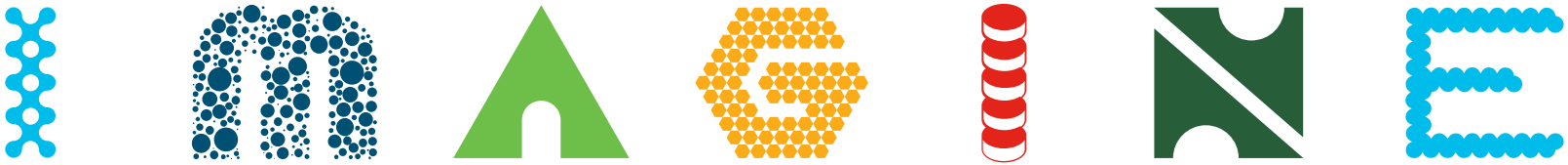


INTUITIVE

Cisco live!

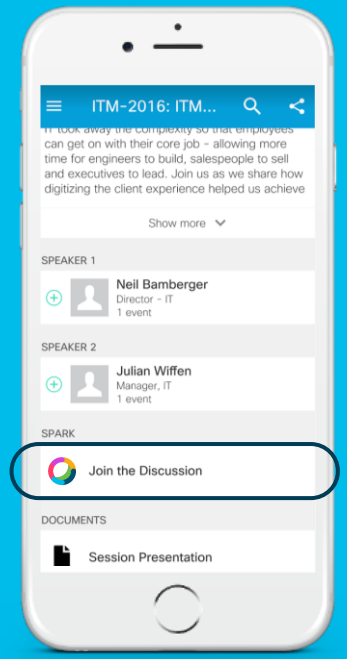
5-8 March 2019 • Melbourne, Australia

#CLMEL

Building 5G xHaul Transport Network

Waris Sagheer, Principal 5G Product Manager

BRKSPG-2680



cs.co/ciscolivebot#BRKSPG-2680

Cisco Webex Teams

Questions?

Use Cisco Webex Teams (formerly Cisco Spark) to chat with the speaker after the session

How

1. Open the Cisco Events Mobile App
2. Find your desired session in the “Session Scheduler”
3. Click “Join the Discussion”
4. Install Webex Teams or go directly to the team space
5. Enter messages/questions in the team space

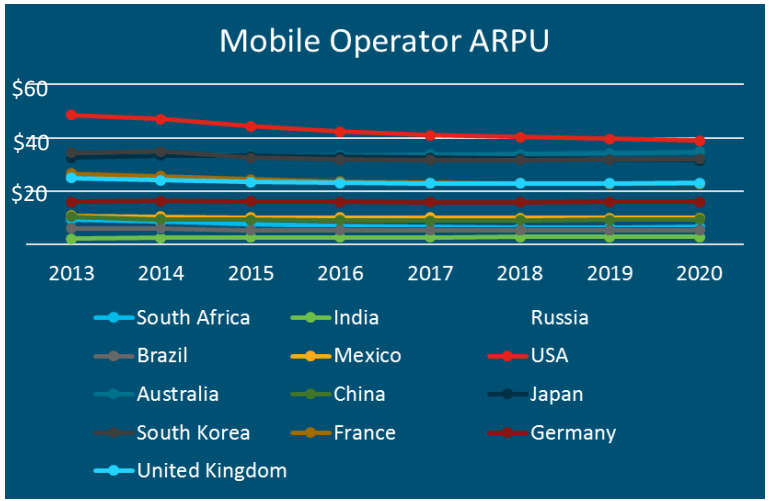
Agenda

- Introduction
- 5G Transport Requirement
- Cisco 5G xHaul Transport Vision and Strategy
- Cisco Converged SDN 5G Transport Solution
- Customer case studies
- Helpful Links

Glossary

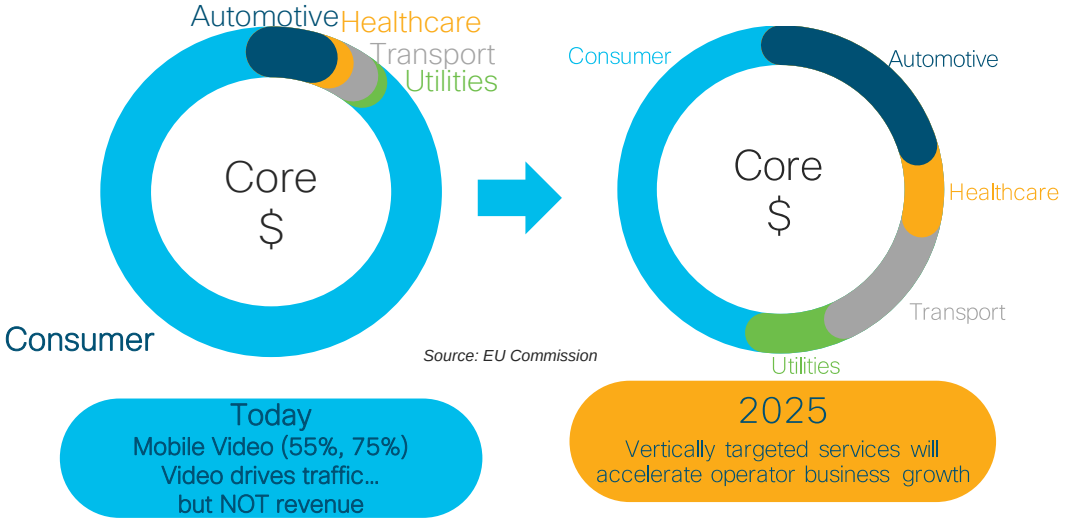
- **UE** (User Equipment)
- **RU** (Radio Unit) RAN (Radio Access Network)
- **BBU** (Baseband Unit)
- **EPC** (Evolved Packet Core)
- **CSR** (Cell Site Router)
- **C-RAN** (Centralised RAN)
- **Remote Radio Head** (RRH)
- **TRxP** (Transmit Receive Point)
- **vEPC** (Virtual EPC)
- **CU-CP** (Centralised RAN Control Plane)
- **CU-UP** (Centralised 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)

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



LTE to 5G

Emergence of **Low Latency** Need for better QOE and to Enable New Applications

5G - Key Use Case Categories

Enhanced Mobile Broadband (inc. Fixed Wireless Access)

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

→ Increased Bandwidth and Capacity

Massive Machine Type Communication

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

→ Scale, Slicing, Flexible deployment, NFV/Virtualisation

Ultra-Reliable Low Latency Communication

- For mission critical use cases (self driving, Public safety, ...)
- Desired 1ms access time only refers to radio interface and would be most useful in near field mission critical apps

→ Push data plane to the edge, Intelligence in Network

Source: Recommendation ITU-R M.2083

Emerging - Low Latency

→ Push data plane to the edge, Intelligence in Network

Low latency applications, entertainment

5G CSP Service Examples

Secure Remote Car Software Update

10 - 100M lines of code and hundreds of subsystems

Vehicle updates, telematics, and infotainment

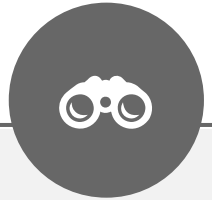
CSP hosted Network Slicing for Public Sector Private Networks

Police, fire, hospitals with strict SLAs and Security

Smart City Enablement

Smart-sensor enabled

Waste and recycling,, parking, smart grid, homes



Augmented / Virtual Reality Delivery

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

Video enablement required

5G eMBB Use Case is now live!

Verizon's 5G

- Residential broadband services in Houston, Indianapolis, Los Angeles, and Sacramento went live on October 1, 2018
- Uses TDD technology in 28 GHz
- Average 300 Mbps with peak speeds up to 1 Gbps

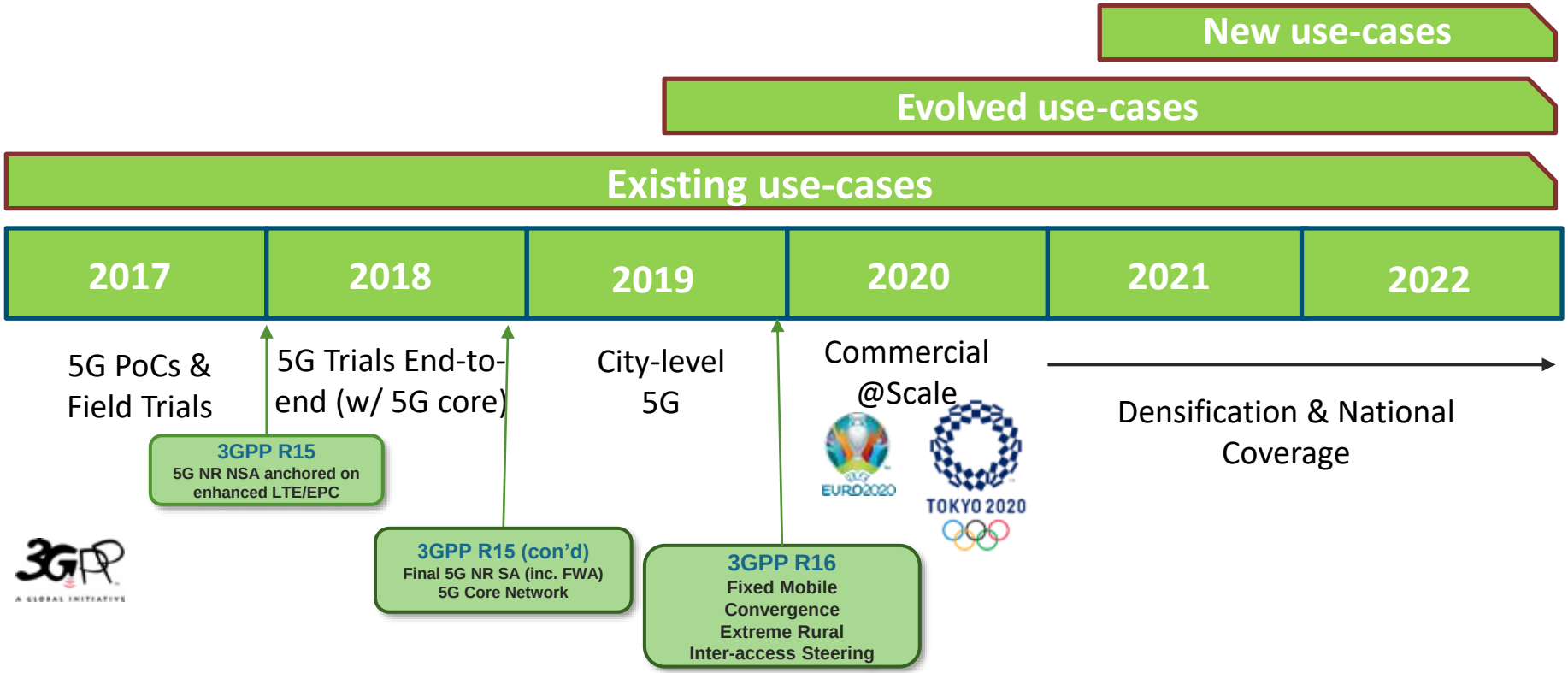
AT&T Launches Mobile 5G in 12 Markets

- 5G Mobile services enabled on Dec. 21st, 2018 across 12 cities
- Using Sub 6 GHz spectrum to support mobility; plan to roll my mmWave in 2020
- Peak rate of 400Mbps; Usage based service

Korea operators turn on commercial 5G networks

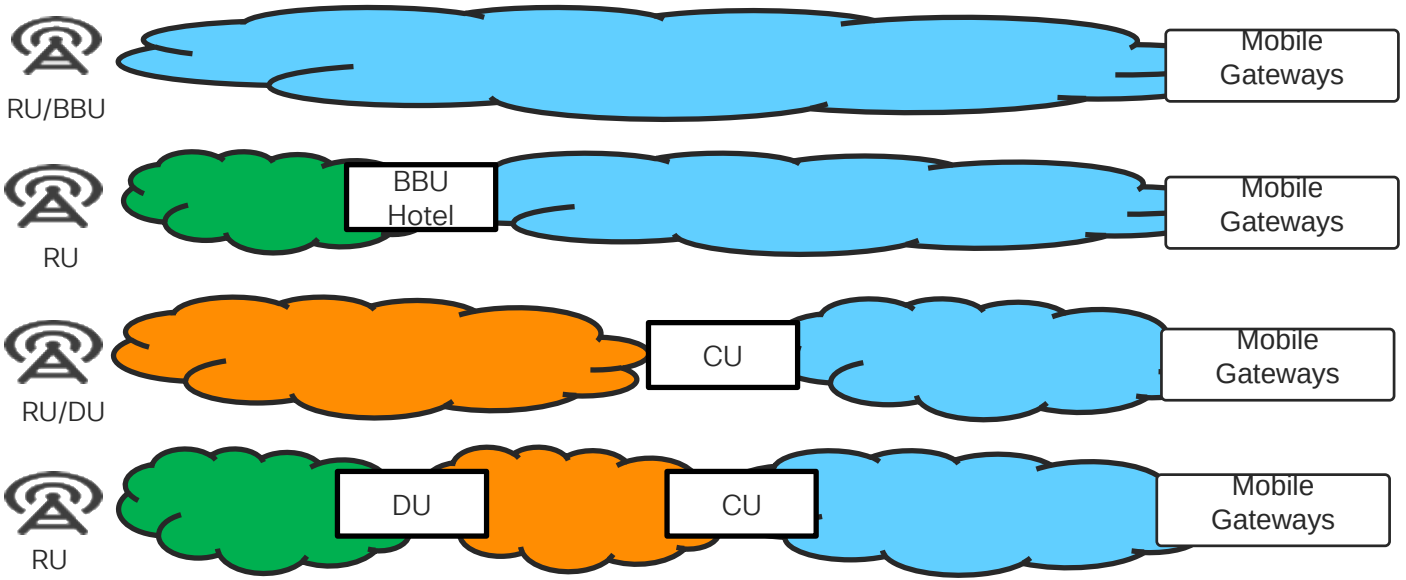
- SK Telecom, KT, and LG Uplus simultaneously turned on 5G on December 1, 2018
- Require 5G mobile routers with 5G handsets planned for March 2019

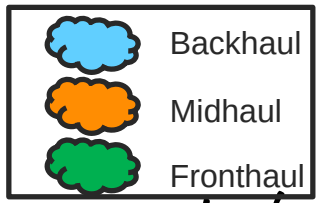
Timeline to 5G @ Scale



5G Transport Requirement

5G RAN Architecture Evolution





Split Groups	Splits	Transport Latency One Way	Bandwidth
Backhaul (S1 / Nx)	None	Service Dependent	~User bandwidth
Midhaul High Split (F1)	Option 2: PDCP-RLC	1- 5 milliseconds	~User bandwidth
Fronthaul Low Split	Option 7/8: PHY Hi- PHY Lo	100 microseconds	Very High

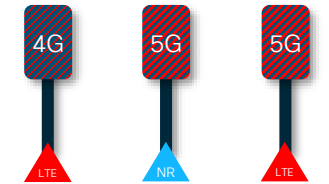
You will hear about 5G Option Splits…

Mobile Core and RAN splits

5G Core Node "Option" Splits

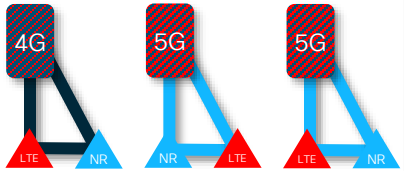
What you need to know

Standalone (SA):
One radio access technology



Option 1 *Option 2* *Option 5*

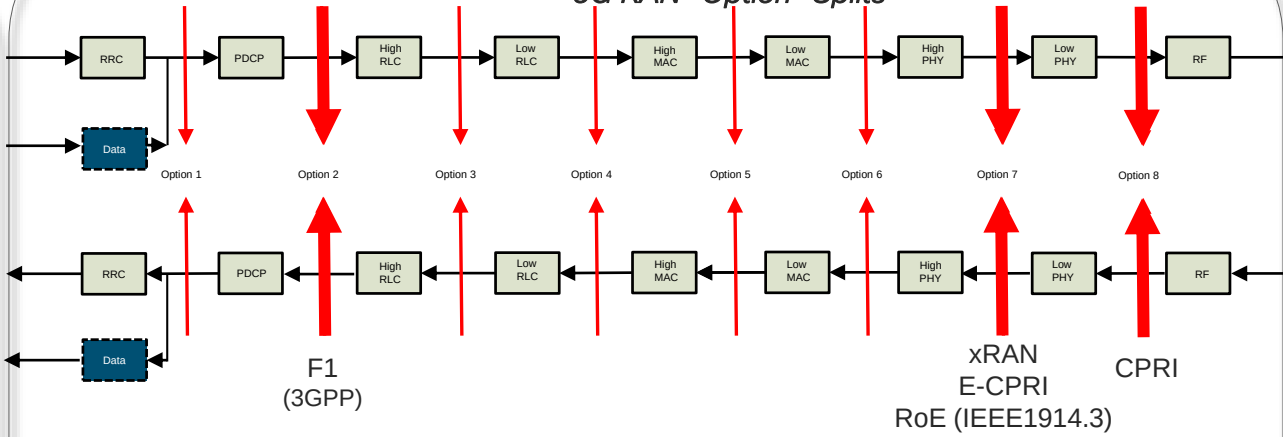
Non-Standalone (NSA):
Multiple radio access technologies



Option 3 *Option 4* *Option 7*

LTE *4G LTE* NR *5G NR*

5G RAN "Option" Splits



Transport costs minimised with higher splits

RF Gains improved with lower splits

Fronthaul Standards

CPRI
Common Public Radio Interface

- CPRI
(Common Public Radio Interface definition to connect RE & REC)
- eCPRI
(Next version of CPRI, connect eRE and eREC over packet based transport)

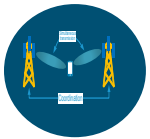
xRAN

- Formed to standardise critical elements of proprietary RAN architectures
- Defines Open Specifications for vendor interoperability

IEEE
Advancing Technology for Humanity

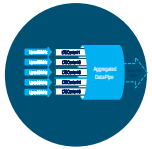
- 1914.1 ROE
- 1914.3 NGFI
(Defines encapsulation and mapping of Radio protocol over ethernet; including Fronthaul functional split definition)
- 802.1CM
(Specifies TSN profiles for Fronthaul)

RAN Evolution Impact on Transport

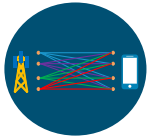


Add Carrier, Sector, Macro Site

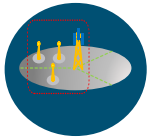
Add new 5G NR to LTE site → 3.5GHz, >24GHz



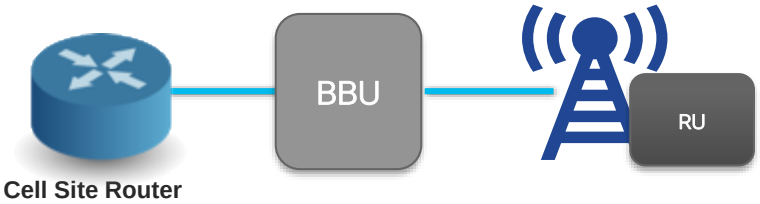
Licensed | UnLicened Carrier Aggregation



Higher Antenna Count → MIMO (4x4, 64T64R)

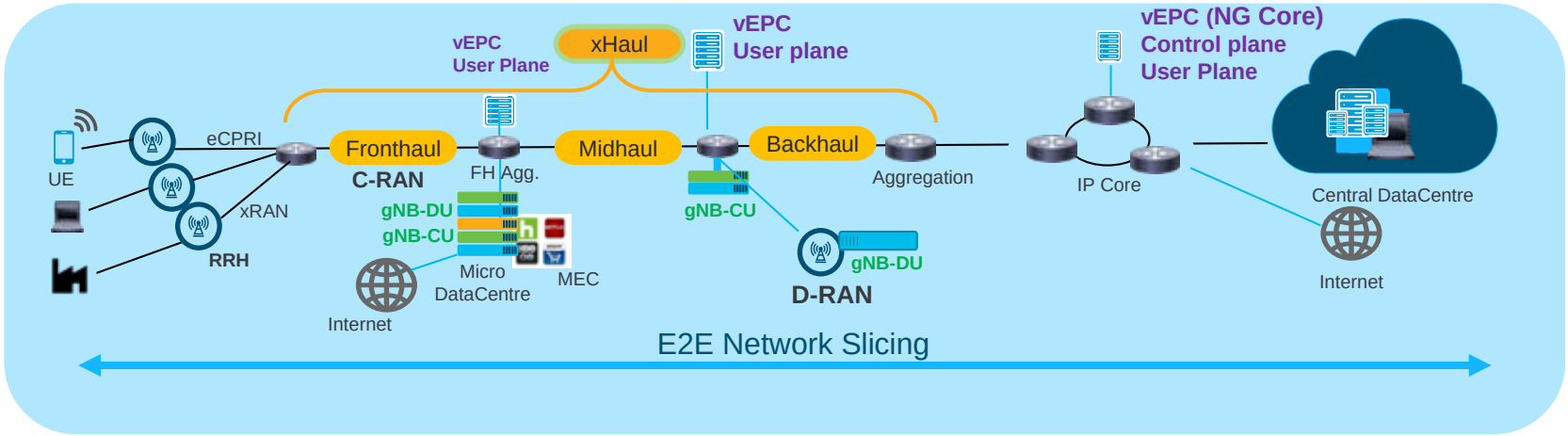


HetNet Layers (Small Cells to offload Macro network)



- 5G NR will have 10G/25G interfaces
- Due to fibre constraint, Bidi optics will be required
- High density of 10G/25G at Access
- Dense100G in Pre-Agg & Aggregation
- 400G in IP Core

5G E2E Network Transport Evolution



- Centralised Services, **North-South** traffic
- **Centralised DC**
- **Separate** wireline & wireless network

- Flexible Service Placement, **East-West** traffic
- **Edge DC or Edge Compute (MEC)**
- **Converged** network: wireline & wireless

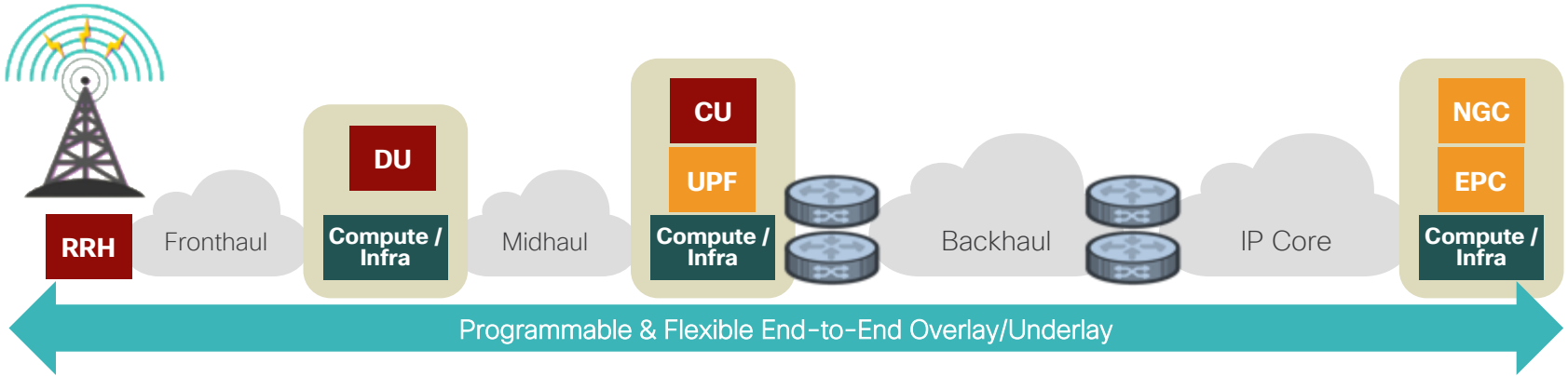
E2E IP is Critical to achieve 5G Transport Requirement

Any-to-Any connectivity - Flexible service placement

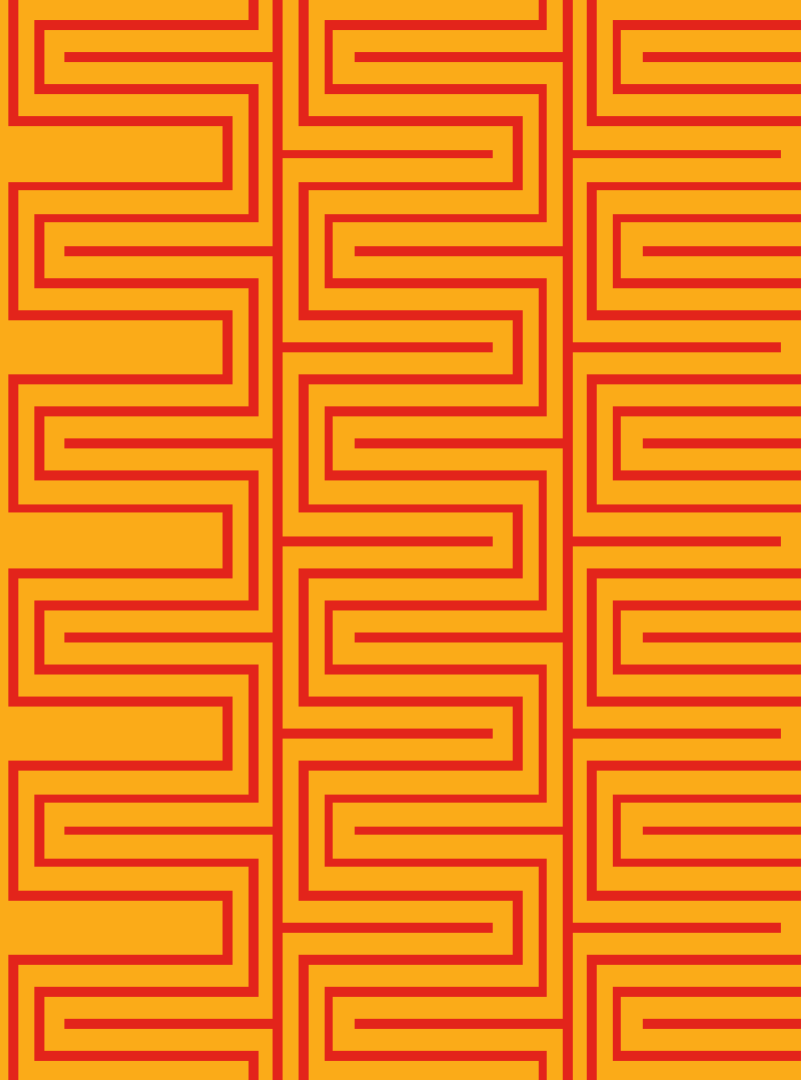
Reduce Network touch points

Soft Network Slicing

End-to-End Security



Cisco 5G xHaul Transport Vision and Strategy



5G xHaul Transport Strategy

Programmable, Massive Bandwidth Portfolio

Converged · Simple (E2E XR) . Mass Scale · Resiliency · Secure· Flexible Service Placement

Network Slicing

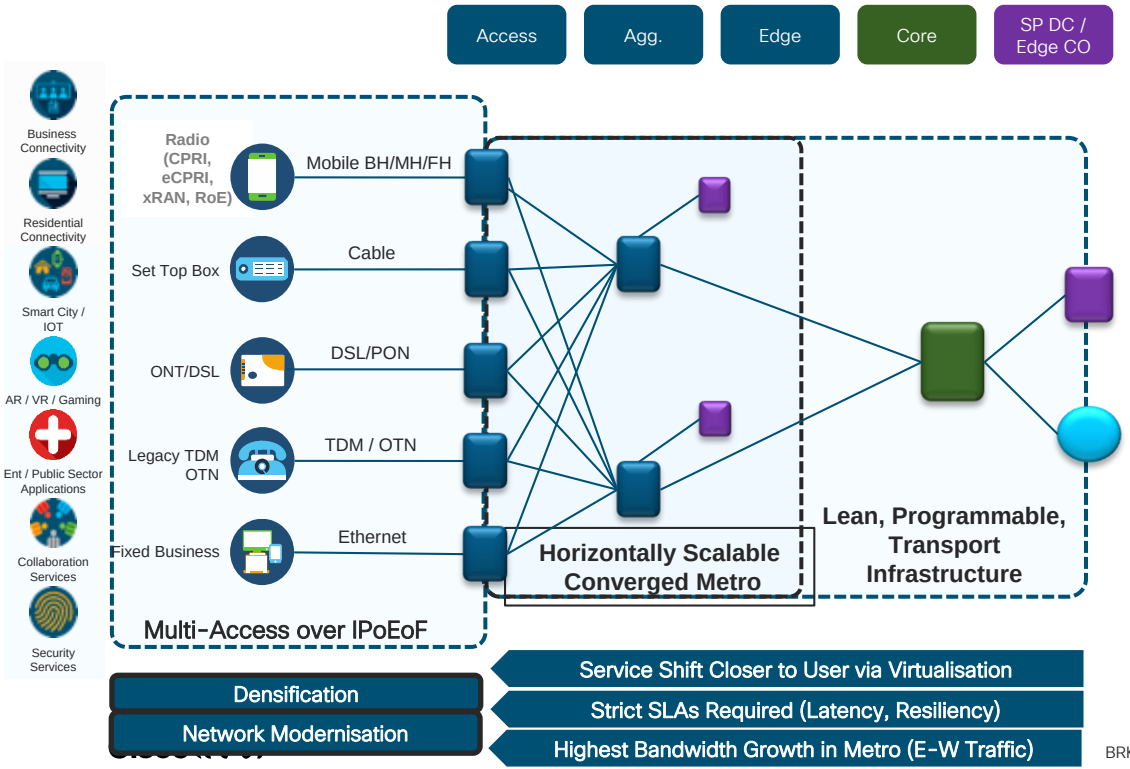
Differentiated Services · Robust SLA · Optimal Infrastructure Efficiency

Open vRAN and Packet-Based Fronthaul

Stat-muxing · Wireline and Any-G Mobile · A la Carte RAN Procurement

Converged Networks
IPoEoF Evolution

Architectural shift



Highlights

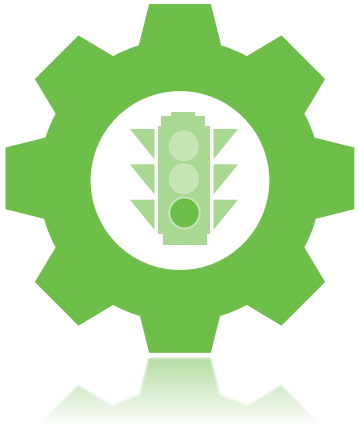
IP over Ethernet over Fiber Infrastructure

Converged Access Infrastructure (Wireline & Wireless)	
Mobile Network Operators (BH/MH/FH)	✓
Cable Operators (Field Router)	✓
Alternate Access Vendor (AAV)	✓
Carrier Ethernet & Business Services	✓

Financial Opportunities

Revenue Opportunities

Network slicing as a Service
Endless Multi-access Edge
Compute Use Cases



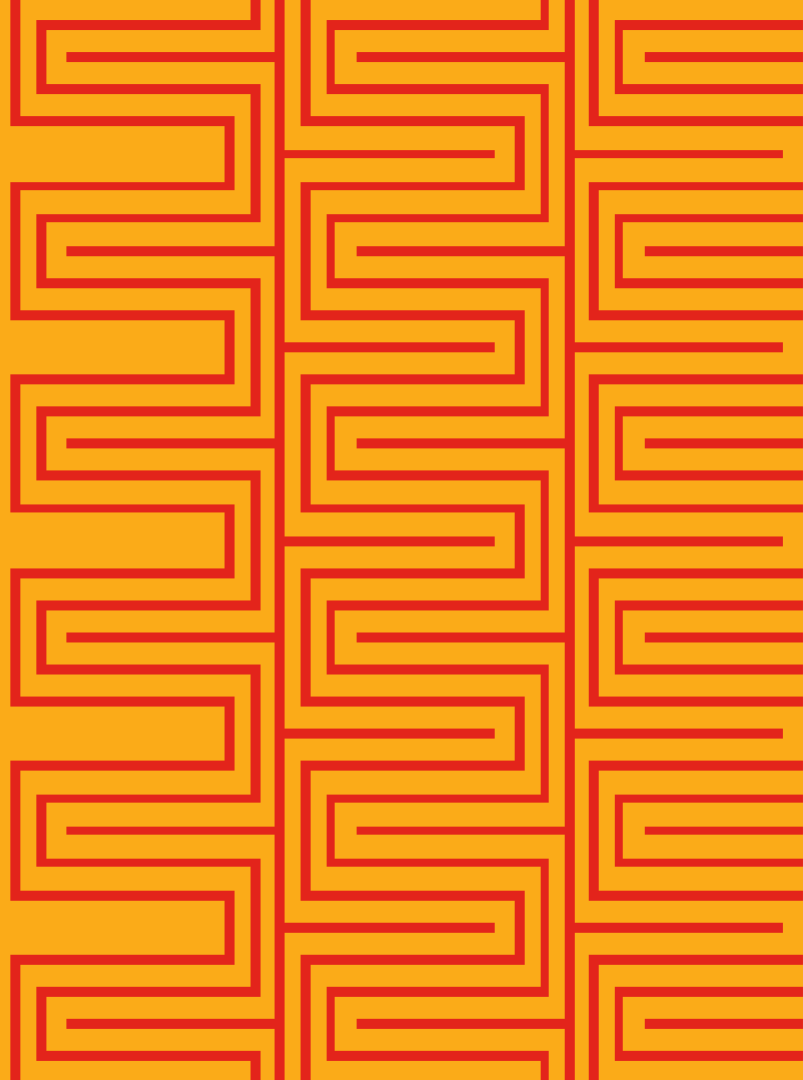
Resource Utilisation

Stat-Muxing · Multi-Services
· Converged Applications

Operating Efficiencies

Simplification · Scale ·
Resiliency · Latency

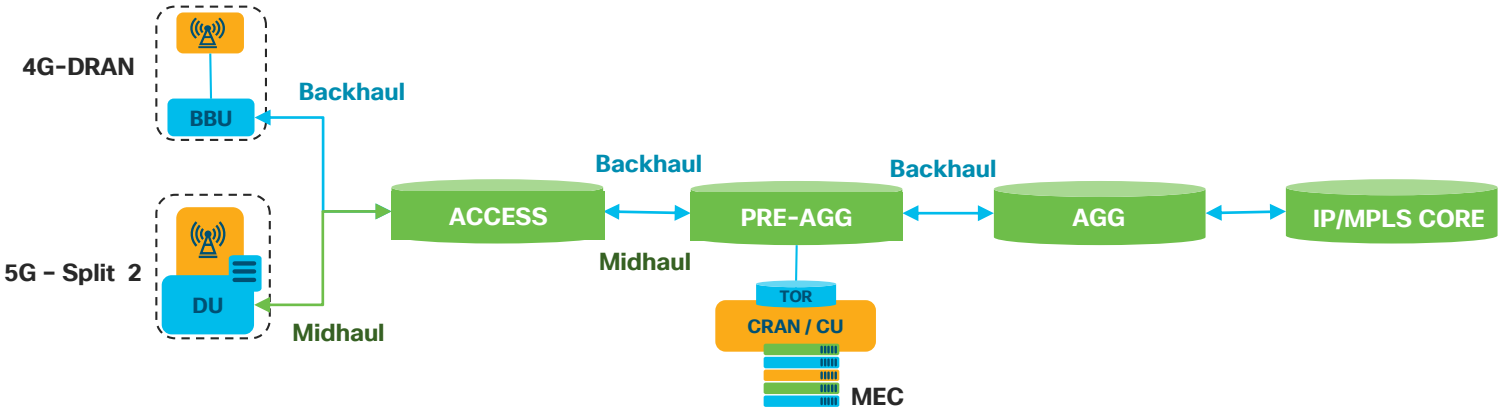
Cisco Converged SDN 5G Transport Solution



Cisco's 5G xHaul Transport Solution

- A single converged packet network infrastructure supporting fixed and mobile services
- 500,000 total network nodes
- Support various 4G / 5G RAN architectures and radio splits
- Support for 5G use cases (eMMB, uRLLC, mMTC)
- Multi-Access Edge Compute (MEC) simply integrated into network fabric
- Concurrent support in transport network for soft transport slicing

“5G Ready” Backhaul and Midhaul Hardware Platforms



C-RAN Fabric	ACCESS	PRE-AGG	AGG	IP Core
• NCS540 Family • NCS550x • NCS560	• NCS540 Family • NCS540	• NCS540 Family • NCS560 • NCS55A1/A2 • ASR990x	• ASR99xx • NCS55xx	• ASR99xx • NCS55xx

Highlights

IOS XR

Dense fixed and modular XR portfolio

Small form factor with low power

Secure with MACSec encryption

IPoDWDM with CFP2 DCO

Wide range from 300G 3.6T

Indoor/outdoor deployments

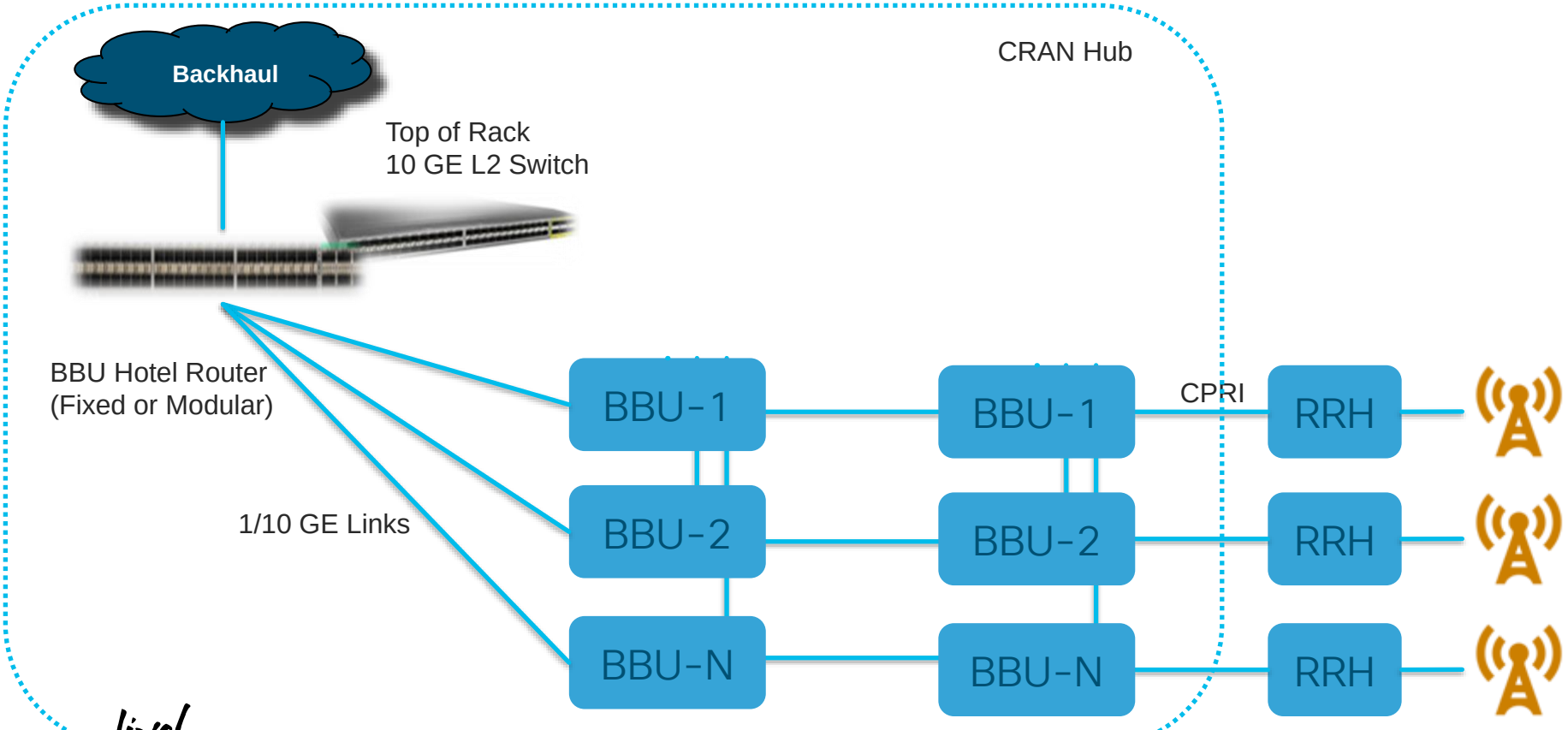
Why Centralised or Cloud RAN (C-RAN)?

Benefits	
Spectral Efficiency Gains Benefits	**Operational Simplicity Benefits (CAPEX/OPEX)**
COMP/eICIC - Increasing capacity and improving performance at cell edges	Reduce power/space overheads – enable Skinny Macro Sites deployments (utility poles, rooftops)
Carrier Aggregation - creating more bandwidth on individual devices by combining the usage of multiple bands	Ease of management (Reduce Cell site management by up to 60%)
Enhanced Radio unit Management and Policy	Enhanced optimisation
Inter-site BBU Pooling	Improved resource efficiency & efficient utilisation of resources
	Benefit of commoditisation (up to 50%)
	Improved policy management & Security

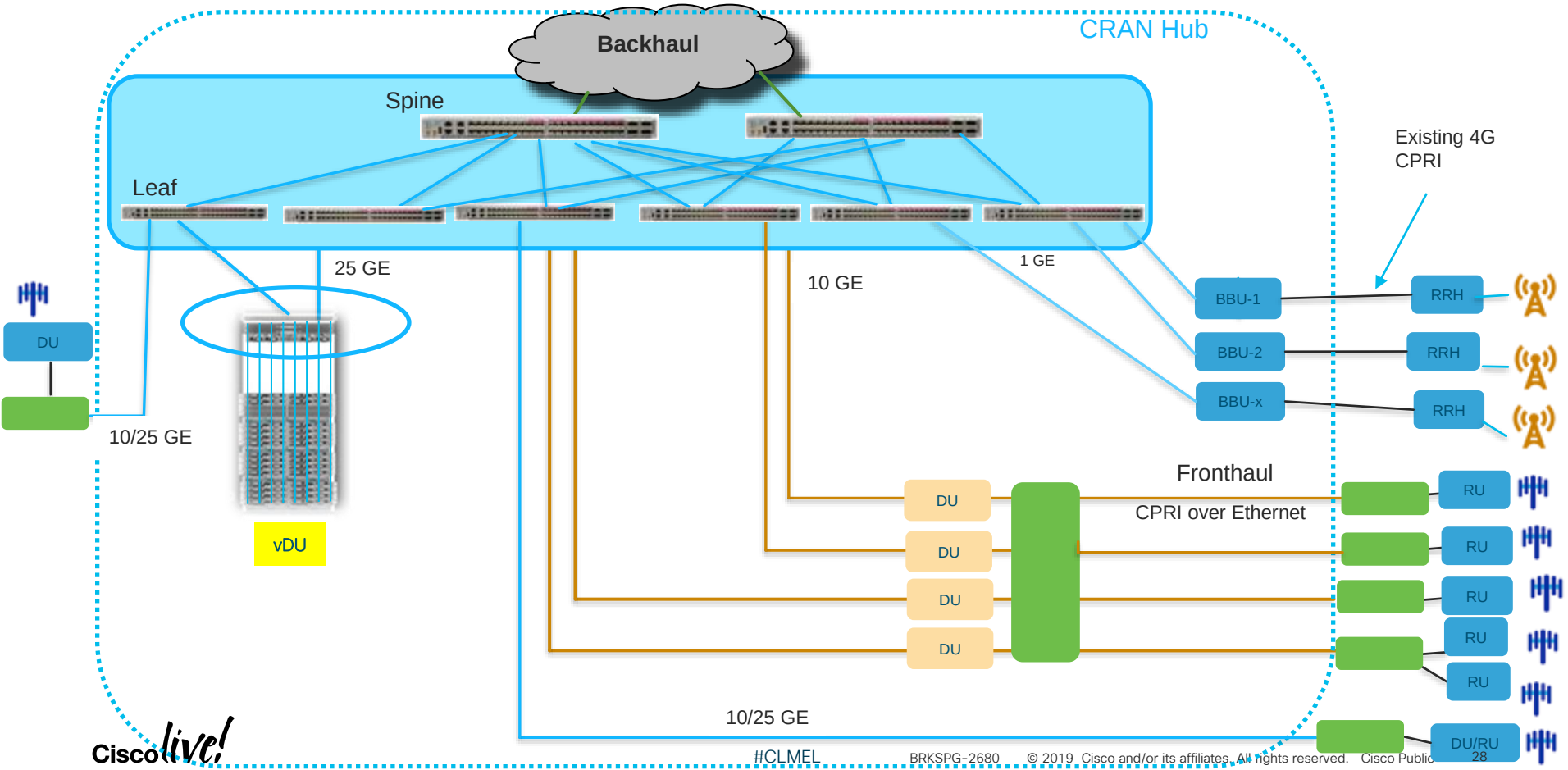
C-RAN Transport Architecture Components

- 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 – cost saving*
- 1588/SyncE – Phase & Frequency clocking support
- Interface Flexibility – 1/10/25G/100G
- Horizontal Scaling for large sites
- Redundancy

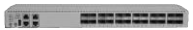
C-RAN Transport Architecture Components



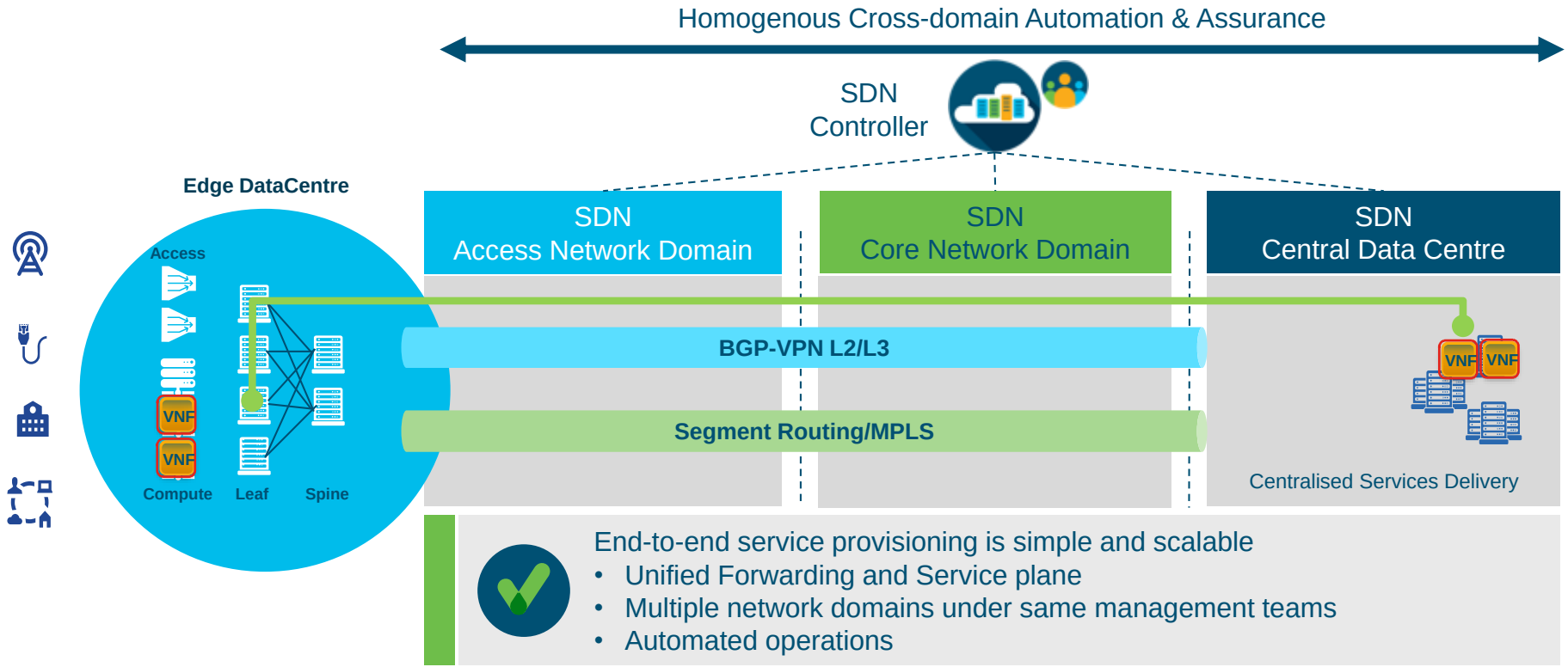
Cisco C-RAN Fabric Architecture



C-RAN (BBU Hotel Router + L2 Switch) 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	Scale only	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 (Bifrost) NCS-55A1-48TQ6H (Turin)	1	1.8 Tbps 900 G	**48 x SFP28 + 6x100G QSFP28** 24x1G/10G ports, 24x1G/10G/25G ports & 6x100G	Y	H1CY19	MEC - Edge Compute ToR
 NCS 540	1	300 Gbps	24x 10GE SFP+ + 8x 25GE SFP28 + 2x 100GE QSFP28	Y	Shipping	MEC - Edge Compute ToR
 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	Q2CY19	

5G xHaul Programmable Transport



Segment Routing: Value Proposition

Create New Revenue Streams
- Differentiate Services with SR Policies
- Intent-Based Value-Add Services

Deploy with Ease
- Seamless Brownfield Integration
- Single Control for Inter Domain Implementations

Monitor Health
- Data Path Validation Including ECMP
- Real Time Per-Link Performance Monitoring with Telemetry

Increase Availability
- Automated 50ms Protection
- Assured Loop-free Convergence upon Recovery

Multi-vendor consensus – Designed and built with network operators

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

Shipping

In Progress

MPLS SR with Controller

MPLS SR: optimised and simplified routing

Centralised management and orchestration

Distributed control plane

Work in Progress

Future

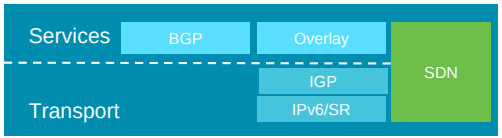
SRv6 with Controller

Further simplification and scaling

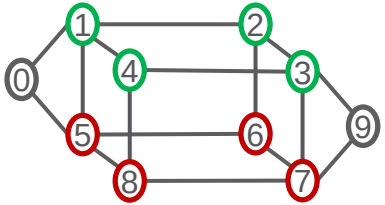
NFV

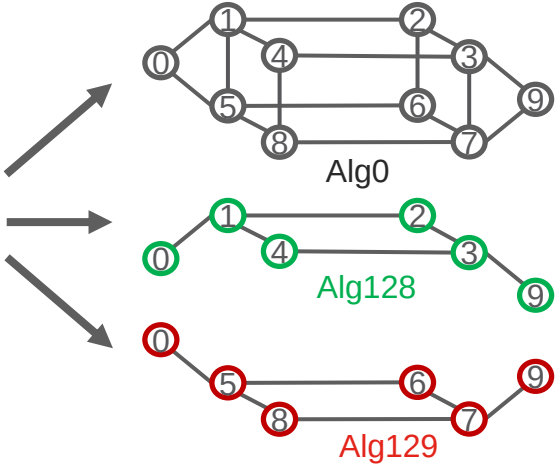
Centralised management and orchestration

Future



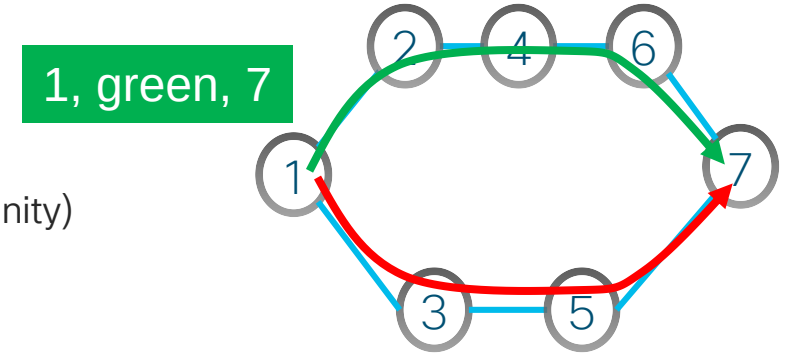
SR: Engineering the Underlay





- **Flex-Algorithm**
  - Builds domain level forwarding tables
  - IGP distributes multiple metrics / affinities
  - Multi-algorithms operational in network
  - SPF, Low Latency, constrained nodes / links (customer chooses)
  - TiLFA per algorithm

- **SR Policies (or SR-TE)**
  - Builds paths between nodes
  - Path computation based multiple constraints (b/w, latency, affinity)
  - Calculated by head-ends or an SR-PCE
  - Multi-domain / disjoint paths require SR-PCE



Example Green: Low latency, Red: IGP path

SR – Service Aware Traffic Steering

- Traffic Steering

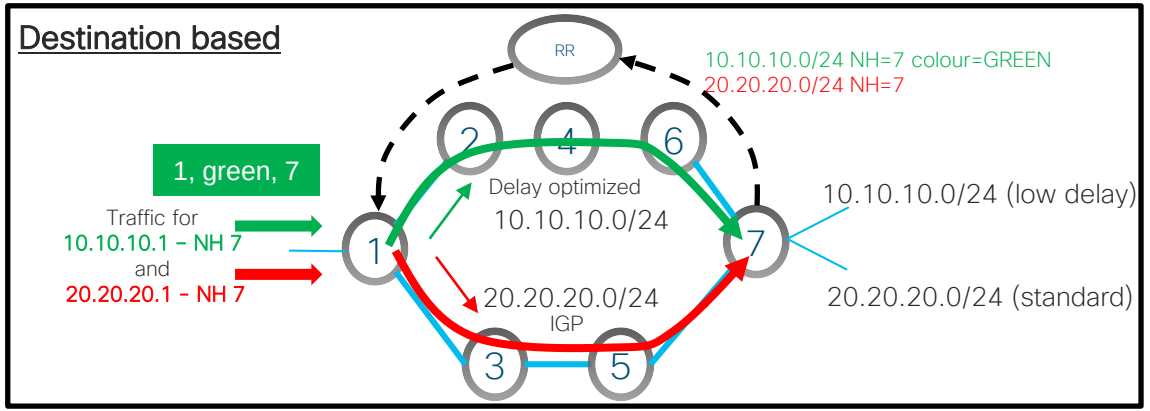
  Mechanism on source router to steer traffic

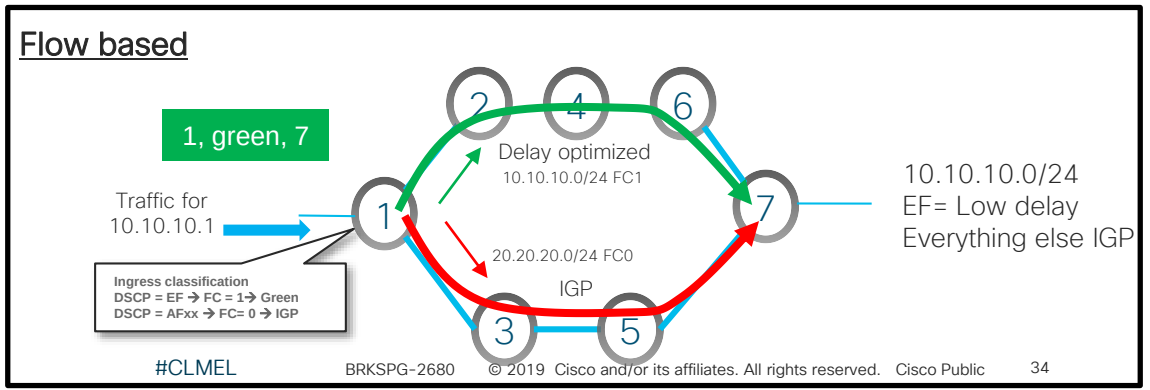
  By default traffic uses IGP path

  Can steer traffic into a SR policy or specific Flex-algos

  Destination TS : destination only

  Flow based TS : destination + QoS criteria





Real-Time Low Delay services

Applicability Examples

Extreme Real-time Communications

Tactile Internet

Voice Communications

Fixed / Mobile

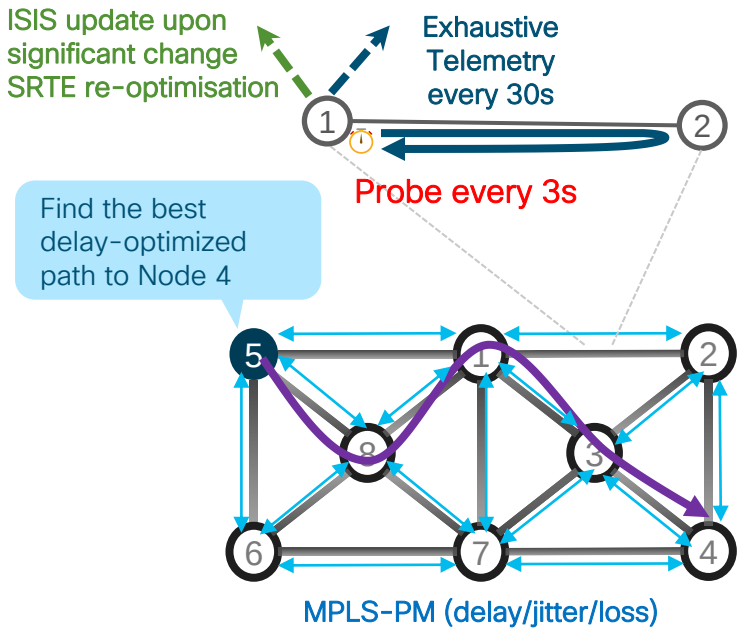
Solution

Compute Low Latency path based on measured link delay/jitter/drop with Performance Monitoring (PM)

Benefits

Simplicity and Automation
Troubleshooting tool
Meet, Maintain and Monitor SLAs at all times

MPLS Performance Monitoring (PM)



SR Path Computation Element (SR-PCE)

SRTE Head-End

Distributed Mode – SR-TE Head-End
Visibility is limited to its own IGP domain

Solution

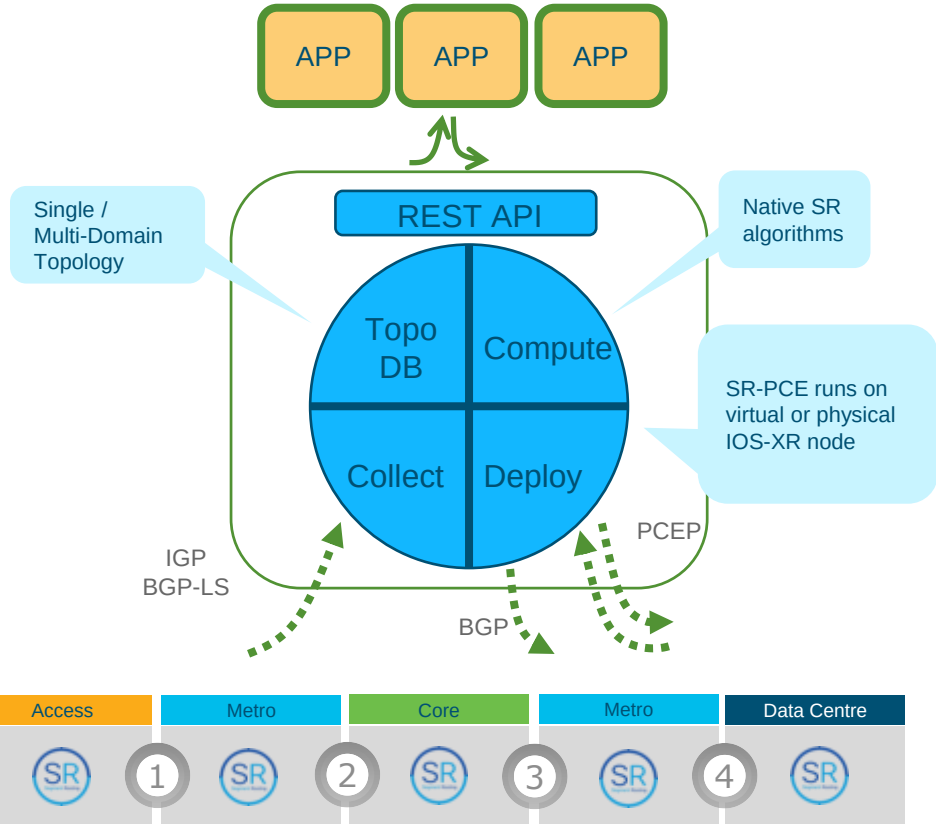
Multi-Domain SRTE Visibility
Centralised SR-PCE for Multi-Domain Topology view

Integration with Applications
North-bound APIs for topology/deployment

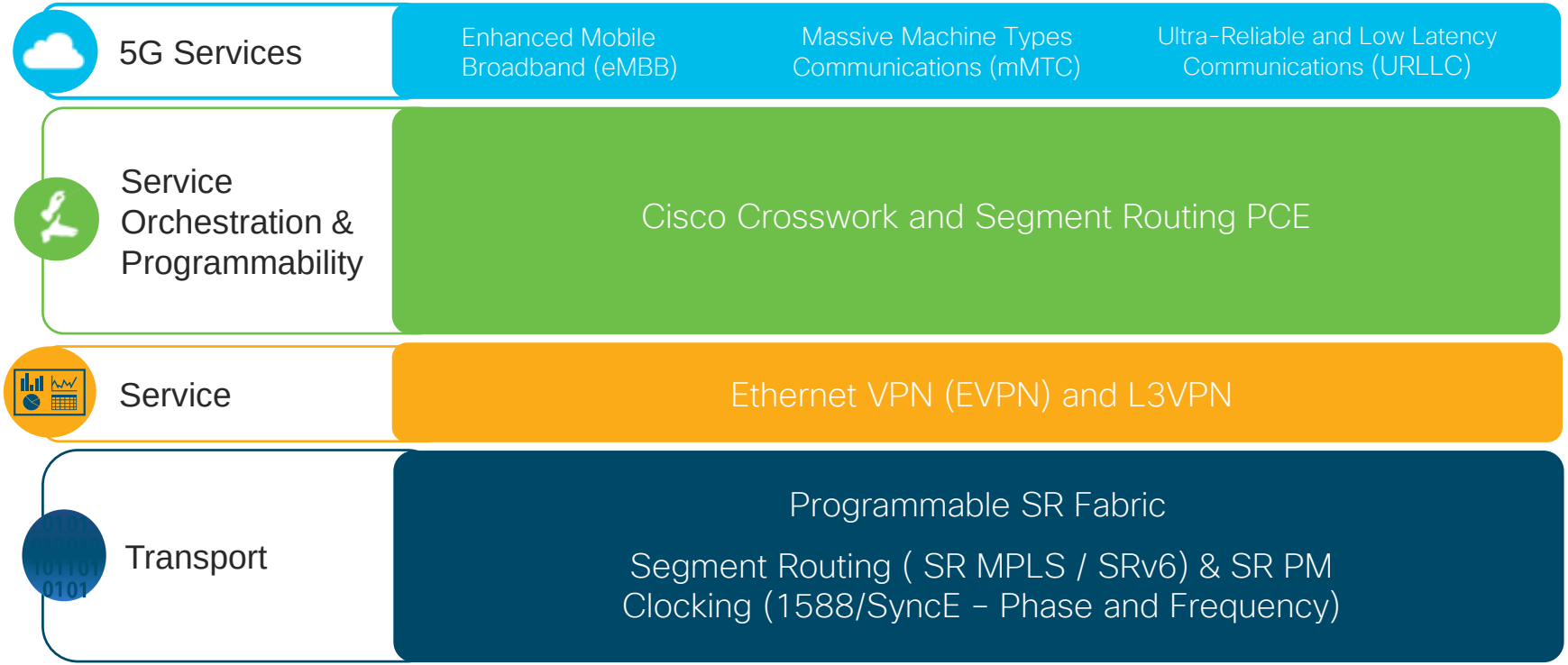
Delivers **across the unified SR Fabric** the SLA requested by the service

Benefits

Simplicity and Automation
End-to-End network topology awareness
SLA-aware path computation across network domains
Disjoint paths
Multi-domain path computation and ODN



“LTE to 5G” Transport Summary



Timing and Synchronisation

Why Synchronisation?

Audio / Video Voice Communications

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

Wireless Networks

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

Application Impacted

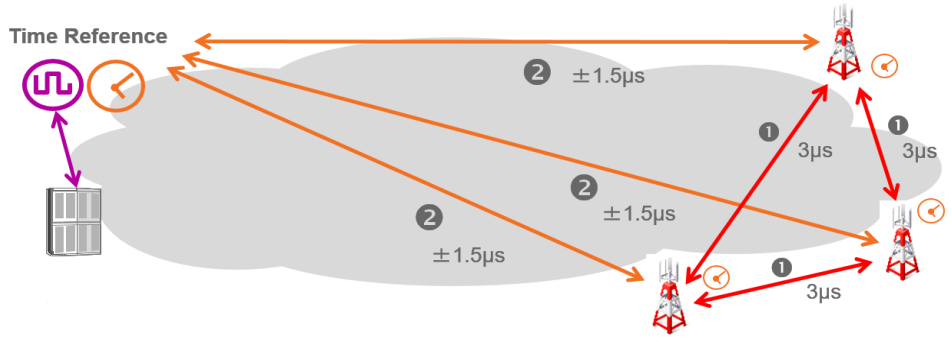
- Location Services
- Industrial Automation
- Smart grid
- IoT
- Network Monitoring

Timing and Synch – New Phase Requirements

- 5G (like modern LTE-A networks) requires phase synchronisation
- New 5G TDD radios definitely require it:
  - ❶ 3GPP: 3µs between base stations (for TDD, LTE-A radio co-ordination)
  - ❷ Radio backhaul network: ±1.5µs from reference time
- 5G Timing and Synch – Fronthaul (eCPRI, xRAN, RoE)

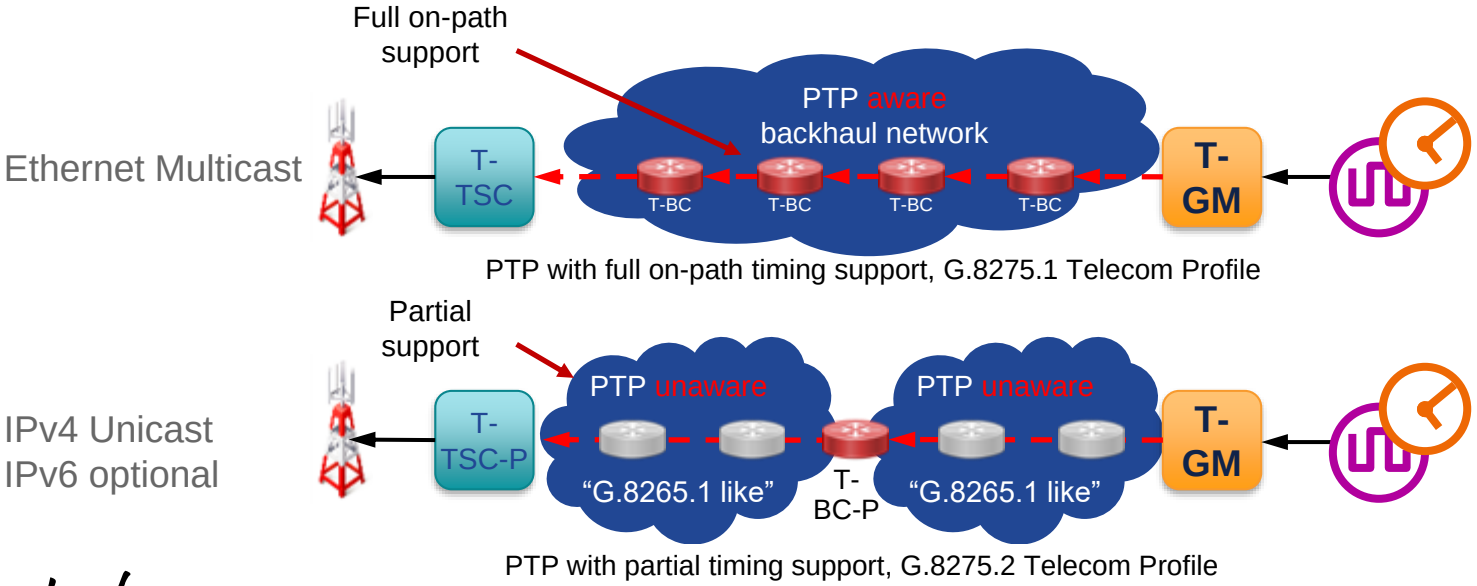
- **GNSS (GPS, Galileo) Receivers**
- **PTP/1588 and SyncE in Transport Network**

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



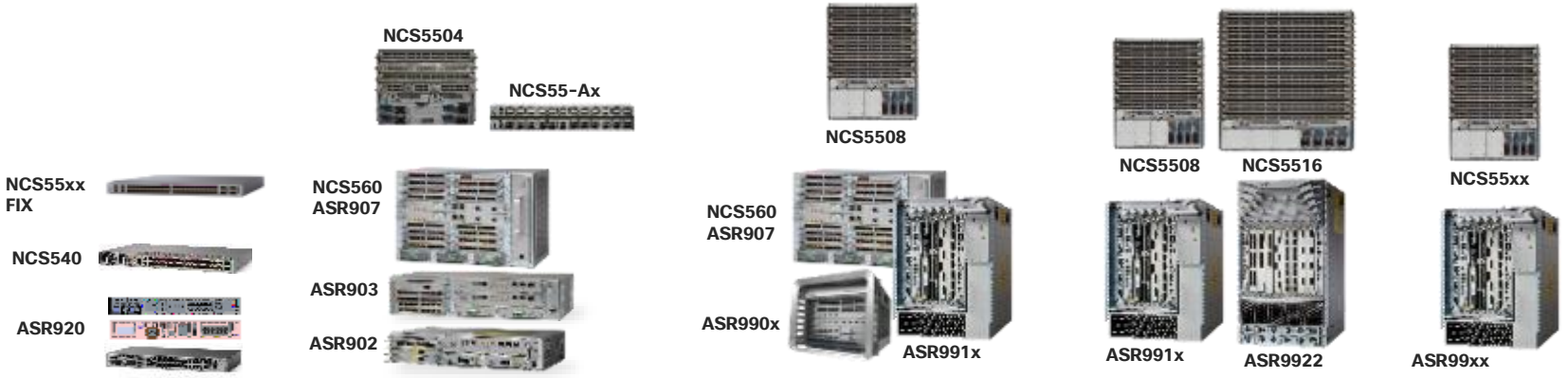
Timing and Synch – PTP Profiles for Phase

- There are various profiles available for use
  - Most operators looking at G.8275.1 – the best timing solution
  - Supported across Cisco ASR900, ASR920, NCS500, NCS5500, ASR9K range



Cisco Timing and Synchronisation

Strong Feature support and roadmap



* SyncE, PTP 1588v2-2008, G.8265.1, G.8275.1, G.8273.2 Class A / B, G.8275.2, Multi-profile support , Asymmetry correction

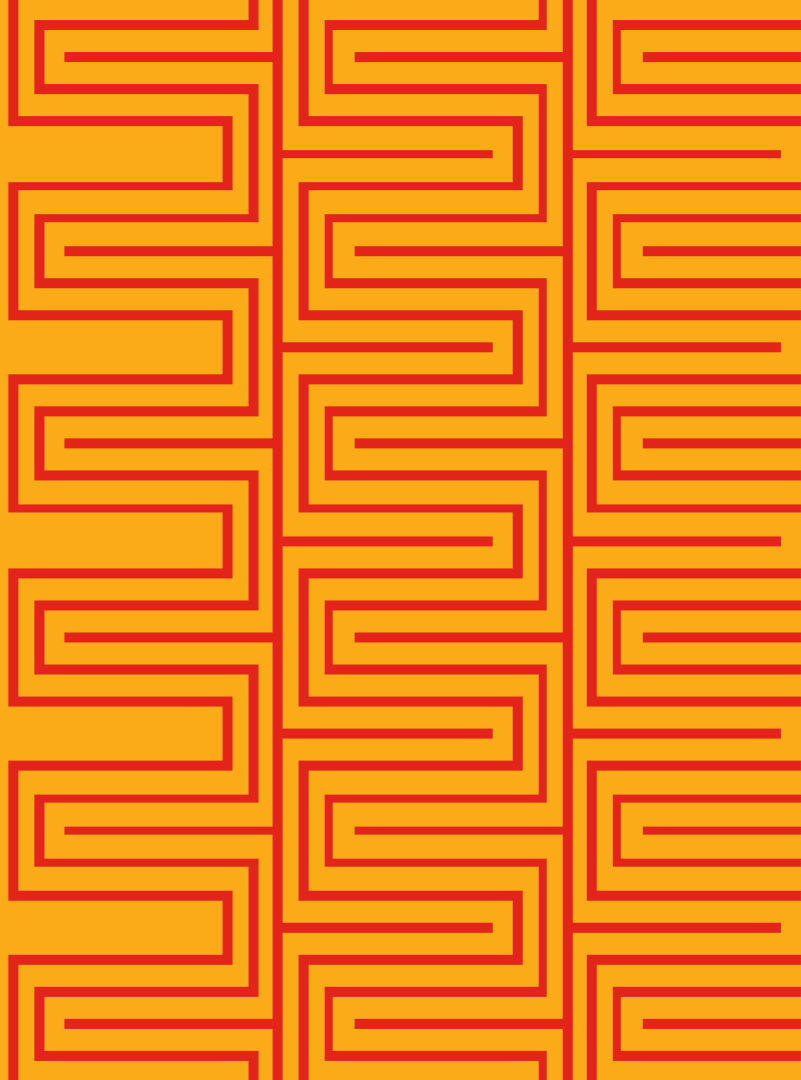
* Roadmap: eEEC, PRTC-B, Class C

802.1Qbu (TSN) Requirement

- 802.1CM - Profile A: Strict Priority & Profile B:802.1Qbu Frame Preemption
- 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 utilisation
- 802.1Qbu is NOT required on 100G interface
- Frame Preemption is a book-ended solution

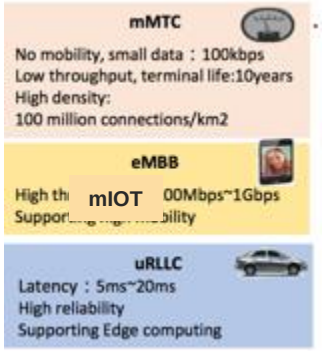
Port Rate	Without Frame Preemption delay (1500 byte delay)	Without Frame Preemption delay (9600 byte delay)	With Frame Preemption (123 byte delay)	Frame Preemption Advantage (compared to 9600 byte delay)
1G	12,000 nsec	76,800 nsec	984 nsec	~ 75 usec
10G	1,200 nsec	7,680 nsec	98.4 nsec	~ 7.5 usec
25G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

Network Slicing

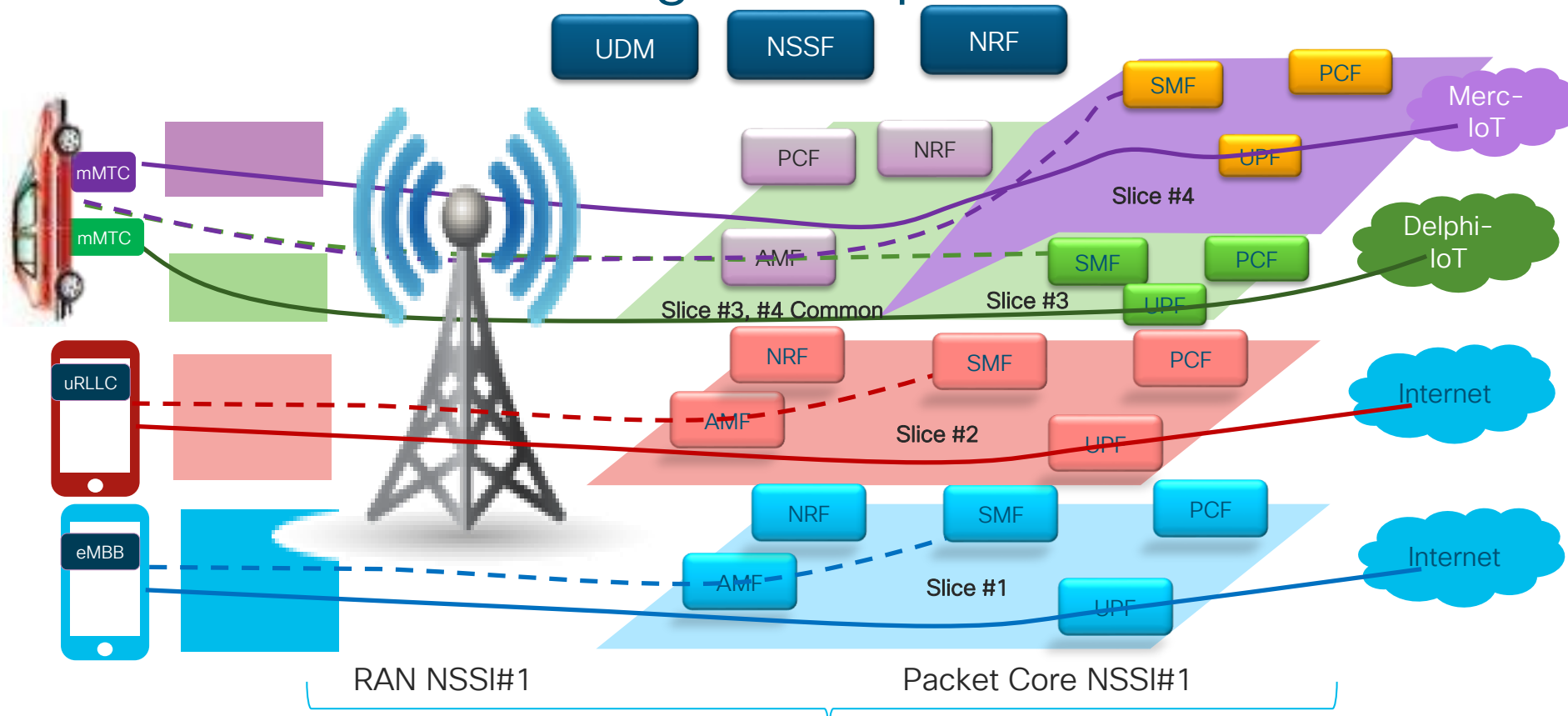


Why Slice?

- **Isolation of traffic** for different SP Customers
  - Customers may be different enterprises
- Create core-networks, transport and RAN **slices tailored to meet KPIs of specific services**
  - Three main service families:
    - mIOT services
    - eMBB services
    - uRLLC services
- Network Slice Instance (NSI)
  - Aggregate of several NSSI
- Network Slice Subnet Instance (NSSI)
  - Group of network function instances belong to a NSI
  - E.g. NSI #1=Packet NSSI #1 + RAN NSSI #1

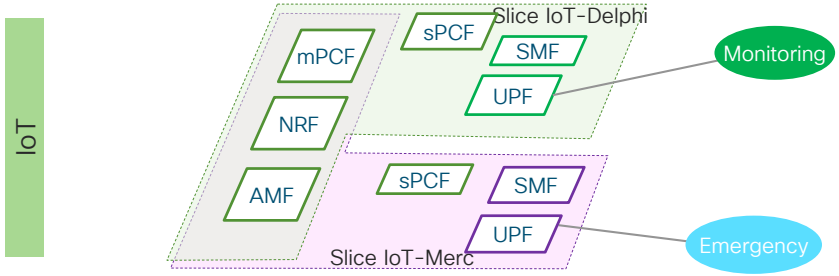


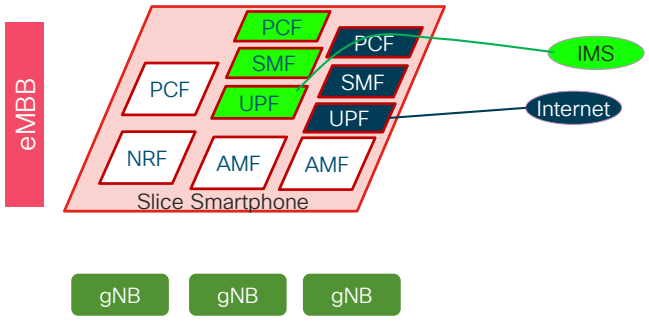
3GPP Network Slicing Concept



Slice ID

UDM





gNB gNB gNB

UDM

Device

SST	Slice Differentiator	DNN
3	SP456	Ent_Monitoring
3	SP103	Ent_Emergency
1	SP007	Ent_Surveillance
1	SP002	SP_Internet
1	SP001	SP_IMS
2	SP225	Ent_LowLatency

Subscribed Slice IDs

SST	Slice Differentiator	DNN
3	SP456	Ent_Monitoring
3	SP103	Ent_Emergency
1	SP007	Ent_Surveillance
1	SP002	SP_Internet

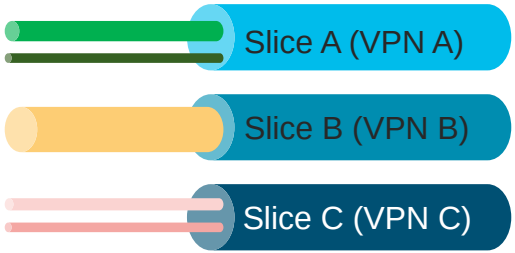
Configured Slice IDs

Slice Type	Slice Type Value
eMBB	1
URLLC	2
mIoT	3

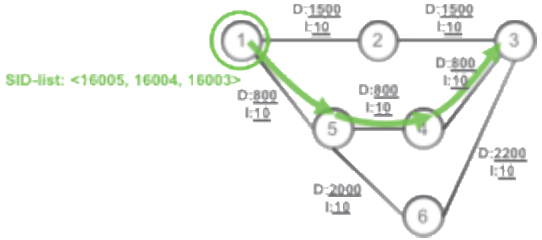
Slide ID = S-NSSAI
Slide ID Set = NSSAI

S-NSSAI: Single Network Slice Selection Information

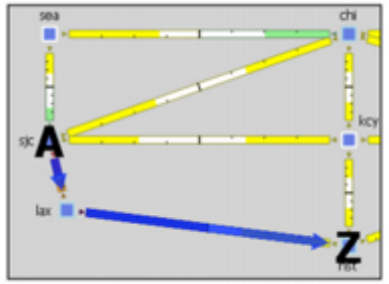
Cisco Soft Network Slicing Transport Solution



Traffic isolation & Differentiated Services



Low Latency Path



Bandwidth Optimization

Network-wide Service Orchestration (NSO)

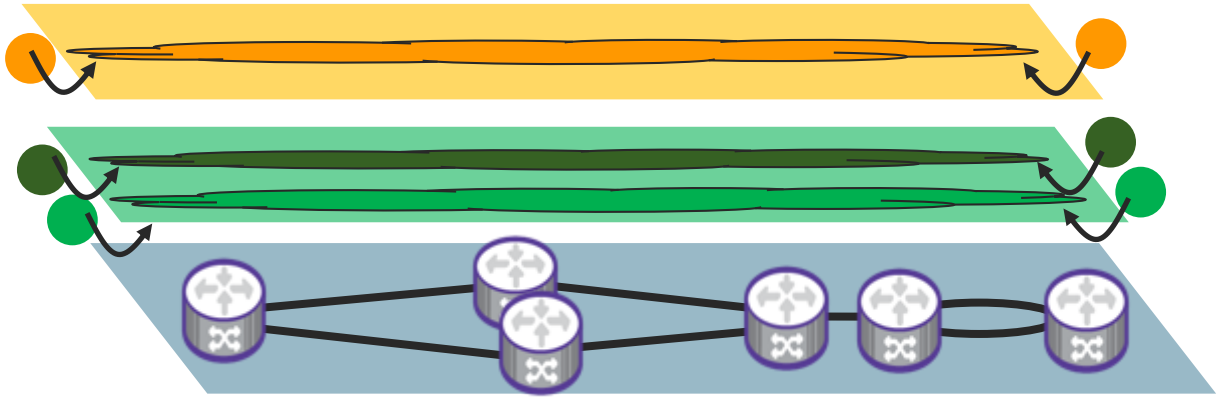
WAE
Network Bandwidth

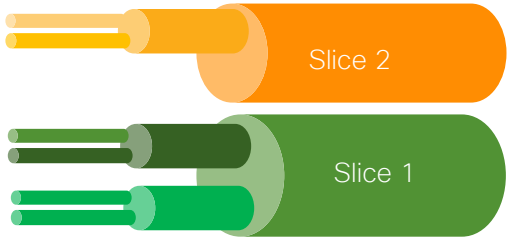
SR PCE
SR PCE Controller

BGP-LS
Topology and Latency

Segment Routing Flex-Algo
Create Logical Network Topologies

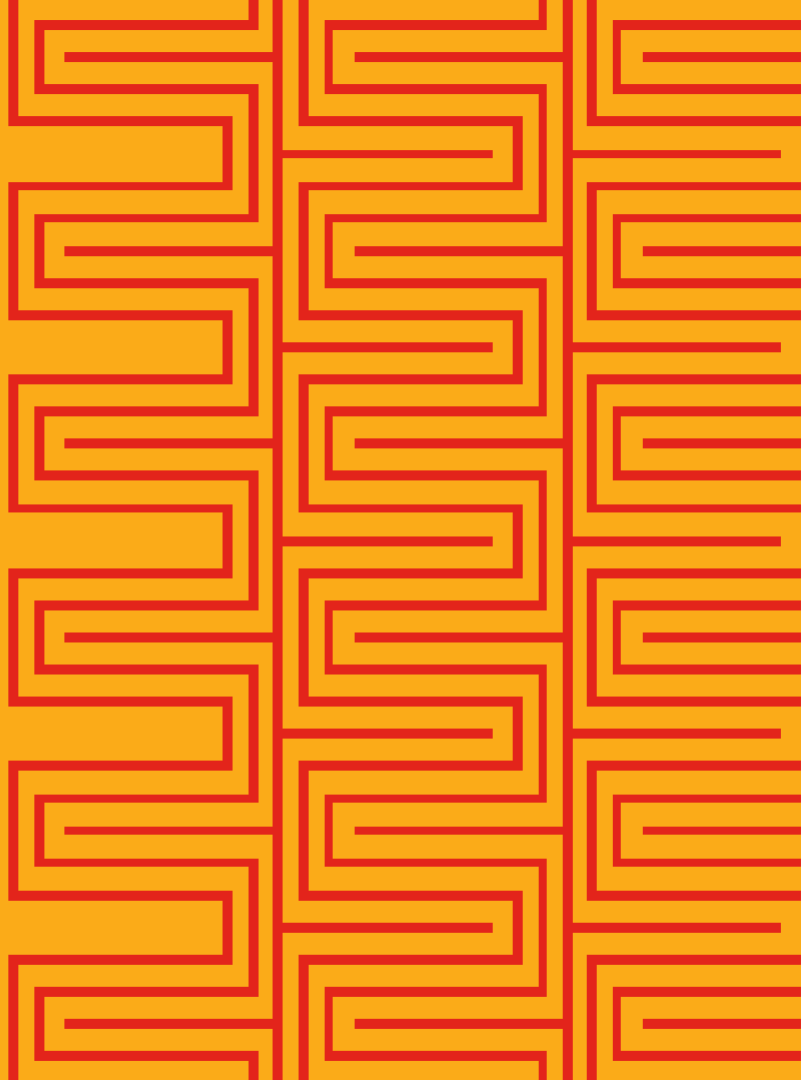
Mapping Customers to Underlay Slice Planes





- L2/L3 VPNs used for customer and service separation
- Potentially large numbers
- Traffic classified and controlled on ingress
- Automated Steering place VPN traffic into correct underlay slice plane

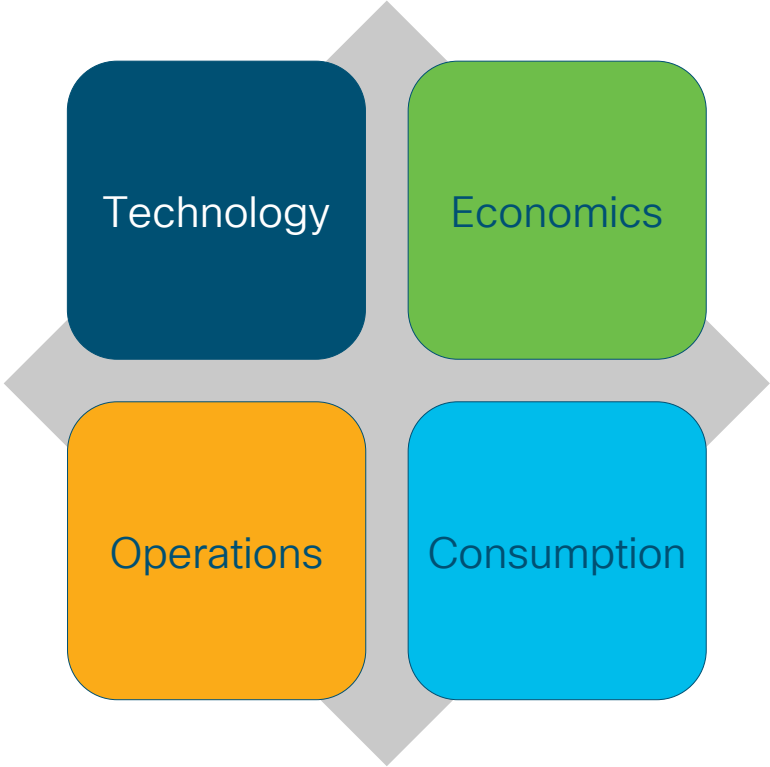
Cisco Open vRAN



Open vRAN Ecosystem Overview

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

Provide Architectural Optionality



Open vRAN Ecosystem Overview

RU

vRAN S/W

Telco Cloud Infra

Mobile Core

Transport

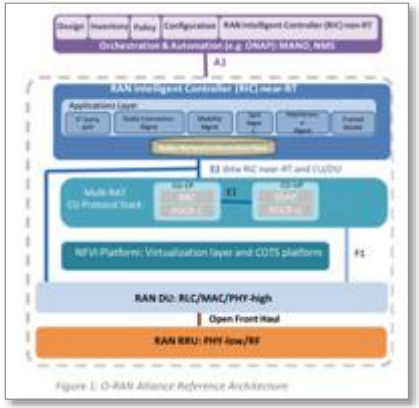
Automation

Services

** PHAZR Acquired by JMA December 2018*

O-RAN ALLIANCE

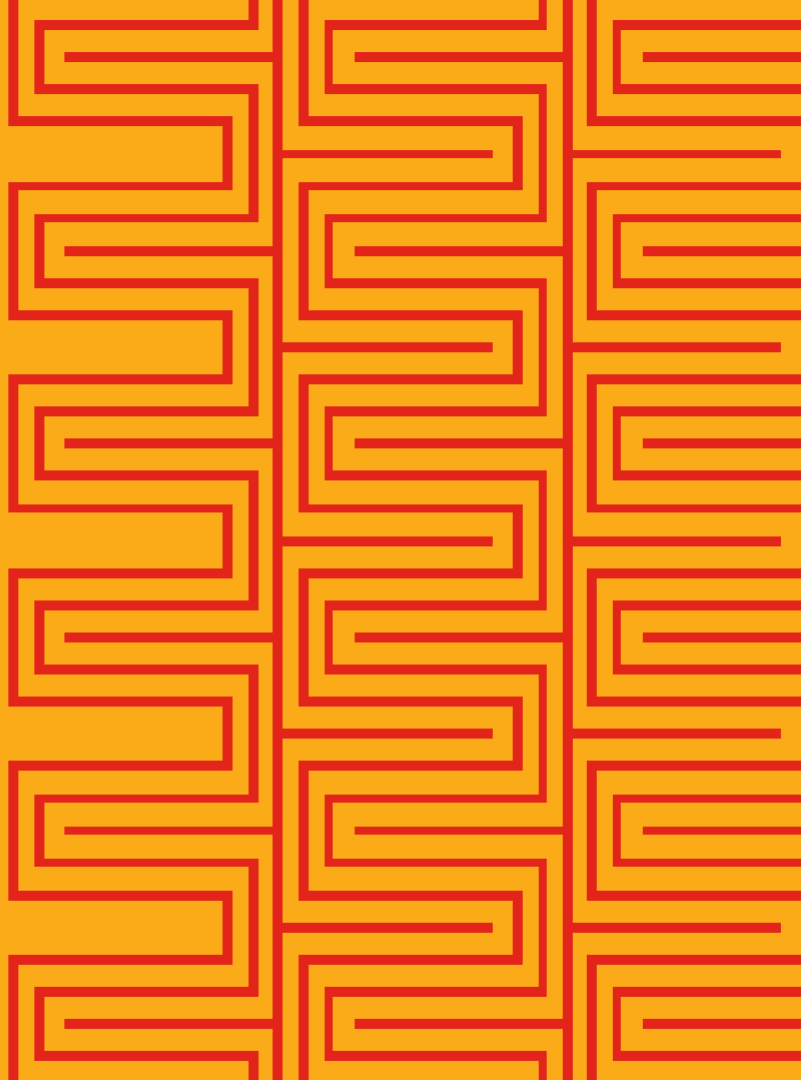
- Operator-Led Industry Alliance
- Key Principles – Open and Intelligent
- Publishing Specifications, conducting testing, PoCs, etc



Open vRAN Ecosystem

- Vendor-led, Operator-driven
- Aligned with O-RAN principles
- Many members contributing to O-RAN specifications, testing, etc
- Accelerating innovation and bringing solutions to market
- Considering additional dimensions of economics, operations, consumption

Multi-Access Edge Compute

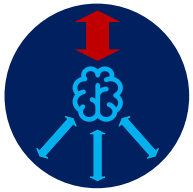


Multi-Access Edge Computing (MEC)

MEC or Edge Computing, is the architectural principle of moving services to locations where they can (1) have lower latency to the device for QoE (2) implement offload for greater efficiency (3) perform computations that augment the capabilities of devices and reduce cost of transport

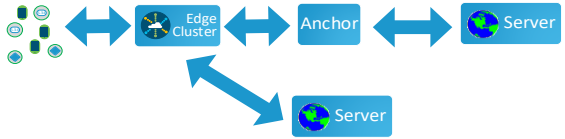
Latency Reduction

Edge Offload



Data Reduction

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



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

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

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

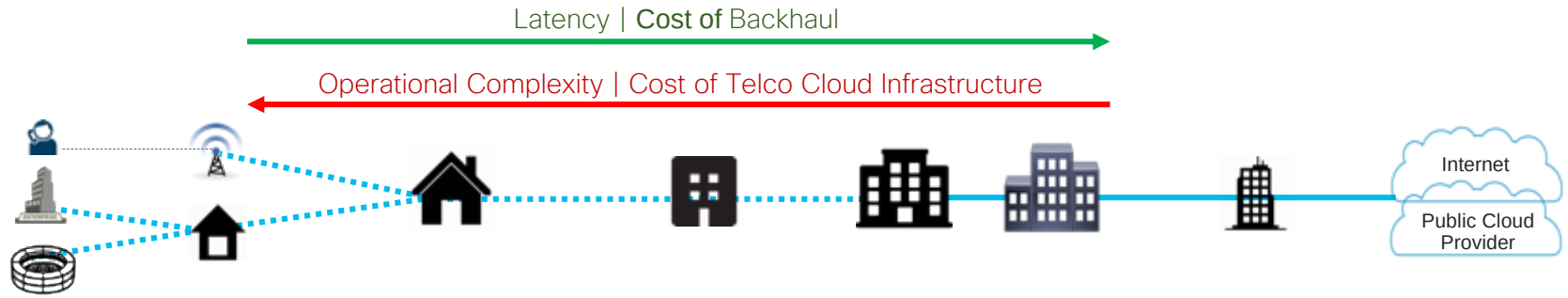
CDN, AR, VR, Connected and Autonomous Vehicle, Fog Computing, Network-Hosted Computing & Enterprise-Hosted Computing

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

Use cases: Brings in partners from which operator derives revenue

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

Automation

Cisco Automation Portfolio

Implement the intent using model-based configuration

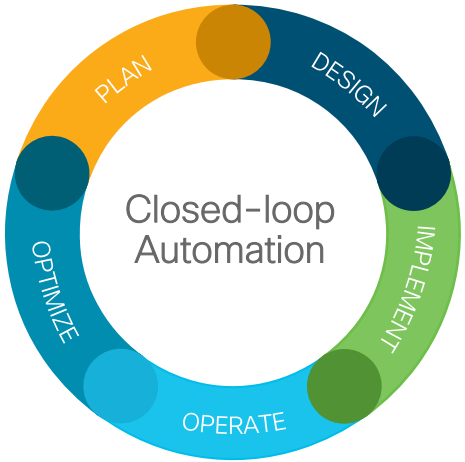
NSO
Network Services Orchestrator

Optimise the network real-time

WAE
WAN Automation Engine (+SR PCE)

Manage a Multi-layer, Multi-service environment

EPNM
Evolved Programmable Network Manager



Cisco Crosswork

Correlate Events and reduce the noise

Crosswork Situation Manager

Automate device operations with playbooks

Crosswork Change Automation

Take action on user defined KPIs

Crosswork Health Insights

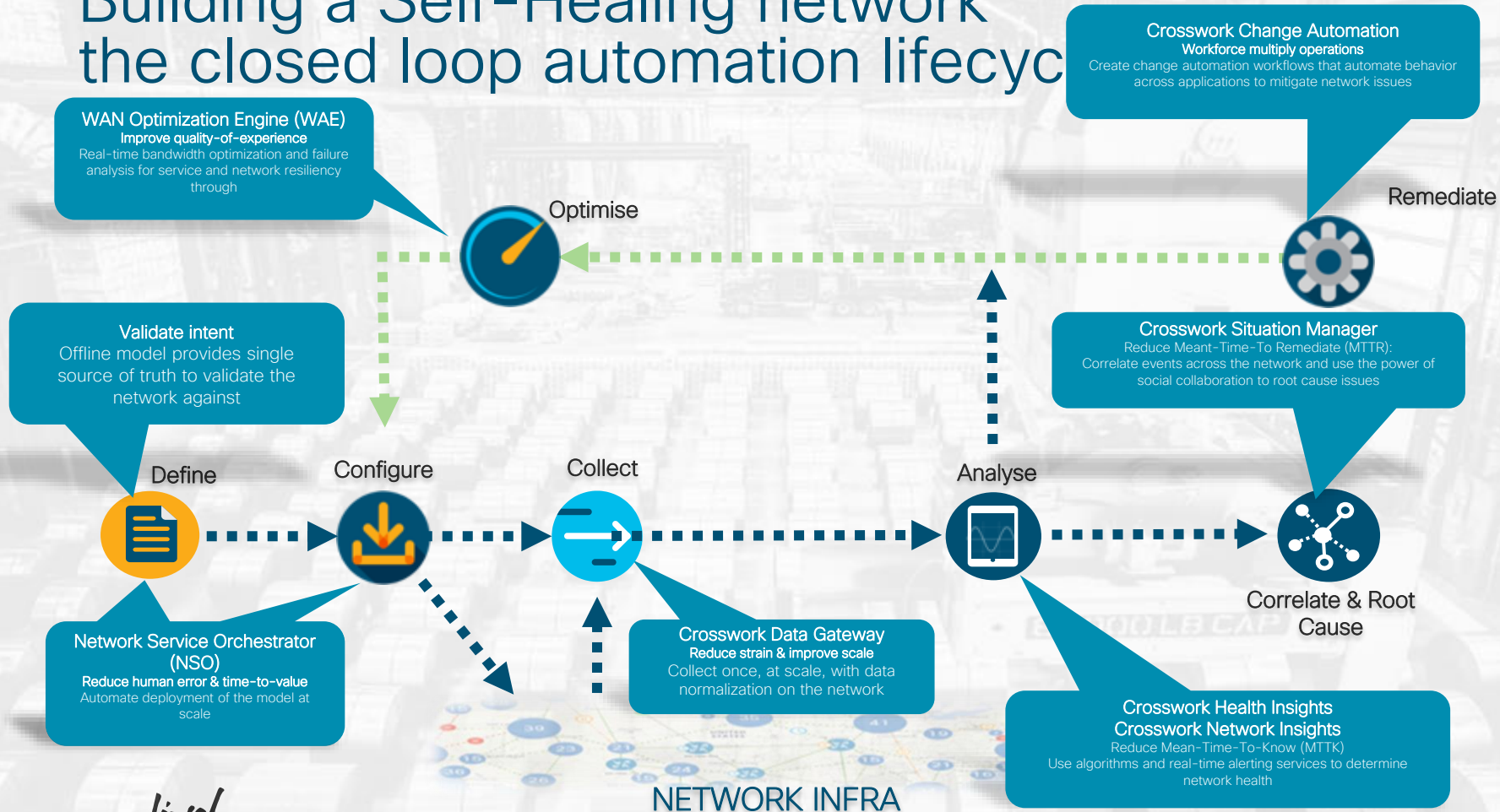
Collect with a common service

Crosswork Data Gateway

Gain visibility with routing analytics

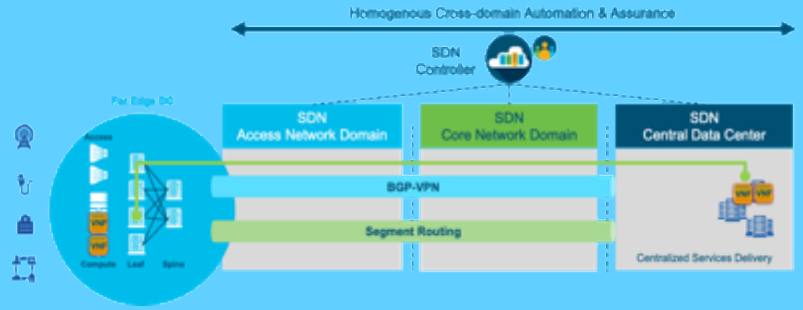
Crosswork Network Insights

Building a Self-Healing network the closed loop automation lifecyc



Customer Case Studies

US Operator



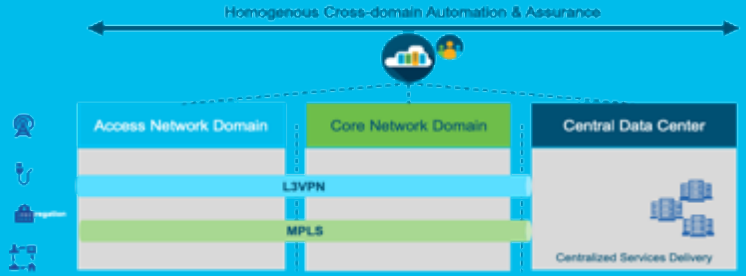
One Network Architecture Delivers All Services with One

Packet based Fronthaul to reduce C-RAN cost

Decomposed Mobile Core for new Services

- Improve 4G LTE coverage and speed the deployment of 5G
- Network Modernisation - Deliver TDM Services over IP
- Deliver high-speed broadband to homes and businesses of all sizes

India Operator



End to End Cisco IP/MPLS Network

5G ready, future-proofing the network

World's Only Exabyte Mobile Data Network

Built on Cisco's Open Network Architecture and Cloud Scale Networking technologies featuring IP/MPLS, spanning areas, including data Centre, WiFi, security and contact Centre solutions

Customer Study

Europe Operator

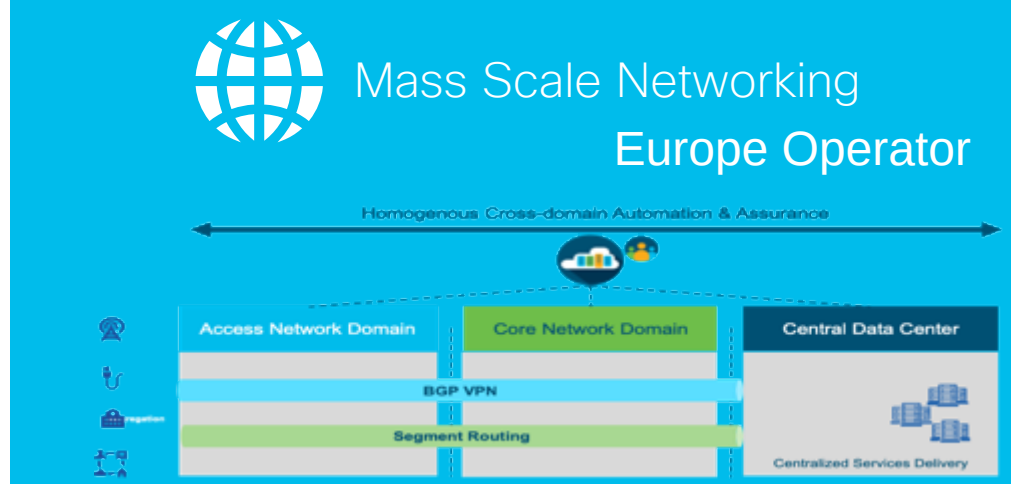
Leadership in Mass-Scale Networking

Approach

Building a transport network to improve customer traffic latency

Business Outcomes

- Dramatically simplify by removing RSVP-TE tunnel full mesh
- Simplify fast re-route configuration by 80%
- Enable programmability and scalability reducing latency by 50%
- Increase network availability through sub-50msec protection on each link and node



Cisco Engagement

Segment routing to help enable increased network simplicity, scale, and programmability.

Why Cisco 5G Network Transport Solution?

Rich Services

- Faster Time-to-Revenue
- Leader in Enterprise, IOT, Wireless
- ML/AI driven service monetization
- Cloud-native strategy

Software Driven

- Open API driven / Programmability
- Flexible OS on any platform
- Flexible consumption model
- License portability

Secure, Mass-scale Portfolio

- Most scalable, high bandwidth E2E transport portfolio
- SDN driven Framework
- Trusted platforms
- FIPS / secure transport product line

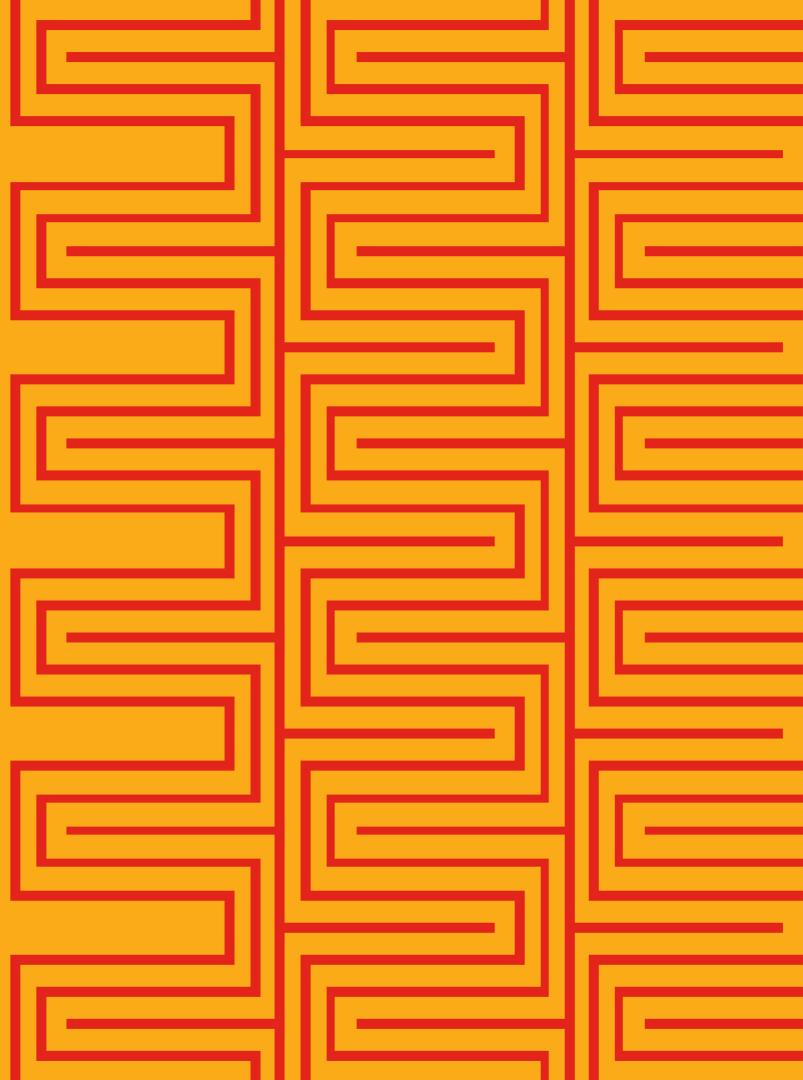
Cross-Domain Automation

- Transformational Operational Model
- Multi-Domain
- ML/AI Driven Framework
- Simplified Operations
- Innovative MTTR

RAN agnostic

- Transport RAN vendor agnostic
- Supports 5G/4G/3G
- Open vRAN consortium
- Yang-model-based fronthaul management

Helpful Links



Cisco xHaul Transport Whitepaper

- "Cisco 5G xHaul Transport" White paper
  - 5G xHaul WP (HTML): https://www.cisco.com/c/m/en_us/network-intelligence/service-provider/digital-transformation/converged-5g-xhaul-transport.html?cachemode=refresh
  - 5G xHaul WP (PDF): https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/mobile-internet/white-paper-c11-741529.pdf
- Lightreading "Cisco 5G xHaul Transport" webinar and whitepaper
  - 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

- Cisco 5G Page: www.cisco.com/go/5g
- Cisco's SP Mobility Page:
  - https://www.cisco.com/c/en/us/solutions/service-provider/mobile-internet/index.html
- Compass "Metro Fabric Design" : https://xrdocs.io/design/
- Segment Routing Information:
  - https://www.cisco.com/c/en/us/solutions/service-provider/cloud-scale-networking-solutions/segment-routing.html
  - www.segment-routing.net
- Cisco Telco Page:
  - http://www.cisco.com/go/telco
- Cisco 5G Security White Paper: https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/service-provider-security-solutions/5g-security-innovation-with-cisco-wp.pdf
- Cisco EPN5.0 & EPN4.0:
  - https://www.cisco.com/c/en/us/solutions/enterprise/design-zone-service-provider/programmable-network.html

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 soft transport slicing
- Cisco Converged SDN-Enabled Transport enables more capex efficiency, better opex utilisation, & faster time to service

Q & A

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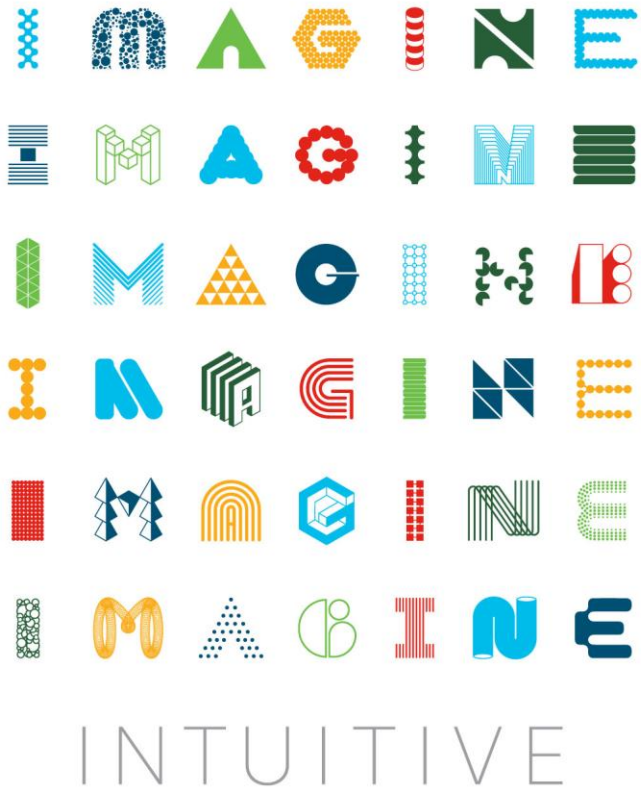
  https://ciscolive.cisco.com/on-demand-library/

Thank you



Backup Slides

L3 and L2 Network Efficiencies Are Almost Same!

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

CPRI/eCPRI Peak Throughput Comparison

Parameters	eCPRI/XRAN	CPRI	Units
Carrier size (5G NR)	100	100	MHz
CPRI sampling rate		122.88	MHz
I/Q quantization	8+8	15+15	bits
Number of TRX		64	
Max # of spatial layers	16		
Overhead	17%	10%	
Compression factor		2	
Peak throughput	**28**	**129.8**	**Gbps**
Ratio	4.7		

"5G RAN CU - DU network architecture, dimensioning and performance requirements" by NGMN Alliance

Dimensioning Transport Network

- Rule of thumb
  - Transport network should be dimensioned in a way that at least 1 sector with peak rates plus the other two sectors with average data rate is supported.
  - Data rates on the air interface with the new NR mmW
    - Peak data rates up to 4 Gbps (assuming 100 MHz carrier bandwidth, 8 MIMO layer)
- Multiple LTE carriers will be upgraded with a NR carrier.

Deployment example:

		Backhaul	HLS
LTE:	30 MHz@1.8 GHz - 3 sectors 4T4R	500 Mbps	
LTE:	20 MHz@2.6 GHz - 3 sectors 4T4R	300 Mbps	
LTE:	10 MHz@0.9 GHz - 3 sectors 2T2R	100 Mbps	~1Gbps
LTE:	10 MHz@0.8 GHz - 3 sectors 2T2R	100 Mbps	
5G NR:	100 MHz@3.5 GHz - 3 sectors 64T64R	8 Gbps	(10-)25Gbps

- 10G optical interface, which would be sufficient
  - 25G interface might be the better choice for future proofing

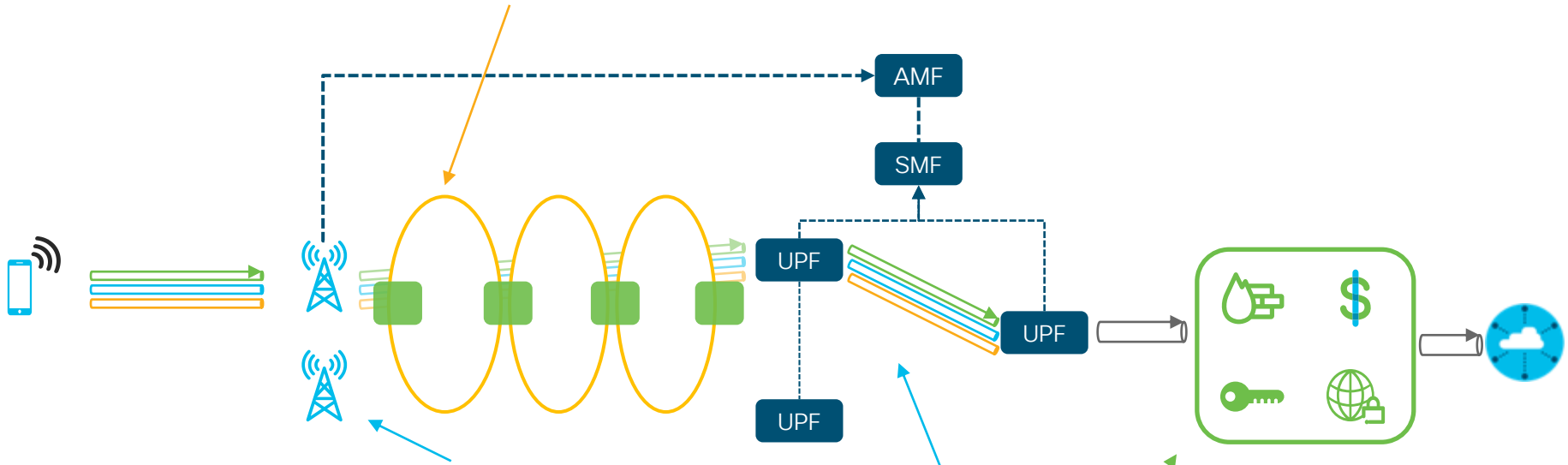
"5G RAN CU - DU network architecture, dimensioning and performance requirements" by NGMN Alliance

C-RAN Deployment Challenges

- Economically viable availability of fibre – Must Requirement
- Economically viable availability of BBU hotel Site Requirement – Must Requirement
- Strict transport requirement
  - < 15 KM distance
  - <75-100 us one-way delay

SRv6 Use-Cases for 5G

(N3) Underlay: Traffic Engineering / Network slicing



(N3 & N9) Overlay: Efficient protocol replacement to GTP-U

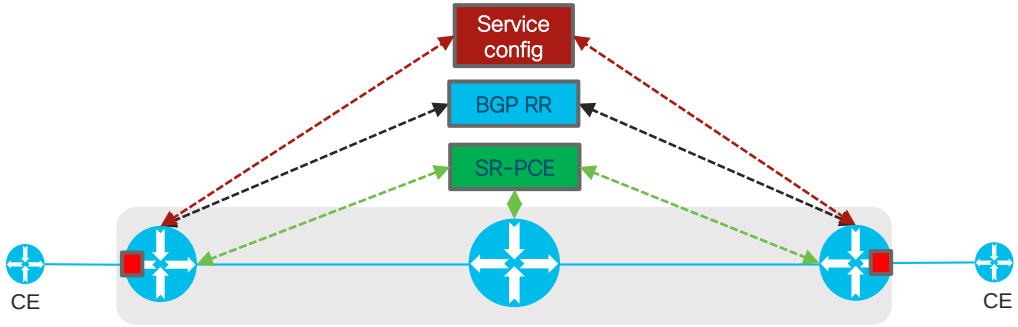
(N6) GiLAN: Scalable and flexible Service Programming

Is Diffserv QoS “Good Enough” for 5G ?

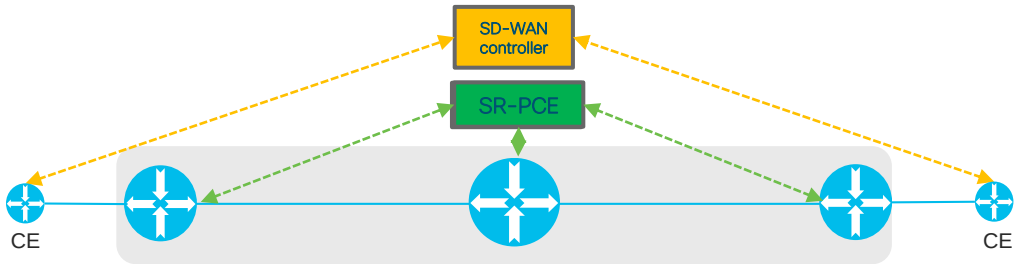
- Yes, as a transport QoS strategy!
  - Slice b/w / class protection through ingress conditioning and marking
  - Class separation and protection with core scheduling
  - Bandwidth reuse
  - QoS aware capacity planning
- FOR LOW LATENCY SERVICES THE OVERALL DESIGN NEEDS CONSIDERATION
- Network delay = propagation delay + switching delay + scheduling delay + serialization delay
- Proximity of gateway functions to users
  - Reduce propagation delay
- Proximity of applications to users
  - Reduce propagation delay
- Serialization delay is a consideration for fronthaul applications (TSN)

Service Infrastructure

- Network based VPNs
  - 5G based BGP VPNs



- Overlay / SDN-WAN based VPNs
  - Enterprise services
  - Inter-DC communications



Frequency and Phase Sync Requirements

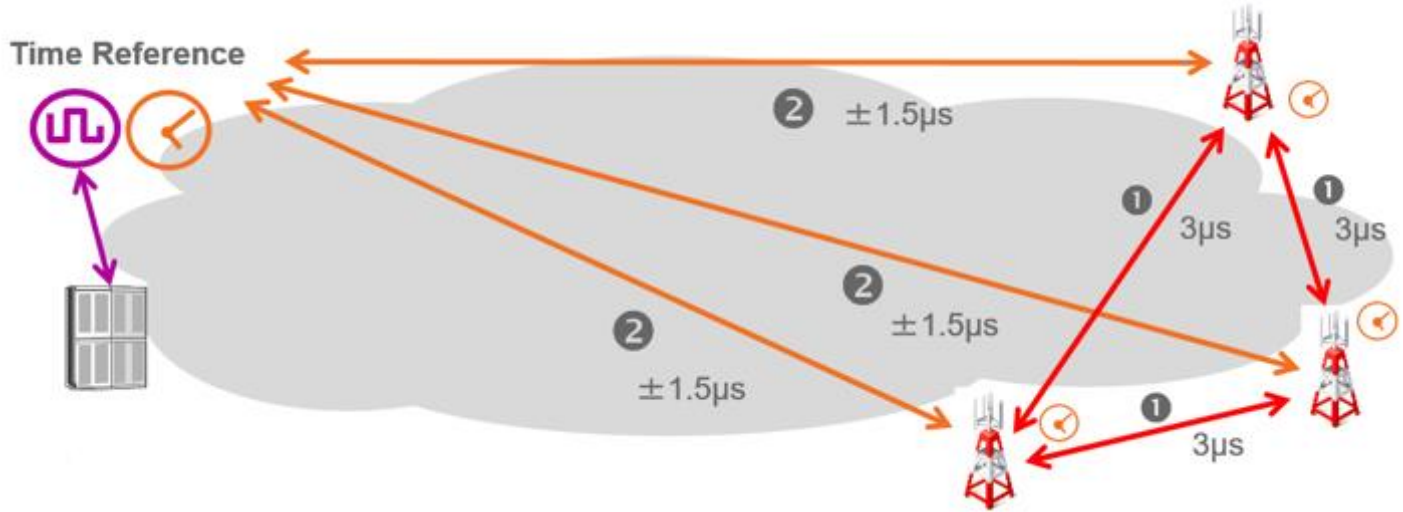
Application	Frequency		Phase		Note
	Backhaul	Air	Backhaul	Air	
LTE-FDD	±16 ppb	± 50 pbb	--	--	--
LTE-TDD	±16 ppb	± 50 pbb	±1.1µs ±4.1µs	±1.5µs ±5µs	< 3Km cell Radius > 3Km cell Radius
LTE-A / LTE-Pro	±50 pbb (Wide area) ±100 pbb (Local area) ±250 pbb (Home eNB)		≤ ±1.1µs	±1.5µs to 5µs	Depending on the application
LTE eMBMS	±16 ppb	± 50 pbb	≤ ±1.1µs	±1.5µs to 5µs	Inter-cell time difference

LTE-Advance	Type of Coordination	Phase	
		Backhaul	Air
eICIC	Enhanced inter-cell interference Coordination	≤ ±1.1µs	±1.5µs to 5µs
CoMP Moderate	UL coordinated scheduling	≤ ±1.1µs	±1.5µs to 5µs
	DL coordinated scheduling		
CoMP Tight	DL coordinated beamforming	≤ ±1.1µs	±1.5µs
	DL non-coherent join transmission	≤ ±1.1µs	±1.5µs to 5µs
	UL Joint processing	≤ ±1.1µs	±1.5µs (±130ns)
	UL selection combining	≤ ±1.1µs	±1.5µs
	UL joint reception	≤ ±1.1µs	±1.5µs
MIMO	Tx diversity transmission at each Carrier frequency	65ns	±32.5ns

1 nano sec / sec = $1x10^{-9}$ (1 ppb)

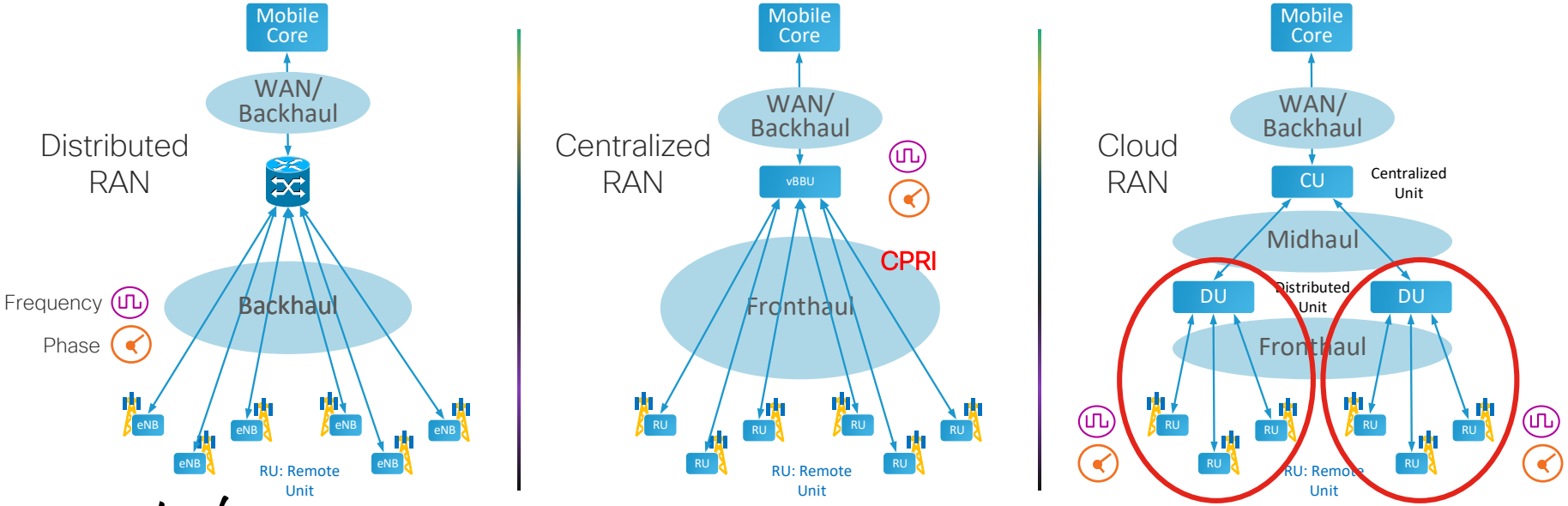
Timing and Synch – New Phase Requirements

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

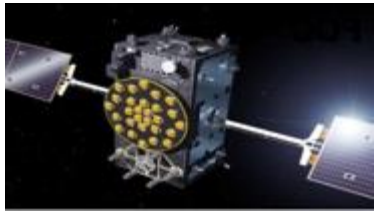


Timing and Synch – Fronthaul

- 5G is also re-engineering the Fronthaul network towards Cloud RAN:
  - CPRI to packet-based Fronthaul/Midhaul impacts timing
  - Much tighter requirements for phase alignment budget



Timing and Synch – Solutions



GNSS (GPS, Galileo) Receivers

- 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

→ Include GNSS receivers inside routers where appropriate

PTP/1588 and SyncE in Transport Network

- 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

→ Routers as high performance T-BC boundary clocks with Class B/C G.8273.2 performance

All of the Above

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

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

Galileo photo © GSA

Phase Performance – G.8273.2
Boundary Clock Performance

Level	Max Total Time Error* max|TE|	Constant Time Error cTE	Dynamic Time Error** dTE
Class A (10 T-BC's)	100 ns	±50 ns	±40 ns
Class B (20 T-BC's)	70 ns	±20 ns	±40 ns
Class C (Oct '18)	30 ns	±10 ns	±10 ns

Time Sensitive Networking 802.1CM
Ethernet for Fronthaul

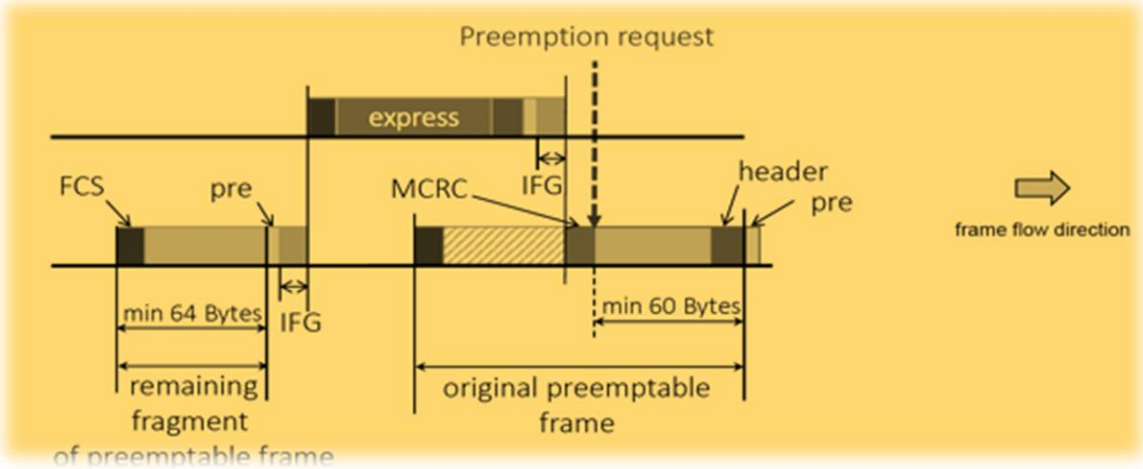
- **Profile A**: Strict priority queuing (no frame pre-emption)
  - Radio data payload frame size max is 2000, C&M max is 1500 octets
  - IQ data traffic belongs to strict priority traffic class - strict priority algorithm
  - C&M data assigned to lower priority than IQ data

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

Ethernet For CPRI Fronthaul (802.1CM)

- TSN techniques to reduce latency of time-sensitive traffic:
  - Should have frame pre-emption (as per Profile “B”)
    - Pre-emption occurs only if 60 octets of pre-emptable frames have been transmitted
    - And at least 64 octets of remain to be transmitted
  - Pre-emption is used to keep max latency to 124 octet times
  - PTP messages in express frames or frames < 124 octets not pre-empted
  - Some configurability on min frame size for pre-emption allowed

802.1Qbu Frame Preemption



- Express frames can suspend the transmission of pre-emptable frames.
- Should have frame pre-emption (as per Profile “B”)
  - Pre-emption occurs only if 60 octets of pre-emptable frames have been transmitted
  - And at least 64 octets of remain to be transmitted
- Pre-emption is used to keep max latency to 124 octet times
- PTP messages in express frames or frames < 124 octets (Cannot be Pre-empted)
- Some configurability on min frame size for pre-emption allowed (Increasing the min size which is 124 octets)

Evolution of Time Synchronization

Synchronization
- Fundamental need for any Telecommunication

Analog to Digital Transition
- Synchronous protocols
- Bulk Data Transfer

Asynchronous Packet Switched network
- Better Bandwidth
- improved efficiency and
- Services flexibility

End to End IP
- Improved user experience – “Any service Any Where”
- Improved revenue with Multi-Services convergence

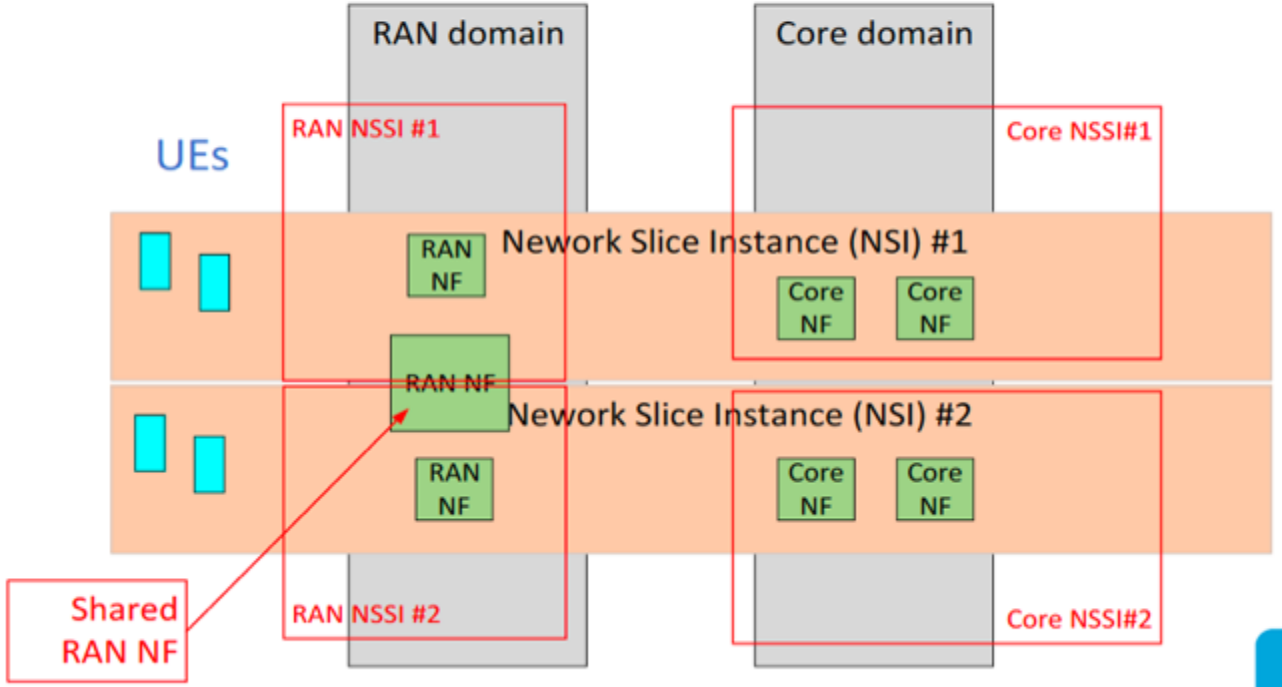
802.1CM for Deterministic Latency

Mode	Radio Traffic	Enterprise Traffic
Strict Priority	Excellent Service Each Node: Moderate ENT queuing delay Each Node: Self-queuing delay	CIR met. SLAs may not guaranteed for Jitter and Delay.
Strict Priority + Preemption	Excellent Service Lowest Latency Each Node: Small ENT queuing delay Each Node: Self-queuing delay	CIR met. Latency / Jitter impact increased due to heavy preemption

	Fronthaul Max. Latency (us)			Fronthaul Frame Delay Variation (us)		
Scenario	1 node	2 node	3 node	1 node	2 node	3 node
SP	3.1	6.3	9.3	3.0	6.0	8.9
SP+P(Qbu*)	0.2	0.4	0.6	0.1	0.2	0.2

SP= Strict Priority
SP+P = Strict Priority + Frame Preemption

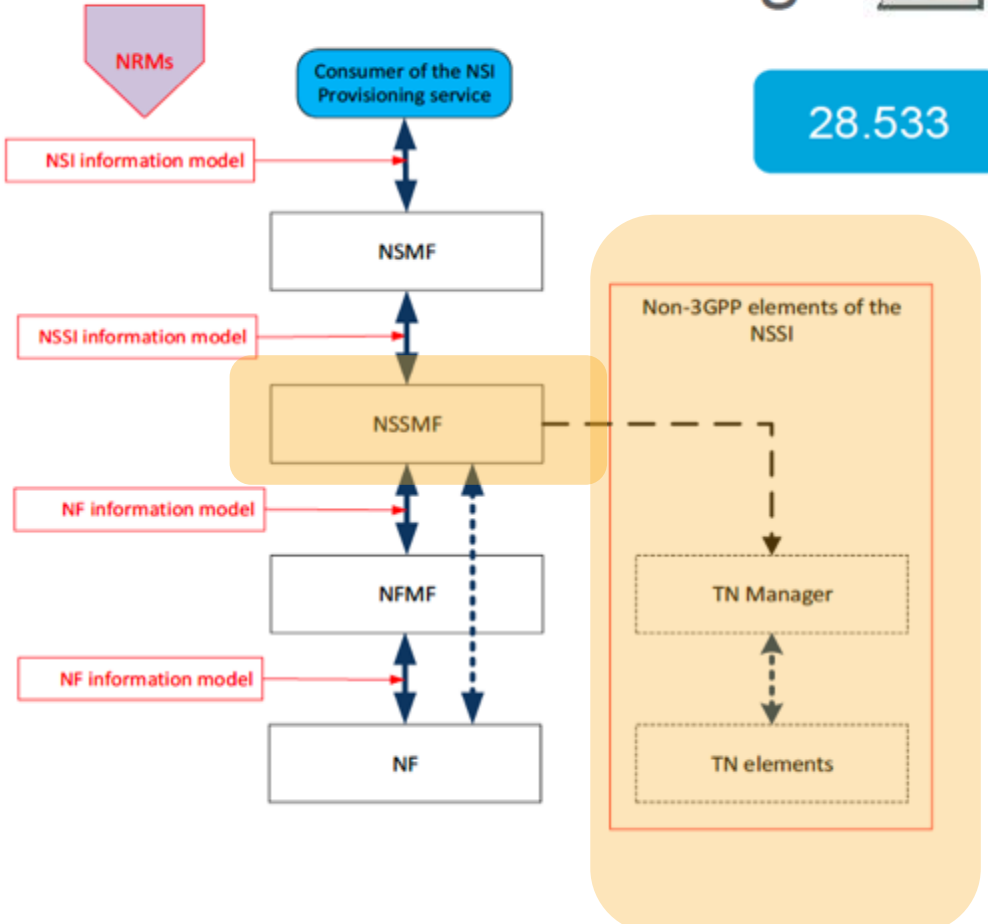
Network Slice Instance (NSI)
Network Slice Subnet Instance (NSSI)



28.530

Functional management architecture: slicing

- Network Slice Management Function (NSMF) provides the management services for one or more NSIs
- Network Slice subnet Management Function (NSSMF) provides the management services for one or more NSSIs
- The NF management Function (NFMF) provides NF performance, NF configuration and NF fault supervision management services

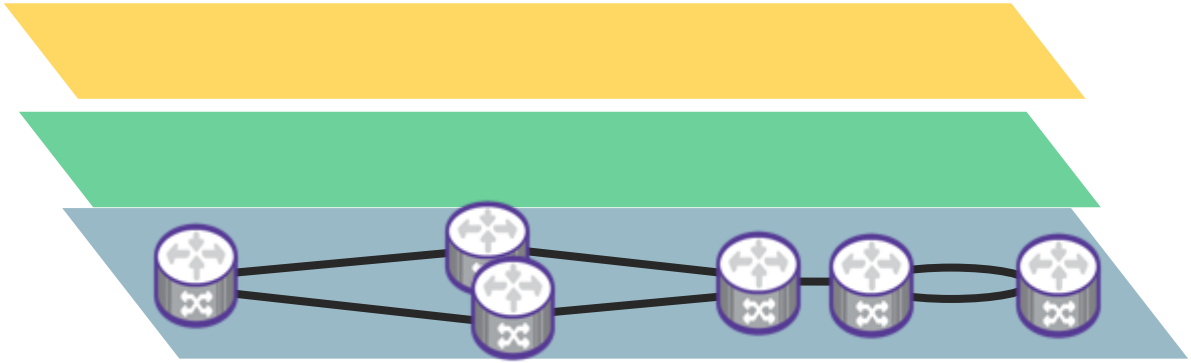


NSSI / NSI Data Model: some parameters

Attribute Name	Documentation and Allowed Values
constituentNSSIList	It is a list IDs of the constituent NSSIs associated with the NSSI or NSI
nNSIId	An attribute uniquely identifies the network slice instance.
perfReq	The perfromance requirements to the NSI, such as Experienced data rate, Area traffic capacity (density) information of UE density
sNSSAIList	The S-NSSAI list to be supported by the NSI
coverageAreaTAList	A list of <TrackingArea> where the NSI can be selected.
latency	Packet transmission latency (ms) through the RAN, CN, and TN part of 5G network
resourceSharingLevel	Whether the resources used by the NSI may be shared with another NSI(s).
sliceProfileList	A list of SliceProfile sets supported by the NSSI network
slice sST	The slice/service type of the network slice.

28.541

Slicing in the Underlay Based on SLA Requirements



- Small number of slice planes defined in underlay (across domains)
  - 5G mobility slices (eMBB, URLLC, mIOT, signalling, etc.)
  - Major Service Type (Wholesale, MVNO, Enterprise, Content, etc.)
- Each Slice plane characterized by
  - Optimization + constraint objective : latency, bandwidth, reliability, topological constraints
- Engineered based on a flex-algorithm (SPF included) or pt-2-pt SR policies
- Slice planes can be “hard” or “soft” depending how they are engineered

References

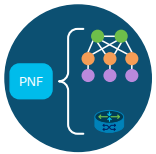
- TS 23.501 Section 5.15 (Network Slicing)
- TS 23.503 Section 6.1.2.2 (URSP, NSSP)
- TS 38.300 Section 16.3 (Network Slicing)

Relevant specifications *Management and orchestration of networks and network slicing*

TS 28.530	Concepts, use cases and requirements
TS 28.531	**Provisioning**
TS 28.532	**Generic management services**
TS 28.533	**Architecture framework**
TS 28.540	5G Network Resource Model (NRM); Stage 1
TS 28.541	**5G Network Resource Model (NRM); Stage 2 and stage 3**
TS 28.550	**Performance assurance**
TS 28.552	**5G performance measurements**
TS 28.554	**5G End to end Key Performance Indicators (KPI)**

Key Characteristics

Functional Decomposition
Functions separated to allow flexible placement and optimization



Disaggregation into SW + HW
Software-centric solutions leveraging COTS hardware

Open
Modular, Open, Multi-vendor, more options = flexibility and lower cost

Multi-Use Case
5GNR, LTE, small cell, indoor/outdoor, mMIMO, low, mid, high-band, mmWave, private/public, enterprise/consumer, etc

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

Enable New Services
Increased service flexibility, velocity

xRAN Forum
Merger of XRAN & CRAN to form ORAN

- Defining an **open**, **multi-vendor interoperable**, **bandwidth efficient**, split-PHY fronthaul interface. Addressing key operator requirements:
  - BBU – RU interoperability based on well specified control, user and management plane interfaces.
  - IP/Ethernet based transport layer solutions.
  - Extensible data models for management functions to simplify integration.
- **Option 7.2x split uses eCPRI transport payload – now also 1914.3**
  - Lower Layer Split Central Unit (lls-CU) controlling Radio Unit (RU)
  - First time NETCONF/YANG is defined for use in the RAN

INTUITIVE