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Cable Access Evolution with DOCSIS 3.1 & Remote PHY

Jeff Riddel – Sr. Solutions Architect

BRKSPG-2505

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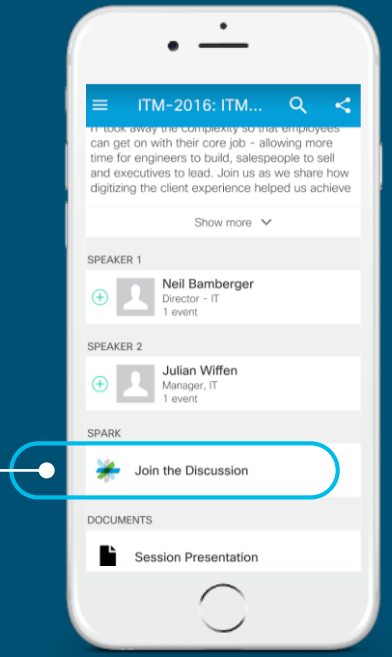

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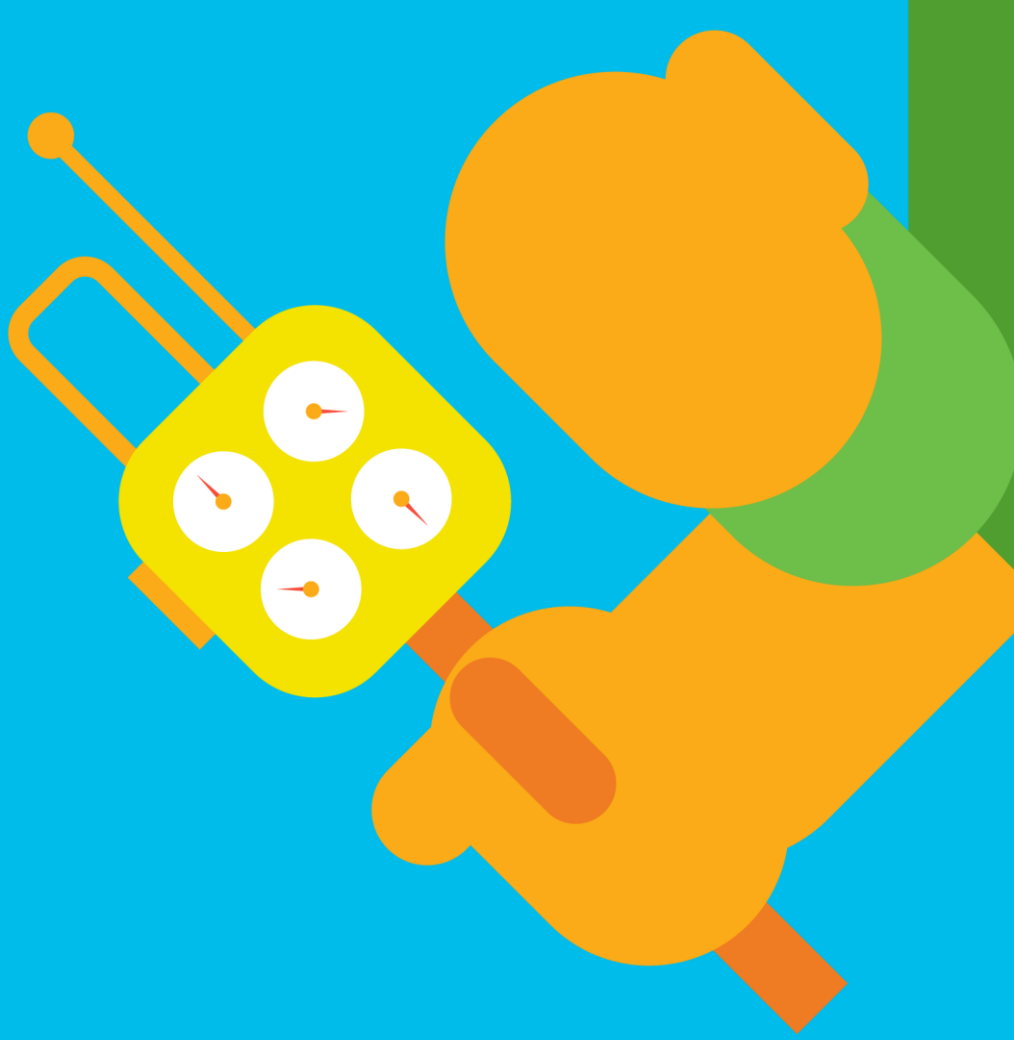
Agenda

- cBR-8 Refresher
- Remote PHY Basics & Configuration
- Advanced Remote PHY Design Topics
- DOCSIS 3.1 Basics & Configuration
- DOCSIS 3.1 Operation & Insertion Strategy
- Conclusion

cBR-8 Refresher



cBR-8 Overview

- **Converged Cable Access Platform scaling**
  200 Gbps of switching capacity in 13 RU CCAP chassis with built-in HA; scalable to 1.6 Tbps
  With HA: 56 SGs, 5,376 DS QAMs & 672 US QAMs[1]
- **Video convergence**
  HSD, VoD, SDV, & Broadcast - “Hub in a Box”
- **DOCSIS 3.1**
  Designed from the ground up with D3.1 in mind
  With HA: 112 OFDM & 224 OFDMA D3.1 channels (in addition to capacity from 1st bullet)
- **Remote PHY**
  SG scaling & hub consolidation; full advantages of DOCSIS 3.1
- **Service & feature velocity with SDN**
  Faster feature implementation; customization

[1] DS numbers for Annex B
Annex A = 4,032 DS QAMs with LCHA

cBR-8 Release Naming & Features

Intern Name	IOS-XE Release	IOS Release	Date	Major HW/SW Features (Note: not all features per release listed)	Latest Rebuild
R0	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
R1	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
R2	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
R3	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
R4	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	3.18.2aSP April 2017
R5	**Polaris 16.4.1**		** Lab release only **		
R6	**Polaris 16.5.1**		April 2017	Remote PHY, DVB Simulcrypt & Tiered DVB VoD (ICCAP), PME VoD (RPHY), Adjust OFDM power, OFDM primary	N/A
R7	**Polaris 16.6.1**		July 2017	Sup 250G, R-PHY D3.1 DS, D3.1 US SW support (ICCAP), PKEY VoD (RPHY), 2 OFDMs/port, D3.1 resiliency, CM-STATUS-ACK	N/A

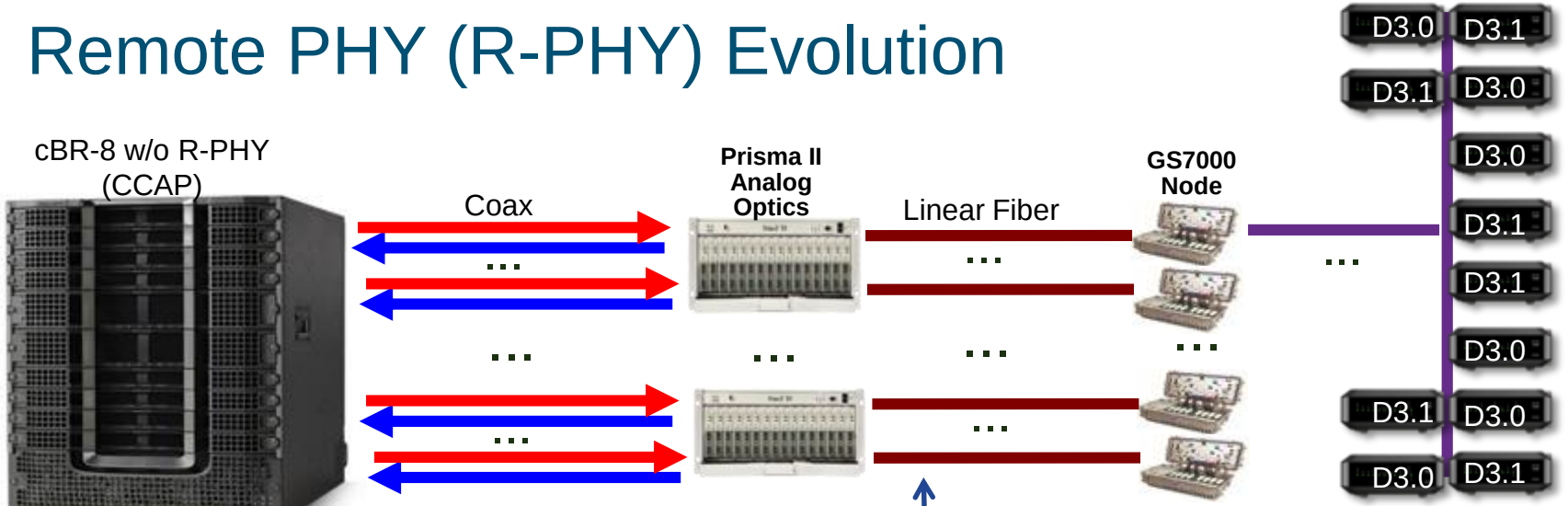
** Feature content available in ECE images 3-4 months before GA release

What is Polaris?

- Common Linux based OS environment for next generation of Cisco products
- 16.X.Y versioning (no dual IOS/IOS-XE versions) ‘Y’ starts with “1”
- For cBR-8 will bring functionality such as:
  - Manage-ability (RESTConf, NETConf, YANG)
  - ISSU across major revisions, SMU based patching
  - Next Gen Routing (Segment Routing, MACSEC)
- Moving to Polaris requires Supervisor & Linecard FW upgrades
- Ansible upgrade scripts available for download on Cisco.com

Remote PHY Basics & Configuration

Remote PHY (R-PHY) Evolution

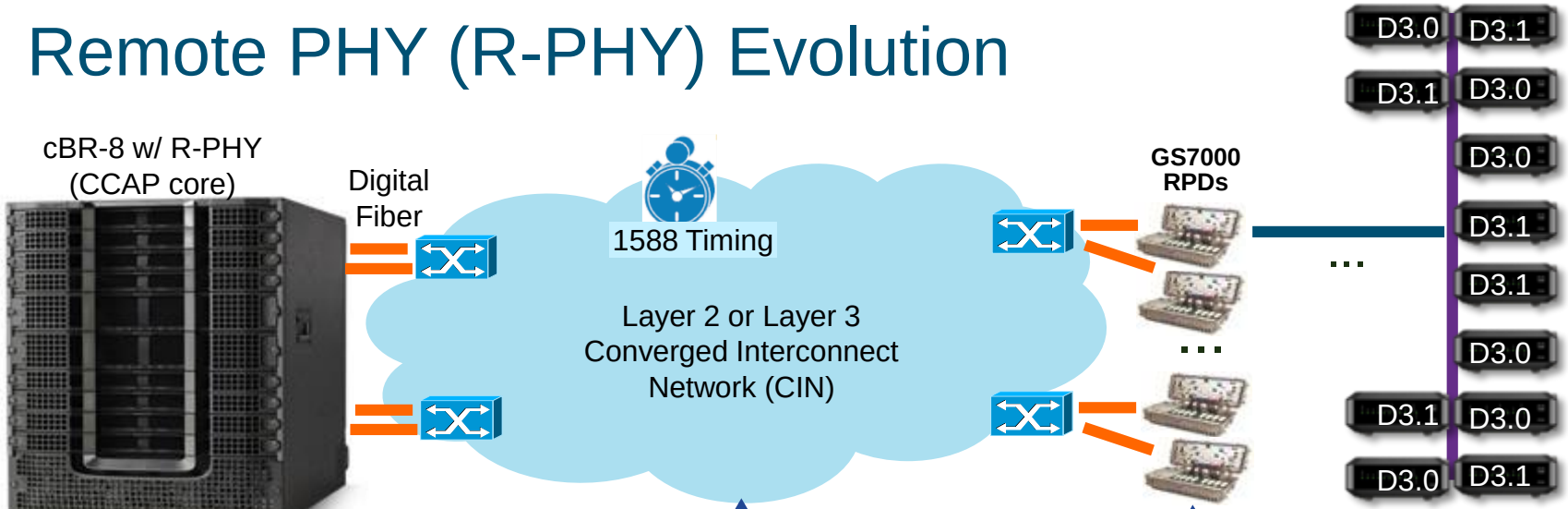


- With HA limited to 56 SGs due to limit of 56 DS ports and 112 US ports

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

- DOCSIS 3.1 modems unable to use higher order modulations

Remote PHY (R-PHY) Evolution



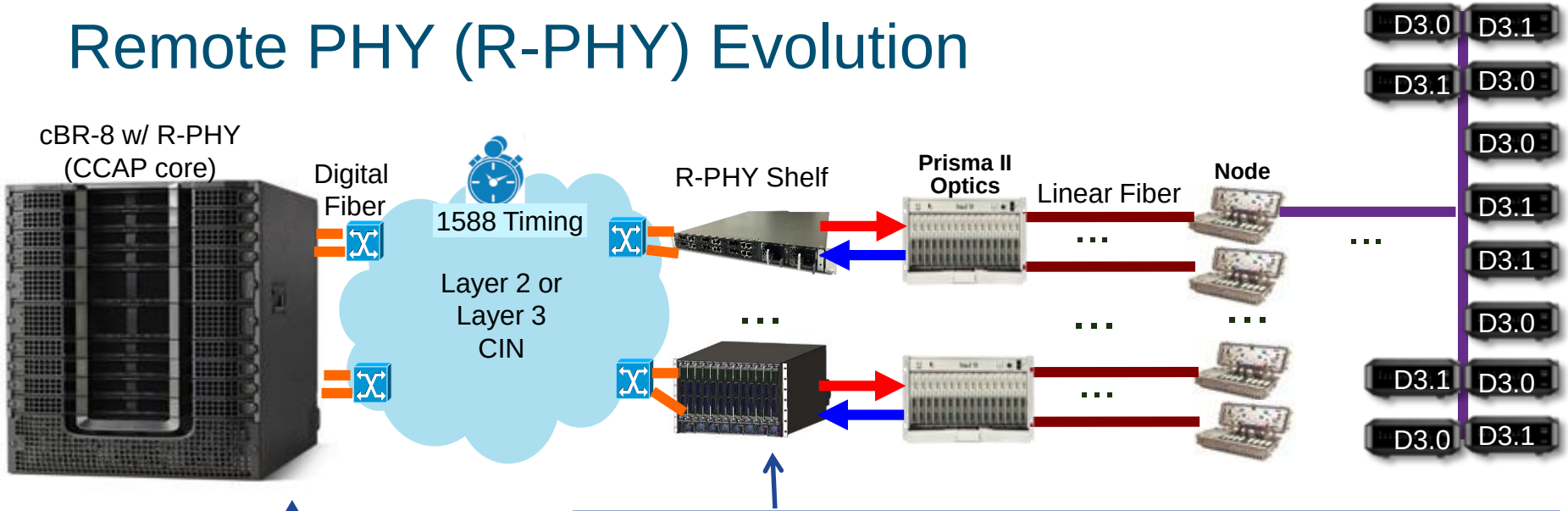
- cBR-8 RF PICs replaced with digital optics PICs
- No longer port constrained
- Space & power savings

- 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

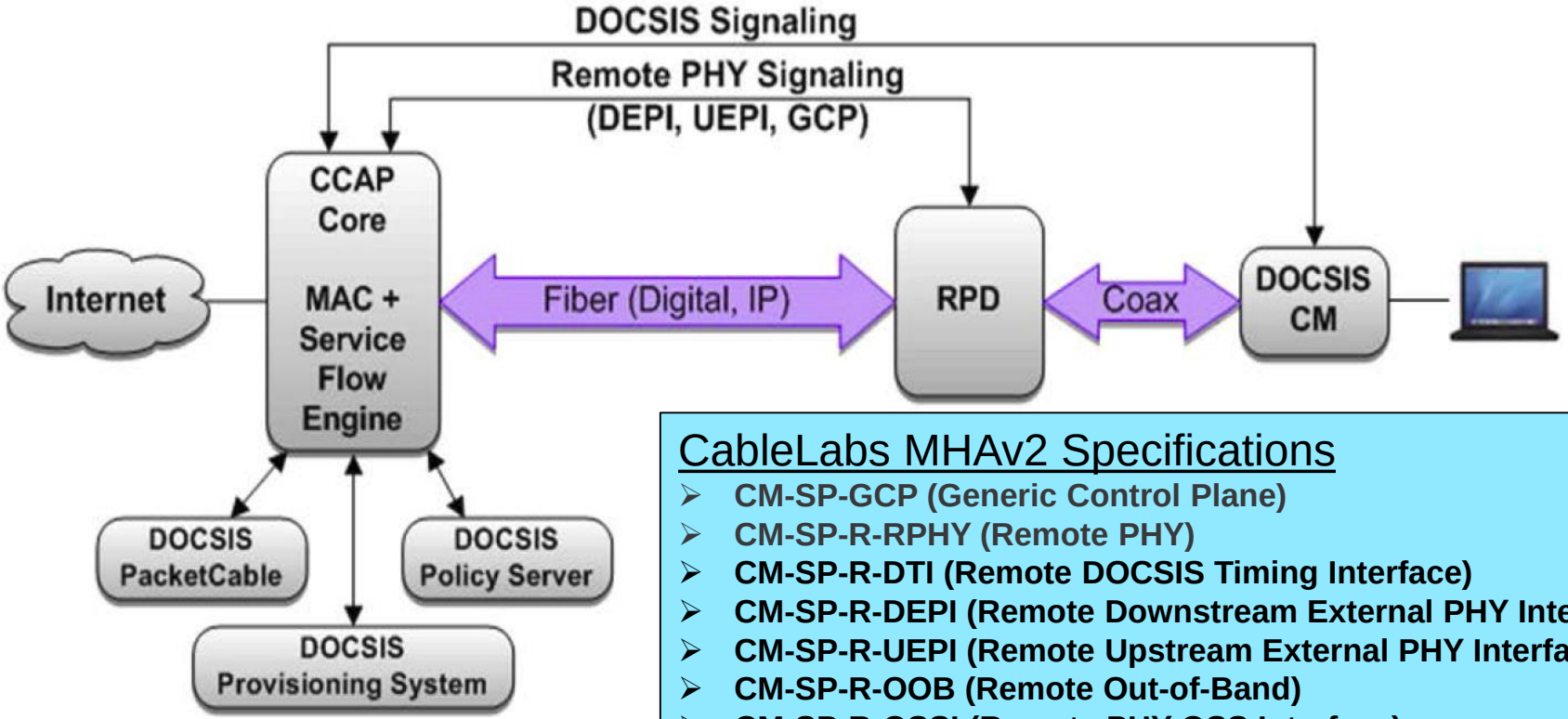


- Digital optics PICs used to enable 2x – 4x SG scaling

- 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 fixed model – Compact R-PHY Shelf

Remote PHY Reference Architecture

Modular Headend Architecture version 2 (MHAv2)



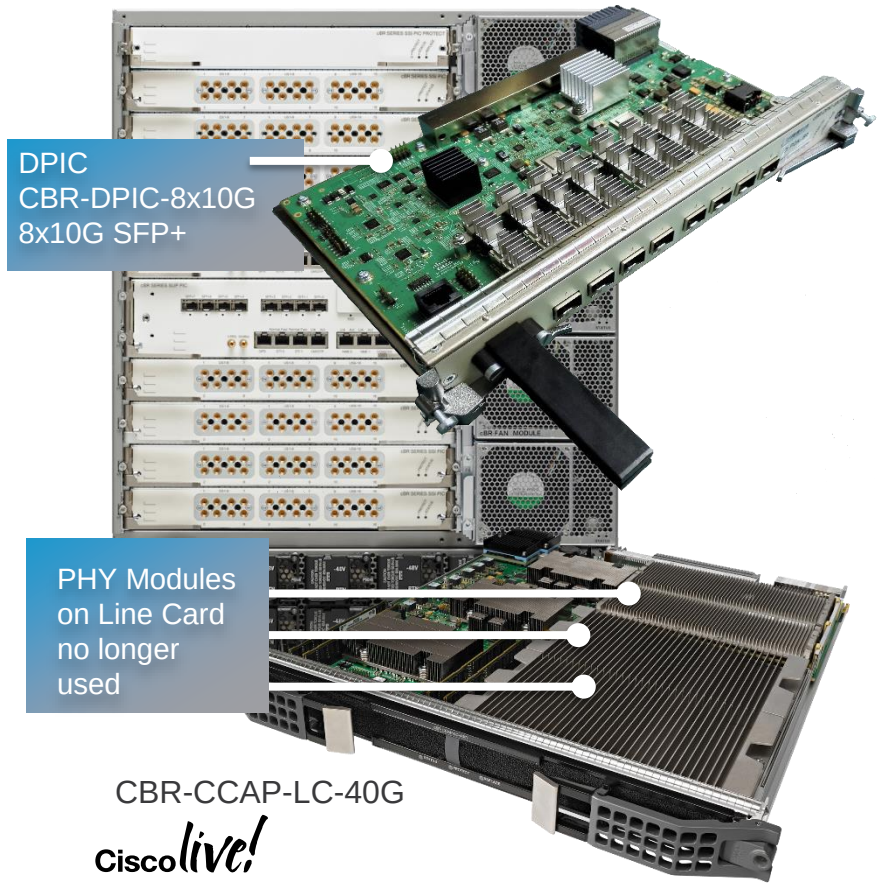
CableLabs MHAv2 Specifications

- 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

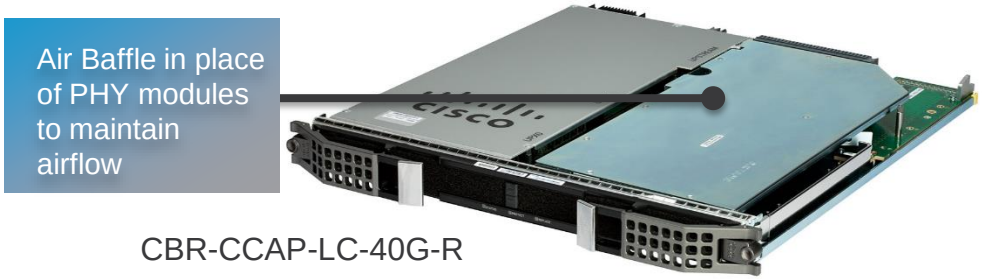
- Remote PHY is the only Distributed Access Architecture (DAA) standard in the industry
- To further accelerate full interoperability for RPDs and collaboration among equipment vendors and silicon manufactures the open-source program OpenRPD was initiated by Cisco and CableLabs®
- The OpenRPD software 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

cBR-8 Remote PHY PIC (Digital PIC)



CBR-CCAP-LC-40G

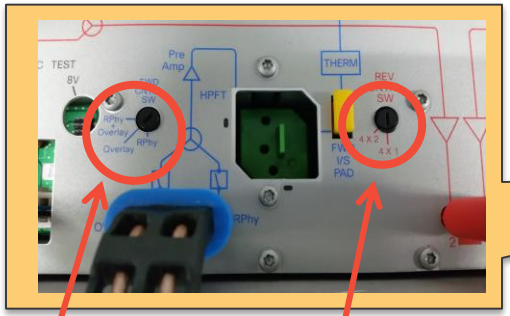
- DPIC can work with an existing CCAP Line Card (CBR-CCAP-LC-40G)
- Or new R-PHY CCAP LC w/o PHY modules (CBR-CCAP-LC-40G-R)
- DPIC supports SR/LR/ER/ZR optics
- DPICs used with active & standby CCAP LCs (no special Protect DPIC)



CBR-CCAP-LC-40G-R

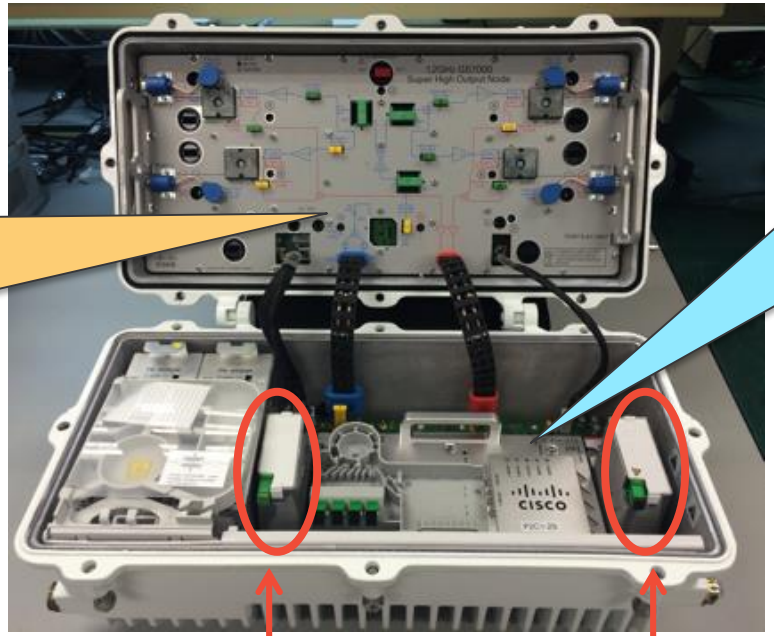
Remote PHY Device in a GS7000 Node

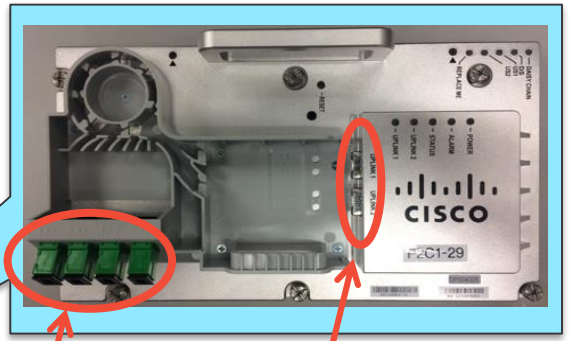
- The RPD (PID RPD-1X2) supports 1 DS port and 2 US ports (1x1 or 1x2)
- Full Spectrum D3.1 HW (160 SC-QAM/6x192 OFDM DS; 12 (A)TDMA/2x96 OFMDA US)



Forward Control SW:
RPhy or RPhy + Overlay options

Reverse Control SW:4x1 or 4x2 options





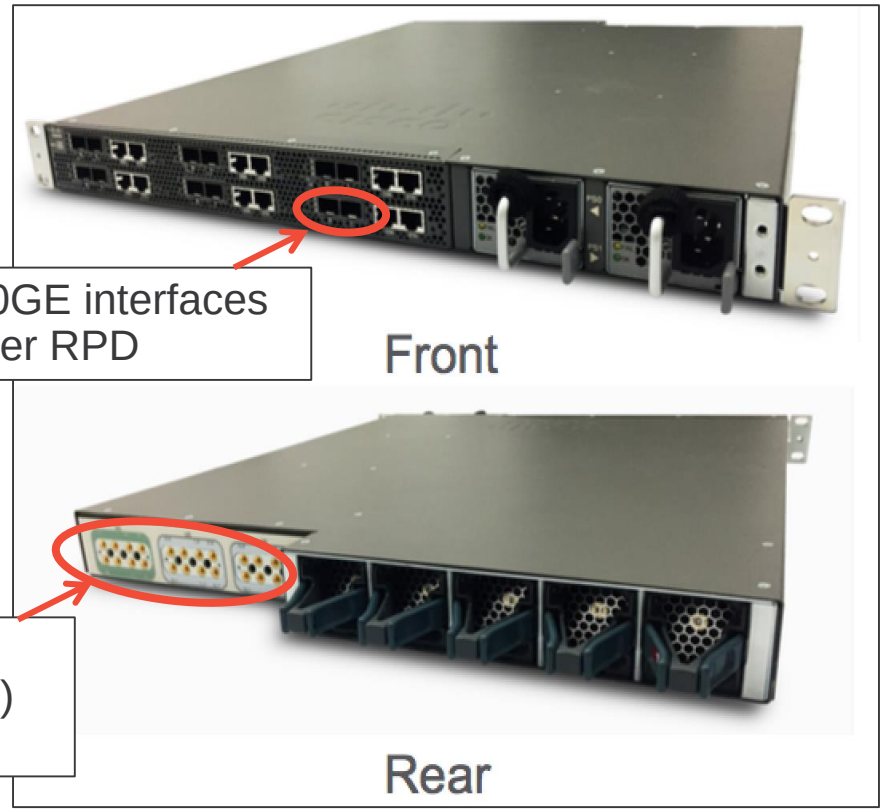
Pair of 10GE interfaces (SFP+)

Adapters for SC connectivity

Ability to include Optical Transmitter & Receiver for Overlay

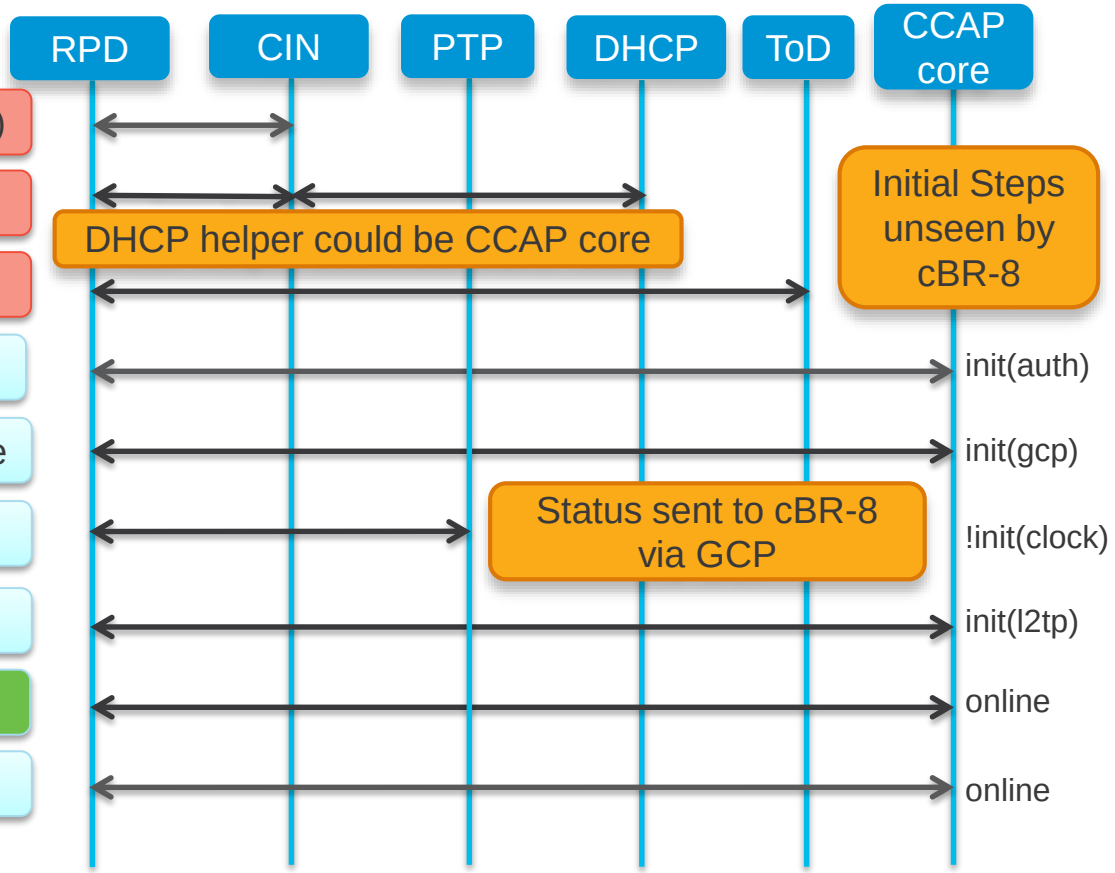
Compact (1RU) Remote PHY Shelf

- Packages 6 GS7000 1x2 RPDs
- 6x12 Service Group Support
- 1+1 Modular Power Supplies (AC or DC)
- N+1 Modular Fans
- Total Power Budget: 480W max
- Stackable for Greater SG densities



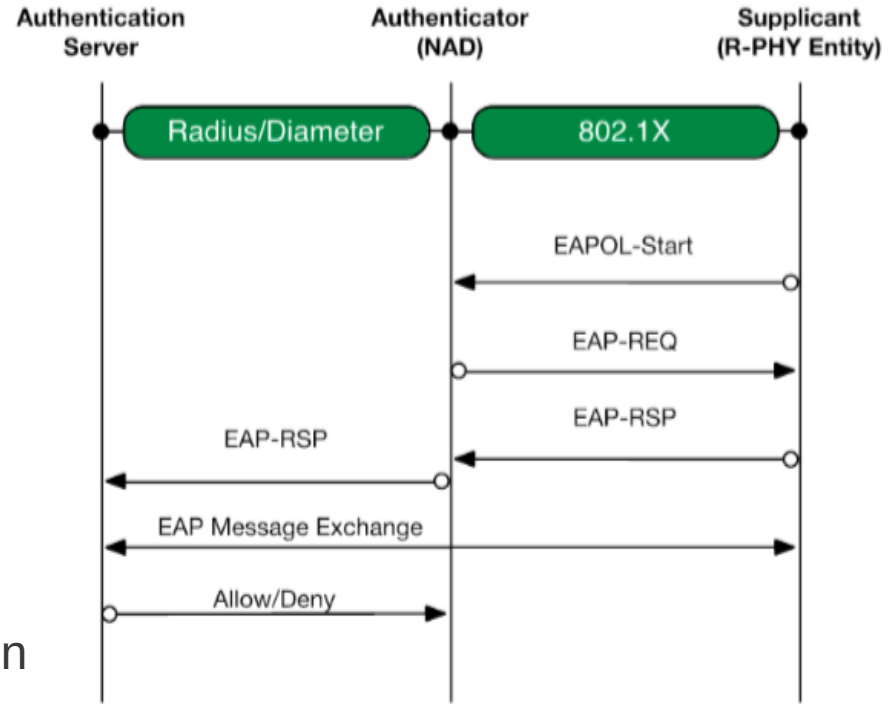
RPD Initialization

- Authentication – 802.1x & MACsec (Optional)
- Address Assignment (DHCP)
- Time of Day (ToD)
- Mutual Authentication (IKEv2) (Optional)
- GCP Session Establishment to Principal Core
- PTP Timing Synchronization
- DEPI & UEPI Session Establishment
- Operational with Principal Core
- Auxiliary Core Connections (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

- Currently IPv6 is not supported for R-PHY protocols (GCP, DEPI, PTP); however the RPD can use DHCPv6 to get an IPv6 address for management purposes only
- During the DHCPv4 initialization the RPD learns about CCAP core(s) via a new DHCP option (43.61) “ccap cores” which needs to be configured in the provisioning server (CPNR screen shot examples below)

List of Option Definitions for *rpd*

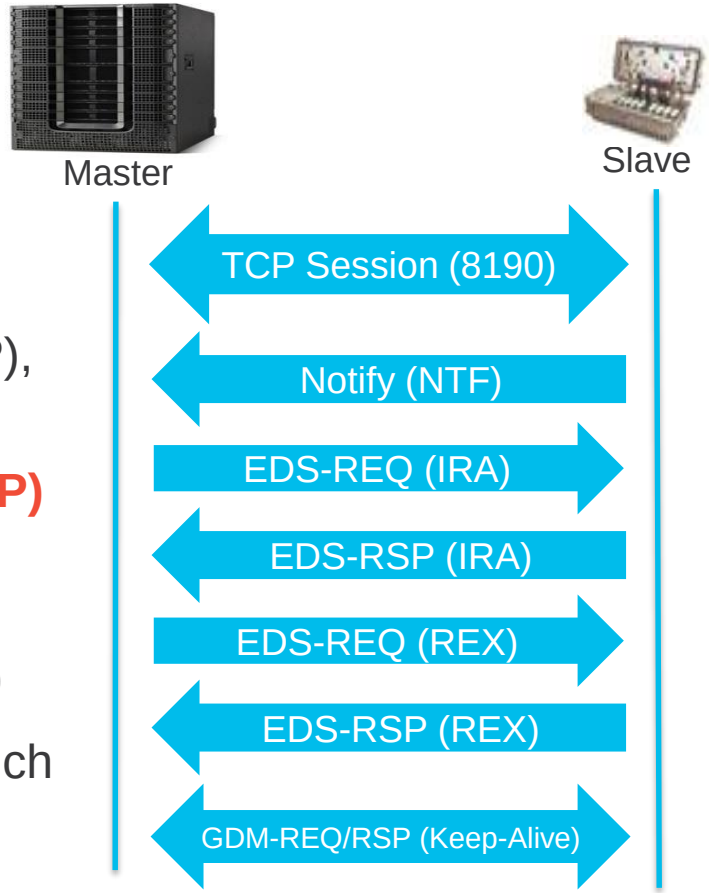
Number		Name	Type	Repeat
⊟43		rpd-option-43	binary	
	61	ccap-cores	IP address	1+

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)



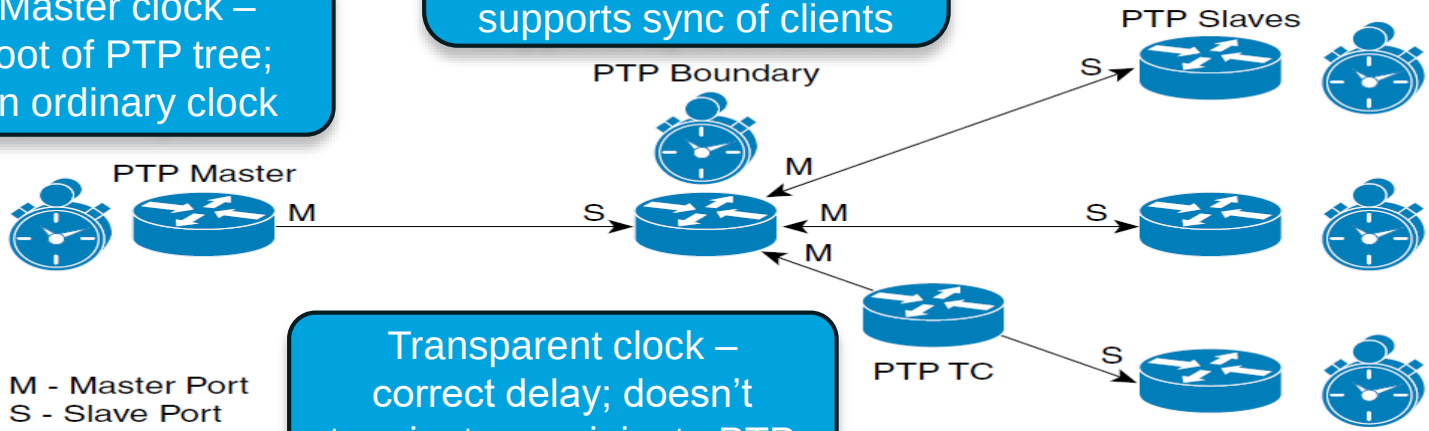
Timing in R-PHY (IEEE 1588 & PTP)

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

Master clock – root of PTP tree; an ordinary clock

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

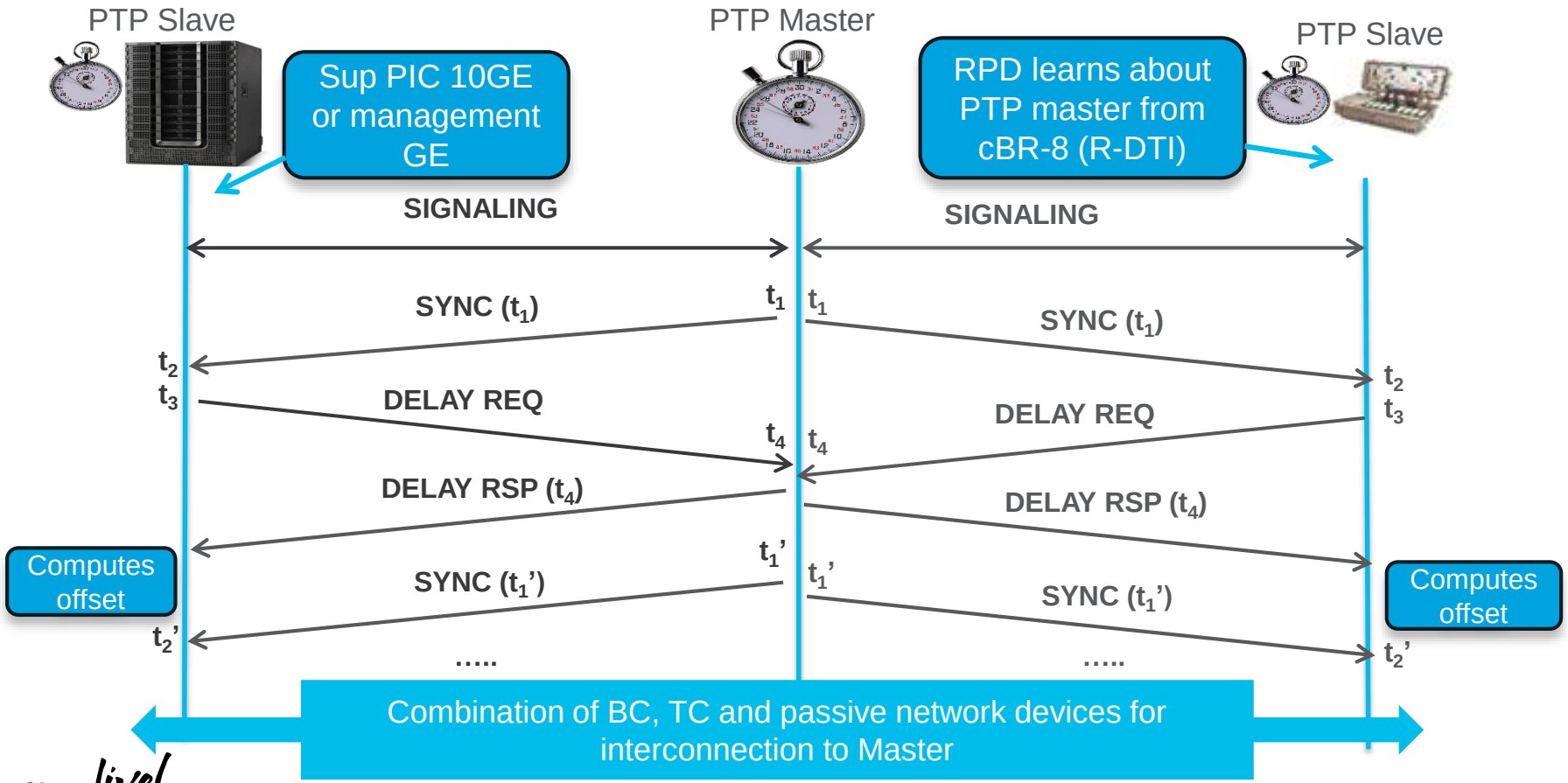
Slave clock – ordinary clock that relies on a master clock for sync



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

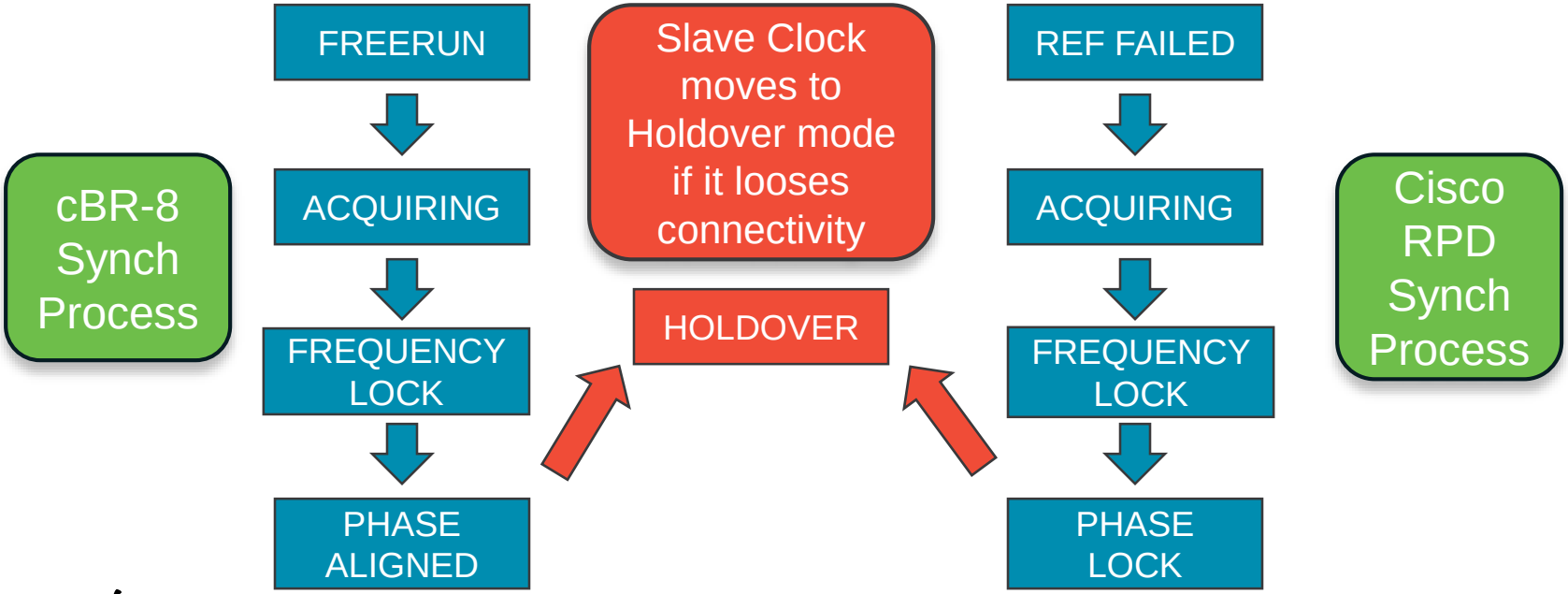
M - Master Port
S - Slave Port

cBR-8 & RPD as PTP Slaves



PTP Synchronization Process

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



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)

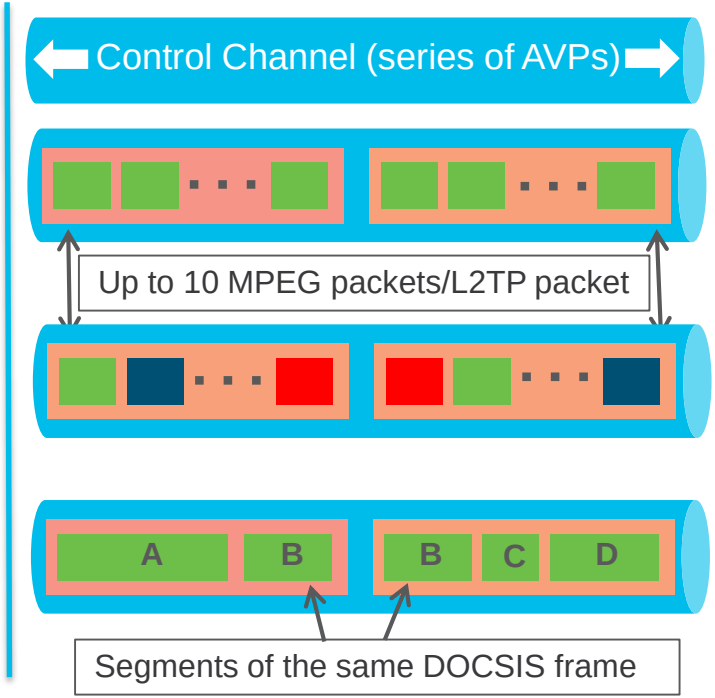
DS MAC

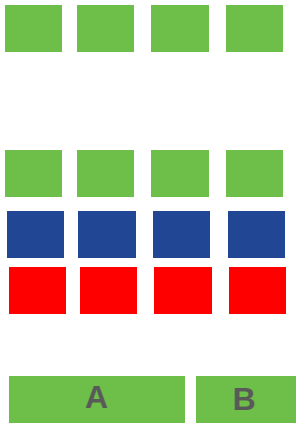
DS PHY

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

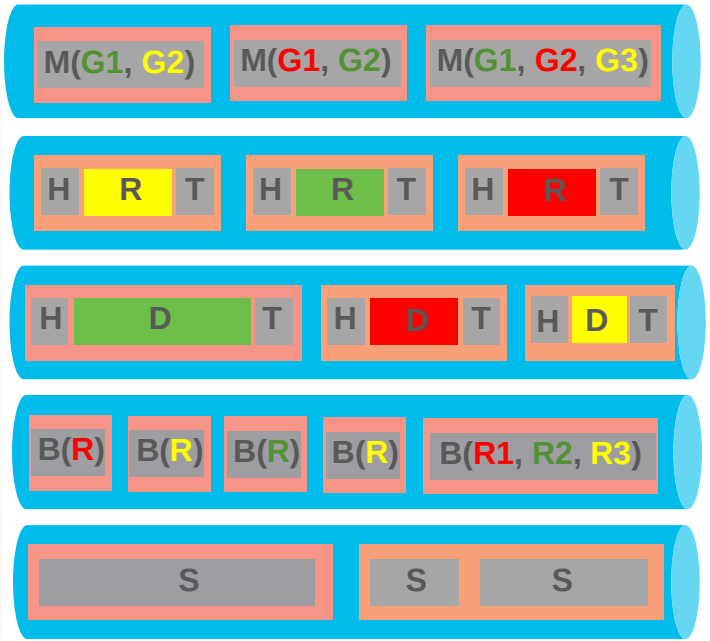
Upstream External PHY Interface (UEPI)

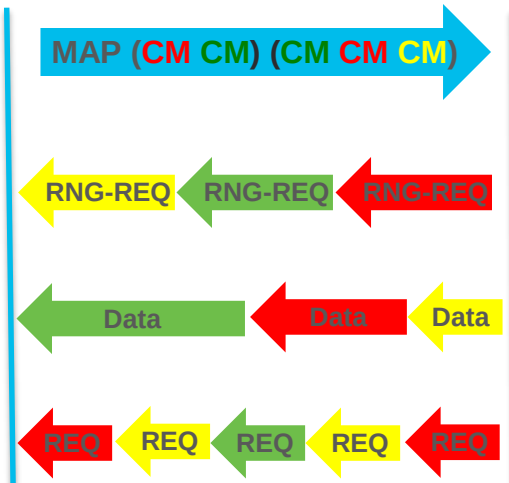
US MAC

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





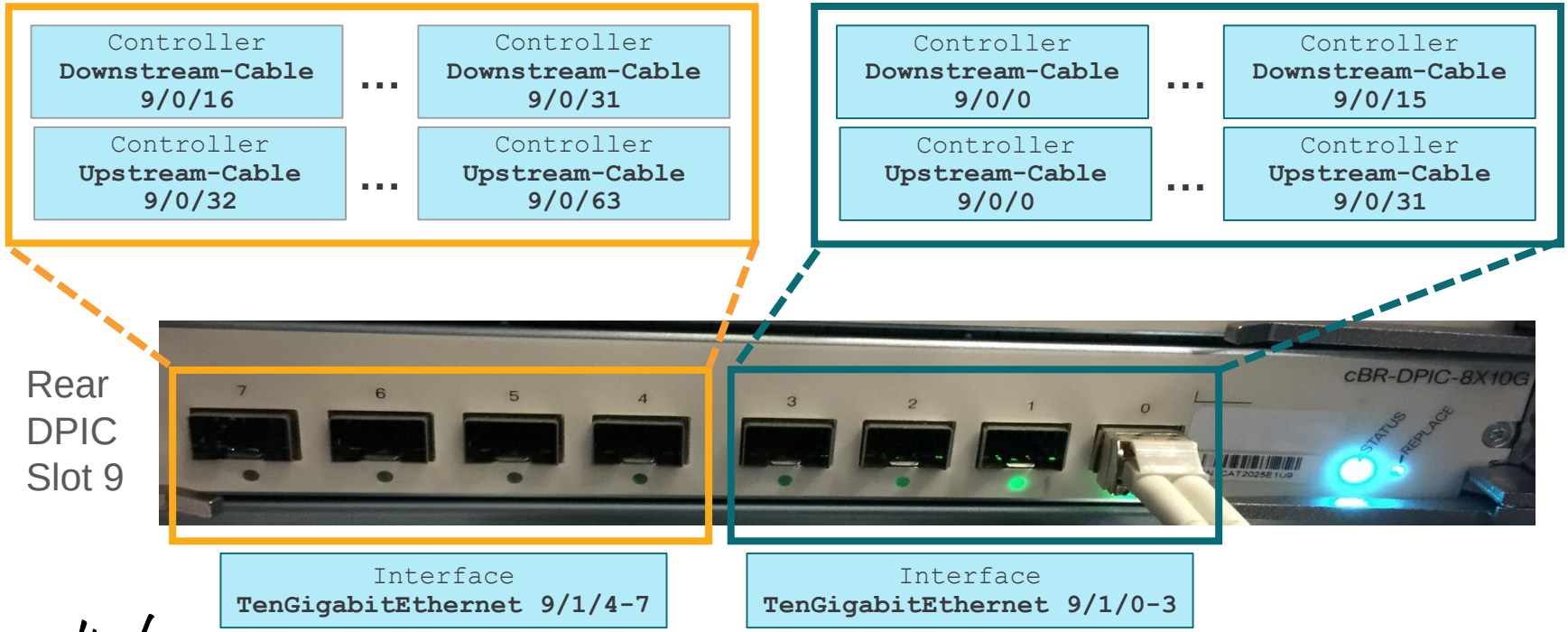
Contains data from RPD's Spectrum Management function

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

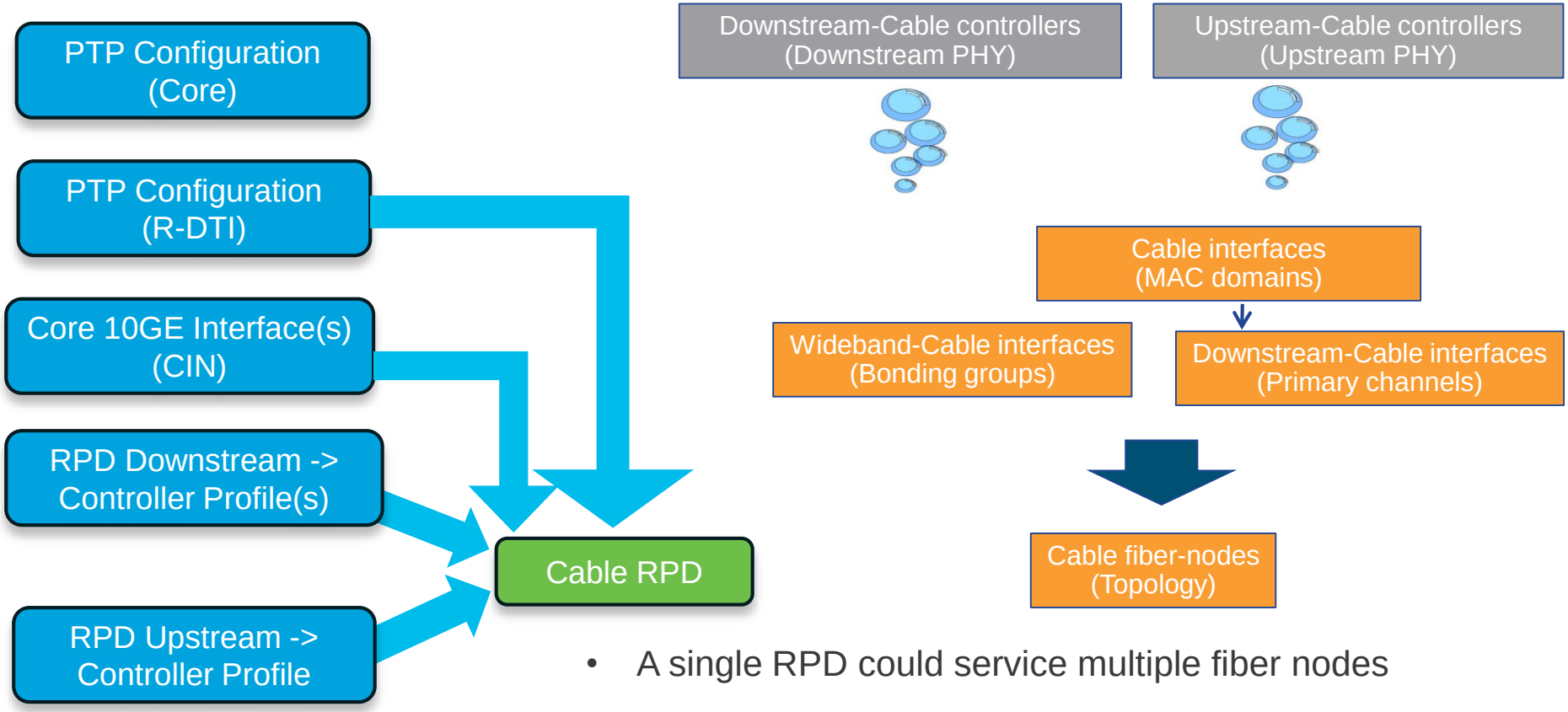
OOB also use UEPI PWs

R-PHY Controllers & PIC Ports

- Note: On 16.5.x/16.6.x SW limited to 8 DOCSIS Service Groups & 32 RPDs per LC



R-PHY Configuration Flowchart



- A single RPD could service multiple fiber nodes

PTP 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 ..” config 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
```

- Ensure the domain number matches with the cBR-8 PTP configuration
- Clock port “1” refers to the 1st 10GE interface on the RPD
- If the clock is connected via an L2 CIN specify the gateway option with the clock source configuration line

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
```

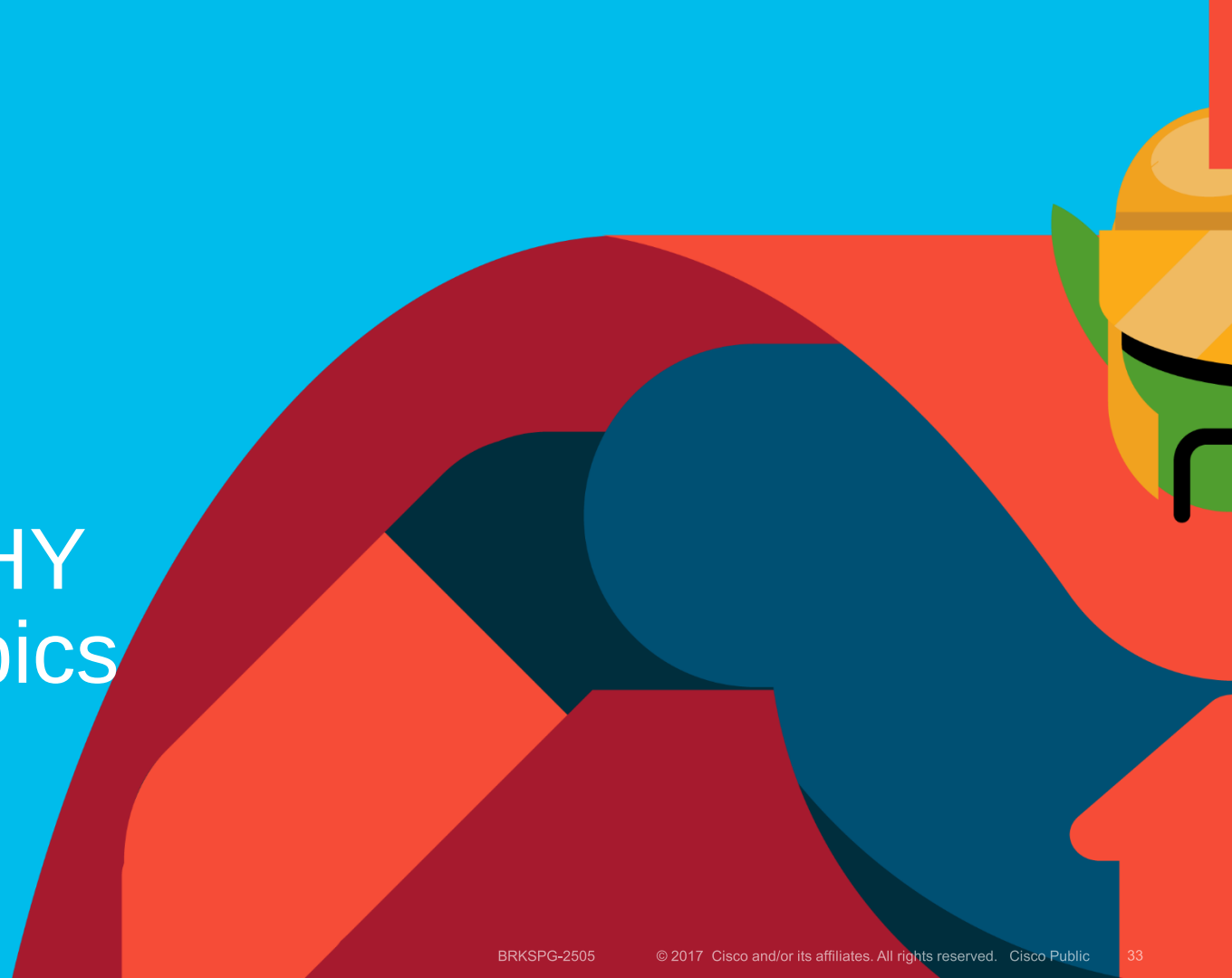
RPD Configuration

```
cable rpd RPD_1
 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
 identifier 0000.abcd.5678
 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
- 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
- Event profile defines how the RPD reports logging events (e.g. locally, to the CCAP core, both) for various priority levels

Advanced Remote PHY Design Topics



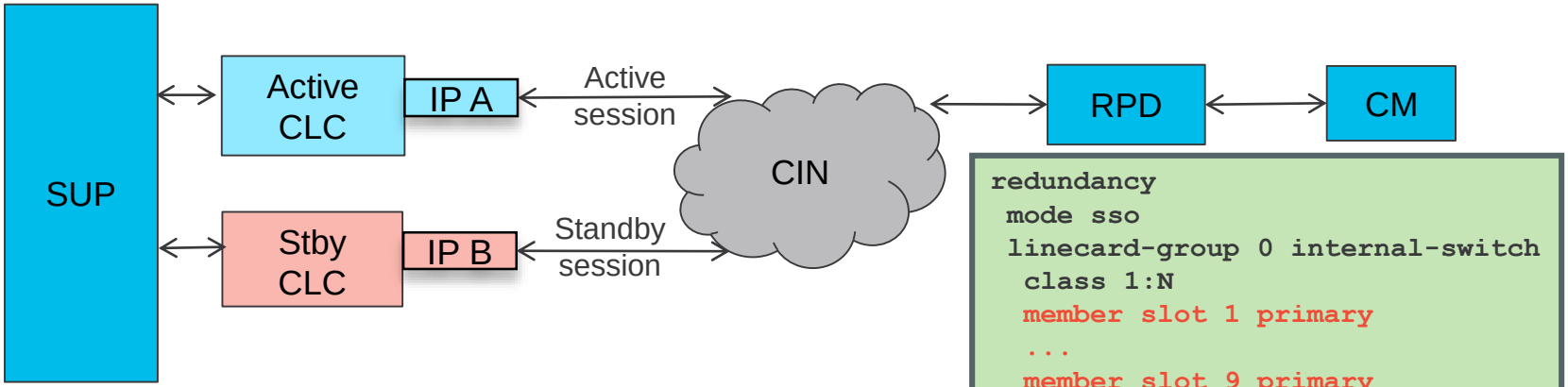
DOCSIS 3.1

- 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
- 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)

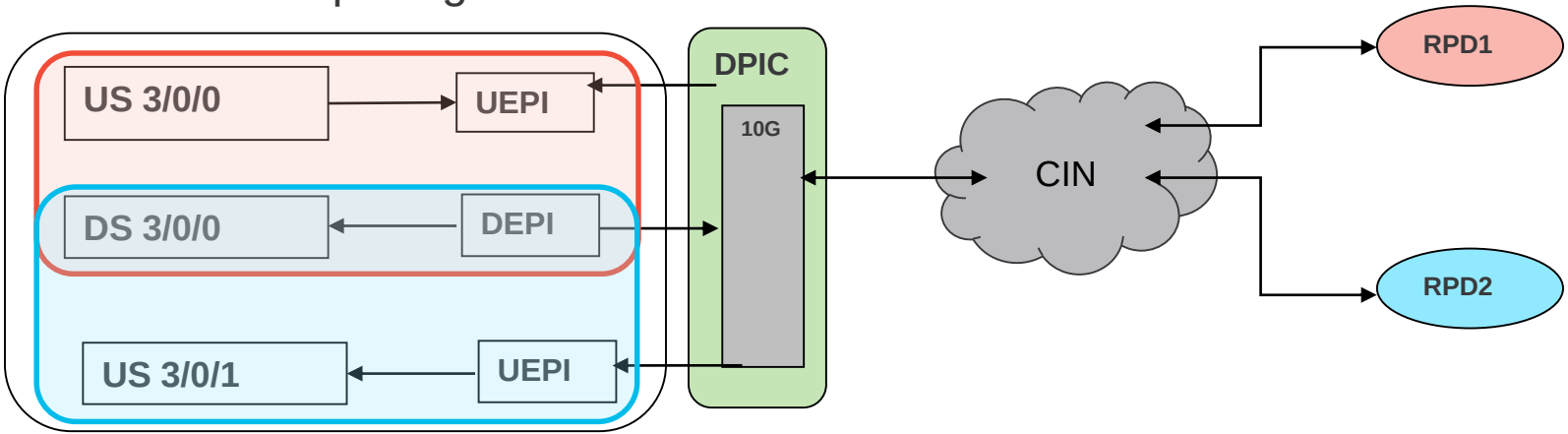
- Supervisor HA
  - RPDs detect the loss of GCP keep-alives and re-establish connections
- Line Card HA
  - RPDs connect to both the active LC and standby LC DPICs
  - Establish “active” and “standby” GCP and DEPI/UEPI sessions
  - **Core** signals the RPD to switch-over its active connection




```
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 SC-QAM & 16 OFDM DS channels per line card
- Solution: DS Splitting via Multicast DEPI



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 snooping to be enabled

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

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
```

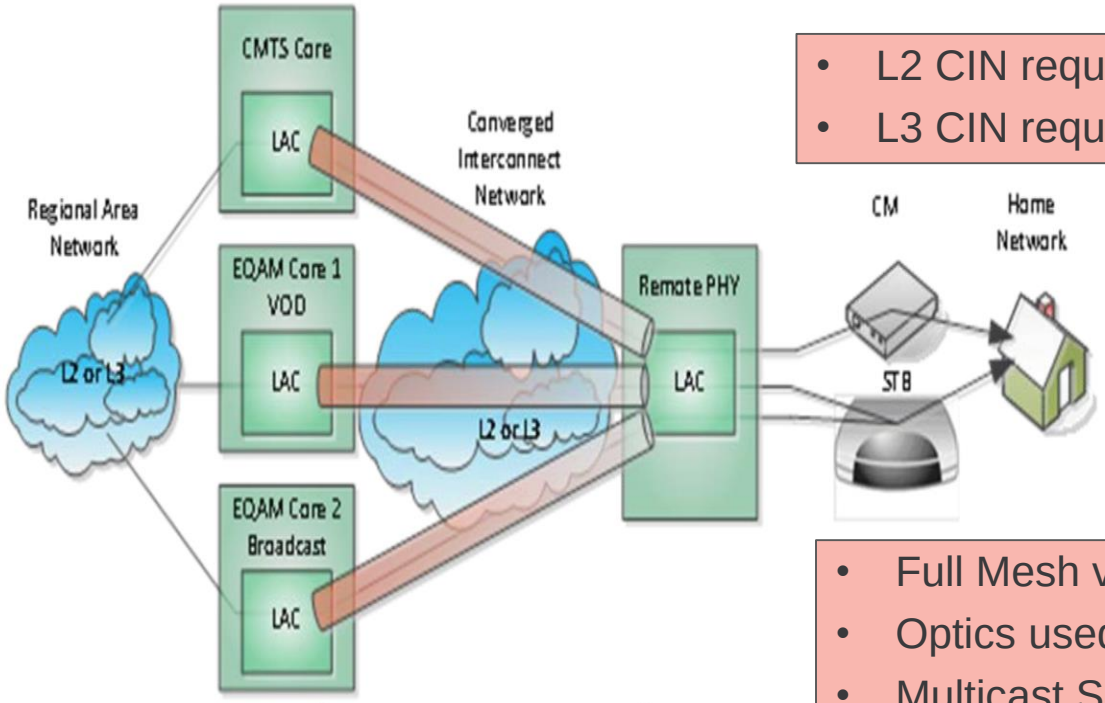
Configure RPDs with auxiliary core(s) for video

```
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
 ...
```

R-PHY Converged Interconnect Network (CIN)

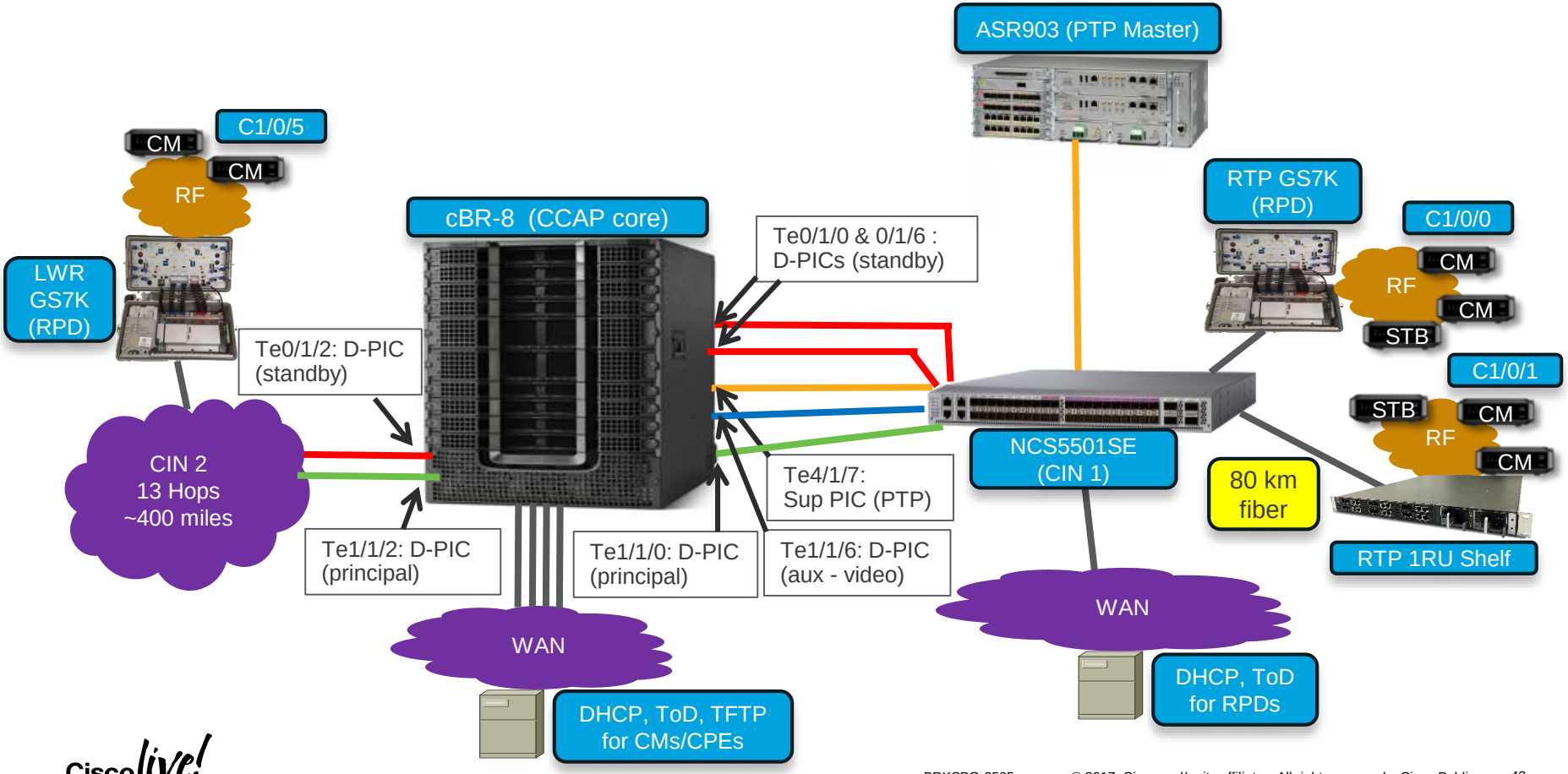


- L2 CIN requires common subnet across cores
- L3 CIN requires routing from each core to RPD

- Full Mesh versus Partial Mesh?
- Optics used in CIN? CIN Provisioning?
- Multicast Support? IPv6?
- PTP Support? CIN support for 802.1x? MACsec?

Remote PHY Demo

R-PHY Demo Topology



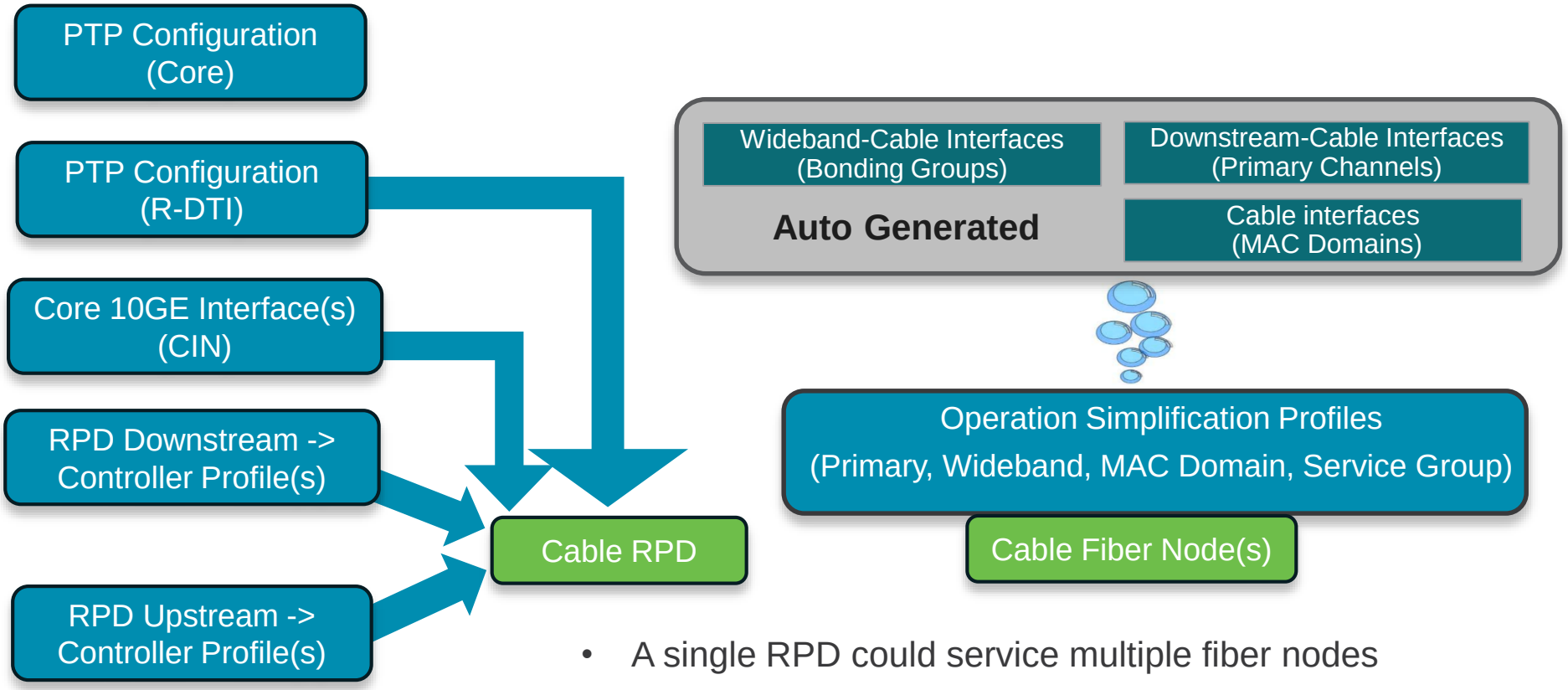
Secure Software Download (SSD)

- 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]
```

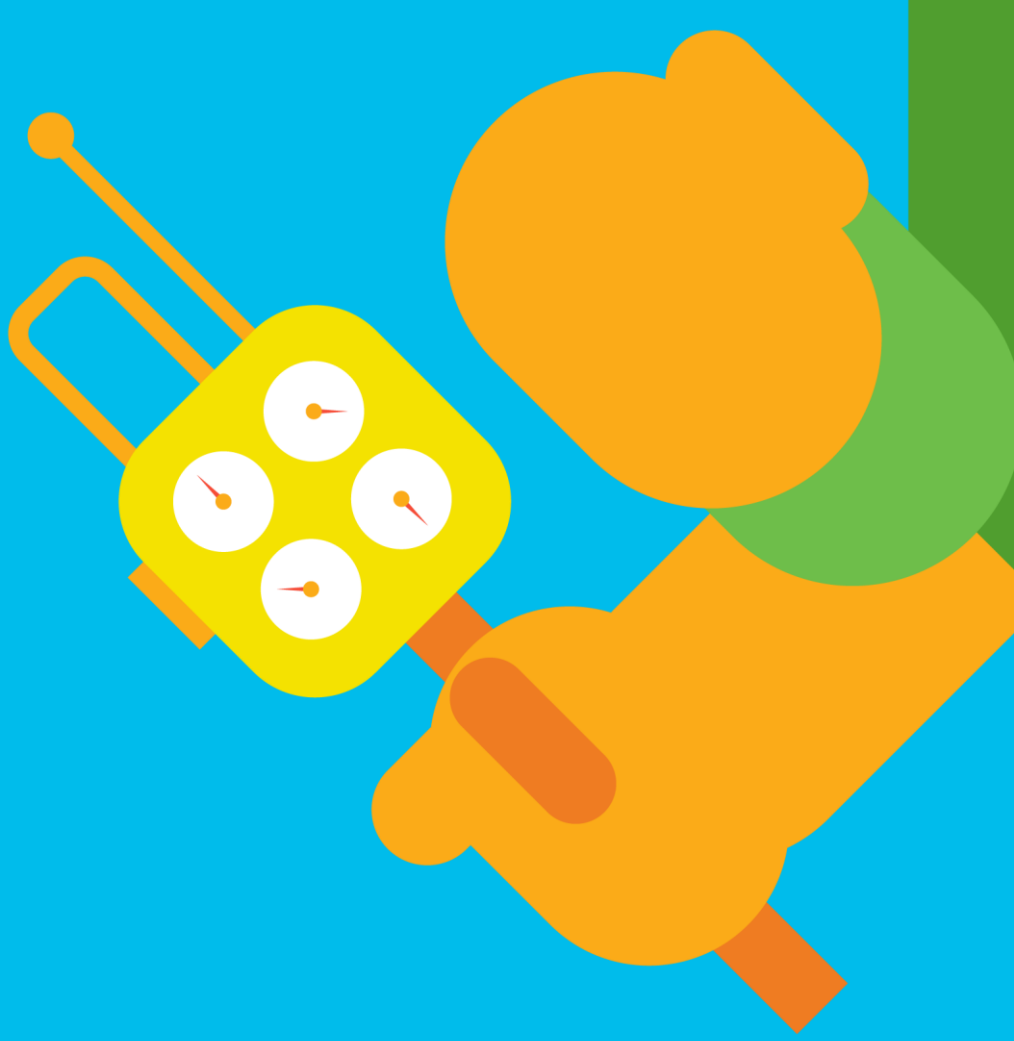
- Useful commands for troubleshooting include **`show cable rpd {RPD IP|RPD MAC} event`** and **`cable rpd {all|MAC|IP} ssd status`**

R-PHY Configuration with OpSimp Flowchart



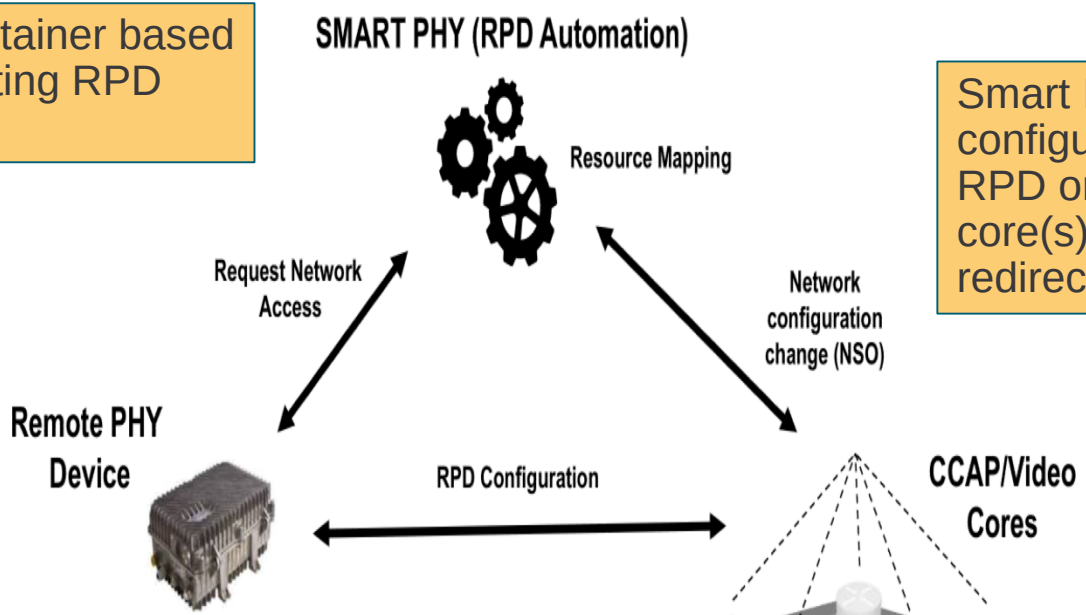
- A single RPD could service multiple fiber nodes

RPD Automation (Smart PHY)



RPD Deployment Automation with Smart PHY

Smart PHY is a container based solution for automating RPD deployment

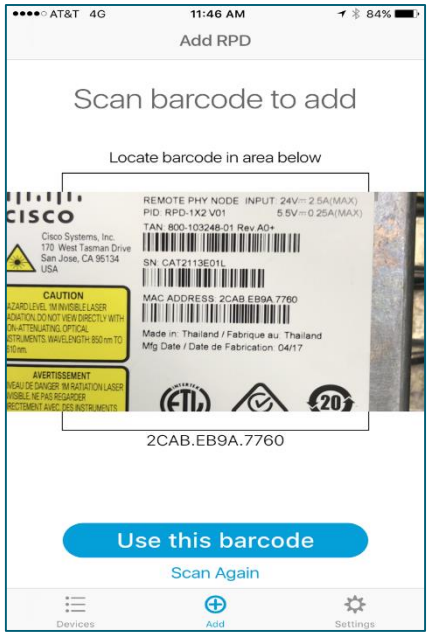


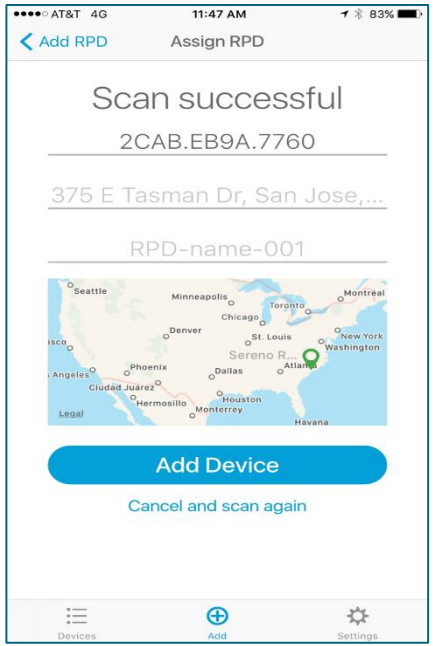
Smart PHY then configures the RPD on the CCAP core(s) and redirects the RPD

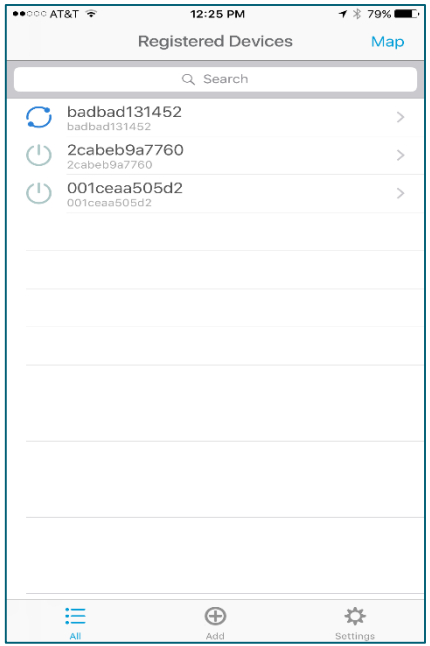
RPDs contact Smart PHY on initialization simplifying DHCP server provisioning

Potentially 100s to 1000s of RPDs need to be provisioned with CCAP core IPs in a full deployment

Smart Phone App to ease device inventory





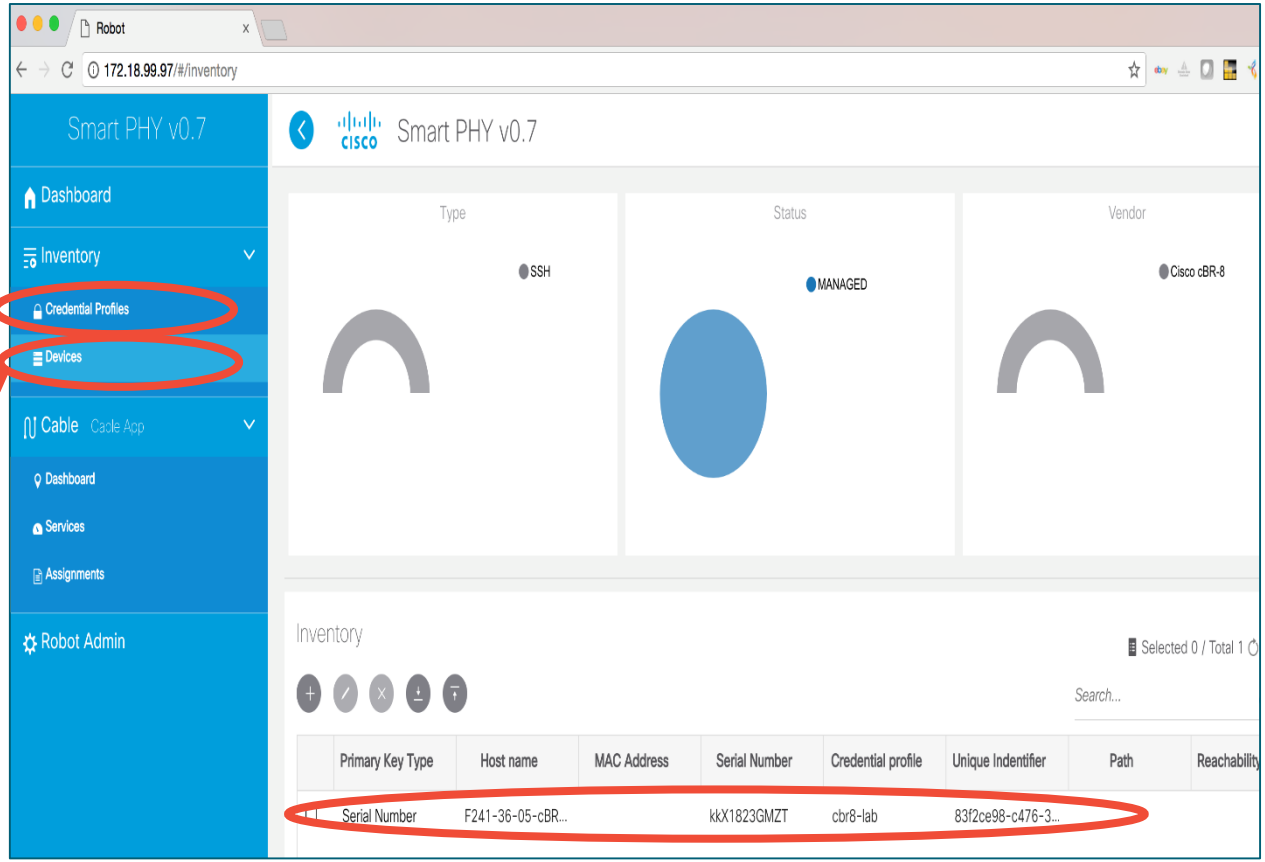


- RPD bar codes can be scanned via the Smart Phone App to automatically add the RPDs to the Smart PHY inventory
- Can also include the phone's GPS coordinates to automatically populate the RPD's location

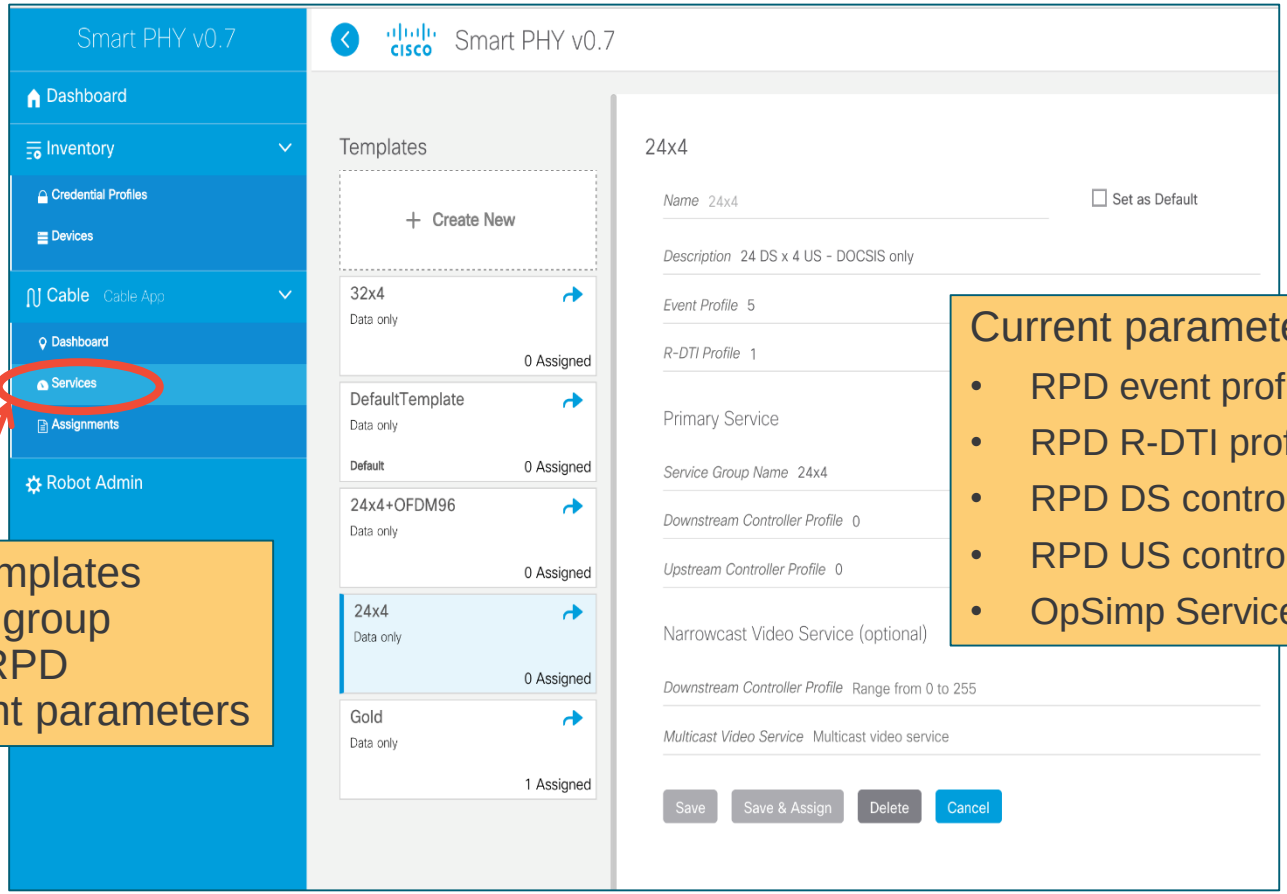
Smart PHY WebUI

Credential Profiles defined for CCAP core access information

CCAP cores can be imported via CSV file or manually added to Smart PHY inventory



Smart PHY WebUI

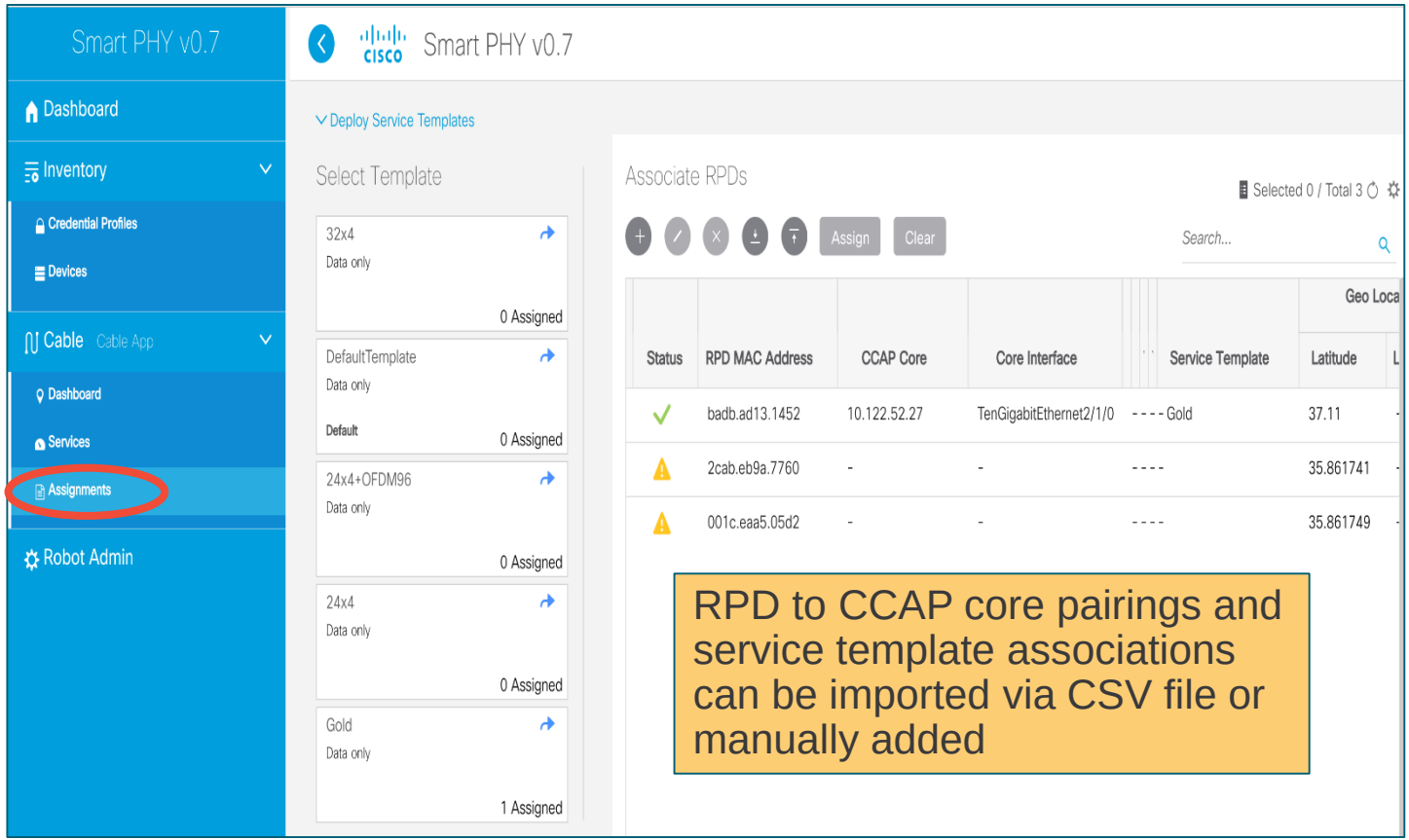


Service templates defined to group common RPD deployment parameters

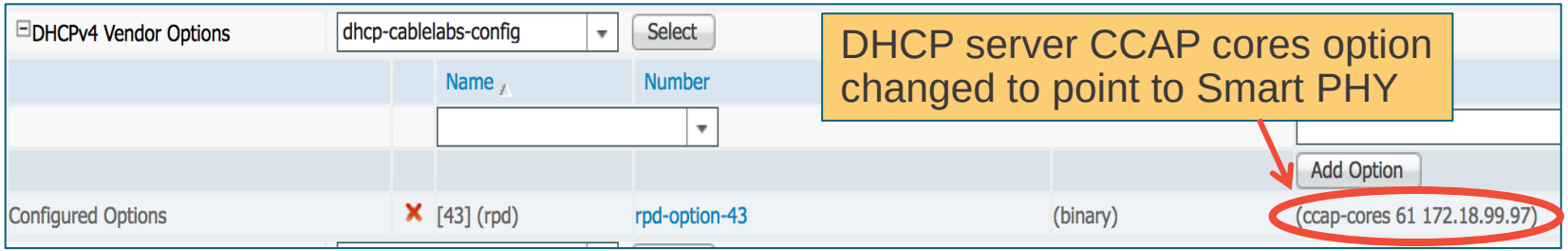
Current parameters include:

- RPD event profile
- RPD R-DTI profile
- RPD DS controller profile(s)
- RPD US controller profile
- OpSimp Service Group profile

Smart PHY WebUI



RPD Initialization with Smart PHY



DHCP server CCAP cores option changed to point to 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

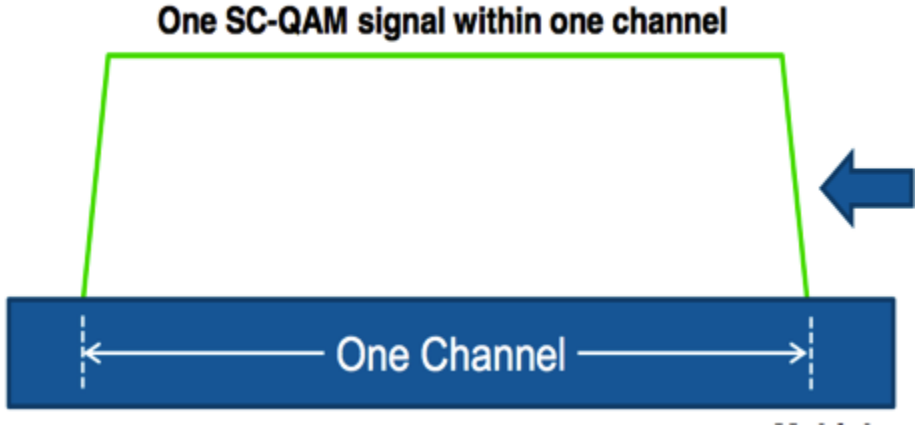
```
R-PHY#show provision all
ID                Interface  IP             Name      State       Role       HA-Mode  Initiated-By
CORE-1230641727   vbh0       13.13.0.238    CCAPCORE  init(gcp)   Principal  Active   GCP_Redirect
```

DOCSIS 3.1 Basics & Configuration

Why DOCSIS 3.1?

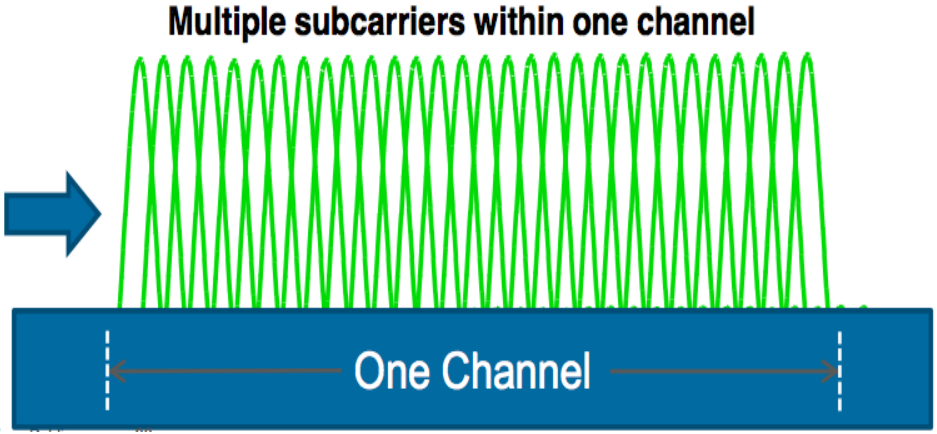
- Goals
  - D3.1 enables services competitive with FTTH
  - Achieve 8+ Gbps in the DS
  - Achieve 1+ Gbps in the US
  - Better spectral efficiency
  - Backwards compatible with DOCSIS 3.0, 2.0, & 1.1
  - Will work without changes to HFC
- Technology
  - OFDM, OFDMA, LDPC
  - New DS and US spectrum
    - ✓Up to 1.218 GHz for the DS
    - ✓Up to 204 MHz for the US

Orthogonal Frequency Division Multiplexing

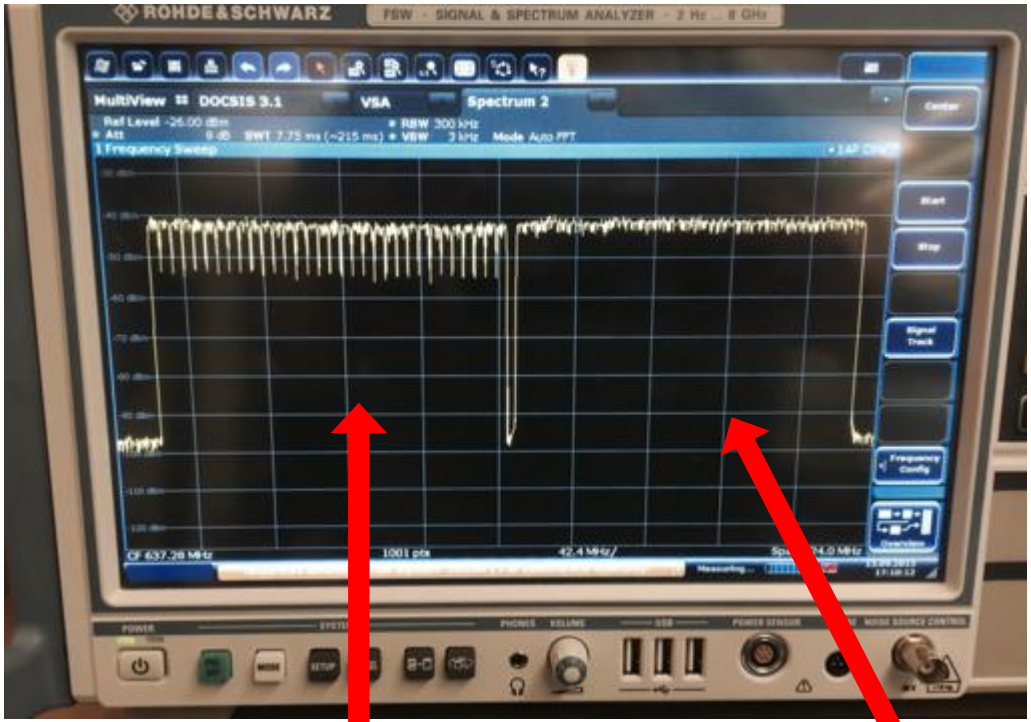


- 6 MHz / 8 MHz wide downstream channel slots can each accommodate one SC-QAM signal
- Symbols sent sequentially at fast symbol rate

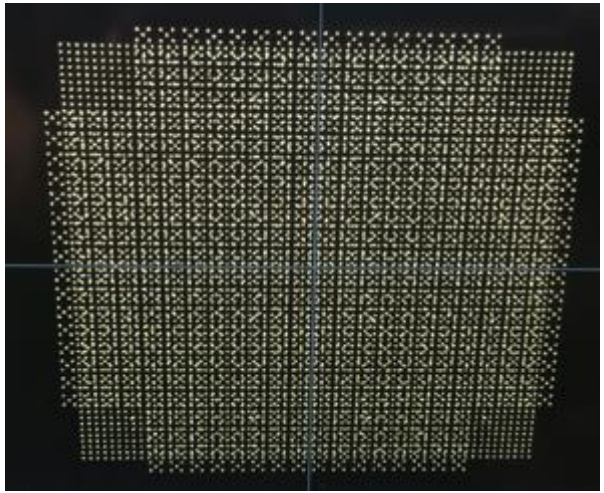
- Imagine transmitting a large number of individual very narrow-bandwidth QAM signals – hundreds or even thousands – within a single channel
- Each narrow-bandwidth QAM signal is called a subcarrier
- Symbols sent in parallel at slow symbol rate



DOCSIS 3.1 OFDM Fundamentals



DOCSIS 3.1 devices can make use of SC-QAMs (32 6-MHz chs pictured)



Increased Orders of Modulation 1024, 2048, 4096 QAM

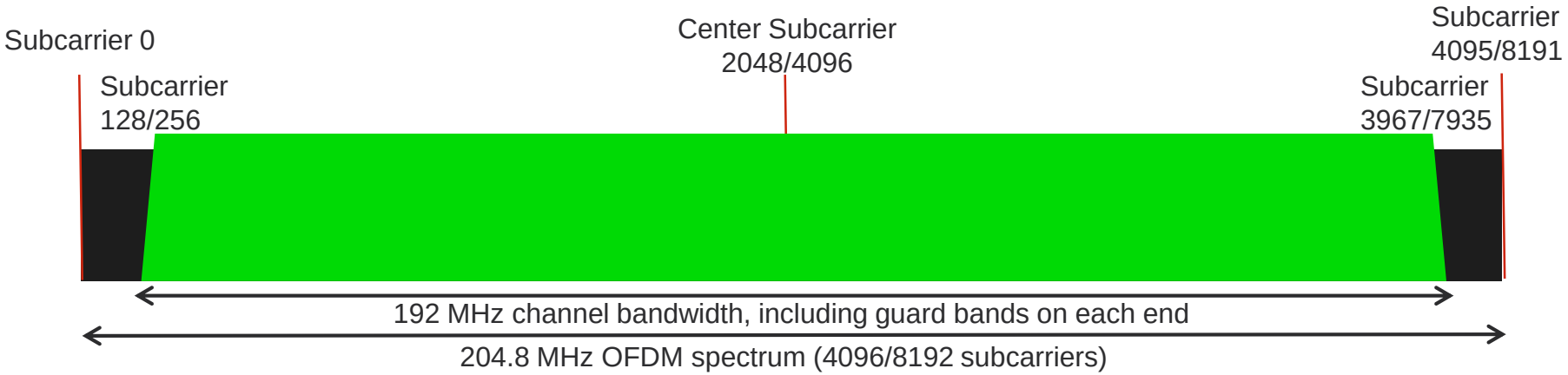
Modulation can vary by subcarrier

Modulation can vary by modem

While also using more spectrum efficient OFDM channel (192 MHz ch pictured)

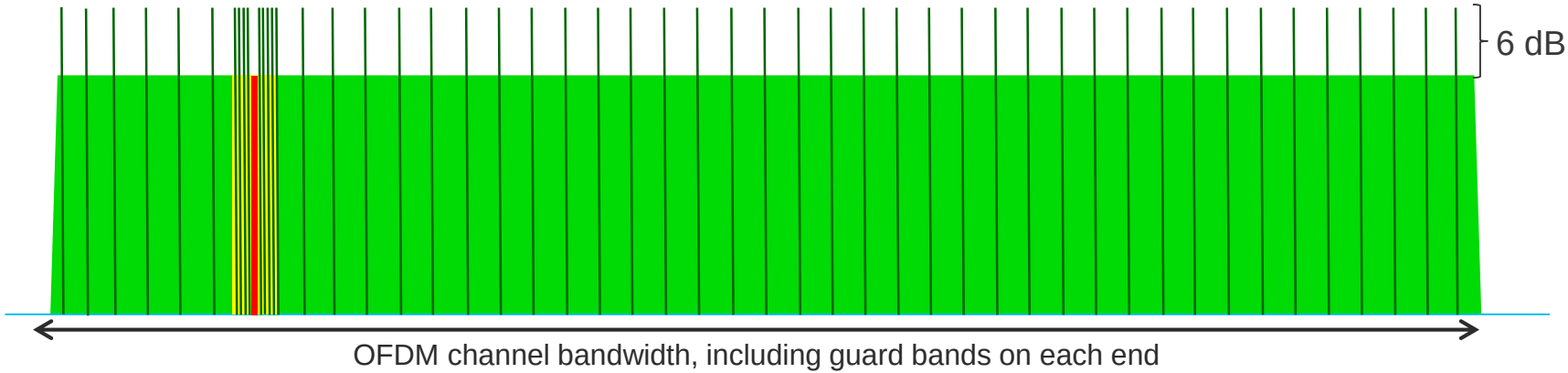
OFDM Basics & Fast Fourier Transforms (FFT)

- Fast Fourier Transform size is either 4096 subcarriers if using 50 kHz spacing or 8192 subcarriers if using 25 kHz spacing
- OFDM FFT spectrum size is number of subcarriers times subcarrier size; thus it is ALWAYS 204.8 MHz (4096 * 50 kHz or 8192 * 25 kHz)
- The OFDM channel width will be at most 192 MHz; subcarriers outside the channel width are nulled just like guard bands and exclusion bands



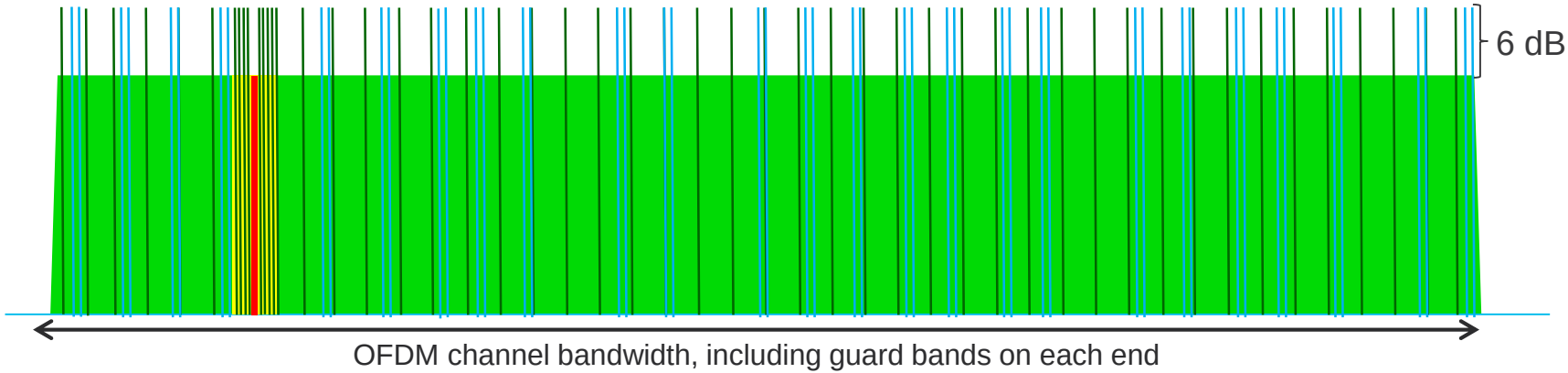
Continuous Pilots

- Used for receiver synchronization and to identify Physical Layer Link Channel (PLC) location; occur at same frequency/subcarrier locations every signal
- BPSK modulated; 6 dB higher than other subcarriers / carry no data
- Number of continuous pilots configurable
  (scale 48 – 120 relative to 192 MHz channel; plus another 8 for PLC)



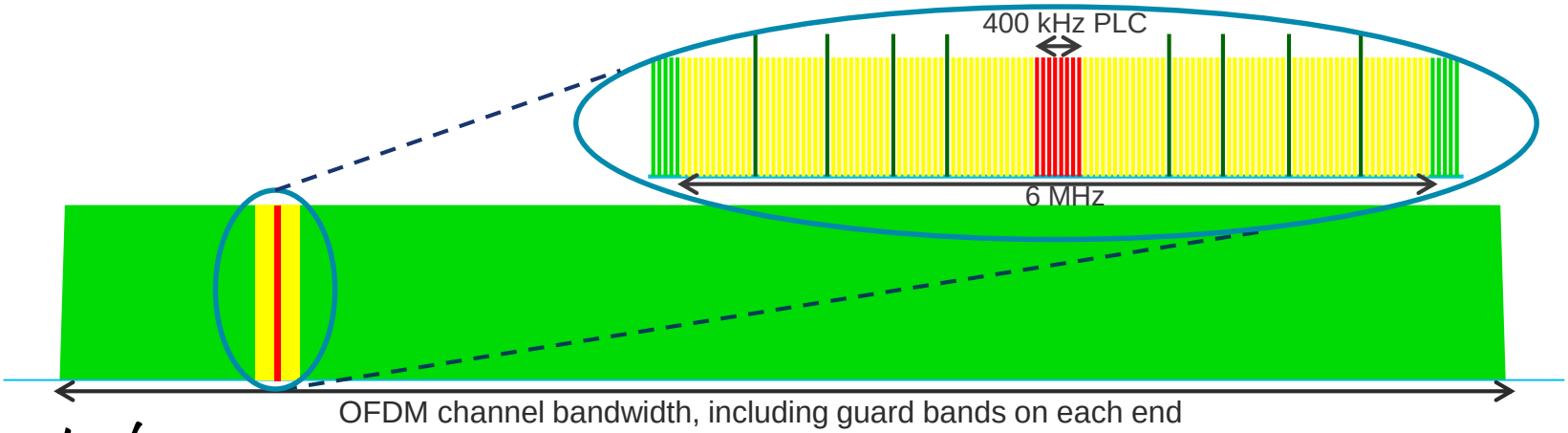
Scattered Pilots

- Location changes with each signal but pattern repeats every 128 symbols; covers all active subcarrier locations
- Used for channel estimation (RxMER/subcarrier measurements)
- BPSK modulated; 6 dB higher than other subcarriers / carry no data



PHY Link Channel (PLC)

- 400 kHz signalling channel centered within a 6 MHz band located in “clean” part of OFDM spectrum
- 128 symbols (8 preamble (BPSK) & 120 data (16-QAM))
  – Same subcarriers for every OFDM symbol
- Receiver first acquires the PLC (based on continuous pilot pattern) and from there gets the parameters to acquire the main channel



PLC Message Channel Block

- Out-of-band signaling channel from CMTS to CMs; used by booting CMs
- Same MMM format and addressing rules as data channel

OFDM Channel Descriptor (OCD)

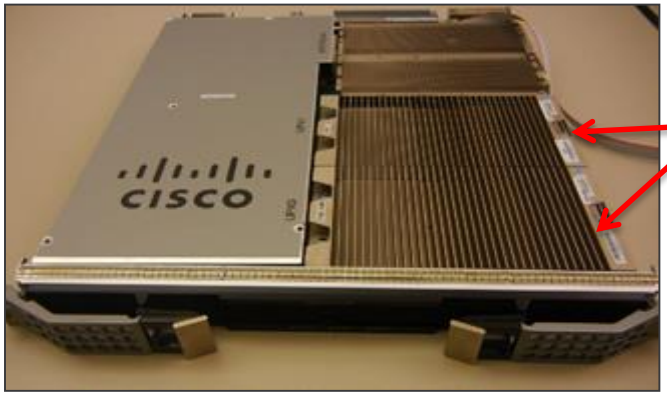
- Static variables that require reboot to change
- Sub-carrier spacing, cyclic prefix, roll-off, subcarrier 0 frequency, interleaver depth
- List/range/vector for excluded SC, continuous pilots, PLC location
- Primary capable indicator

Downstream Profile Descriptor (DPD)

- Dynamic variables that change on the fly
- Profile ‘A’ (profile ID ‘0’) DPD and NCP (profile ID ‘255’) DPD
- List/range/vector for bit loading

DOCSIS 3.1 DS on the cBR-8

- Ensure using supported SW (>= 3.18SP) & HW (D31-DS-MOD) & FW



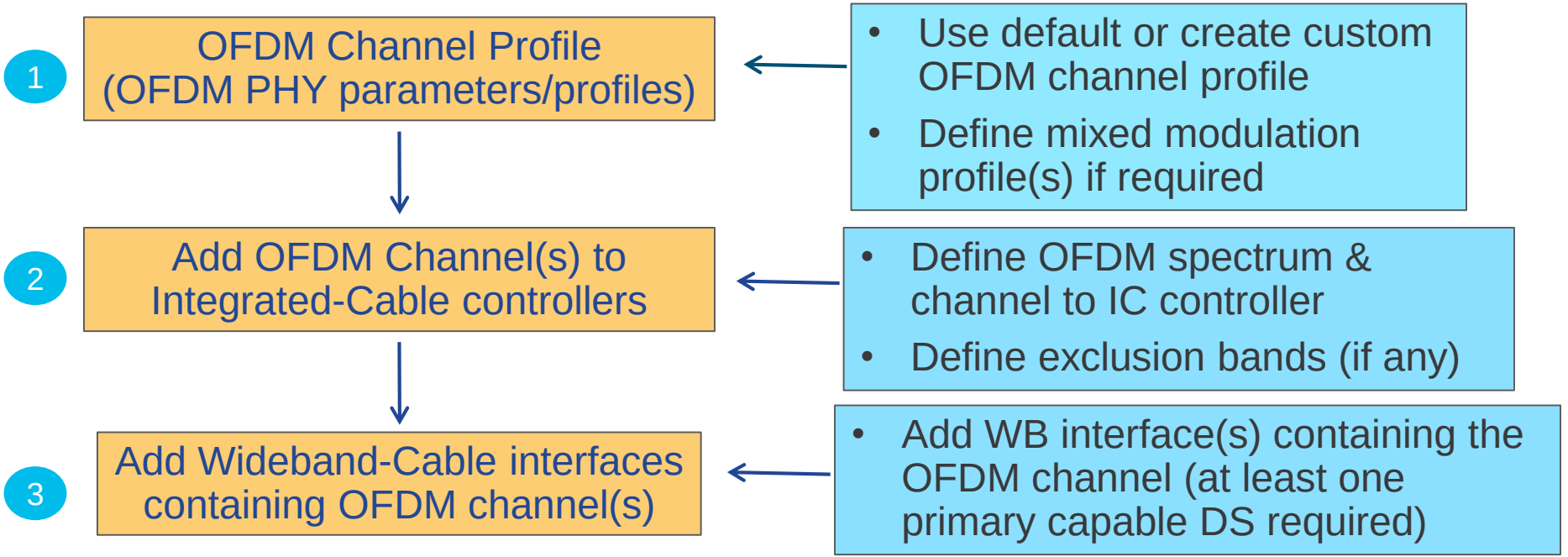

```
cbr8#show inventory
NAME: "CLC Downstream PHY Module 3/0", DESCR:
"Cable PHY Module"
PID: CBR-D31-DS-MOD    , VID: V01 , SN: CAT1915E0F4

NAME: "CLC Downstream PHY Module 3/1", DESCR:
"Cable PHY Module"
PID: CBR-D31-DS-MOD    , VID: V01 , SN: CAT1915E0E1
```

```
cbr8#sh cable card 3/0 ds-phy display | i micro ver
micro ver 30019, sector(1 base) 2, apollo ver 4484b, sector(0 base) 2
micro ver 30019, sector(1 base) 2, apollo ver 4484b, sector(0 base) 2
```

To upgrade: **`upgrade hw-programmable cable <> dsphy auto pkg_name <>`**

To activate new FW: **`hw-module slot <> reload`**

DOCSIS 3.1 DS Configuration Flowchart



Note: OFDM channels can NOT be primary capable until 16.5.1; support for 2 OFDM channels per port starts with 16.6.1.

1 OFDM Channel Profiles

```
cable downstream ofdm-chan-profile 102
  cyclic-prefix 192
  interleaver-depth 16
  pilot-scaling 48
  roll-off 128
  subcarrier-spacing 25KHZ
  profile-control modulation-default 256-QAM
  profile-ncp modulation-default 64-QAM
  profile-data 1 modulation-default 1024-QAM
  profile-data 2 modulation-default 2048-QAM
  profile-data 3 modulation-default 4096-QAM
```

Values 0-19 reserved; 20-255 configurable

Control profile is also referred to as Profile 0 or Profile A
Used for MAC Management and for data if no data profiles defined
Also used for data prior to any RxMER info being received

Up to 5 data profiles can be defined
Profiles 1(B), 2(C), 3(D), 4(E), & 5(F)
CMTS can promote modems to these profiles based on RxMER or can be statically assigned via CLI

*** Red font indicates non-default values

RxMER to Bit Loading Mapping

DOCSIS 3.1 PHY Spec – Table 7-41

RxMER (in ¼ dB)	RxMER (in dB)	QAM	Bit Loading
60	15	16	4
84	21	64	6
96	24	128	7
108	27	256	8
122	30.5	512	9
136	34	1024	10
148	37	2048	11
164	41	4096	12
184	46	8192	13
208	51	16384	14

Note: On cBR-8 use the CLI: **`show cable ofdm-rxmer-qam-bl-table`**

1 OFDM Mixed Modulation Profiles

```
cable downstream ofdm-chan-profile 100
  <snip>
  profile-data 1 modulation-profile 96
```

- Can be used for control or data profiles
- Each supports up to 5 ranges
- Define absolute or relative frequencies

```
cable downstream ofdm-modulation-profile 96
  subcarrier-spacing 50KHZ
  width 96000000
  start-freq 642000000
  assign modulation-default 1024-QAM
  assign modulation 512-QAM range-subcarriers freq-abs 724050000 width 12000000
  assign modulation 4096-QAM range-subcarriers freq-abs 644000000 width 70000000
```

2 Integrated Cable Controller - OFDM

```
controller Integrated-Cable 3/0/0
 max-ofdm-spectrum 96000000
 max-carrier 32
 base-channel-power 34
 rf-chan 0 23
  type DOCSIS
  frequency 591000000
  rf-output NORMAL
  power-adjust 0
  qam-profile 1
  docsis-channel-id 1
 rf-chan 158
  power-adjust 0.0
  power-profile <>
  docsis-channel-id 159
  ofdm channel-profile 102 start-frequency
732000000 width 96000000 plc 734000000
```

Combination of **max-ofdm-spectrum** and **max-carrier** values determine **base-channel-power** range

RF channel numbers 0-157 reserved for SC-QAMs; OFDM starts with 158

Use either **power-adjust** or **power-profile**
power-profile is a new CLI with 16.5.1
Enables tilt to be defined across the OFDM channel

OFDM channel width from 24 – 192 MHz
By default PLC put in the middle of the active spectrum but can be specified explicitly

Max Carrier/OFDM to Base Channel Power

Example Supported Ranges in dBmV

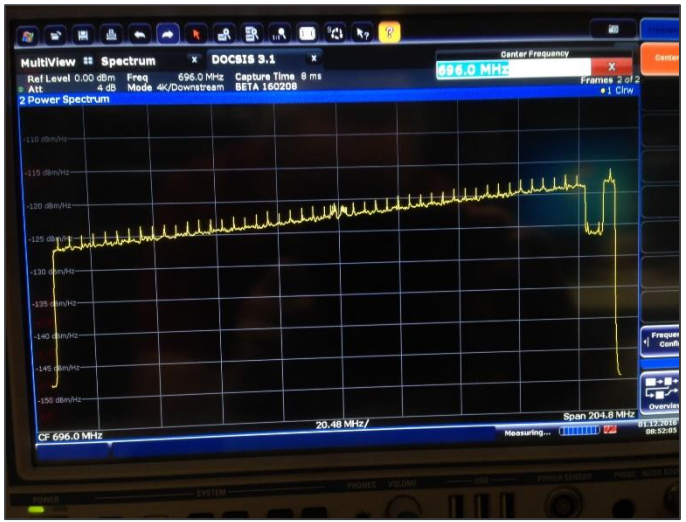
Max Carrier	No OFDM	24 MHz OFDM	48 MHz OFDM	96 MHz OFDM	144 MHz OFDM	192 MHz OFDM	384 MHz OFDM
8	**41 – 50**	39 – 48	37 – 46	35 – 44	34 - 43	32 – 41	29 – 38
16	**37 – 46**	36 – 45	35 – 44	34 – 43	32 - 41	31 – 40	29 – 38
24	**35 – 44**	34 – 43	34 – 43	32 – 41	31 - 40	31 – 40	28 – 37
32	**34 – 43**	33 – 42	32 – 41	31 – 40	31 - 40	30 – 39	28 – 37
48	**31 – 40**	31 – 40	31 – 40	30 – 39	29 - 38	29 – 38	27 – 36
64	**30 - 39**	30 – 39	29 – 38	29 – 38	28 - 37	28 – 37	26 – 35
96	**28 – 37**	28 – 37	27 – 36	27 – 36	27 - 36	26 – 35	25 – 34
128	**26 – 35**	26 – 35	26 – 35	26 – 35	25 - 34	25 – 34	24 – 33
158	**25 – 34**	25 – 34	25 – 34	25 – 34	24 - 33	24 – 33	- NA -

Note: Base Channel Power Range maximum value is 1 dB above DOCSIS DRFI specification

2 OFDM Power Profile

- Channel Power Profile and Power Adjust configurations mutually exclusive
- Common Power Profile can be applied to multiple OFDM channels
- Power Adjust levels can be set on individual 6 MHz bands in the OFDM channel
- Power Tilt can be defined across the channel

```
cable downstream ofdm-power-profile 1
  ofdm-channel-width 192000000
  power-adjust-default -4.0
  power-tilt-linear 8.0
  band-index 30
    power-adjust -4.0
```



2 Integrated Cable Controller - Exclusion Bands

- Excluded subcarriers are forced to zero modulation at transmitter
  - Used to prevent interference from other transmissions that occupy the same spectrum.
  - Subcarriers also excluded outside the active OFDM bandwidth
- Excluded subcarriers are common to all profiles
- Minimum size is 1 MHz and require a minimum guard band of 1 MHz on each edge if excluding a SC-QAM channel (e.g. for 1 channel needs to be 10 MHz)

```
controller Integrated-Cable 3/0/0
 max-ofdm-spectrum 96000000
 max-carrier 32
 base-channel-power 39
 ofdm-freq-excl-band start-frequency 777000000 width 26000000
```

…

3 Wideband-Cable Interface Configuration

- Wideband-Cable interface configuration consists of the OFDM channel(s) and typically some number of SC-QAM channels
  - At least one primary capable channel MUST be included in the Wideband-Cable interface configuration

```
interface Wideband-Cable3/0/0:11
 description 24 CH DS + OFDM BG #1
 cable bundle 10
 cable rf-channels channel-list 0-23 158 bandwidth-percent 1
```

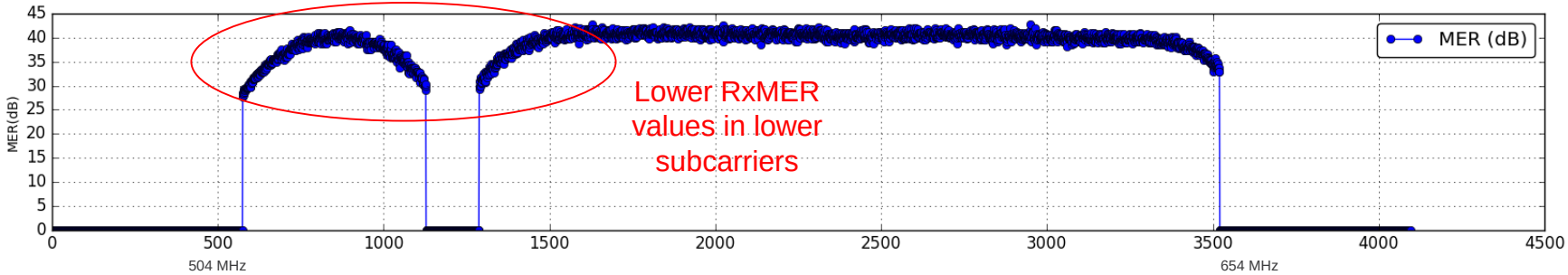
- As of 16.6.1 DS resiliency is supported for D3.1 modems; new trigger option for OFDM (optional) else requires same configuration steps as D3.0 DS resiliency

```
cable ofdm-rf-change-trigger percent 70 count 10
cable resiliency ds-bonding
interface Wideband-Cable3/0/0:63
 cable ds-resiliency
```

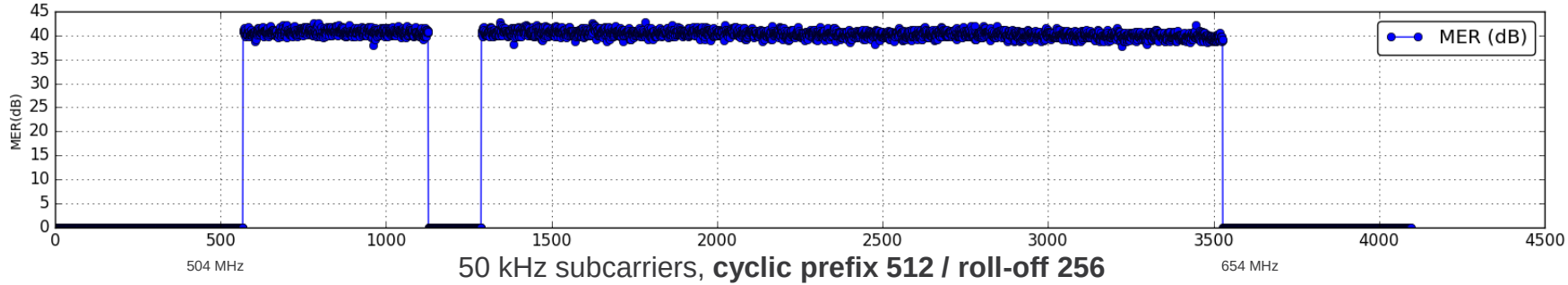
DOCSIS 3.1 Operation

Cyclic Prefix Impact

150 MHz OFDM channel 504 MHz – 654 MHz with node plus 5 amplifiers



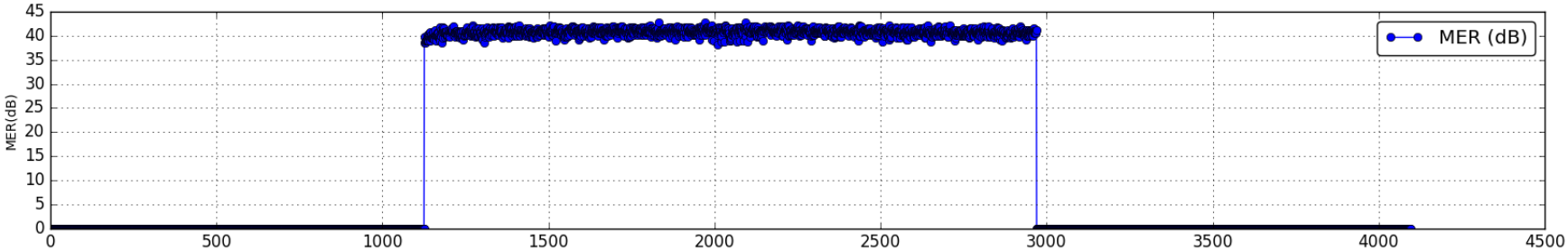
50 kHz subcarriers, **cyclic prefix 192 / roll-off 128**
Channel speed 1342 Mbps @ 4096-QAM (1230 Mbps @ 2048-QAM)



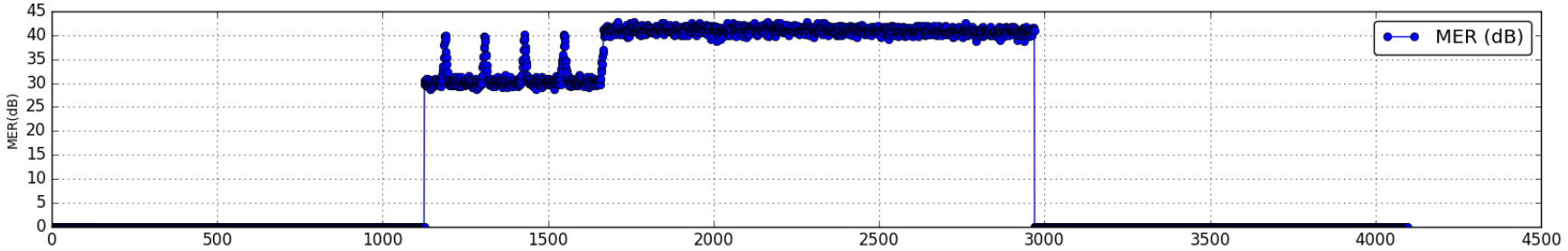
50 kHz subcarriers, **cyclic prefix 512 / roll-off 256**
Channel speed 1265 Mbps @ 4096-QAM

DOCSIS 3.1 More Robust To Impairment

LDPC and frequency interleaving in D3.1 makes channel very robust to impairments



96 MHz OFDM channel running 4096-QAM no uncorrectable FEC codewords
(cBR8 would recommend 2048-QAM profile by default)



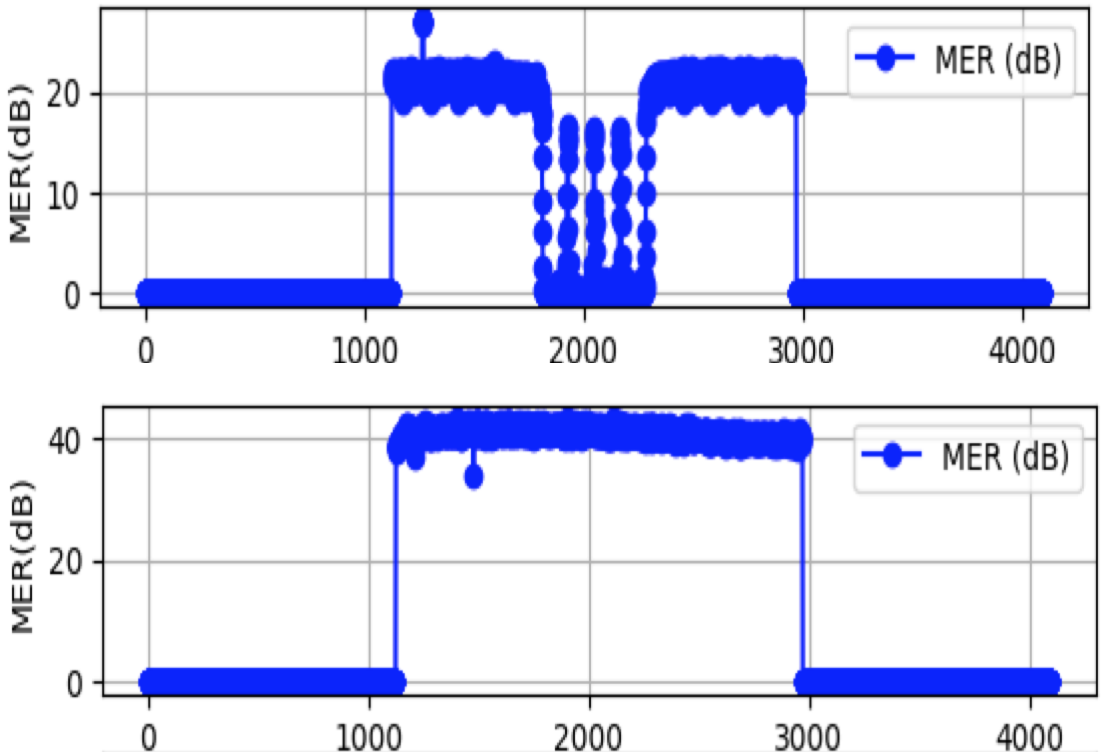
Same 96 MHz OFDM channel (now with 30 MHz interference) still running 4096-QAM no uncorrectable FEC codewords
(cBR8 would recommend 256-QAM profile by default)

Usefulness of RxMER data

RxMER data collection can be very useful in pinpointing plant problems

In this example it was found that some equipment was running tests from over a year ago across 4 channels and was never disabled

In the top diagram you can see the MER for the entire OFDM spectrum is degraded; the bottom diagram shows the spectrum after removing the interfering carriers



OFDM Settings To Maximize Speeds

- **`cyclic-prefix 192`**
  - For larger channels (>= 96 MHz(50), >= 144 (25)) use lowest value (192)
  - For smaller channels (< 96 MHz(50), < 144 (25)) use 256 to allow larger roll-off
- **`pilot-scaling 48`**
  - Keep at lowest setting – default is 48
- **`roll-off 128`**
  - Make as large as possible but must but be less than cyclic prefix value
- **`subcarrier-spacing 25KHZ`**
  - Less overhead for 25 kHz
- **`profile-data 1 modulation-default 1024-QAM`**
  - Make data profile as high as HFC plant will support
- **`profile-ncp modulation-default 64-QAM`**
  - Make NCP as high as plant will support

OFDM Downstream Speed Estimates (50 kHz)

Channels	Spectrum	DOC 3.0 Annex B	DOCSIS 3.1 (50 kHz subcarrier)		
		256 QAM	1024 QAM	2048 QAM	4096 QAM
4 channel	24 MHz	151 Mbps	156 Mbps*	172 Mbps*	187 Mbps*
8 channel	48 MHz	302 Mbps	350 Mbps*	385 Mbps*	420 Mbps*
16 channel	96 MHz	603 Mbps	741 Mbps**	815 Mbps**	889 Mbps**
24 channel	144 MHz	905 Mbps	1135 Mbps**	1248 Mbps**	1362 Mbps**
32 channel	192 MHz	1206 Mbps	1529 Mbps**	1682 Mbps**	1835 Mbps**
64 channel	384 MHz	2412 Mbps	3058 Mbps**	3364 Mbps**	3670 Mbps**

Assumes all subcarriers using same modulation order

* ***50 kHz subcarriers***, *1.350 MHz guard bands, roll-off 192, cyclic prefix 256, NCP (64 QAM)*

** ***50 kHz subcarriers***, *1.900 MHz guard bands, roll-off 128, cyclic prefix 192, NCP (64 QAM)*

OFDM Downstream Speed Estimates (25 kHz)

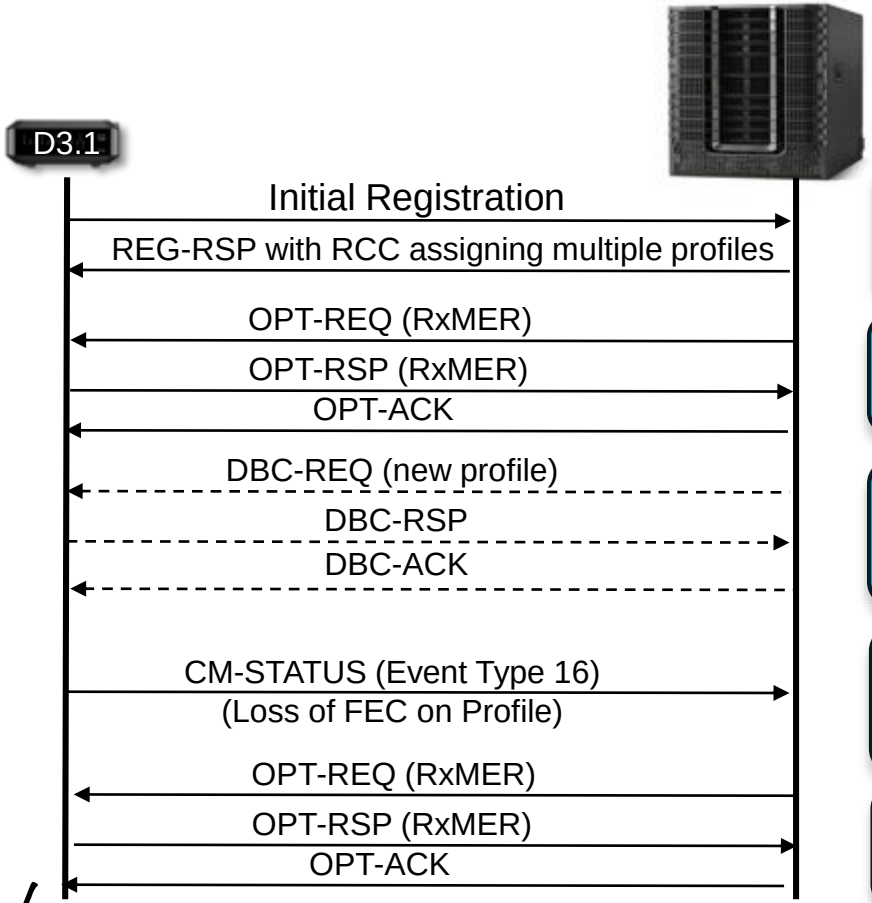
Channels	Spectrum	DOCSIS 3.0	DOCSIS 3.1 (25 kHz subcarrier)		
		256 QAM	1024 QAM	2048 QAM	4096 QAM
4 channel	24 MHz	151 Mbps	172 Mbps*	189 Mbps*	206 Mbps*
8 channel	48 MHz	302 Mbps	373 Mbps*	410 Mbps*	448 Mbps*
16 channel	96 MHz	603 Mbps	776 Mbps*	853 Mbps*	931 Mbps*
24 channel	144 MHz	905 Mbps	1178 Mbps*	1296 Mbps*	1414 Mbps*
32 channel	192 MHz	1206 Mbps	1584 Mbps**	1742 Mbps**	1910 Mbps**
64 channel	2x192 MHz	2412 Mbps	3168Mbps**	3484 Mbps**	3802 Mbps**

Assumes all subcarriers using same modulation order

* ***25 kHz subcarriers***, *1.175 MHz guard bands, roll-off 192, cyclic prefix 256, NCP (64 QAM)*

** ***25 kHz subcarriers***, *1.725 MHz guard bands, roll-off 128, cyclic prefix 192, NCP (64 QAM)*

OFDM Data Profile Assignment Logic



New modem; assign up to 4 data profiles and use the control profile (Profile 0/A) for data for now

Collect RxMER data for all sub-carriers and switch to recommended profile

If modem already assigned recommended profile start using; if not send a DBC to assign that profile

Modem indicated a problem with the recommended profile; mark that unfit and switch to the downgrade profile

Collect RxMER data for all sub-carriers and switch to recommended profile

OFDM Profile Management Settings

- **`cable downstream ofdm-prof-mgmt prof-dwngrd-auto`**
  - Allow automatic profile downgrades after a profile declared unfit (default on)
- **`cable downstream ofdm-prof-mgmt rxmer-poll-interval`**
  - Period of RxMER polling (default 60 mins)
- **`cable downstream ofdm-prof-mgmt exempt-sc-pct`**
  - Percentage of sub-carriers allowed to be below the MER margin (default 2%)
- **`cable downstream ofdm-prof-mgmt recommend-profile-age`**
  - How long to cache recommended profile (default 120 mins)
- **`cable downstream ofdm-prof-mgmt unfit-profile-age`**
  - How long to cache unfit profile (default 60 mins)
- **`cable downstream ofdm-prof-mgmt mer-margin-qdb`**
  - Offset in 1/4 dB for MER margin determination

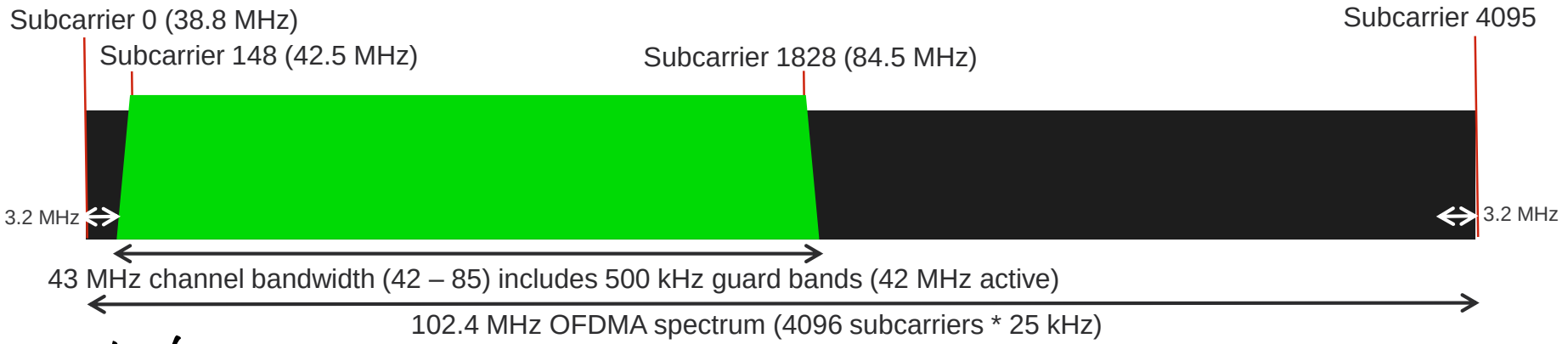
DOCSIS 3.1 Upstream

DOCSIS 3.1 US - OFDMA

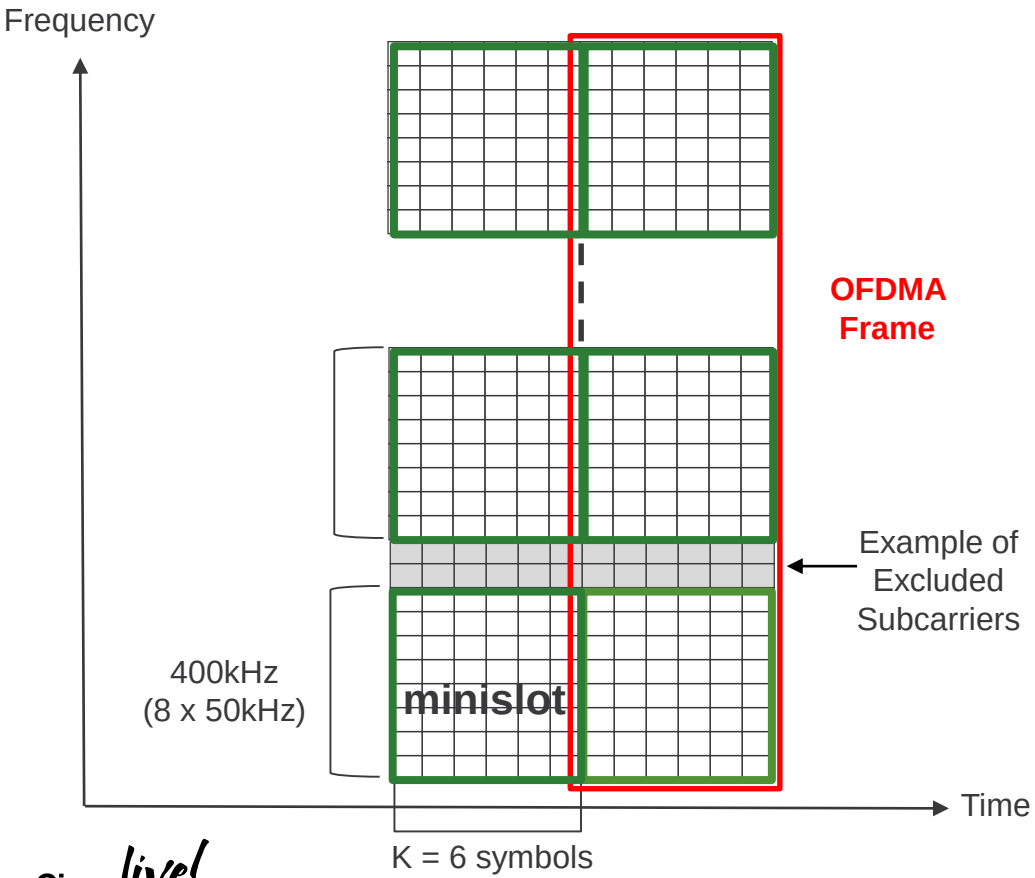
- Same 25 kHz / 50 kHz subcarrier spacing options as DS OFDM
- OFDMA FFT spectrum size is 102.4 MHz
- 11* – 96 MHz (50 kHz) & 7.4* – 96 MHz (25 kHz) channel widths
- *Guard bands are fixed at 0.5 MHz per edge
- Expanded US spectrum range (5 – 204 MHz)
- US spectrum divided into groups of sub-carriers called ***minislots***
- No excluded subcarriers within a ***minislot***
- Pilots & Complementary Pilots for synchronization & channel estimation

OFDMA Basics & Fast Fourier Transforms (FFT)

- FFT size is either 2048 subcarriers (50 kHz spacing) or 4096 subcarriers (25 kHz); thus OFDMA spectrum size is ALWAYS 102.4 MHz (2048 * 50 kHz or 4096 * 25 kHz)
- Unlike OFDM, OFMA is NOT centered on configured channel bandwidth
- At least 3.2 MHz nulled out on each side (102.4 – 96)/2
- Following example with OFDMA configured from 42 – 85 MHz and 25 kHz spacing



OFDMA Minislot In DOCSIS 3.1



- OFDMA frame comprised of ‘K’ symbols (configurable)
- Always 400 kHz minislot size (ex. 8 x 50 kHz subcarriers)
- All data subcarriers in a minislot use same modulation order
- Modems assigned one or more minislots in a transmission burst
- Can have different modulation orders in different minislots within OFMDA frame

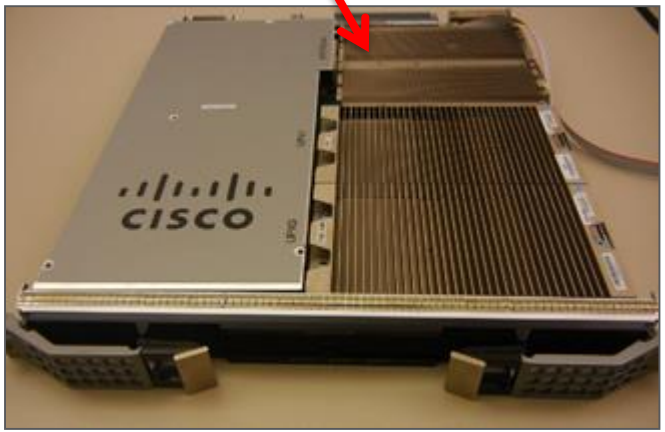
OFDMA Data Transmission

- CMTS MAPs minislots to modems as needed
- Determine number of minislots and codewords needed (long, medium and short) based on modem request
- Interval Usage Code (IUC) 13 is default and intended to be most robust
- Can assign each OFDMA channel up to seven IUCs (5, 6, 9 -13) and each can have different modulation order and pilot pattern
- Each D3.1 modem can have one or two Assigned OFDMA Upstream Data Profile (OUDP) IUCs
- Different D3.1 modems can transmit at the same time in different minislots on the same OFDMA channel possibly with different modulations and pilot patterns
- D3.1 modems can bond on both OFDMA and SC-QAM

DOCSIS 3.1 US on the cBR-8

- Ensure using supported SW (>= 16.6.1) & HW (D31-US-MOD)

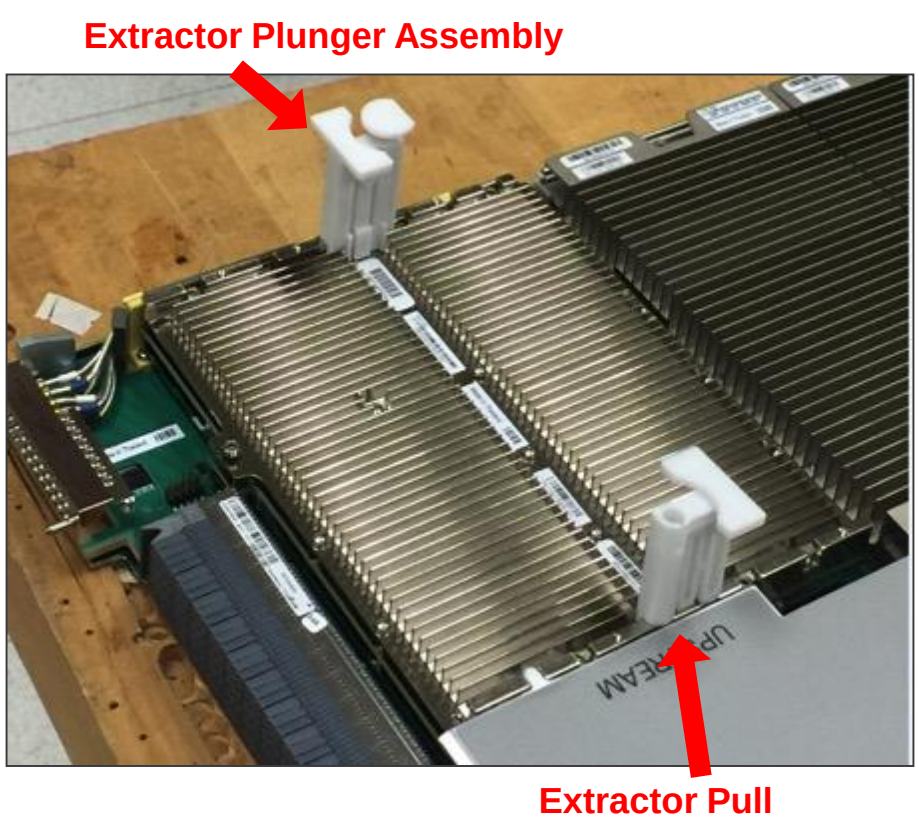
```
cbr8#show inventory
NAME: "CLC Upstream PHY Module 0/2", DESCR: "Cable
PHY Module"
PID: CBR-D31-US-MOD    , VID: V01 , SN: CAT1915E0F4
```

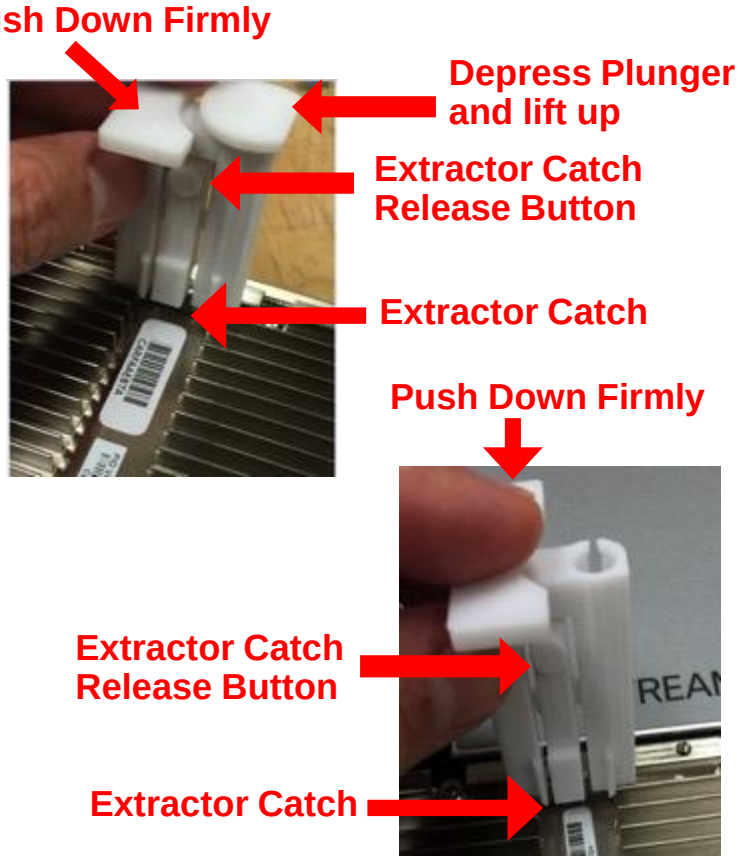


16.6.1 Support

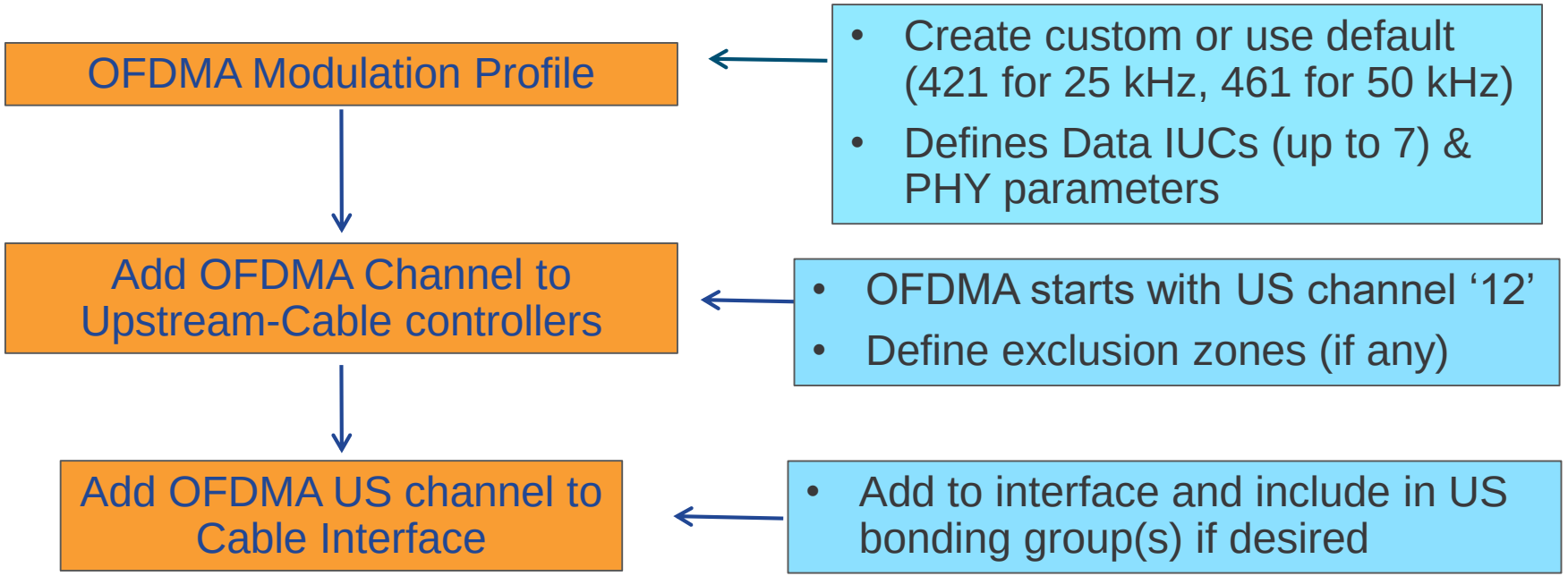
- 1 OFDMA channel/port (5-85 MHz)
- Up to 1024-QAM modulation
- 4 SC-QAM + 1 OFDMA bonding
- 7 Mod profiles (IUCs) per channel
- 3 Mod zones per OFDMA channel
- Dynamic Profile Selection
- Exclusion bands

Replacing RF Linecard US PHY Module





DOCSIS 3.1 US Configuration Flowchart



DOCSIS 3.1 Upstream Configuration

```
cable mod-profile-ofdma 423
  subcarrier-spacing 25KHz
  initial-rng-subcarrier 64
  fine-rng-subcarrier 128
  data-iuc 11 modulation 1024-QAM pilot-pattern 8
  data-iuc 12 modulation 512-QAM pilot-pattern 8
  data-iuc 13 modulation 256-QAM pilot-pattern 9
```

- Initial Ranging used when coming online for coarse power & timing
- Fine Ranging used for minor adjustments
- Pilots used for synchronization & channel estimation

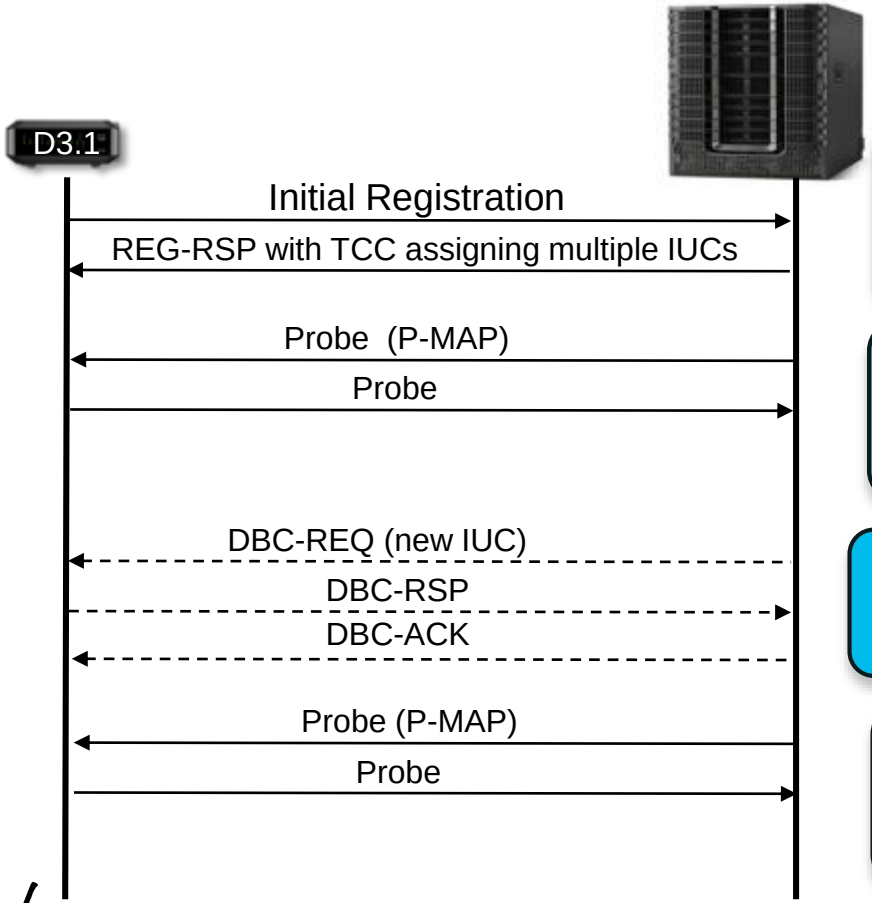
```
controller Upstream-Cable 1/0/0
 ...
 us-channel 12 docsis-mode ofdma
 us-channel 12 subcarrier-spacing 25KHz
 us-channel 12 modulation-profile 423
 us-channel 12 frequency-range 42000000 85000000
 us-channel 12 cyclic-prefix 96 roll-off-period 0
 us-channel 12 symbols-per-frame 9
 no us-channel 12 shutdown
```

- OFDMA starts with channel 12
- Define OFDMA frequency range
- Define sub-carrier spacing; modulation profile; cyclic prefix; & symbols/frame (K)

```
interface Cable1/0/0
 …
  upstream 4 Upstream-Cable 1/0/0 us-channel 12
```

- Enable the OFDMA channel in the MAC domain
- Create bonding groups with OFDMA channel if desired (not shown)

OFDMA Data IUC Assignment Logic



Each modem can be assigned 2 data IUCs; IUC 13 is default and intended to be the most robust – will always be one of the 2 assigned IUCs

Calculate RxMER data for all active sub-carriers and determine average value per minislot; determine recommended IUC

If modem isn't currently assigned recommended IUC send a DBC to assign that IUC; IUC 13 used during change

Calculate RxMER data for all active sub-carriers and determine average value per minislot; determine recommended IUC

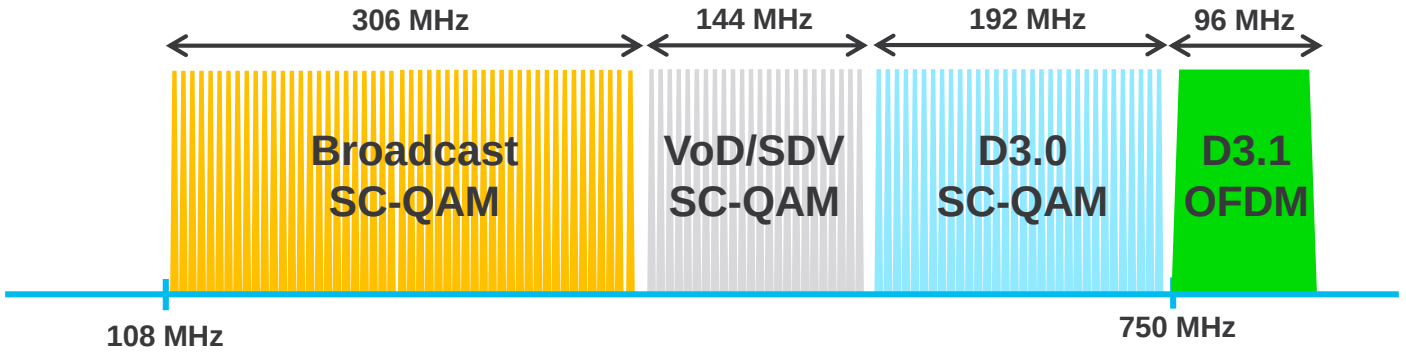
OFDMA Profile Management Settings

- **`cable upstream ofdma-prof-mgmt prof-upgrade-auto`**
  - Allow automatic profile upgrade (default off*) – default to change in later code
- **`cable upstream ofdma-prof-mgmt rxmer-poll-interval`**
  - Period of RxMER polling (default 60 mins)
- **`cable upstream ofdma-prof-mgmt exempt-mslot-pct`**
  - Percentage of minislots allowed to be below the MER margin (default 2%))
- **`cable upstream ofdma-prof-mgmt mer-margin-qdb`**
  - Offset in 1/4 dB for MER margin determination
- **`cable upstream ofdma-prof-mgmt active-scs-threshold-pct`**
  - Percentage of active subcarriers allowed to be below the MER margin (default 2%))

DOCSIS 3.1 Demo

DOCSIS 3.1 Insertion Strategy

DOCSIS 3.1 Downstream Migration



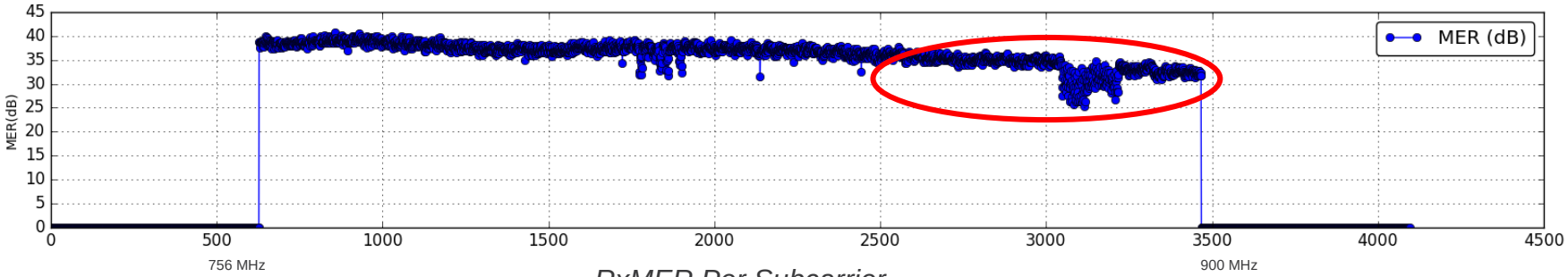
- Need clear downstream spectrum for D3.1 (24 MHz minimum)
- D3.1 modem will have 32 DS x 8 US **plus** two 192 MHz OFDM blocks in DS and two 96 MHz OFDMA blocks in US
- Still retain D3.0 downstream channels and **ADD** OFDM capacity
- D3.1 modems can use **BOTH** 3.0 and 3.1 channels for higher speeds

Where Can I Locate The OFDM Channel?

- Target marginal spectrum with impairments or in roll-off
  - + Much of this spectrum unusable by other devices
  - + Field testing demonstrated an OFDM channel can operate in the roll-off beyond the upper bound of forward HFC plant
  - - Operation in roll-off may depend on HFC equipment
  - - Roll-off may decrease RxMER and limit modulation order

- Target prime spectrum with minimal impairments
  - + Only D3.1 modems can actually take advantage of better RxMER with higher order modulations (above 256-QAM)
  - - Might need to relocate video or DOCSIS channels

Target Capacity In Roll-Off Spectrum

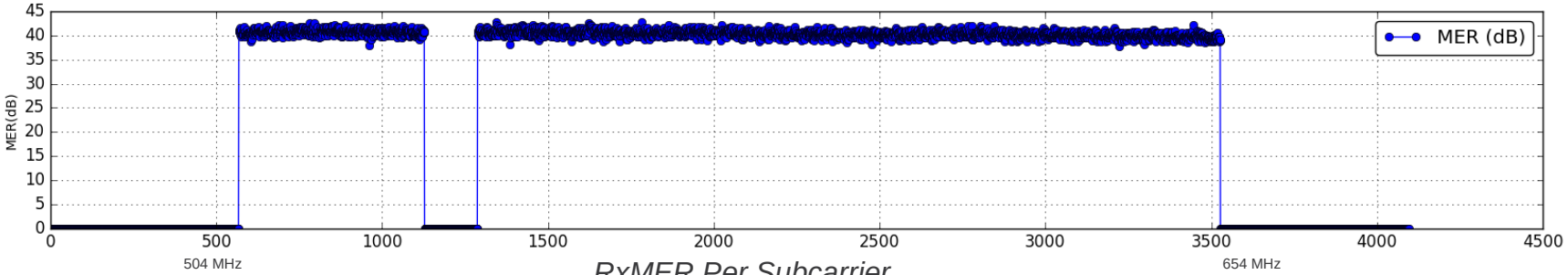


RxMER Per Subcarrier

144 MHz OFDM channel 756 MHz – 900 MHz with 5 amplifier cascade

- RxMER levels begin to decrease after 860 MHz (~subcarrier 2600)
- RxMER levels decrease more with longer cable runs and higher amplifier cascades
- D3.1 modem can reliably run 1024-QAM
- Lower RxMER in roll-off is not improved with any OFDM configuration changes

Target Capacity In Prime Spectrum



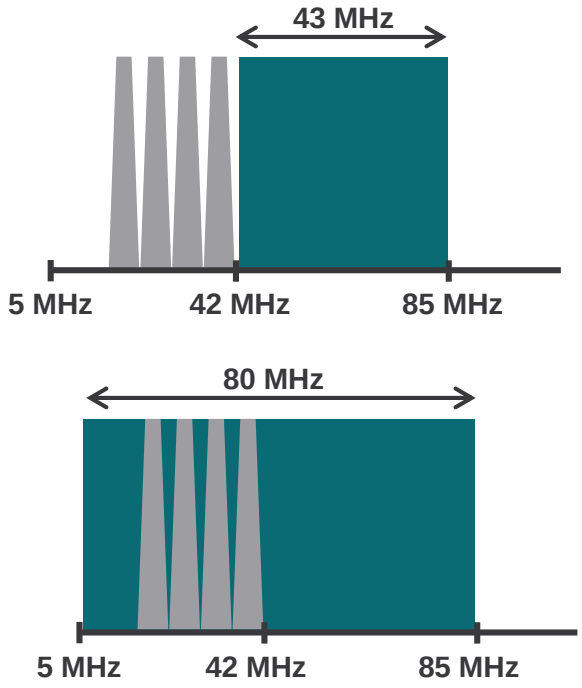
RxMER Per Subcarrier

150 MHz OFDM channel 504 MHz – 654 MHz with 5 amplifier cascade

- Spectrum available after increased video compression and analog video reclamation
- RxMER levels consistent throughout channel
- Now requires an exclusion band around a pilot channel
- D3.1 modem can now reliably run 4096-QAM

DOCSIS 3.1 Upstream Migration Examples

- Assuming 4 6.4MHz ATDMA US channels exist in the 5-42 MHz spectrum (25.6 MHz of spectrum)
- Use the 42-85 MHz spectrum for OFDMA
- In the future TaFDM support enables the same US spectrum to be shared by ATDMA and OFDMA US channels
- Can now have 80 MHz OFDMA channel



Conclusion

Conclusion

- DOCSIS 3.1 at scale enabling multi-gigabit downstream speeds
- Tweak OFDM data profiles and channel parameters to achieve maximum performance
- Enable OFDMA to achieve increased upstream speeds
- Remote PHY architecture enabling hub consolidation and full benefits of D3.1
- Increase expertise by knowing the RPHY protocols and components
- Deploy full RPHY services at scale via HA, multiple cores, and virtual splitting

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Appendix

For Your Reference

Useful Links

- Remote PHY Solution Guide
  - http://www.cisco.com/c/en/us/td/docs/cable/RemotePhy/InstallConfig/guide/b-remotePHY-install-config-guide.html
- cBR-8 Documentation
  - http://www.cisco.com/c/en/us/support/video/cbr-8-converged-broadband-router/model.html
- cBR-8 Install/Upgrade Guides
  - http://www.cisco.com/c/en/us/support/video/cbr-series-converged-broadband-routers/products-installation-guides-list.html
- cBR-8 Polaris Information
  - http://www.cisco.com/c/dam/en/us/td/docs/cable/cbr/Cisco-cBR/IOS-XE-16-5-1/index.html

For Your Reference

Other DOCSIS 3.1 Configuration Commands

- To disable D3.1 on a MAC domain: `cBR8(config-if)#no cable d31-mode`
- To statically map a modem to a particular data profile:
  `cBR8(config)#cable downstream ofdm-flow-to-profile profile-data <1-5> mac-address <>`
- To modify profile management parameters: (default values shown)
  - `cBR8(config)#cable downstream ofdm-prof-mgmt prof-dwngrd-auto`
  - `cBR8(config)#cable downstream ofdm-prof-mgmt rxmer-poll-interval 60`
  - `cBR8(config)#cable downstream ofdm-prof-mgmt exempt-sc-pct 2`
  - `cBR8(config)#cable downstream ofdm-prof-mgmt recommend-profile-age 120`
  - `cBR8(config)#cable downstream ofdm-prof-mgmt unfit-profile-age 60`
  - `cBR8(config)#cable downstream ofdm-prof-mgmt mer-margin-qdb 0`

Useful DOCSIS 3.1 Show Commands

For Your Reference

- To view configured OFDM channel profiles/modulation profiles
  `cBR8#show cable ofdm-chan-profile|ofdm-modulation-profile configuration`
- To verify OCD, DPD message content:
  `cBR8#show cable mac-domain cable <> ocd|dpd`
- To verify OCD, DPD, MDD message counters incrementing:
  `cBR8#show interface cable <> controller | include \[OCD`
- To verify the OFDM channel is operational and view OFDM channel details such as subcarrier assignments per profile:
  `cBR#show controllers Integrated-Cable <> rf-channel 158 [prof-order | verbose]`
- To view the OFDM channel utilization:
  `cBR#show controllers Integrated-Cable <> counter ofdm-channel`
- To verify the OFDM channel OCD/DPD statistics; MAC domain DOCSIS 3.1 operation:
  `cBR#show controllers Cable <> | begin MD OCD`
- To view DOCSIS 3.1 modems and their current status:
  `cBR8#show cable modem docsis version d31-capable`
- To view DOCSIS 3.1 modem profile information (detailed):
  `cBR8#show cable modem <> prof-mgmt`
- To view DOCSIS 3.1 modem profile information (brief):
  `cBR8#show cable modem [<>] phy ofdm-profile`

For Your Reference

Useful cBR-8 Remote PHY Show Commands

- To check status of PTP (1588)
  `cBR8#show ptp clock running`
- To view all RPDs
  `cBR8#show cable rpd`
- To view reported capabilities of a given RPD
  `cBR8#show cable rpd <> capability`
- To view a concise list of GCP transactions
  `cBR#show cable rpd gcp-transaction`
- To view details of each GCP transaction
  `cBR#show cable rpd gcp-transaction verbose`
- To verify the details of the DEPI and UEPI sessions
  `cBR#show cable rpd depi`

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