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The bridge to possible

Architecting Modern Broadband Networks

Rob Piasecki, Principal Architect
Chris Olson, Senior Systems Architect
Marty Fierbaugh, Principal Architect

BRKSPG-2039

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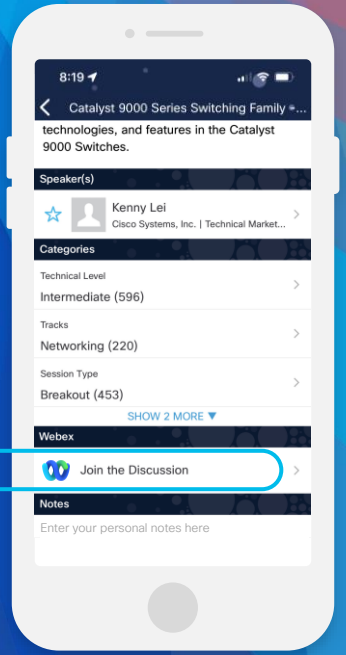

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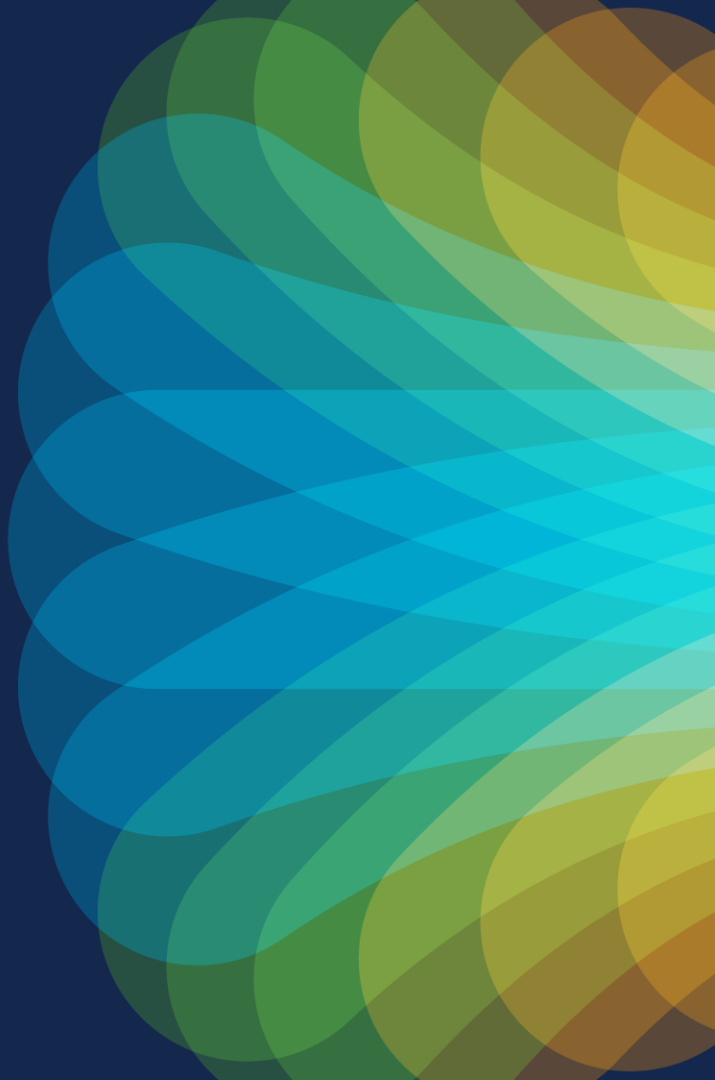
Agenda

- Why a Modern Design Approach?
- Evolved Network Architecture
- Edge Cloud and Compute
- Subscriber Edge
- Conclusion

Why a modern design approach?



What's Driving the Need for Broadband Network Transformation?

8K and 12K Video

Immersive experience requires pushing streaming content distribution closer to the subscriber

Augmented / Virtual Reality

Business to consumer applications and advertising evolve to create a more realistic experience. Examples: Retail, real estate, social media

Enhanced Gaming Experience

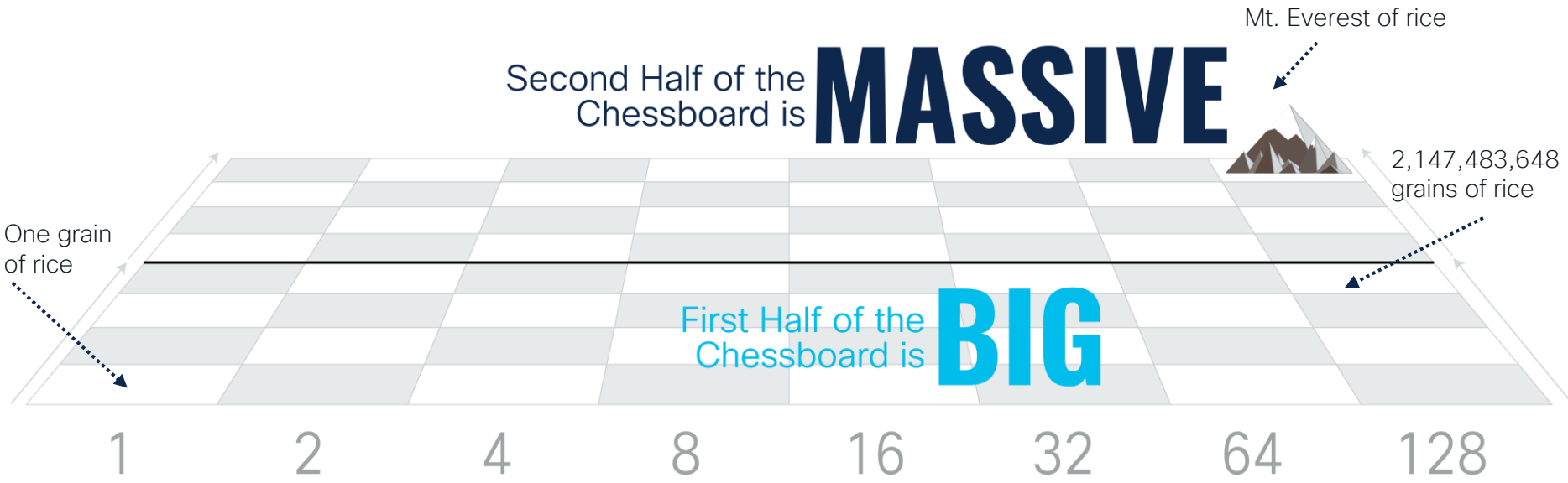
Low latency, high bandwidth, application-layer coordination with Service Provider networks

Enhanced Business Services

Business quality access to collaboration tools and applications, SD-WAN SLAs

The Exponential Growth of the Internet & Broadband Services

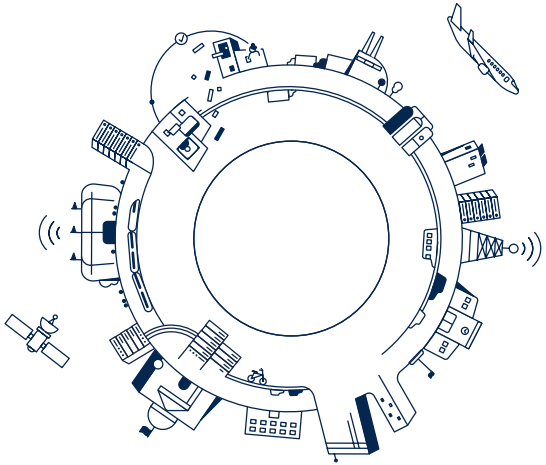
The Story of the Emperor, Inventor, and the Game of Chess



The Second Half of the Chess Board – The need for broadband network transformation

20x increase in data demand by 2032, driven by metaverse and streaming video[1]

75% of enterprise-generated data will be created and processed at the edge by 2025[2]



75% of people think hybrid work requires broadband services to improve dramatically[4]

29.3B networked devices in 2023 – up from 18.4B in 2018[5]

50% average percentage of CSP's total OpEx will be network-related[3]

10% growth in power consumption by network operators in 2021[6]

This is a demand-side view. Is it how the broadband market really works though...?

Sources: 1: A Guide to the Next-Gen Internet, Credit Suisse, 2022 | 2: Gartner analysis | 3: Telco Opex Analyzer, 2016-21, MTN Consulting | 4: Cisco Global Broadband Index 2022 | 5: Cisco Annual Internet Report, 2018-2023 | 6: MTN Consulting analysis

Innovation in Network Architectures

Innovations in ASIC Design
Optimized forwarding performance and cost

- Bifurcation of routing and switching silicon
- Massive reduction in power consumption
- Shared memory architecture for higher scale

Network Programmability
Intent-based underlay network to build services

- Segment Routing and network slicing
- Centralized view of network topology (controller)
- Simplified configuration and resiliency

Automation and Software
Untangling the complexity of integration

- Disaggregation of hardware and software
- Well defined APIs between systems
- Native platform data models, open/industry models

Optical and Optic Innovation
Converging optical and IP networks

- Shift in economics – cost moving to the transceiver
- Coherent optics extending reach and bandwidth
- Traffic demands almost entirely packet

Broadband networks have not kept pace with the innovation

Lack of innovation has led to… and what a new, better way looks like

Traditional access network architecture

Difficult to fully monetize

- Vendor-proprietary interfaces and lock-in of ONT and CPE
- Challenges in achieving fill rate and return on infrastructure investment
- Resource management complexity
- Disparate network underlays with limited SLA differentiation

Software-defined access network architecture

Enables new, innovative business models

- Open interfaces with well-documented APIs, and open ONT/CPE choice
- ‘Pay as you grow’, and ease of capacity management and planning
- Automation of infrastructure and service provisioning
- Network underlay with policy intent to differentiate services based on subscriber experience

Introducing Cisco Silicon One

A New Silicon Architecture

Innovations in ASIC Design
Optimized forwarding performance and cost

ONE Unified Silicon Architecture

- Comprehensive routing with switching efficiency
- Multiple segments: web and service provider
- Multiple functions: system-on-a-chip, line card, and fabric
- Multiple form-factors: fixed or modular

Delivers Performance Without Compromise

- First routing silicon to break 10Tbps barrier
- Leading performance over current industry routing silicon
- 2x more power efficient
- Global route scale, deep buffering, P4 programmable

Cisco Silicon One Family

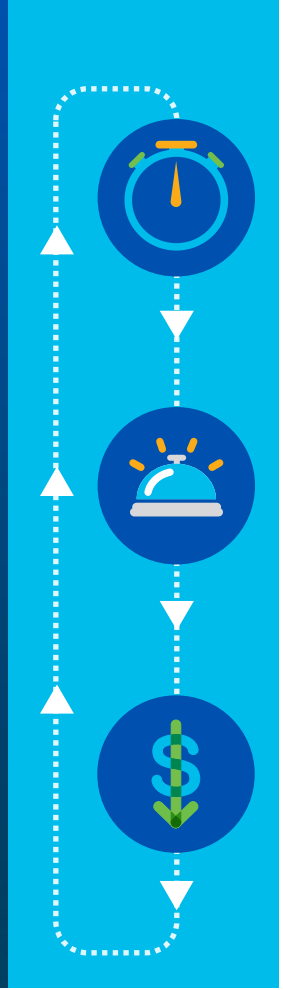
Innovations in ASIC Design
Optimized forwarding performance and cost

Network Programmability
Intent-based underlay network to build services

Simplicity Always Prevails

SR
Segment Routing

Segment Routing provides complete control over the forwarding paths by combining simple network instructions. It does not require any additional protocol. Indeed, in some cases it removes unnecessary protocols simplifying your network



Reduced Time to Deploy
Simplicity reduces time to deploy
- 60% reduction in internal testing (qualification) vs previous network design
- 4x improvement for software upgrade with fabric-style SP architectures

Better Productivity
Simplicity increases productivity
- 48% reduction in troubleshooting efforts vs previous network design

Reduced Capex
Low-End platforms also support SR
- 66% reduction in CapEx by optimizing the usage of feature-rich / higher-cost platforms only where it is needed, and using lighter platforms for simpler access / pre-aggregation / backhaul

Cisco IOS XR 7

Redefining software for better operations

Simple

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

Modern

- Open APIs
- Customizable software images
- Cloud-enhanced

Trustworthy

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

50% Less Memory Footprint

50% Faster Boot Times

40% Smaller Image Sizes

40% Faster Download

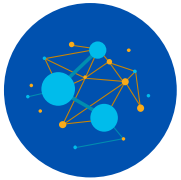
IOS XR 7

Flexible architecture for all deployments

Automation and Software
Untangling the complexity of integration

Elastic

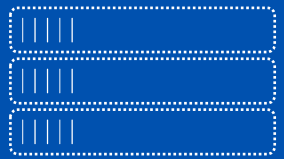
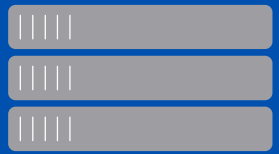
Cost Optimized



Ultra-high Density

Critical Infrastructure

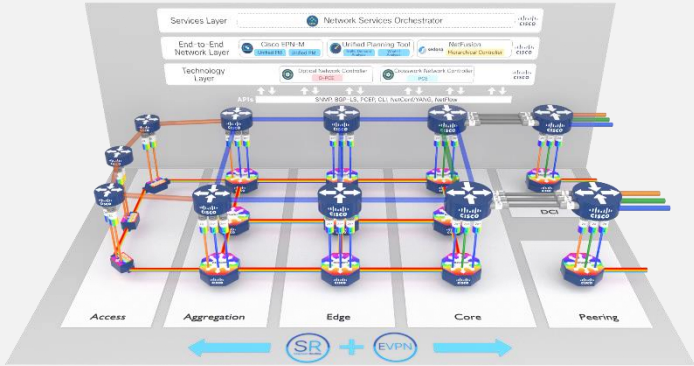
Programmable and Automatable

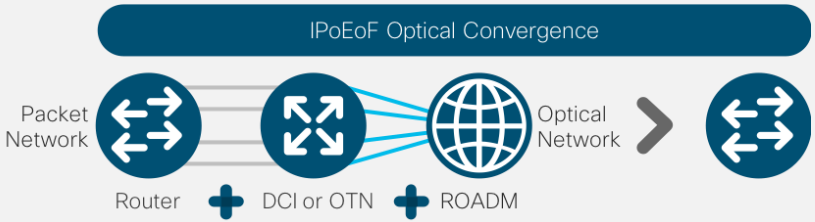
VNF	Qualified third-party hardware	Cisco HW with Merchant Silicon	Cisco HW with Custom Silicone
			
x86 data plane	Fixed hardware, merchant data plane	Fixed and modular hardware, merchant data plane	Fixed, modular, and multi-chassis hardware; Cisco data plane

IOS XR – Common SP Operating System across physical and virtual data planes

RON Architecture Transition

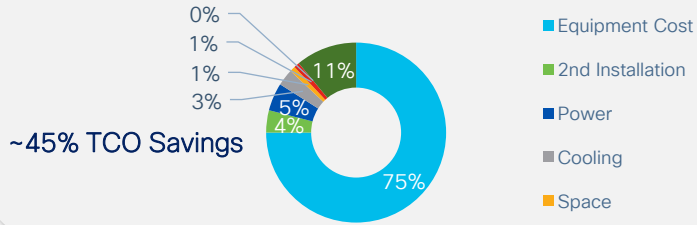
Optical and Optic Innovation
Converging optical and IP networks





- Converges all services onto a single network layer
- Eliminates siloed IP & Optical operational layers
- Integrates transponders & eliminates “grey” optics
- Integrates OTN Services & ROADMs
- Space, power & operational savings
- Shorter Time-to-Market for services

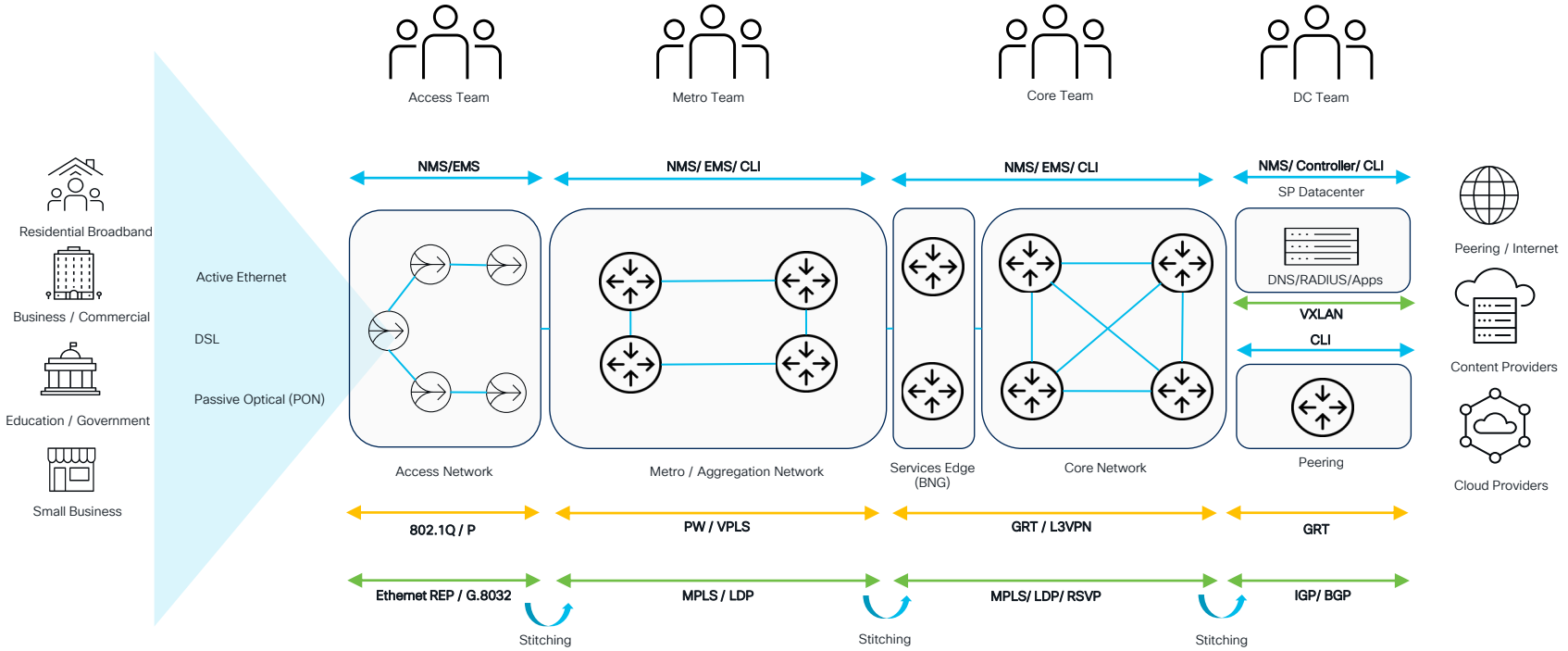
5 Years Savings Breakdown



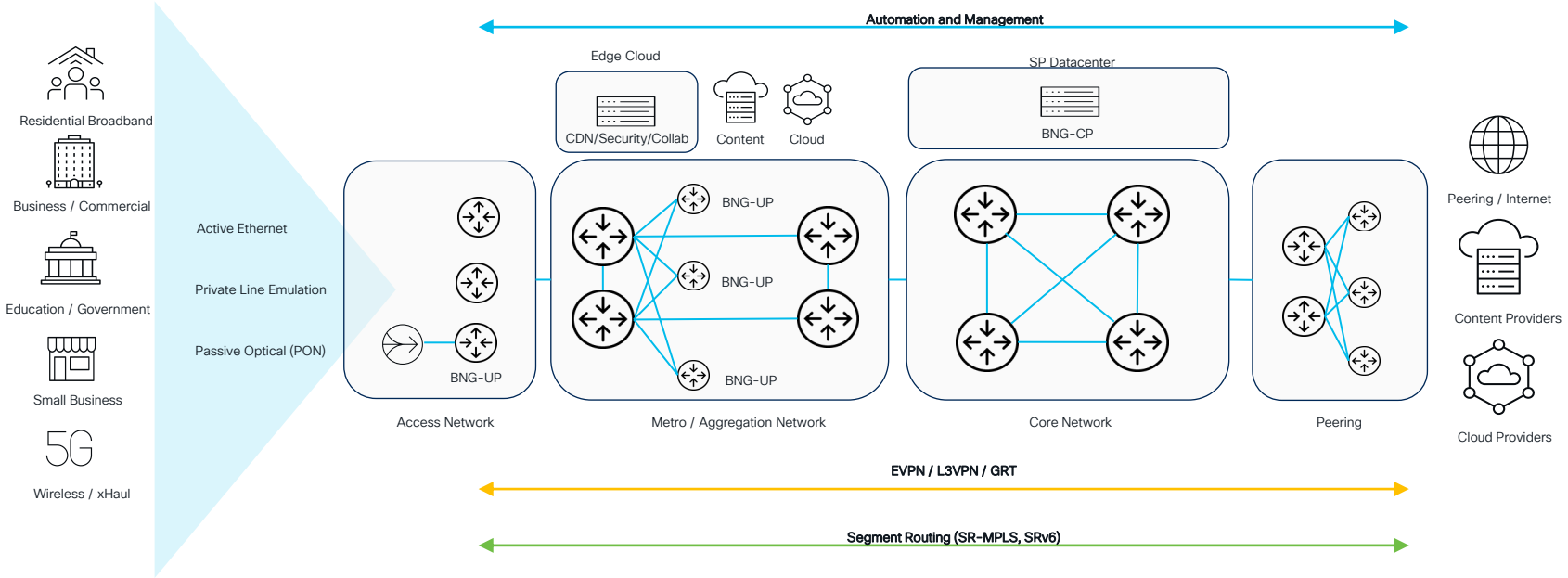
~45% TCO Savings

Evolved Network Architecture

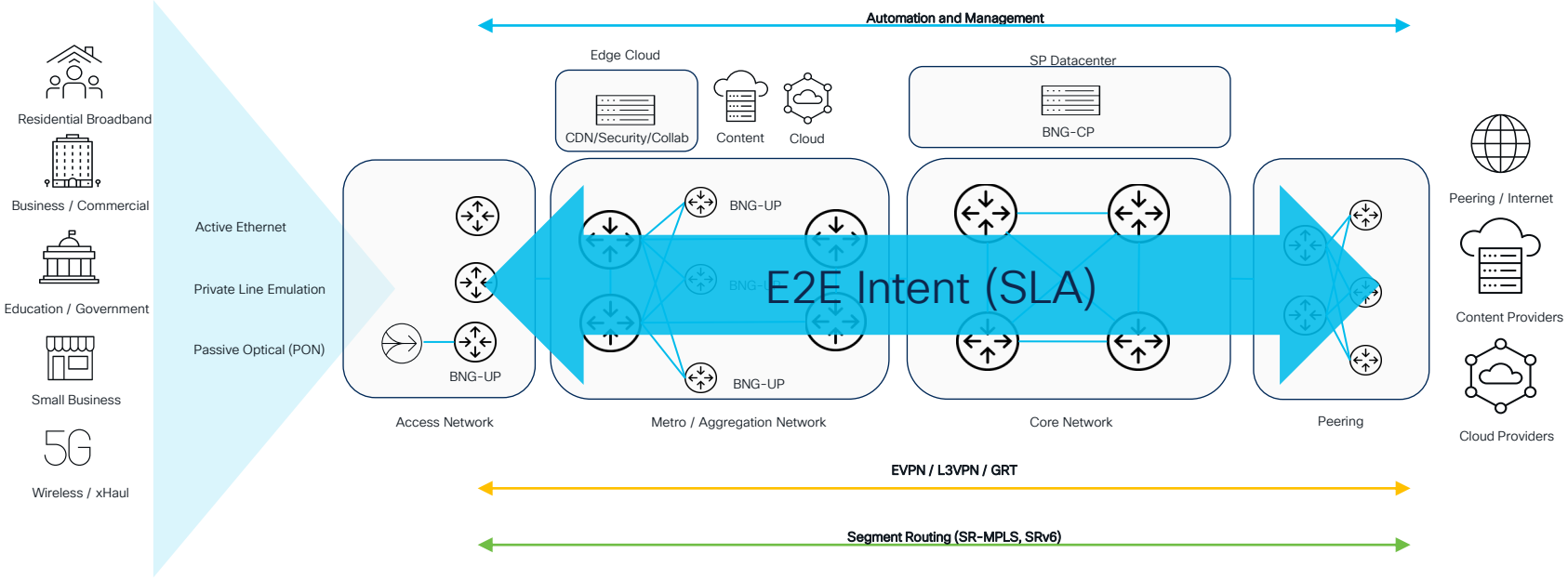
High Level Network Architecture



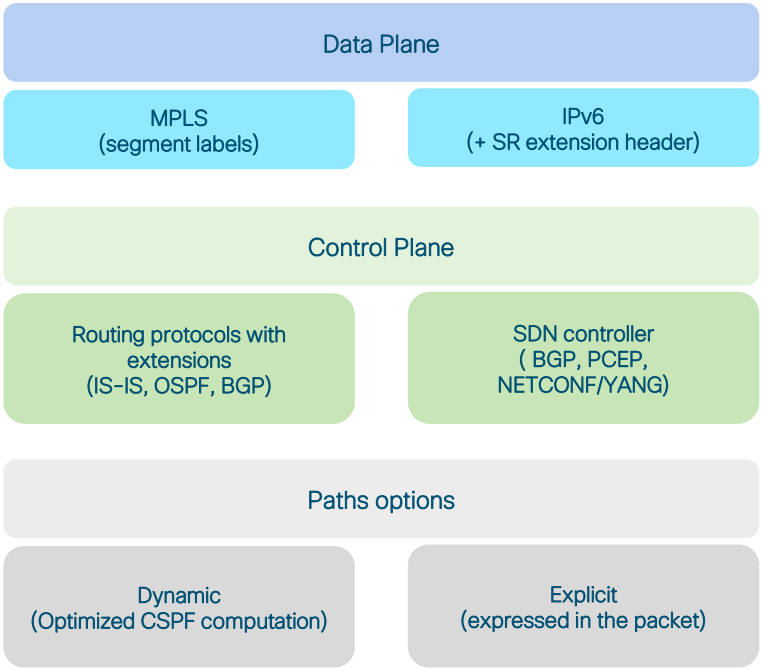
High Level Network Architecture



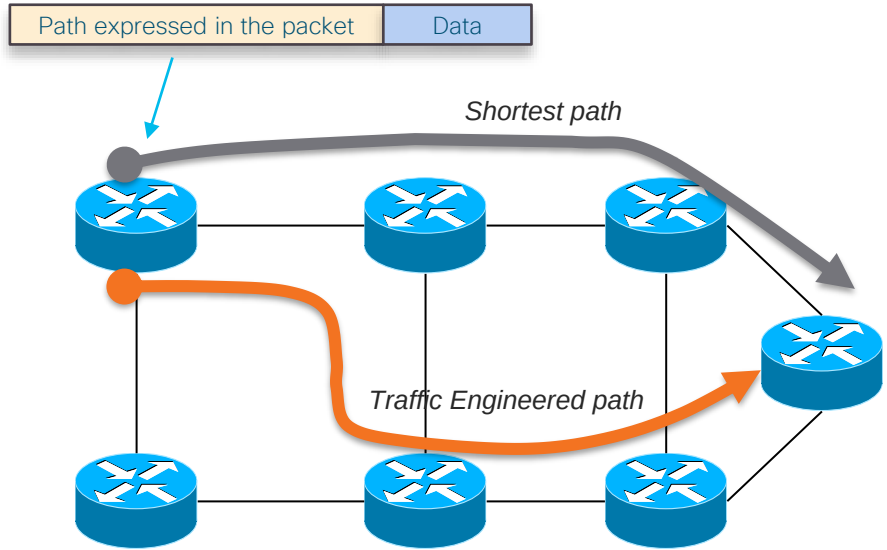
High Level Network Architecture



Segment Routing



- Source Routing paradigm
  - Stateless IP fabric !!!



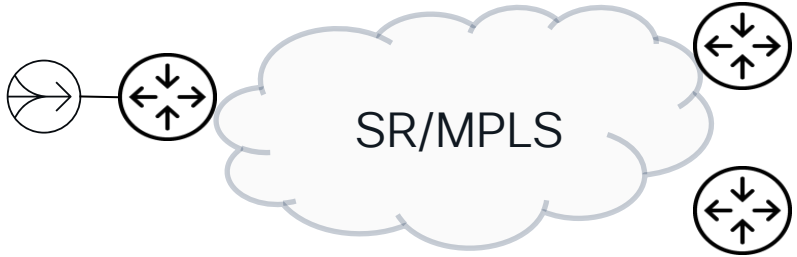
SR/MPLS transport (RFC 8660)

- Uses traditional MPLS encapsulation
- More flexible than legacy ethernet
- Uses IGP extension for label distribution
- Provides IP based underlay with built in path protection
- Provides intent-based path for overlay service

For a deeper understanding of
SR/MPLS Transport

Preparing for a Successful Segment Routing Deployment - BRKMPL-2135

Jose Liste, Technical Marketing Engineer, Cisco Systems, Inc.



SRv6 transport (RFC8986)

- Uses native IPv6
- Highly scalable
- Supports prefix summarization at IGP boundaries
- Include all SR/MPLS benefits

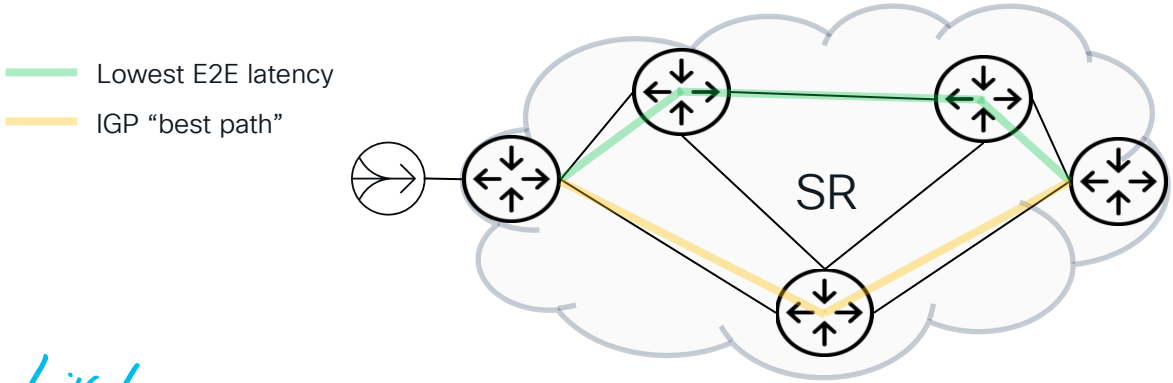
For a deeper understanding of SRv6 Transport

SRv6 for Next-Generation Transport Networks - BRKMPL-2205

Brent Foster, Principal Architect, Sales, Cisco Systems, Inc.

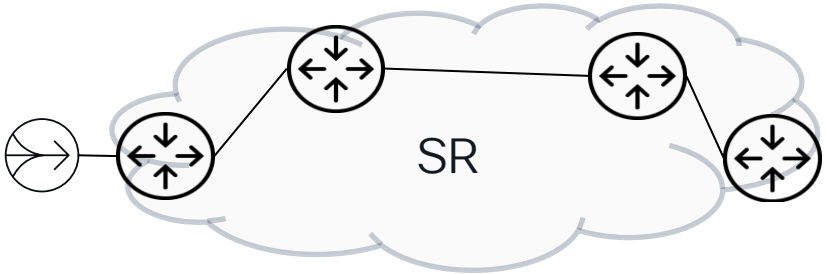
SR Policy (RFC9256)

- Allows network to be programed with service intent
- Maps services to intent to provide SLA
- Applies to SR/MPLS and SRv6

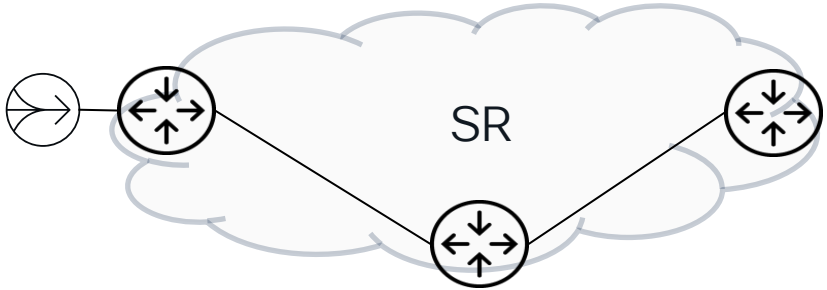


SR Flexible Algorithm (RF9350)

- Enables network “Slicing”
- Apply same intent at SR Policy to a “slice” of the network
- Map services to a slice
- Fast re-route per slice



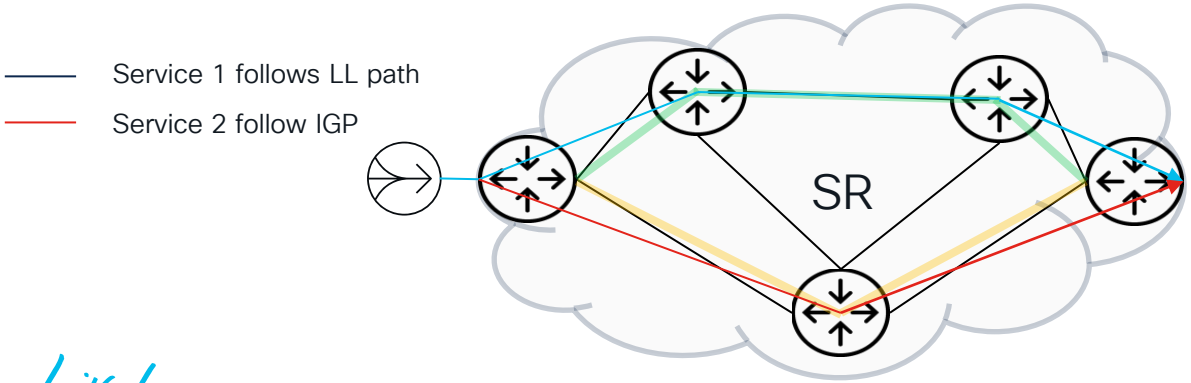
Lowest E2E latency Algo



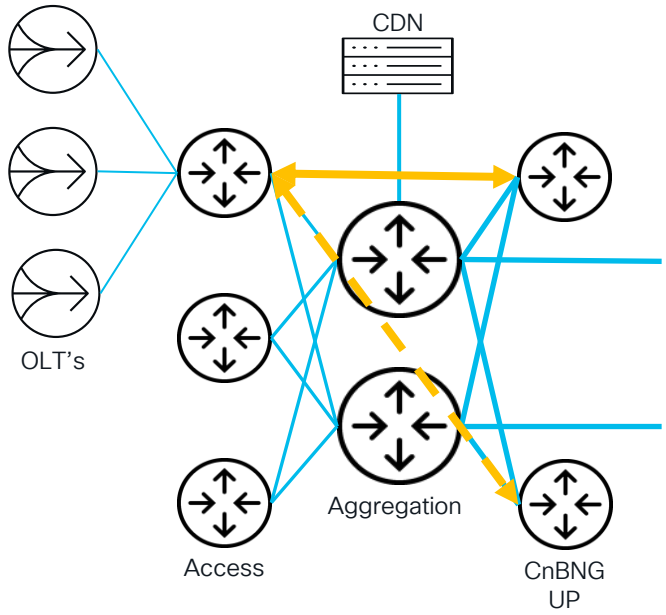
Lowest Cost Algo

EVPN Services (RFC7209, 7432)

- Overlay services for P2P, P2MP, IRB
- Natively supports single-homed and multi-homed devices
- BGP control plane for all mac/IP advertisement (mac routing)
- All overlay service in MP/BGP, one protocol to troubleshoot



SR/MPLS Example



SR/MPLS review: Infra

```
segment-routing
 global-block 100000 116767
!
router isis LAB
 address-family ipv4 unicast
  metric-style wide
  router-id Loopback0
  segment-routing mpls
!
interface Loopback0
  passive
  address-family ipv4 unicast
   prefix-sid index 10
!
```

1. Define SRGB or use default
2. Configure IGP to include Segment Routing extensions
3. Define prefix SID

SR/MPLS review: Service

Attachment Circuits

```
interface TenGigE0/0/0/0.100 l2transport
 description OLT1_pon_Basic_HSI
 encapsulation dot1q 100
 rewrite ingress tag push dot1q 10 symmetric
!
interface TenGigE0/0/0/1.100 l2transport
 description OLT2_pon_Gaming_HSI
 encapsulation dot1q 100
 rewrite ingress tag push dot1q 11 symmetric
!
interface TenGigE0/0/0/2.100 l2transport
 description OLT3_pon_Gaming_HSI
 encapsulation dot1q 100
 rewrite ingress tag push dot1q 12 symmetric
!
```

1. Set up attachment circuits
2. Define the service

Service

```
l2vpn
 flexible-xconnect-service vlan-unaware 1
  interface TenGigE0/0/0/0.100
  interface TenGigE0/0/0/1.100
  interface TenGigE0/0/0/2.100
  neighbor evpn evi 10010 target 1
 !
```

SR/MPLS review: Transport Policy

```
Policy (Define SLA)
segment-routing
 traffic-eng
  on-demand color 100
   dynamic
    metric
     type latency
!
Color Routes
extcommunity-set opaque BLUE
  100
end-set
!
route-policy BLUE
  if evpn-route-type is 1 or evpn-route-type is 3
then
    set extcommunity color BLUE
  endif
end-policy
```

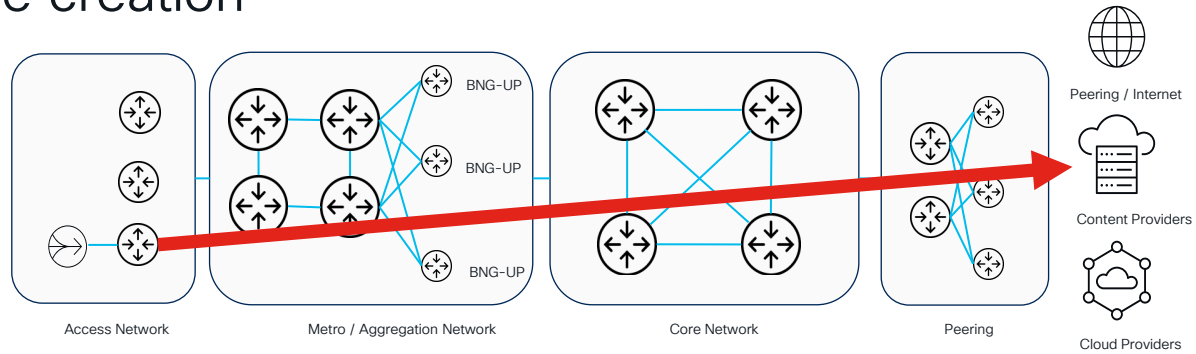
1. Define the policy (SLA Intent)
2. Color route advertisement
3. Assign the SLA

```
Service Color (Assign SLA)
evpn
 evi 10010
  bgp
   route-policy export BLUE
```

Edge Cloud and Compute

Current CSP options don’t scale and limit business growth

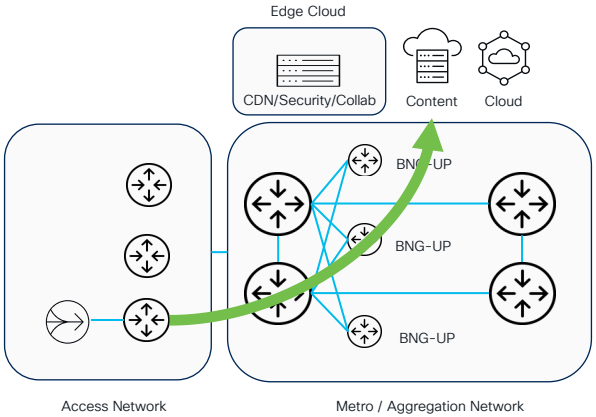
- Core bottlenecks and congestion
- No traffic visibility and control
- Complex deployment and operations
- Blind capacity upgrades
- No value creation



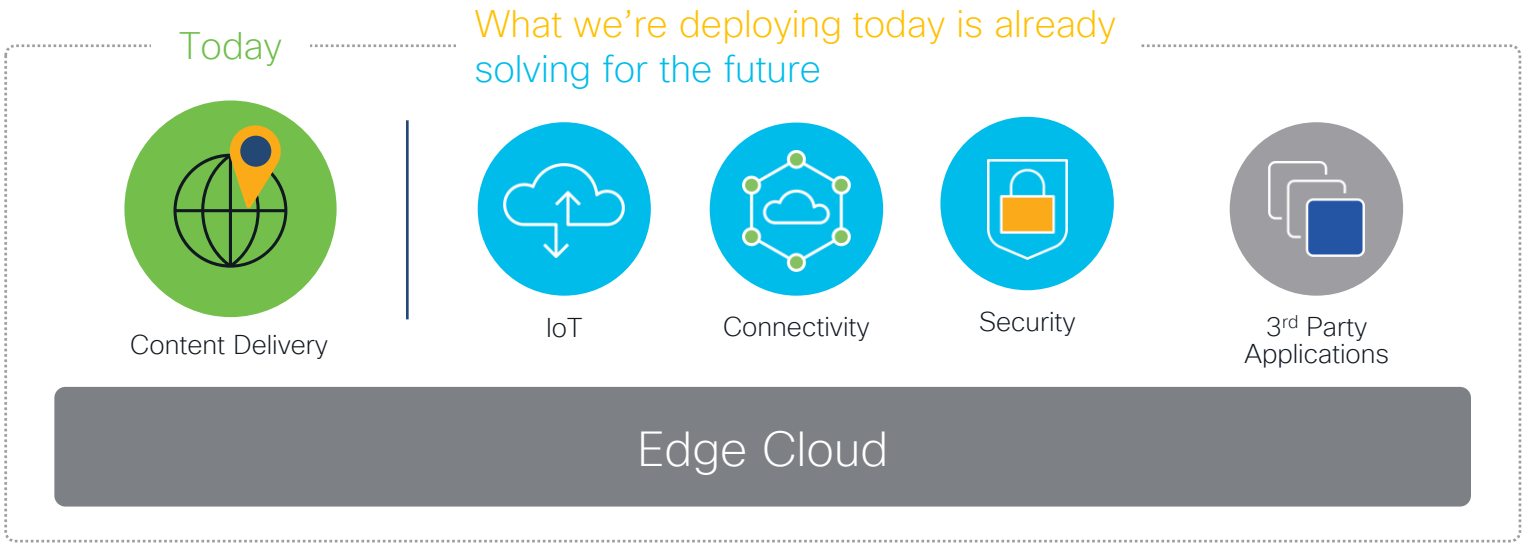
Systems are deployed at the edge for low latency, fast processing, and storage of data created by edge applications

Edge Compute Benefits

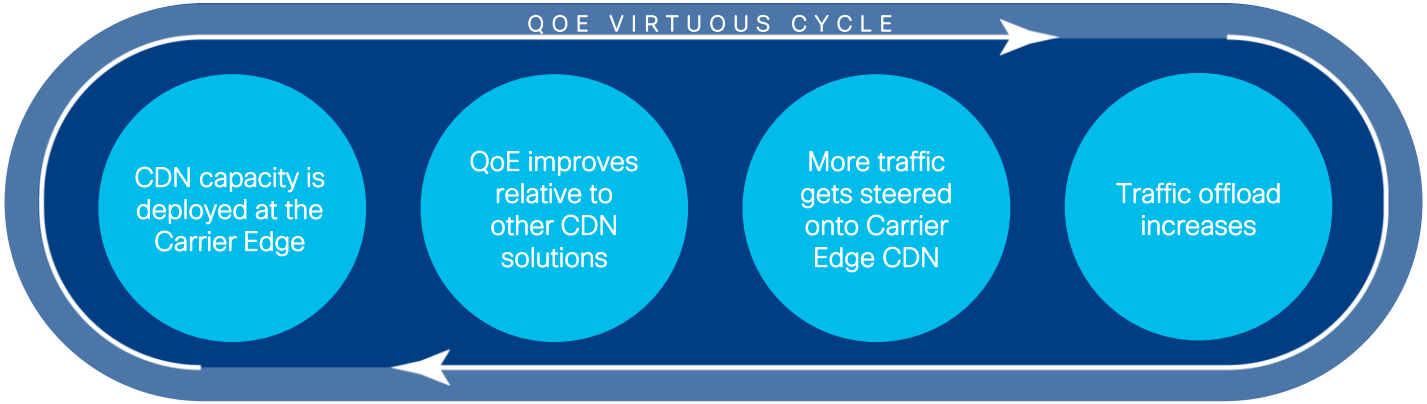
- Perform data analytics ad computation at the edge, so network connectivity and bandwidth issue are reduced
- Reduce latency in accessing compute facilitating NG applications
- Access big data analytics for Artificial Intelligence (AI), machine learning



Extending Enterprise Applications to the Edge



Best in Class Quality of Experience (QoE)



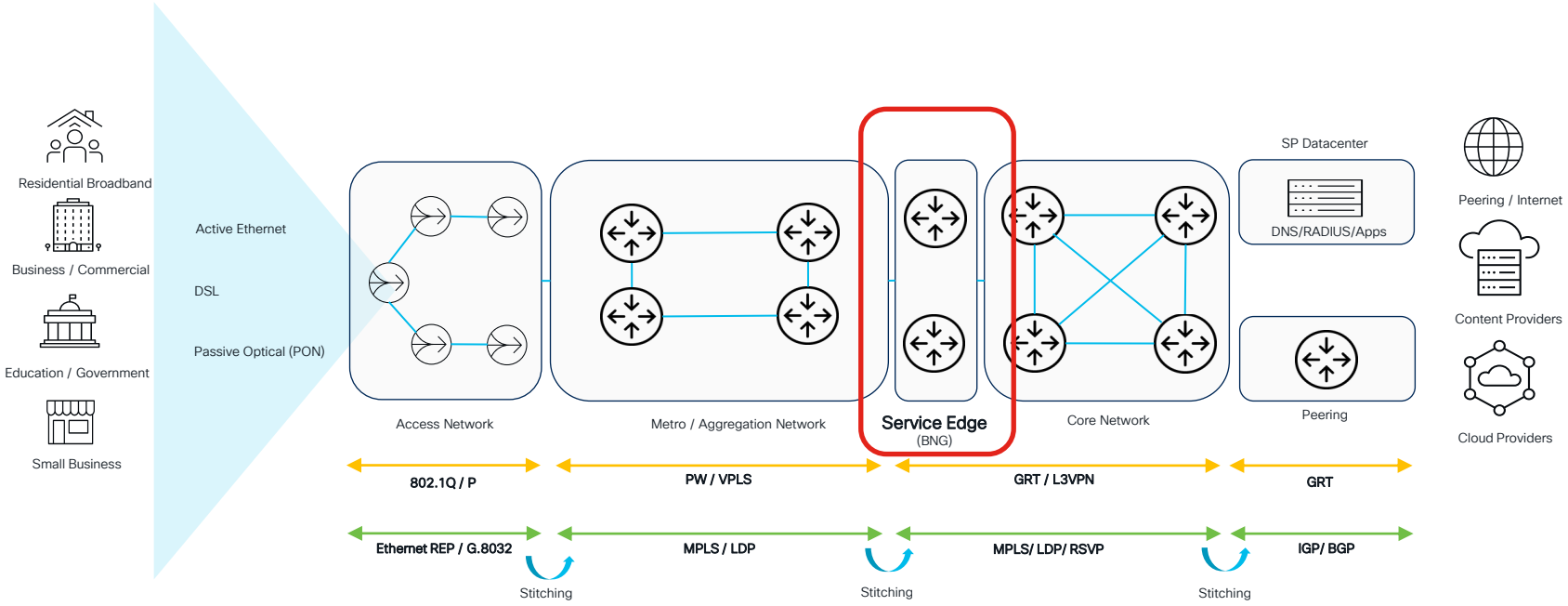
Metrics* Defining the Experience

9.4%	31%	55%	13%
Decrease in Error Rate	**Faster** Time to First Frame (TTFF)	**Quicker** Buffering Time	**Improvement** in Average Bit Rate (ABR)

Selected Metrics Comparing deep caching to average of Commercial CDNs;
Client-Side Video Analytics during live events; Major Global Streaming Platform

Subscriber Edge

Today’s Broadband Network Gateway (BNG)



Today's Broadband Network Gateway (BNG)

Very centralized - Regional

Large modular platforms (chassis)

Subscriber termination of 10s-100s of thousands

Large failure domain -> Subscriber redundancy groups

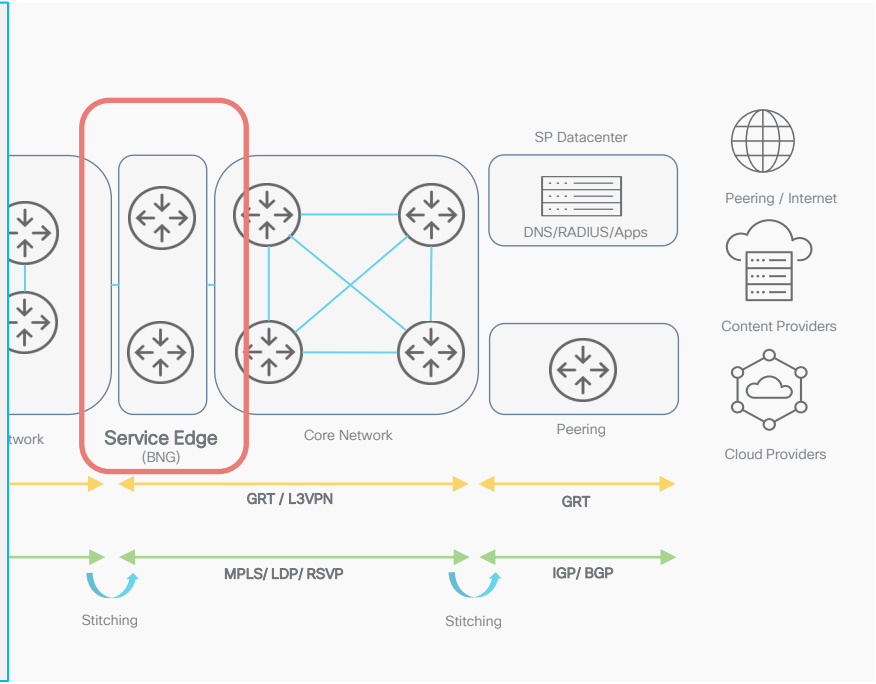
Policy enforcement point per subscriber

- Queuing for 100s of thousands (eTM, HQoS)
- Hardware dependency on complex ASICs

Direct OSS/BSS Integration

Large IP address pools managed on each BNG node

Highly integrated and customized control-plane and data-plane functions on a single BNG



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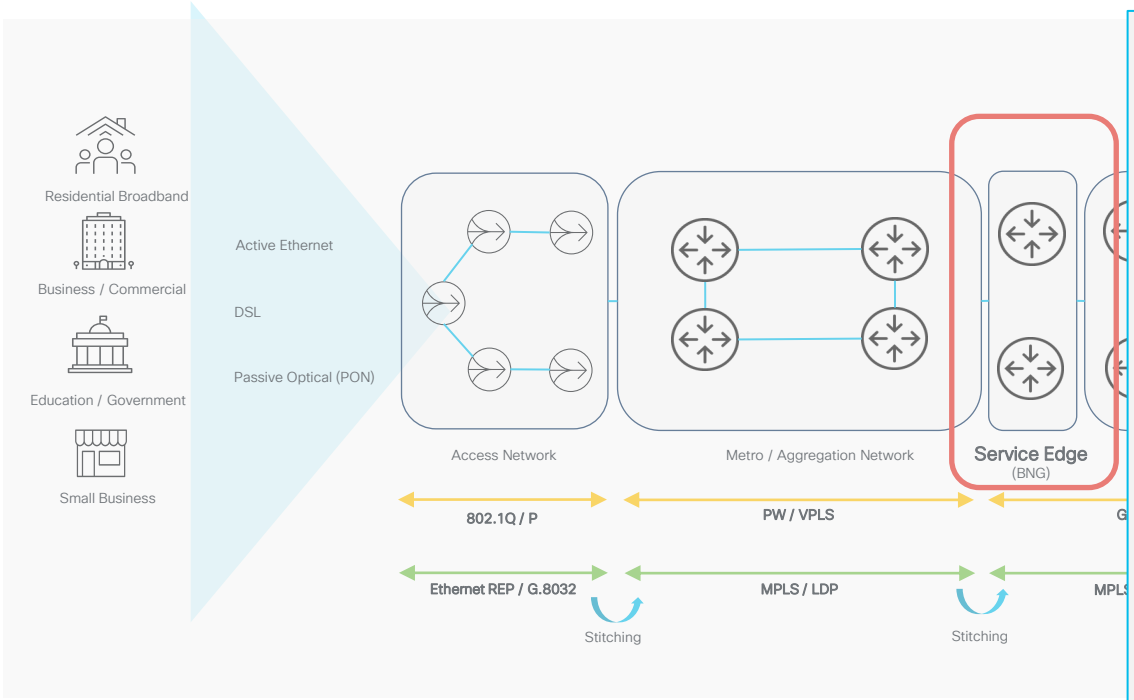


Control Plane Functions

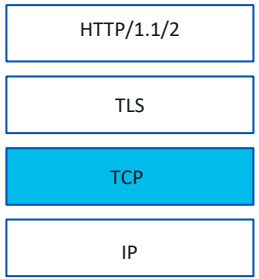
- Authentication
- Authorization
- Accounting-data reporting
- Address assignment
- Security and policy management

Data Plane Functions

- Access termination
- Accounting data collection
- Security and Policy enforcement
- Quality of service (QoS)

Evolving application and subscriber behavior
Challenging the legacy assumptions of queuing

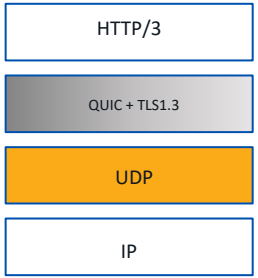
Old App Stack



Relies on the network
TCP Congestion Control
Per flow
Queuing required

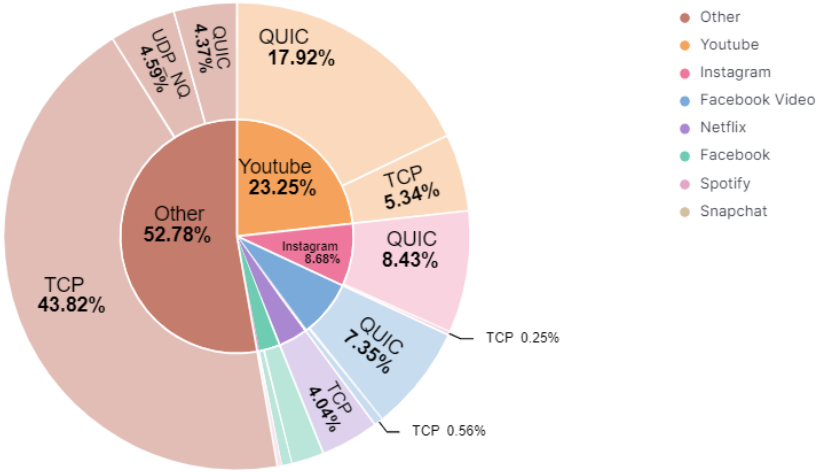
New App Stack

QUIC – RFC 9000
HTTP/3 – RFC9114



UDP = No congestion control
QUIC = flow scheduling / pacing
Application controls the flow
Queuing unnecessary

Traffic Volume (as of Nov '22)



For a deeper understanding of QUIC and Encrypted Traffic

The New, Encrypted Protocol Stack Taking over the Internet and How to Deal with It - BRKSPM-2024

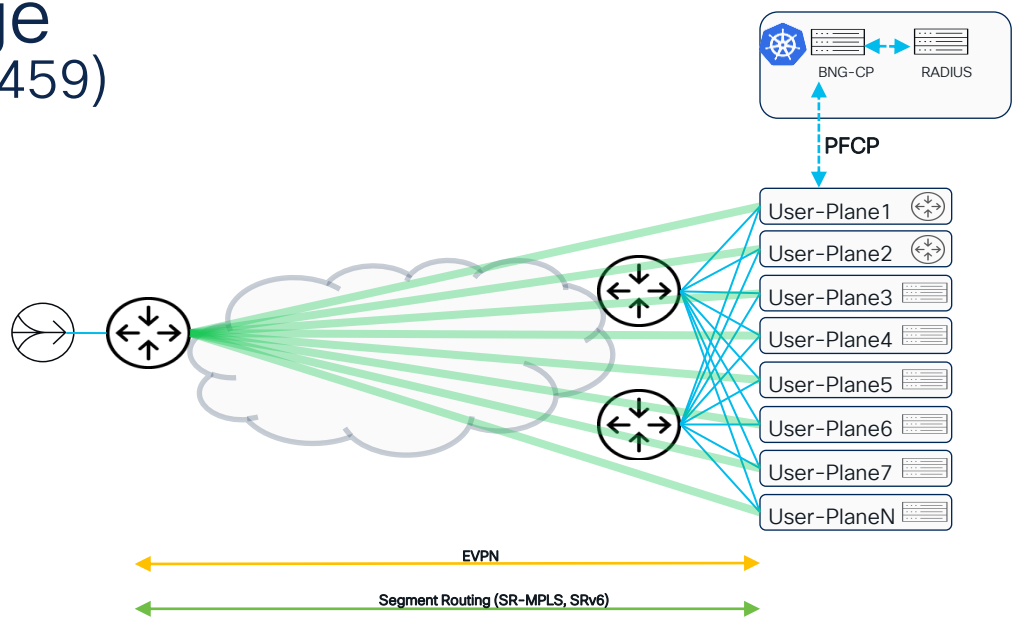
Andreas Enotiadis, CTO, Global Provider Mobility Sales, Cisco Systems, Inc.
Bart Van de Velde, Sr. Director, Engineering, Cisco Systems, Inc.

Mapping requirements of subscriber edge

Requirement	Traditional Broadband Services	Optimized Broadband Services
SLA Type	Best Effort, Non-guaranteed Throughput, Quota	Per Device SLA, Flat-rate per month
QoS Type	Heavy H-QoS per home, Shaper per traffic class (4+)	Simplified QoS, reduced traffic classes (1-2)
Bandwidth	Low bandwidth per home – less the few Mbps	High bandwidth per home – In the order of few 100s Mbps
OSS Integration	Heavy OSS integration, mostly snmp or vendor EMS on proprietary NBI, mono vendor dependency	Multi vendor, Open APIs from CP to NBI, Abstracted and simplified
Accounting	Strict accounting for charging and policy, App level accounting for usage control	Light accounting for reporting and monitoring
Policy & Charging	Complex Policy logic, down to app level charging control	Flat policy for unlimited broadband, Flat charging per month
Access Type	Fixed Access Only, DSL and PON	Wireline and Wireless/FWA - Converged
BNG Type	**Physical Edge router – Complex ASICs**	**Physical Edge Router - Lighter ASIC, or virtual User-plane**

Cisco Subscriber Edge
cnBNG (aligned with BBF TR-459)

- Multi-Service Disaggregated Broadband Network Gateway
- Separation of control-plane and user-plane (CUPS)
- Control-plane moves to cloud / centralized
- User-plane: Hardware or software, centralized or distributed.

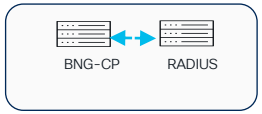


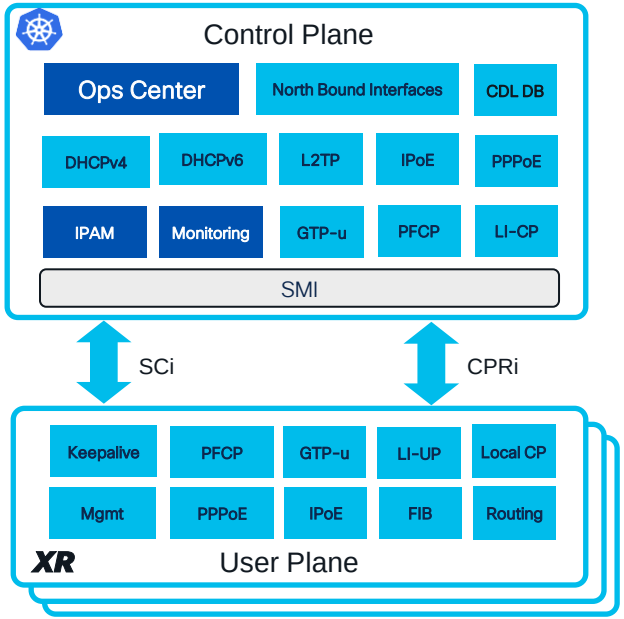
Scale to 100s of user-planes with a single control-plane

Single OSS/BSS interface for millions of subscribers

Simplified address pool management

BNG Control Plane





- **Control Plane:**
  - Built as cloud-native application for greater resiliency
  - Runs on SMI (Cisco CaaS) which is a common infrastructure for BNG and Mobility
  - Key BNG functions split into multiple containers
  - Multiple containers allow: in-service upgrade, independent patching, easy scale-in/out of services, faster feature delivery
  - Network wide licensing model
  - Varying deployment models: VMWare, CVIM, Openstack, Baremetal, Public cloud

- **User/Data Plane:**
  - ASR9k IOS-XR
  - Third Party TR459 compliant User-planes

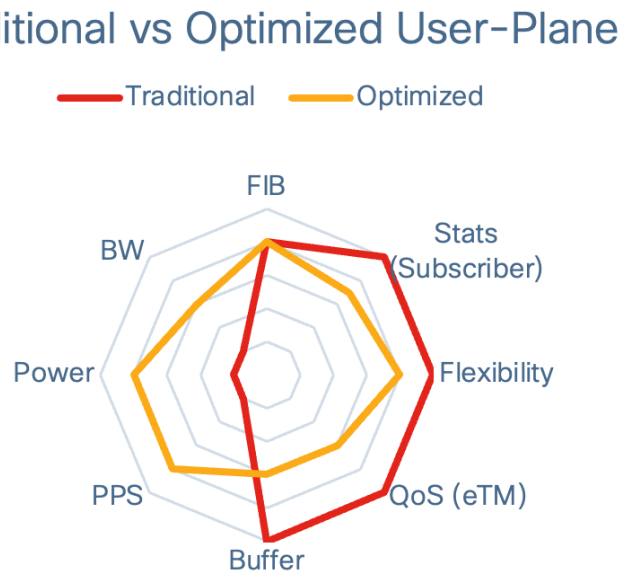
Optimizing the BNG-UP

Traditional User-Plane

- 4+ Queues per Subscriber
- 32K-256K Subscribers per User-Plane
- Low per subscriber bandwidth

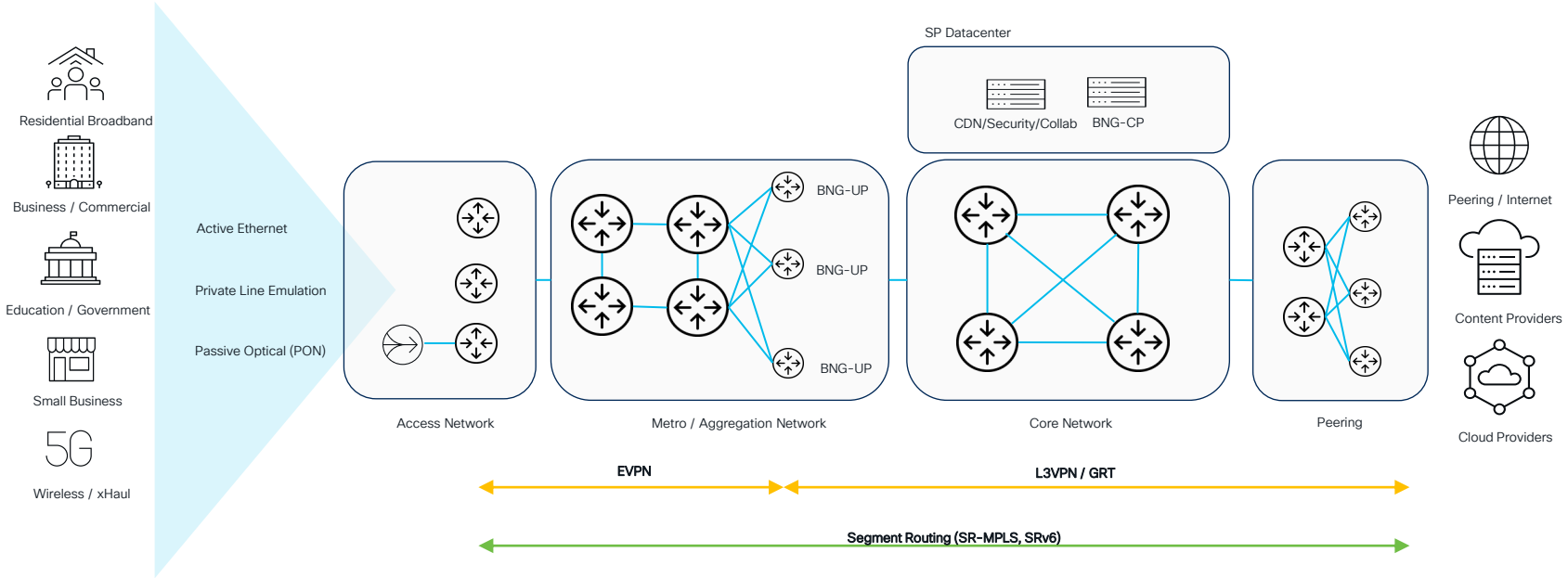
Optimized User-Plane

- Reduced QoS Requirements (1-2 Queues)
- 6K-32K subscribers
- Higher bandwidth per subscriber

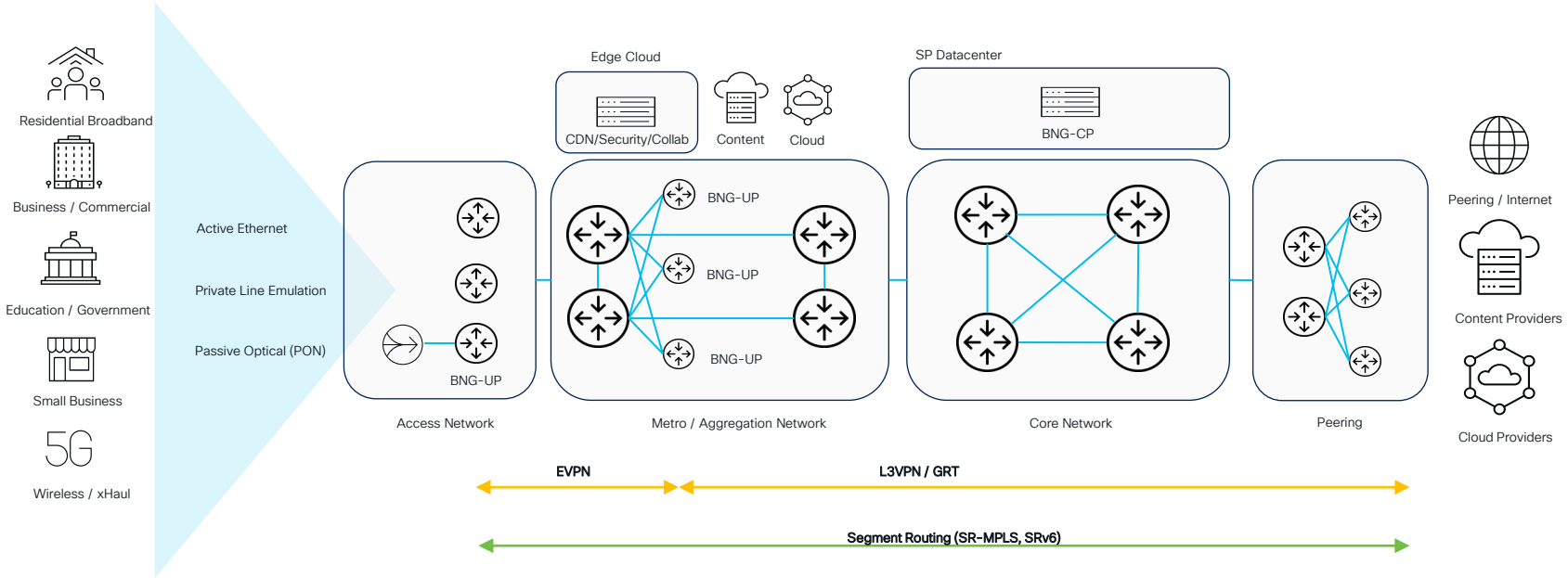


Alignment with industry silicon development and speeds

Centralized Placement of BNG-UP



Distributed placement of BNG-UP

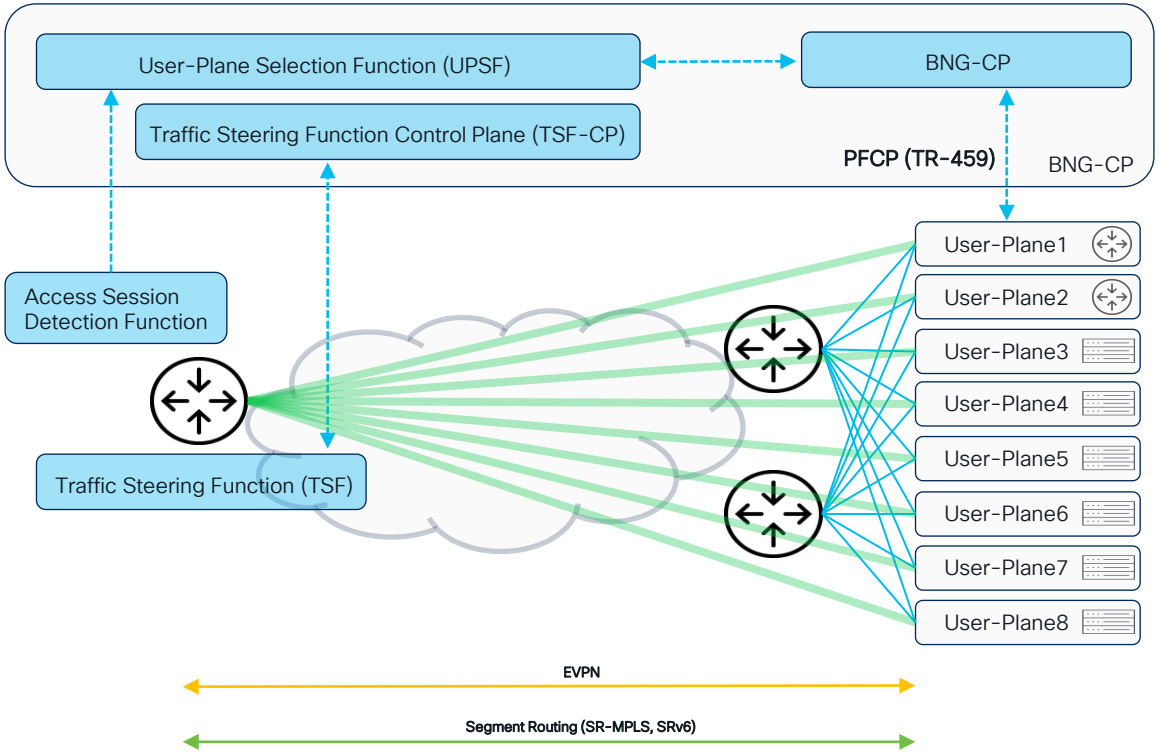


Subscriber session steering

- Work in progress, Broadband Forum (WT-474)
- Dynamically assign traffic to user-planes based upon policy

Use Case	Examples
Dynamic load-balancing across user-planes	Per network policy, use the least loaded user-plane
Dynamic re-allocation of subscriber sessions	Network maintenance, user-plane failure
Optimization of subscriber session placement	Hardware user-plane vs software user-plane vs DPU-enabled user-plane, cost or power optimizations
Edge services	Firewall Services, Enterprise applications, Gaming, new services
Subscriber SLA	Mapping of subscriber services to network SLA
Dynamic scaling	Dynamically scale up/down based upon traffic thresholds, saving power during non-peak hours.

Subscriber Session Steering



- Established EVPN-VPWS over SR/SRv6 to each user-plane
- BNG-CP receives subscriber session set up
- BNG-CP sends UP lookup request to UPSF
- User-plane selected based upon policy (ex: least load)
- UPSF responds with UP
- BNG-CP completes session setup
- TSF-CP notifies TSF to steer subscriber traffic to correct EVPN-VPWS to BNG-UP
- Per-subscriber policy can determine the BNG-UP (group-id)

Conclusion

Summary

Innovations in ASIC Design
Optimized forwarding performance and cost

- TCO Impact for transport and subscriber edge
- Lower power consumption

Network Programmability
Intent-based underlay network to build services

- Optimal forwarding
- Differentiated Services
- Better use of fiber assets

Automation and Software
Untangling the complexity of integration

- Configuration management and consistency
- Operational advantages

Optical and Optic Innovation
Converging optical and IP networks

- Longer reach with Coherent
- Simplification with a single plane to manage

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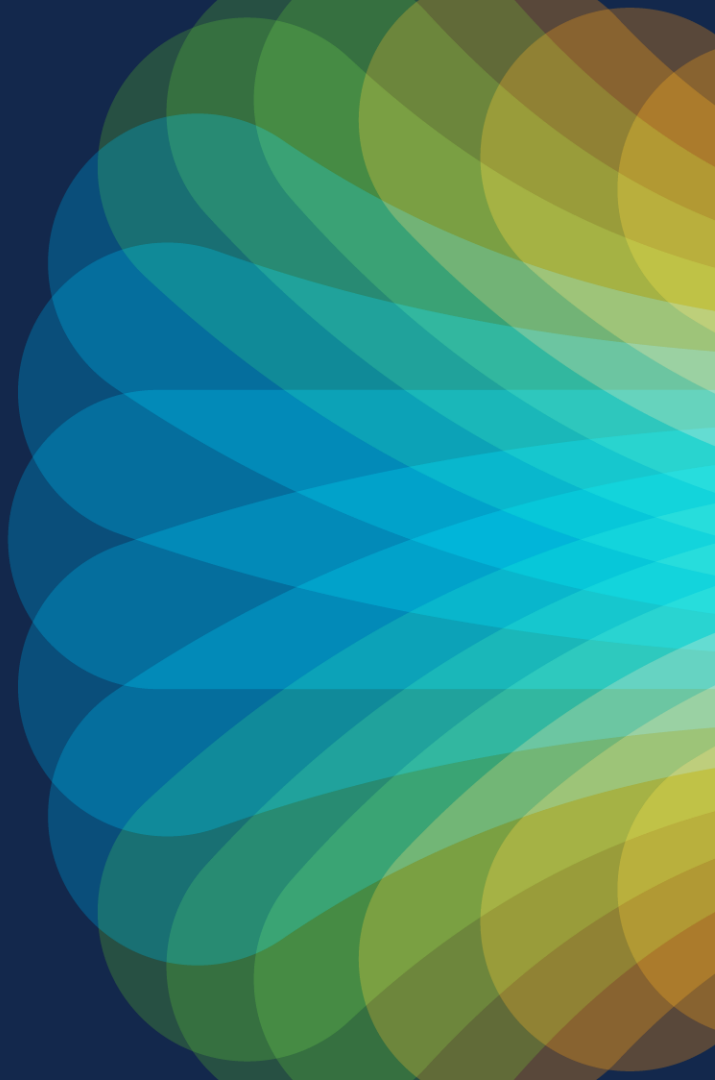
- Attend the interactive education with DevNet, Capture the Flag, and Walk-in Labs
- Visit the On-Demand Library for more sessions at www.CiscoLive.com/on-demand

The bridge to possible

Thank you



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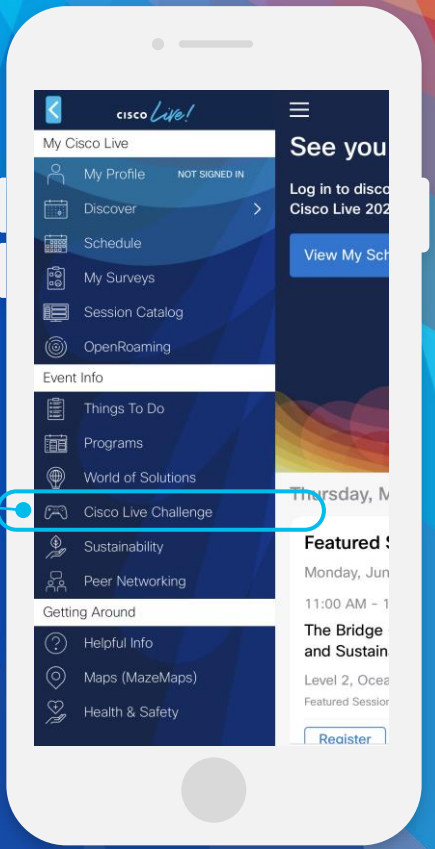

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