The bridge to possible

Transforming Subscriber Services Networks in the era of 5G and Metaverse

Gurpreet Singh, MiG TME

Cisco Webex App

Questions?
Use Cisco Webex App to chat
with the speaker after the session

How

1. Find this session in the Cisco Live Mobile App
2. Click "Join the Discussion"
3. Install the Webex App or go directly to the Webex space
4. Enter messages/questions in the Webex space

Webex spaces will be moderated
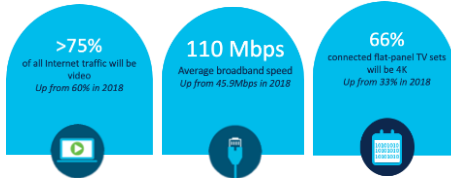until February 24, 2023.

Agenda

- Overview

- Transformation

- Cisco Subscriber Edge (formerly cnBNG)
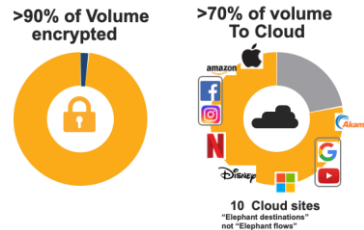
- Conclusion

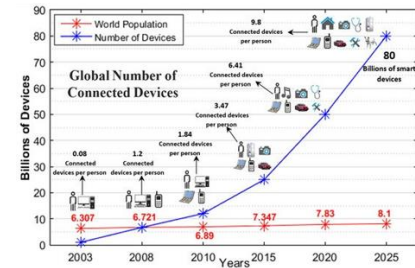# Overview

Subscriber and Traffic Trends

High BW

- >75% of all Internet traffic will be video *Up from 60% in 2018*
- 110 Mbps Average broadband speed *Up from 45.9Mbps in 2018*
- 66% connected flat-panel TV sets will be 4K *Up from 33% in 2018*

Encrypted

- >90% of Volume encrypted
- >70% of volume To Cloud
- 10 Cloud sites "Elephant destinations" not "Elephant flows"

Destination: All-encrypted world
Cloud: Concentrating the Internet

Nomadic

9.8 Connected devices per home

BNG Deployment Options – So Far…

Centralized

Aggregation
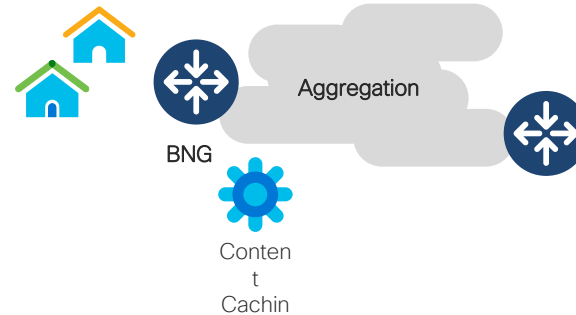
BNG

Content
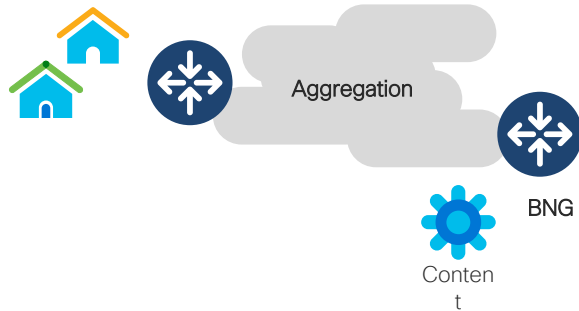
- Recommended for Lower N/w wide subscriber density
- Recommended for Lower Per Subscriber Bandwidth
- Easier to manage and troubleshoot
- **Challenge:** Higher Bring-up time in case of outages
- **Challenge:** Frequent network wide bandwidth upgrades required

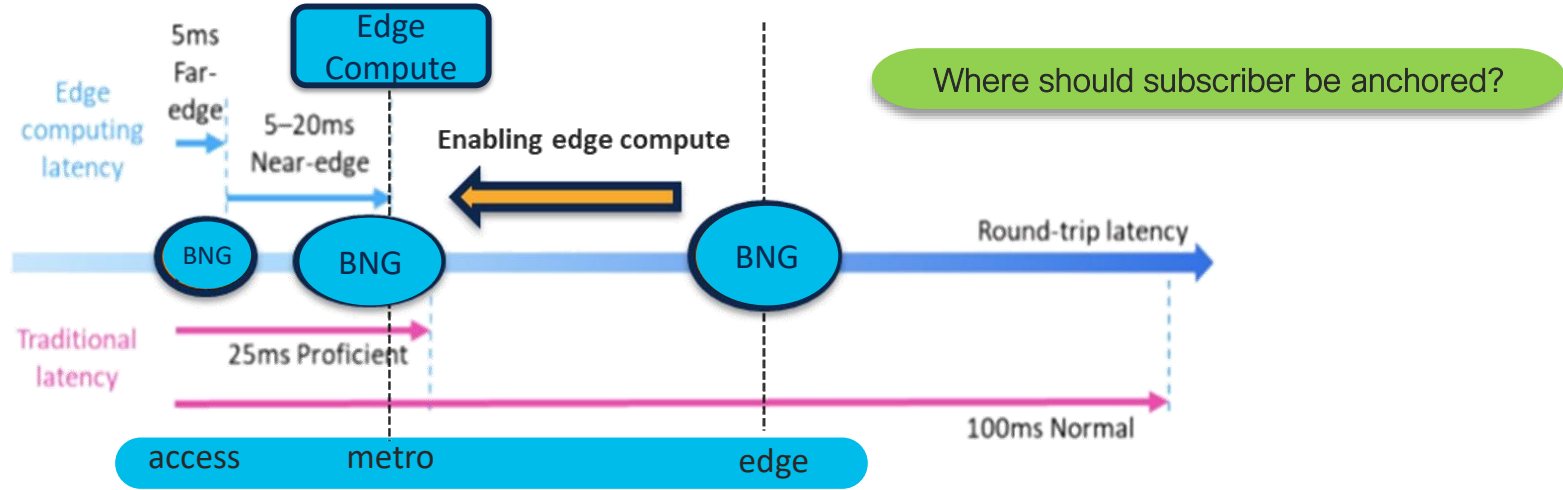## Distributed

Aggregation

BNG

Content Cachin

- Recommended for High Network wide subscriber density
- Recommended for High Speed Per Subscriber bandwidth
- Localization of failure
- Local Service insertion at the distributed location (CDN)
- **Challenge:** Cost & Complexity increases with Distribution?

How to achieve best of both?

What we never thought before? Latency

Edge computing latency

5ms Far-edge

5–20ms Near-edge

Edge Compute

Enabling edge compute

Where should subscriber be anchored?

Round-trip latency

Traditional latency

25ms Proficient

100ms Normal

access metro edge

- Latency is critical for applications especially gaming and metaverse
- Subscriber termination and edge compute placement determines the latency
- Edge compute for wireline is moving to Near Edge

In Summary

Broadband Service offerings are getting lean and flat

Subscriber GW scale and functional requirements are getting lighter

Demand for better connection quality has direct impact on the design

Traffic profiles are getting lighter and end user device Traffic Managers handle more

New transport protocols (QUIC, TCPLS) optimize traffic behavior that no longer require heavy network level QoS

Transformation

Architecture Drivers

Services closer to subscriber with flexible GW options

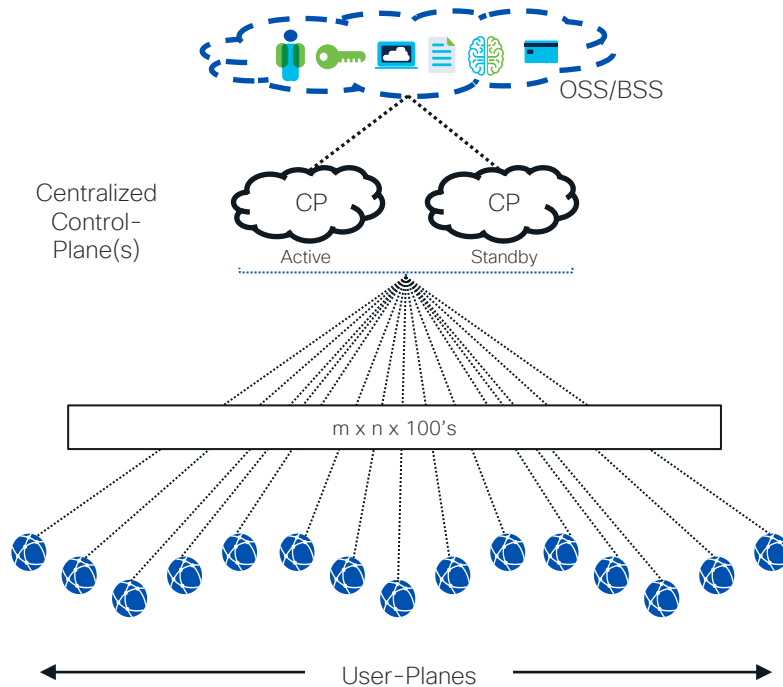Independent CP and UP scaling and ease of integration

Common Infrastructure, Common Policy, Convergence, New Business Models

New and Differentiated Broadband Offerings

Control Plane and User Plane Separated Architecture

Centralized Control-Plane(s)

OSS/BSS

CP Active

CP Standby

m x n x 100's

User-Planes

CUPS means Control and User Plane Separation

- Defined by Broadband Forum in TR-459

CUPS BNG means separation of

- BNG Control Plane and BNG data/user plane

With CUPS BNG

- BNG Control Plane moves to Cloud (centralized)
- OSS/BSS Interacts with Centralized Control Plane Function
- CP becomes centralized entity to manage and troubleshoot entire distributed BNG deployment base
- Customization possible in Cloud Based CP for easier OSS/BSS integration
- BNG Data Plane can be either: Hardware or Software
- Leaner Data Plane as control functions move to cloud

CUPS Function Split and simplification of Data Plane

Control-Plane(s)

CP
Active

CP
Standby

OSS/BSS

m x n x 100's

User-Planes
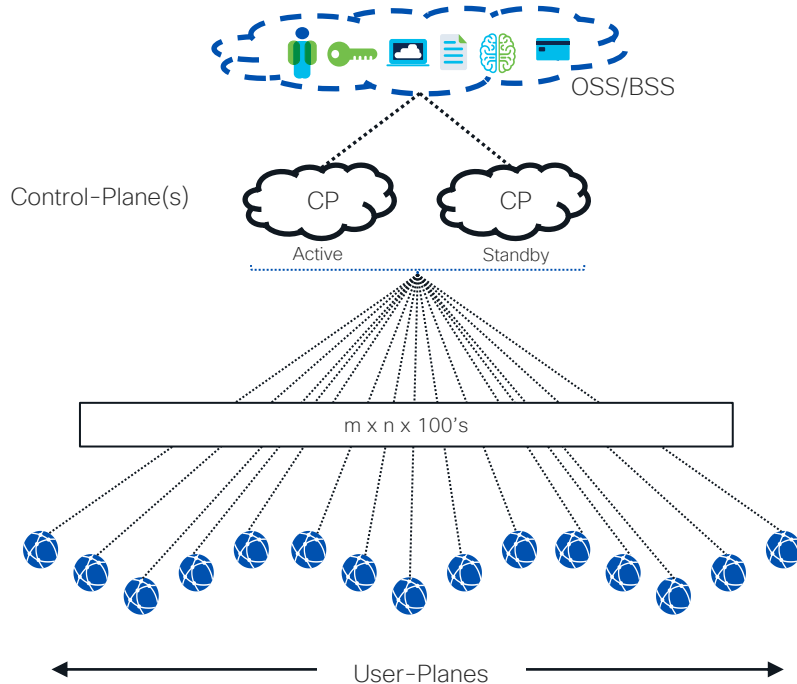
Control Plane functions

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

Data Plane functions

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

Control Plane and User Plane Separation Benefits

OSS/BSS

Centralized Control-Plane(s)

CP Active

CP Standby

m x n x 100's

Distributed User-Planes
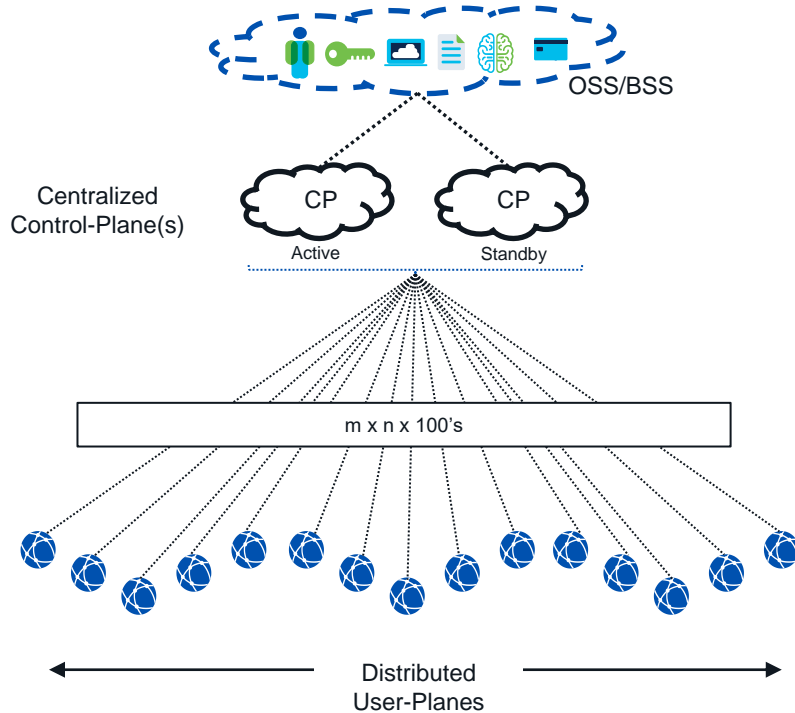
Easier OSS/ BSS Integration

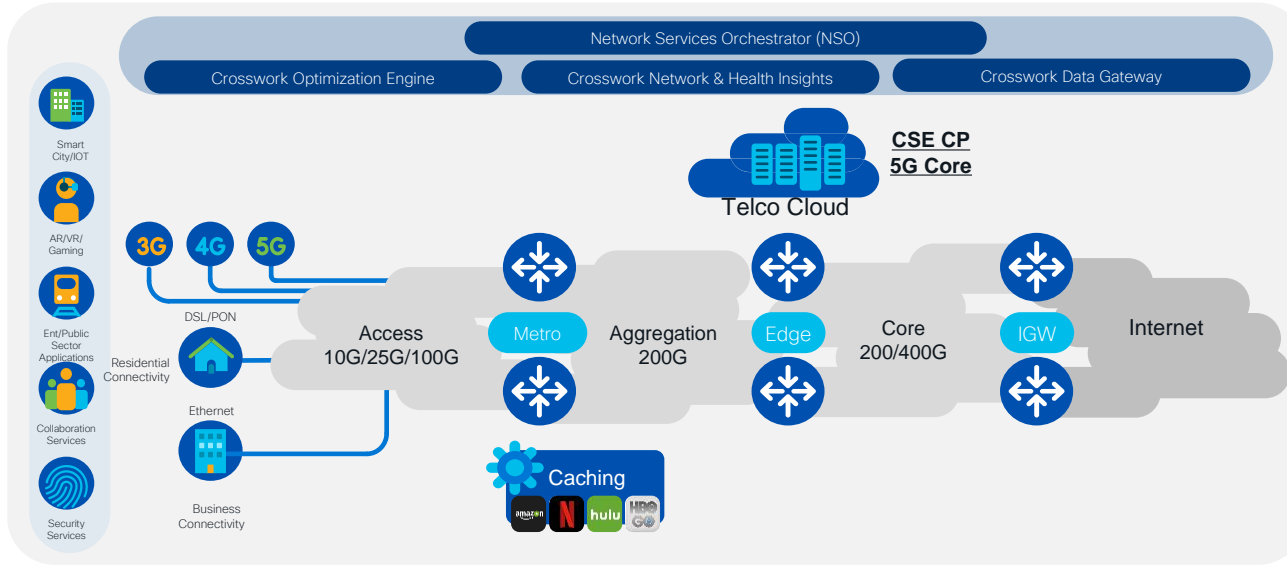Faster Time To Market

TCO Reduction

Grow when Required

Cisco Subscriber Edge
(formerly cnBNG)

Cisco Subscriber Edge

Reduced OpEx: 5x less OSS/BSS integration points   Reduced CapEx: 50%+ savings vs traditional deployments

Supports all session types (v4+v6):

- IPoE
- PPPoE PTA
- L2TP LAC
- L2TP LNS

Containerized Control Plane for better resiliency and operations
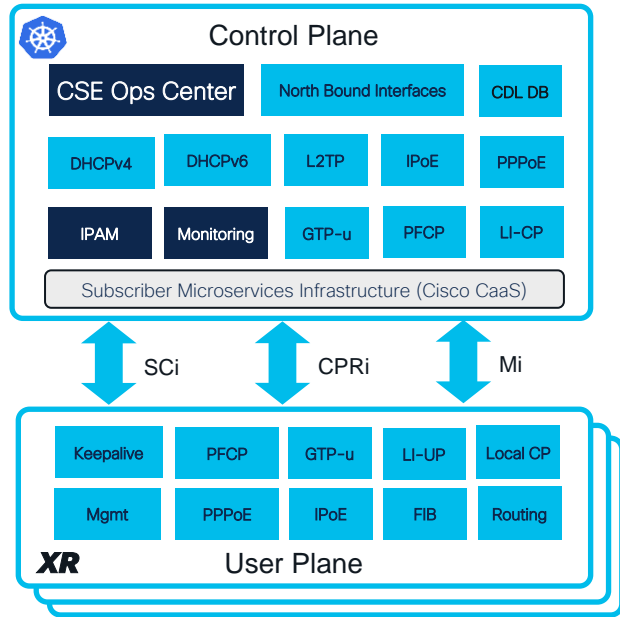
Simpler | Distributed | Resilient | Optimized

Converged Architecture

High Level Architecture
Aligned with Broadband Forum TR-459

Control Plane

CSE Ops Center | North Bound Interfaces | CDL DB

DHCPv4 | DHCPv6 | L2TP | IPoE | PPPoE

IPAM | Monitoring | GTP-u | PFCP | LI-CP

Subscriber Microservices Infrastructure (Cisco CaaS)

SCi   CPRi   Mi

Keepalive | PFCP | GTP-u | LI-UP | Local CP

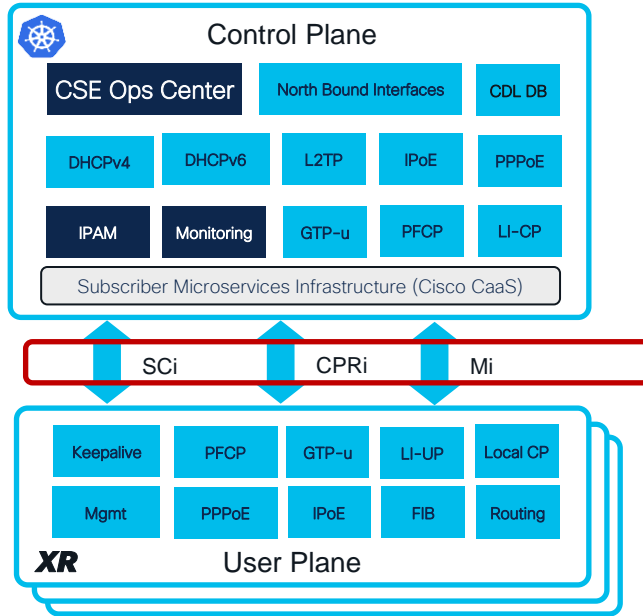Mgmt | PPPoE | IPoE | FIB | Routing

XR User Plane

Control Plane:

- Built as cloud-native application for greater resiliency
- Runs on SMI (Cisco CaaS) which is a common infrastructure for Subscriber Management (Wireline and/or Mobility)
- Key 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: VM Based, Baremetal, Public cloud

User/Data Plane:

- ASR9k IOS-XR based UP
- XRv9k Virtual UP

CUPS Interfaces

Control Plane

CSE Ops Center | North Bound Interfaces | CDL DB

DHCPv4 | DHCPv6 | L2TP | IPoE | PPPoE

IPAM | Monitoring | GTP-u | PFCP | LI-CP

Subscriber Microservices Infrastructure (Cisco CaaS)

SCi | CPRi | Mi

User Plane

Keepalive | PFCP | GTP-u | LI-UP | Local CP

Mgmt | PPPoE | IPoE | FIB | Routing

XR

- CUPS Interfaces as per TR-459

- State Control Interface (SCi):
  - programming and management of dynamic Subscriber Interfaces including accounting

- Control Packet Redirect Interface (CPRi)
  - Redirection of control packets between User plane and Control plane
  - Control Packets: DHCP DORA, DHCPv6, PPPoE, L2TP

- Management Interface (Mi)

Control Plane Main Functions
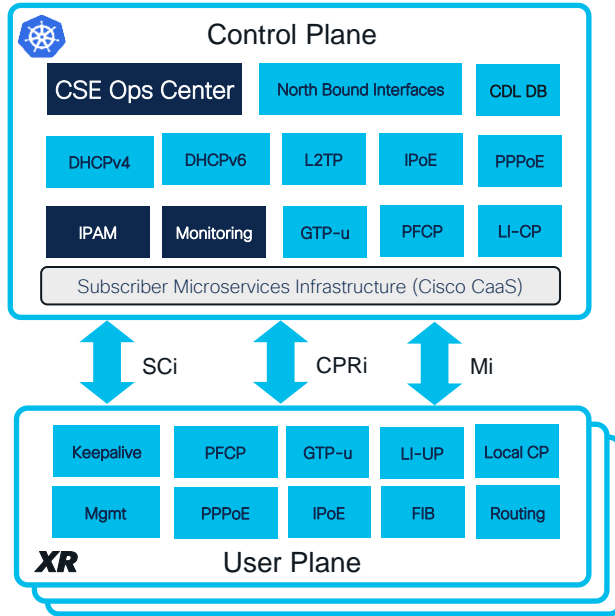
- **CSE Ops Center:**
  - Provides netconf/ restconf/ cli interface
  - Abstracts K8s details for day2day operations

- **IPAM:**
  - Stands for IP Address Manager
  - Provides a centralized mechanism to manage IP address

- **Subscriber Monitoring:**
  - A unified view of BNG Deployment
  - Exposes 100s of metrics and KPIs for BNG monitoring
  - Includes an in-built Grafana dashboard
  - Can generate alerts through Alert Manager

CSE Ops Center

- **Ops Center embeds Cisco Conf-D and Provides:**
  - Easier operations for Network Engineers
  - Standard NETCONF, RESTCONF, and CLI interfaces
  - NSO integration without custom NED
  - YANG Models for configurations and operations
    - Both Native and Openconfig models are supported
- Cisco Smart Licensing integration
- Abstracts Helm and K8s functions

```
Welcome to the bng CLI on cnbng-tme-lab/bng
Copyright © 2016-2020, Cisco Systems, Inc.
All rights reserved.

User admin last logged in 2022-03-12T11:01:40.300121+00:00, to ops-center-bng-bng-ops-cen
admin connected from 192.168.107.165 using ssh on ops-center-bng-bng-ops-center-86d89bd45
[cnbng-tme-lab/bng] bng# show system
Sat Mar  12 11:04:34.555 UTC+00:00
system uuid 0b4a9586-6327-4ba6-91fe-dcbc38ae78bb
system status deployed true
system status percent-ready 100.0
system ops-center repository https://charts.192.168.107.165.nip.io/bng.2022.02.m0.i46
system ops-center-debug status false
system synch running true
system synch pending false
[cnbng-tme-lab/bng] bng# show subscriber session filter { mac 0010.9400.0059 }
Sat Mar  12 11:04:37.782 UTC+00:00
subscriber-details
{
  "subResponses": [
    {
      "records": [
        {
          "cdl-keys": [
            "16784206@sm",
            "acct-sess-id:cnbng-tme-lab DC 16784206@sm"
```
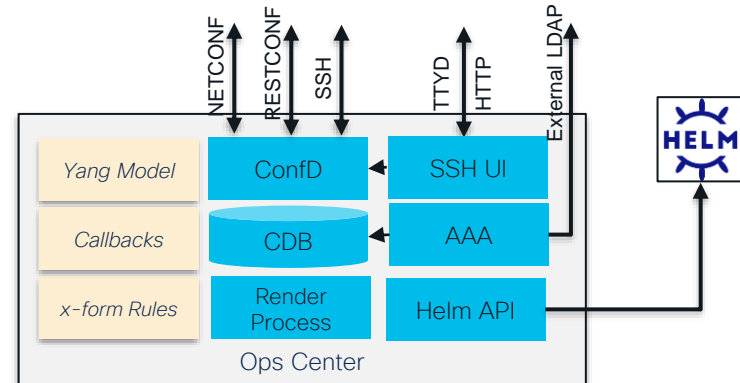
IP Pool and Address Management: IPAM

```
[svi-cn-bng-tb3/bng] bng# show ipam pool

=============================================================================
PoolName           Ipv4Utilization  Ipv6AddrUtilization  Ipv6PrefixUtilization
=============================================================================
POOL_2              1.46%            4.01%               1.00%
POOL_1              1.46%            4.01%               1.00%
POOL_3              2.86%            18.30%              1.14%
=============================================================================
```

```
ipam
 instance 1
 address-pool POOL_2
 address-quarantine-timer 60
 vrf-name          default
 ipv4
  split-size
   per-dp   256
  exit
  address-range 12.0.0.2 12.10.255.254
 exit
```

Dynamic/Static Pool Assignment

Userplane

SGRP/SRG

Interface
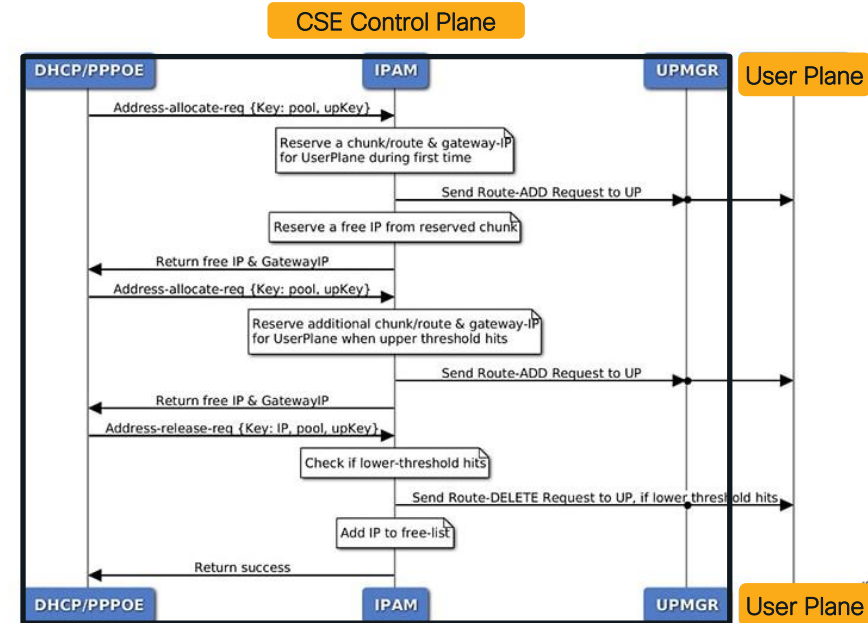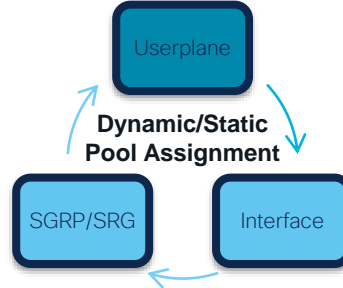
CSE Control Plane

Simplified Subscriber Monitoring

Collection	Visualization	Alerts

- Controlplane metric collection inbuilt
- Model Driven Telemetry for UP stats collection
- 100s of subscriber metrics already available from Control Plane

- Metrics Visualization on Inbuilt Dashboard (Grafana)
- Integration with external visualization also supported

- Alert Manager for generating alerts
- Alerts via Email, Webhooks, SNMP or on Grafana dashboard
- Netconf/ Restconf/ CLI to set alerts
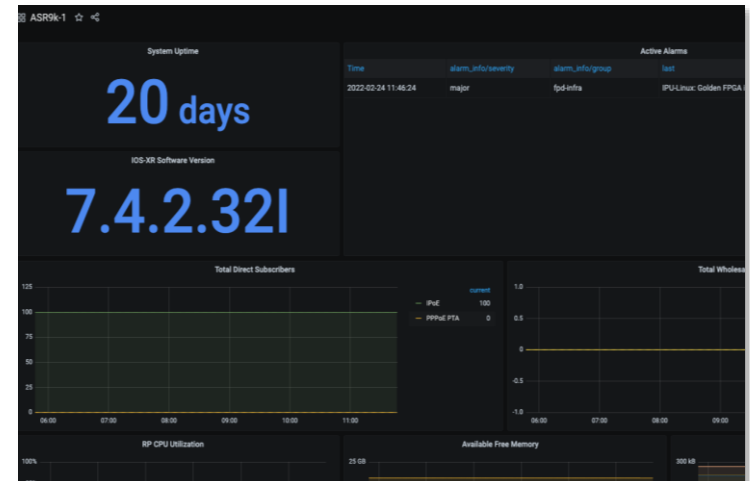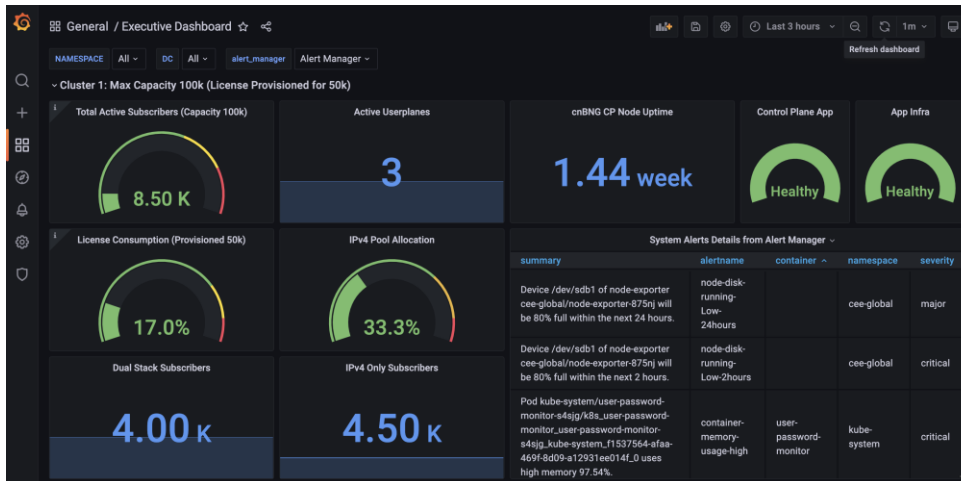
Simplified Subscriber Monitoring (contd)
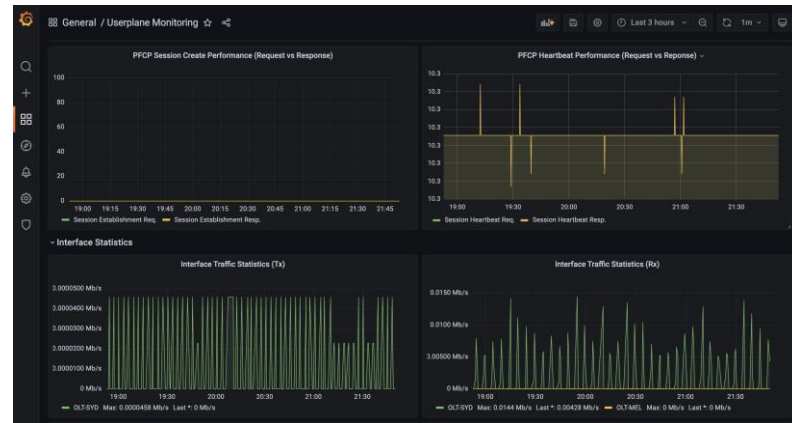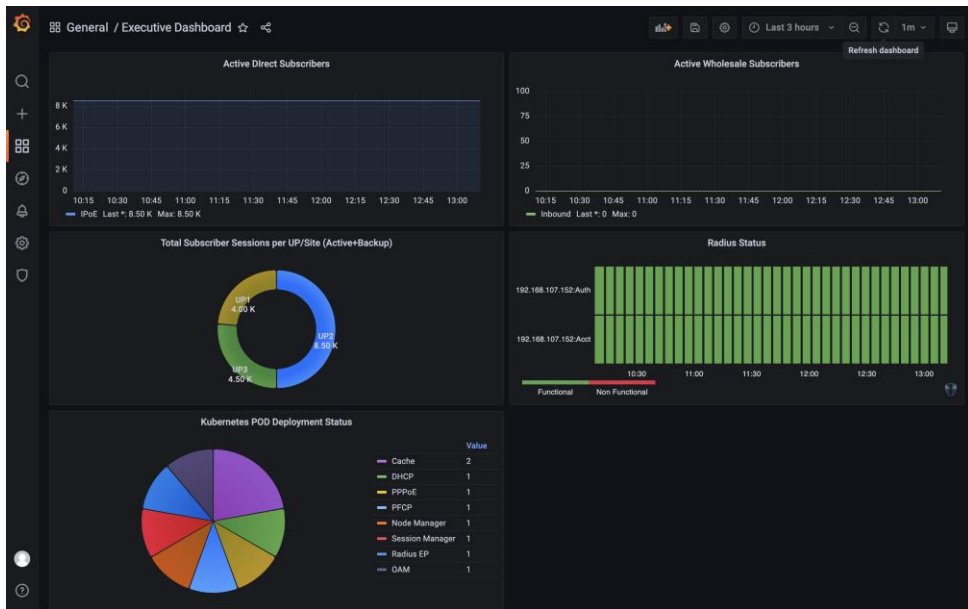
Simplified Subscriber Monitoring (contd)

Control Plane Deployment Options

Multi VM

CSE CP cNF	CSE CP cNF		CSE CP cNF
Guest OS	Guest OS	. . .	Guest OS

VMWare vCenter/ESXi
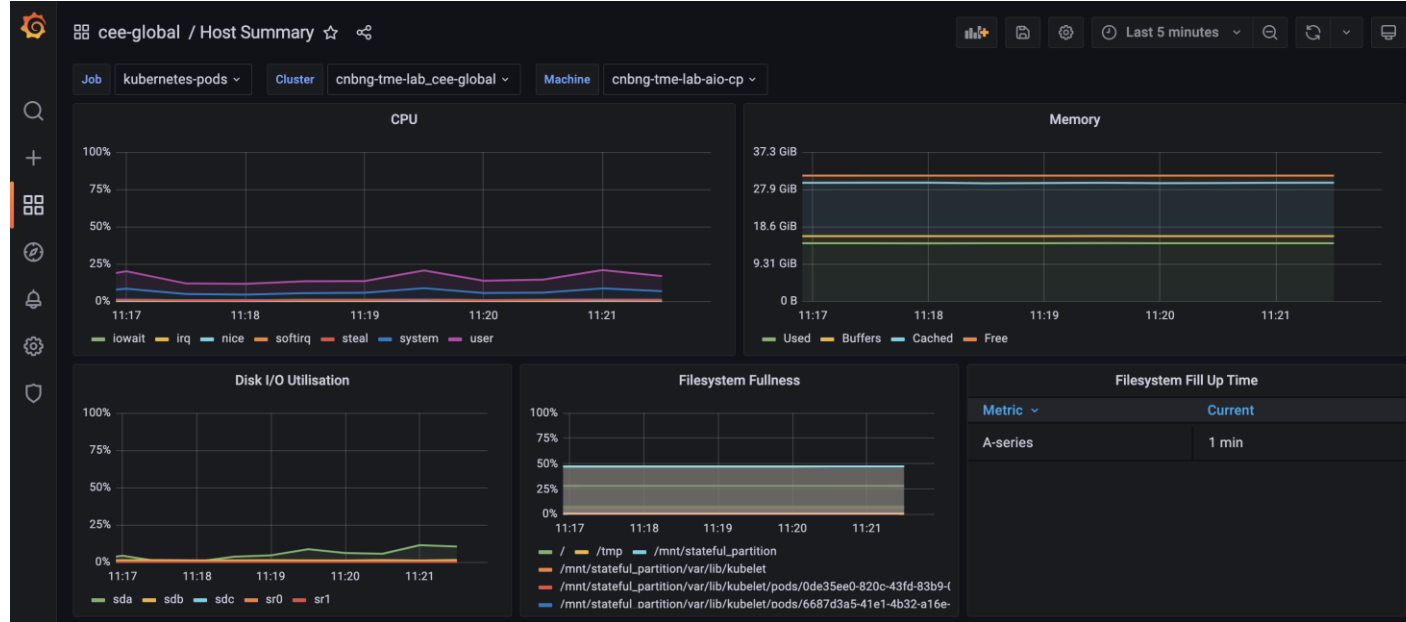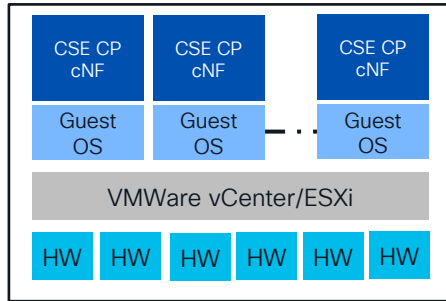
| HW | HW | HW | HW | HW | HW |

- For limited deployments only
- Deploy CSE CP in multiple VMs for Scale

All-in-one

CSE CP cNF	Other VNF	- - . . .	Other VNF
Guest OS	Guest OS		Guest OS

VMWare vCenter/ESXi

HW

CSE CP cNF

UCS
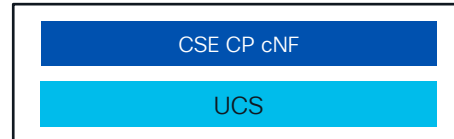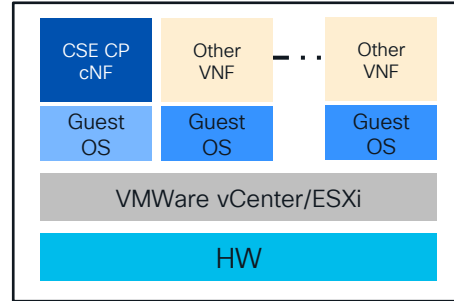
- Deploy CSE CP in a single VM or a UCS Server

Baremetal

CSE CP cNF	CSE CP cNF	CSE CP cNF	CSE CP cNF
Host OS	Host OS	Host OS	Host OS
UCS	UCS	UCS	UCS
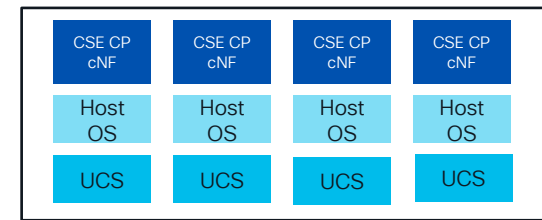
- Run containers directly on bare metal; i.e. no VIM layer
- Removes hypervisor overhead & license Cost
- 20% to 30% more available CPU cores
- Server savings in the magnitude of 4 to 9 blades
- Single monitoring endpoint for both server and application health
- Upto N-servers in a single Cluster

Control and User Plane Association Call Flow

- For SCi Association Formation:
  - User Plane sends PFCP Association Request Message to Control Plane
  - Control Plane acknowledges association using PFCP Association Response Message

- After Association is formed, both CP and UP create a default CP-UP GTP-u tunnel for control packet exchanges

- Association is maintained through PFCP Heartbeat messages

- IOS-XR/ASR9k User Plane operates in Native mode of operations with CSE Control Plane

- Native mode of operation optimizes channel between CP and UP

ASR9k-1 UP	CSE CP

Association Request →
← Association Response
Heartbeat Request →
← Heartbeat Response

——— SCi
- - - - CPRi
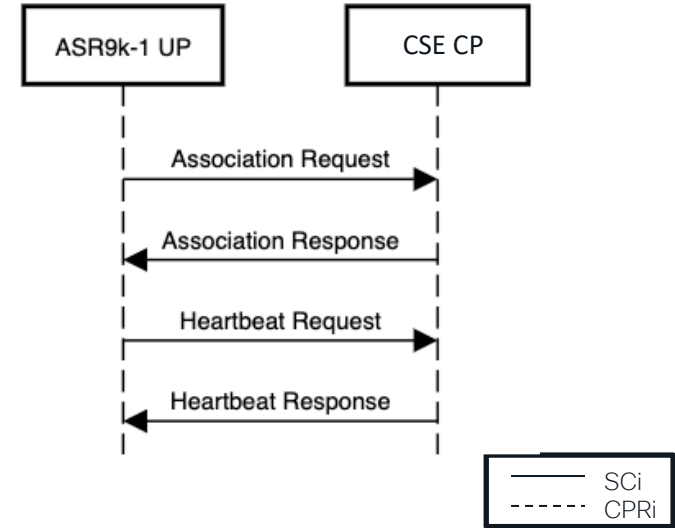
IPoE Call Flow

Detailed Call flow Steps 🔍

1. DHCP Discover (from CPE) received on User Plane access interface is forwarded to Control Plane over CP-UP GTP-u tunnel
2. After successful auth, IPAM function in CSE Control Plane allocates IP Subnet to UP or to SRG, which is programmed using PFCP Association Update message
3. IPAM allocates an IP address from already programmed subnet and DHCP Offer is then sent over GTP-u tunnel from CP to UP. Which is decapsulated on UP and forwarded to CPE
4. DHCP Request message received on User Plane access Interface is then forwarded to Control Plane over CP-UP GTP-u tunnel
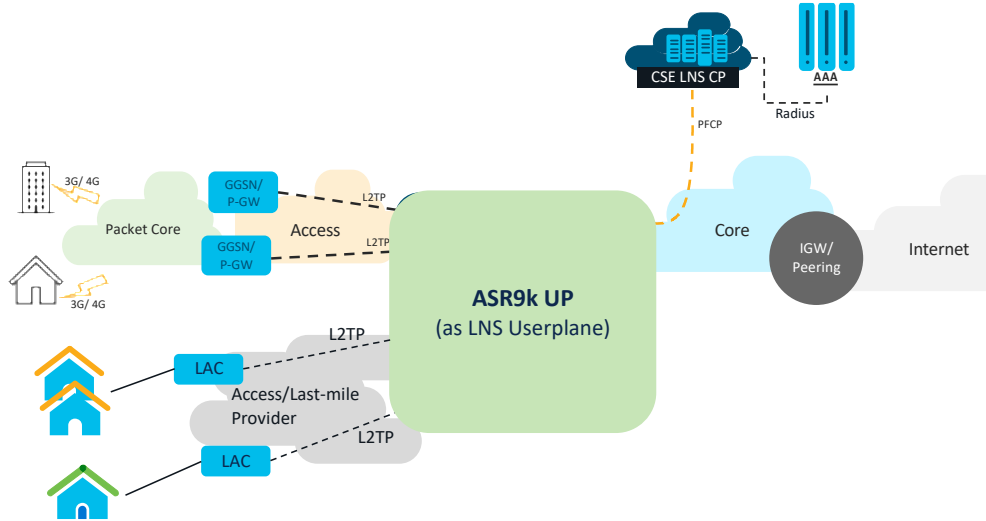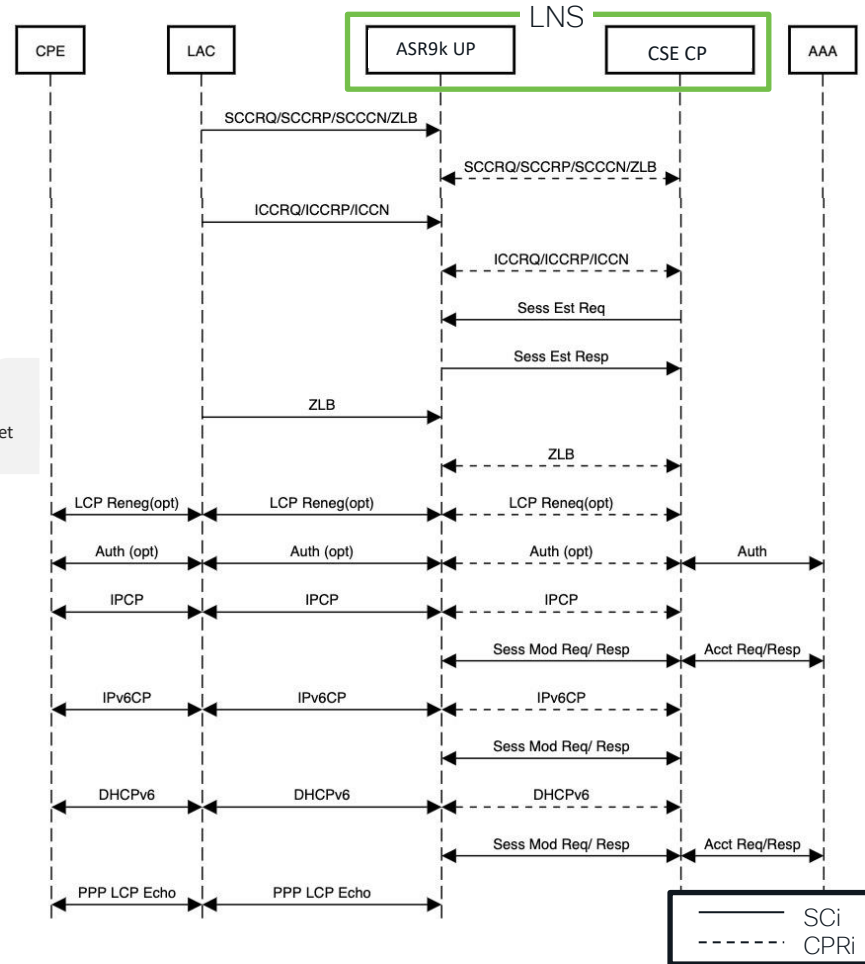5. Control Plane then programs subscriber session dynamically on User Plane using PFCP Session Establishment Request message
6. Once session is successfully created on User Plane, User Plane sends acknowledgement using PFCP Session Establishment Response message.
7. Control Plane then sends DHCP Ack message over CP-UP GTP-u tunnel to User Plane, which User Plane decapsulates and forwards to CPE.

CPE — ASR9k-1 UP — CSE CP — Radius

- DHCPv4 Discover (CPE → ASR9k-1 UP)
- DHCPv4 Discover (ASR9k-1 UP → CSE CP)
- Access Request (CSE CP → Radius)
- Access Accept (Radius → CSE CP)
- Association Update Request — Subscriber GW/ Route programming (CSE CP → ASR9k-1 UP)
- Route Programming
- Association Update Response (ASR9k-1 UP → CSE CP)
- **First session of the pool or subnet only**
- DHCPv4 Offer (CSE CP → ASR9k-1 UP)
- DHCPv4 Offer (ASR9k-1 UP → CPE)
- DHCPv4 Request (CPE → ASR9k-1 UP)
- DHCPv4 Request (ASR9k-1 UP → CSE CP)
- Session Est Request (ASR9k-1 UP → CSE CP)
- Session Est Response (CSE CP → ASR9k-1 UP)
- DHCPv4 Ack (CSE CP → ASR9k-1 UP)
- DHCPv4 Ack (ASR9k-1 UP → CPE)

Legend:
— SCi
- - - CPRi

CISCO *Live!*

L2TP LNS Session Support

ASR9k UP (as LNS Userplane)

AVAILABLE NOW

LNS

| CPE | LAC | ASR9k UP | CSE CP | AAA |

SCCRQ/SCCRP/SCCCN/ZLB
SCCRQ/SCCRP/SCCCN/ZLB
ICCRQ/ICCRP/ICCN
ICCRQ/ICCRP/ICCN
Sess Est Req
Sess Est Resp
ZLB
ZLB
LCP Reneg(opt) — LCP Reneg(opt) — LCP Reneg(opt)
Auth (opt) — Auth (opt) — Auth (opt) — Auth
IPCP — IPCP — IPCP
Sess Mod Req/ Resp — Acct Req/Resp
IPv6CP — IPv6CP — IPv6CP
Sess Mod Req/ Resp
DHCPv6 — DHCPv6 — DHCPv6
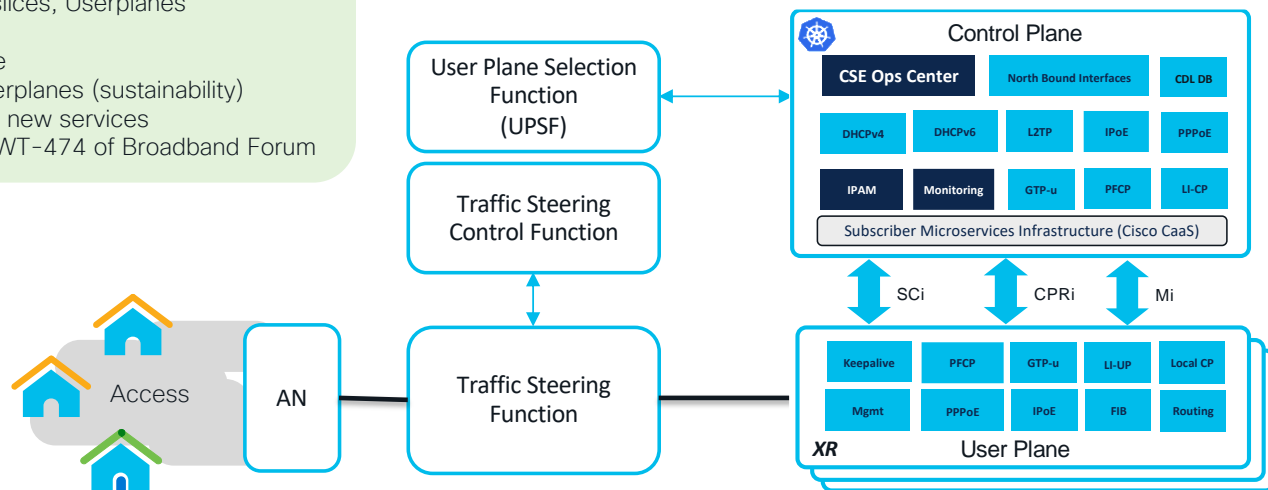Sess Mod Req/ Resp — Acct Req/Resp
PPP LCP Echo — PPP LCP Echo

SCi
CPRi

CSE enables New Broadband Offerings with Optimized Operations

- Creating new revenues:
  - Service offerings based on UP capabilities
  - Differentiated Plans:
    - Night plan vs Day plan
    - Platinum, Gold and Best-effort plans
- Optimizing Operations and TCO
  - Load balancing across transport slices, Userplanes
  - Service specific UP investments
  - Intelligent Offload for maintenance
  - Offload subscribers to smaller userplanes (sustainability)
  - New capability trials and rollout of new services
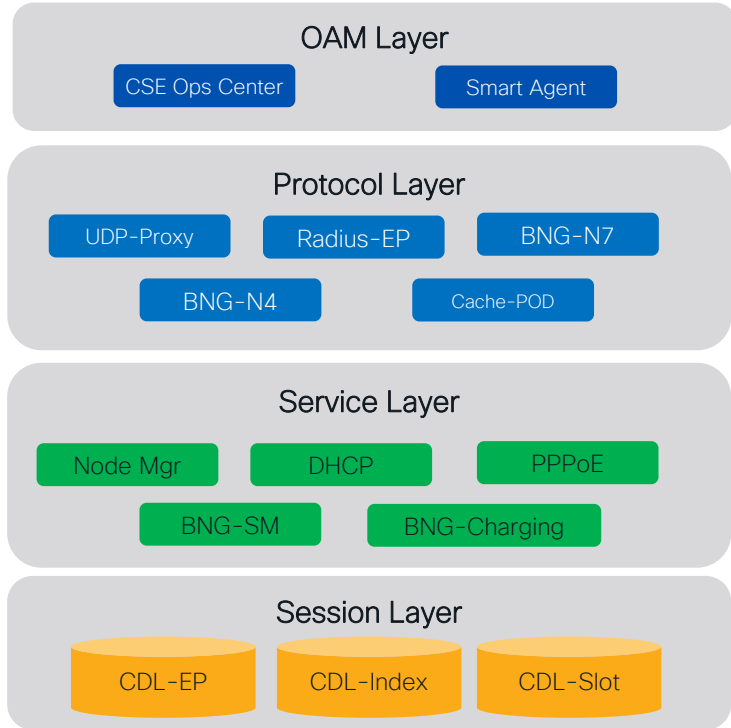- Subscriber Session Steering is defined in WT-474 of Broadband Forum

- CUPS Architecture allows Session Steering, to terminate subscriber dynamically on any Userplane
- Traffic steering function can either be on *Wireline Access (MSAN,OLT,DSLAM)* , *Access Router* or *Default UP*

Resiliency

Resilient Control Plane Layered Architecture

OAM Layer
- CSE Ops Center
- Smart Agent

Protocol Layer
- UDP-Proxy
- Radius-EP
- BNG-N7
- BNG-N4
- Cache-POD

Service Layer
- Node Mgr
- DHCP
- PPPoE
- BNG-SM
- BNG-Charging

Session Layer
- CDL-EP
- CDL-Index
- CDL-Slot

Multiple k8s Nodes can be deployed per Layer

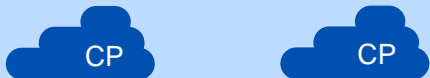K8s Node labeling is used to separate deployments

Multi-replicas of similar container are possible within each Layer

All containers are stateless except CDL which can be Local or Geo Redundant

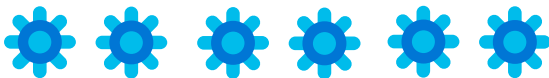# Control Plane and User Plane Geo-redundancy

Better Customer Experience

Multiple Geographically Separated Control Planes

CP   CP

Multiple Geographically Separated User Planes

Access Nodes (DSLAM/OLT)

CPE

Stateful Redundancy

Cisco CSE CP and UP can be geographically spread out with L3 connectivity. No dedicated/direct link required for synchronization

1:1, M:1 and M:N Redundancy support for User Planes
1:1 Active-Active Redundancy support for Control Plane through CDL DB

Hot-standby and Warm-Standby Redundancy Models for User Plane Geo-Redundancy in case of
- Access/Core Link Failures, CP-UP link failure
- UP Failures: Line Card, RP, Chassis Failures
- Site Failures

Control Plane Geo Redundancy in case of
- Local Monitoring failure: Node, POD, IP Connectivity or Data Center
- Peer Health Check failure/degradation
- Reception of Control Traffic on Backup Control Plane

Multiple Technology Support

Access Nodes are dual/multi-homed for redundancy using a variety of technologies based on the SP network design and choices - MCLAG, Dual Homed, Ring (G.8032), PWHE, Routed etc…

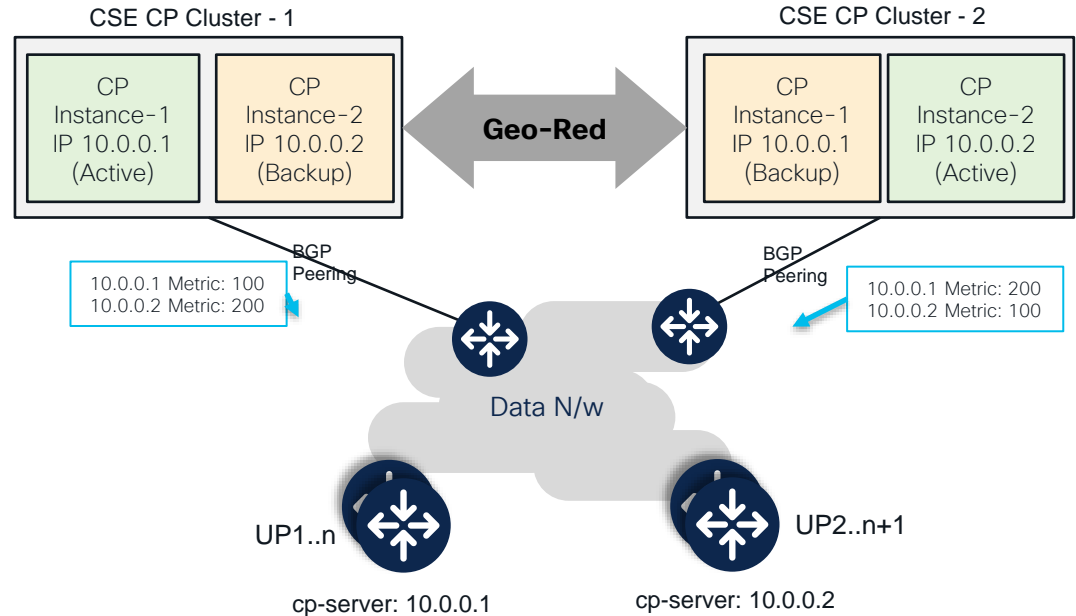## Transparent Switching

CPEs see one Gateway

Control Plane Geo-Redundancy

Instance is a logical Entity that segregates subscriber sessions

Local and Remote Instances per cluster

Redundancy in case of

- Node, POD, IP Connectivity or Data Center failure
- Peer Health Check failure/degradation
- Reception of Control Traffic on Backup

CSE CP Cluster - 1

| CP Instance-1 IP 10.0.0.1 (Active) | CP Instance-2 IP 10.0.0.2 (Backup) |

Geo-Red

CSE CP Cluster - 2

| CP Instance-1 IP 10.0.0.1 (Backup) | CP Instance-2 IP 10.0.0.2 (Active) |

BGP Peering

10.0.0.1 Metric: 100
10.0.0.2 Metric: 200

BGP Peering

10.0.0.1 Metric: 200
10.0.0.2 Metric: 100

Data N/w

UP1..n

UP2..n+1

cp-server: 10.0.0.1

cp-server: 10.0.0.2

User Plane Geo-Redundancy

- SRG is a set of subscriber sessions

- SRG could be resilient or non-resilient

- A resilient SRG is

  - A unit of failover for geo redundancy
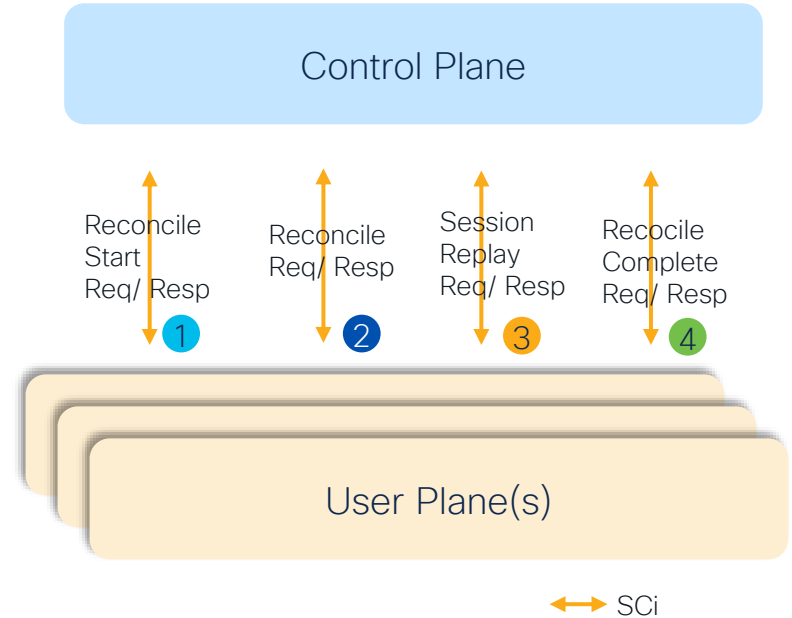
  - Defined as a set of access interfaces: Port, VLAN, BE, PWHE, Mix

  - Provisioned in consideration of the redundancy design in access & core networks – capacity planning, load balance, routing preference, etc.

- Active and Standby state is defined at Control Plane

- Control Plane determines the state of SRGs on User Planes and controls subscriber traffic flows
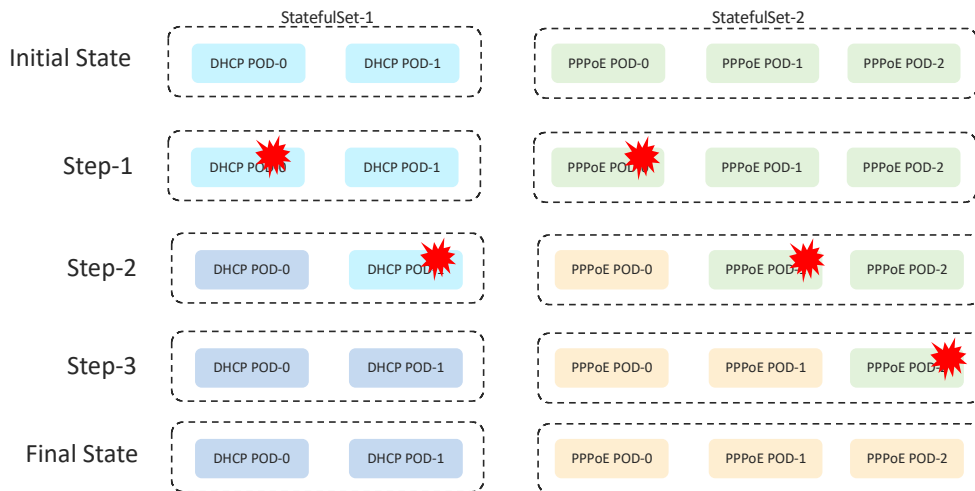
- No Accounting change at backend
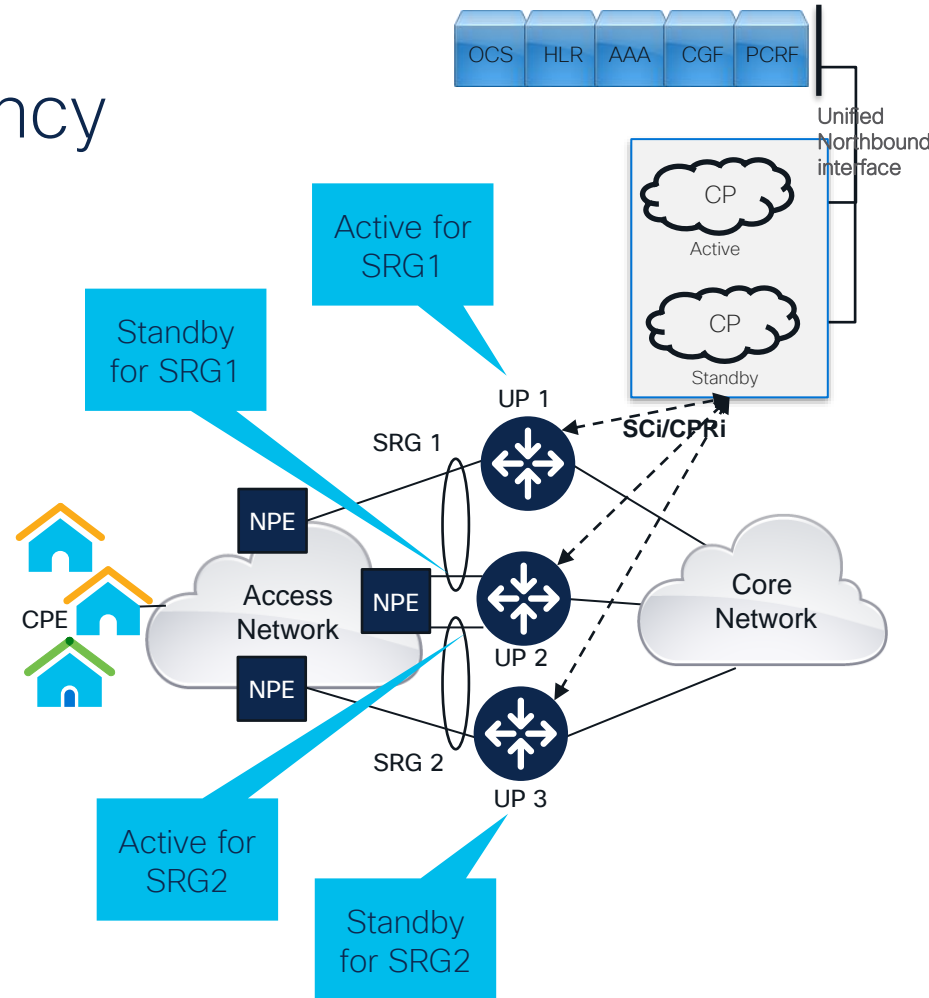
Reconciliation

- Synchronization of subscriber state between CP and UP is maintained through Reconciliation

- Reconciliation allows Control Plane to detect Inconsistency

- Reconciliation procedure checks SRG state, Subscribers and Subscriber states on User Plane

- Session Replay from Control Plane helps restore lost or stale sessions

- Reconciliation can be triggered:
  - Through Configuration
  - On failures: Link, LC, RP, UP, Association etc.
  - Periodically

Control Plane

Reconcile Start Req/ Resp ①

Reconcile Req/ Resp ②

Session Replay Req/ Resp ③

Recocile Complete Req/ Resp ④

User Plane(s)

⟷ SCi

Control Plane In-service Software Upgrade

- Utilizes K8s rolling update strategy to upgrade POD images

- PODs of a StatefulSet are updated sequentially
  - This ensures ongoing control-plane operations remains unaffected

- Update can be controlled from Deployer and is fully automated

	StatefulSet-1		StatefulSet-2		
Initial State	DHCP POD-0	DHCP POD-1	PPPoE POD-0	PPPoE POD-1	PPPoE POD-2
Step-1	DHCP POD-0	DHCP POD-1	PPPoE POD-0	PPPoE POD-1	PPPoE POD-2
Step-2	DHCP POD-0	DHCP POD-1	PPPoE POD-0	PPPoE POD-1	PPPoE POD-2
Step-3	DHCP POD-0	DHCP POD-1	PPPoE POD-0	PPPoE POD-1	PPPoE POD-2
Final State	DHCP POD-0	DHCP POD-1	PPPoE POD-0	PPPoE POD-1	PPPoE POD-2

CP ISSU Procedure

- One-by-one PODs in StatefulSets are terminated

- Terminating PODs exit gracefully after completing ongoing processing

- New PODs with updated images take the place of terminated PODs

- This process continues till all the replicas of the StatefulSet are updated

- During upgrade other PODs continue to function seamlessly without causing service disruption

Cisco CSE CP supports ISSU from Day1

Conclusion

Summary

Shifts and Transformations

Cisco Subscriber Edge Solution
- With specific focus on CUPS/Cloud Native BNG

Unique Usecases which Architecture Enables

References

Explore and learn more

Configuration Guides

- CP
  - https://www.cisco.com/c/en/us/td/docs/routers/cnBNG/cnBNG-CP/2022-04-x/Config-Guide/b_cnbng-cp-config-guide-2022-04.html
- ASR9k UP
  - https://www.cisco.com/c/en/us/td/docs/routers/asr9000/software/asr9k-r7-8/cloud-native-bng/configuration/guide/b-cnbng-user-plane-cg-asr9000-78x.html

XRDocs Tutorials/Blogs

- https://xrdocs.io/cnbng/

XRDocs Youtube Channel

- https://youtube.com/xrdocs

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