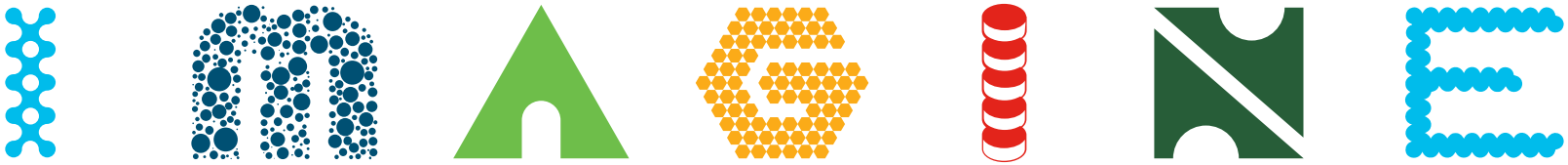

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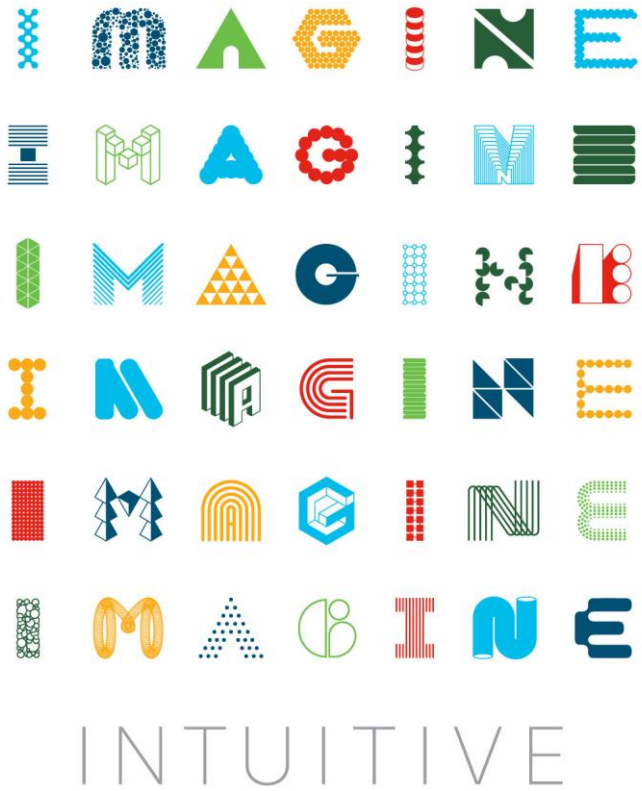
#CLUS

Cable Access Evolution with Remote PHY

Jeff Riddel – Sr. Solutions Architect

BRKSPG-2505



Cisco Webex Teams

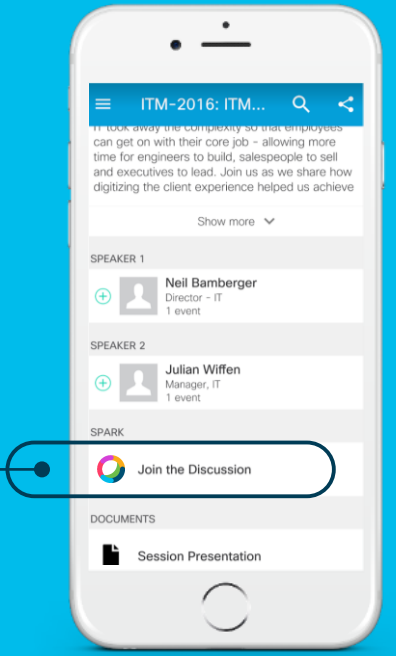
Questions?

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

How

1. Find this session in the Cisco Event App
2. Click “Join the Discussion”
3. Install Webex Teams or go directly to the team space
4. Enter messages/questions in the team space

Webex Teams will be moderated by the speaker until June 18, 2018.

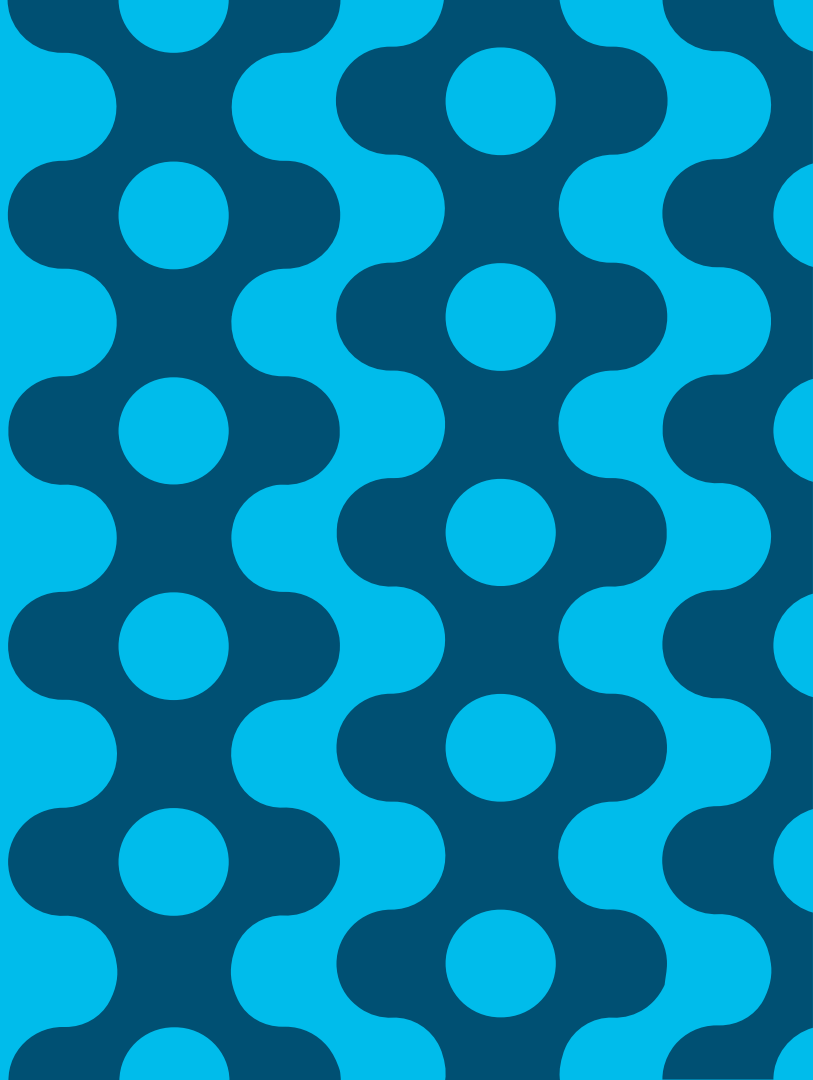


cs.co/ciscolivebot#BRKSPG-2505

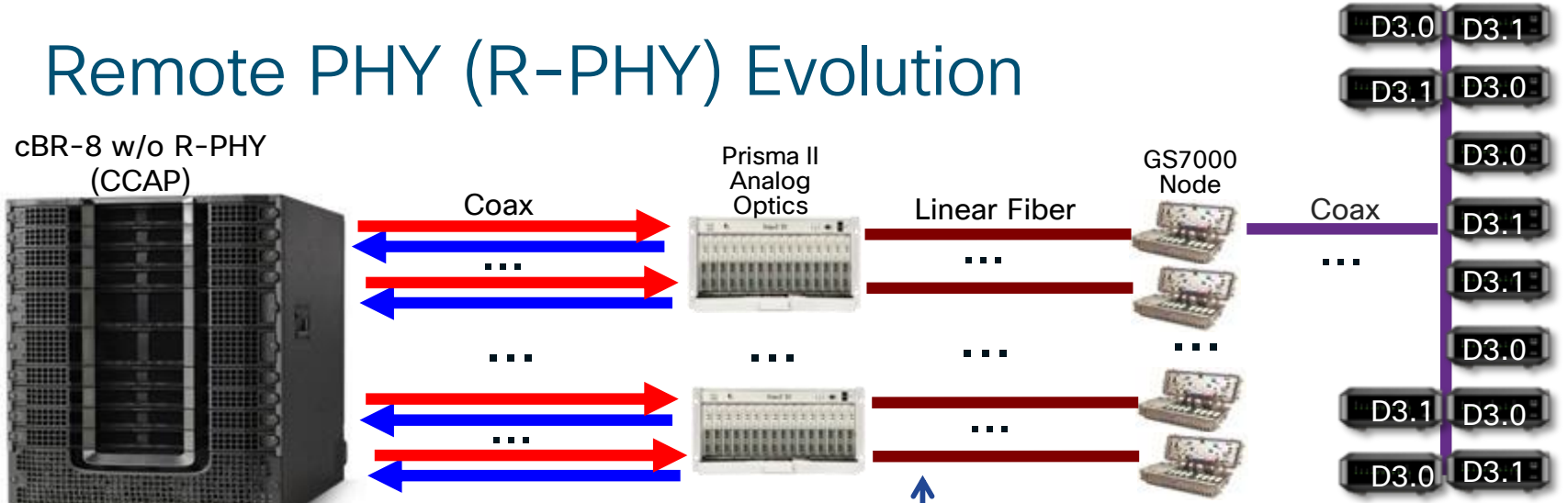
Agenda

- Remote PHY (R-PHY) Motivation & Protocols
- R-PHY Components
- R-PHY Implementation
- R-PHY Automation
- R-PHY Demo
- Summary

Remote PHY Motivation & Protocols



Remote PHY (R-PHY) Evolution

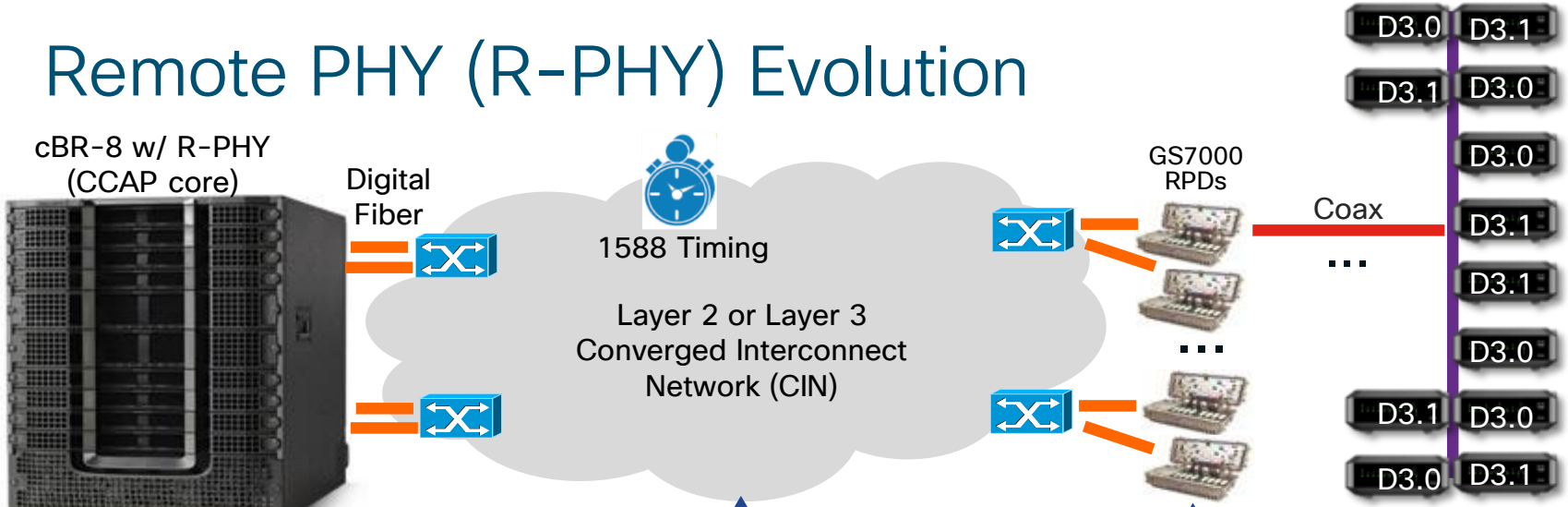


- With HA limited to 56 SGs due to limit of 56 DS ports and 112 US ports

- Linear fiber limits achievable MER (max 35-38 dB)
- Linear fiber distance limited and supports fewer usable wavelengths

- DOCSIS 3.1 modems may be unable to use higher order modulations

Remote PHY (R-PHY) Evolution



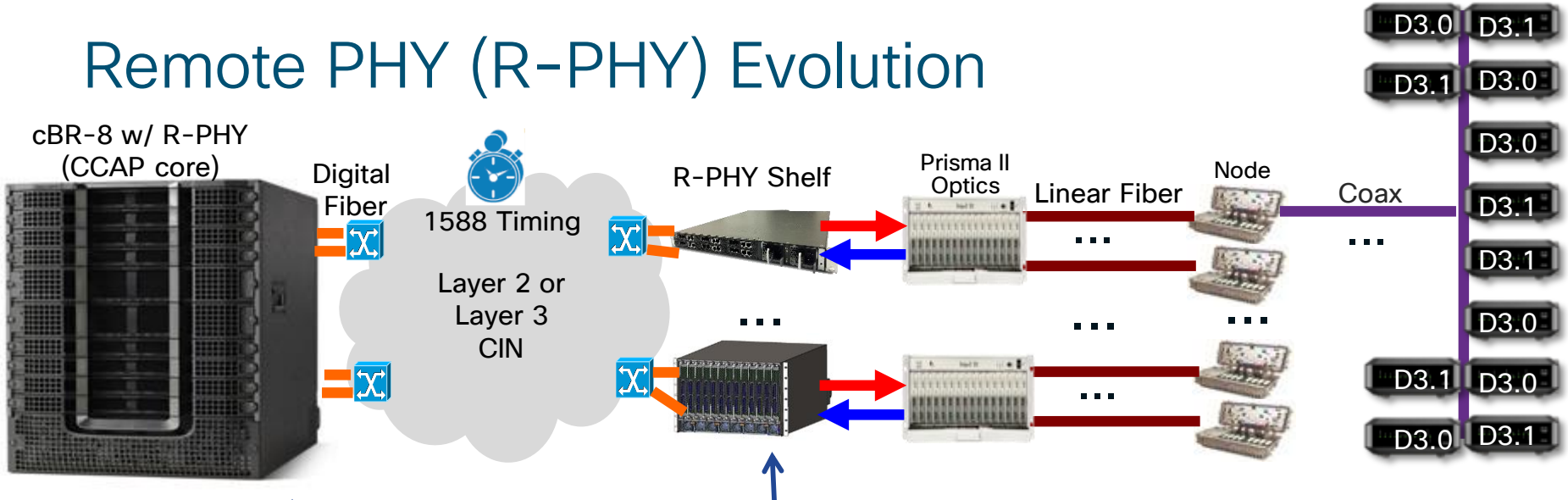
- cBR-8 RF PICs replaced with digital optics PICs
- No longer port constrained
- Space & power savings

- Digital fiber enables higher MER
- Supports 3-4x more wavelengths
- Links could be over a L2 or L3 CIN

- RPD – Remote PHY Device
- R-PHY module added to GS7000 nodes

- DOCSIS 3.1 modems now able to use higher order modulations

Remote PHY (R-PHY) Evolution

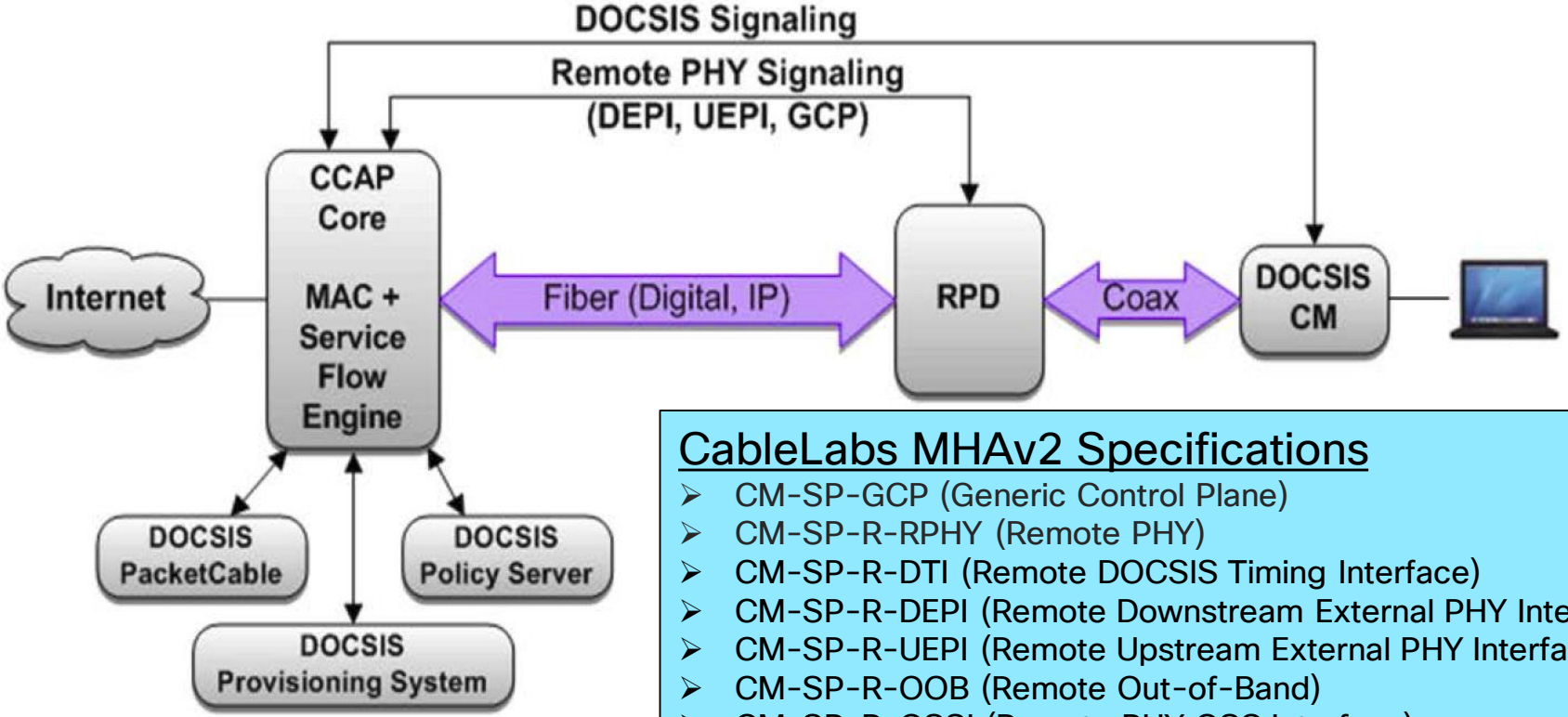


- Digital optics PICs used to enable 2x – 4x SG scaling

- R-PHY Shelf enables cBR-8 port capacity increase while keeping existing outside plant equipment
- Could be used in smaller sites for hub consolidation or co-located with cBR-8 to augment capacity
- Cisco's initial model – Compact R-PHY Shelf

Remote PHY Reference Architecture

Modular Headend Architecture version 2 (MHAv2)



CableLabs MHAv2 Specifications

- CM-SP-GCP (Generic Control Plane)
- CM-SP-R-RPHY (Remote PHY)
- CM-SP-R-DTI (Remote DOCSIS Timing Interface)
- CM-SP-R-DEPI (Remote Downstream External PHY Interface)
- CM-SP-R-UEPI (Remote Upstream External PHY Interface)
- CM-SP-R-OOB (Remote Out-of-Band)
- CM-SP-R-OSSI (Remote PHY OSS Interface)

OpenRPD

- Remote PHY is the first Distributed Access Architecture (DAA) standard in the industry
- To further accelerate full interoperability for RPDs and collaboration among equipment vendors and silicon manufactures the open-source program OpenRPD was initiated by Cisco and CableLabs®
- The OpenRPD software effort allows the cable industry to quickly transition to DAA by enabling faster development of RPD products
- OpenRPD allows companies to focus on their added value and accelerate time to market

RPD Initialization

802.1x Authentication (Optional)

Address Assignment (DHCP)

Time of Day (ToD)

Mutual Authentication (Optional)

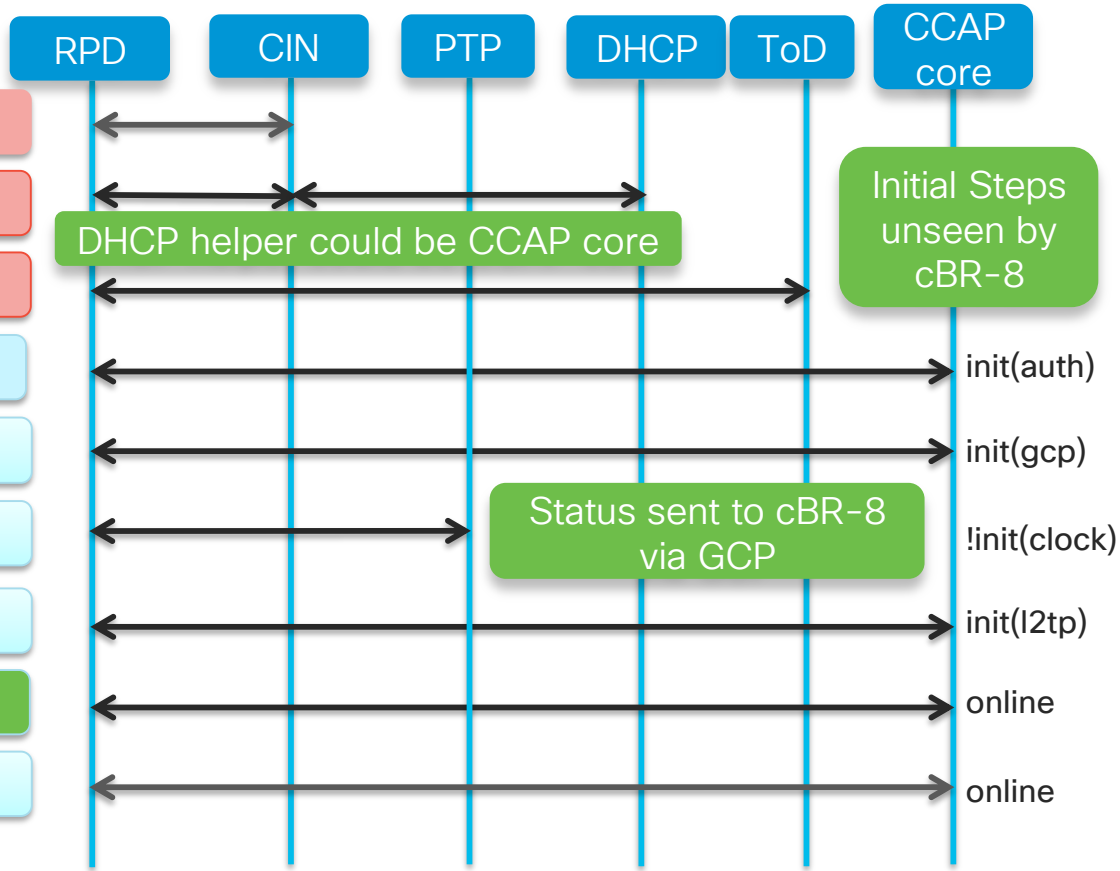
GCP Session to Principal Core

PTP Timing Synchronization

DEPI & UEPI Establishment

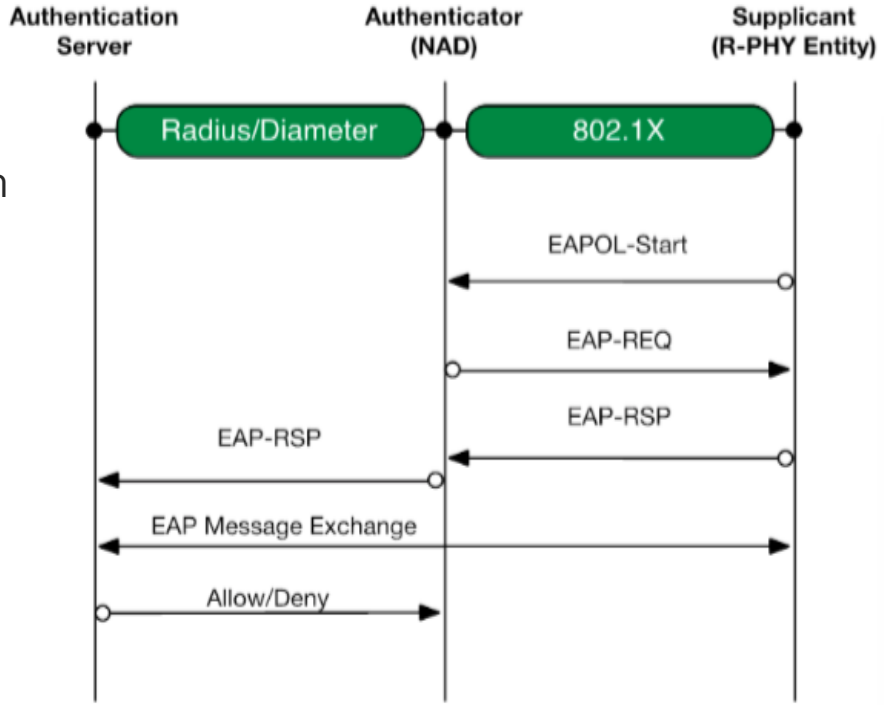
Operational with Principal Core

Auxiliary Core (Optional)



Initial Steps – Authentication

- Network Authentication (802.1x) can be used to provide security when the RPD resides in an “untrusted” network
- 802.1x uses the EAP (Extensible Authentication Protocol)
- Requires Certificates on the RPD and Authentication Server
- RPD always attempts to authenticate; whether or not it actually does depends on upstream device
- MACSec (802.1ae) is a link layer encryption mechanism that can be implemented



Initial Steps – DHCP & ToD

- Each RPD can provision via either IPv4 or IPv6 (as of 16.7.1)
- During DHCP initialization the RPD learns about CCAP core(s) via a new DHCP option "ccap-cores" (43.61 for IPv4, 17.61 for IPv6) which needs to be configured in the provisioning server (CPNR IPv4 screen shot example below)

List of Option Definitions for *rpd*

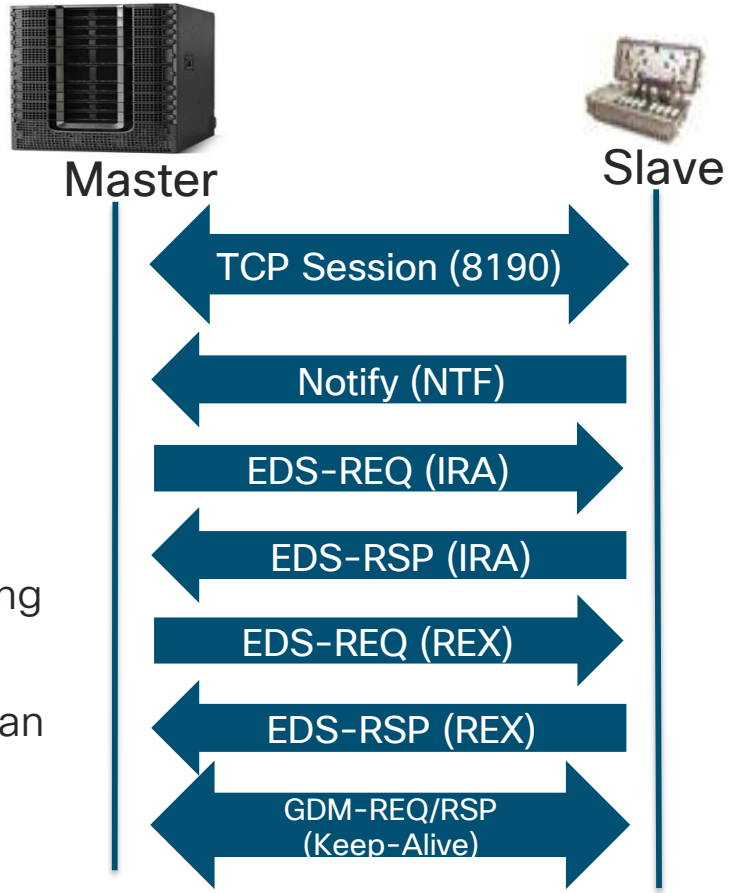
Number	Name	Type	Repeat
43	rpd-option-43	binary	
61	ccap-cores	IP address	1+

rpd-option-43 (binary) DPIC 10GE IP(s) → (ccap-cores 61 13.13.0.226,13.13.0.198)

- Time of Day (ToD – RFC 868) establishment occurs after DHCP; used for logging timestamps & certificate validation

Generic Control Plane (GCP)

- Imitates major functionality existing over a HW bus between CPU and peripheral chip (e.g. read/write registers, power up/down)
- GCP Messages:
  Notify, GCP Device Management (GDM – REQ/RSP), Exchange Data Structure (EDS – REQ/RSP)
- Application of GCP – R-PHY Control Protocol (RCP)
- RCP Messages:
  Notification (NTF), Identification and Resource Advertising (IRA), and RCP Object Exchange (REX)
- RCP REX messages consist of a series of TLVs which can leverage existing specs (e.g. DOCSIS MULPI)



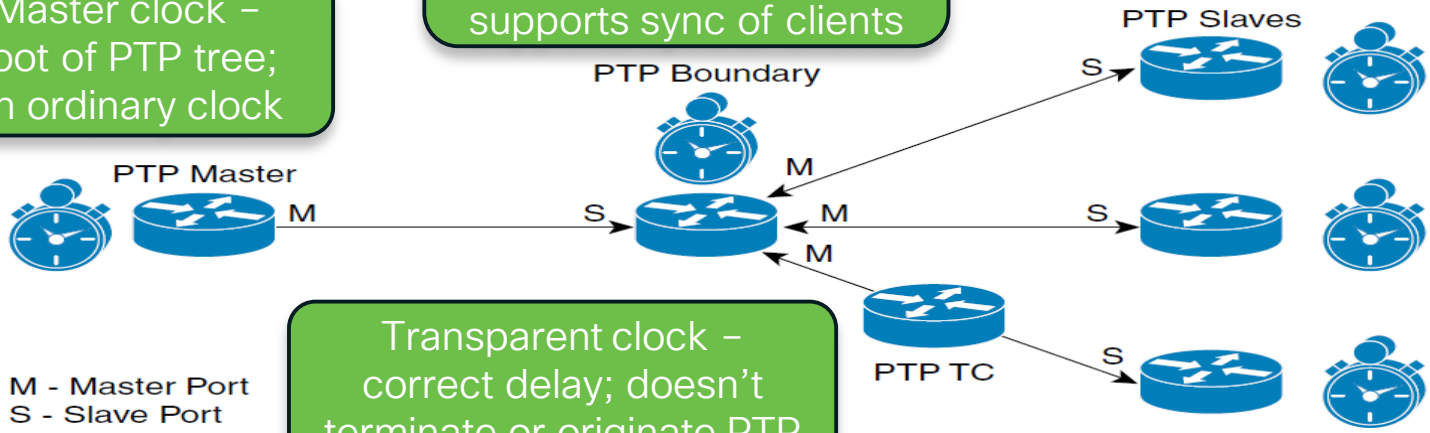
Timing in R-PHY (IEEE 1588 & PTP)

- IEEE 1588 – *Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*
- Precision Time Protocol (PTP) is the implementation of 1588

Boundary clock – multiple interfaces; syncs with master supports sync of clients

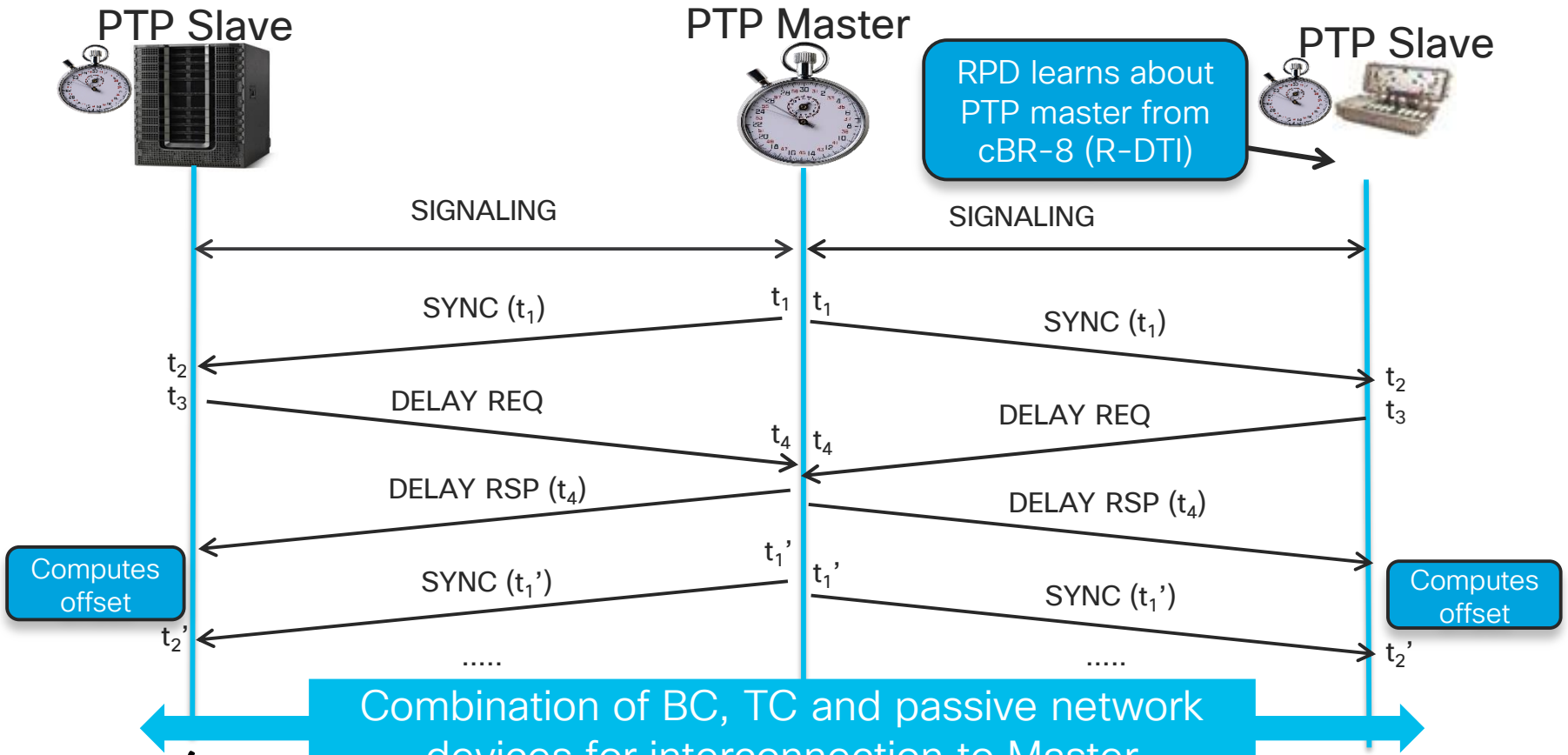
Master clock – root of PTP tree; an ordinary clock

Slave clock – ordinary clock that relies on a master clock for sync



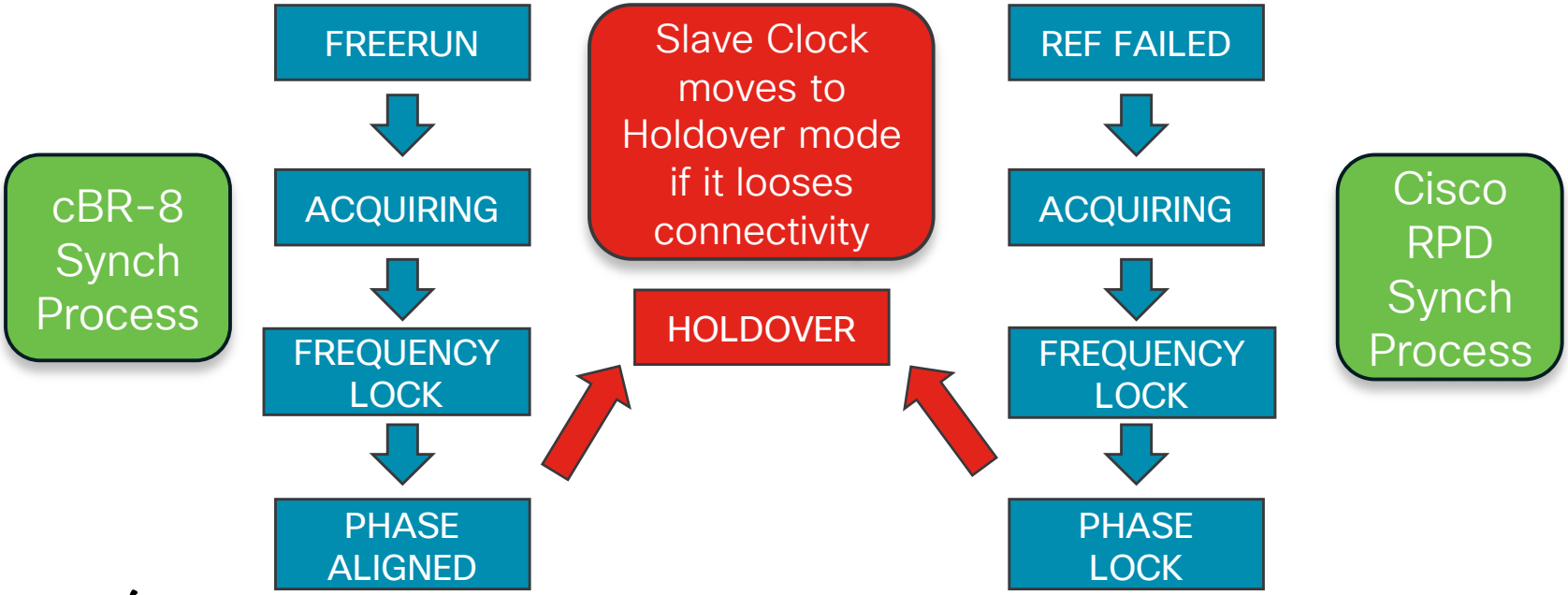
Transparent clock – correct delay; doesn't terminate or originate PTP

cBR-8 & RPD as PTP Slaves



PTP Synchronization Process

- The Sync/Delay Request/Delay Response messages repeat and ultimately the PTP slave is able to synchronize it's clock (typically 3-5 minutes)



PTP Profiles

- "*The purpose of a PTP profile is to allow organizations to specify specific selections of attribute values and optional features of PTP that, when using the same transport protocol, inter-work and achieve a performance that meets the requirements of a particular application.*" [1]
- ITU_T has defined 3 profiles for use in mobile telecommunications
  - G.8265.1 – IP unicast delivery over a PTP unaware network (no BC/TC) for frequency distribution
  - G.8275.1 – Ethernet multicast delivery over a full on-path support network for frequency & phase distribution
  - G.8275.2 – IP unicast delivery over a partial on-path support network for frequency & phase distribution

[1] Clause 19.3.1.1 of IEEE 1588

DEPI & UEPI

- DEPI is the Downstream External PHY Interface between the CCAP core MAC layer and the RPD PHY layer
- Consists of a control session and some number of data sessions for sending DOCSIS frames, video packets, and OOB packets from the CCAP core to the RPD
- UEPI is the Upstream External PHY Interface between the CCAP core MAC layer and the RPD PHY layer
- Consists of some number of data sessions for sending DOCSIS frames and OOB packets from the RPD to the CCAP core
- UEPI data sessions are created by the same control session as DEPI data sessions

Downstream External PHY Interface (DEPI)

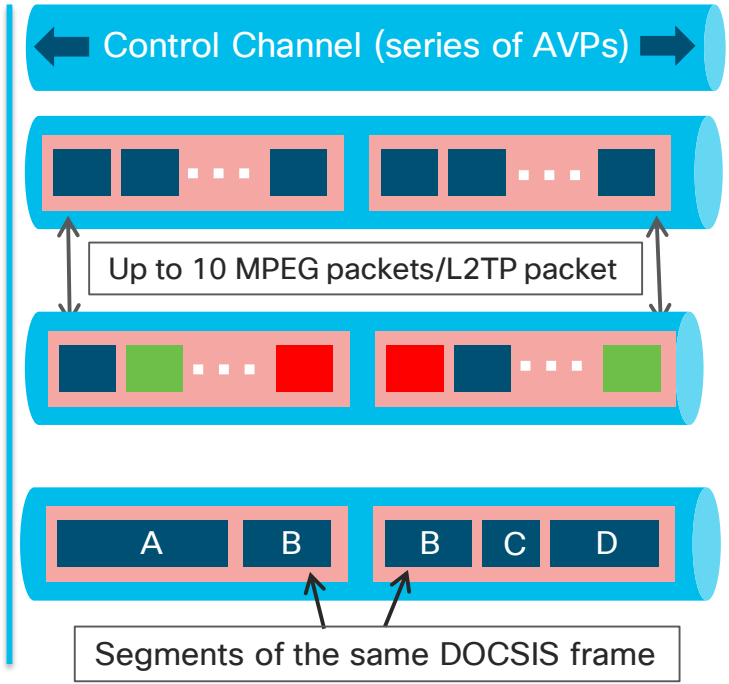
DS MAC

DS PHY

MPEG Packet Transport (MPT) Pseudowire

Multi-Channel MPT (MCM) Pseudowire

Packet Streaming Protocol (PSP) Pseudowire



Can be used for DOCSIS SC-QAM, Video & Out-Of-Band (OOB) channels

Can be used by for DOCSIS SC-QAM & Video channels

Can be used by DOCSIS SC-QAM channels; used for OFDM, OFDM PLC, and UEPI

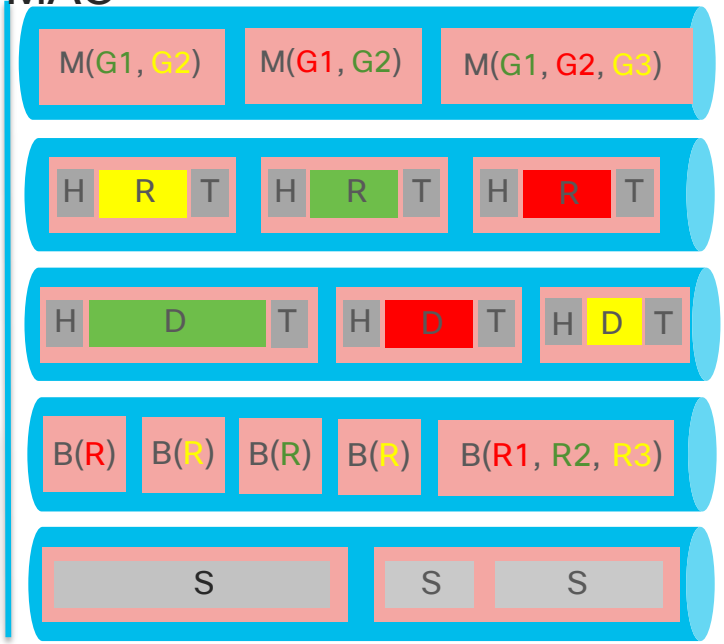
Upstream External PHY Interface (UEPI)

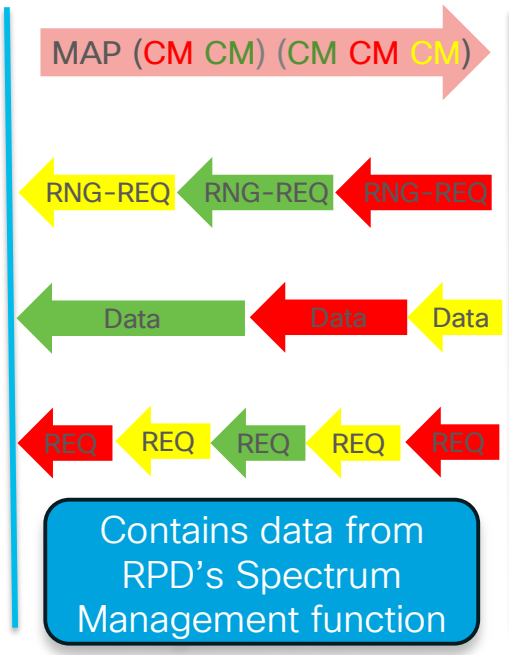
US MAC

US PHY

UEPI PSP PWs:
MAP (M)
RNG-REQ (R)
DATA (D)
Unique per US channel

UEPI PSP PWs:
BW-REQ (B)
Spec Mgmt (S)
Can be grouped



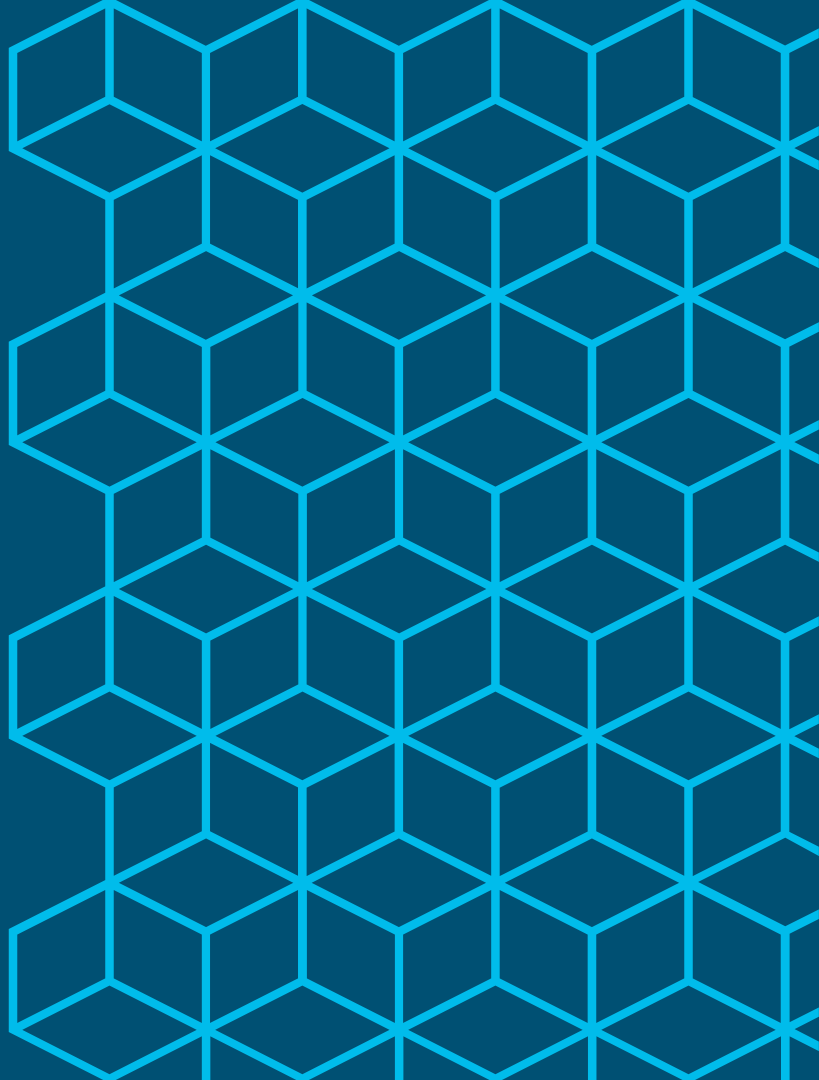


Contains data from RPD's Spectrum Management function

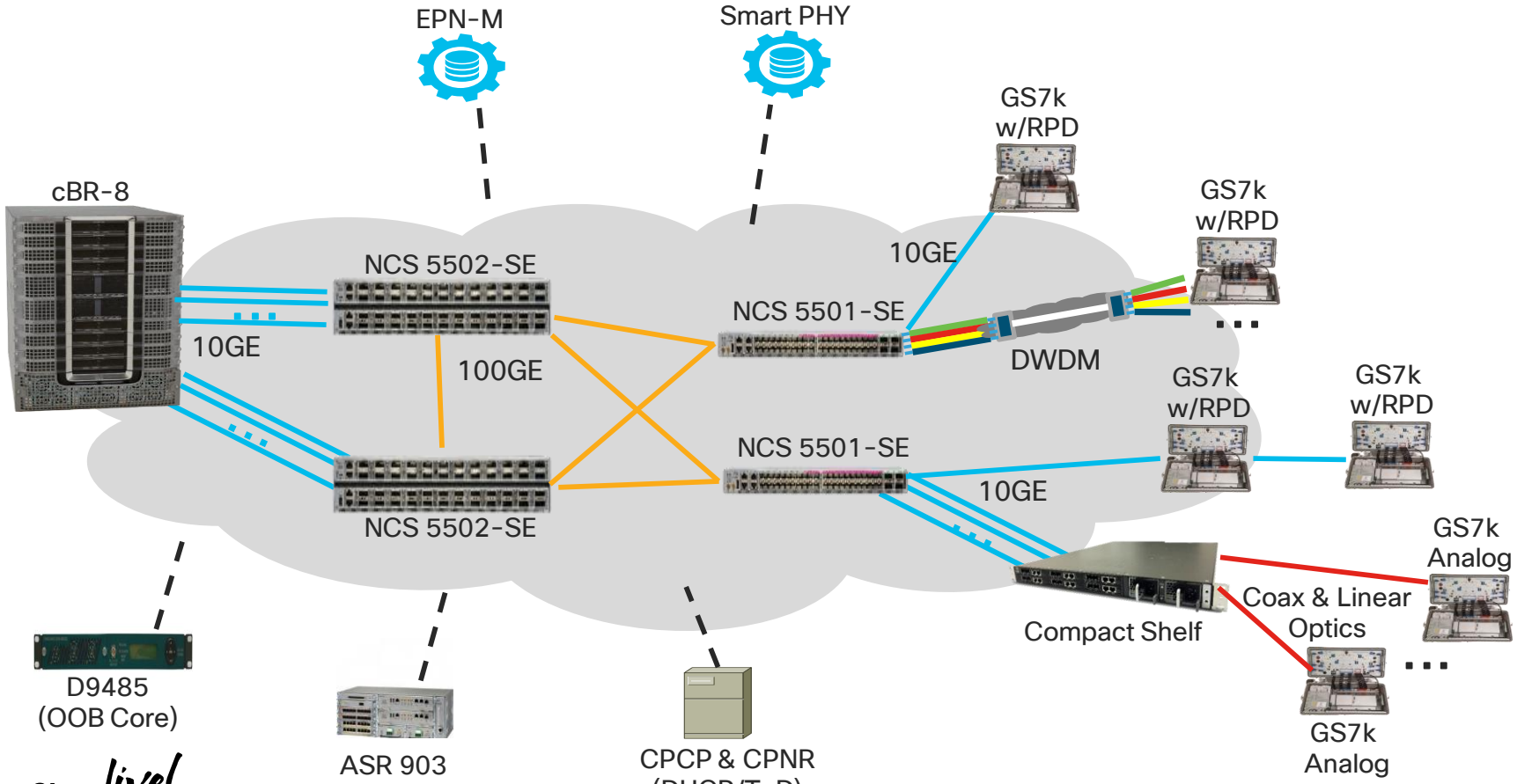
OFDMA also uses a Probe PW and a PNM PW instead of Spectrum Management

OOB also use UEPI PWs

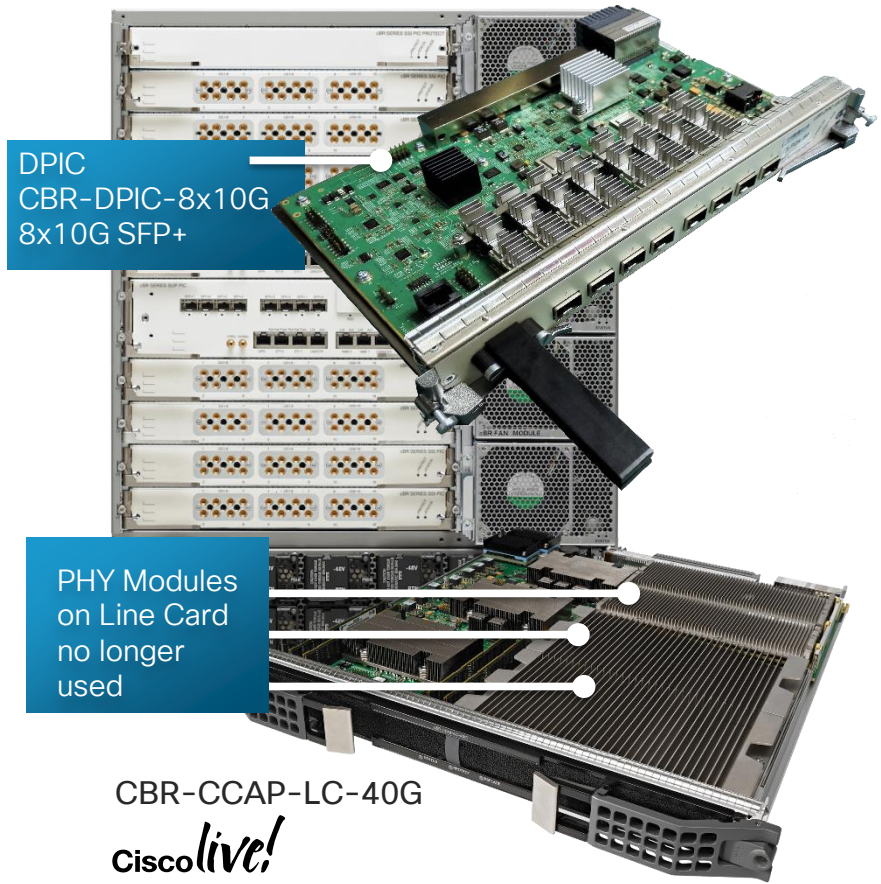
Remote PHY Components



Remote PHY Architecture Components

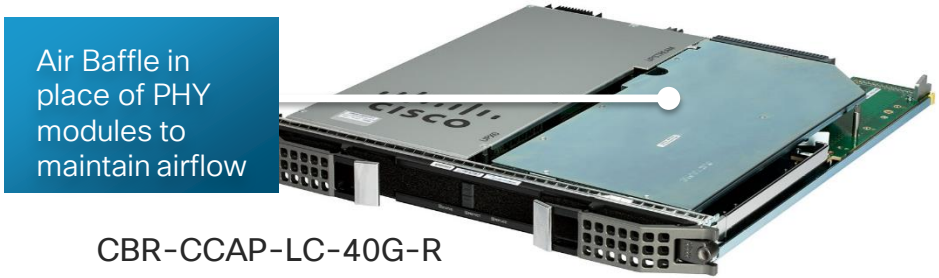


cBR-8 Remote PHY PIC (Digital PIC)



CBR-CCAP-LC-40G

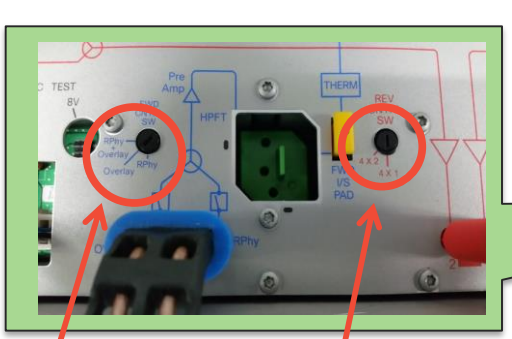
- DPIC can work with an integrated CCAP Line Card (CBR-CCAP-LC-40G)
- Or R-PHY CCAP LC w/o PHY modules (CBR-CCAP-LC-40G-R)
- DPIC supports SR/LR/ER/ZR optics
- DPICs used with active & standby CCAP LCs (no special Protect DPIC)



CBR-CCAP-LC-40G-R

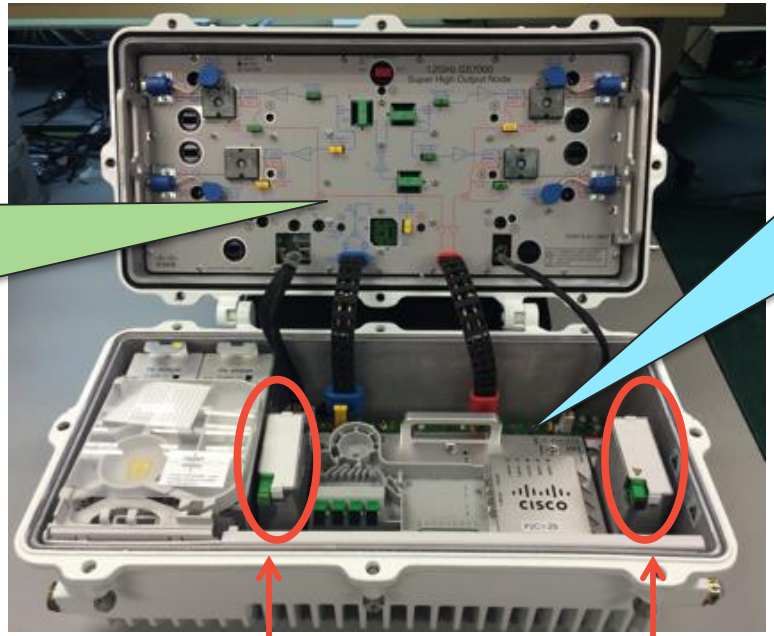
Remote PHY Device in a GS7000 Node

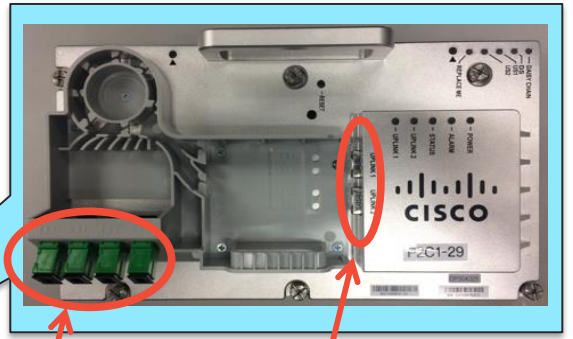
- The RPD occupies the middle 6 slots in the GS7000 lid



Forward Control SW:
RPhy or RPhy + Overlay options

Reverse Control SW:
4x1 or 4x2 options





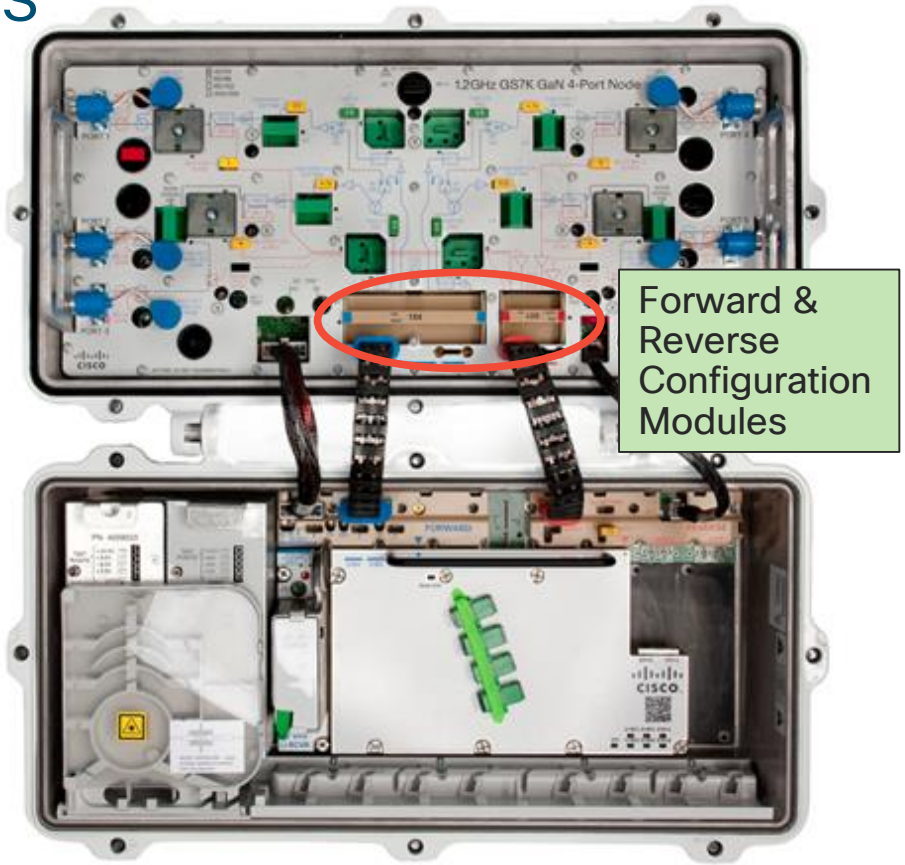
Pair of 10GE interfaces

Adapters for SC connectivity

Ability to include Optical Transmitter & Receiver for Overlay

GS7000 SHO & BAU nodes

- Initial GS7000 node supporting the RPD is the SHO (Super High Output) node capable of supporting fiber deep deployments with longer coaxial runs without amplification
- There is also now a BAU (Business As Usual) GS7000 RPD capable node supporting traditional deployments with amplifier cascades
- The BAU node supports different RPD DS & US to RF port mappings depending upon the Forward & Reverse Configuration Modules (FCM/RCM) installed



Nodes & RPDs

Smart PHY 120 (1x2) RPD

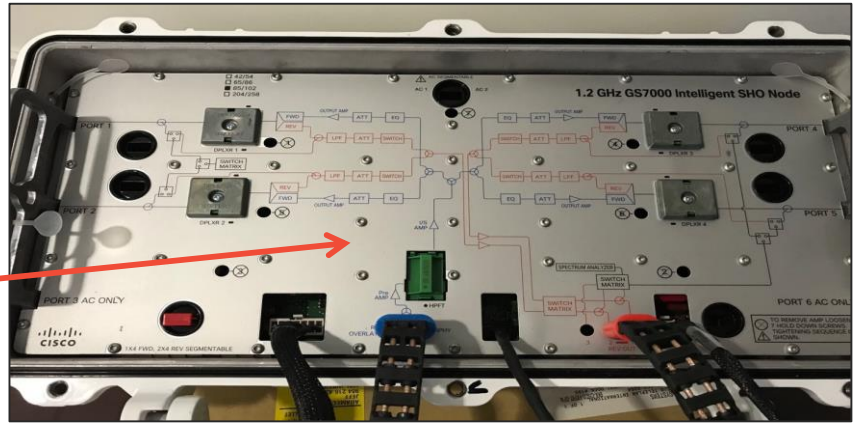
- Supports 1 Service Group (1x1 or 1x2)
- Can be used in either SHO or BAU GS7K node
- Full Spectrum D3.1 HW capable:
  - 160 SC-QAMs or 6 x 192 OFDMs or a mix on the DS port
  - 12 ATDMA or 2x96 OFMDA or a mix per US port
- Video & OOB support

Smart PHY 220 (2x2) RPD

- Supports 2 Service Groups (2x2)
- Can only be used in 2x2 mode in a BAU GS7K node
- Designed for BAU deployment:
  - 384 MHz of narrowcast DS support (2 OFDMs, 64 SC-QAMs, or any mix) per port
  - 96 channels of broadcast video per port & OOB support
  - 4 ATDMA & 1 48MHz OFDM per port

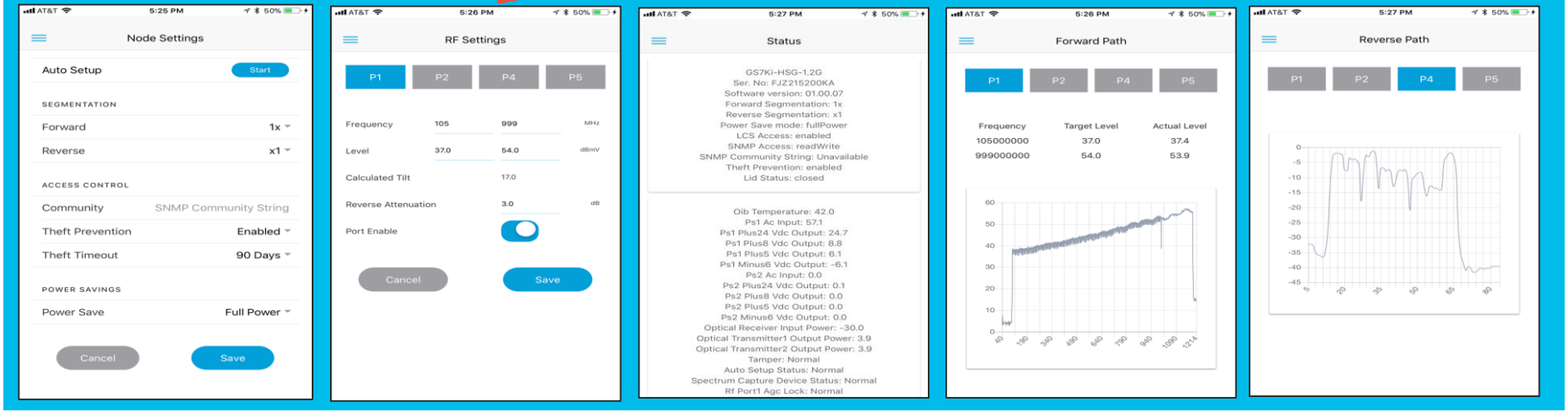
GS7000 Intelligent Node

GS7K iNode is a full-featured configurable node capable of touchless provisioning



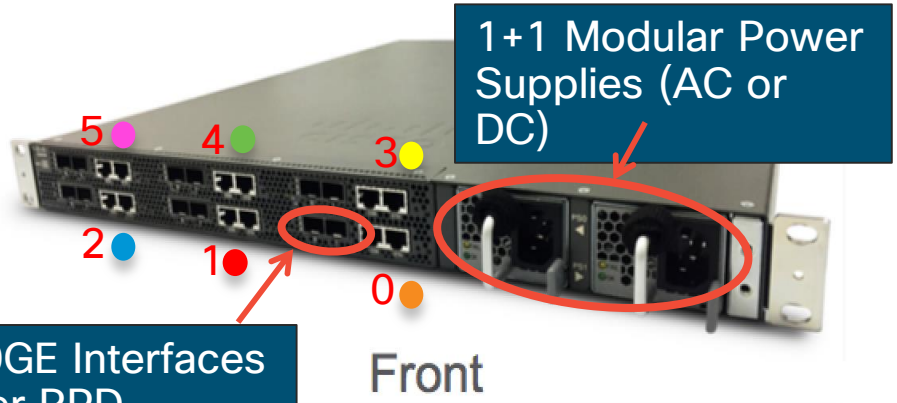
Streamlined setup (no pads, EQs, etc.)

Configure/Adjust/Measure parameters locally or remotely

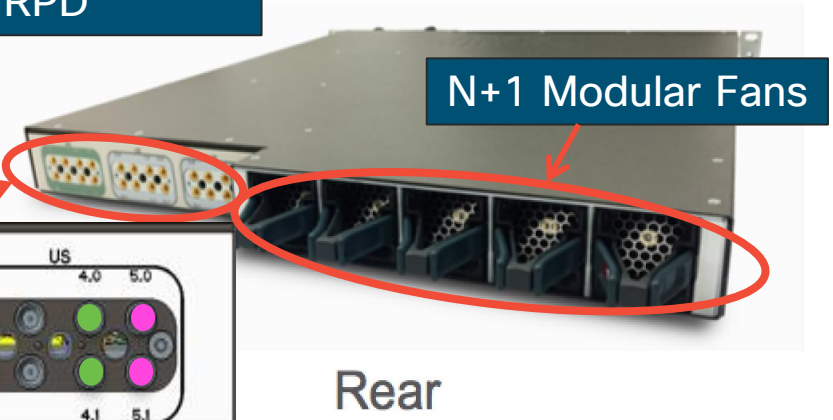


Compact (1RU) Remote PHY Shelf

- Smart PHY 600 – 6x12 Service Group support
  Smart PHY 300 – 3x6 Service Group support
- Packages 6 (or 3) 1x2 RPDs
- Total Power Budget: 480W max
- Stackable for Greater SG densities

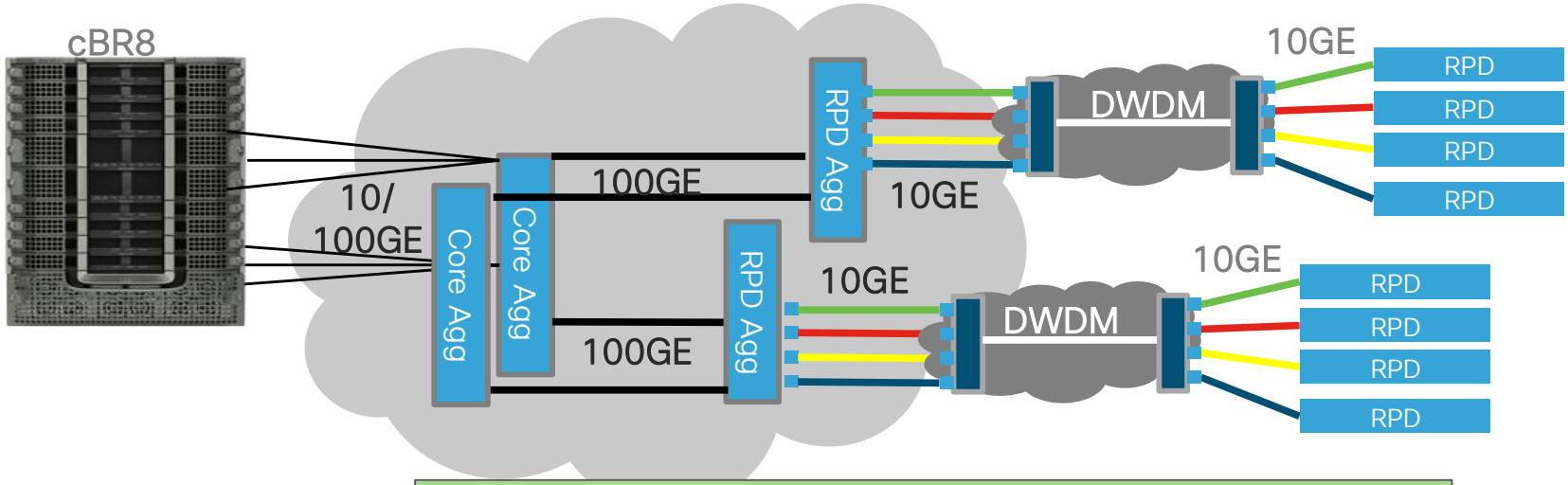


Pair of 10GE Interfaces (SFP+) per RPD



Similar UCH8 header blocks (1 DS & 2 US) as cBR-8 RF PIC

Converged Interconnect Network (CIN)



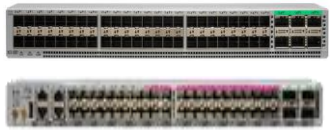
- High capacity / Low power?
- Optics used in CIN? DWDM support?
- Layer 3 or Layer 2? BVI, VRRP capabilities?
- Multicast Support? IPv6?
- PTP Support? CIN support for 802.1x? MACsec?
- CIN Provisioning? Automation capabilities?

NCS 5500 Product Family

- Modular and Fixed IOS-XR OS based platforms for high-scale WAN aggregation
- Flexible 10/25/40/100GE interface support
- Low power, high performance
- Automation, Telemetry, Programmability

NCS 540

300 Gbps – 1 RU
Power ~200W



NCS 5501/5501-SE

800 Gbps – 1 RU
Power ~250W

NCS 5502/5502-SE

4.8 Tbps – 2 RU
Power ~1450W

NCS 5504

3.6Tbps per slot
14.4 Tbps – 7 RU
Power ~0.25W/Gbps

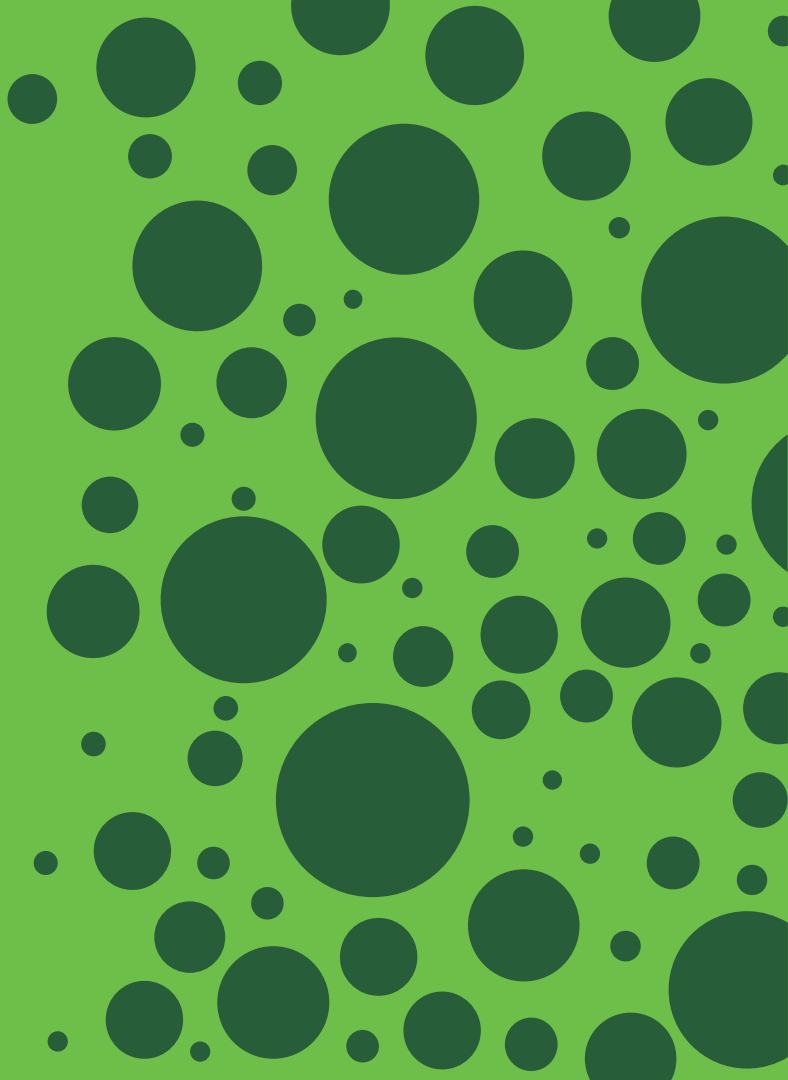
NCS 5508

3.6Tbps per slot
28.8 Tbps – 13 RU
Power ~0.24W/Gbps

RPD Aggregation, Leaf

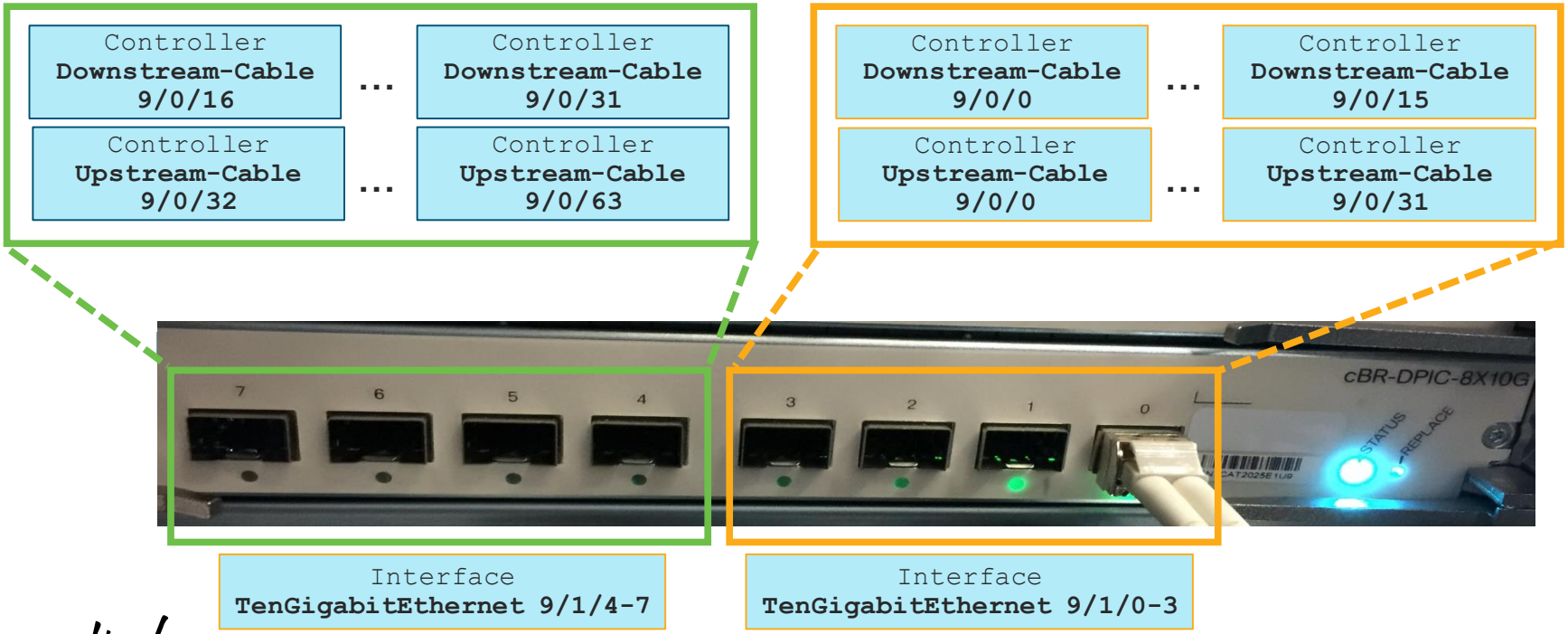
R-PHY Core Aggregation, Spine

R-PHY Implementation



R-PHY Controllers & PIC Ports

- As of 16.7.1 can do 16 DOCSIS SGs & 64 RPDs per LC

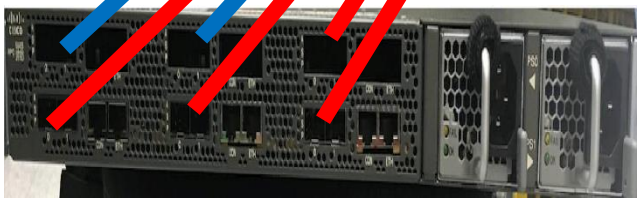


Compact Shelf Mapping (16 RPDs/LC)
No DS splitting (4 RPDs per DPIC core)

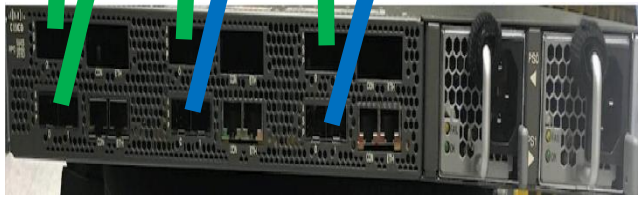
```
controller DCable 1/0/0-3
interface Cable1/0/0-3
controller DCable 1/0/8-11
interface Cable1/0/4-7
controller DCable 1/0/16-19
interface Cable1/0/8-11
controller DCable 1/0/24-27
interface Cable 1/0/12-15
```

DPIC
Slot 1

CIN



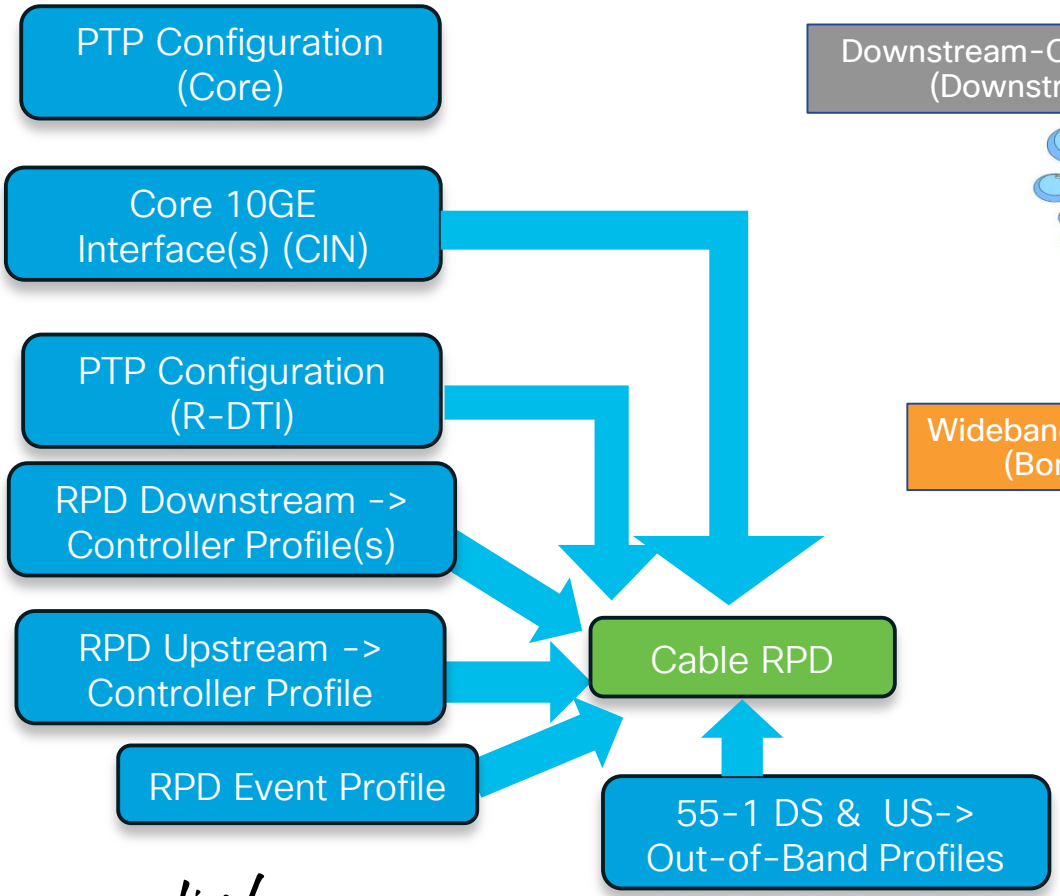
RPHY Shelf 1

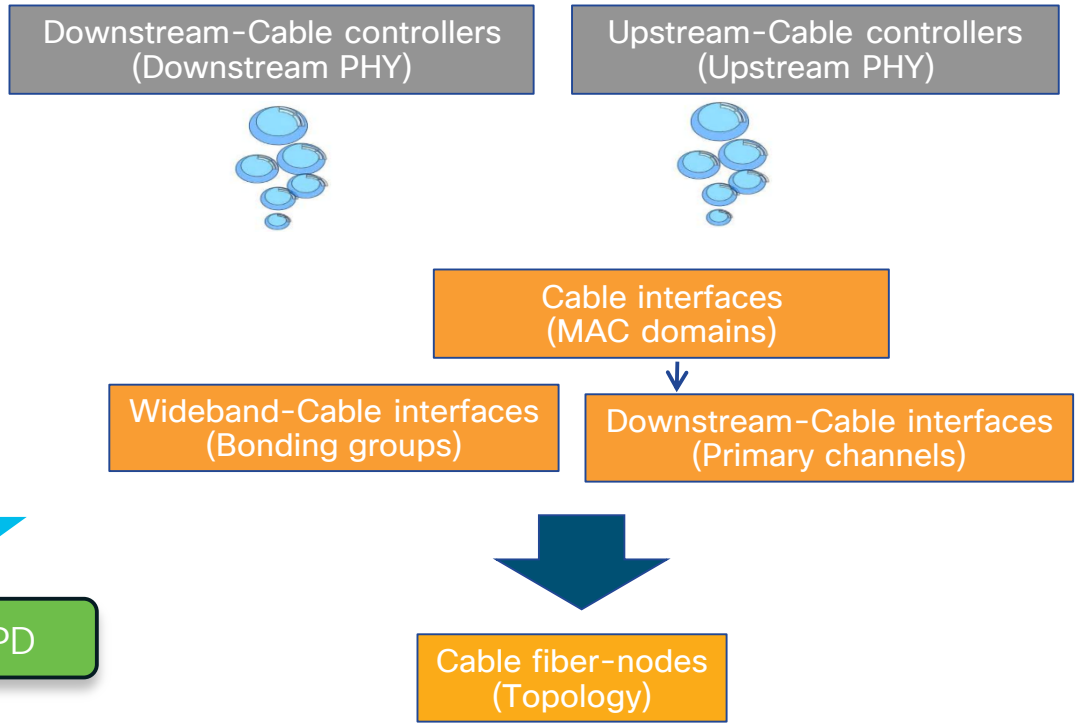


RPHY Shelf 2

RPHY Shelf 3

R-PHY Configuration Flowchart





- A single RPD could service multiple fiber nodes

DPIC (CIN) Interface Configuration

```
interface TenGigabitEthernet1/1/0
 vrf forwarding lc1_p0
 ip address 13.159.20.34 255.255.255.252
 load-interval 30
 cdp enable
 ipv6 address 2001:420:27C1:8FF:FFFF:FFFF:FFFF:FFDE/126
!
interface TenGigabitEthernet0/1/0
 vrf forwarding lc0_p0
 ip address 13.159.20.2 255.255.255.252
 load-interval 30
 cdp enable
 ipv6 address 2001:420:27C1:8FF:FFFF:FFFF:FFFF:FFFE/126
```

DPIC Interface configuration is fairly straight forward; one option is to put each 10GE in its own VRF

In the case of a Layer 3 CIN default static routes added for each DPIC 10GE VRF pointing to the next hop

```
ip route vrf lc1_p0 0.0.0.0 0.0.0.0 TenGigabitEthernet1/1/0 13.159.20.33
ipv6 route vrf lc1_p0 ::/0 TenGigabitEthernet1/1/0 2001:420:27C1:8FF:FFFF:FFFF:FFFF:FFDD
!
ip route vrf lc0_p0 0.0.0.0 0.0.0.0 TenGigabitEthernet0/1/0 13.159.20.1
ipv6 route vrf lc0_p0 ::/0 TenGigabitEthernet0/1/0 2001:420:27C1:8FF:FFFF:FFFF:FFFF:FFFD
```

PTP & R-DTI Configuration

```
ptp clock ordinary domain 0
 servo tracking-type R-DTI
 clock-port slave-from-903 slave
  delay-req interval -4
  sync interval -5
  sync one-step
  transport ipv4 unicast interface Lo0 negotiation
  clock source 188.188.188.188
```

- Currently only one PTP domain is supported
- The “servo ..” configuration allows the cBR-8 clock to synch much faster
- Ensure the cBR-8 loopback has IP connectivity to the clock source

```
ptp r-dti 1
 ptp-domain 0
 clock-port 1
  clock source ip 188.188.188.188
```

```
ptp r-dti 2
 ptp-domain 0
 clock-port 1
  transport ipv6
  clock source ipv6 2001:DB8::1588
```

- Ensure the domain number matches with the cBR-8 PTP configuration
- If the clock is connected via an L2 CIN specify the gateway option with the clock source configuration line

Event Profile Configuration

```
cable profile rpd-event 5
 priority emergency 0x3
 priority alert 0x3
 priority critical 0x3
 priority error 0x3
 priority warning 0x3
 priority notice 0x3
 priority informational 0x3
 priority debug 0x3
 enable-notify
```

- Tells the RPD how to report various events
- Set event flags for each priority level
  - 0x0 – no event logging
  - 0x1 – RPD records event to local log
  - 0x2 – RPD reports event to CCAP core
  - 0x3 – RPD records event to local log AND reports event to CCAP core
- “enable notify” MUST be set to report any events

Controller Profile Configuration

```
cable downstream controller-profile 1
 rf-chan 0 31
  type DOCSIS
  frequency 489000000
  rf-output NORMAL
  qam-profile 1
  docsis-channel-id 1
```

- Define profiles one time for common RPD downstream and upstream configurations
- Such as 32 downstream DOCSIS SC-QAM channels; 4 upstream DOCSIS channels; etc.
- Multiple RPDs reference common profiles

```
cable upstream controller-profile 1
 us-channel 0 channel-width 6400000
6400000
 us-channel 0 docsis-mode atdma
 us-channel 0 equalization-coefficient
 us-channel 0 frequency 17500000
 us-channel 0 minislot-size 2
 us-channel 0 modulation-profile 221
...
 us-channel 3 channel-width 6400000
6400000
 us-channel 3 docsis-mode atdma
 us-channel 3 equalization-coefficient
 us-channel 3 frequency 37500000
 us-channel 3 minislot-size 2
 us-channel 3 modulation-profile 221
```

RPD Configuration

```
cable rpd RPD_1
 description Test GS7K RPD
 identifier 0000.abcd.1234
 core-interface Te1/1/0
  principal
  rpd-ds 0 downstream-cable 1/0/0 profile 1
  rpd-us 0 upstream-cable 1/0/0 profile 1
 r-dti 1
 rpd-event profile 5
```

```
cable rpd RPD_2
 description Test Compact Shelf RPD
 identifier 0000.abcd.5678
 type shelf
 rpd-ds 0 max-carrier 32
 rpd-ds 0 base-power 36
 core-interface Te1/1/0
  principal
  rpd-ds 0 downstream-cable 1/0/1 profile 1
  rpd-us 0 upstream-cable 1/0/1 profile 1
 r-dti 1
 rpd-event profile 5
```

- Identifier is the RPD MAC address
- For RPHY Shelves set the type to expand power related ranges
- Core Interface is the DPIC port used to communicate to the RPD
- Define the RPD RF ports by assigning controllers and associating to profiles
- R-DTI configuration enables the core to send required PTP timing information to the RPD

DEPI Latency Measurement (DLM)

- Measurement of the CIN latency between the CCAP Core and RPD enabling the DOCSIS scheduler to accurately adjust MAP advance

CCAP Core places current 32-bit DTI Timestamp the DOCSIS Timestamp Start field

RPD inserts DTI timestamp (T2) in the DOCSIS Timestamp End field

```
cable rpd GS7K-LWR
 description RPD located in Lawrenceville
 identifier badb.ad13.1476
 core-interface Te1/1/2
  principal
  rpd-ds 0 downstream-cable 1/0/5 profile 2
  rpd-us 0 upstream-cable 1/0/5 profile 1
  network-delay dlm 10
 r-dti 2
 rpd-event profile 0
```

```
[no] network-delay dlm [interval in secs] {measure-only}
```

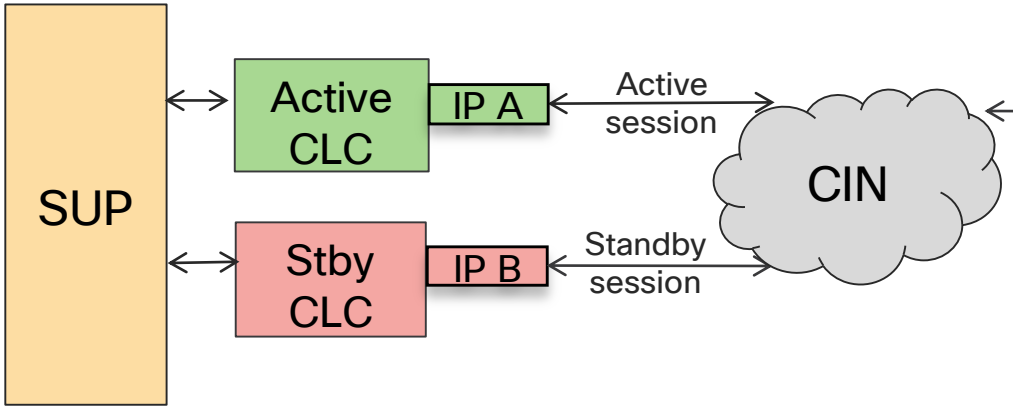
DOCSIS 3.1

- DOCSIS 3.1 support for R-PHY starts with 16.6.1
  - 1 OFDM channel (up to 192 MHz) supported per RPD
  - Similar feature parity to 3.18.1aSP for I-CCAP
- 16.8.1/v4.1 adds support for OFDM primary & DS resiliency
- Configuration steps are similar to I-CCAP except the OFDM channel is configured under the DS controller profile

```
cable downstream controller-profile 35
 …
 max-ofdm-spectrum 192000000
 rf-chan 0 31
  …
 rf-chan 158
  docsis-channel-id 159
  ofdm channel-profile 7 start-frequency 690000000 width 192000000 plc 783000000
```

High Availability (HA)

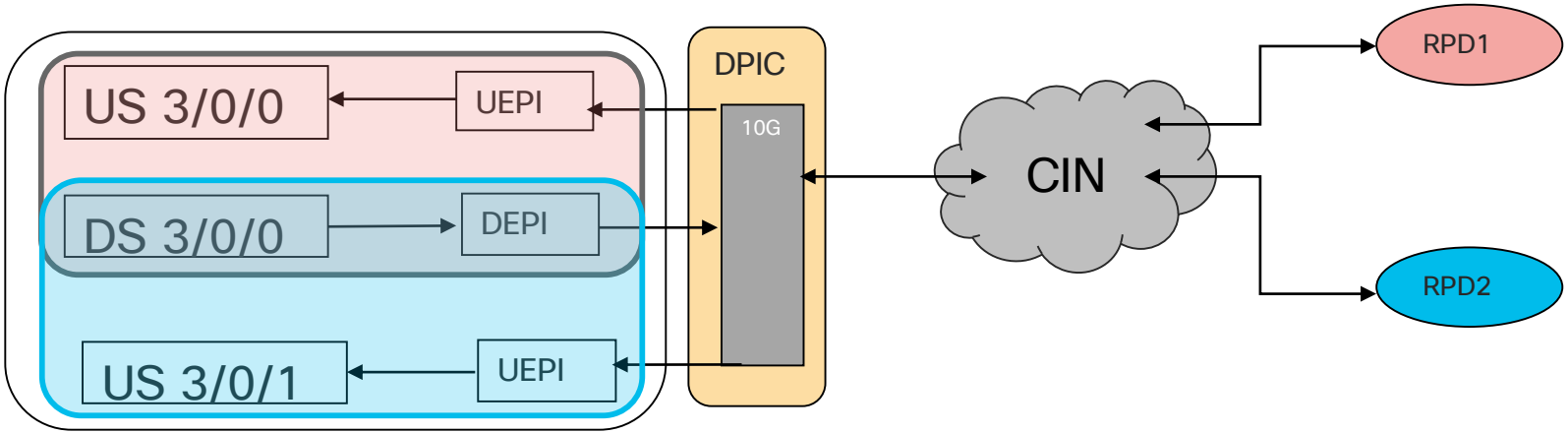
- RPDs connect to both the active LC and standby LC DPICs
- Establish “active” and “standby” GCP and DEPI/UEPI sessions
- Core signals the RPD to switch-over its active connection




```
redundancy
 mode sso
 linecard-group 0 internal-switch
  class 1:N
  member slot 1 primary
  ...
  member slot 9 primary
  member slot 0 secondary
  no revertive
```

Downstream Channel Splitting

- Does it make sense to dedicate Downstream Channels per RPD?
  - As fiber moves deeper the number of subs per node decreases
  - Inefficient use of CCAP core MAC layer resources
  - Still constrained to 768/576 SC-QAM & 16 OFDM DS channels per line card
- Solution: DS Splitting via Multicast DEPI

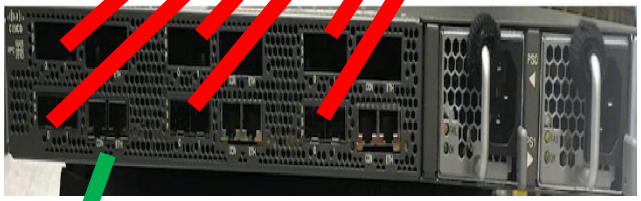


Compact Shelf Mapping (32 RPDs/LC)
1:2 DS splitting (8 RPDs per DPIC core)

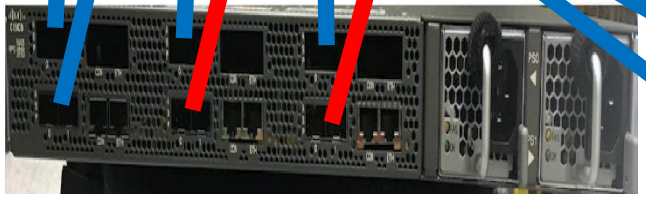
```
controller DCable 1/0/0-3
interface Cable1/0/0-3
controller DCable 1/0/8-11
interface Cable1/0/4-7
controller DCable 1/0/16-19
interface Cable1/0/8-11
controller DCable 1/0/24-27
interface Cable 1/0/12-15
```

DPIC
Slot 1

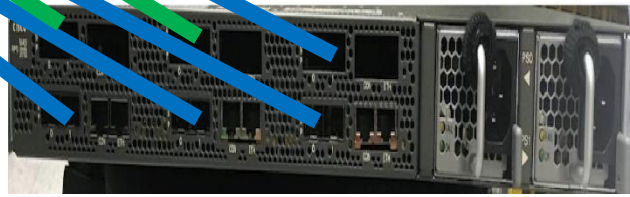
CIN



RPHY Shelves 1 & 4



RPHY Shelves 2 & 5



RPHY Shelves 3 & 6

DS Splitting Configuration Flowchart

Create multicast DEPI pool(s)

```
cable depi multicast pool 1
  ip address 232.232.232.0 255.255.255.0
```

Enable multicast under DS controller profile

```
cable downstream controller-profile 10
 multicast-pool 1
 ...
```

Configure RPDs with same DS controller # AND profile

```
cable rpd RPD_1
 core-interface Te1/1/0
  rpd-ds 0 downstream-cable 1/0/0 profile 10
  rpd-us 0 upstream-cable 1/0/0 profile 1
```

```
cable rpd RPD_2
 core-interface Te1/1/0
  rpd-ds 0 downstream-cable 1/0/0 profile 10
  rpd-us 0 upstream-cable 1/0/1 profile 1
```

Enable multicast on CBR-8

```
ip multicast-routing distributed
```

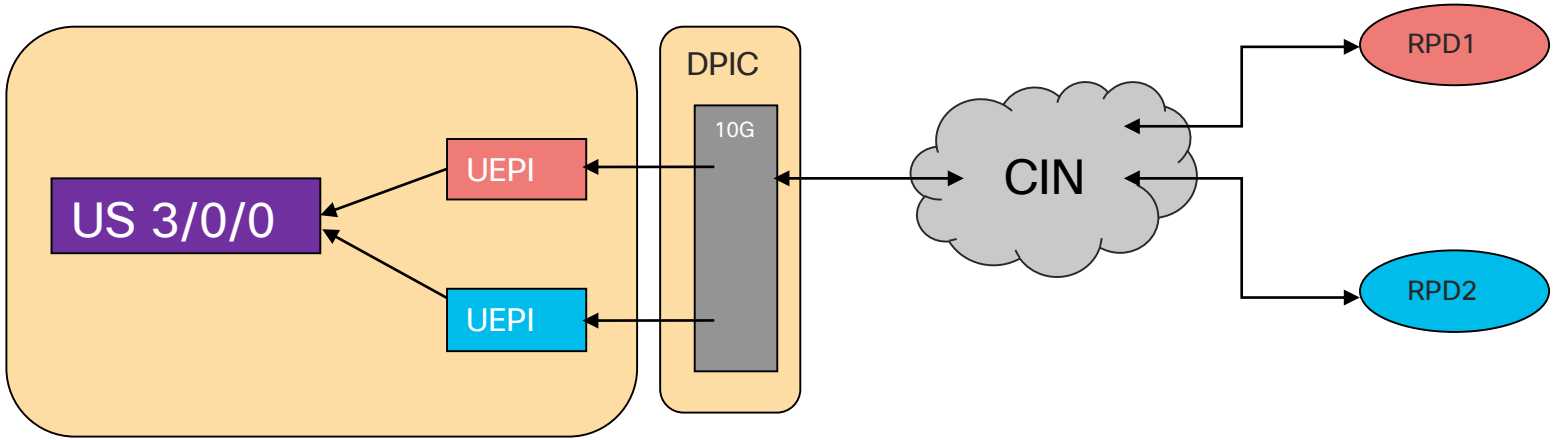
Enable multicast in CIN

A Layer 2 CIN may require IGMP/MLD snooping to be enabled

A Layer 3 CIN requires IGMP/MLD, PIM, SSM to be enabled

Upstream Channel Combining

- Virtual Combining is the complimentary upstream feature to DS Splitting
- Multiple RPDs US ports are combined/shared by the same US controller MAC resources on the cBR-8
- cBR-8 MAC scheduler treats cable modems across these RPDs as if they were on common physical upstream channels



Video & Auxiliary Cores

- Narrowcast video services (e.g. Video on Demand (VoD), Switched Digital Video (SDV)) CAN be specified on the same DS controller as the DOCSIS channels
- If DOCSIS and Video service groups aren't 1:1 aligned they can be defined on different controllers which may or may not be serviced by the same DPIC port (Best practice to have them on the same DPIC port if possible)
- Broadcast video services can be specified by a single controller from any LC and DPIC port and be used by several or all of the RPDs
- The video cores become auxiliary cores and are associated to RPDs. Video out-of-band (OOB) cores are also defined as auxiliary cores.
- Multicast addressing is used to deliver the same auxiliary core to multiple RPDs as with Downstream Channel Splitting

Video Configuration Flowchart

Configure DS controller profile(s) with video channels

```
cable downstream controller-profile 10
 multicast-pool 1
 rf-chan 0 31
  type DOCSIS
  <snip>
 rf-chan 32 39
  type VIDEO SYNC
  frequency 405000000
  rf-output NORMAL
  qam-profile 5
```

```
cable downstream controller-profile 20
 multicast-pool 1
 rf-chan 40 63
  type VIDEO SYNC
  frequency 261000000
  rf-output NORMAL
  qam-profile 5
```

Configure RPDs with auxiliary core(s) for video

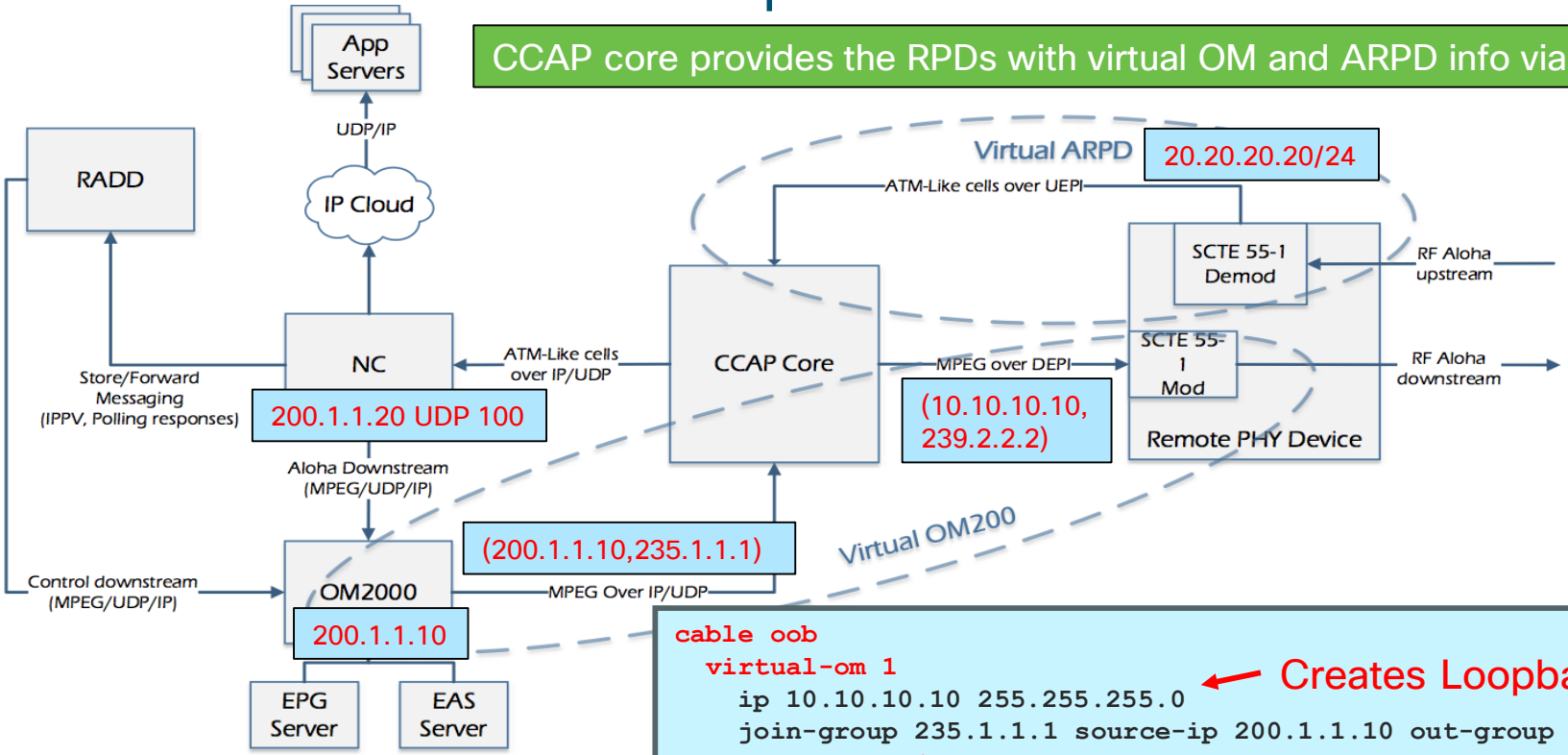
```
cable rpd RPD_1
 identifier 0000.abcd.1234
 core-interface Te1/1/0
  principal
  rpd-ds 0 downstream-cable 1/0/0 profile 10
  rpd-us 0 upstream-cable 1/0/0 profile 1
 core-interface Te9/1/6
  rpd-ds 0 downstream-cable 9/0/31 profile 20
 r-dti 1
 rpd-event profile 5
```

In the *cable video* configuration the Service Distribution Groups (SDGs) now reference RPD downstreams

```
cable video
 ...
 service-distribution-group sdg1 id 1
  rpd downstream-cable 1/0/0
 service-distribution-group sdg2 id 1
  rpd downstream-cable 1/0/1
 ...
 service-distribution-group bcast id 1
  rpd downstream-cable 9/0/31
 ...
```

55-1 Remote PHY Implementation

CCAP core provides the RPDs with virtual OM and ARPD info via GCP




```
cable oob
  virtual-om 1
    ip 10.10.10.10 255.255.255.0
    join-group 235.1.1.1 source-ip 200.1.1.10 out-group 239.2.2.2
  virtual-arpd 1
    ip 20.20.20.20 255.255.255.0
    nc 200.1.1.20 udp-port 100
    source-id 1
```

← Creates Loopback2000

← Creates Loopback1000

55-1 Configuration – OOB Profiles & RPDs

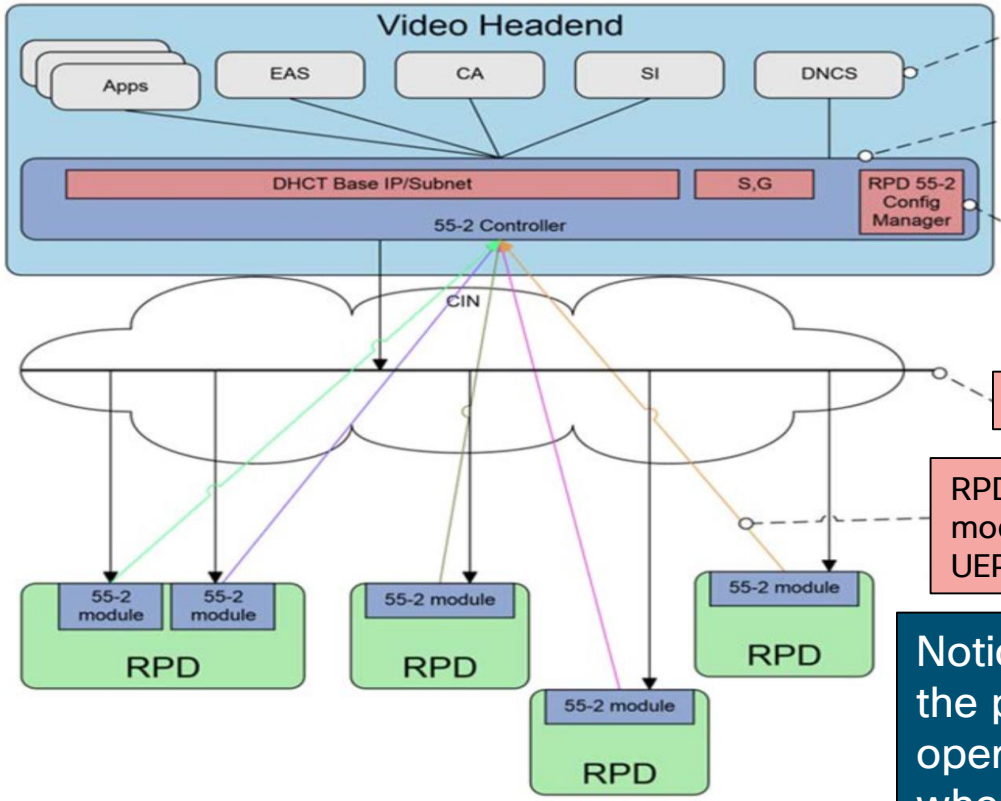
```
controller downstream-oob 55d1-profile 100
  no ds-channel 0 rf-mute
  no ds-channel 0 shutdown
  ds-channel 0 frequency 70000000
  ds-channel 0 poweradjust 0
  no ds-channel 0 sf-mute
  no ds-channel 0 sf-shutdown
  ds-channel 0 second-frequency 130000000
  ds-channel 0 sf-poweradjust 10
```

```
cable rpd 1
 identifier badb.ad13.419a
 core-interface Te7/1/0
  principal
  rpd-ds 0 downstream-cable 7/0/0 profile 2
  rpd-ds 0 downstream-oob-vom 1 profile 100
  rpd-us 0 upstream-cable 7/0/0 profile 221
  rpd-us 0 upstream-oob-varpd 1 profile 201
  rpd-us 1 upstream-oob-varpd 1 profile 202
 ptp profile 1
```

```
controller upstream-oob 55d1-profile 201
  no us-channel 0 shutdown
  us-channel 0 frequency 5216000
  us-channel 0 varpd-portid 1 varpd-demodid 0
  us-channel 1 shutdown
  us-channel 1 frequency 5416000
  us-channel 1 varpd-portid 1 varpd-demodid 1
  no us-channel 2 shutdown
  us-channel 2 frequency 5616000
  us-channel 2 varpd-portid 1 varpd-demodid 2

controller upstream-oob 55d1-profile 202
  no us-channel 0 shutdown
  us-channel 0 frequency 5816000
  us-channel 0 varpd-portid 1 varpd-demodid 0
  us-channel 1 shutdown
  us-channel 1 frequency 6016000
  us-channel 1 varpd-portid 1 varpd-demodid 1
  no us-channel 2 shutdown
  us-channel 2 frequency 6216000
  us-channel 2 varpd-portid 1 varpd-demodid 2
```

55-2 Remote PHY Implementation



- Existing Apps & Services remain as is
- D9485 55-2 Controller manages DHCT IPs, routing, network segmentation as is
- D9485 55-2 Controller uses GCP to manage RPD 55-2 resources as Auxiliary core
- Multicast DEPI MPT PW & UEPI PSP PW

RPDs equipped with 55-2 module(s) each having a dedicated UEPI PW and shared DEPI PW

Notice the Principal CCAP core is not in the picture; it's unaware of 55-2 operation. This is different from 55-1 where the CCAP core is very involved in OOB operation.

Figure 1 - 55-2 Remote PHY Solution from RPHY OOB specification

55-2 Implementation continued

D9485 Back

D9485 uses Ethernet interface to source 55-2 OOB

```
** Maintenance -> Upgrade **

0 Back
     |-------------------------|
     | System Release | 2_51_37 |
     |----------------|---------|

     |-- System Upgrade ------------------------------------|
     |------------------------------------------------------|
1    | TFTP or HTTP Server  | 13.135.8.104                  |
     | Upgrade Pathname     | D9485_REL_4P_2_51_33.bin.signed |
     | Target Firmware Type | ROOB                          |
     | Last attempt at      | Tue Apr 17 15:53:15 2018      |
```

Configure D9485 to operate in ROOB mode (instead of RF mode); requires a license

Add D9485 address to DHCP "CCAP Cores" option

[17] (dhcp6-cablelabs-config)	cablelabs-17	(vendor-opts)	(enterprise-id 4491((syslog-servers 34 2001:420:2280:2008:250:56ff:feb2:126c)(rfc868-servers 37 2001:420:2280:2008:250:56ff:feb2:126c)(time-offset 385h)(ccap-cores 61 2001:db8:cb8:110::2,2001:db8:cb8:10::2 2001:db8:daa:552:2eab:a4ff:feff:f497))

NCS Configuration Examples

```
interface TenGigE0/0/0/23
 description RPD port
 l2transport
 !
interface TenGigE0/0/0/27
 description RPD port
 l2transport
 !
interface BVI1
 description RPD subnet
 mtu 9126
 ipv4 address 13.52.0.81 255.255.255.240
!
l2vpn
 bridge group RPDs
  bridge-domain RPDs
   igmp snooping profile rpd
   interface TenGigE0/0/0/23
   !
   interface TenGigE0/0/0/27
   !
   routed interface BVI1
   !
  !
```

```
interface TenGigE0/0/0/22
 description RPD subnet
 mtu 9126
 ipv6 nd other-config-flag
 ipv6 nd managed-config-flag
 ipv6 address 2001:db8:daa:5::1/64
 ipv6 enable
!
interface TenGigE0/0/0/25
 description RPD subnet
 mtu 9126
 ipv6 nd other-config-flag
 ipv6 nd managed-config-flag
 ipv6 address 2001:db8:daa::1/64
 ipv6 enable
```

Each RPD on its own Layer 3 interface

Common subnet used across RPD facing ports via BVI interface and IRB configuration

NCS Configuration Examples

DHCP Relay example configuration for both IPv4 and IPv6 use cases

```
dhcp ipv4
 profile rpd relay
  helper-address vrf default 172.18.98.57
  helper-address vrf default 172.18.98.59
  relay information option
 !
 interface BVI1 relay profile rpd
!
dhcp ipv6
 profile rpd6 relay
  helper-address vrf default 2001:420:2280:2008:250:56ff:feb2:126c
  helper-address vrf default 2001:420:2280:2008:250:56ff:feb2:48c8
 !
 interface TenGigE0/0/0/22 relay profile rpd6
 interface TenGigE0/0/0/25 relay profile rpd6
!
```

NCS Configuration Examples

10GE interfaces connected to cBR-8 DPIC ports

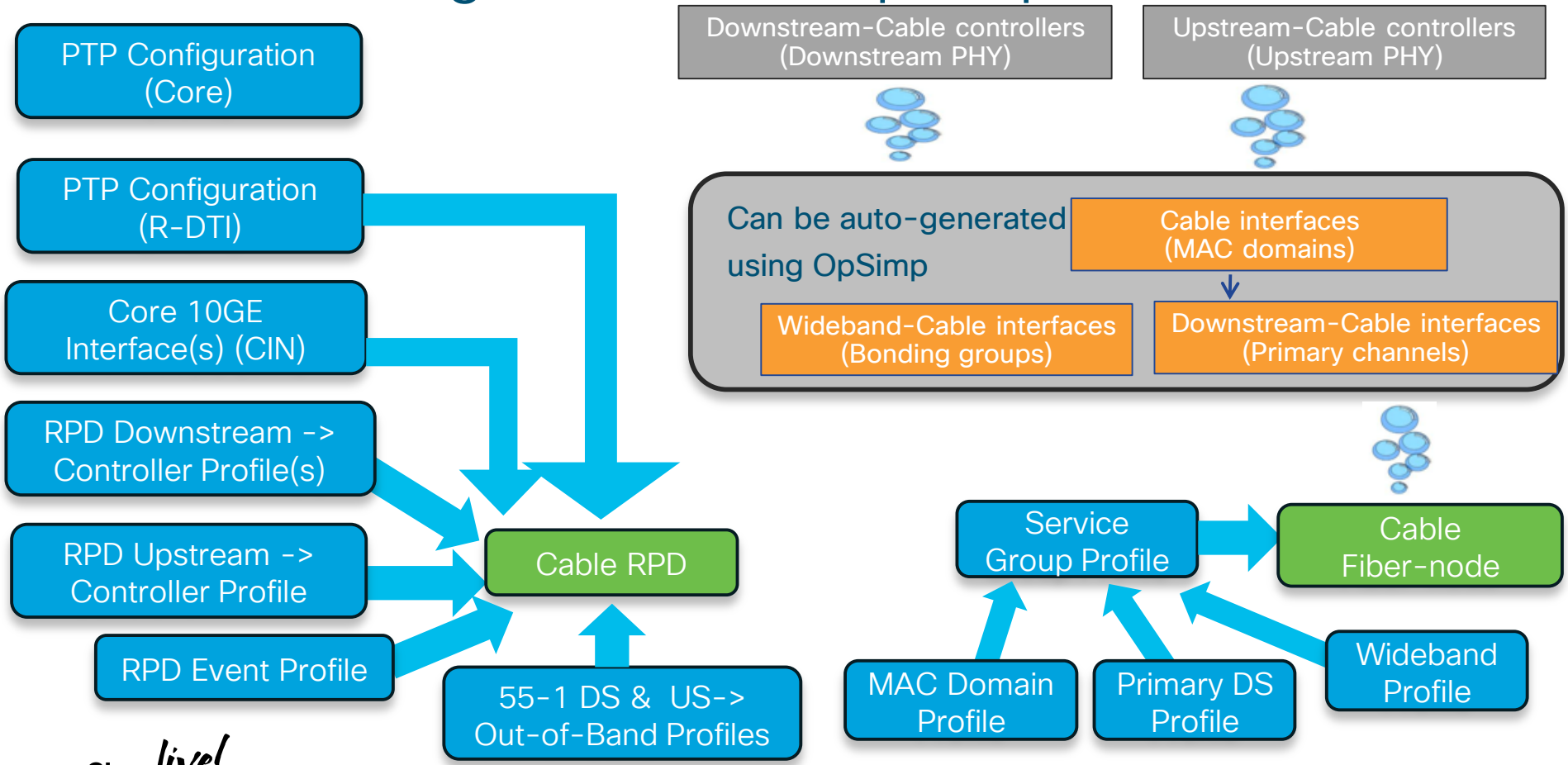
```
interface TenGigE0/0/0/2
 description F241-36-05-cBR8-0 Te0/1/0
 cdp
 mtu 9126
 ipv4 address 13.13.0.197 255.255.255.252
 ipv6 address 2001:db8:cb8:10::1/64
 load-interval 30
!
interface TenGigE0/0/0/3
 description F241-36-05-cBR8-0 Te1/1/6
 cdp
 mtu 9126
 ipv4 address 13.13.0.217 255.255.255.252
 ipv6 address 2001:db8:cb8:116::1/64
 load-interval 30
```

IPv4 & IPv6 multicast enabled on all interfaces

```
multicast-routing
 address-family ipv4
  interface all enable
 !
 address-family ipv6
  interface all enable
 !
!
igmp snooping profile rpd
```

RPD Automation

R-PHY Configuration with OpSimp Flowchart



Operation Simplification Configuration

```
cable profile mac-domain MD1
 cable ip-init ipv6
 cable dynamic-secret reject
 cable privacy mandatory
 cable privacy bpi-plus-policy total-
enforcement

cable profile wideband-interface WB1
 load-interval 30

cable profile downstream DS1
 cable rf-bandwidth-percent 20
```

Configure profiles one time

Configure Service Group topology profile

```
cable profile service-group 24x4
 cable bundle 1
 mac-domain 0 profile MD1
  downstream sg-channel 0 4 8 12 16 20 profile DS1
  upstream 0 sg-channel 0
  upstream 1 sg-channel 1
  upstream 2 sg-channel 2
  upstream 3 sg-channel 3
  us-bonding-group 1
   upstream 0
   upstream 1
   upstream 2
   upstream 3
 wideband-interface 0 profile WB1
  downstream sg-channel 0-3 rf-bandwidth-percent 1
 wideband-interface 1 profile WB1
  downstream sg-channel 4-7 rf-bandwidth-percent 1
 <snip>
 wideband-interface 6 profile WB1
  downstream sg-channel 0-7 rf-bandwidth-percent 1
 <snip>
```

Operation Simplification Configuration – continued

```
cable fiber-node 1
 downstream Downstream-Cable 1/0/0
 upstream Upstream-Cable 1/0/0
 downstream sg-channel 0 23 downstream-cable 1/0/0 rf-channel 0 23
 upstream sg-channel 0 3 Upstream-Cable 1/0/0 us-channel 0 3
 service-group profile 24x4
!
cable fiber-node 3
 downstream Downstream-Cable 2/0/0
 upstream Upstream-Cable 2/0/0
 downstream sg-channel 0 23 downstream-cable 2/0/0 rf-channel 0 23
 upstream sg-channel 0 3 Upstream-Cable 2/0/0 us-channel 0 3
 service-group profile 24x4
```

Configure fiber nodes to reference SG topology

Simplified configuration generated

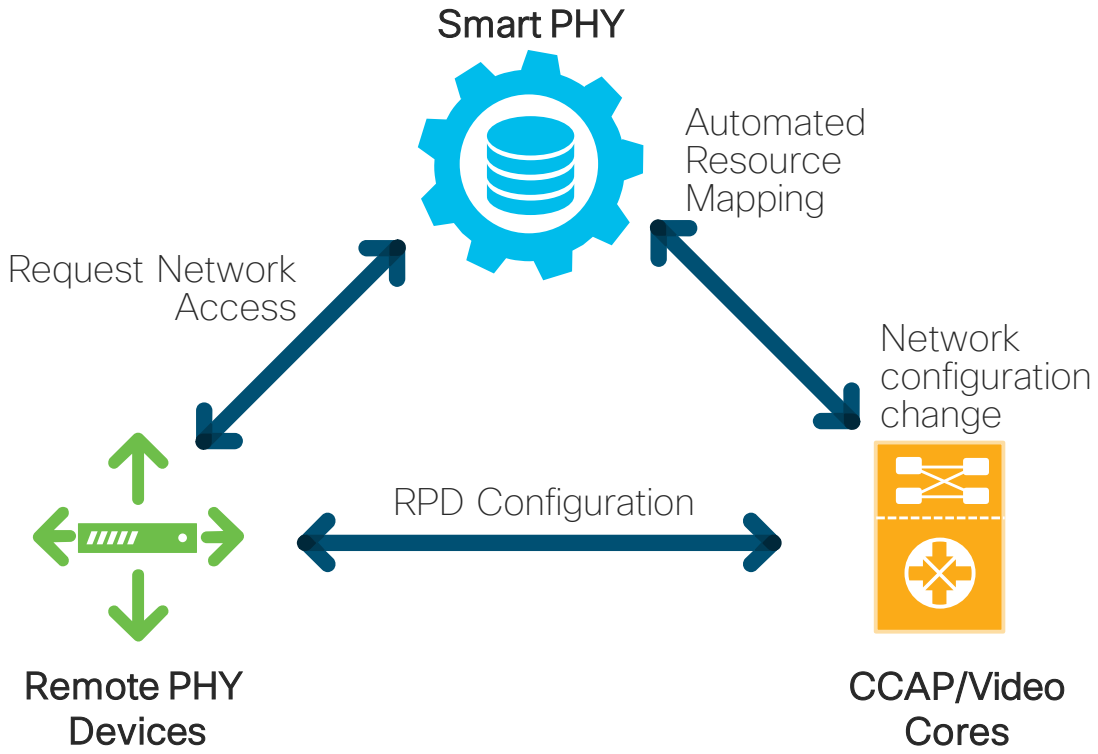
```
interface Downstream-Cable1/0/0:0
 cable bundle 1
 cable managed fiber-node 1
```

```
interface Wideband-Cable1/0/0:0
 cable bundle 1
 cable managed fiber-node 1
 cable wideband-profile WB1
```

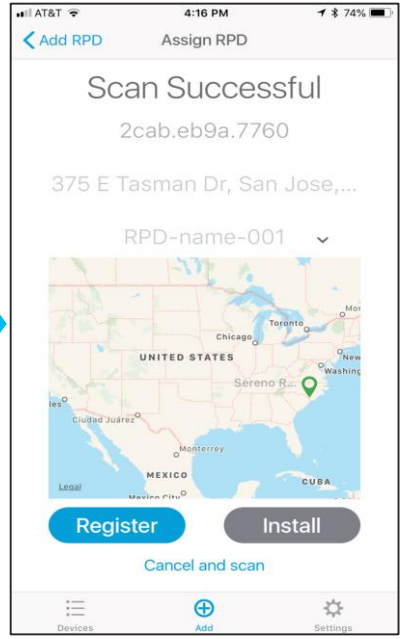
```
interface Cable1/0/0
 cable mac-domain-profile MD1
 cable bundle 1
 cable managed fiber-node 1
```

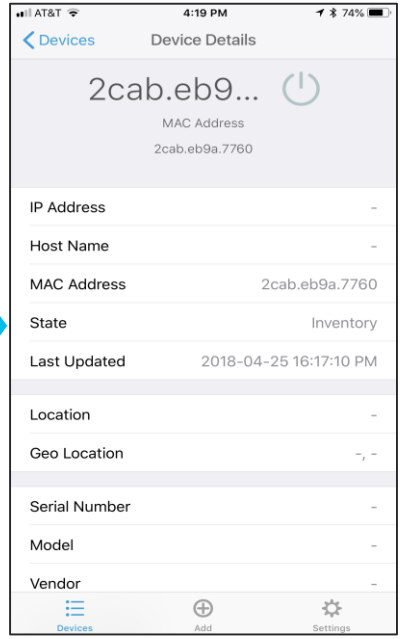
Smart PHY – RPD Deployment Automation

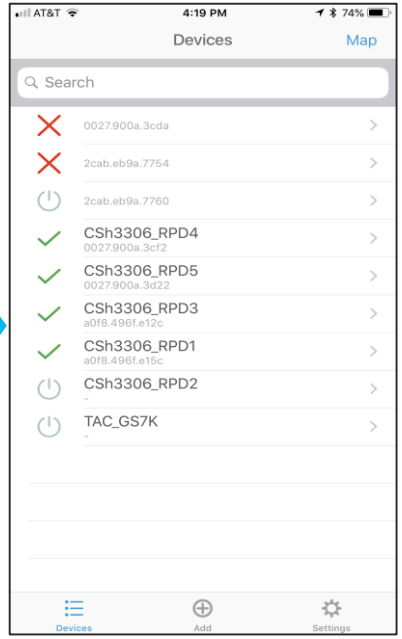
- **Deployment Simplified**
  - Resource Selection
  - DOCSIS & Video
  - cBR-8 and RPD orchestration
- **Unified Provisioning**
  - Common DHCP Policy
  - Flexible RPD to SG mapping without managing one-offs
- **Cisco Crosswork Platform**
  - Common Infrastructure
  - API-Centric Design
- **Advanced Monitoring & Troubleshooting**



Smart Phone Application

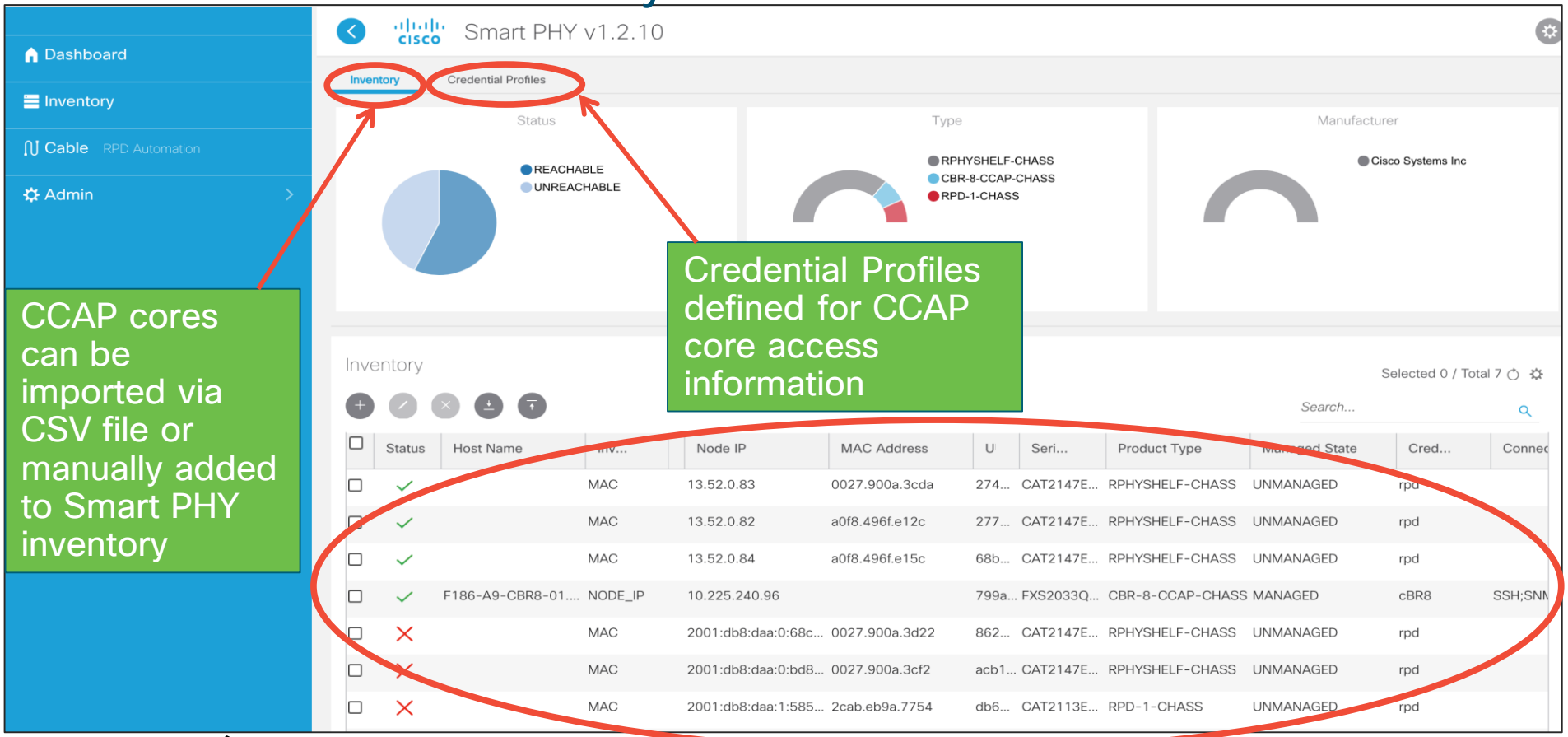




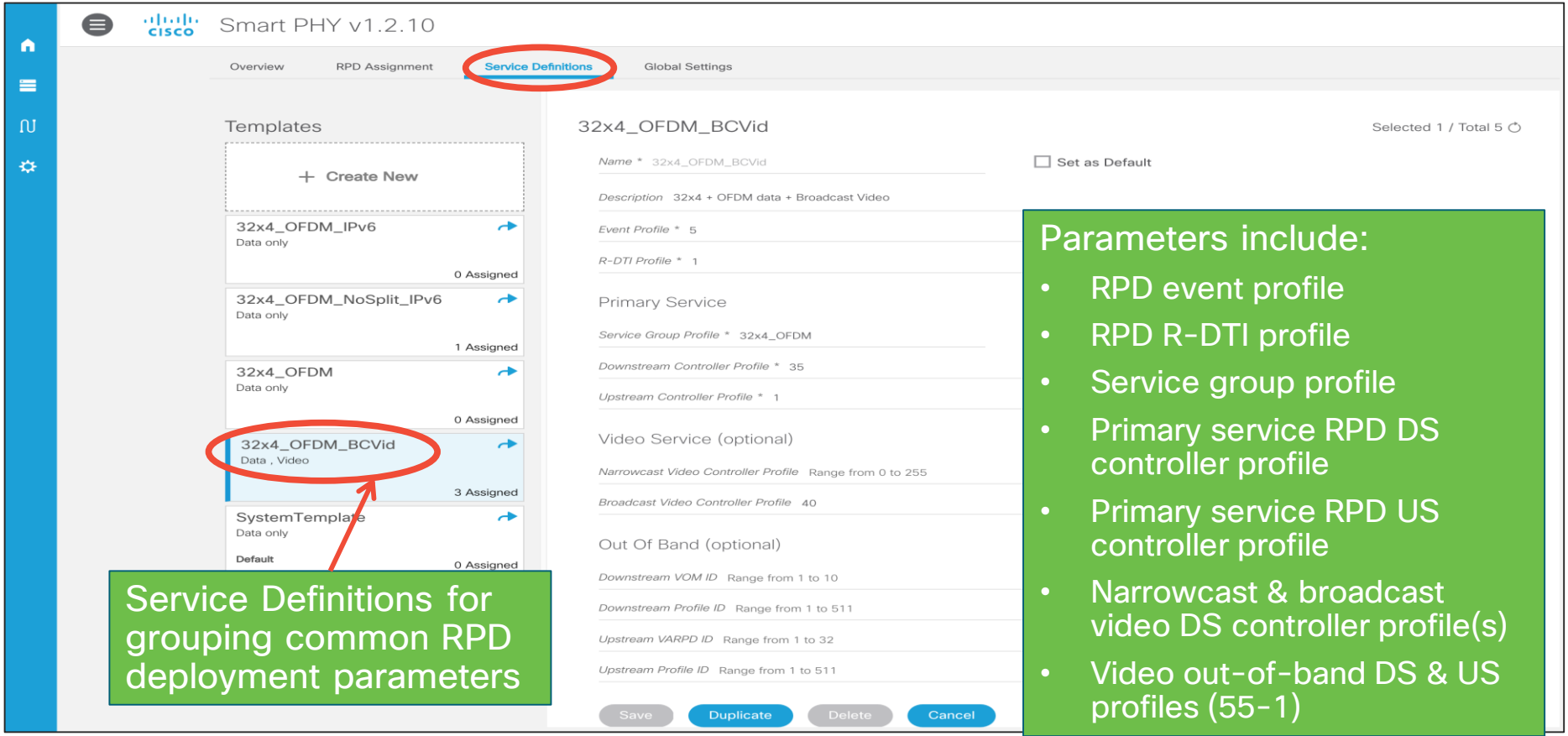


- RPD bar codes can be scanned via the Smart Phone App to automatically add the RPDs to the Smart PHY inventory
- Can also include the phone's GPS coordinates to automatically populate the RPD's location
- App can be used for both staging and installation workflows

Smart PHY Inventory



Smart PHY Service Definitions

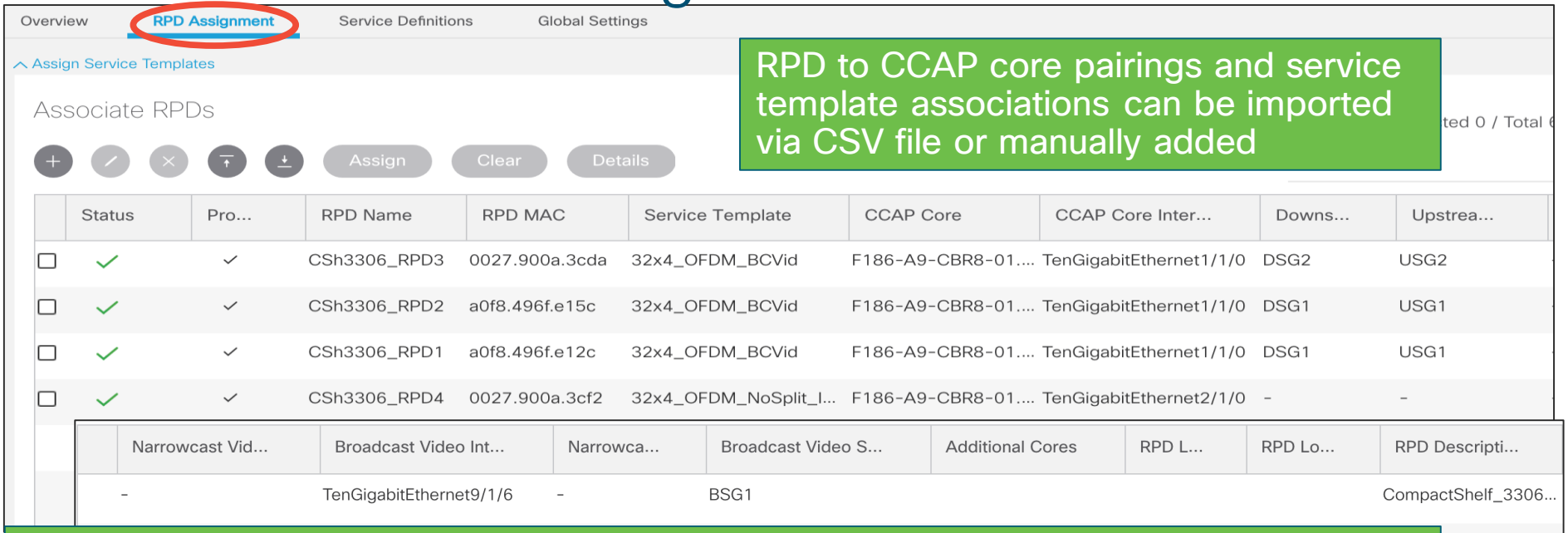


Service Definitions for grouping common RPD deployment parameters

Parameters include:

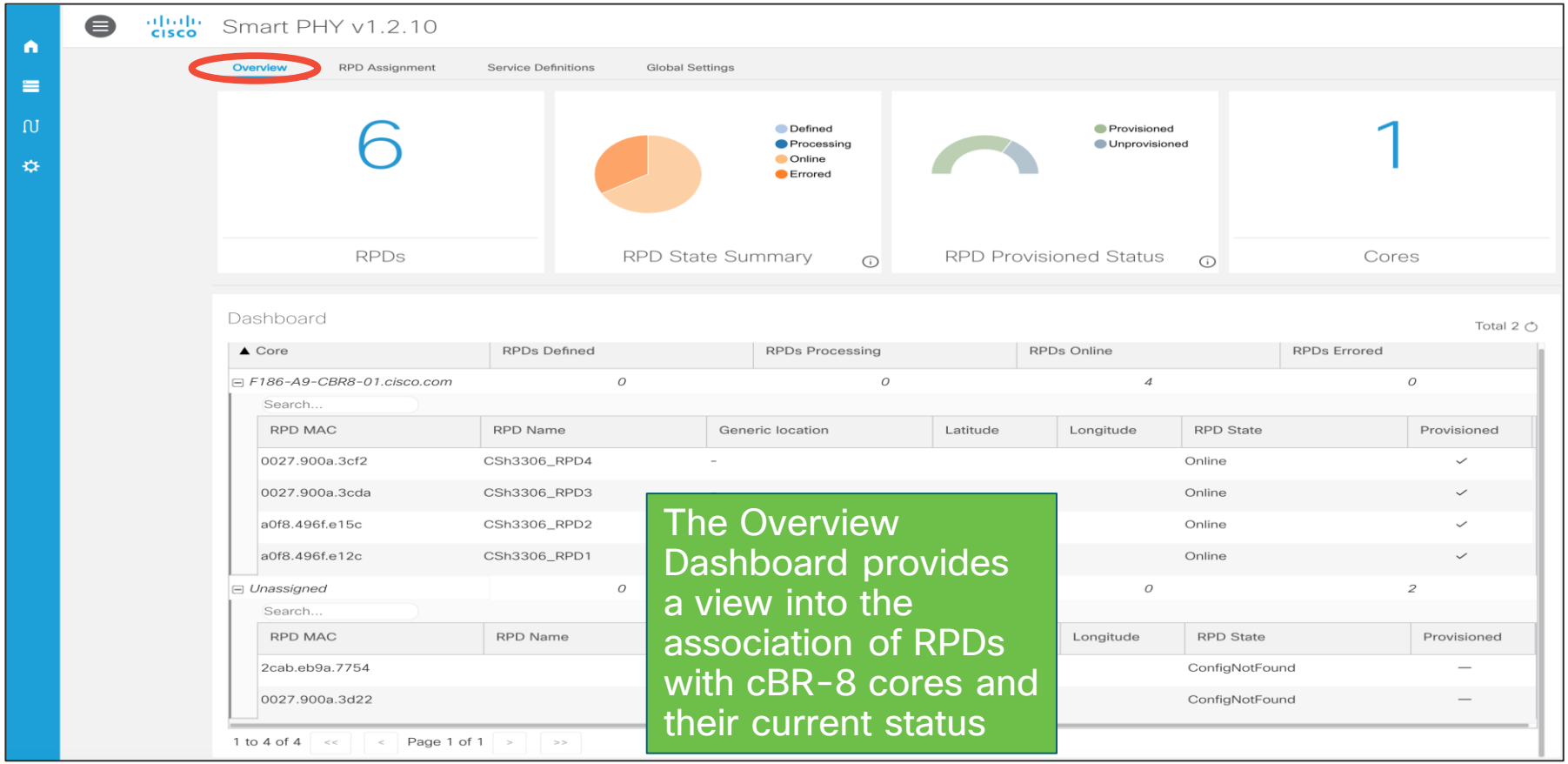
- RPD event profile
- RPD R-DTI profile
- Service group profile
- Primary service RPD DS controller profile
- Primary service RPD US controller profile
- Narrowcast & broadcast video DS controller profile(s)
- Video out-of-band DS & US profiles (55-1)

Smart PHY RPD Assignment

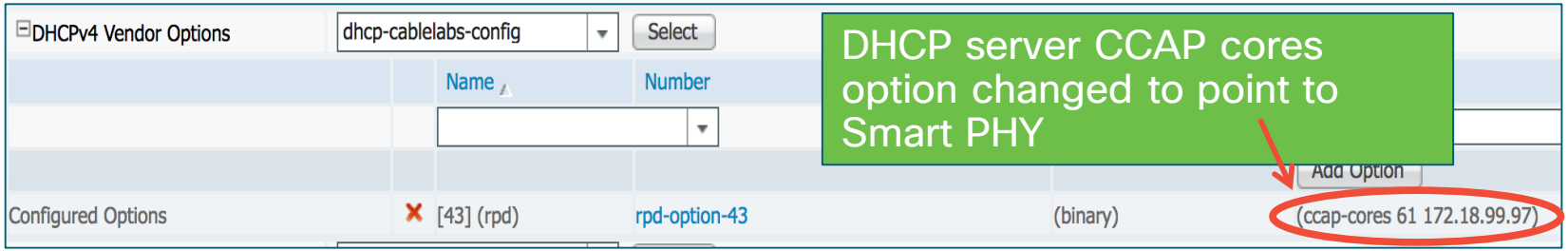


- RPDs anchored by RPD Name
- Fields include Service Template, CCAP Core, and interfaces used for cores
- “Service Group” fields used indicate associations for Virtual Splitting & Combining
- Additional Cores used for 55-2 OOB

Smart PHY Overview Dashboard



RPD Initialization with Smart PHY

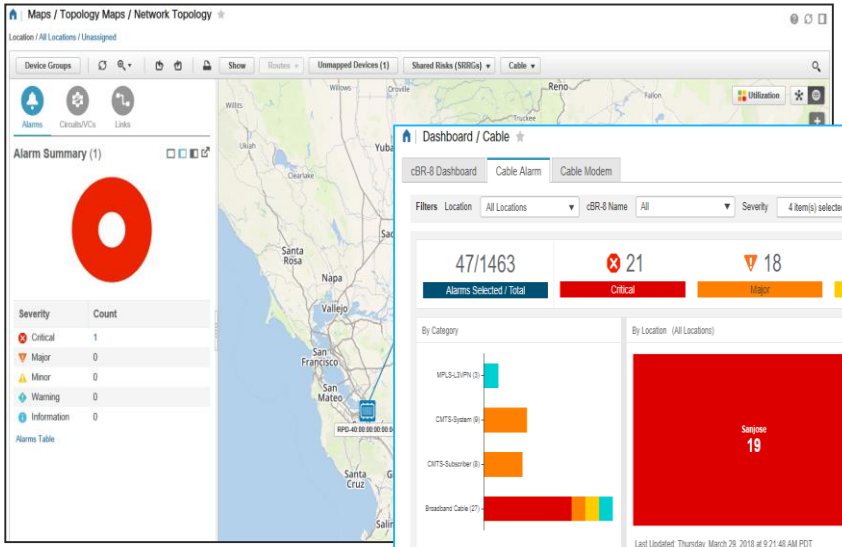



```
R-PHY#show dhcp
Interface            IP-Address          Subnet-Mask
vbh0                 13.52.0.19          255.255.255.240
Details:
------------------------------------------------------------
Interface:                    vbh0
TimeServers:                  172.18.98.57
TimeOffset:                   -18000
LogServers:                   172.18.98.57, 172.18.98.59
CCAPCores:                    172.18.99.97
```

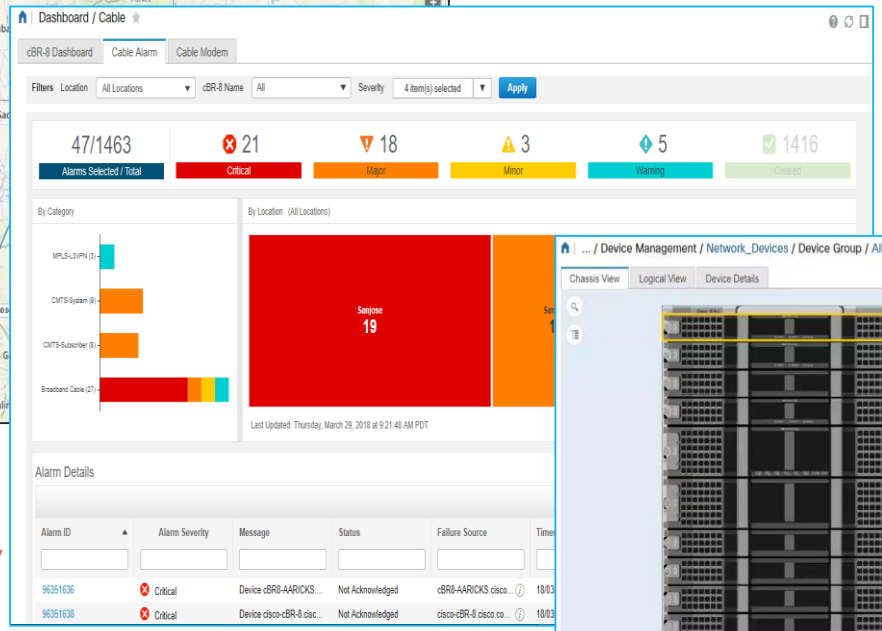
The RPD initially establishes GCP with Smart PHY which then redirects to the appropriate CCAP core(s) based upon defined pairings

```
R-PHY#show provision all
ID                Interface  IP             Name      State       Role       HA-Mode  Initiated-By
CORE-1230641727   vbh0       13.13.0.238    CCAPCORE  init(gcp)   Principal  Active   GCP_Redirect
```

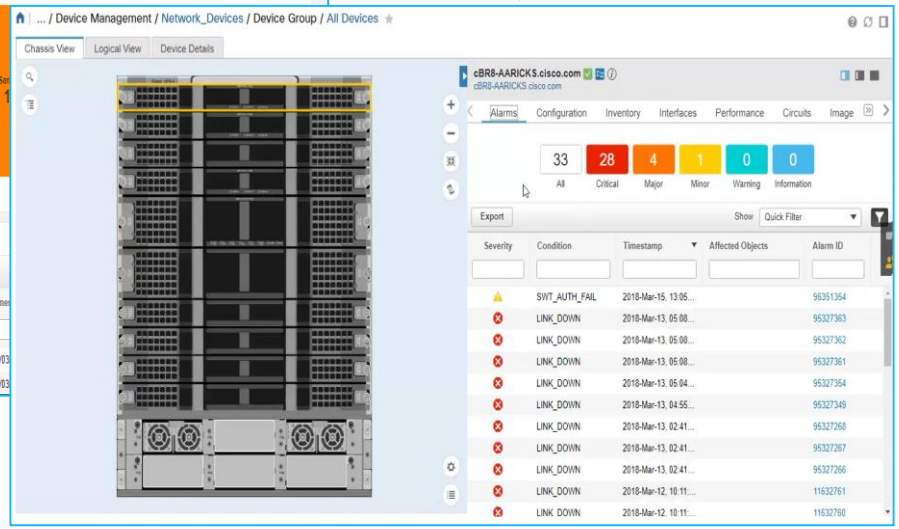
Evolved Programmable Network Manager (EPN-M)



Physical & Logical topology views



Contextual alarms



Alarm dashboard with filtering

Secure Software Download (SSD)

- SSD ensures only legit code is installed on an RPD
- Code authenticated via certificate chains and digital signatures
- RPD upgrades can be initiated directly from the cBR-8 using the GCP connection

```
cable rpd {all|oui|slot|RPD IP|RPD MAC} ssd server_IP {tftp|http}
file_name [c-cvc-c|m-cvc-c] [CVC Chain File Name]
```

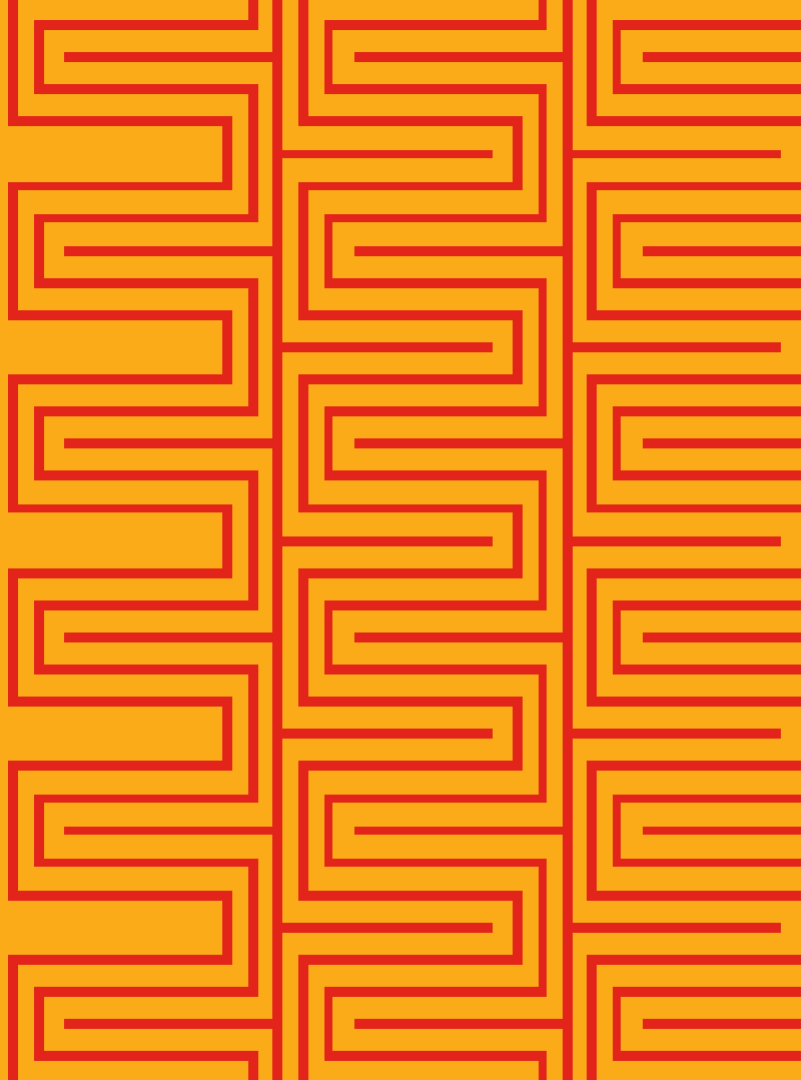
- Useful commands for troubleshooting include **show cable rpd {RPD IP|RPD MAC} event** and **cable rpd {all|MAC|IP} ssd status**
- Can also be initiated via SSH session on the RPD assuming IP connectivity established

Summary

Summary

- Moving to a Remote PHY architecture enables hub consolidation, full benefits of D3.1, an improved usage of cBR-8 MAC resources, increased usability of DWDM wavelengths, service consolidation in the CIN, future technologies such as Cloud Native Broadband Router (cnBR) and Full Duplex DOCSIS, and more
- Increase expertise by knowing the RPHY protocols (GCP/RCP, DEPI/UEPI, PTP) and components (CCAP cores, RPD nodes & shelves, CIN routers, etc.)
- Deploy full RPHY services at scale via virtual splitting & combining, DWDM, and RPD daisy chaining
- Automate RPD configuration using the Smart PHY platform
- EPN-M can help operate the end-to-end cable network

Useful Information



PTP related FAQs

- Will RPDs work when there's a large delay to the PTP Master?
  In most cases yes, note RPD to PTP master latency is independent from RPD to CCAP core latency. Also Path Delay Variation (PDV) tends to be much more critical than end-to-end latency, a PDV <= 10ms is required
- When would I need to use PTP Boundary clocks?
  One major reason is to enable scale as there's a limited # of unicast sessions supported on the PTP Master; most Cisco platforms are limited to 64 clients
- Why G.8275.2?
  The unspecified default profile has no guarantees for timing goal, end-to-end budget, performance requirements, network model, etc.
- Does my Grandmaster clock need to have external timing?
  RPD and cores should work without external timing however there can be issues recovering from service disruption; also needed when using redundant sources
- What are the requirements for redundant clock sources?
  Need a common GM and/or have external timing (i.e. GNSS); for G.8275.2 need to configure the cBR-8 as a Boundary Clock to enable multiple clock ports

Miscellaneous FAQs

- What can cause modems to get stuck in the init(o) state when using R-PHY?
  Could be caused by a MTU limitation in the CIN; recommend increasing to at least 2350 bytes. Improper MTU settings can also cause poor throughput.
- RPD is online but no modems are showing up?
  Possible reasons include: missing MAC domain configs, no route to the RPD subnet via the DPIC, issue with multicast operation in the CIN, RPD & Core not synched to a common PTP source, longer Core to RPD distance requiring DLM, issue with the GS7K configuration (missing pads, wrong setting for FCM or RCM, etc.)
- Can I enable my existing GS7000 nodes to support R-PHY?
  Yes, but will need to replace the Optical Interface Board (OIB) as well as the Forward & Reverse Configuration Modules (FCMs/RCMs). The OIB can be replaced on its own but its easier to simply replace the whole lid containing the proper OIB.
- Why do I see high throughput on the DPIC ports when there's no modems or STBs?
  Most likely due to the existence of Video QAMs in the downstream controller; Video uses DEPI MPT mode which sends a steady stream of MPEG packets to the RPDs.

cBR-8 Releases & Features

IOS-XE Release	IOS Release	Date	Major HW/SW Features (Note: not all features per release listed)	Latest Rebuild
3.15.0S	15.5(2)S	March 2015	Initial release – SCH feature parity with exceptions, Smart licensing, Patching availability, PPRL, ACFE phase 1	3.15.1S June 2015
3.16.0S	15.5(3)S	July 2015	D3.1 Downstream module, LCHA (N+1), 96 Upstream channels, Sup ISSU, SGAC Phase 1, Battery 1x1	3.16.2S Feb 2016
3.17.0S	15.6(1)S	Nov 2015	Sup 60G, Operation simplification, Licensing enforcement, Dynamic DS D3.0 LB, RFoG, SGAC Phase 2, ACFE phase 2	3.17.1S March 2016
3.18.0S	15.6(2)S	March 2016	D3.1 Upstream module, 16 US per Mac Domain, 3 step modulation, Energy management, Partial Service via MER, PowerKEY & PME Video on Demand, D6 interface, CEM	3.18.1S July 2016
3.18.0SP	15.6(2)SP	July 2016	DOCSIS 3.1 DS SW support, IPv6 DQoS Lite, LI: Multiple Taps, SDV w/GQI, Pre-encrypt broadcast, Video monitor & provision apps	3.18.3bSP Jan 2018
16.5.1		April 2017	Remote PHY, DVB Simulcrypt & Tiered DVB VoD (ICCAP), PME VoD (RPHY), Adjust OFDM power, OFDM primary	N/A
16.6.1		July 2017	R-PHY D3.1 DS, D3.1 US SW support (ICCAP), PKEY VoD (RPHY), 2 OFDMs/port, D3.1 resiliency, CM-STATUS-ACK	16.6.2 Nov 2017
16.7.1		Nov 2017	Sup 250G, Dynamic BGs, Port level tilt; TaFDM; Major release ISSU, Netconf; OpSimp Phase 2, ICMTS Contr Profs R-PHY: Scaling, IPv6, SDV, DVB VoD	16.7.2 May 2018
16.8.1		March 2018	D3.1 to 204 MHz (ICCAP), R-PHY: D3.1 resiliency, OFDM primary, Dynamic BGs, Virtual Combining, RPD Daisy Chaining, PTP Slave thru DPIC, G8275.2 support	N/A
16.9.1		July 2018	80G LC (RPHY), CPB Licensing, Telemetry Testing Enablement RPHY: D3.1 US with TaFDM, DPIC link redundancy	

RPD & NCS 5500 Releases

RPD Release	Compatible cBR8 release	Date	Major Features	Latest Rebuild
v1.1	16.5.1	March 2017	Initial release; DOCSIS 3.0 US/DS, PME VoD, Pre-encrypted Broadcast, 55-1 OOB	N/A
v2.1	16.6.1	July 2017	DOCSIS 3.1 DS, PKEY VoD, 55-2 OOB	v2.2 (Nov 2017)
v3.1	16.7.1	Nov 2017	DEPI over IPv6, SDV, DVB VoD, GCPP	v3.1.1 (Jan 2018)
v4.1	16.8.1	March 2018	OFDM primary, RPD Daisy Chaining	v4.1.1 (April 2018)
v5.1	16.9.1	July 2018	DOCSIS 3.1 US with TaFDM	

Version	Date	Features
6.2.3	Dec 2017	EVPN, VPWS, MPLS, BGP, ISIS, OSPF, Segment Routing
6.3.2	March 2018	DWDM limiting modules (20,40), IGMP Snooping, IPv4 Multicast over IRB, PTP BC for 5501-SE?, PIM SSMv6, MLD, DHCPv6 relay
6.5.1	July 2018	DWDM limiting modules (80, tunable), PTP 8275.2 support, VRRP w BVI, 100/200G CFP2 DCO (coherent)

NMS/OSS Component Releases

Product	Version	Date	Comments
Smart PHY	v1.0.9	Nov 2017	Base functionality – Dashboard, Service Templates, RPD Associations, Mobile apps, etc
Smart PHY	v1.1.14	Feb 2018	IPv4 & IPv6, Virtual splitting, Video, OOB, EPN-M integration
Smart PHY	v1.2.10	May 2018	Name based workflow, RPD grouping, Virtual combining
EPN-M	v2.1.3	June 2017	cBR-8 monitoring, dashboard, topology
EPN-M	v2.2	April 2018	Smart PHY integration, cable dashboard enhancements, topology enhancements
Prime Cable Provisioning (PCP)	v6.0	August 2017	RPD Support
PCP	v6.1	March 2018	New features not directly related to Cable
Prime Network Registrar (PNR)	v9.0	Dec 2016	New features not directly related to Cable
PNR	v9.1	Dec 2017	New features not directly related to Cable

Useful cBR-8 RPHY show commands

- To check status of PTP (1588) - **`show ptp clock running {domain <>}`**
- To see the RPD a certain modem is connected to - **`show cable modem <> verbose | include rpd`**
- To see details of a downstream controller profile or current usage **`show cable downstream controller-profile [<> | association | configured]`**
- To see details of a upstream controller profile or current usage **`show cable upstream controller-profile [<> | association | configured]`**
- To view multicast DEPI group assignments - **`show cable depi multicast [ip | ipv6] all`**
- To view associations of RPD to a downstream controller - **`show controllers downstream-Cable <> rpd`**

Useful cBR-8 RPD show commands

- To view all RPDs - **`show cable rpd`**
- To pull an RPDs event log - **`cable rpd <> event [pending | locallog]`**
- To view a concise list of GCP transactions - **`show cable rpd gcp-transaction {verbose}`**
- To verify the details of the DEPI and UEPI sessions - **`show cable rpd depi`**
- To see all modems connected to a certain RPD - **`show cable modem rpd <>`**
- To see the RPD a certain modem is connected to - **`show cable modem <> verbose | include rpd`**
- To view RPD DEPI Latency Measurement (DLM) information - **`show cable rpd <> dlm`**
- To view event logs for a particular RPD - **`show cable rpd <> event`**
- To view RPD CPU/memory/disk information - **`show cable rpd <> host-resources`**
- To view RPD/controller/MAC domain mappings - **`show cable rpd <> md-association`**
- To view RPD HW/SW versions, serial #s, etc. - **`show cable rpd <> identification`**

Useful RPD show commands

- To halt auto rebooting – **`set reboot hold`**
- To see RPD code levels, MAC address, serial number, etc. – **`show version`**
- To view DHCP returned options – **`show dhcp`**
- To view ToD status – **`show tod`**
- To view provisioned cores and their status or see historical data – **`show provision [all | history]`**
- To view PTP configuration or status – **`show ptp clock 0 [config | state | statistics]`**
- To verify the details of the downstream channels and DEPI sessions
  `show downstream [channel [configuration | counter] | depi configuration]`
- To verify the details of the upstream channels and UEPI sessions
  `show upstream [channel configuration <> <>] | iuc counter <> <> | map counter <> <> | uepi configuration | ...]`
- To validate certificate chain – **`show certificate status`**
- To view environmental data such as temperature and power readings – **`show environment all`**

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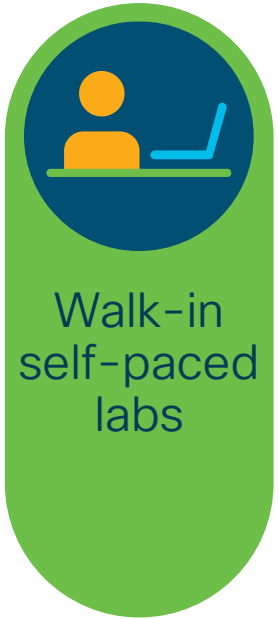

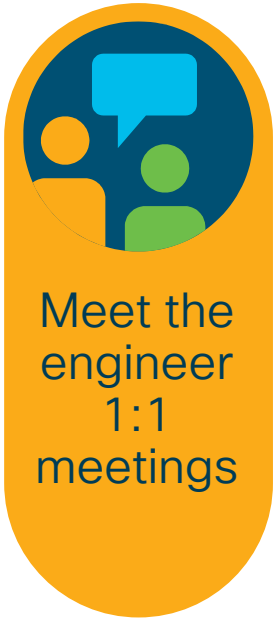

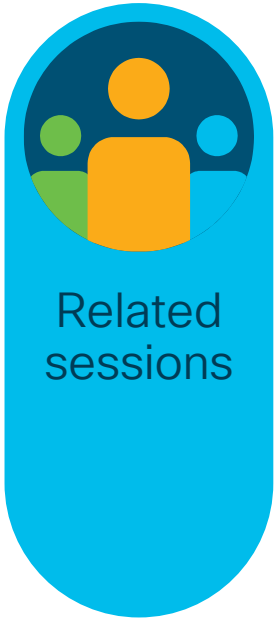

Thank you

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