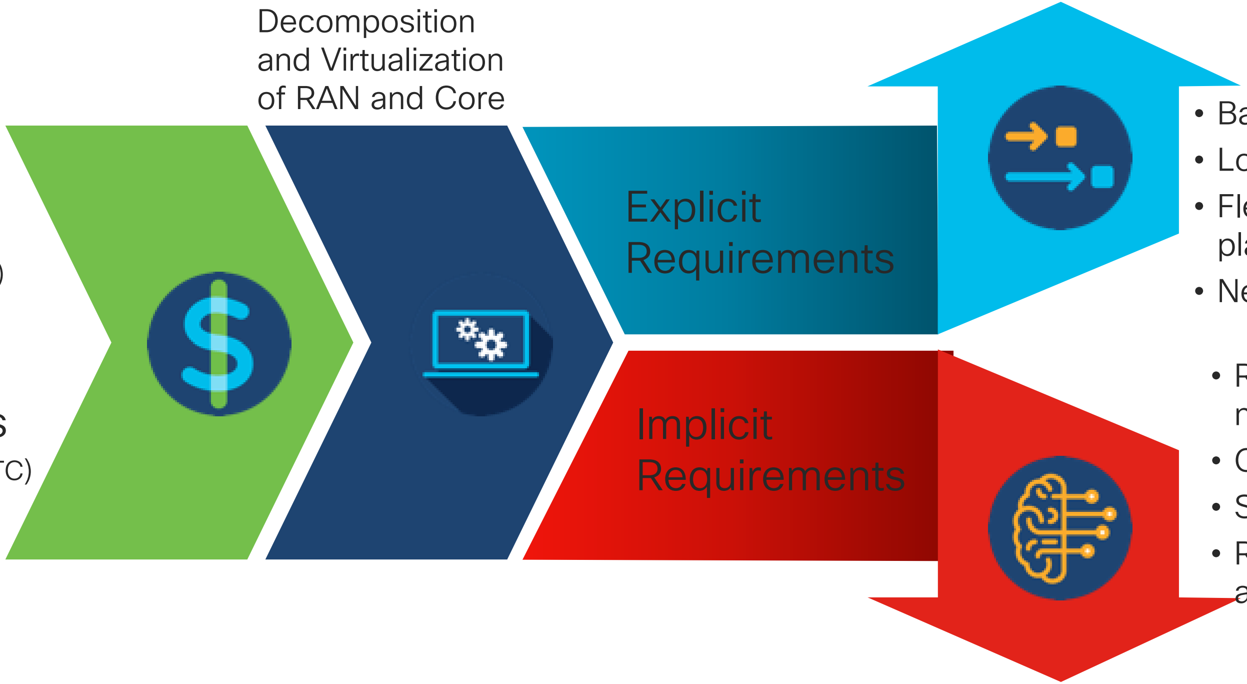
Ring Architecture

- 8 Nodes in a ring
- Per CSR node bandwidth Requirement=20Gbps
  - LTEA+5G = 8 – 9 Gbps
  - Consumer Broadband + Enterprise = 10Gbps
- 20 x 8 (CSR) = 160 Gbps
- Required Ring = I-Temp 100G LR/ER uplink
- 80 KM = I-Temp 100G/200G DCO optics

What’s Different in 5G Transport?

5G RAN
(Sub-6Ghz, mmW)
+
5G Services
(eMBB, URLLC, mMTC)

Decomposition
and Virtualization
of RAN and Core

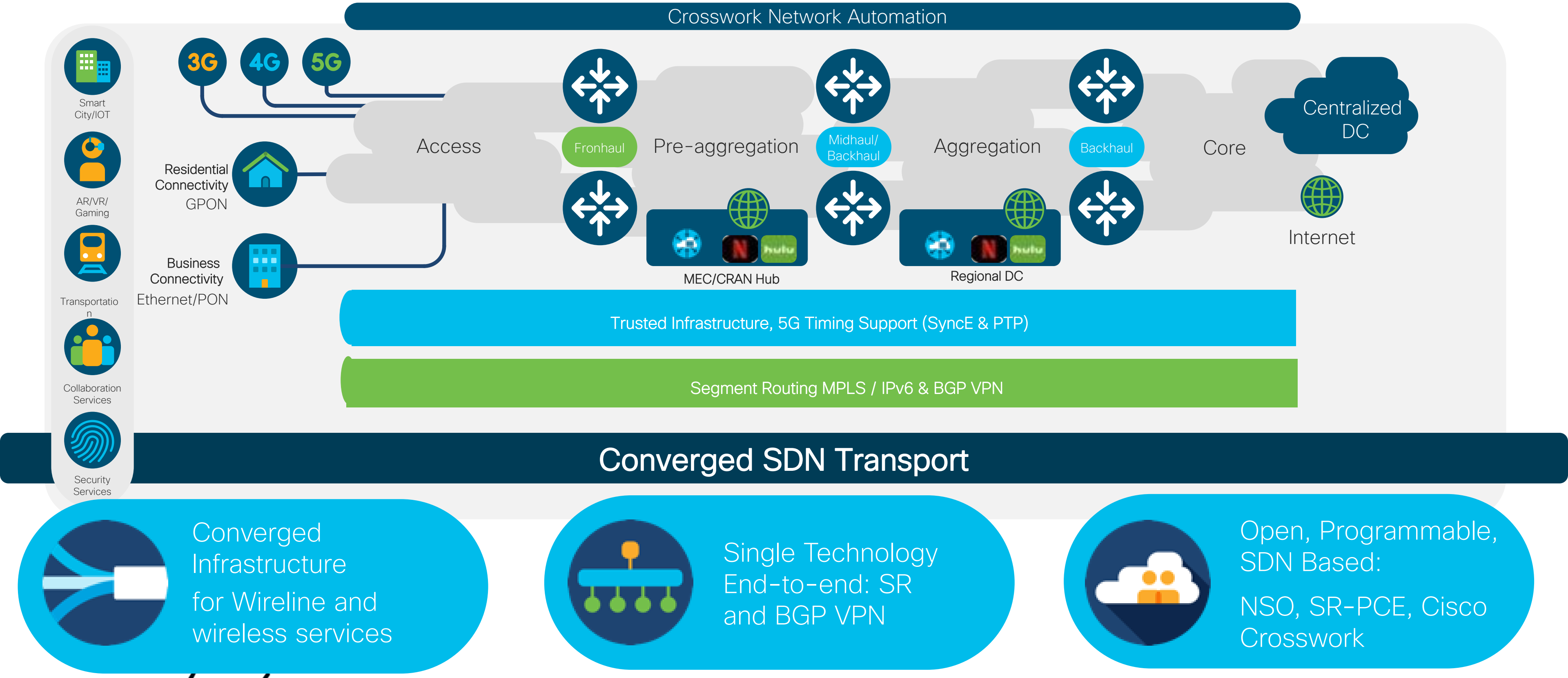


- Bandwidth and scale
- Low latency
- Flexible service placement
- Network slicing

- Re-architect the network (MEC)
- Operational efficiency
- Simplification
- Reliability and awareness

Cisco 5G xHaul Transport Strategy & Solution

Cisco Transport Strategy



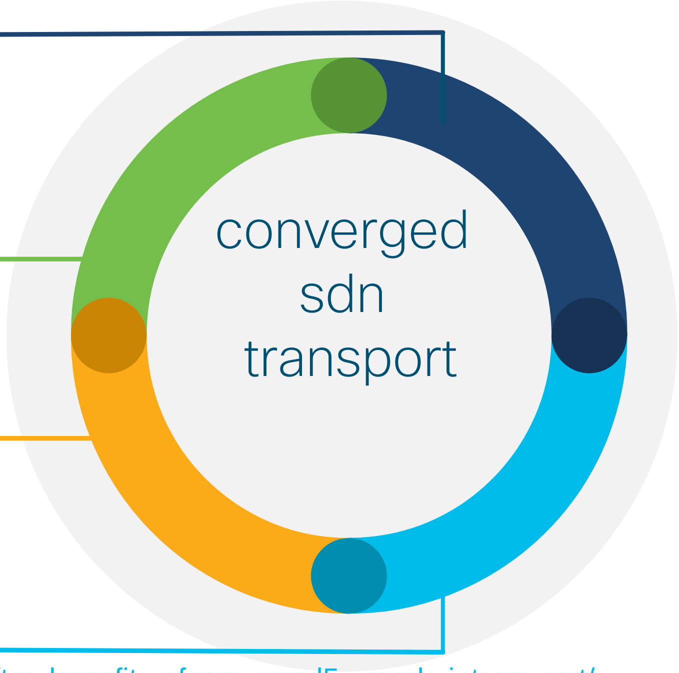
IP Transport Foundations “Done Right”

high-performance, 5G-ready portfolio

trusted infrastructure

cross domain automation

software-driven simplification



Lowering TCO by 62%

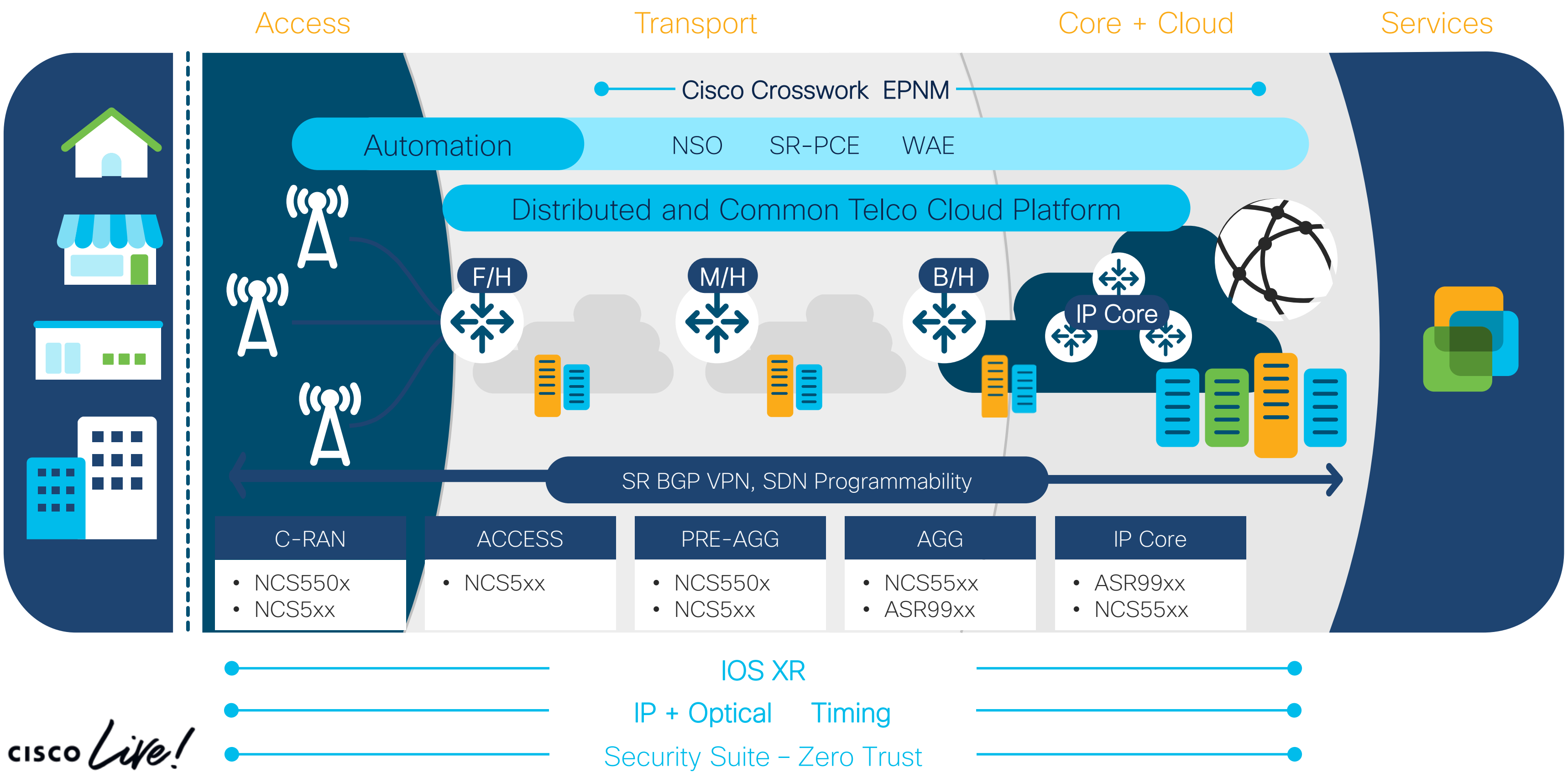
60% improved capital efficiency

66% better OPEX utilization

81% faster time-to-service

ACG Research https://www.acgcc.com/tco-benefits-ofconverged5g-ready-iptransport/

Converged SDN Transport Solution



Forwarding Plane Evolution

Complete

Unified MPLS

No Service stitching required: Reduce Touch Points, Build once-Use Many

End-to-End BGP Label Unicast

Fast Convergence: Remote LFA & BGP PIC

Services
- BGP
- T-LDP

Transport
- BGP-LU
- RSVP-TE
- MPLS LDP
- IGP
- IP/MPLS

In Progress

MPLS SR with Controller

MPLS SR: optimised and simplified routing

Centralised management and orchestration

Distributed control plane

Services
- BGP
- Overlay

Transport
- T-LDP
- IGP/SR
- IP/MPLS

SDN

Evolution

SRv6

Further simplification and scaling

NFV

Centralised management and orchestration

Services
- BGP
- Overlay

Transport
- IGP
- IPv6/SR

SDN

SRv6

Network Simplification **Network Programming** **Hyperscale: Simplicity beyond 500K nodes (Prefix Aggregation)**

Network Availability

Protect with automatic TI LFA FRR
Stabilize with microloop avoidance
Operate with Advanced Monitoring and blackhole detection
Plan with SR traffic matrix
SR Performance Management

New Revenue Streams

Path Disjointness
Real-Time Low Latency Services
Bandwidth Optimization
Egress Peer Engineering (EPE)
Point-to-Multipoint with Tree-SID

Intent-Based Traffic Engineering

IGP Flex-Algo
On-Demand Next-Hop (ODN) + Automated steering (AS)
Multi-Domain intent with SR-PCE
Intent-Based Per-Flow Automated Steering
Multi-plane Network Slicing using IGP Flex Algorithms

Flexible & Smooth Transition for Brownfield

From
Any Legacy
Technology

To
SR-MPLS

To
SRv6
(future)

Smooth Migration

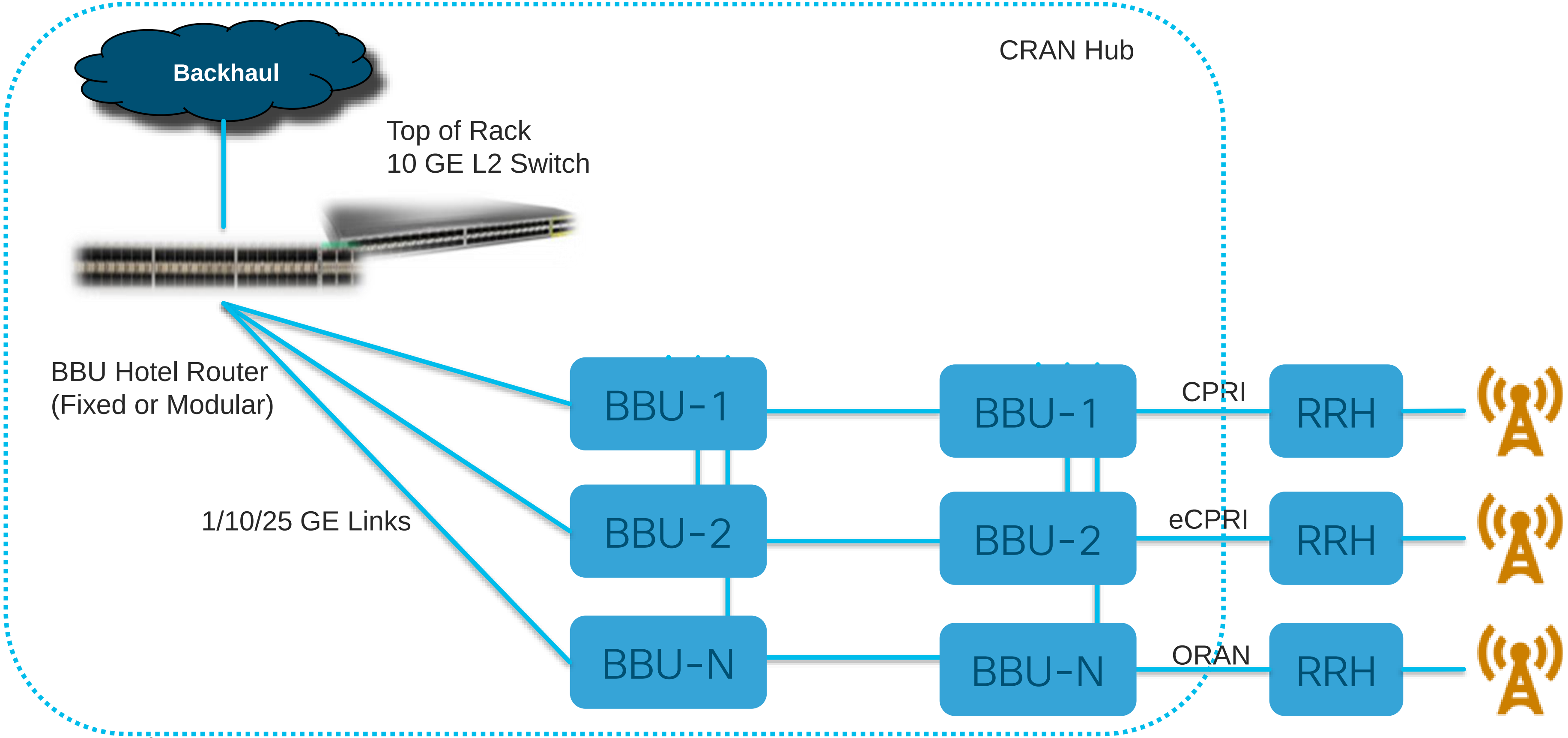
- SR interoperates, co-exists with LDP
- SR Multi-vendor
- NSO can facilitate the migration from legacy technologies

CRAN

Why Centralized or Cloud RAN (C-RAN)?

Benefits	
Spectral Efficiency Gains Benefits	**Operational Simplicity Benefits (CAPEX/OPEX)**
ERAN capability is being introduced for enhanced user throughput experience due to activation of LTE Advanced features such as Carrier Aggregation (CA), Uplink Co-Ordinated Multi-Point (UL COMP)	Reduce power/space overheads – enable Skinny Macro Sites deployments (utility poles, rooftops) *[Consolidation of power distribution and battery backup systems, floor space, rack space, air conditioning at a common baseband hotel]*
Inter-site BBU Pooling (ERAN)	Ease of management (Reduce Cell site management by up to 60%)
	Cost reduction by reducing number of ports as compare to DRAN sites
	Improved efficient utilization of resources, vDU pooling
	Enhancing network resiliency & availability down to BBU (Dual homes, TX Path protection using L3 routing)

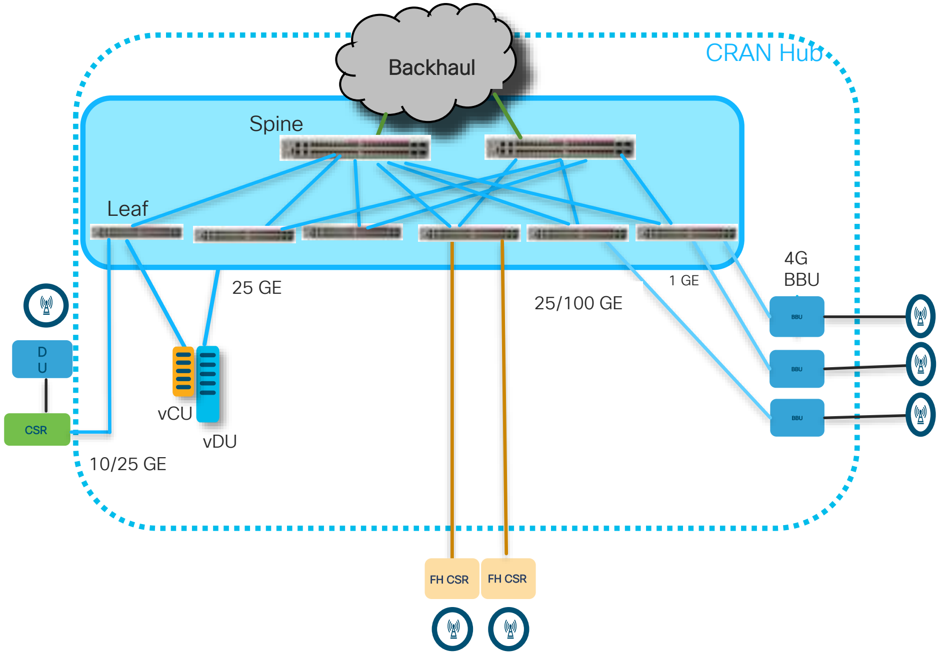
C-RAN Transport Architecture Components



C-RAN Transport Architecture Components

- Economically viable availability of fiber – Must Requirement
- Economically viable availability of BBU hotel Site Requirement – Must Requirement
- Strict transport latency requirement based on fronthaul specification
- Baseband Hotel Router depending on the size of BBU Hotel
  - Fixed
  - Modular
- Low latency L2 switch in case of Carrier Aggregation and COMP features
  - *Cisco Solution combines above two functionalities into single node – cost saving*
- 1588/SyncE – Phase & Frequency clocking support
- Interface Flexibility – 1/10/25G/100G
- Horizontal Scaling for large sites
- Redundancy

Scalable Cloud-RAN Fabric Architecture



Fabric allow for flexible deployment – Aggregation and Access

Network Scale

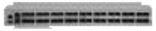
Horizontal Scalability

Interface Flexibility

Smaller Failure Domain

Traffic Patterns (east and west)

C-RAN Fabric Portfolio

Fixed Platform	Space (RU)	Capacity	Port Density	Timing 1588/Sync-E	FCS	
 NCS 5501 (SE)	1	**800 Gbps**	**Base: 48x 1/10G + 6x 100G** **Scale: 40x 1/10G + 4x 100G**	**Y**	**Shipping**	
 NCS-55A1-36H-SE	**1**	**3.6 Tbps**	**36 x QSFP28 or QSFP+**	**Y**	**Shipping**	
 NCS-55A1-24H	**1**	**1.8 Tbps**	**24 x QSFP28**	**Y**	**Shipping**	
 NCS55A1-48Q6H **NCS-55A1-24Q6H-S**	**1**	**1.8 Tbps** **900 G**	**48 x SFP28 + 6x100G QSFP28** 24x1G/10G ports, 24x1G/10G/25G ports & 6x100G	**Y**	**Shipping**	MEC - Edge Compute ToR
 NCS 540 (Tortin & Everglade	**1**	300 Gbps	24x 10GE SFP+ + 8x 25GE SFP28 + 2x 100GE QSFP28 **16x10G+4x1G Cu+8x25G+2x100G**	**Y**	**Shipping**	
 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**	**Shipping**	

Modular Platform

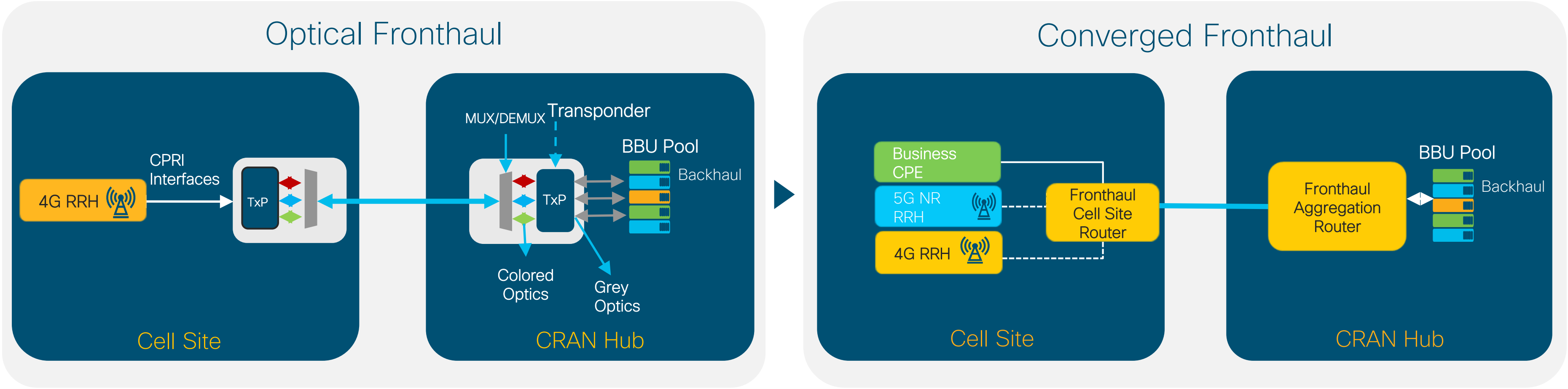
7 slot	800 Gbps	**Modular. 4 x 100G QSFP28, 40 x 10G SFP+, 96 x 1G CSFP**	**Y**	Shipping
4 slot	800 Gbps	**Modular. 4 x 100G QSFP28, 32 x 10G SFP+ or 72 x 1G CSFP**	**Y**	Shipping

Fronthaul

Limitations of WDM Fronthaul?

- Darks fiber – very expansive and difficult to scale
- Passive WDM
  - Limited to lambda scale
  - Lack of OAM and remote troubleshooting capabilities – increase OPEX
- Active WDM including WDM-PON
  - Expensive due to colored optics
  - Active tunable optics have challenge of meeting I-TEMP

Packet based Converged Fronthaul



Benefits

Convergence of 5G and 4G radio (CPRI/eCPRI/RoE)

New enterprise services using fronthaul network (TSN)

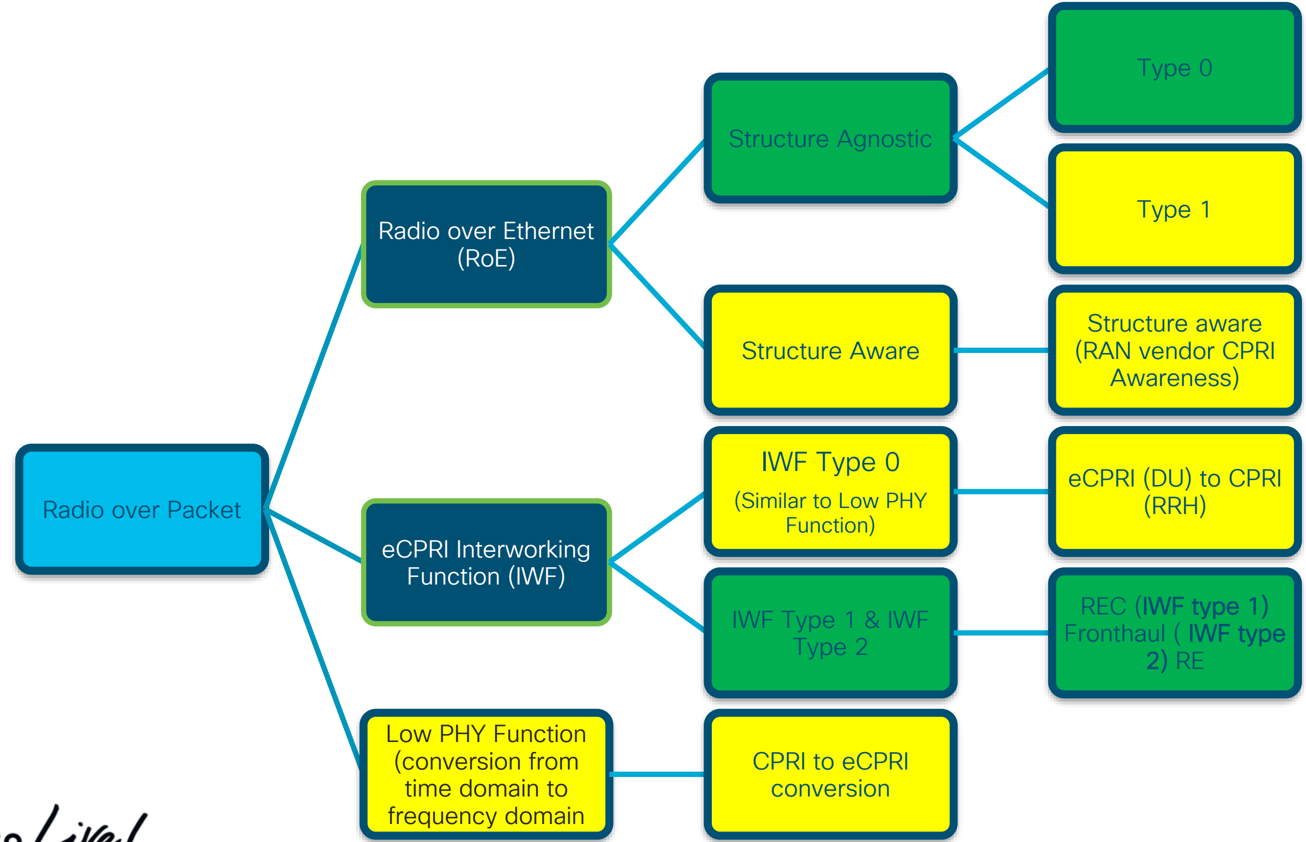
Supports point to point (p-2-p) and ring topology

Capex Savings
- 81% over roadm
- 59% over p-2-p active optical
- 11% over p-2-p passive optical

Packetized radio stat-mux that enables SPs to increase margins

Redundancy

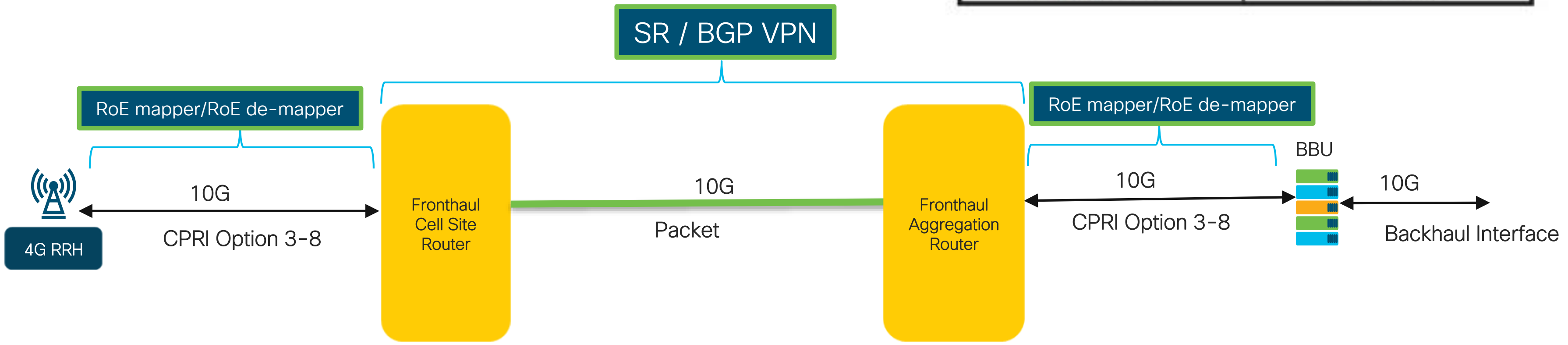
Radio over Packet Options



RoE: Type “0” & Type “1”

Table 1—RoE EtherType

Purpose	EtherType
RoE packet	0xFC3D



- Single Sector Carrier
- Each CPRI link needs to have 1:1 mapping between BBU and RRH
  - Example: 10G BBU to 10G RRH
- ❑ Bookended or paired configuration

802.1Qbu (TSN)

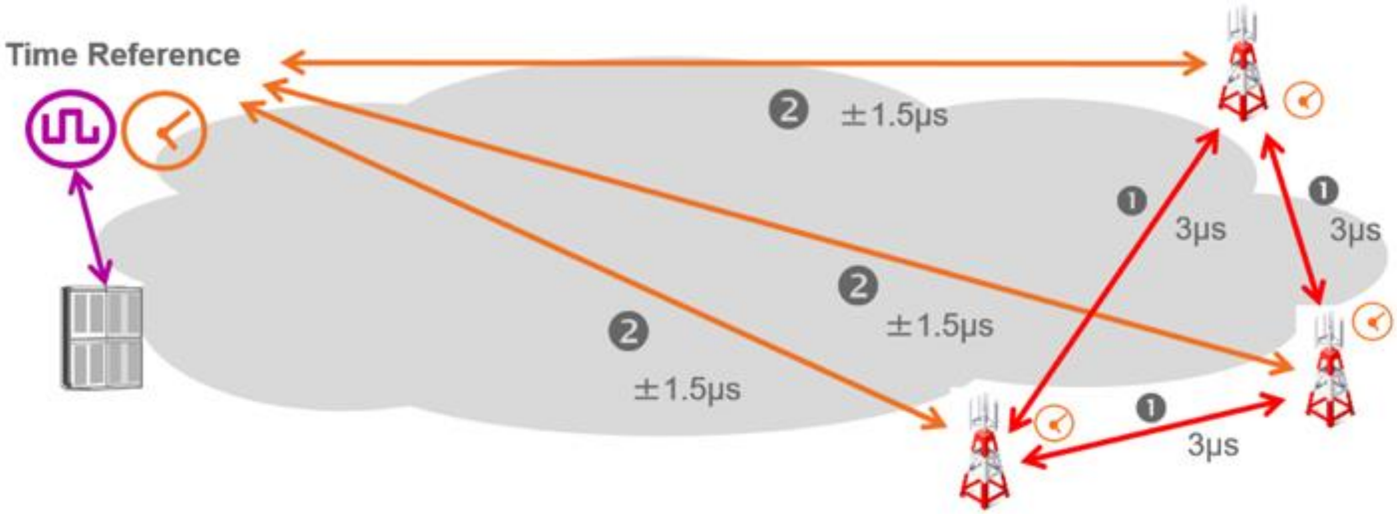
- Converged platform will have mix of fronthaul and enterprise traffic towards NNI.
  - FH radio traffic can get behind jumbo-packets of enterprise flows (9600 bytes) leading to additional latency
- 802.1Qbu should only be supported on uplink interfaces only and will be supported on 1G/10G/25G interfaces
- 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 byte delay)	Without Frame Preemption delay (9600 byte delay)	With Frame Preemption (123 byte delay)	Frame Preemption Advantage (compared to 9600 byte 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

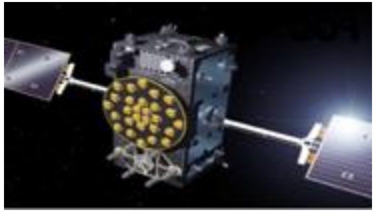
Timing and Synchronization

Timing and Synch – Phase Requirements

- 5G (like modern LTE-A networks) requires phase synchronization
- New 5G radios require:
  - ❶ 3GPP: 3μs between base stations (for TDD, LTE-A radio co-ordination)
  - ❷ Radio backhaul network: ±1.5μs from reference time



Phase Timing and Synch – Approaches



GNSS (GPS, Galileo) Receivers → Include GNSS receivers inside routers where appropriate

- Effective solution where site conditions allow (Sky view, $$)
- Susceptible to jamming (and increasingly spoofing)
- Time source for cell sites, PTP GM's and monitoring equipment

PTP/1588 and SyncE in Transport Network → Routers as high performance T-BC boundary clocks with Class B/C G.8273.2 performance

- Great solution: G.8275.1 with "on path support" for PTP
- Needs good network design in combination with SyncE
- End-to-end timing "budget" with accurate boundary clocks

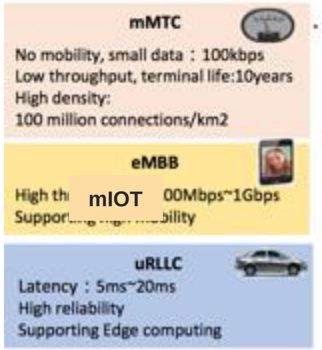
Combination of the Above → Flexibility in the design of the equipment allows them to be used in any situation

- PTP/SyncE as a backup to GNSS receiver outages
- GNSS where it's cost effective, PTP everywhere else

Network Slicing

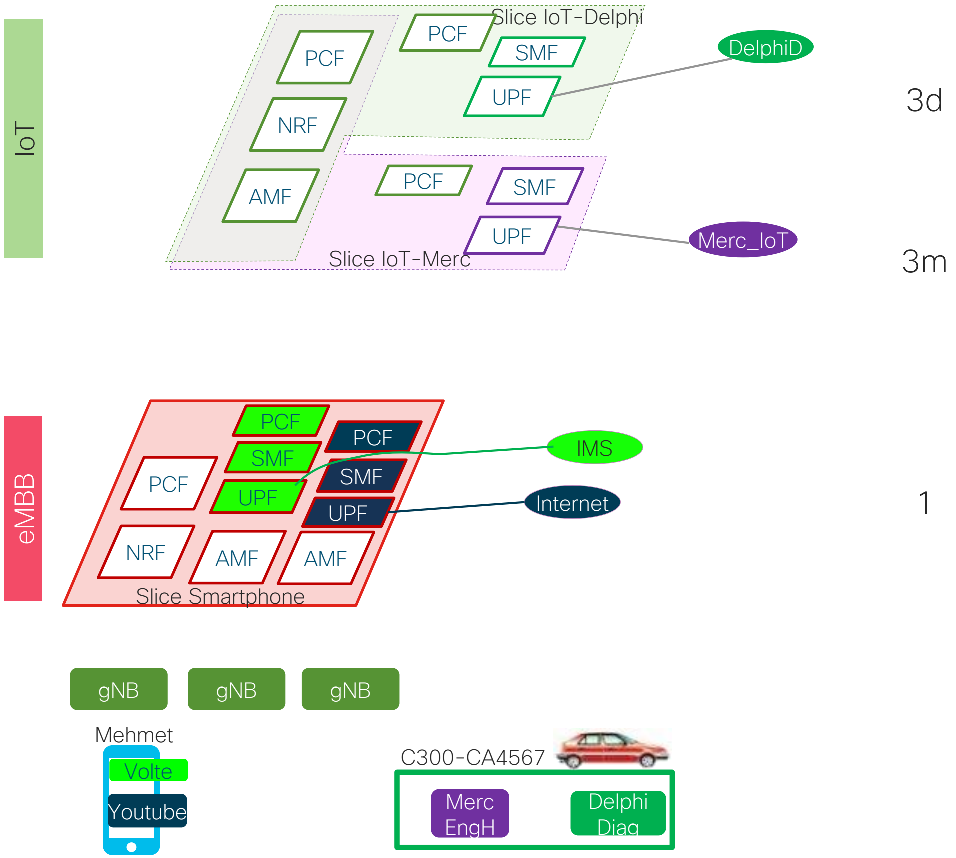
Slice Definition

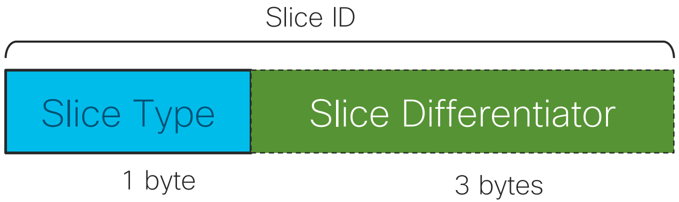
- Isolation of traffic for different Customers
  - Customers may be different enterprises
- Three main service families:
  - mIOT services
  - eMBB services
  - uRLLC services



Slice Topology and Slice IDs

Slice IDs





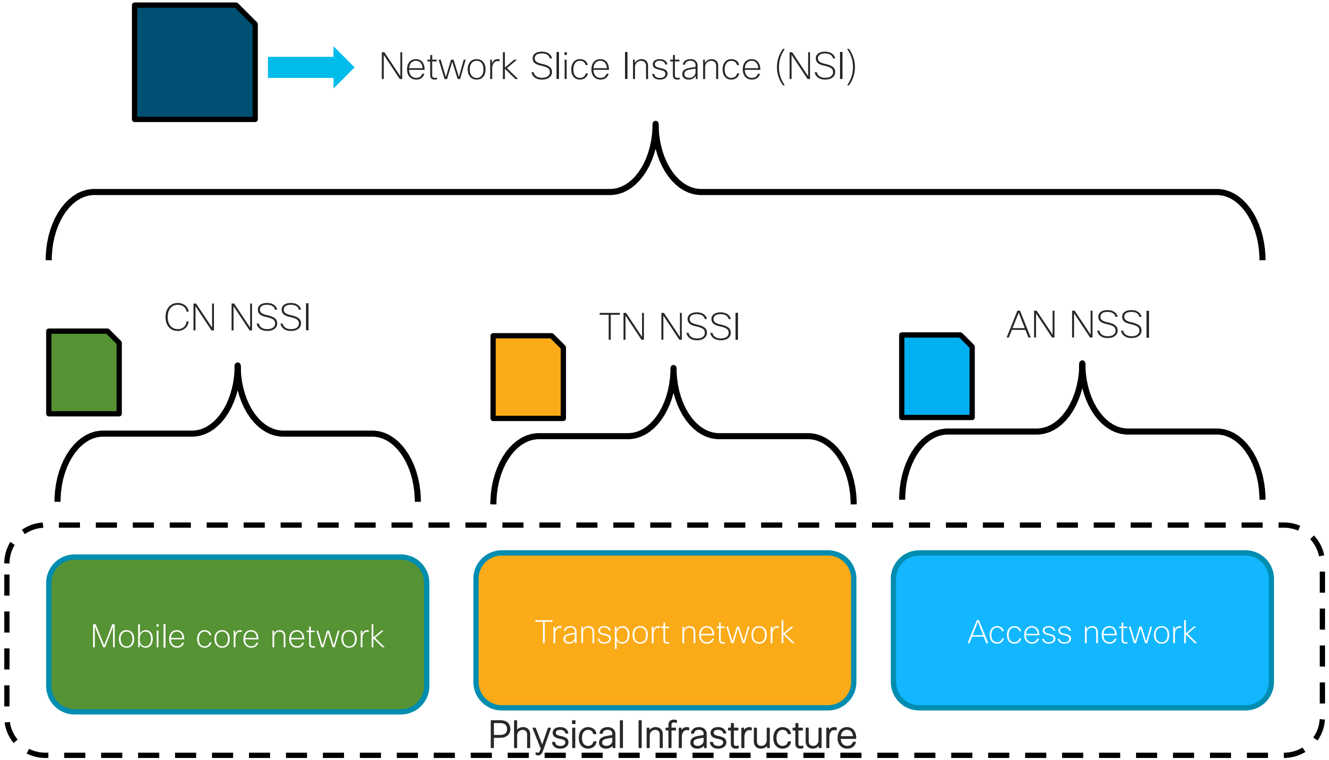
Slice Type	Slice Type Value
eMBB	1
URLLC	2
mIoT	3

Slide ID	= S-NSSAI
Slide ID Set	= NSSAI

S-NSSAI: Single Network Slice Selection Information

Key Concept & Slice Terminology defined by 3GPP

Network Slice Instance, Network Slice template, Network Slice Subnet Instance



A slice can be:
- 1:1:1 (Radio/Core/Transport)
- 1:n:m (Radio/Core/Transport)

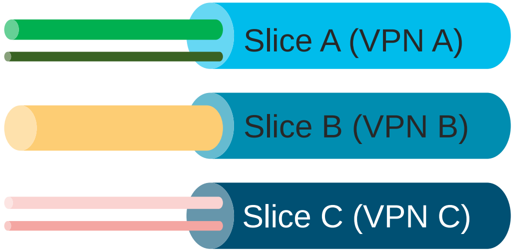
Network Slice Template (NST)

Network Subnet Slice Templates (NSST)

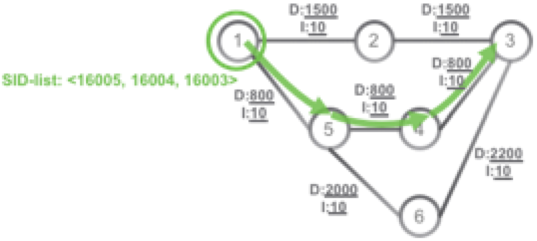
Multiple NSSIs per NSI
NSSI CAN BE CASCADED

Ref 3GPP TS 28.530 & 3GPP TS 28.531

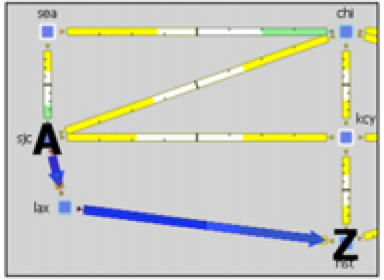
Network Slicing Transport Solution



Traffic isolation & Differentiated Services

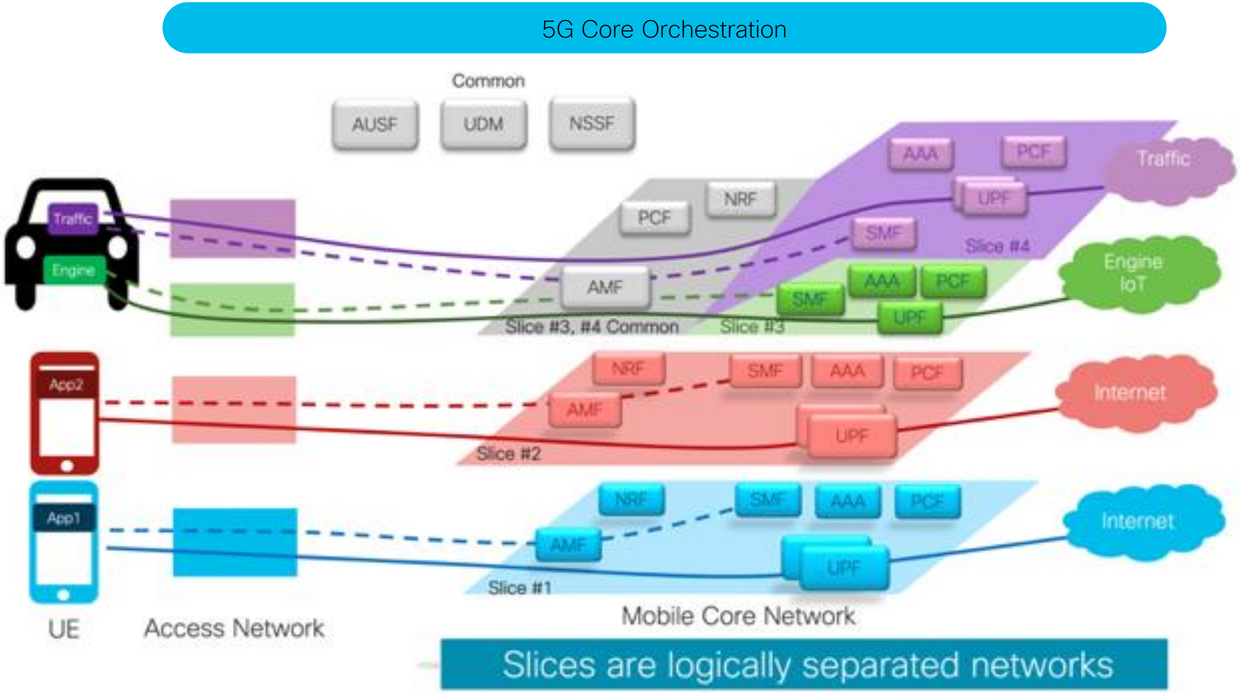


Low Latency Path



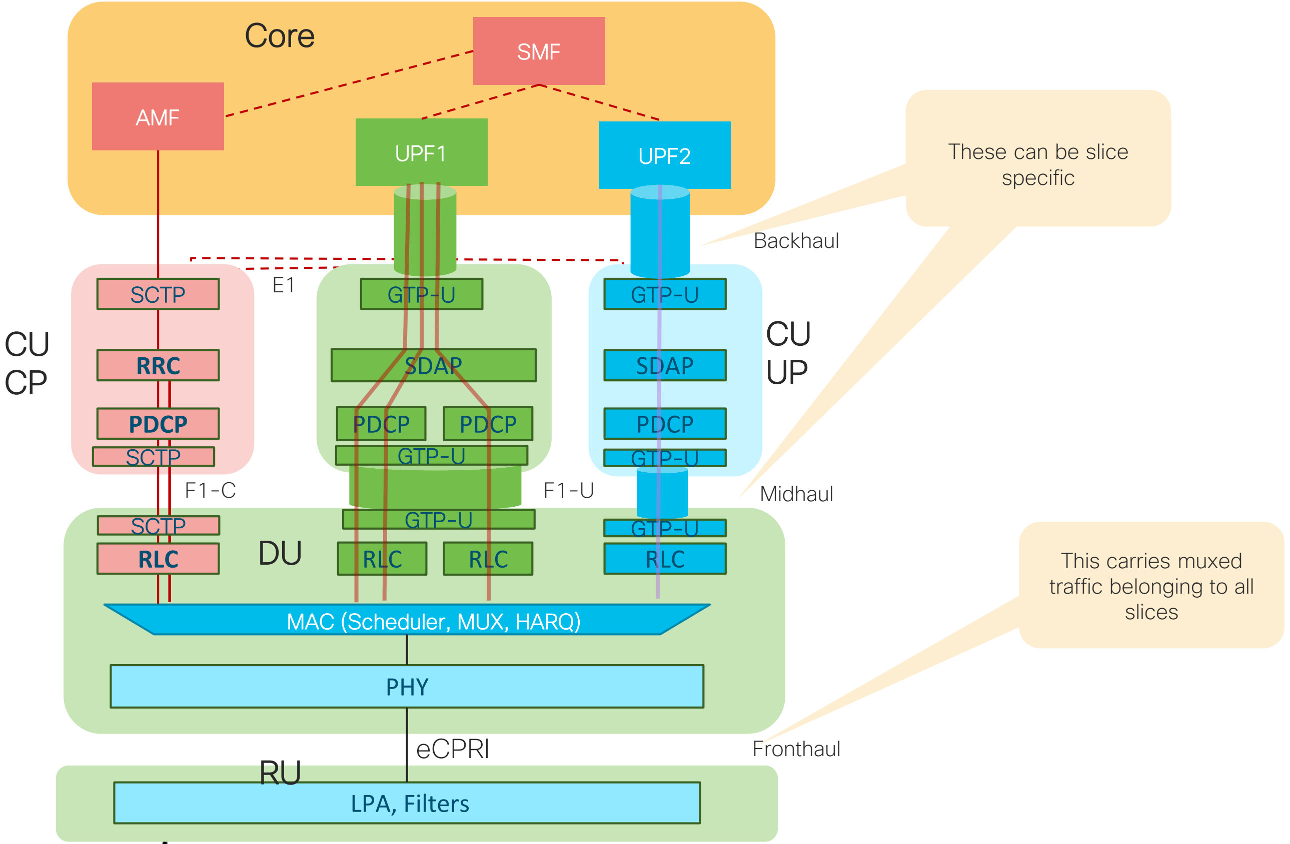
Bandwidth Optimization

Cisco Network Slicing for 5G core Network



- Leverage VNF and CNF to disaggregate Control Plan from User Plan to distribute and Scale 5 Core Functions.
- Implement the NSI, NSSI for Slice isolation.
- Use the NSSAI in conjunction with the AMF and NSSF for the slice selection (8 slices per UE)
- Slice Management Authentication
- **Dedicated UPFs per slice**
- An Orchestration Layer to create, deploy, configure, modify, scale delete Slices

Slicing impact on Backhaul/Midhaul/Fronthaul



Toolset for transport level slicing

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

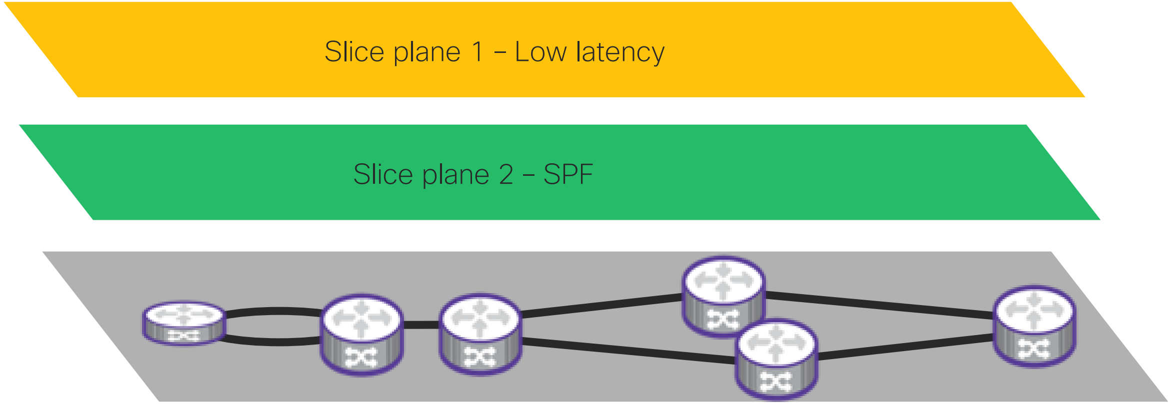
Creating and managing the slice forwarding plane

Combining these offer different levels of transport slice separation

- Virtual Private networks : L2 / L3 VPNs
- ODN and Automated traffic Steering (AS)
- VPN performance management tools
- Slice X-domain and domain orchestration

Customer slice instances and mapping to slice forwarding planes.

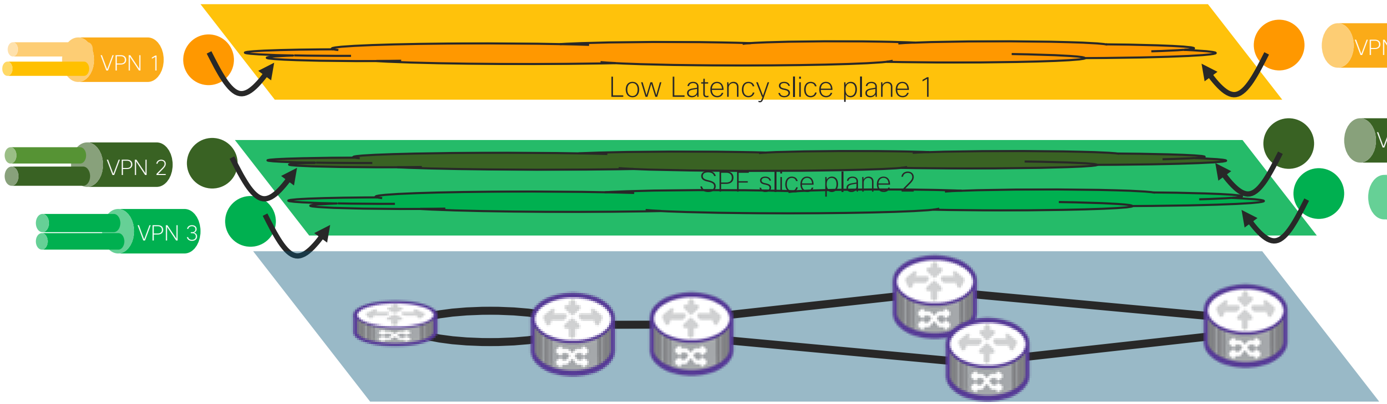
Transport slice planes based on SLA requirements



- Small number of slice planes defined in underlay (across domains)
  - 5G services (eMBB, URLLc, MMTc)
  - Major customers / verticals
- Slice planes aims to support a set of behavioural characteristics
  - Delay, loss, topology
- Slice forwarding planes can be “hard” or “soft” depending how they are engineered

Mapping customers to underlay slice planes

VPNs or QoS mapping to slice planes



- L2/L3 VPNs + RT filtering used for customer / service / 5G component isolation
- Potentially large numbers
- Traffic pushed into correct underlay slice plane
  - SR Automated Steering – QoS or prefix based
  - More complicated than it may appear – dependent on how radio / UPF set-up
- 1 VPN to 1 slice plane or more likely many VPNs to 1 slice plane

QOS

- 5G QOS Identifier (5QI)
- E2E QOS Profile needs to be created
  - Packet Core
  - Transport
  - RAN
- SR label range to QOS mapping
  - HQOS
  - Similar to VLAN ranges
  - Under investigation

5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
1		20	100 ms	10^{-2}	N/A	2000 ms	Conversational Voice
2		40	150 ms	10^{-3}	N/A	2000 ms	Conversational Video (Live Streaming)
3		30	50 ms	10^{-3}	N/A	2000 ms	Real Time Gaming, V2X messages, Electricity distribution - medium voltage, Process automation - monitoring
4		50	300 ms	10^{-6}	N/A	2000 ms	Non-Conversational Video (Buffered Streaming)
65		7	75 ms	10^{-2}	N/A	2000 ms	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66		20	100 ms	10^{-2}	N/A	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67	GBR	15	100 ms	10^{-3}	N/A	2000 ms	Mission Critical Video user plane
75							
71		56	150 ms	10^{-6}			
72		56	300 ms	10^{-4}			
73		56	300 ms	10^{-8}	N/A	2000 ms	"Live" Uplink Streaming
74		56	500 ms	10^{-8}			
76		56	500 ms	10^{-4}			
5		10	100 ms	10^{-6}	N/A	N/A	IMS Signalling
6		60	300 ms	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		70	100 ms	10^{-3}	N/A	N/A	Voice, Video (Live Streaming) Interactive Gaming
8		80	300 ms	10^{-6}	N/A	N/A	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9	Non-GBR	90					
69		5	60 ms	10^{-6}	N/A	N/A	Mission Critical delay sensitive signalling (e.g., MC-PTT signalling)
70		55	200 ms	10^{-6}	N/A	N/A	Mission Critical Data (e.g. example services are the same as 5QI 6/8/9)
79		65	50 ms	10^{-2}	N/A	N/A	V2X messages
80		68	10 ms	10^{-6}	N/A	N/A	Low Latency eMBB applications Augmented Reality
82		19	10 ms	10^{-4}	255 bytes	2000 ms	Discrete Automation
83	Delay Critical GBR	22	10 ms	10^{-4}	1354 bytes	2000 ms	Discrete Automation
84		24	30 ms	10^{-5}	1354 bytes	2000 ms	Intelligent transport systems
85		21	5 ms	10^{-5}	255 bytes	2000 ms	Electricity Distribution - high voltage

Automation

Automation
Cisco Crosswork

Cisco Crosswork Cloud

Network & Trust Insights
Analyze and identify routing anomalies. Determine integrity of infrastructure

Prepare / Design	Plan / Integrate	Implement	Operate	Optimize

WAN Automation
Planning and predictive modelling to analysis potential scenarios

Integration Qualification
Rapid qualification and integration to support new feature and software delivery into production

EPN-M Manager
Optical, Cable, IP Manageability in Multi-layer, Multi-service environment

Network Service Orchestrator
Mass scale intent-based configuration across multi-vendor

Situation Manager
Connect events across multi domains and provide root cause analysis

Health Insights
learn and measure health of network elements

Change Automation
safely execute operational tasks with structured workflows

Optimization Engine
optimize network paths to improve utilization & efficiency (SR-PCE)

Data Gateway
large scale distributed data collection

SP Validated Designs Converged SDN Transport

Cisco Validated Design Document

SP Validated Designs Home Page:

- https://xrdocs.github.io/design/

Converged SDN Transport High Level Design

- https://xrdocs.github.io/design/blogs/latest-metro-fabric-hld/

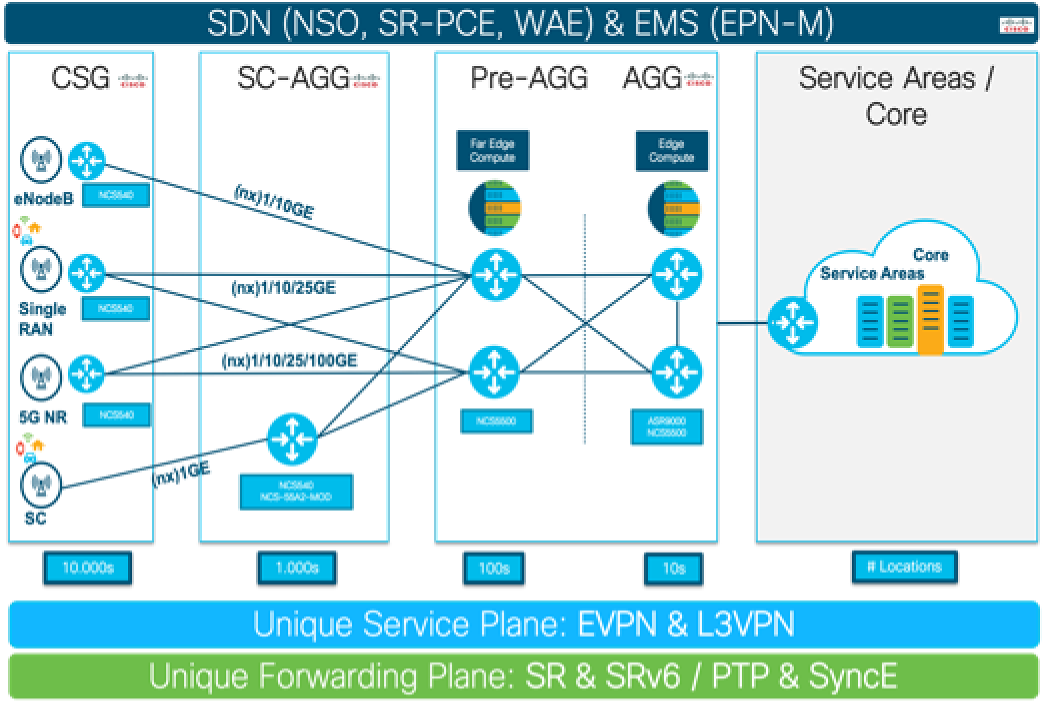
Topology & Configs

- https://github.com/ios-xr/design/tree/master/

Customer Case Studies

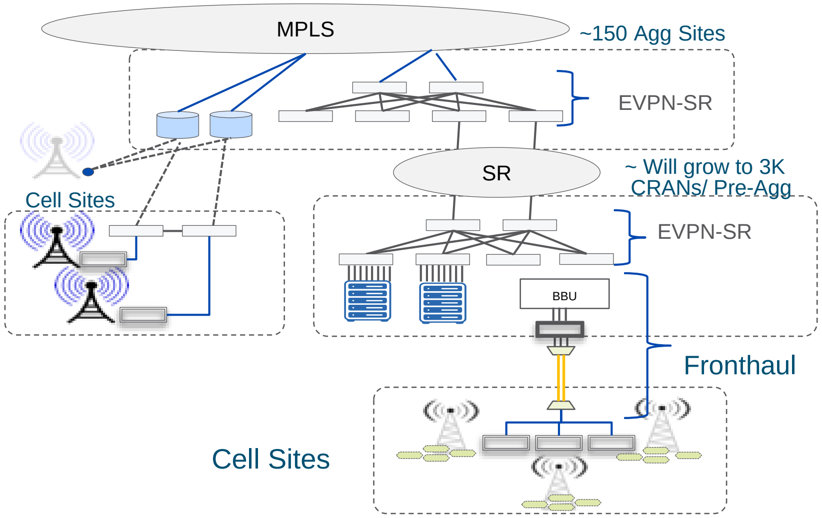
Tier 1 European Customer

- Objective
  - 5G network transport modernization
    - Simplification
    - Scalability
    - SDN
    - Network slicing
- Cisco Solution
  - Unified Forwarding & Service plane with SR/BGP VPN
    - Evolution to SRv6 in two to three years
  - End-to-end 5G xhaul with IOS XR NCS540/ NCS5500
  - SR-PCE for cross domain path computation
  - Best-in-class timing capabilities: Class C, 1588 profiles
- Outcome
  - 5G service live in multiple cities



Tier 1 US Customer

NSO



Backhaul and Cloud RAN

Access, pre-aggregation and aggregation layers

Platforms: NCS-55xx, NCS-540 family for DRAN, CRAN and aggregation sites

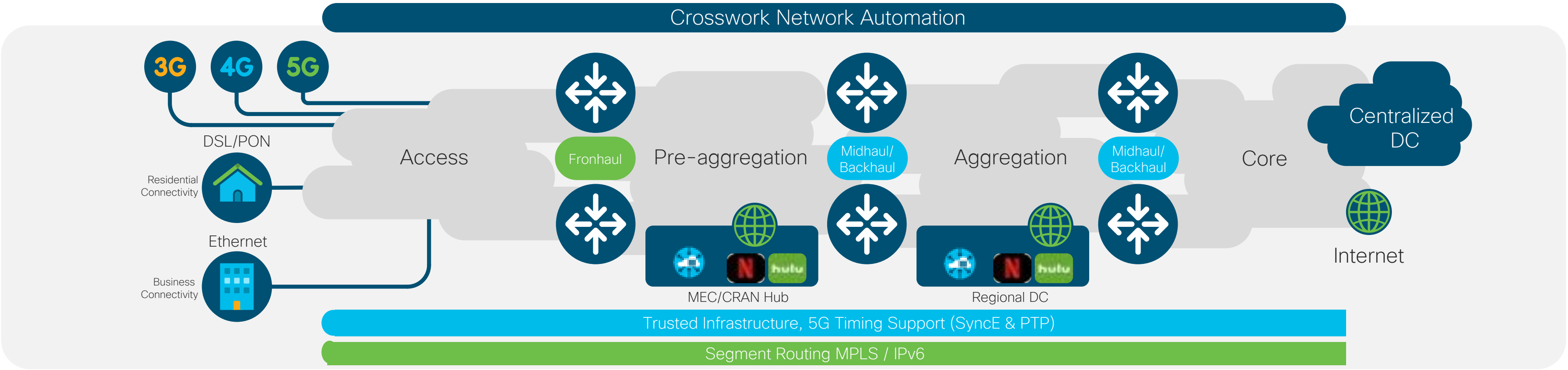
Technology Strategy: SR/EVPN fabric design in pre-agg and aggregation sites and SR/EVPN for transport

Early engagement to drive highly scalable SR/EVPN fabric based architecture

New consumption model focused on customer cost transformation initiatives

Expeditious and cost-effective 5G rollout

Tier 1 ANZ Customer



- Goal
  - 5G converged transport for wireless and wireline access network for all services
- Outcome
  - 5G converged transport for wireless and wireline access network for all services – with lower TCO

- Cisco Solution
  - Design leadership with with Cisco 5G converged SDN transport reference architecture
  - SR transport, aligned to customer's future state architecture
    - SR-MPLS / BGP VPN transport from access to core
  - Simplified metro transport with digital coherent optics solution

Helpful Links

Cisco Converged SDN Transport Resources

- Converged SDN Transport
  - https://www.cisco.com/c/en/us/solutions/service-provider/mobile-internet/5g-converged-sdn-transport.html?cachemode=refresh
- Light Reading webinar September 2019
  - https://www.lightreading.com/webinar.asp?webinar_id=1475
- 5G xHaul Transport" Light Reading webinar and whitepaper Jan 2019
  - https://www.lightreading.com/webinar.asp?webinar_id=1324
  - https://www.lightreading.com/lg_redirect.asp?piddl_lgid_docid=748878&piddl_lg_pcode=wprightcolumn
- "Cisco 5G xHaul Transport" Podcast
  - https://packetpushers.net/podcast/weekly-show-417-meeting-5g-demands-with-ciscos-5g-xhaul-transport-sponsored/
- "5G xHaul Transport" Cisco Knowledge Network (CKN) webinar recording
  - https://www.cisco.com/c/m/en_us/network-intelligence/service-provider/digital-transformation/knowledge-network-webinars.html

Additional Resources

- ”5G xhaul” session Cisco Live US 2019
  - https://www.ciscolive.com/global/on-demand-library.html?zid=clus&search=waris%20sagheer#/session/1539670737443001ICxi
- ”Clocking” session Cisco Live US 2019
  - https://www.ciscolive.com/global/on-demand-library.html?zid=clus&search=5G%202019#/session/1538629875288001C3te
- Radio and Band info
  - https://www.sharetechnote.com/ (Radio tutorial)
  - Simple lookup for LTE bands
  - http://niviuk.free.fr/lte_band.php (Simple lookup for LTE bands)
  - Simple lookup for 5G (new radio) bands
  - http://niviuk.free.fr/nr_band.php (Simple lookup for 5G (new radio) bands)

Summary

- To cater the divergent requirements of 5G services eMBB, uRLLC & mMTC, Cisco Converged SDN 5G transport enables high bandwidth, low latency & scale in 5G networks
- Cisco Converged Transport Solution is 5G Ready "Today" for Backhaul, Midhaul and C-RAN hub site
- "Converged" supporting wireline as well as wireless (AnyG), secure, simplified operations and resilient
- Massive bandwidth Portfolio, Programmable Transport (SR/BGP VPN) enabling flexible placement of services through end to end IP & Fabric based Cloud-RAN (Far Edge with MEC)
- Concurrent support in transport network for network slicing
- Cisco Converged SDN-Enabled Transport enables more capex efficiency, better opex utilization, & faster time to service

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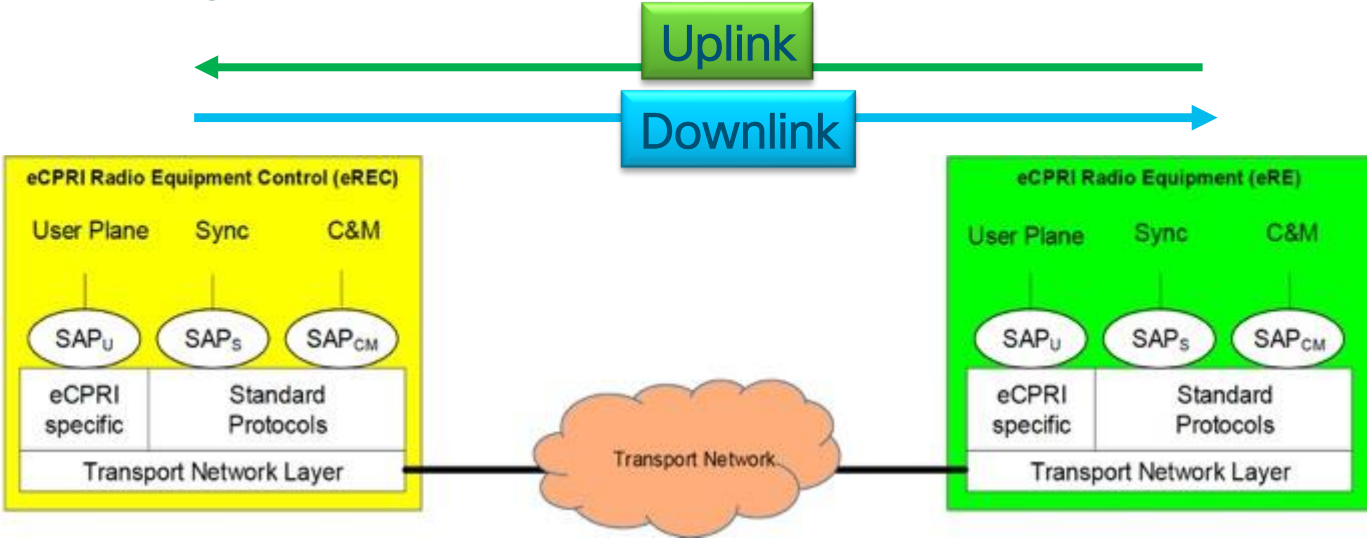
You make **possible**

Backup Slides

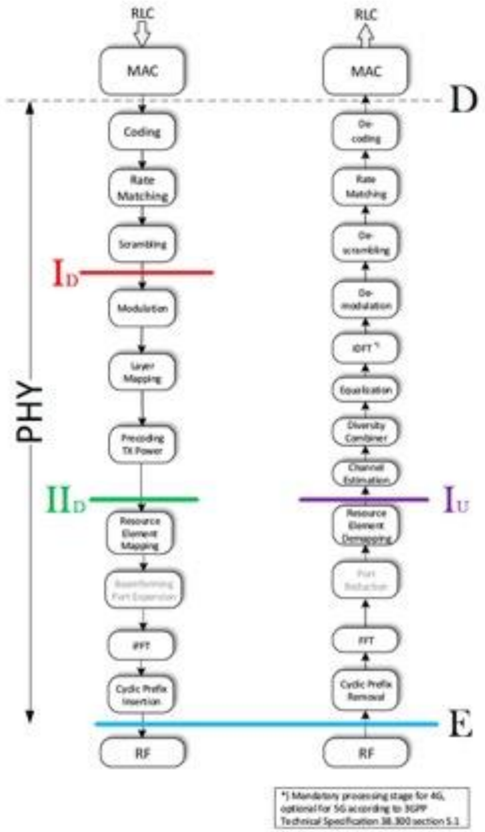
eCPRI 2.0



- 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. Source: eCPRI 2.0

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.

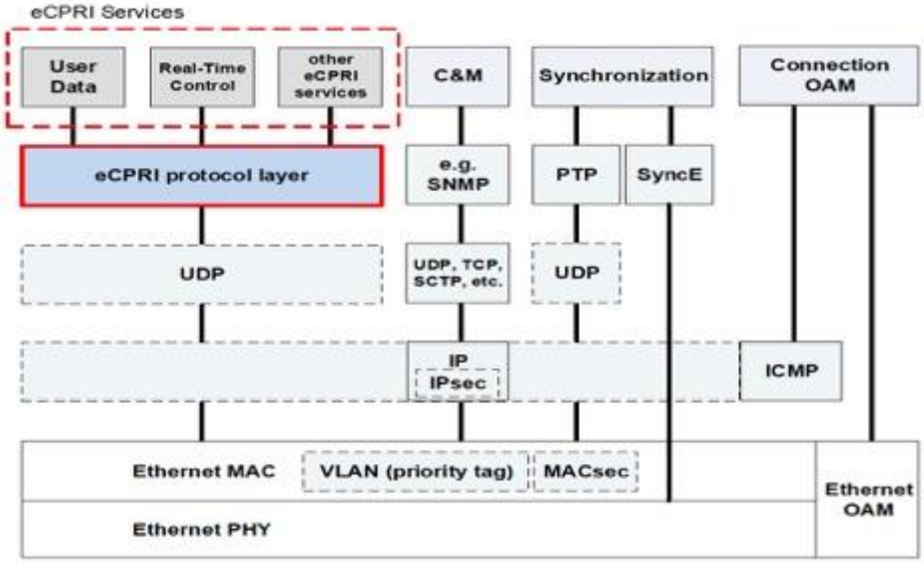


Figure 6: eCPRI protocol stack over IP / Ethernet

eCPRI 2.0 contd..

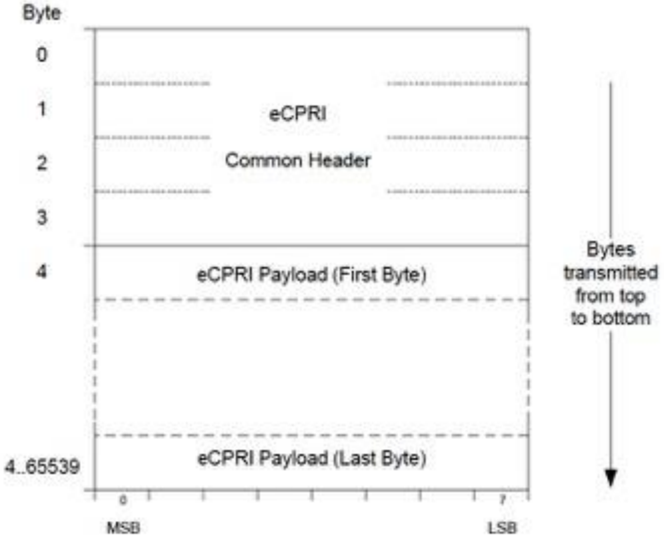


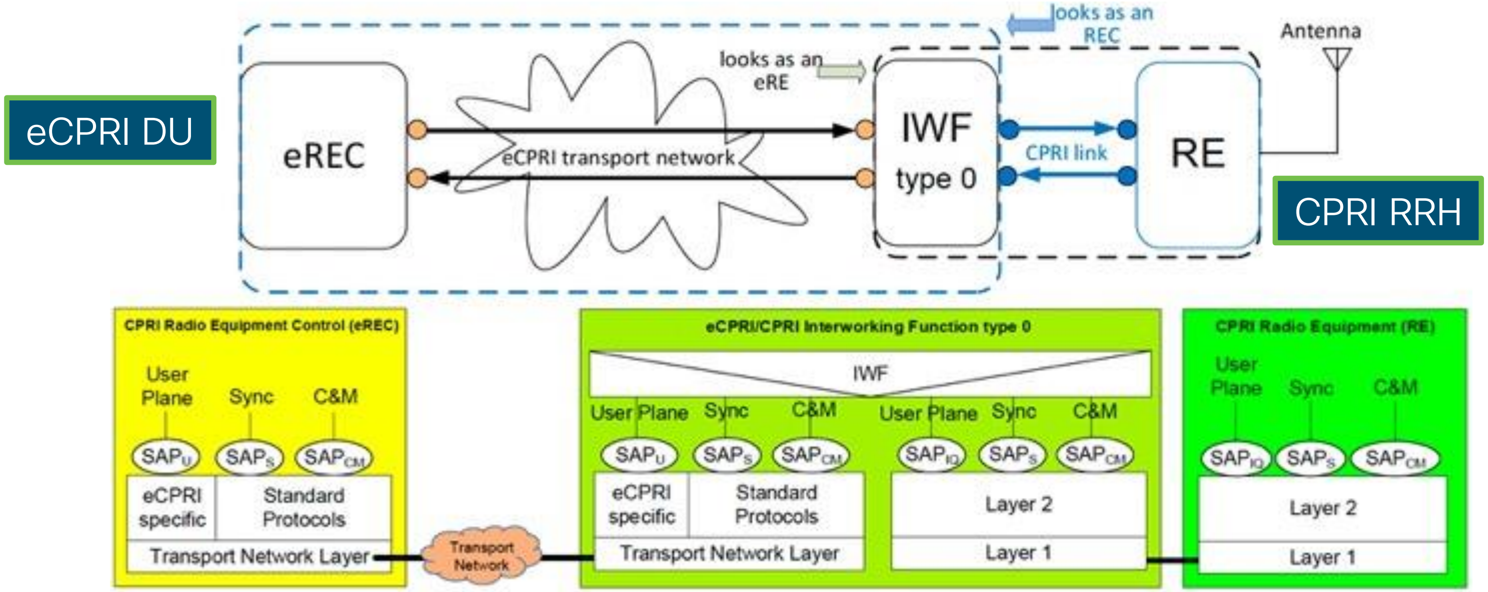
Figure 7: eCPRI message format

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

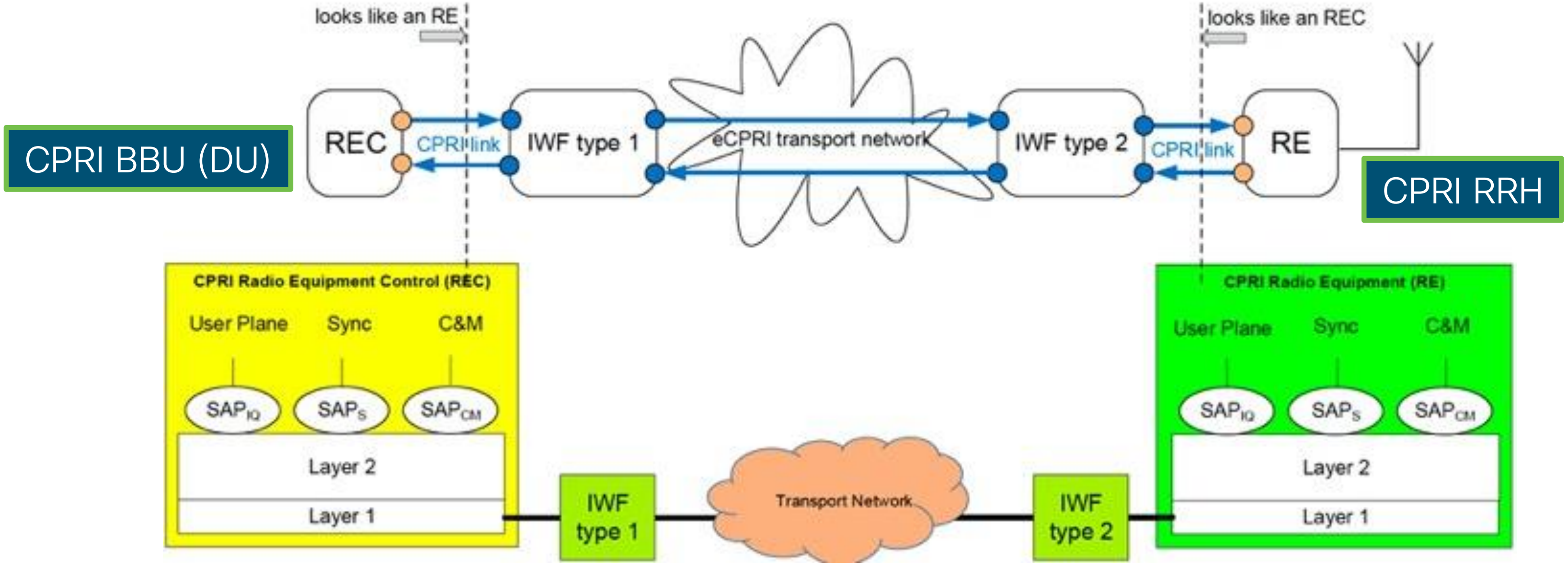
eCPRI IWF Type 0



The Interworking Function type 0 is located between the eCPRI transport network and one/several CPRI RE node(s).

Source: eCPRI 2.0 IWF presentation

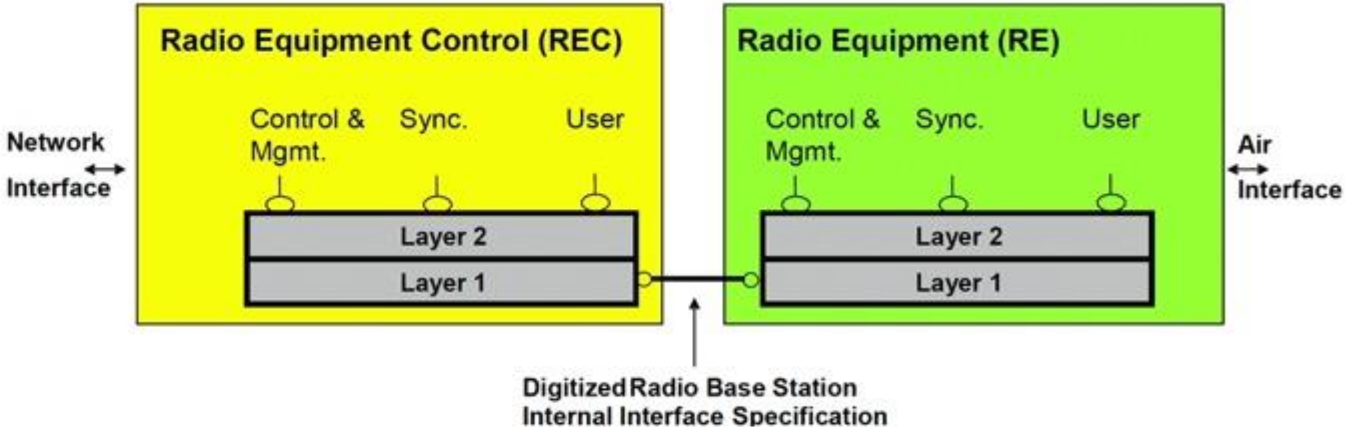
eCPRI IWF Type1 & Type 2



The Interworking Functions of type 1 and 2 are located between the respective CPRI nodes and the transport network.

Source: eCPRI 2.0 IWF presentation

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)

Source: CPRI 7.0

CPRI v7.0 contd..

- 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

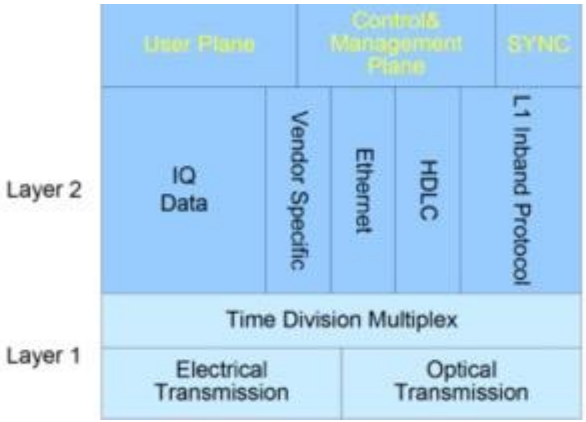
Table 1AA: Functional decomposition between REC and RE (valid for the GSM standard)

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.



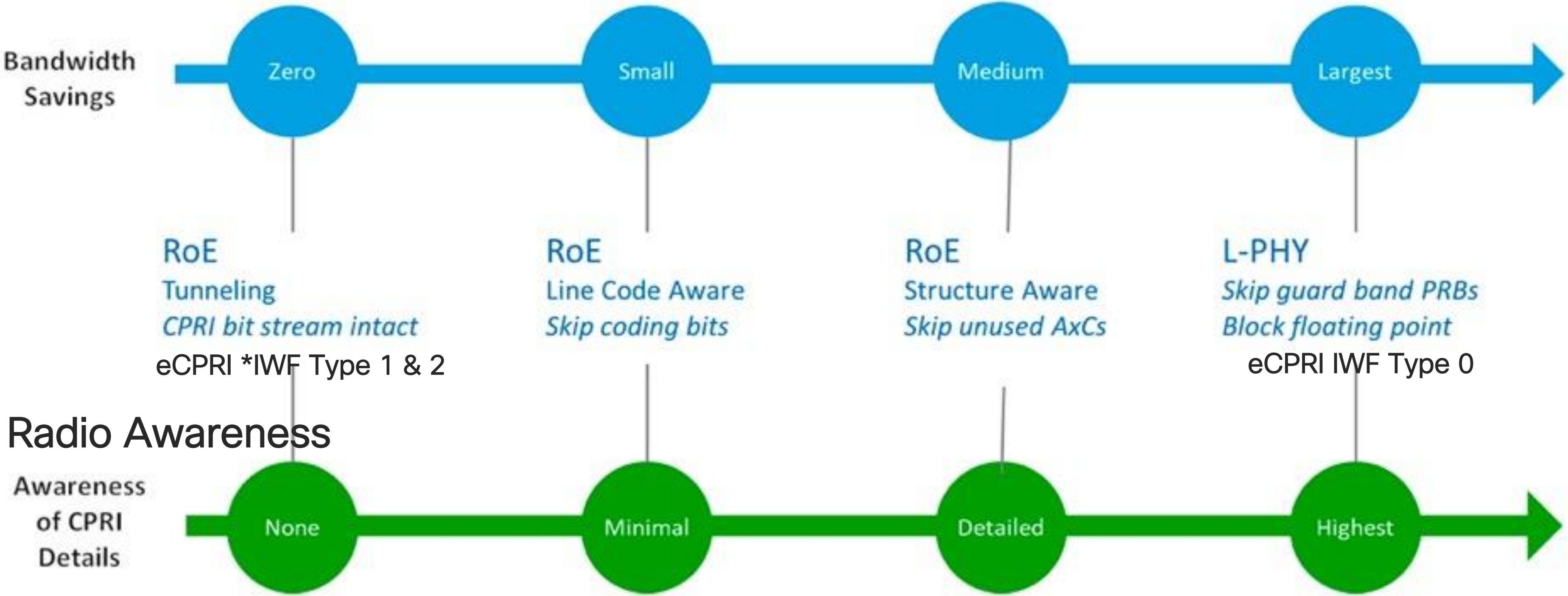
Source: CPRI 7.0

CPRI Line Bit Rate Options

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)

How to transport CPRI over Ethernet Network?



Source OCP Telcos Project: AT&T Fronthaul Gateway (FHG) requirements and Use Cases Revision

*IWF = Interworking Function

RoE: Structure-Agnostic (Mapper Type 0) or Tunneling Mode

- Tunneling mode is expected to be compatible with all RAN suppliers' equipment.
  - There is no manipulation of the CPRI structure, therefore specific CPRI details are not required. RoE
- Simplest of the RoE modes
- The CPRI Stream is partitioned and encapsulated into Ethernet frames.
- RoE Tunneling mode does not provide any fronthaul bandwidth reduction.

Source OCP Telcos Project: AT&T Fronthaul Gateway (FHG) requirements and Use Cases Revision 1.0

RoE: Structure-Agnostic (Mapper Type 1) or Line Code Aware Mode

- To support this mode, RAN supplier specific information such as AxC frame position and AxC Frame length must be known by the Frouthaul router
  - CPRI stream is converted to frames, the Line coding information from the 8b/10b CPRI stream is removed.
  - By removing the line code, the fronthaul bandwidth of the resulting Ethernet traffic is reduced by approximately 20 percent.
- It may be problematic for RoE Line Code Aware Mode to interwork with all RAN Suppliers' equipment because of proprietary CPRI implementations.
- RoE Type 1 writeup

Microsoft Word Document

Source OCP Telcos Project: AT&T Fronthaul Gateway (FHG) requirements and Use Cases Revision 1.0

Cisco Open vRAN

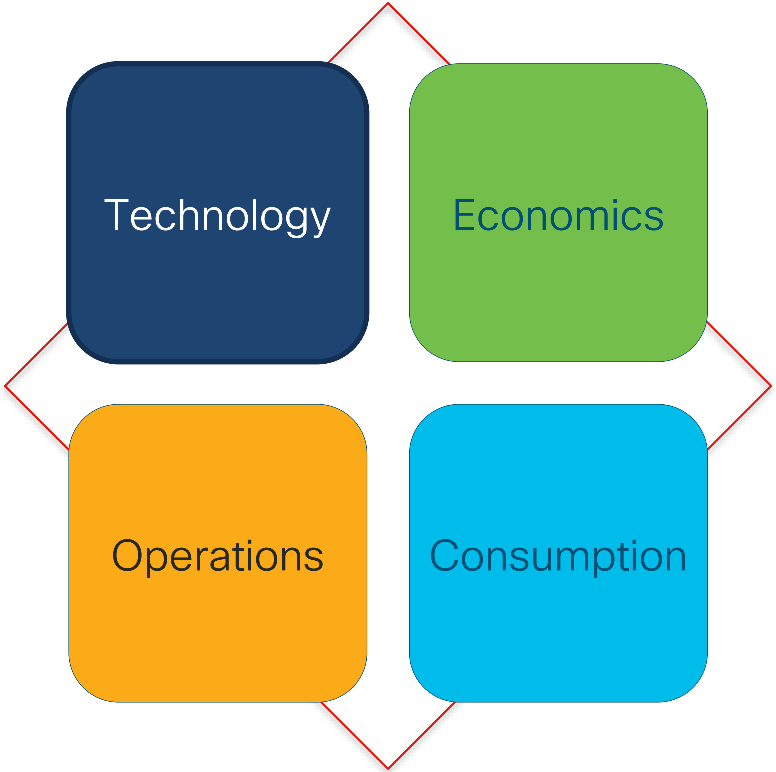
There is a Better Way with a Software-Driven Decomposed Mobile Network

From:		**To:**
Monolithic, proprietary, single-vendor	→	Flexible, disaggregated, multi-vendor
Closed, inefficient, limited choices	→	Open, modular, e2e IP
Network defined (and constrained) by RAN	→	Network defined by the services, and desired operational model

Open vRAN Ecosystem Overview

Accelerate the viability
and adoption of open virtualized RAN (vRAN)
solutions and ensure their extension into a
broader software-defined network architecture

Provide Architectural Optionality

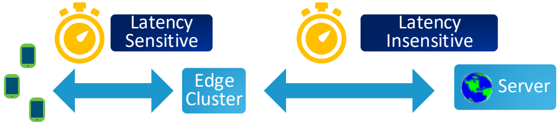


Multi-Access Edge Compute

Multi-Access Edge Computing (MEC)

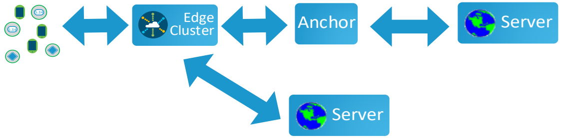
MEC or Edge Computing, is the architectural principle of moving services to locations

Latency Reduction

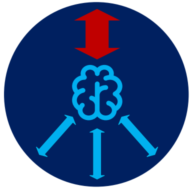


Reducing latency between services and consumers will create a better QoE & allow for new B2B2X services

Edge Offload



Edge offload will enable less expensive and lower latency path from the edge hosts towards the services



Data Reduction

Edge nodes can perform data analytics (ML inference) to perform bandwidth reduction and/or compute offload compensating for less capable devices

Edge Computing Use Cases

RAN Architecture: with decomposition of RAN, edge clouds will be deployed

Automation: enables “lights-out” low OPEX services and is essential for APIs to work

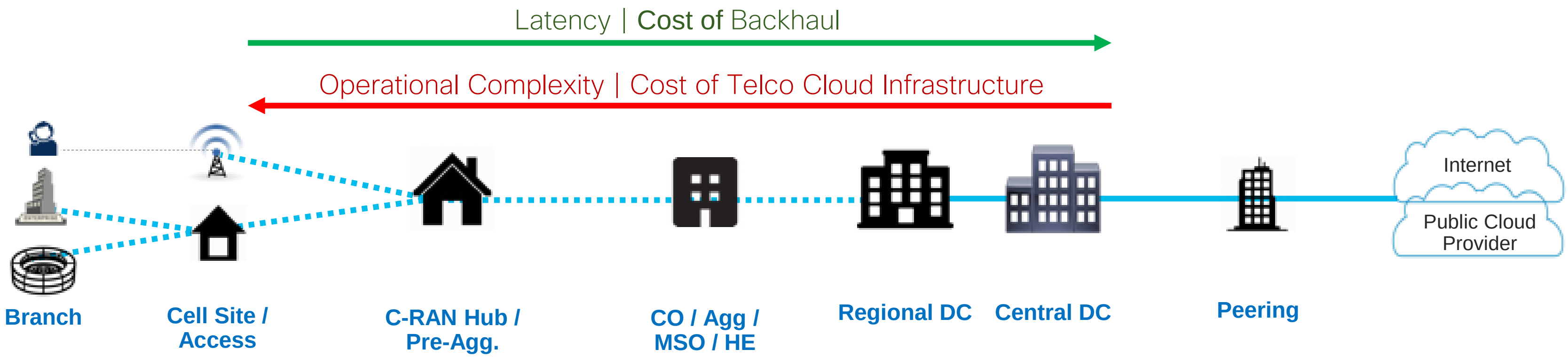
Fixed & Mobile Terminations: with decomposition of fixed & mobile subscriber management, edge terminations will be deployed

Use cases: Brings in partners from which operator derives revenue

CDN, AR, VR, Connected and Autonomous Vehicle, Fog Computing, Network-Hosted Computing & Enterprise-Hosted Computing

APIs: enable the consumption of edge services in the operator network

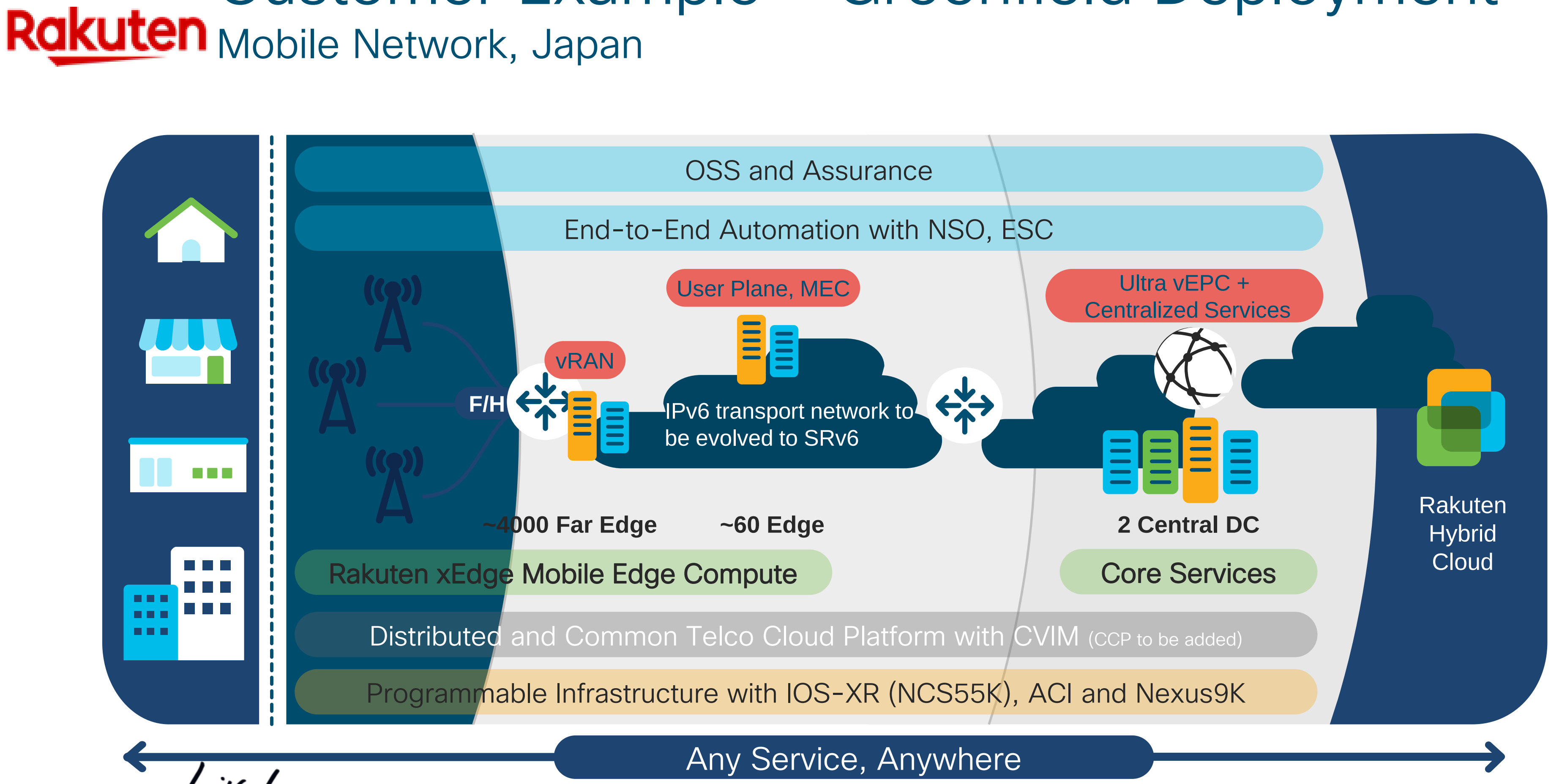
Multi-Access Edge Compute - Edge Transformation



	Branch / Venues	Cell Site / Access	Pre-Agg / C-RAN Hub	CO / Agg / MSO / Headend	Central / Regional DC	Peering Point
#	10,000s	10,000s	1000s	100s	10s	10s
Services	Enterprise and Venue centric low latency & Edge Services	Operators in general are not considering this location type for any services deployment	Mostly Cloud-RAN, some SPs evaluating these sites for low latency apps	Emerging location type of low latency and Edge Services	Majority of SP's production and backend services have some/all components here	Cloud Services Interconnect with bum-in-the wire functions, Security services
Constraints	Could vary, typical target footprint is small	Very constrained on space, power, depth and environmental	Typically not DC locations, no raised floors, racks are power/HVAC constrained with max 600mm depth, NEBS/ext. temp requirement		Mostly Data Centre type locations, typically unconstrained	Mix of Telco/IT DC and Co-location facilities, typically unconstrained

Customer Example – Greenfield Deployment

Mobile Network, Japan



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