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cBR-8 Technical Overview & Deployment Considerations

Jeff Riddel – Solutions Architect

BRKSPG-2505

Agenda

- cBR-8 Introduction
- Hardware & Software Overview
- Features & Functionality New to the cBR-8
- DOCSIS 3.1 Basics & Configuration
- DOCSIS 3.1 Insertion Strategy
- Glimpse into Remote PHY
- Summary

cBR-8 Introduction

cBR-8 Introduction

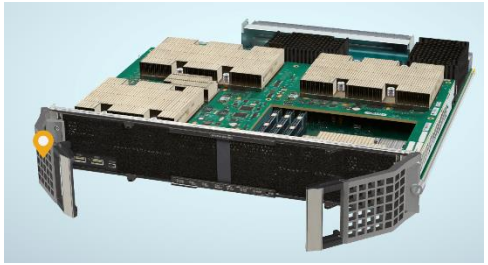
- **Converged Cable Access Platform scaling**
  200 Gbps of switching capacity in 13 RU CCAP chassis with built-in HA; scalable to 1.6 Tbps
  With HA: 56 SGs, 5,376 DS QAMs & 672 US QAMs[1]
- **Video convergence**
  HSD, VoD, SDV, & Broadcast - “Hub in a Box”
- **DOCSIS 3.1**
  Designed from the ground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

Hardware & Software Overview

cBR-8 Hardware Overview

- The Kaon tool is an interactive 3D virtual demo to showcase Cisco products such as the cBR-8
- Can run online on a browser or can be downloaded locally
- URL: http://log.v-central.com/c/cs
- App Store:
  Cisco 3D Interactive Catalog
- cBR-8 password: 1984



Cisco cBR-8 Chassis - Front

13RU,10-Slot Mid-Plane Design

Integrated N+1 RF Switch

2 Supervisor Slots
200 Gbps forwarding

8 Cable Linecard Slots
Initial cards support up to 40 Gbps
576 DS SC-QAMs[1] & 96 US QAMs
+ 16 OFDM DSs & 32 OFDMA USs

Up to 6 AC or DC Power Entry Modules

[1] DS numbers for Annex A; for Annex B 768 SC-QAMs per card

Cisco cBR-8 Chassis - Back

Connectivity on back via Physical Interface Cards (PICs) enabling "wire-once" operation

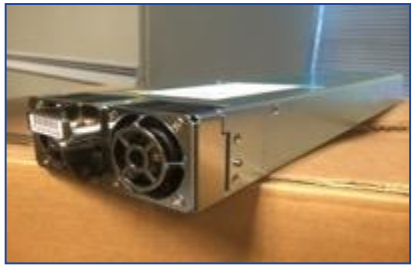
2 Supervisor PICs
each has 8x10GE SFP+ ports

8DSx16US RF PICs
3 UCH.8 connector blocks
1 Downstream / 2 Upstream

AC or DC Facility Power Entry Module (FPEM) for power connections

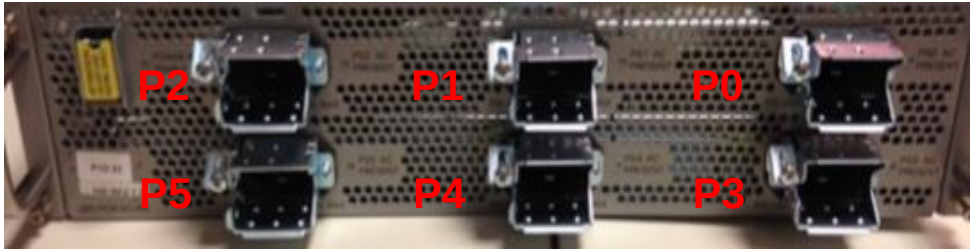
5 Fan modules (Each module has 2 overlapped fans) Front to Back airflow

Cisco cBR-8 Power



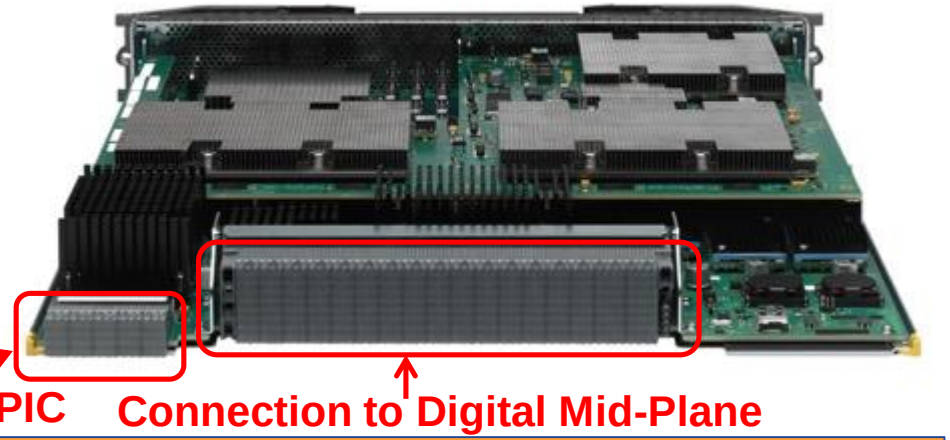
DC FPEM

AC FPEM



- AC or DC Power Options; up to **6 Power Modules** housed in a **Power Cassette Module**
- Chassis cooling capacity (9 kW) – 4x1 DC or 3x1 or 3x3 AC (load shared across modules)
- Typical power load of full chassis @ 25 C – 5–5.4 kW with D3.1 HW, 4.4-4.8 kW with D3 HW
- Power connections made in the back via the **Facility Power Entry Module (FPEM)**
  - Also has AC/DC variants

Supervisor

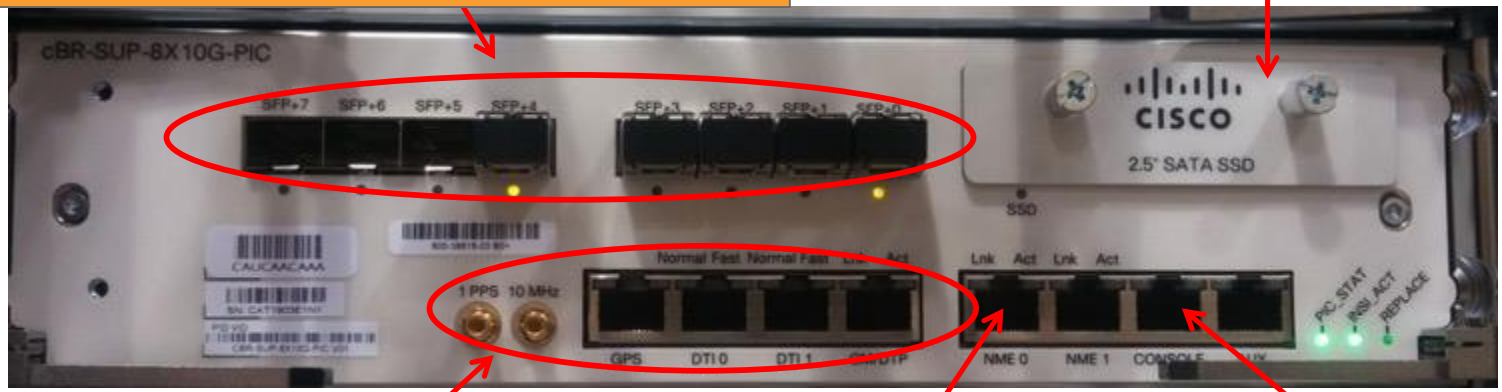


- Consists of forwarding processor (FP) complex and route processor (RP) complex
- FP performs packet forwarding and operations such as:
  - MAC classification, QoS classification, security ACLs, policing, shaping, etc.
- RP performs route processing & chassis management
  - Also distribution of timing, controlling fans, collecting health information, etc.

Cisco cBR-8 Supervisor PIC

8 10G SFP+ ports per Sup PIC
Supported optics:
SFP-10G-SR, SFP-10G-LRM, SFP-10G-LR, SFP-10G-ER, SFP-10G-ZR

100 GB Solid State Drive



Timing Connectivity (future use)

Management => GigbitEthernet0

Console => 9600bps

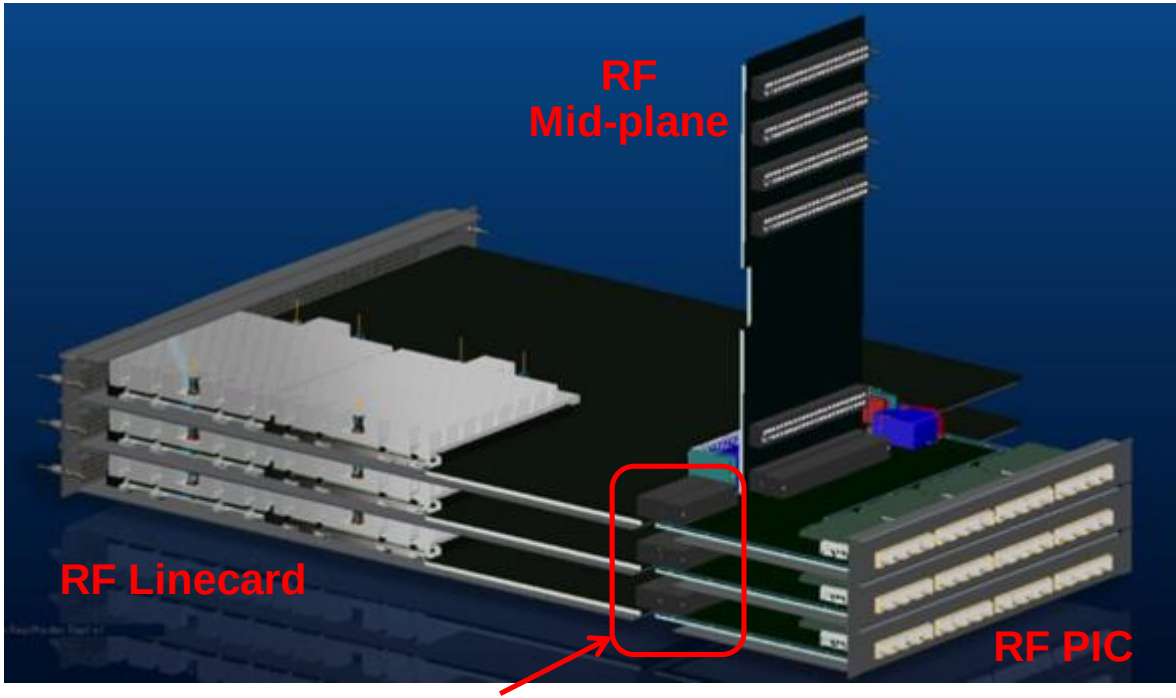
Supervisor/Supervisor PIC Functionality

- Provides data plane and control plane connectivity to/from all interface cards
- Two Supervisor versions available – 200 Gbps & 60 Gbps
- 1 + 1 redundancy with hitless failover
- **Active FP handles 200 Gbps aggregate forwarding across BOTH Supervisor PICs with 160 Gbps of connectivity**
- **Failed SUP's associated PIC remains fully functional as long as it remains inserted**
- **SUP removal from chassis will power down associated SUP-PIC and its interfaces will go down**

cBR-8 RF Architecture

Three components with RF connectivity:

- RF Linecard
- RF PIC
- RF Mid-plane

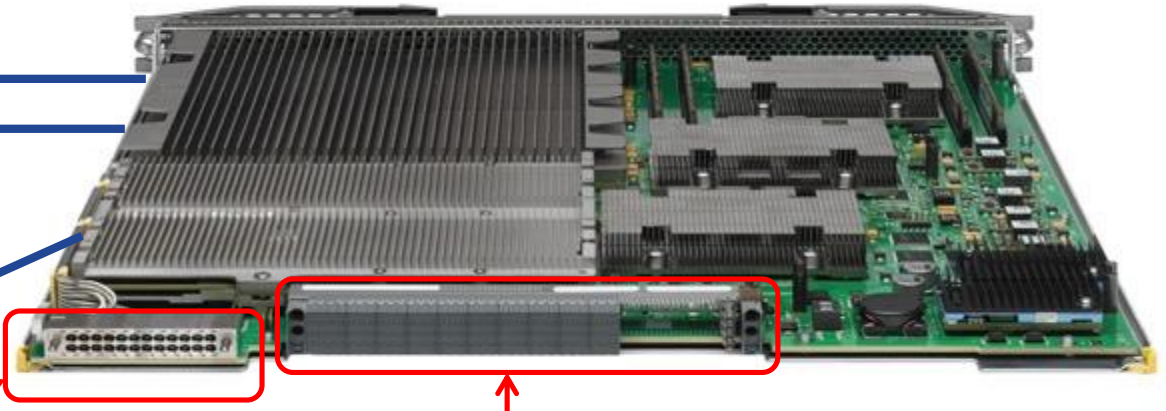


Downstream & Upstream RF directly connected between RF Linecard & PIC

Cisco cBR-8 RF Linecard

Downstream PHY
CBR-D30-DS-MOD or
CBR-D31-DS-MOD

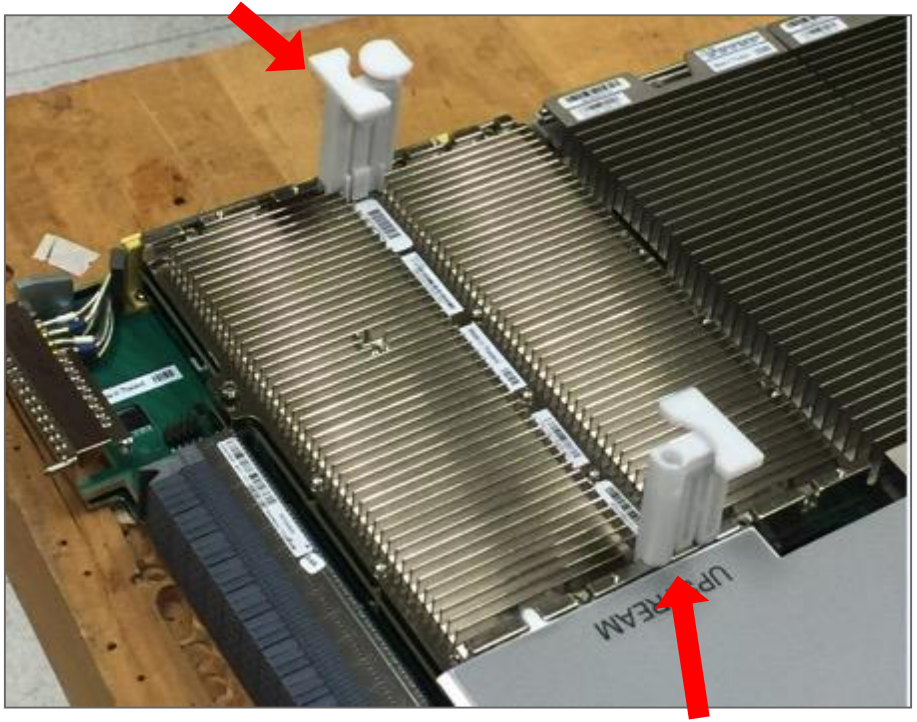
Upstream PHY
CBR-D30-US-MOD or
CBR-D31-US-MOD

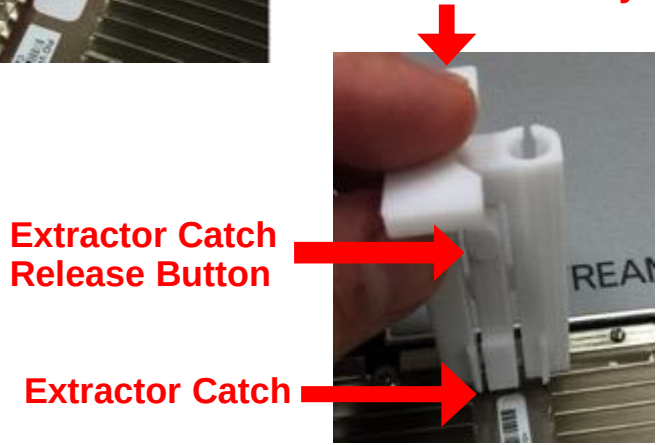


RF connection directly to RF PIC **Connection to Digital Mid-Plane**

- Field Replaceable PHY modules enabling transition to DOCSIS 3.1
- Mix of PHY module types in the same chassis supported ONLY during transition
- 2 DS PHY modules each supporting 4 ports and 384 Annex B (288 Annex A) QAMs
  768 (576) DS QAMs per LC; 6,144 (4,608) per chassis (5,376 (4,032) w/ HA)
- 1 US PHY module supporting 16 ports and 96 QAMs
  96 US QAMs per LC; 768 per chassis (672 w/ HA)
- D31 modules ADD support for 2 OFDM channels per DS port and 2 OFDMA channels per US port

Replacing RF Linecard US PHY Module

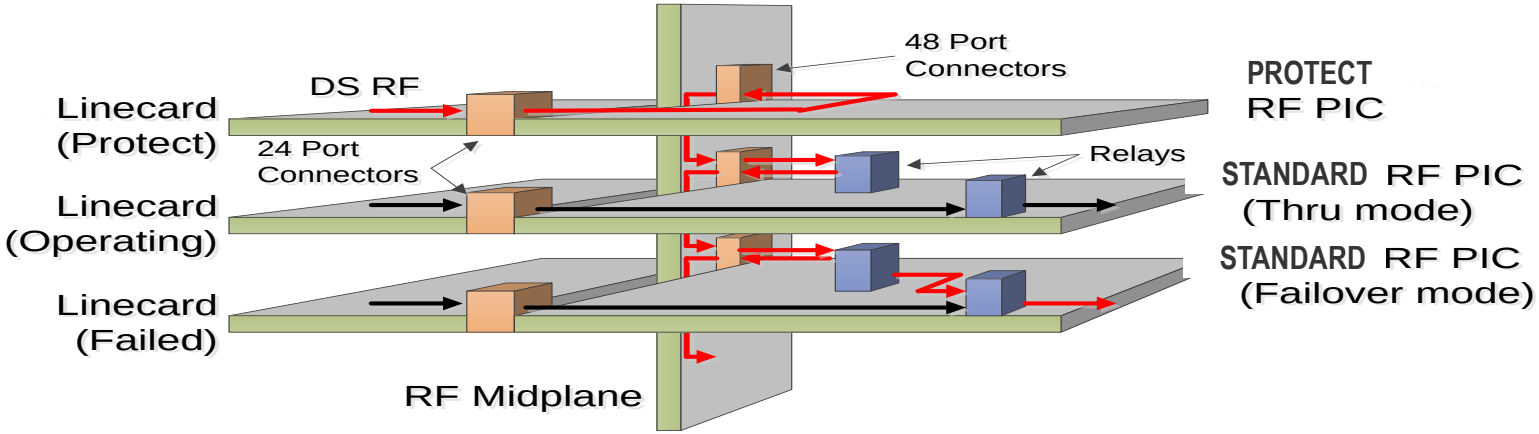




Cisco cBR-8 RF PIC

RF PIC (8DSX16US)
8 DS ports + 16 US ports per card (24 total ports)
UCH8 (2 x 4 layout)

Cable Linecard N+1 Redundancy



- Protect RF PIC installed in uppermost slot
- cBR-8 uses a ‘daisy-chain’ switching topology for RF linecard HA
- Each RF PIC connects to the ‘next-adjacent’ RF PIC above and below via an RF midplane (RFMP)

Cisco cBR-8 Chassis Numbering

Cable resources numbered

`<slot #>/0/<port #>`

Example Cable LC #3 has 8 downstream ports:

`controller Integrated-Cable 3/0/0-7`

and 16 upstream ports:

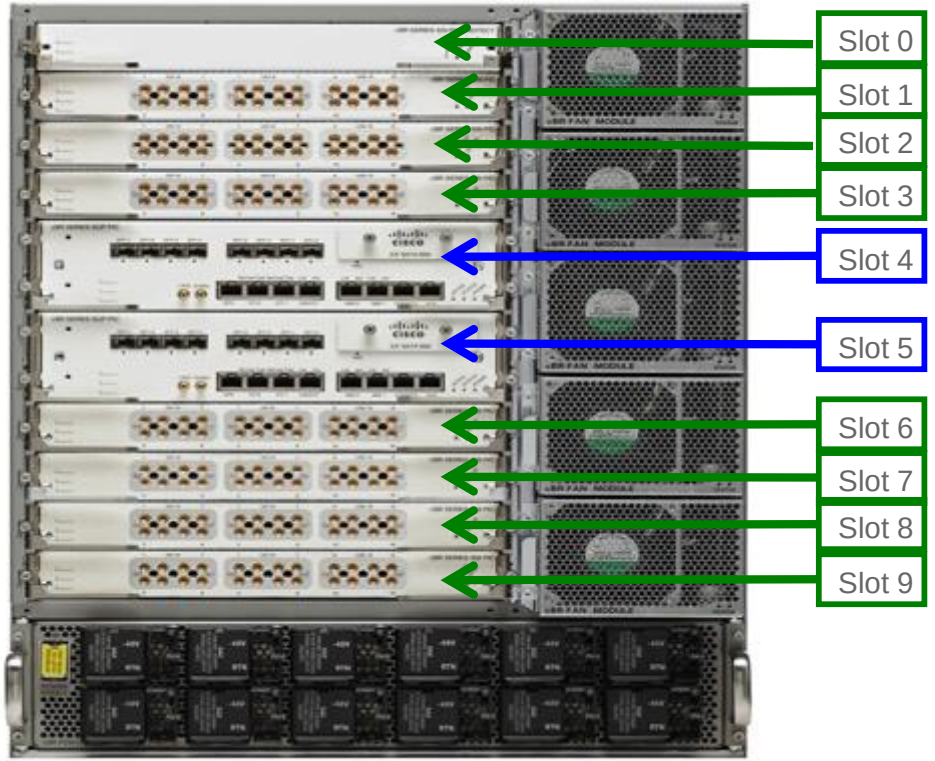
`controller Upstream-Cable 3/0/0-15`

10GE interfaces numbered

`<slot #>/1/<port #>`

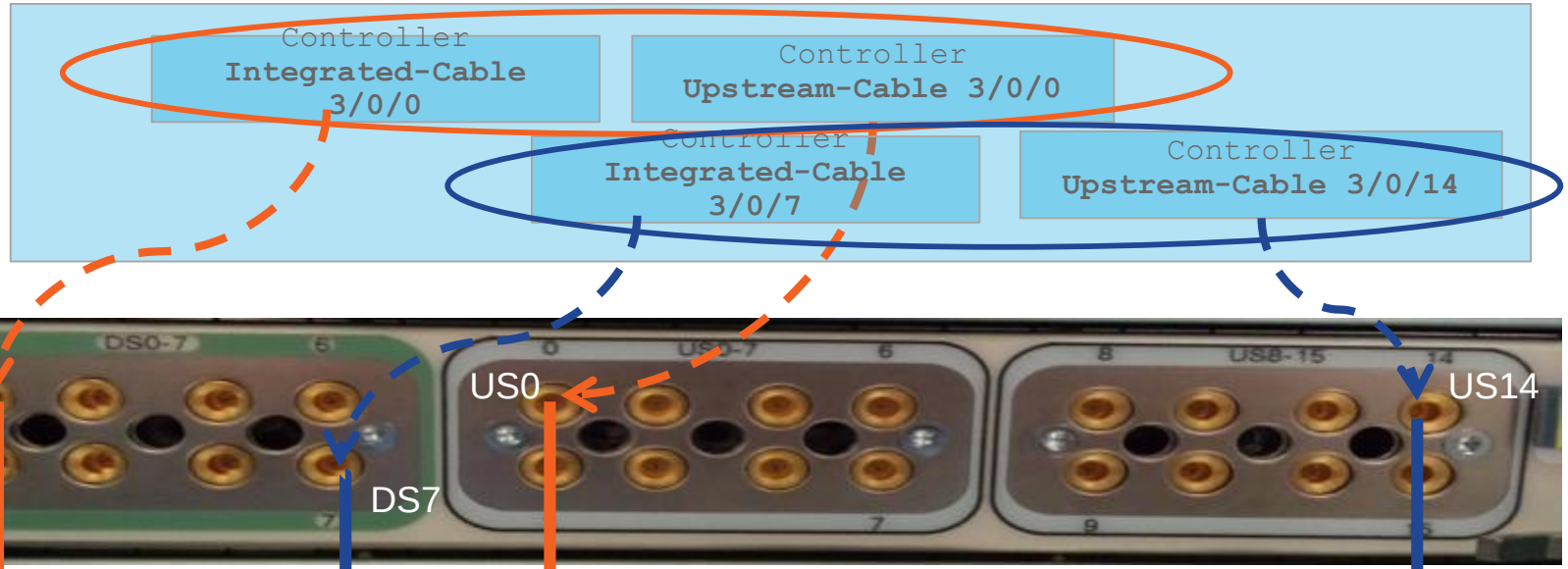
Example Supervisor PIC #4 has 8 10GE interfaces:

`interface TenGigabitEthernet4/1/0-7`



Cable Interfaces/MAC Domains/PIC Ports

Front
Cable LC
Slot 3

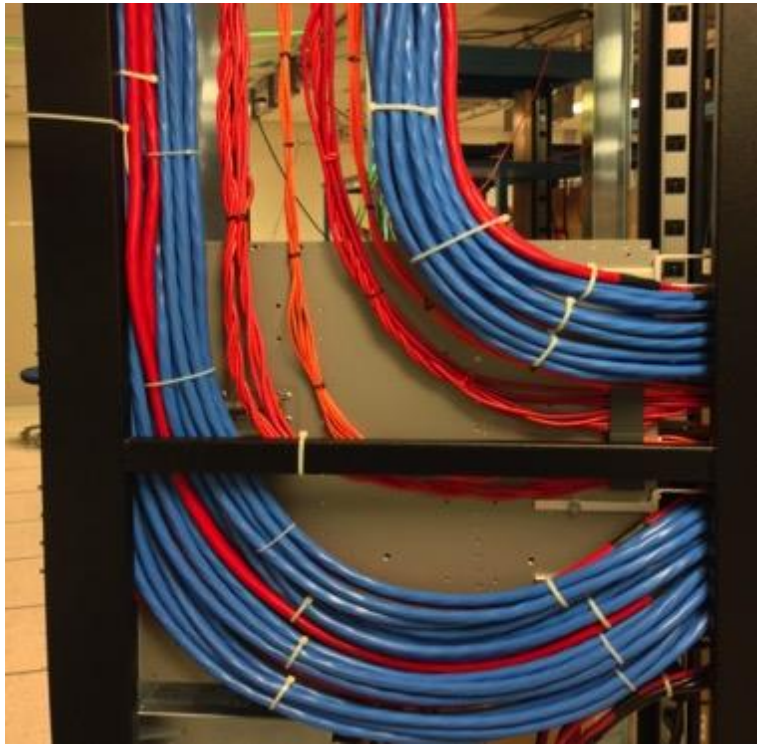


Rear
RF LC PIC
Slot 3

SG#1 (Cable 3/0/0)

SG#8 (Cable 3/0/7)

Wiring Illustrations



Side View

Rear View

Software Notes

- Linux kernel based operating system
- Runs IOS-XE which leverages IOS
- Traditional IOS runs as a daemon (IOSd)
- **Same look and feel as IOS enabling easy migration**
  - **Majority of configuration and show CLIs are the same**
- HW interfaces implemented as Linux level drivers
- Functionality split across processes –
  IOSd, US scheduler, Chassis Management, Video, Video Encryption
- **Process modularity allows for hitless recover, restartability and patchability**

cBR-8 Release Naming & Features

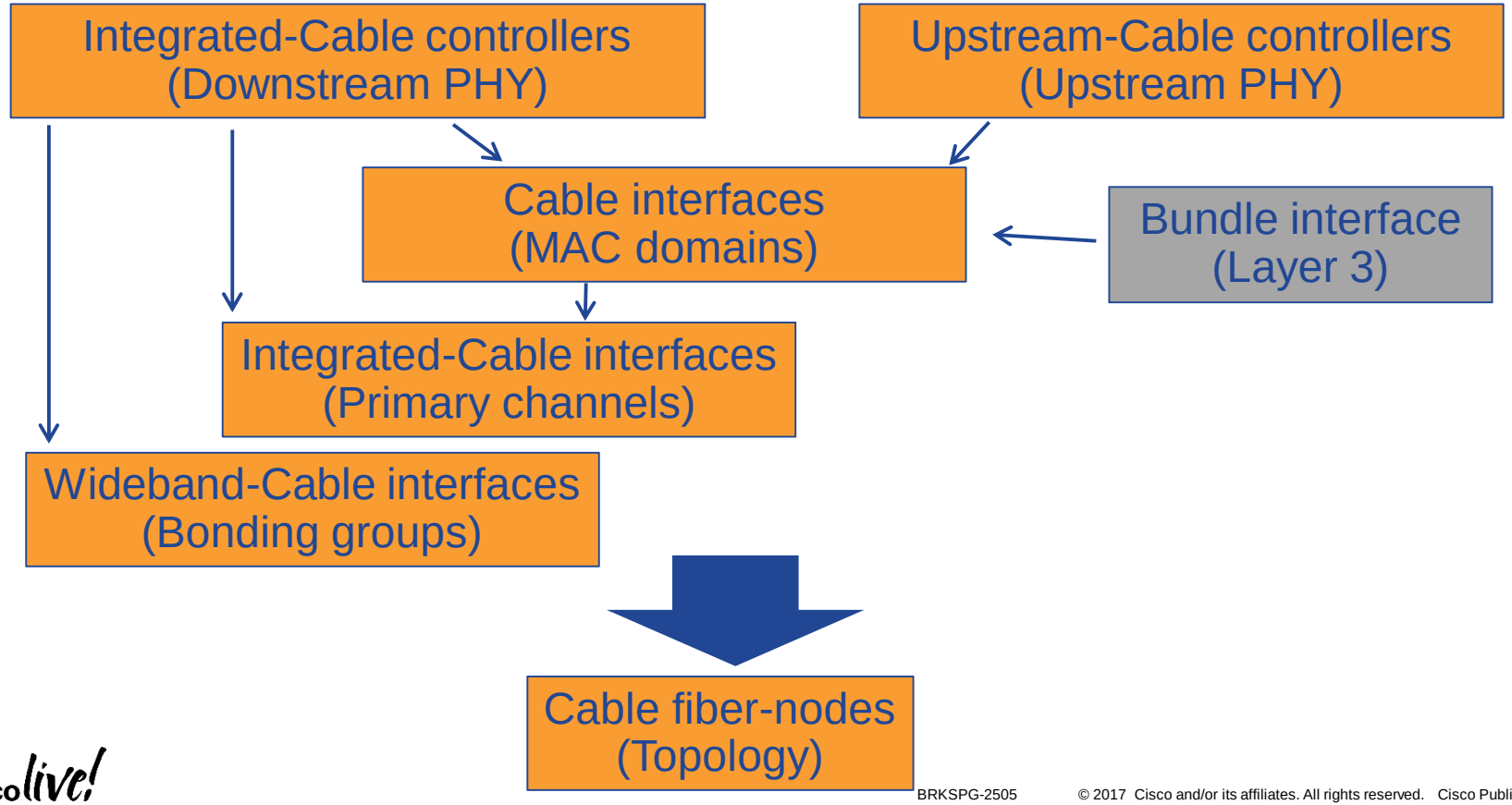
Intern Name	IOS-XE Release	IOS Release	Date	Major HW/SW Features (Note: not all features per release listed)	Latest Rebuild
R0	3.15.0S	15.5(2)S	March 2015	Initial release – SCH feature parity with exceptions, Smart licensing, Patching availability, PPRL, ACFE phase 1	3.15.1S June 2015
R1	3.16.0S	15.5(3)S	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	3.18.1aSP Dec 2016
R5	**Polaris 16.4.1**			** Lab release only **	
R6	**Polaris 16.5.1**		March 2017	Remote PHY, DVB Simulcrypt & Tiered DVB VoD (ICCAP), PME VoD (RPHY), Adjust OFDM power, OFDM primary, 1G & DWDM optics	N/A
R7	**Polaris 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	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

Cable Configuration Flowchart



Integrated-Cable Controller

```
controller Integrated-Cable 3/0/0
 max-carrier 32
 base-channel-power 42
 freq-profile 0
 rf-chan 0 23
  type DOCSIS
  frequency 591000000
  rf-output NORMAL
  power-adjust 0
  qam-profile 1
  docsis-channel-id 1
```

- max-carrier can be set up to 158
- base-channel-power will adjust accordingly
- Changes to freq-profile or max-carrier requires RF channels to be in shutdown state

- **ONLY APPLICABLE** if using D3.0 DS-PHY
  4 Frequency Profiles created by default
  0 (Annex B/Low), 1 (Annex B/High),
  2 (Annex A/Low), 3 (Annex A/High)

- 6 QAM Profiles created by default
  0 (Annex B/64 QAM), 1 (Annex B/256 QAM)
  2 (Annex A/64 QAM), 3 (Annex A/256 QAM)
  4 & 5 added in 3.18 for video

Upstream-Cable Controller

```
controller Upstream-Cable 3/0/0
 us-channel 0 frequency 17600000
 us-channel 0 channel-width 6400000 6400000
 us-channel 0 docsis-mode atdma
 us-channel 0 minislot-size 2
 us-channel 0 modulation-profile 224
 us-channel 0 equalization-coefficient
 no us-channel 0 shutdown
…
 us-channel 5 frequency 37500000
 us-channel 5 channel-width 6400000 6400000
 us-channel 5 docsis-mode atdma
 us-channel 5 minislot-size 2
 us-channel 5 modulation-profile 224
 us-channel 5 equalization-coefficient
 no us-channel 5 shutdown
```

- From 3.16 onwards a maximum of 12 TDMA/ATDMA channels can be configured per controller adjacent pair
- Default mapping is 6 per connector

Cable Interface

```
interface Cable3/0/0
 downstream Integrated-Cable 3/0/0 rf-channel 0
 downstream Integrated-Cable 3/0/0 rf-channel 8
 downstream Integrated-Cable 3/0/0 rf-channel 16
 upstream 0 Upstream-Cable 3/0/0 rf-channel 0
 upstream 1 Upstream-Cable 3/0/0 rf-channel 1
 upstream 2 Upstream-Cable 3/0/0 rf-channel 2
 upstream 3 Upstream-Cable 3/0/0 rf-channel 3
 cable upstream balance-scheduling
 cable upstream bonding-group 1
  upstream 0
  upstream 1
  upstream 2
  upstream 3
  attributes 80000000
 cable bundle 1
 cable dynamic-secret reject nocrypt
 cable ip-init ipv6
 cable cm-status enable 3 9-10
 cable privacy mandatory
 cable privacy bpi-plus-policy total-enforcement
 cable sid-cluster-group num-of-cluster 2
 cable sid-cluster-switching max-request 2
```

- Up to 16 MAC domains/cable interfaces per card
- By default a MAC domain contains ZERO channels
- Maximum of 32 primary channels per MAC domain
- As of 3.18 support up to 16 US per MD (previous releases limit is 8)
- MAC domain and DS/US channels must be of the same slot

Integrated-Cable and Wideband-Cable Interfaces

```
interface Integrated-Cable3/0/0:0
 cable bundle 1
 cable rf-bandwidth-percent 10
```

- IC numbering is a static mapping to IC controller and RF channel
- Default BW % is 1%
- Bundle inherited from MAC domain

```
interface Wideband-Cable3/0/0:0
 cable bundle 1
 cable rf-channel channel-list 0-7 bandwidth-percent 1
```

Multiple channels can now be defined with a single line of configuration

Up to 64 WB interfaces per controller (512 WB interfaces max per card)

Note: Example RF BW percentages assuming `cable acfe enable` configured

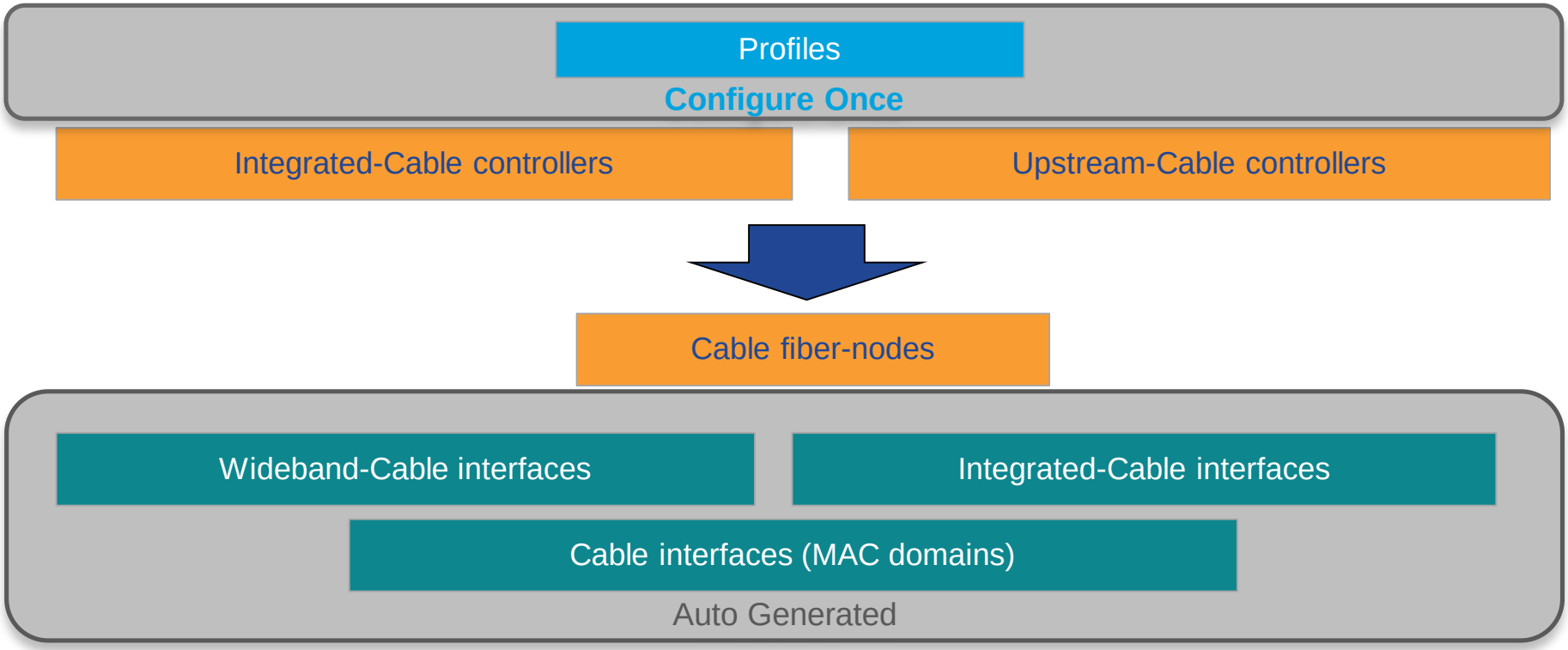
Fiber-node

```
cable fiber-node 1
 downstream Integrated-Cable 3/0/0
 upstream Upstream-Cable 3/0/0
```

- Up to 512 fiber nodes per chassis
  - Practical max is 128 (one FN per US port)
- No longer need rf-channel set with downstream controller configuration (all DS channels associated)
- Upstream configuration changes to refer to controller (all US channels associated)

Features & Functionality New to the cBR-8

Operation Simplification - Configuration Flowchart



Example 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

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>
```

Example Configuration - continued

```
cable fiber-node 30
 downstream Integrated-Cable 2/0/0
 upstream Upstream-Cable 2/0/0
 downstream sg-channel 0 23 integrated-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
!
cable fiber-node 40
 downstream Integrated-Cable 2/0/1
 upstream Upstream-Cable 2/0/2
 downstream sg-channel 0 23 integrated-cable 2/0/1 rf-channel 0 23
 upstream sg-channel 0 3 Upstream-Cable 2/0/2 us-channel 0 3
 service-group profile 24x4
```

Configure fiber nodes to reference SG topology

Simplified configuration generated

```
interface Integrated-Cable2/0/0:0
 cable bundle 1
 cable managed fiber-node 30
```

```
interface Wideband-Cable2/0/0:0
 cable bundle 1
 cable managed fiber-node 30
 cable wideband-profile WB1
```

```
interface Cable2/0/0
 cable mac-domain-profile MD1
 cable bundle 1
 cable managed fiber-node 30
```

Recreating Cisco Licensing

Smart Software Licensing is not just a new licensing tool. It transforms how you think about Cisco and the Software Lifecycle Management.

Limited View
Customers do not know what they own.

PAK Registration
Manually register each device. Unlock with license key.

Device Specific
Licenses specific to only one device.

Locked
You cannot use more than you paid for.

Complete View
Software, services, devices in one easy to use portal.

Easy Registration
No PAKs. Easy activation. Device is ready to use.

Company Specific
Flexible licensing, use across devices.

Unlocked
Add users and licenses as needed.

Smart Licensing on the cBR-8

- Smart Licensing is enabled by default on the cBR-8
- Legacy node locking licensing NOT supported
- Initial (3.15) licensed parameters included DOCSIS DS & US channels and Supervisor 10GE ports
- Licensed functionality enabled by “no shutting” an interface or RF channel
- Chassis based licenses; no licenses for protect card RF channels
- LCHA licensed as of R2 (3.17) – one license per working card protected
- R3 (3.18) adds licensing for narrowcast video channels, QAM replication, and video encryption; happens at “bind” configuration
- R4 (3.18SP) adds licensing for DOCSIS 3.1 DS channels and broadcast video

Balancing Simplicity with Security

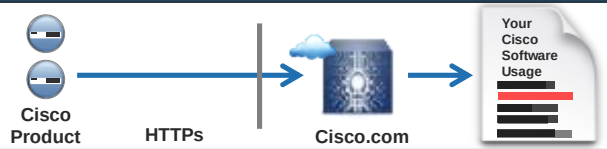
Ease of use

Security Policy

Options

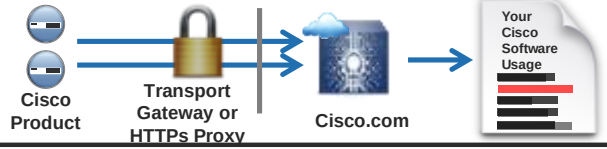
1 Direct cloud access

Cisco product sends usage information directly over the internet.
No additional components are needed.



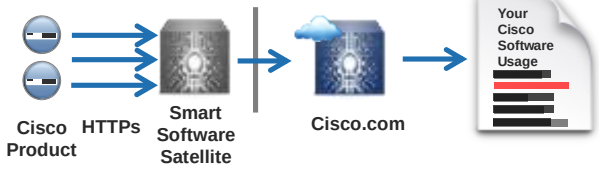
2 Access through an HTTPS proxy

Cisco Products send usage information over the internet via a Proxy Server – Smart Call Home Transport Gateway (Free VM Download) or off-the-shelf Proxy (such as Apache).



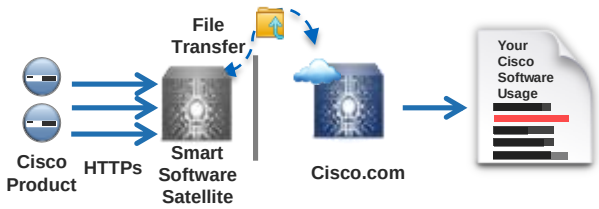
3 Access through an on-premise license management - Smart Software Satellite connected

Cisco Products send usage information to a local connected collector, which acts as a local license authority. Periodically, an exchange of information will be performed to keep the databases in sync.



4 Access through an on-premise license management - Smart Software Satellite disconnected

Manually transfer usage information to/from SSM satellite
Once a month, an exchange of human readable information will be performed to keep the databases in sync.



cBR-8 IOS-XE Boot Overview

- Two boot mode options available
  - Single/consolidated image binary boot
  - Sub-package mode boot
- Single binary images are published on CCO
- Single image consists of 15 sub-packages which are extracted during the boot process
- Package mode boot require the CCO published image to be extracted into sub-packages and stored on a file system on the cBR8
- In sub-package mode individual sub-packages can be upgraded (i.e. patched) independently

Sub-Package Extraction

- Load the image to be extracted in a directory on the cBR-8 bootflash
- Extract using **`request platform software package expand file`**
- Along with the sub-packages a **`packages.conf`** and a descriptive .conf file (ex: **`cbrsup-packages-universalk9.03.18.01.S.156-2.S1-ext.conf`**) are created in the directory
- Boot commands point to one of these .conf files instead of the .bin file

```
cBR-8#request platform software package expand file bootflash:cbrsup-
universalk9.03.18.01.S.156-2.S1-std.SPA.bin to bootflash:/XE3181 wipe
Tue May 31 20:24:43 edt 2016 Verifying parameters
Tue May 31 20:24:43 edt 2016 Validating package type
Tue May 31 20:25:15 edt 2016 Copying package files
Tue May 31 20:26:49 edt 2016 SUCCESS: Finished expanding all-in-one software
package.
```

cBR-8 Patch-ability Updates

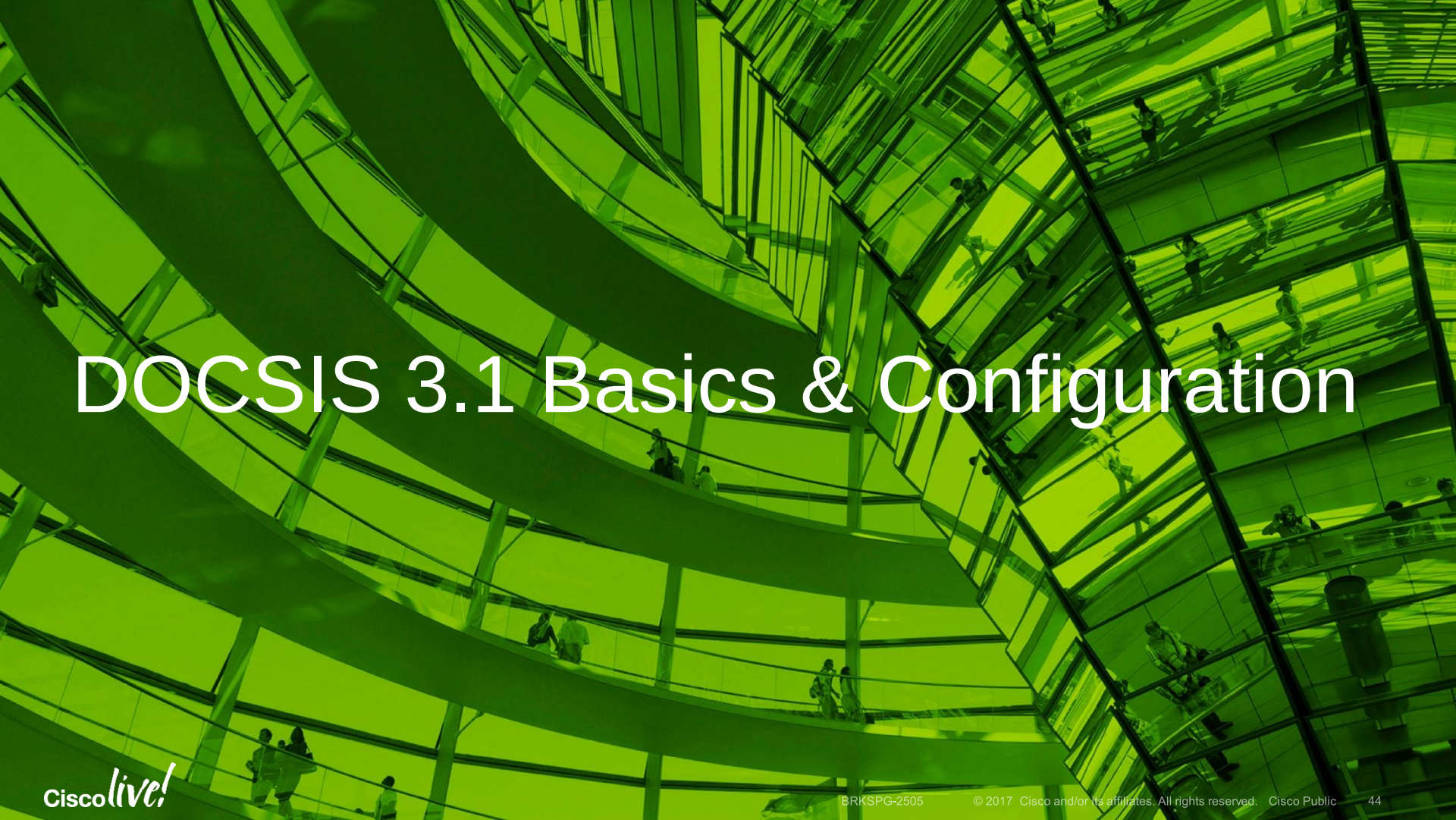
- Focus
  - Minimize code changes needed to pick up specific bug fixes
- Patching ability at sub-package level
  - Software architecture supports running different versions of sub-packages together
  - Key sub-packages include IOSd-RP, IOSd-CLC, LC Scheduler
  - Enables faster qualification in smaller code packages
  - Simplified one-shot CLI approach for operational simplicity and consistency
- Additional considerations for patching
  - Support focused on typical bug fixes with no inter-module message changes
  - Non-restartable sub-packages require corresponding HW module reload
  - Patches specific to a major / minor release (i.e. specific to “rebuild”)

Patching in Sub-Package Mode

- System MUST be booted in Sub-Package Mode
- Copy patch tar file to the same directory as sub-packages
- The **`request platform software package install node`** … command will update the system .conf file to point to new version of the package
  - Add the **`noreload linecard`** option if upgrading LCs via process restart
- Supervisor based package upgrade via ISSU (starting in 3.16)
- Cable LC based package upgrades require either reboot of LC or Process Restart (**`request platform software process restart`**)
- Process Restart support for some packages:
  - IOS (3.16), CDMAN (US Scheduler) (3.17), Video (3.18), Enhancements in 3.18SP

cBR-8 In-Service Software Upgrade (ISSU)

- Rebuild to rebuild software upgrades (e.g. 3.18.0 to 3.18.1)
- Sequential Supervisor and N+1 linecard ISSU upgrades
- One-shot ISSU with single CLI with minimal user intervention and monitoring
  `request platform software package install node` …
- Supported with both consolidated and sub-package mode
- Rollback capability support
- Supervisor patches utilize SUP-only ISSU

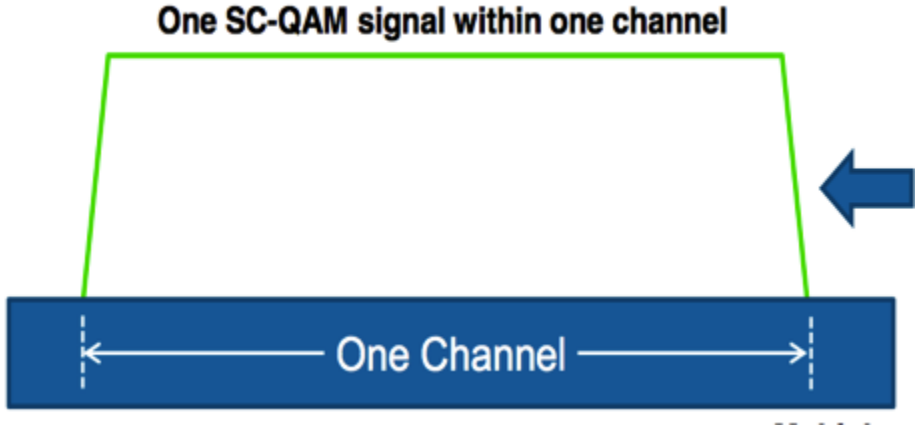


DOCSIS 3.1 Basics & Configuration

Why DOCSIS 3.1?

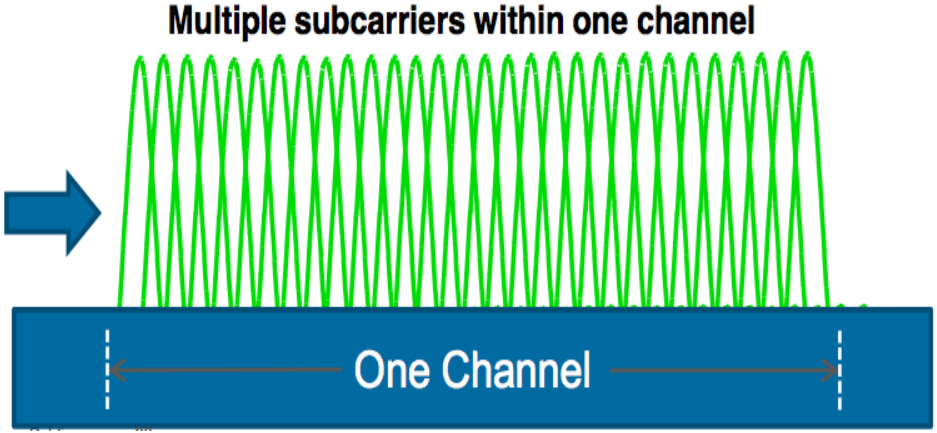
- Goals
  - D3.1 enables services competitive with FTTH
  - Achieve 8+ Gbps in the DS
  - Achieve 1+ Gbps in the US
  - Better spectral efficiency
  - Backwards compatible with DOCSIS 3.0, 2.0, & 1.1
  - Will work without changes to HFC
- Technology
  - OFDM, OFDMA, LDPC
  - New DS and US spectrum
 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

Orthogonal Frequency Division Multiplexing

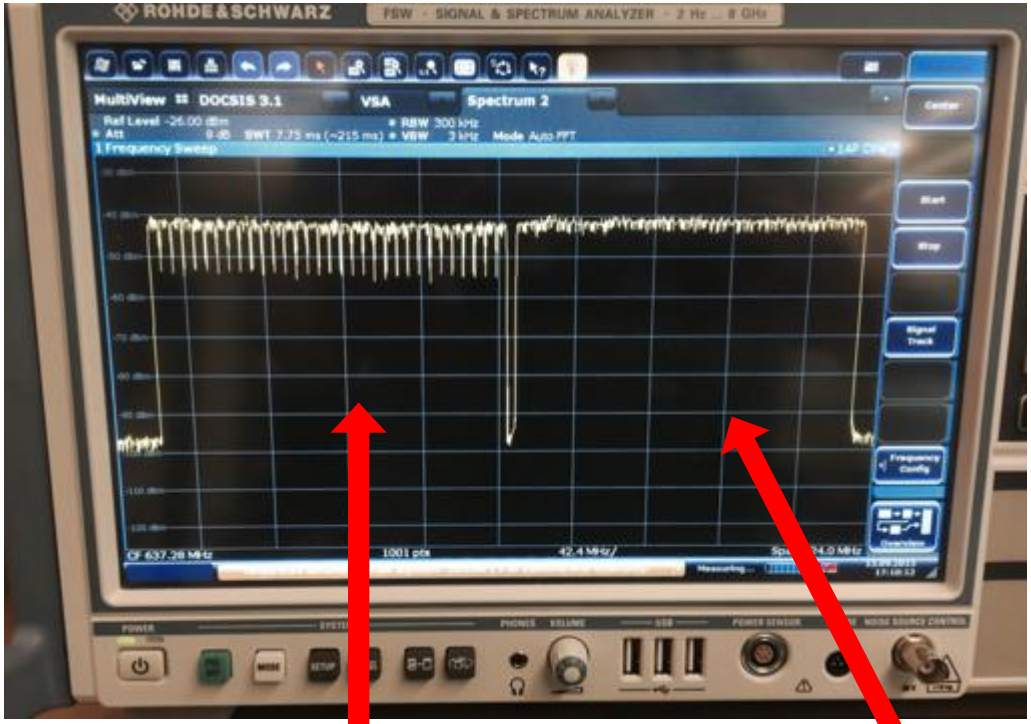


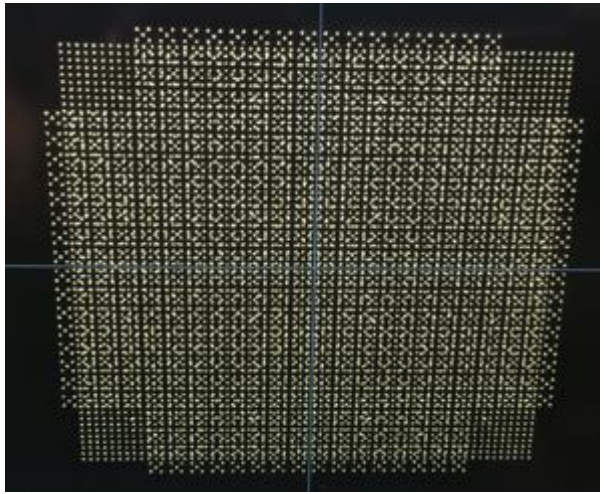
- 6 MHz / 8 MHz wide downstream channel slots can each accommodate one SC-QAM signal
- Symbols sent sequentially at fast symbol rate

- 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





Increased Orders of Modulation
1024, 2048, 4096 QAM

Modulation can vary by subcarrier

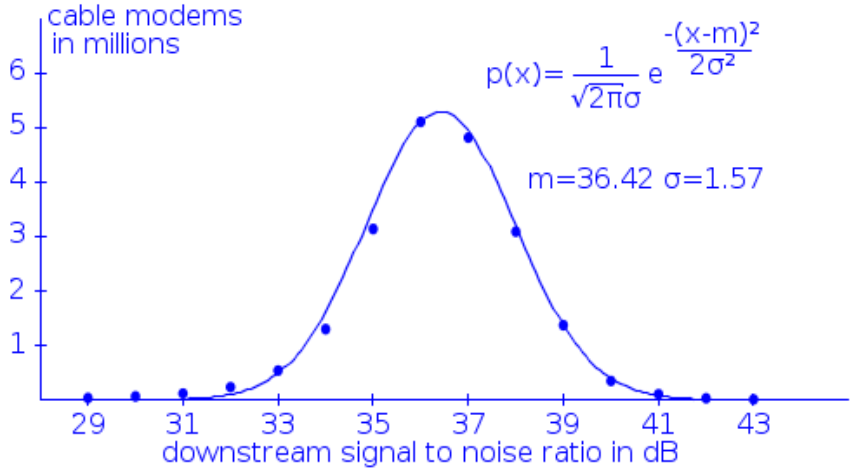
Modulation can vary by modem

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

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

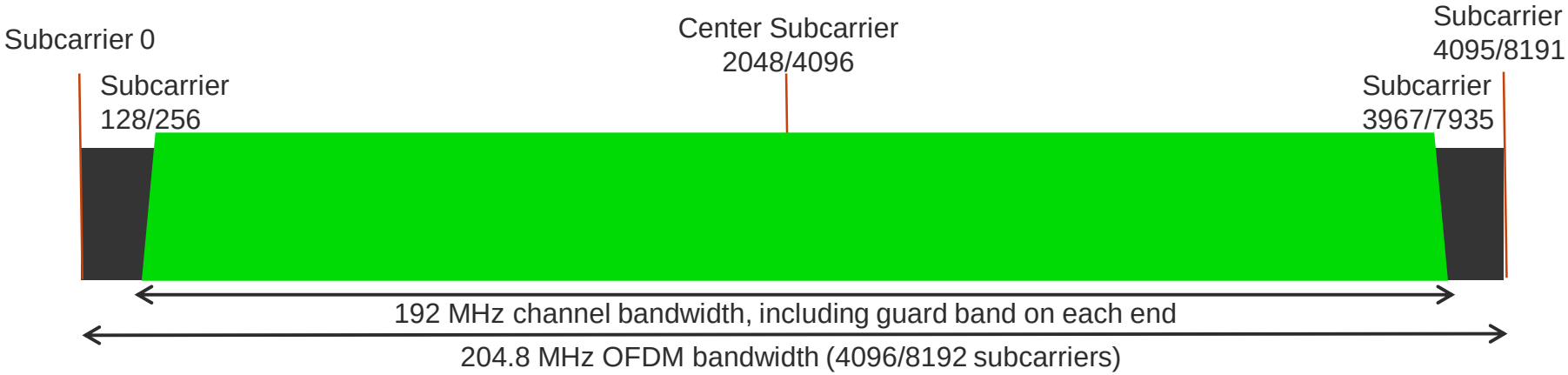
Downstream Data Profiles

- A profile defines the modulation for each subcarrier
- The HFC plant has at least an 8 dB variation in CNR across the plant
- Multiple downstream profiles could enable operators to leverage SNR variation to improve system capacity
- An example with four profiles:
  - A: Worst (mostly 256-QAM)
  - B: Average (mostly 1K-QAM)
  - C: Better (mostly 2K-QAM)
  - D: Best (mostly 4K-QAM)



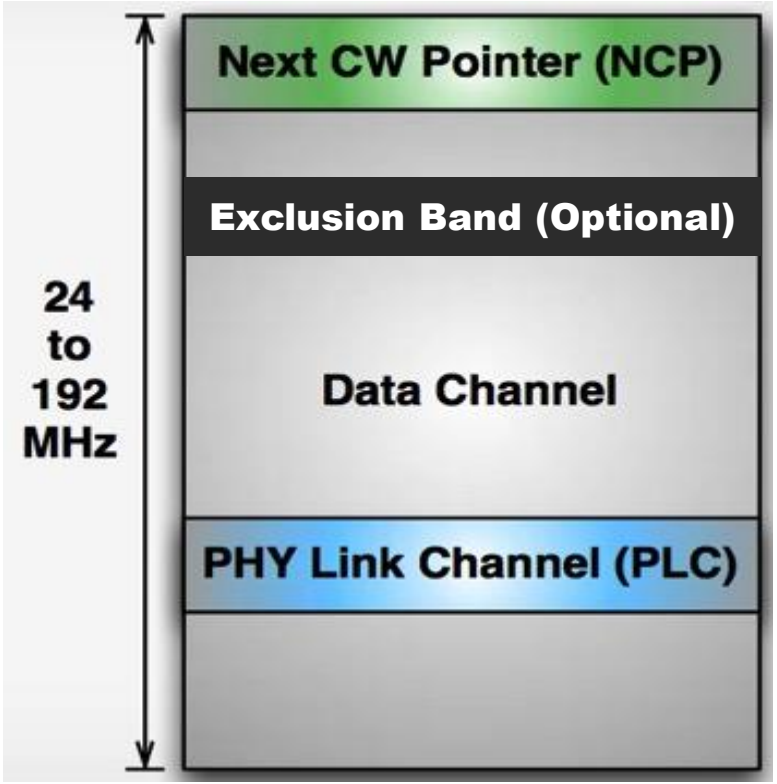
OFDM Basics & Fast Fourier Transforms (FFT)

- 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



OFDM Channel Components

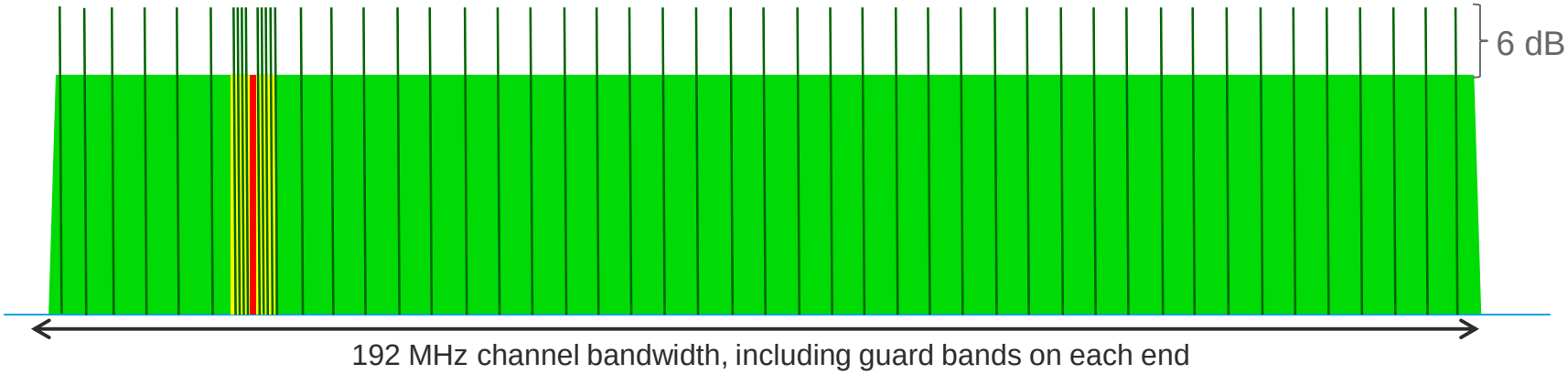
Pre-Interleaver View



- Pilots (2 Types)
  - Continuous (NOT Interleaved)
  - Scattered (Interleaved)
- Data Channel (Interleaved)
  - All data packets and operational MMM
  - Broken into codewords
- Next Codeword Pointers (Interleaved)
  - Use for locating FEC codewords and assigning profiles
- PHY Link Channel (NOT Interleaved)
  - Used for booting CMs, timestamps, energy management
- Exclusion Bands (Optional - NOT Interleaved)

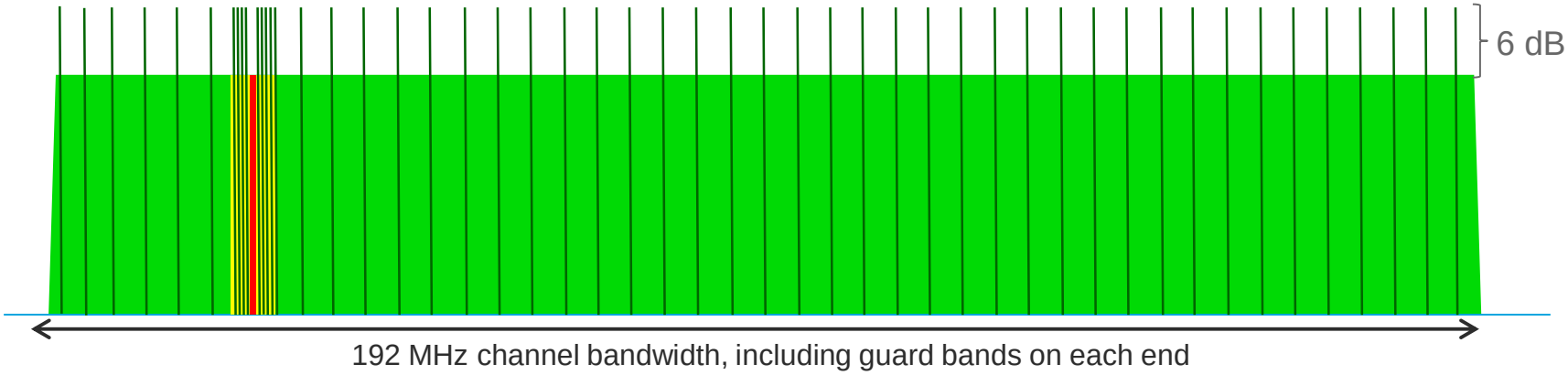
Continuous Pilots

- 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



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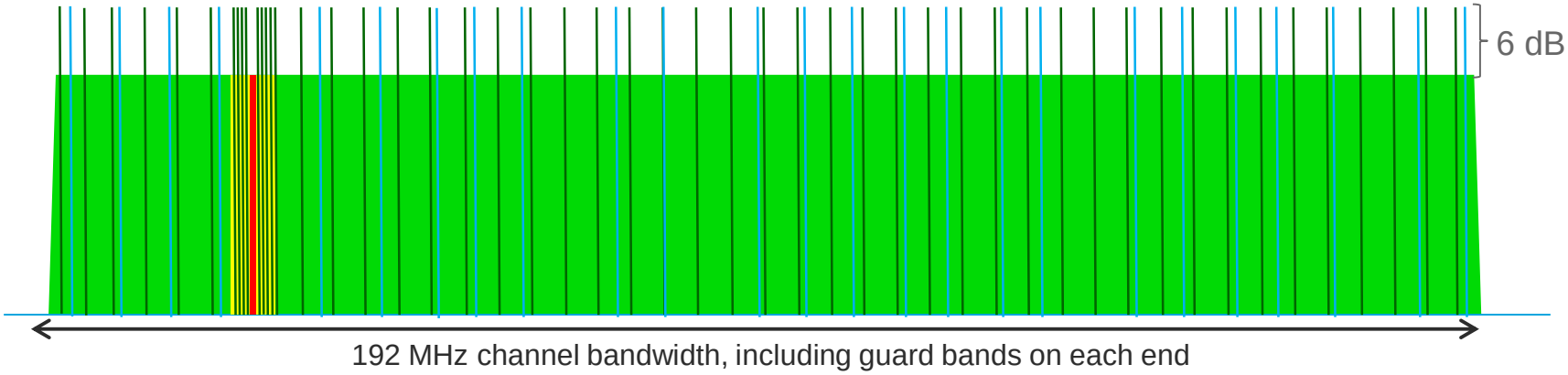

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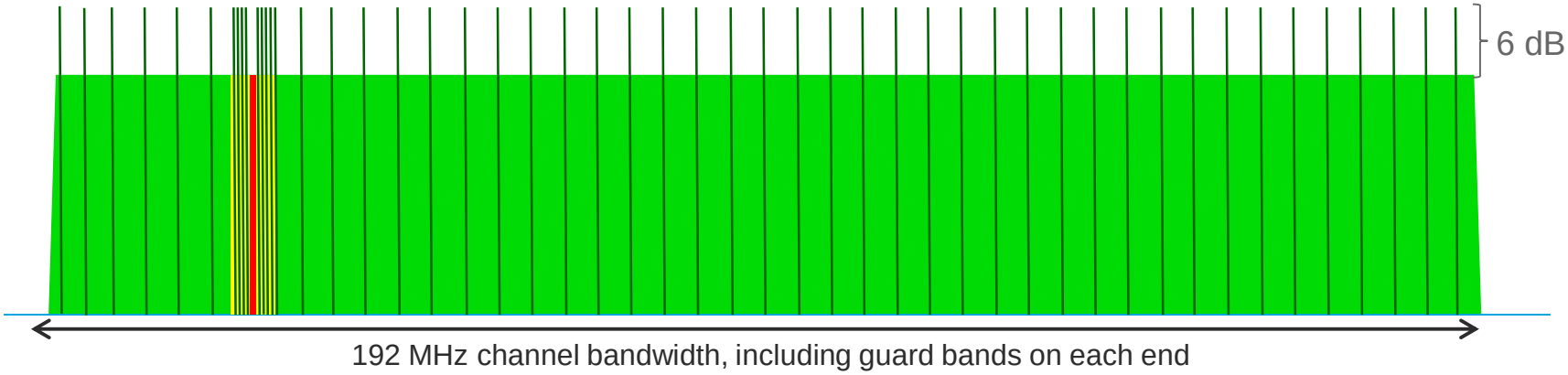

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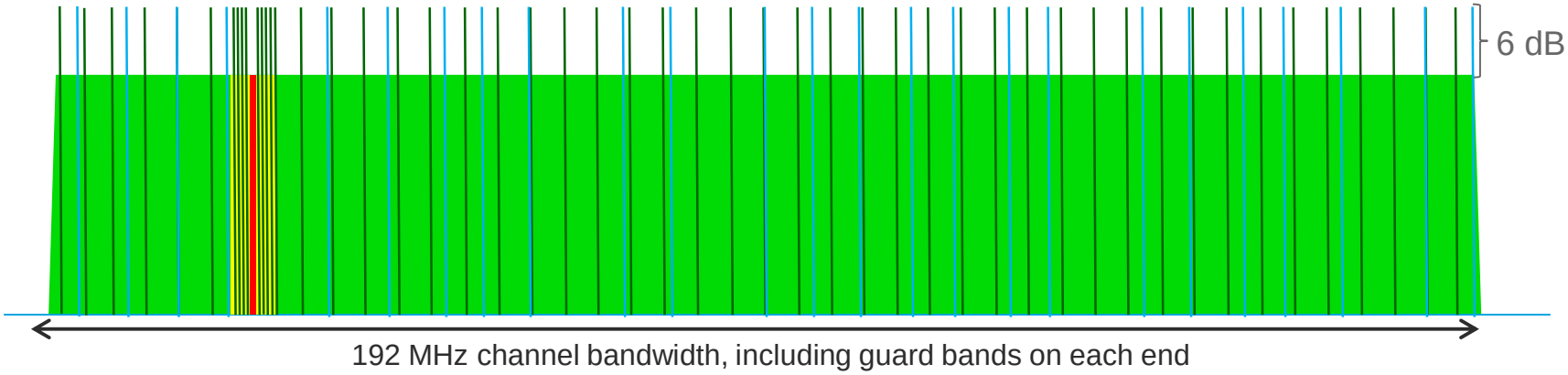
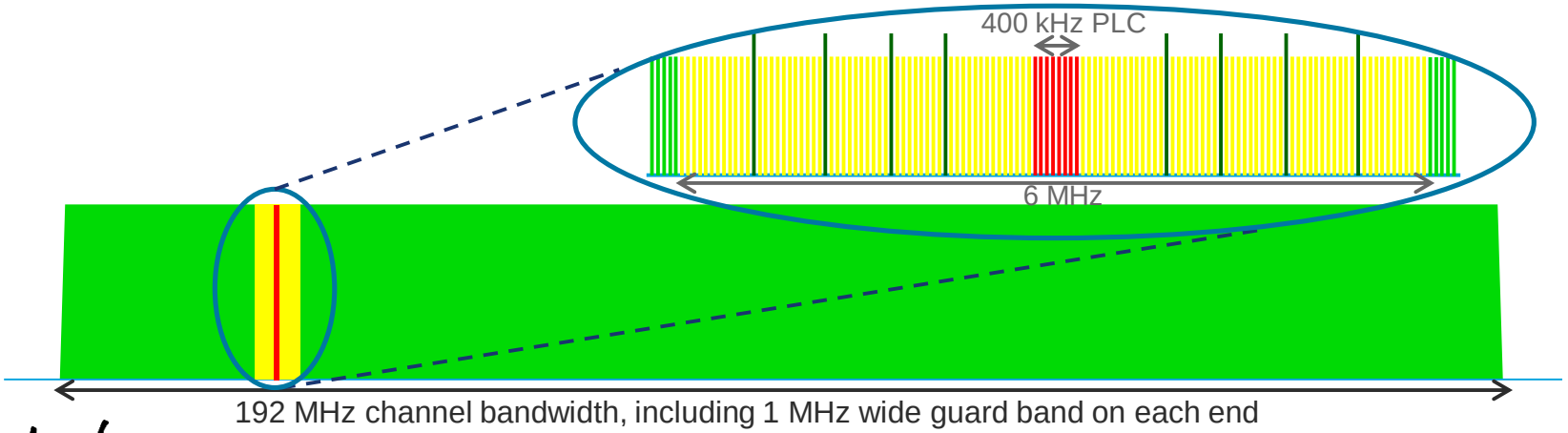


PHY Link Channel (PLC)

- 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

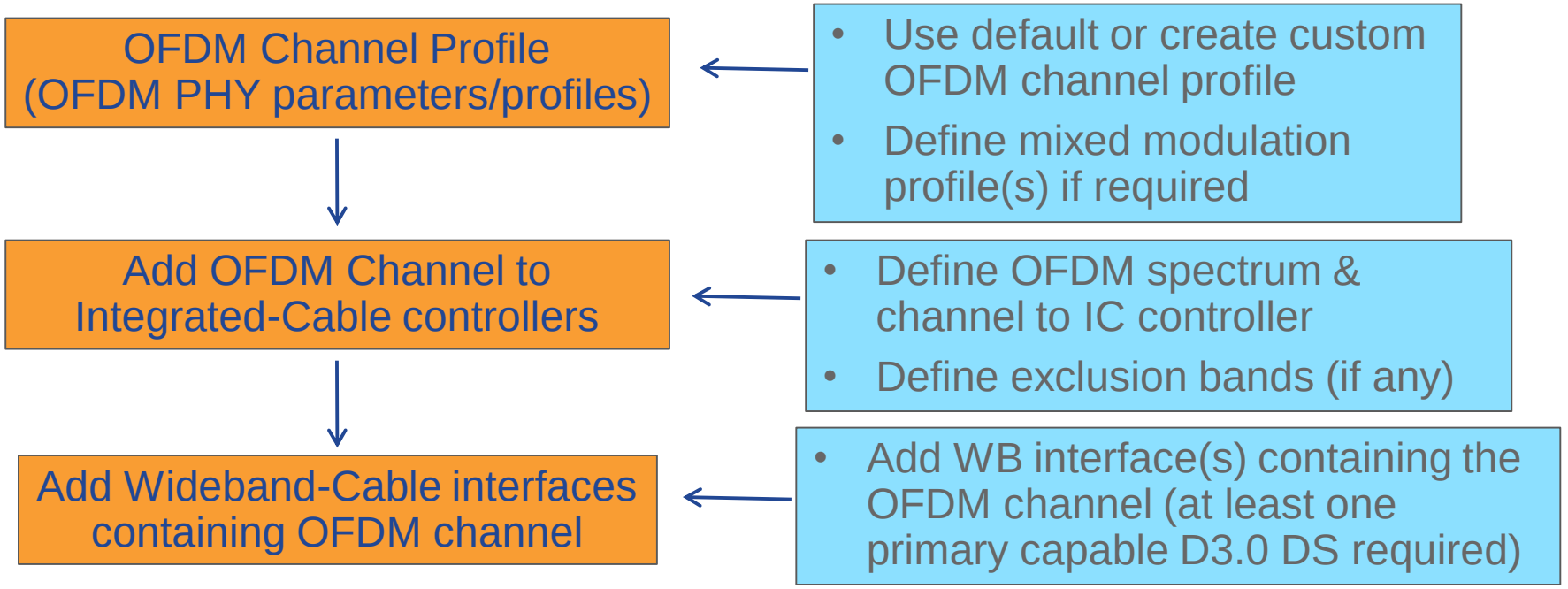

```
cbr8#show inventory
NAME: "CLC Downstream PHY Module 3/0", DESCR: "Cable
PHY Module"
PID: CBR-D31-DS-MOD     , VID: V01 , SN: CAT1915E0F4

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 30016, sector(1 base) 2, apollo ver 44147, sector(0 base) 2
micro ver 30016, sector(1 base) 2, apollo ver 44147, 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; if not primary no modifications to Cable interfaces or additional Integrated-Cable interfaces needed

OFDM Channel Profiles

```
cable downstream ofdm-chan-profile 102
  cyclic-prefix 192
  interleaver-depth 16
  pilot-scaling 48
  roll-off 128
  subcarrier-spacing 50KHZ
  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
```

*** Red font indicates non-default values

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

Profile 1 or Profile B
Default data profile used for all modems

Profile 2(C), 3(D), 4(E), & 5(F)
More aggressive data profiles
CMTS can promote modems to these profiles based on RxMER or can be statically assigned via CLI

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

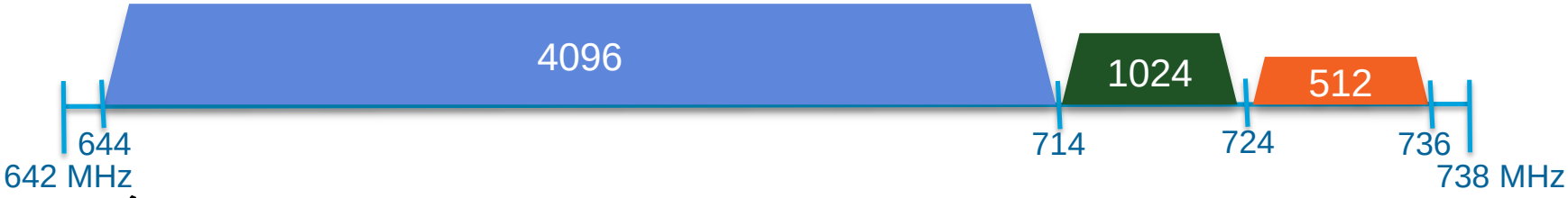
Note: On cBR-8 use the CLI: **`show cable ofdm-rxmer-qam-bl-table`**

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
```



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

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

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
```

…

Wideband-Cable Interface Configuration

- OFDM channels cannot be used as a primary channel until 16.5.1
  - If not primary there is no need to configure the OFDM channel under the Cable interface nor is there any Integrated-Cable interface configuration for the OFDM channel
- Wideband-Cable interface configuration is required; which consists of the OFDM channel and 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
 load-interval 30
 cable bundle 10
 cable rf-channels channel-list 0-23 158 bandwidth-percent 1
```

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 but more testing to date with 50 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**

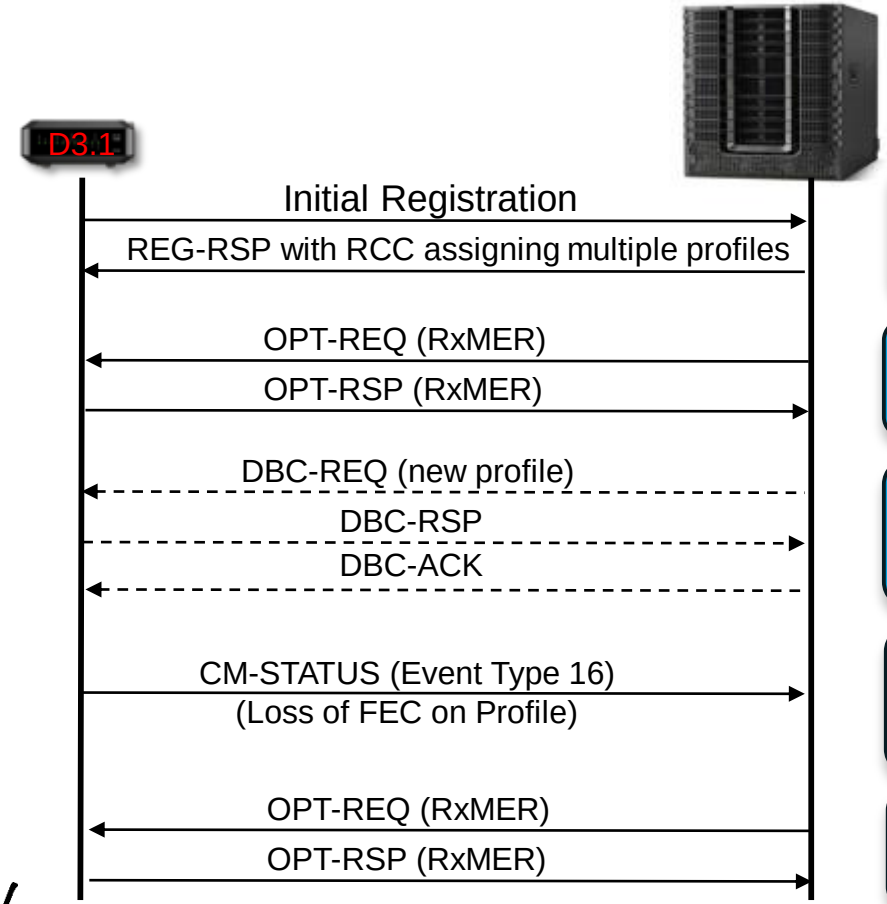
Optimize roll-off for channels under 96 MHz

Assumes all subcarriers using same modulation order

* ***50 kHz subcarriers***, *1.350 MHz guard bands, roll-off 192, cyclic prefix 256, 2 x NCP (64 QAM)*

** ***50 kHz subcarriers***, *1.900 MHz guard bands, roll-off 128, cyclic prefix 192, 2 x NCP (64 QAM)*

OFDM Data Profile Assignment Logic



New modem; assign up to 4 profiles and use the robust profile (Profile 1/B) 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

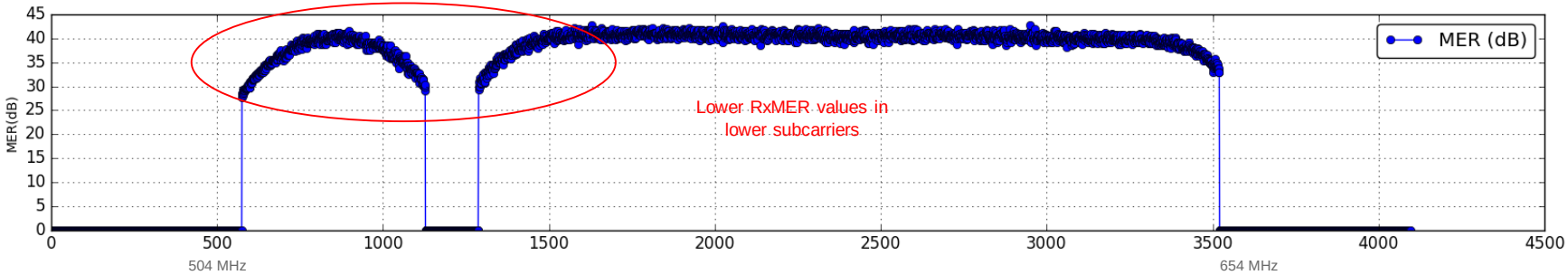
Collect RxMER data for all sub-carriers and switch to recommended profile

OFDM Profile Management Settings

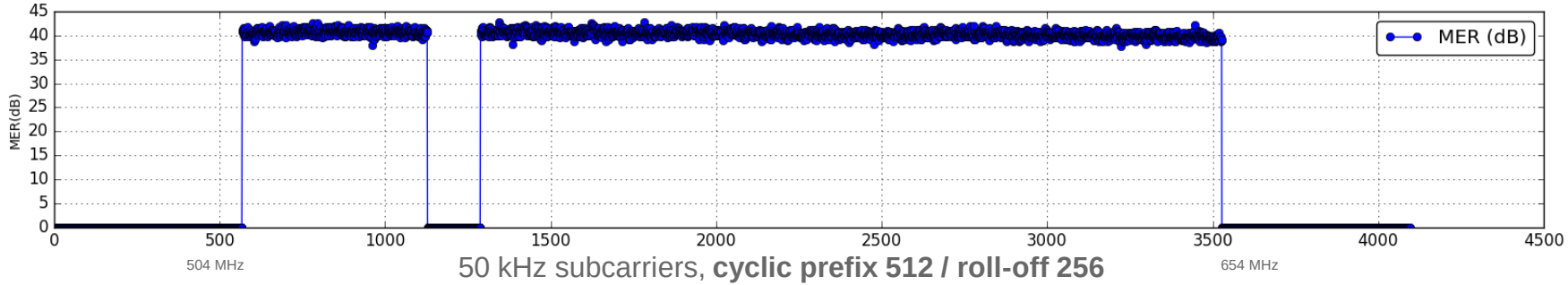
- **`cable downstream ofdm-prof-mgmt prof-dwngrd-auto`**
  - Allow automatic profile downgrades after a profile declared unfit (default on)
- **`cable downstream ofdm-prof-mgmt rxmer-poll-interval`**
  - Period of RxMER polling (default 60 mins)
- **`cable downstream ofdm-prof-mgmt exempt-sc-pct`**
  - 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

Cyclic Prefix Impact

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



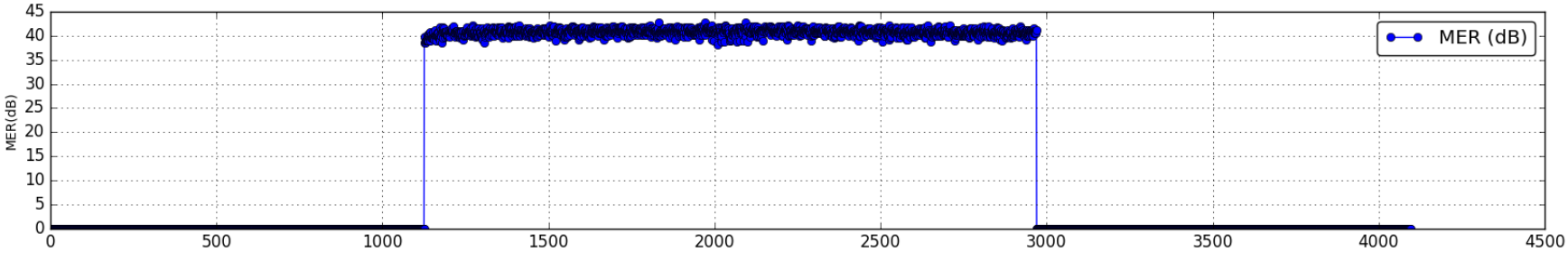
50 kHz subcarriers, **cyclic prefix 192 / roll-off 128**
Channel speed 1342 Mbps @ 4096-QAM (1230 Mbps @ 2048-QAM)



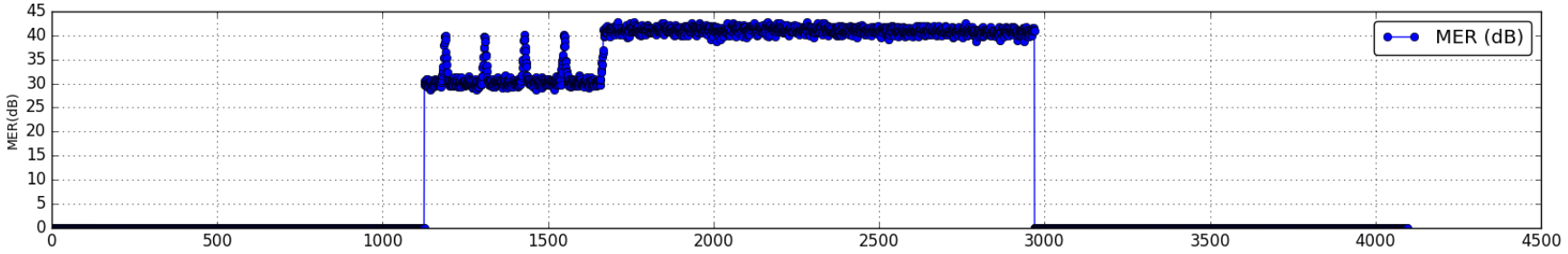
50 kHz subcarriers, **cyclic prefix 512 / roll-off 256**
Channel speed 1265 Mbps @ 4096-QAM

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)



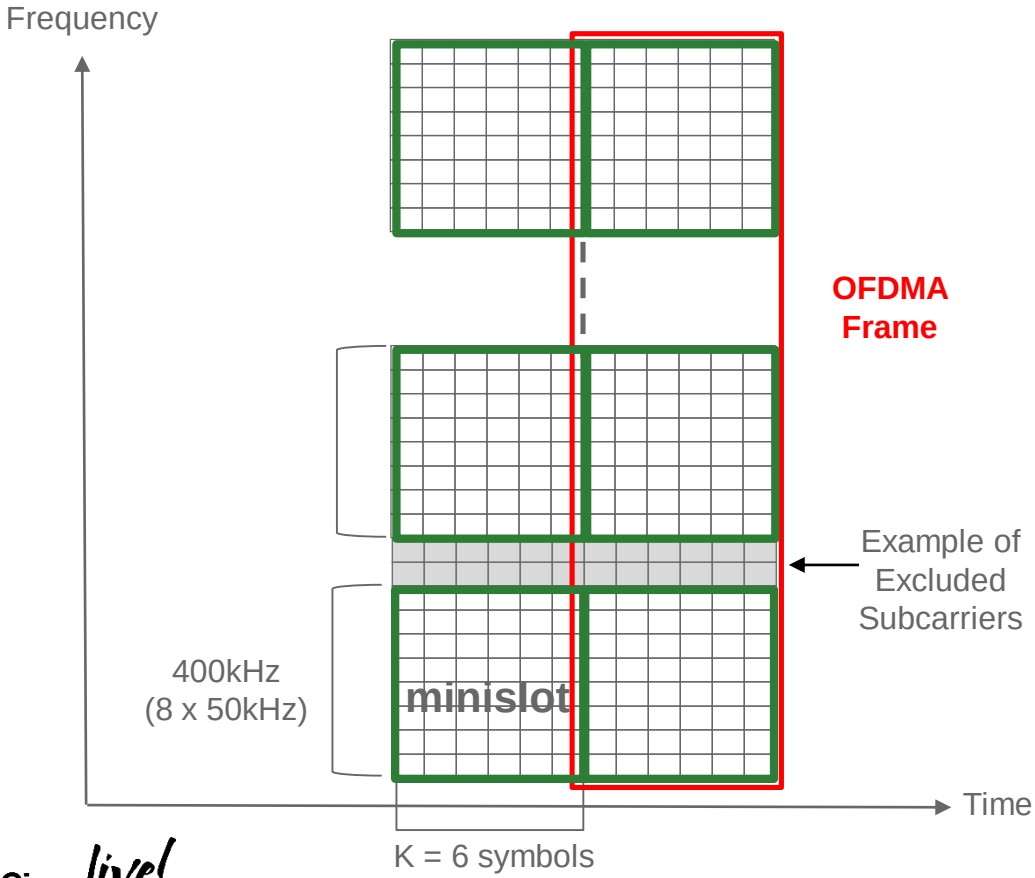
Same 96 MHz OFDM channel (now with 30 MHz interference) still running 4096-QAM no uncorrectable FEC codewords
(cBR8 would recommend 256-QAM profile by default)

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
- US spectrum divided into groups of sub-carriers called minislots
- No excluded subcarriers within a minislot
- Pilots & Complementary Pilots for synchronization & channel estimation

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

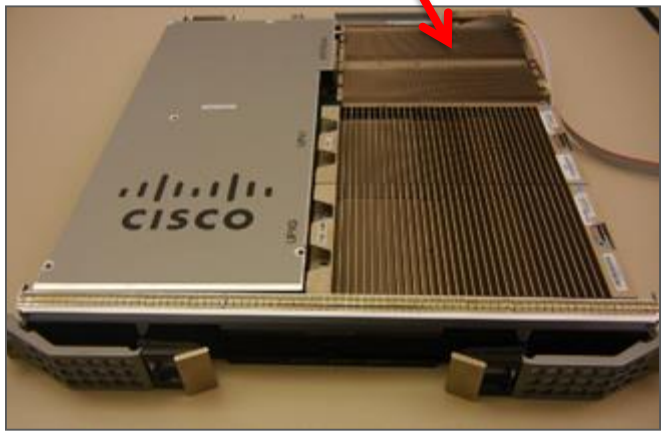
OFDMA Data Transmission

- 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)

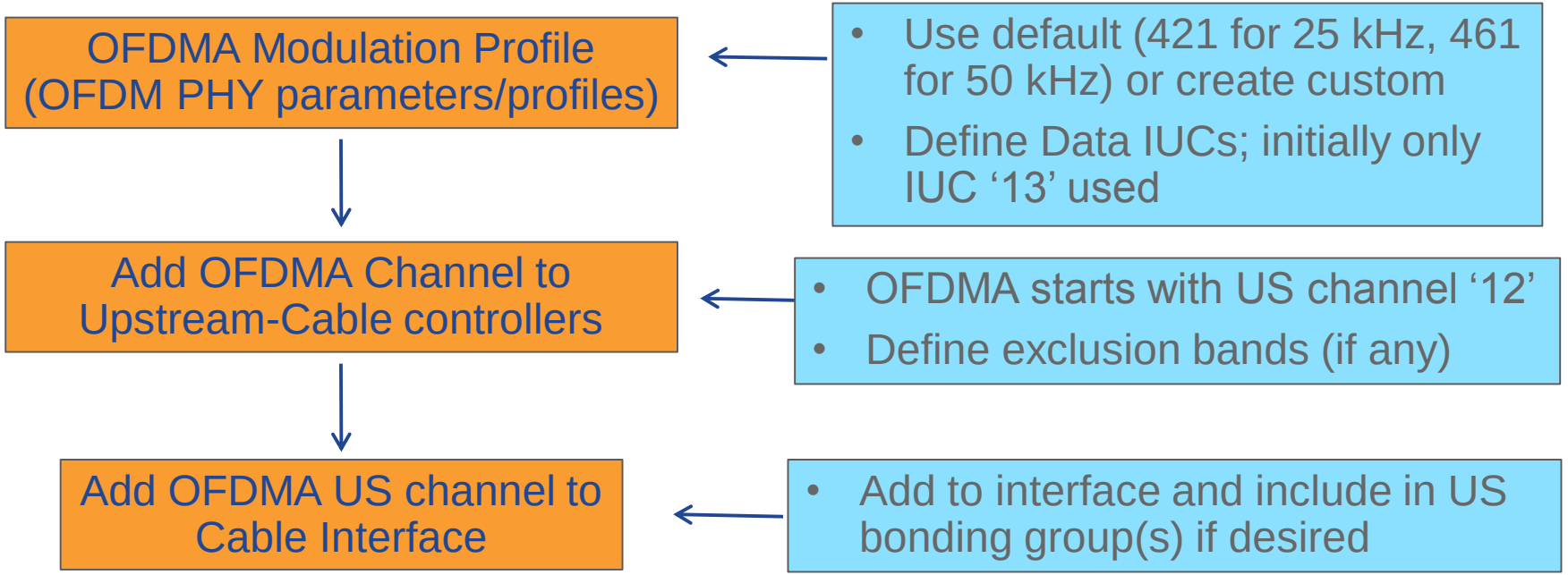
```
cbr8#show inventory
NAME: "CLC Upstream PHY Module 0/2", DESCR: "Cable
PHY Module"
PID: CBR-D31-US-MOD     , VID: V01 , SN: CAT1915E0F4
```



Planned 16.6.1 Support

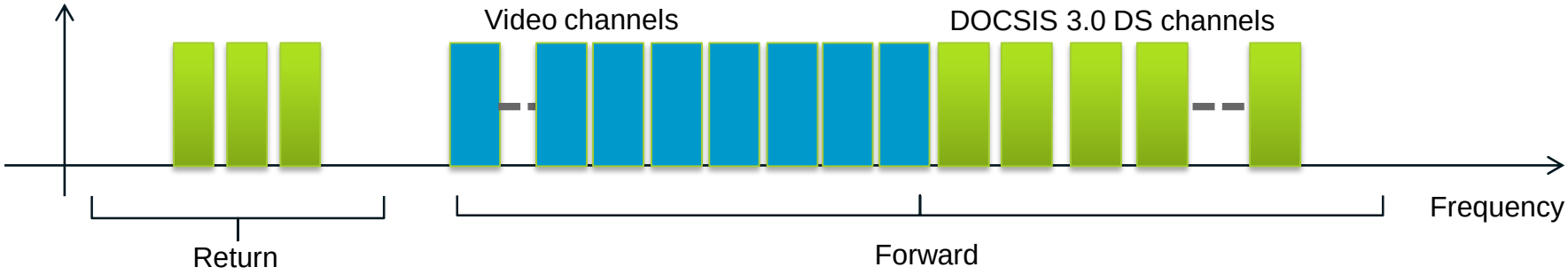
- 1 OFDMA channel/port (5-85 MHz)
- 4 SC-QAM + 1 OFDMA bonding
- 7 Mod profiles (IUCs) per channel
- 3 Mod zones per OFDMA channel
- Dynamic Profile Selection

DOCSIS 3.1 US Configuration Flowchart



DOCSIS 3.1 Insertion Strategy

DOCSIS 3.1 Migration



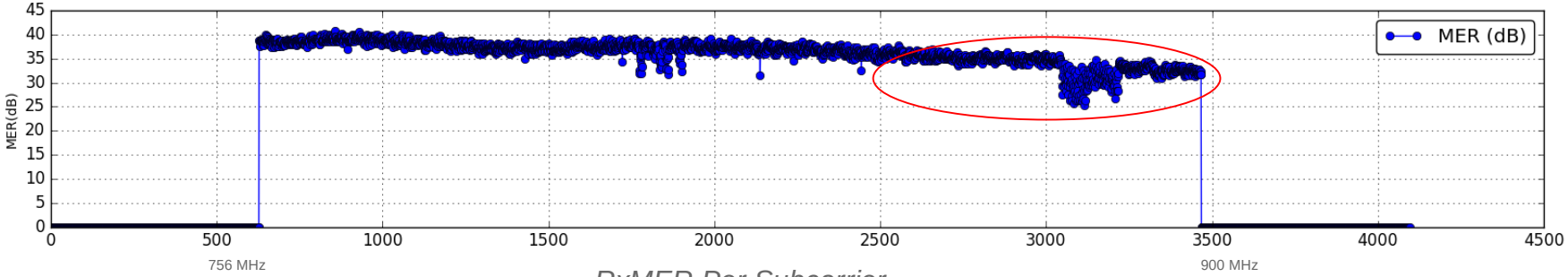
- Need clear downstream spectrum for D3.1 (24 MHz minimum)
- D3.1 modem will have 32 DS x 8 US plus two 192 MHz OFDM blocks in DS and two 96 MHz OFDMA blocks in US
- Still retain D3.0 downstream channels and **ADD** OFDM capacity
- D3.1 modems can use **BOTH** 3.0 and 3.1 channels for higher speeds

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

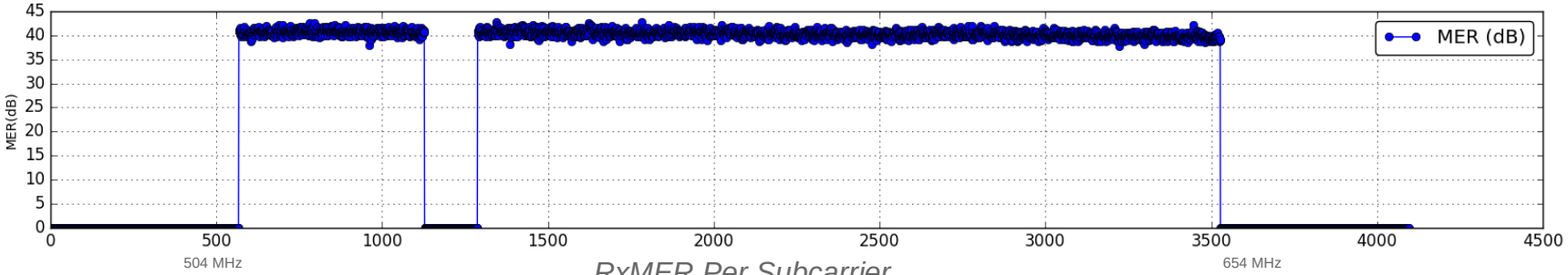
Target Capacity In Roll-Off Spectrum



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



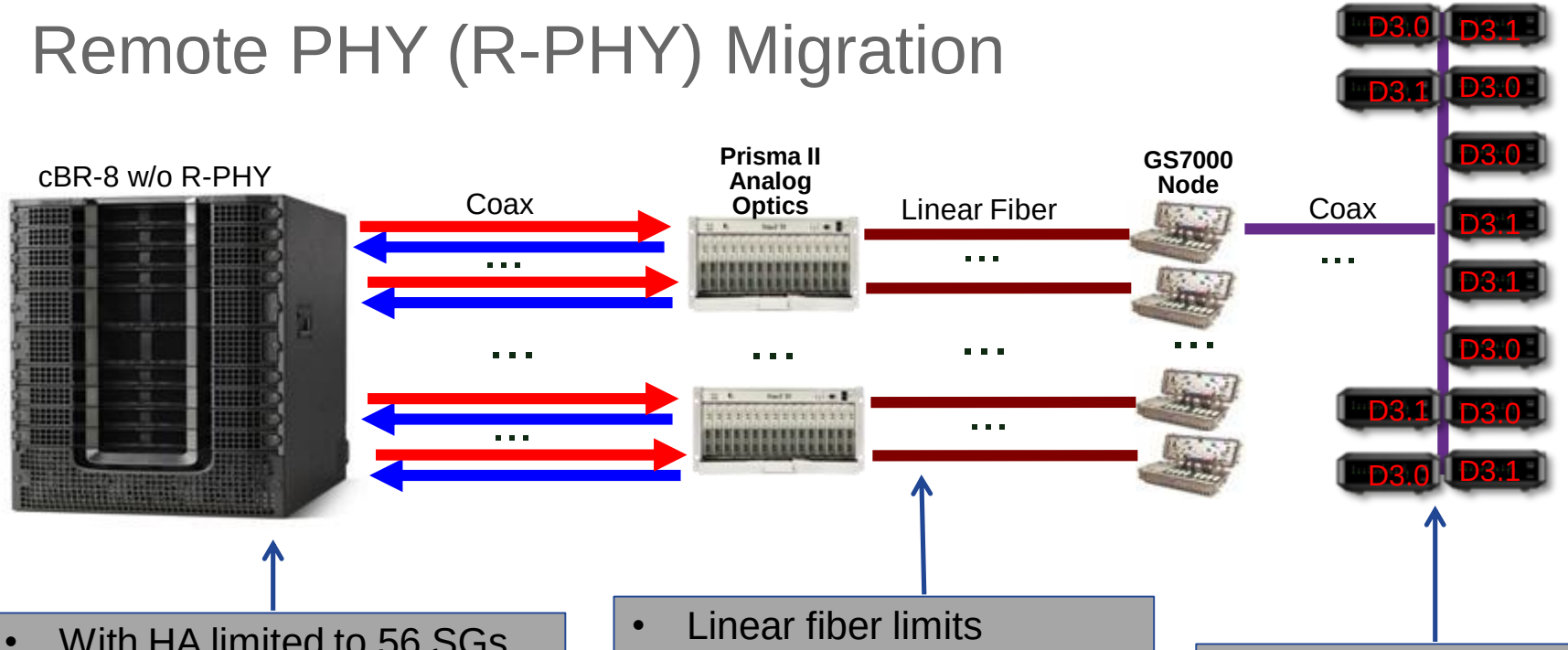
RxMER Per Subcarrier

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 require an exclusion band around a pilot channel
- D3.1 modem can now reliably run 4096-QAM

Glimpse into Remote PHY

Remote PHY (R-PHY) Migration

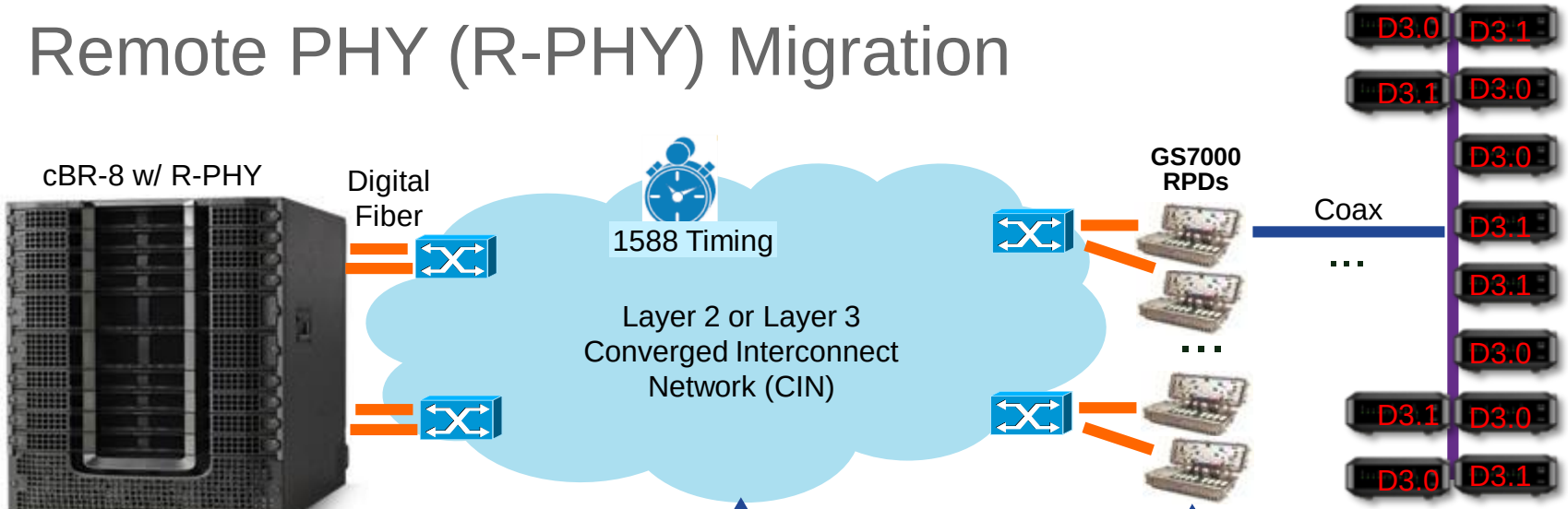


- With HA limited to 56 SGs due to limit of 56 DS ports and 112 US ports

- 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) Migration



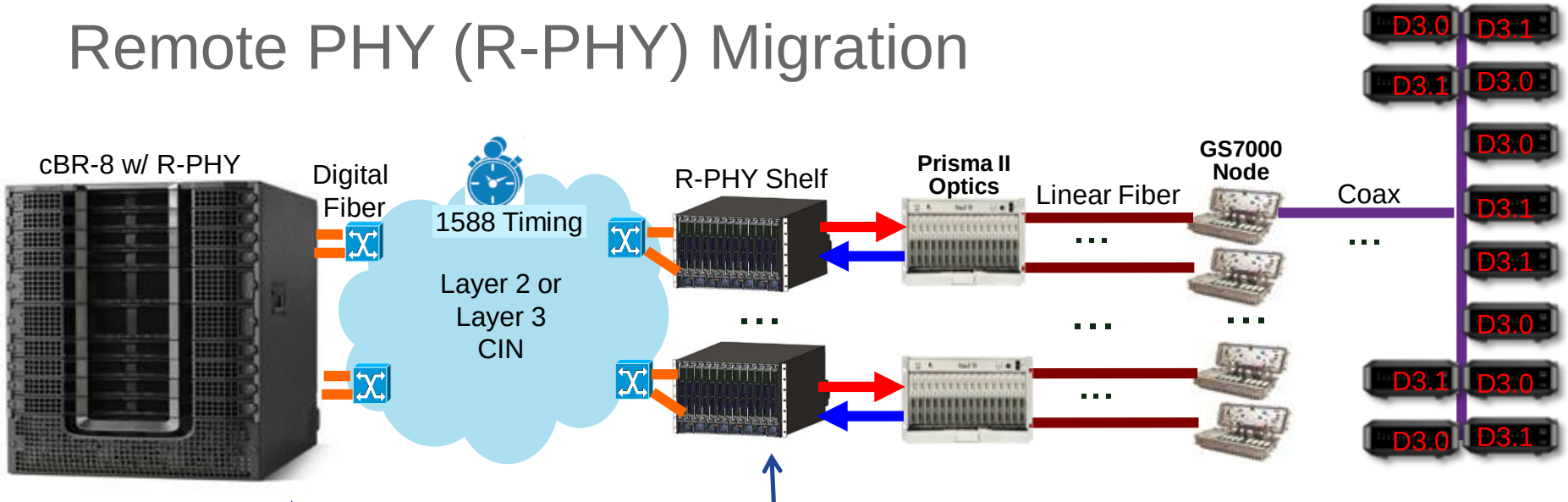
- cBR-8 RF PICs replaced with digital optics PICs (i.e. 10GE)
- No longer port constrained (can grow to 2x – 4x number of SGs)

- 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

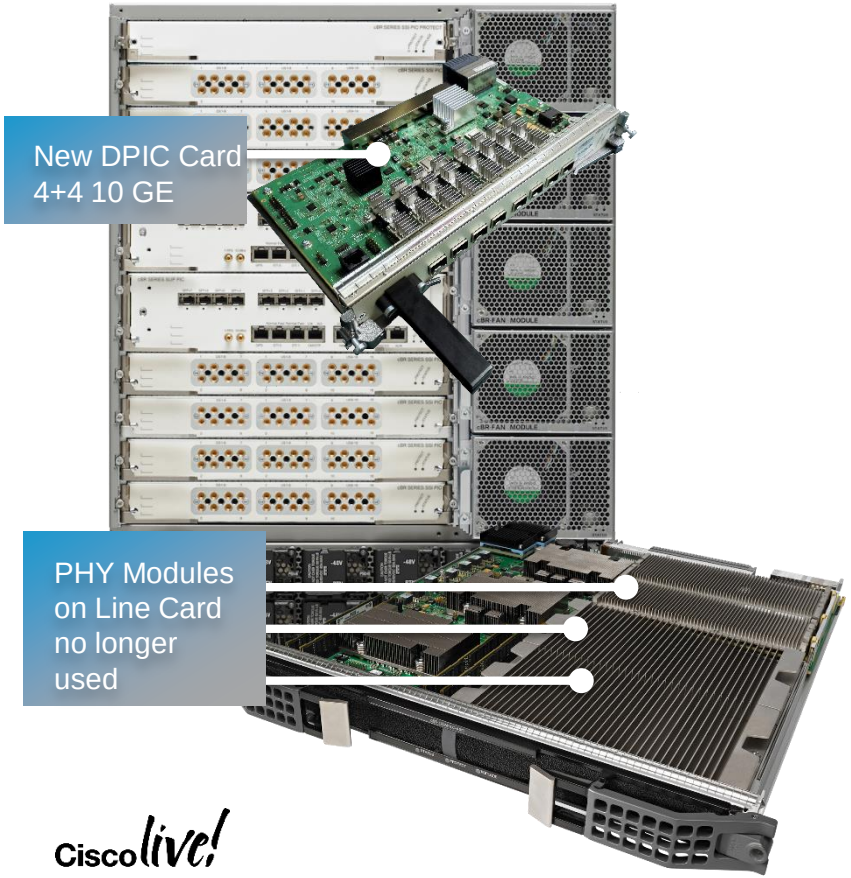
Remote PHY (R-PHY) Migration



- 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 – 1 RU, 6x12, No HA

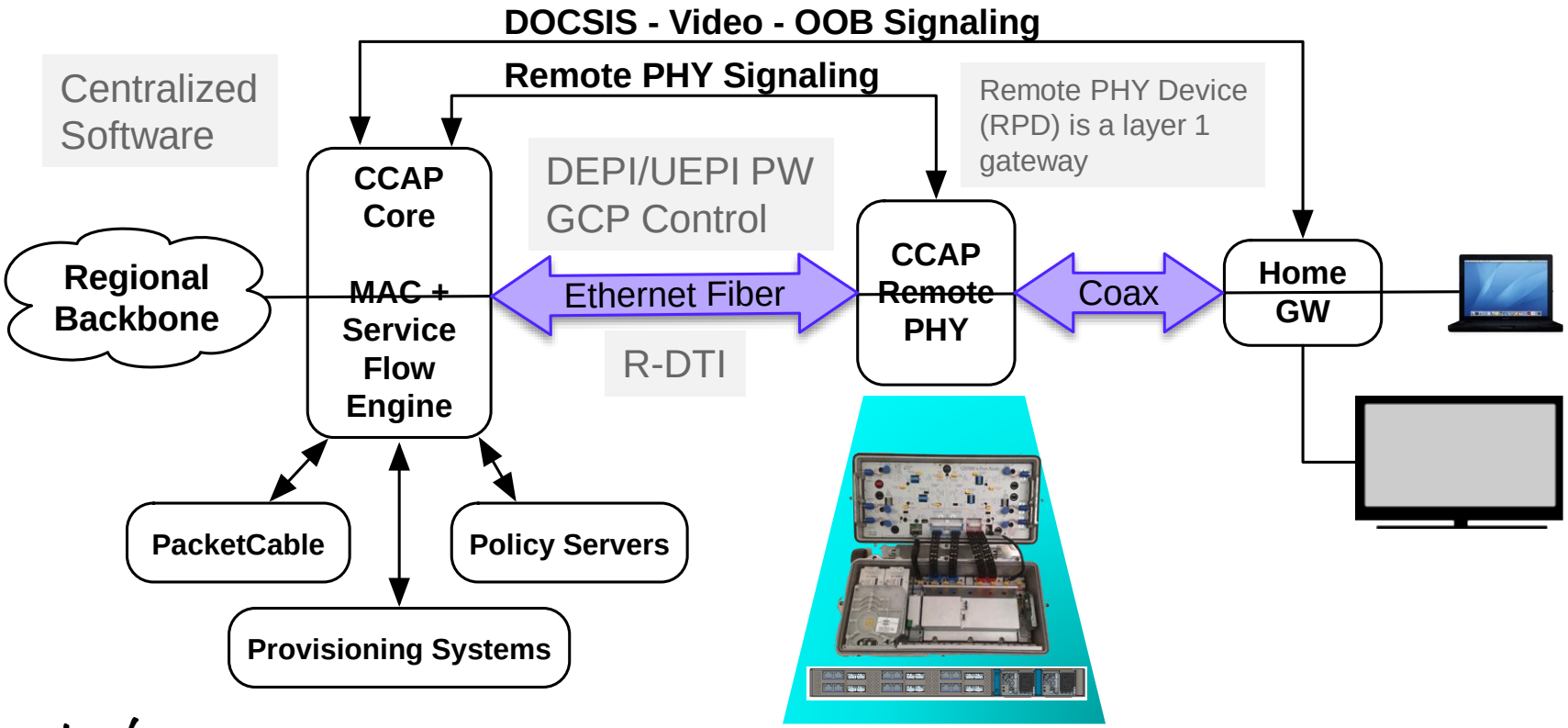
cBR-8 Remote PHY PIC (Digital PIC)



- Replace RF PIC for R-PHY operation
  - CBR-DPIC-8x10G
- Works with existing CCAP Line Card or new R-PHY CCAP LC w/o PHY modules
- 8x10G SFP+ per DPIC with 40G+40G
  - 4 active links to CIN
  - 4 redundant links to CIN (future)
- Used with active & standby CCAP LCs (no special Protect DPIC)
  - All DPICs connected to CIN
  - For LC failover switching performed in CIN

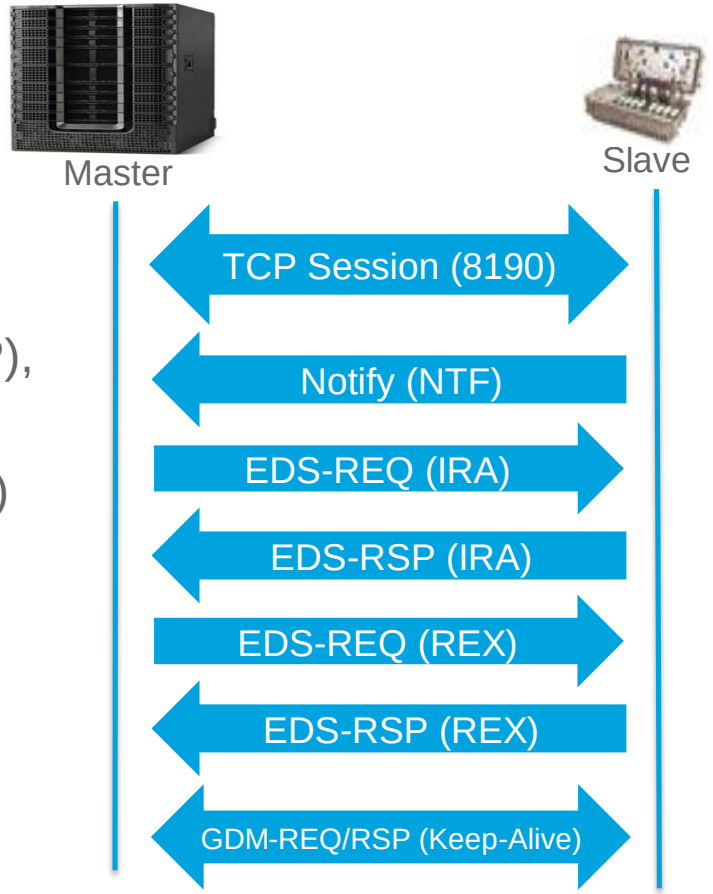
Remote PHY Architecture

Modular Headend Architecture version 2 (MHAv2)



Generic Control Plane (GCP)

- Imitates major functionality existing over a HW bus between CPU and peripheral chip (i.e. 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:
  Identification and Resource Advertising (IRA), RCP Object Exchange (REX), Notification (NTF)
- Messages consist of a series of TLVs leveraging existing specs (i.e. DOCSIS MULPI)



Downstream External PHY Interface (DEPI)

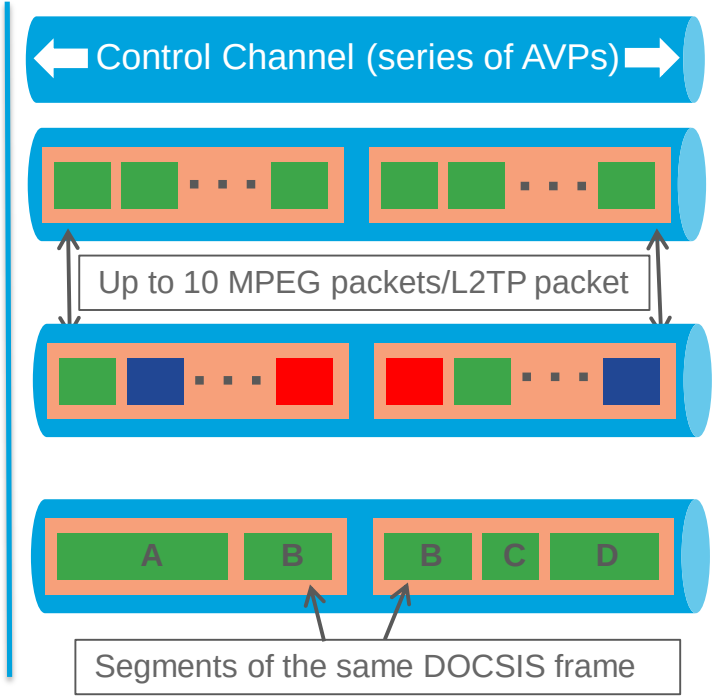
DS MAC

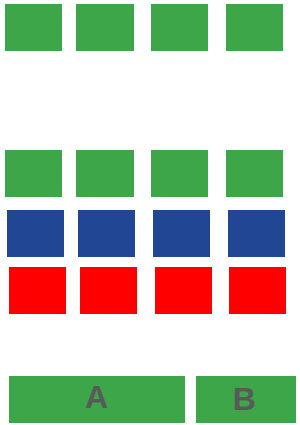
DS PHY

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

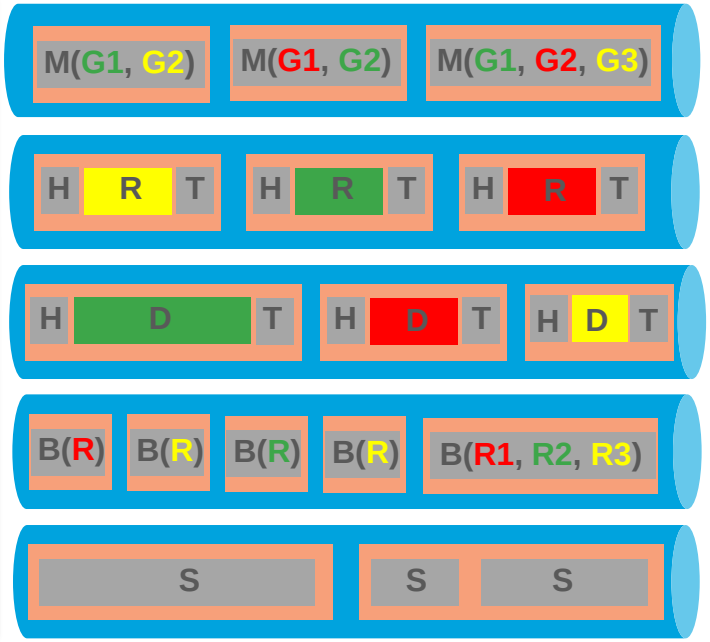
Upstream External PHY Interface (UEPI)

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

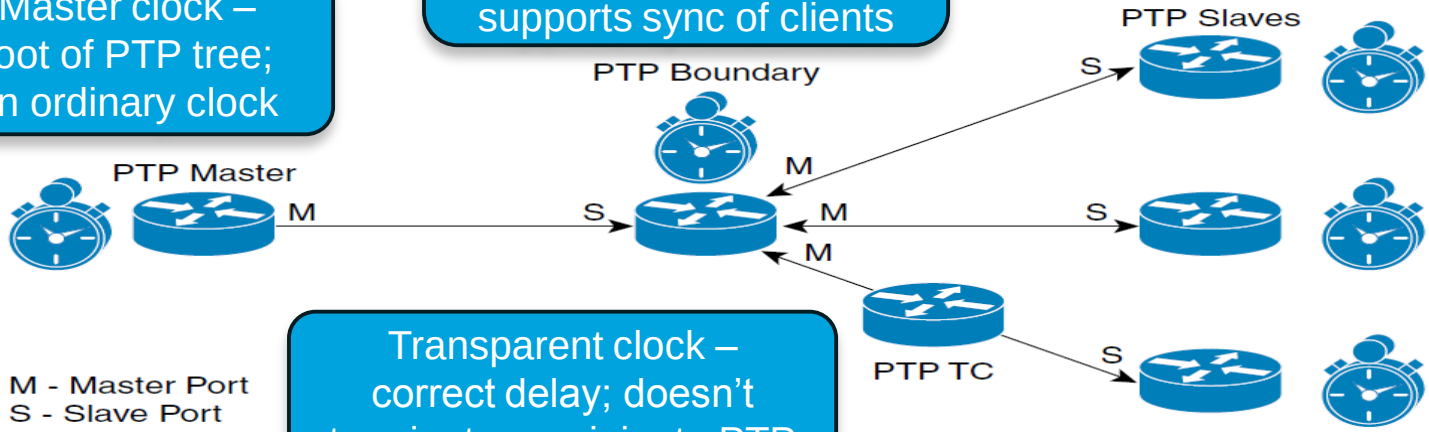
OOB also use UEPI PWs

Remote DOCSIS Timing Interface – R-DTI

- 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

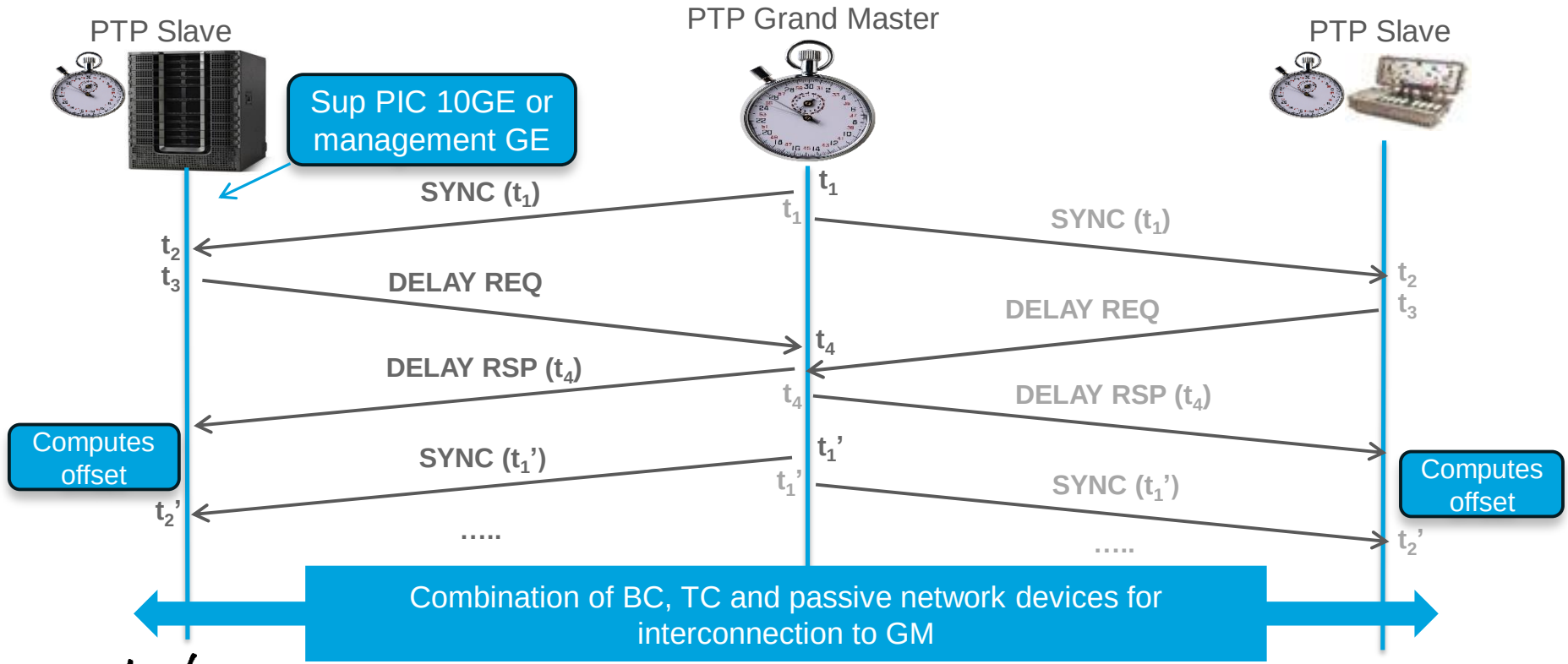
Master clock – root of PTP tree; an ordinary clock



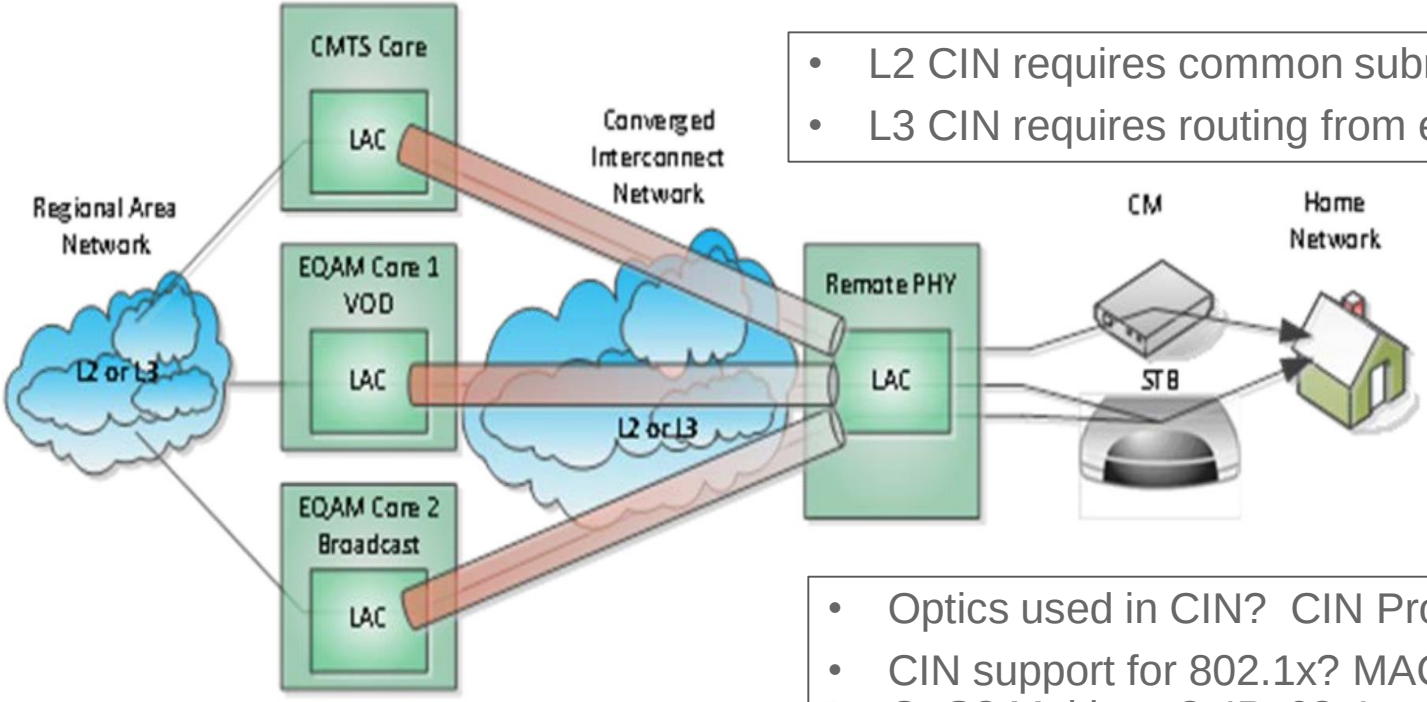
Slave clock – ordinary clock that relies on a master clock for sync

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

Timing Option – cBR-8 as PTP Slave



R-PHY Converged Interconnect Network (CIN)

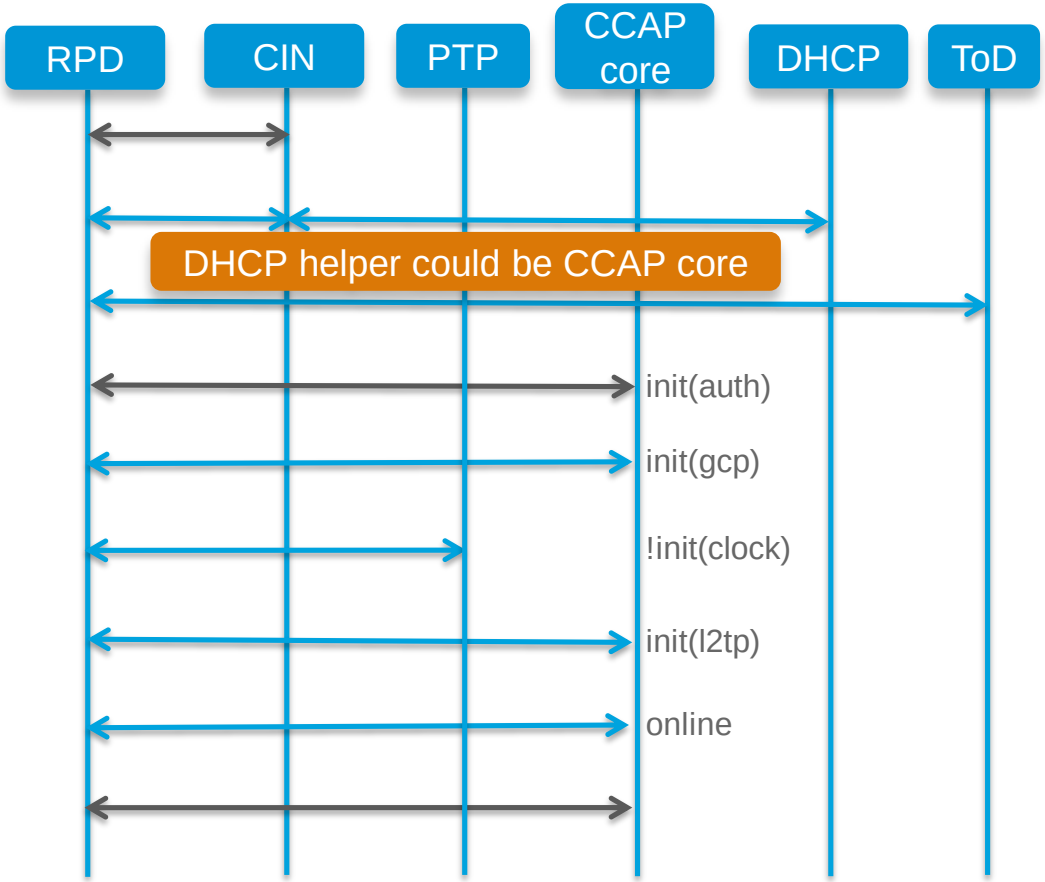


- L2 CIN requires common subnet across cores
- L3 CIN requires routing from each core to RPD

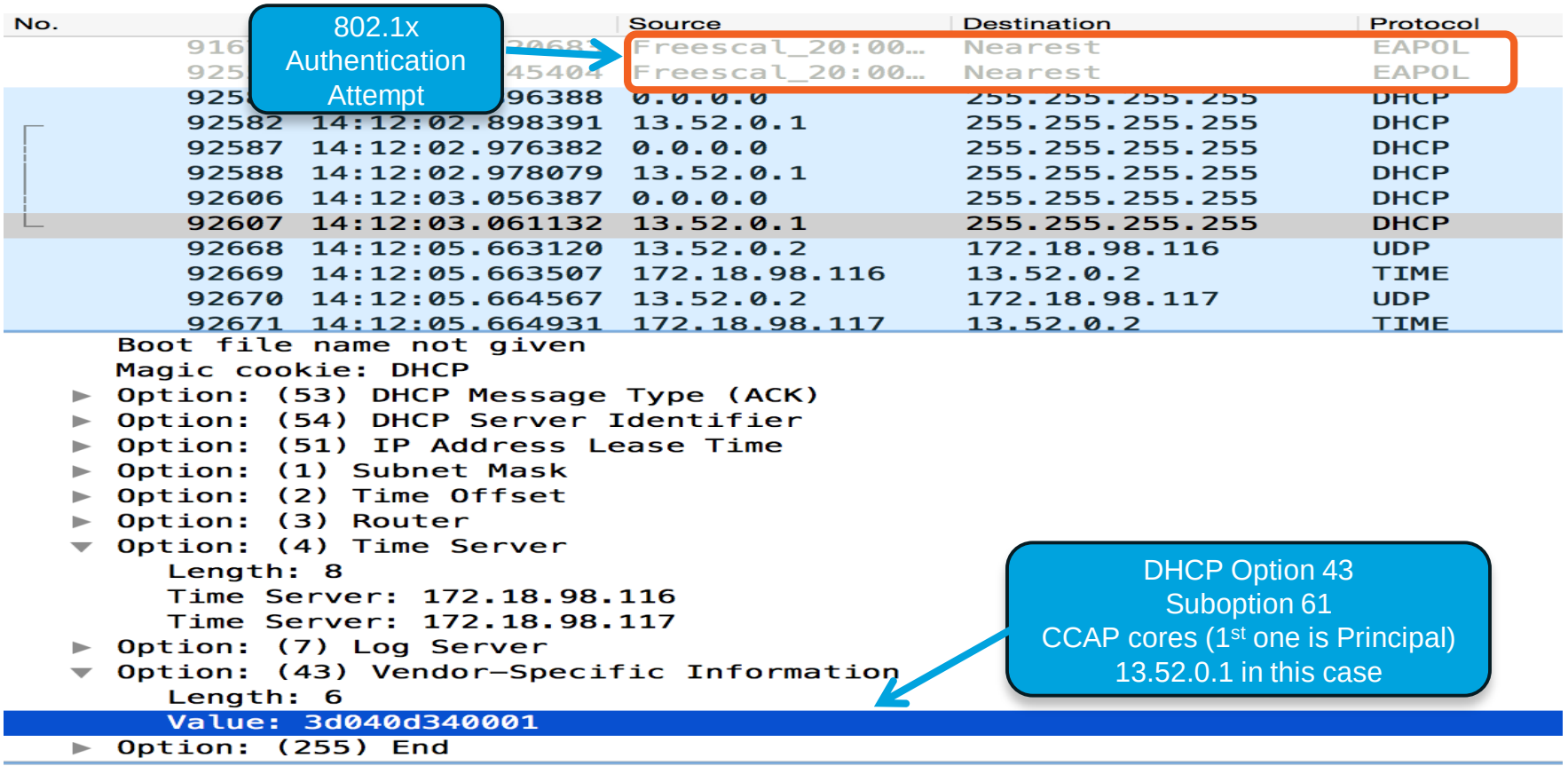
- Optics used in CIN? CIN Provisioning?
- CIN support for 802.1x? MACsec? PTP? QoS? Multicast? IPv6? Increased MTU?

RPD Initialization

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



RPD Initialization (DHCP, ToD) – Packet Capture



RPD Initialization (GCP) – Packet Capture

Source	Destination	Protocol	Destination Port	Message Id	RCP Message Type
10.10.17.1	10.10.17.36	TCP	44037 (44037)		
10.10.17.36	10.10.17.1	TCP	gcp-rphy (8190)		
10.10.17.1	10.10.17.36	RPHY GCP	44037 (44037)	GDM	
10.10.17.36	10.10.17.1	TCP	gcp-rphy (8190)		
10.10.17.1	10.10.17.36	RPHY GCP	44037 (44037)	GDM	
10.10.17.36	10.10.17.1	TCP	gcp-rphy (8190)		
10.10.17.36	10.10.17.1	RPHY GCP	gcp-rphy (8190)	GCP Notify	NTF
10.10.17.1	10.10.17.36	TCP	44037 (44037)		
10.10.17.1	10.10.17.36	RPHY GCP	44037 (44037)	EDS	IRA
10.10.17.36	10.10.17.1	TCP	gcp-rphy (8190)		
10.10.17.36	10.10.17.1	RPHY GCP	gcp-rphy (8190)	GDM Rsp	
10.10.17.1	10.10.17.36	TCP	44037 (44037)		
10.10.17.36	10.10.17.1	RPHY GCP	gcp-rphy (8190)	GDM Rsp	
10.10.17.1	10.10.17.36	TCP	44037 (44037)		
10.10.17.36	10.10.17.1	RPHY GCP	gcp-rphy (8190)	EDS Rsp	IRA
10.10.17.1	10.10.17.36	TCP	44037 (44037)		
10.10.17.1	10.10.17.36	RPHY GCP	44037 (44037)	EDS	REX
10.10.17.36	10.10.17.1	RPHY GCP	gcp-rphy (8190)	EDS Rsp	REX
10.10.17.1	10.10.17.36	RPHY GCP	44037 (44037)	EDS	REX

KeepAlives

KeepAlives

RPD Initialization (PTP) – Packet Capture

Source	Destination	Protocol	Dest Port	PTP message
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
13.52.0.2	188.188.188.188	PTPv2		Signalling Message
13.52.0.2	188.188.188.188	PTPv2		Signalling Message
188.188.188.1…	13.52.0.2	PTPv2		Signalling Message
188.188.188.1…	13.52.0.2	PTPv2		Signalling Message
13.52.0.1	13.52.0.2	TCP	40213 (40213)	
13.52.0.2	13.52.0.1	TCP	gcp-rphy (819…	
13.52.0.1	13.52.0.2	TCP	40213 (40213)	
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
13.52.0.2	188.188.188.188	PTPv2		Delay_Req Message
188.188.188.1…	13.52.0.2	PTPv2		Delay_Resp Message
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
188.188.188.1…	13.52.0.2	PTPv2		Announce Message
13.52.0.2	188.188.188.188	PTPv2		Delay_Req Message
188.188.188.1…	13.52.0.2	PTPv2		Delay_Resp Message
188.188.188.1…	13.52.0.2	PTPv2		Sync Message
13.52.0.2	188.188.188.188	PTPv2		Delay_Req Message
188.188.188.1…	13.52.0.2	PTPv2		Delay_Resp Message

RPD Initialization (DEPI/UEPI) – Packet Capture

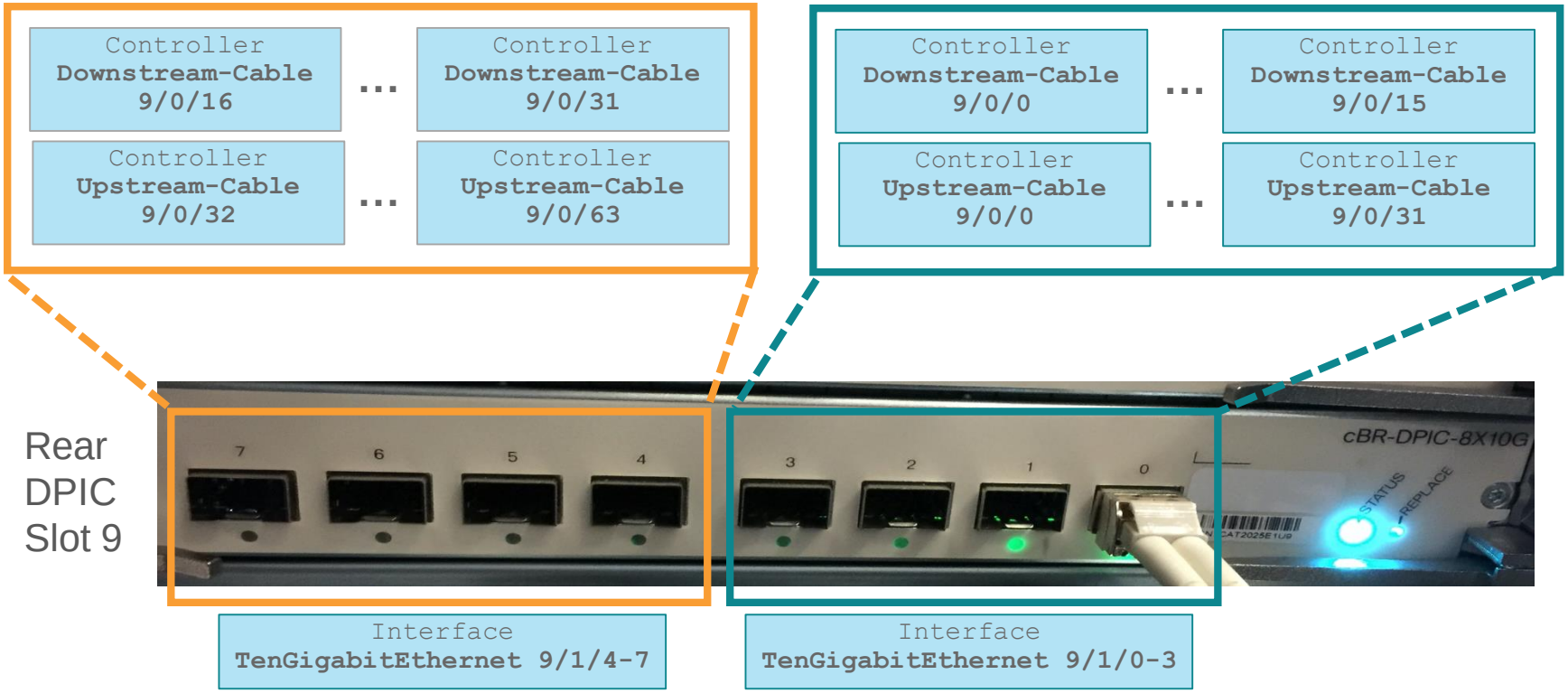
Source	Destination	Protocol	Session ID	Message Type	PW Type
10.10.17.1	10.10.17.36	L2TPv3	0	Start_Control_Request	MPEG-TS Payload Type (MPTPW),Packet Streaming Protocol (PSPPW)
10.10.17.36	10.10.17.1	L2TPv3	0	Start_Control_Reply	MPEG-TS Payload Type (MPTPW),Packet Streaming Protocol (PSPPW)
10.10.17.1	10.10.17.36	L2TPv3	0	Start_Control_Connected	
10.10.17.1	10.10.17.36	L2TPv3	0	Incoming_Call_Request	
10.10.17.1	10.10.17.36	L2TPv3	0	Incoming_Call_Request	
10.10.17.1	10.10.17.36	L2TPv3	0	Incoming_Call_Request	
10.10.17.36	10.10.17.1	L2TPv3	0	Incoming_Call_Reply	
10.10.17.36	10.10.17.1	L2TPv3	0	Incoming_Call_Reply	
10.10.17.36	10.10.17.1	L2TPv3	0	Incoming_Call_Reply	

Control DEPI session

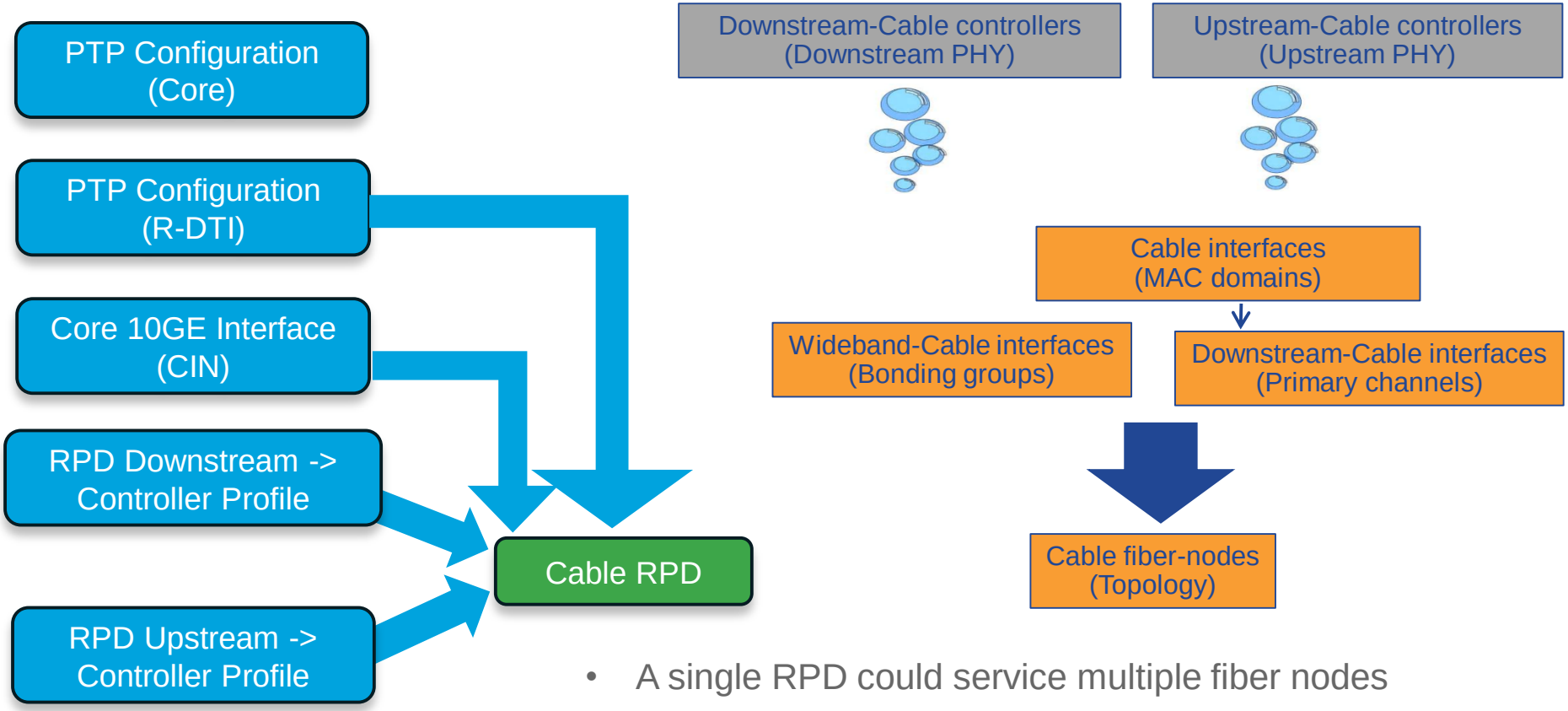
Source	Destination	Protocol	L2TP Session ID	Segment Coun	Sequence Number	Type
Cisco_05:dc:79	DOCSIS-CM	DOCSIS MGMT	0x00000400	1	20772	Upstream Bandwidth Allocation
10.10.17.1	10.10.17.36	PSP MCM	0x00010d01	1	57322	
Cisco_05:dc:79	DOCSIS-CM	DOCSIS MGMT	0x00000400	1	20773	Upstream Bandwidth Allocation
10.10.17.1	10.10.17.36	PSP MCM	0x00010d02			
Cisco_05:dc:79	DOCSIS-CM	DOCSIS MGMT	0x00000400			Bandwidth Allocation
10.10.17.1	10.10.17.36	PSP MCM	0x00010d03			
Netgear_f3:59…	Cisco_05:dc:78	DOCSIS MGMT	0x4004000c	3	9	Ranging Request
Cisco_05:dc:78	Netgear_f3:59…	DOCSIS MGMT	0x00000407	1	32976	Ranging Response
Cisco_05:dc:78	DOCSIS-CM	DOCSIS MGMT	0x00000407	1	18767	Upstream Bandwidth Allocation
10.10.17.1	10.10.17.36	PSP MCM	0x00000d00	1	56976	
Cisco_05:dc:78	DOCSIS-CM	DOCSIS MGMT	0x00000407	1	18768	Upstream Bandwidth Allocation

Data DEPI/UEPI sessions

R-PHY Controllers & PIC Ports

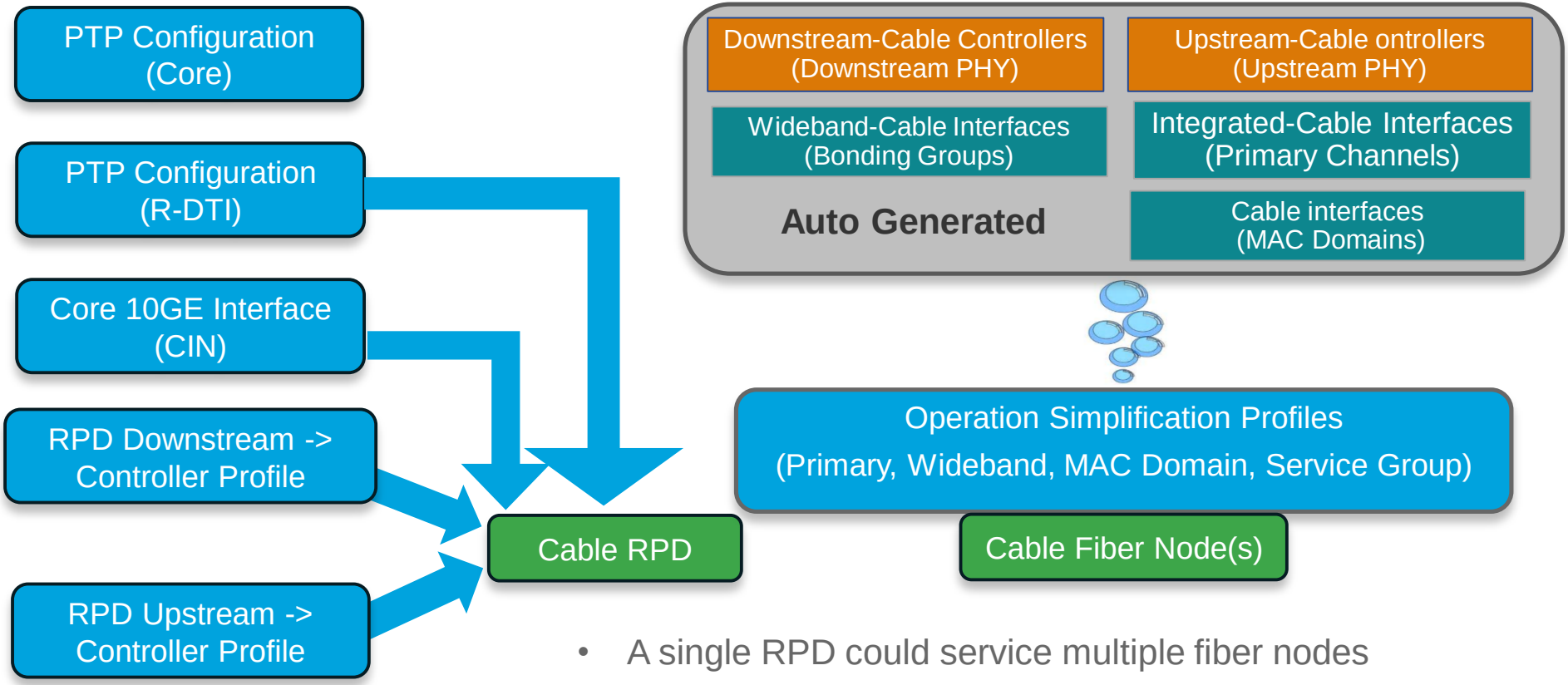


R-PHY Configuration Flowchart



- A single RPD could service multiple fiber nodes

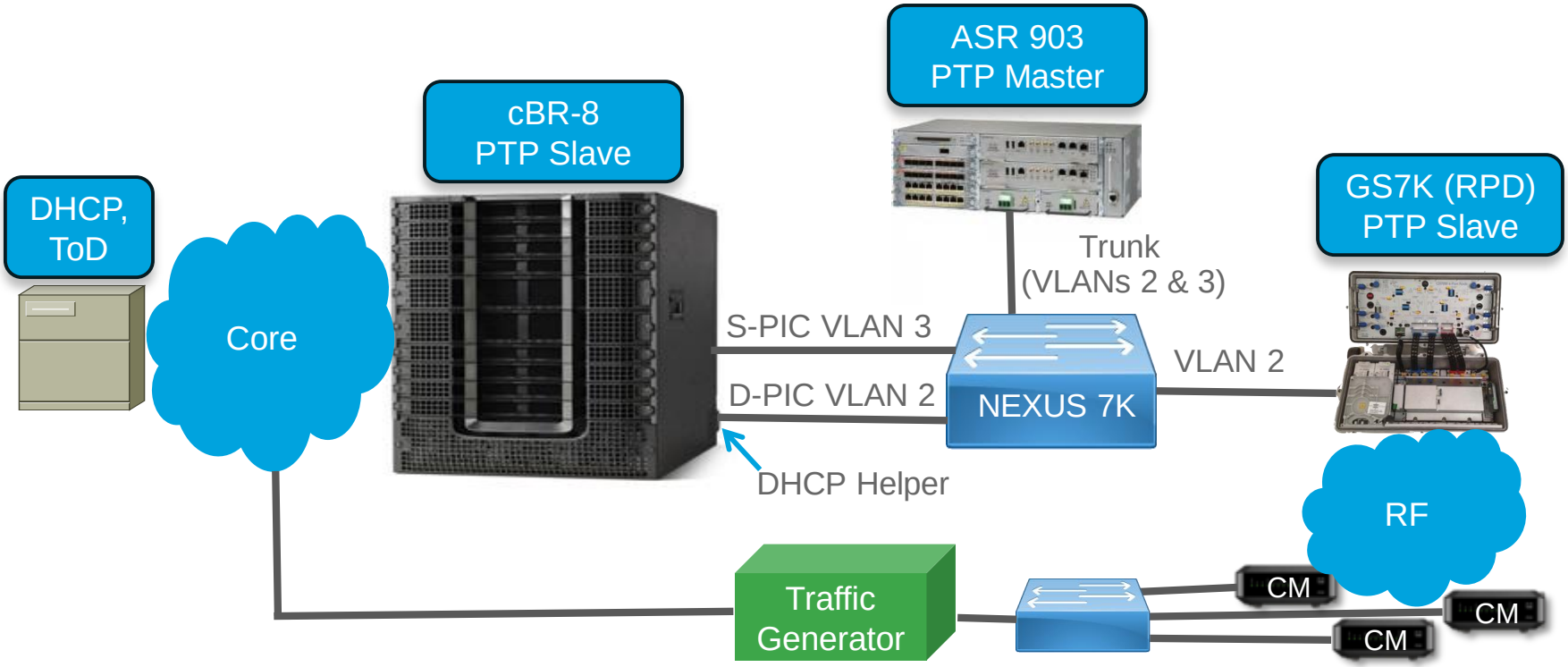
R-PHY Configuration with OpSimp Flowchart



- A single RPD could service multiple fiber nodes

Remote PHY Demo

R-PHY Demo Topology



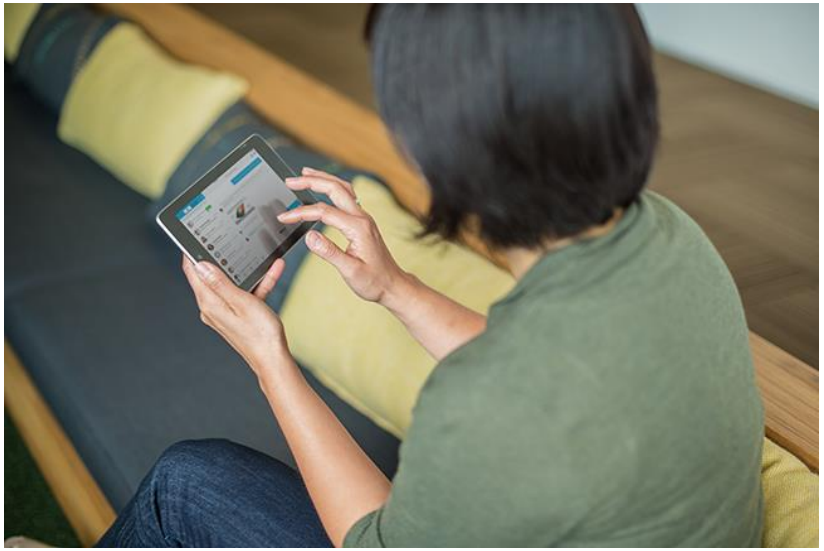
Summary

Summary

- Over 6,000 downstream channels and 200 Gbps of switching capacity (scalable to 1.6 Tbps) in a 13 RU chassis with built-in HA
- Simplified licensing model and resilient SW architecture with process modularity allowing for hitless recovery, patching & restartability
- Video convergence for VoD, SDV, and Broadcast services with dedicated video resources
- DOCSIS 3.1 at scale enabling multi-gigabit downstream speeds
- Service & feature velocity via SDN applications
- Remote PHY roadmap enabling hub consolidation and full benefits of D3.1

Complete Your Online Session Evaluation

- Please complete your Online Session Evaluations after each session
- Complete 4 Session Evaluations & the Overall Conference Evaluation (available from Thursday) to receive your Cisco Live T-shirt
- All surveys can be completed via the Cisco Live Mobile App or the Communication Stations



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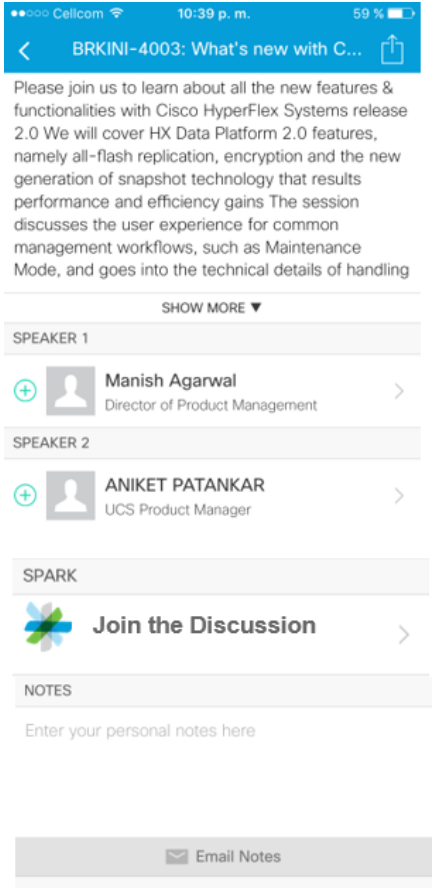


Thank You

Appendix

For Your Reference

Useful Links

- 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
- Smart Licensing Introduction
  - www.cisco.com/go/smartlicensing
- Smart Licensing Portal
  - https://software.cisco.com/?route=module/SmartLicensing

Features of Note

- Data Burst MER Resiliency
  - US Bonding Partial Mode
- Battery Mode (BM) and Energy Management (EM) 1x1 Support
  - BM enables modems to run longer on battery by dropping to 1x1 mode (uses CM-STATUS)
  - EM enables idle modems to save power by dropping to 1x1 mode (uses EM-REQ)
- 3-level Dynamic Modulation and Advanced Spectrum Management
- Dynamic DS D3.0 Utilization Load Balance (DBC support)
- Online Offline Diagnostics (OOD)
  - Means for testing and verifying hardware related line card issues
- 802.1q L2VPN Uplink Redundancy and 802.1q L2VPN Etherchannel Support

Improved CPU Protection

- The uBR10K Divert Rate Limiting (DRL) feature used to protect against high CPU from DOS attacks is greatly enhanced on the cBR-8
  - Now referred to as Punt Path Rate Limiting (PPRL)
- Includes multi-levels of protection:
  - Control Plane Policing (CoPP), Source Based Rate Limiting (SBRL), per-punt cause policing, AND global policing; in that order
- uBR10K DRL only has SBRL and limited per-punt cause policing
- PPRL's use of CoPP and ACLs enables the configuration of any number of trusted (and non-trusted) sites
- SBRL uses an enhanced statistics algorithm and has the ability to dynamically identify an attack and place the attacker in a quarantine state

Example Configuration

For Your Reference

Make sure trusted devices (such as NMS/OSS devices) aren't rate limited

Optional step to improve mass registration events is to throttle DHCP packets

```
policy-map copp_policy
 class sbrl_trusted_v4
  police rate 1000 pps conform-action transmit  exceed-action transmit
 class sbrl_trusted_v6
  police rate 1000 pps conform-action transmit  exceed-action transmit
 class dhcp_drop_v4
  police rate 100 pps conform-action transmit  exceed-action drop
 class dhcp_drop_v6
  police rate 100 pps conform-action transmit  exceed-action drop
 class class-default
  set qos-group 99

control-plane
 service-policy input copp_policy
```

Triggers SBRL

Enable CoPP

Example Configuration - continued

Rate limit incomplete adjacency (10), packets destined to a CMTS address (11), and glean adjacency (24) punts to 4 packets per second per source address

```
platform punt-sbrl wan punt-cause 10 rate 4
platform punt-sbrl wan punt-cause 11 rate 4
platform punt-sbrl wan punt-cause 24 rate 4 quarantine-time 10 burst-factor 100

platform punt-sbrl subscriber rate 16
```

Quarantining provides further protection by blocking all the punts from the source for a specified period of time (10 mins in this case) if the rate exceeds a certain amount (in this case 400 pps : burst factor * rate)

Subscriber side (i.e. cable) punts limited to 16 pps (Note: ARPs handled separately by ARP filter)

```
platform punt-policer 24 50
platform punt-policer 24 50 high
platform punt-policer 100 100
```

Punt policer aggregates punts by cause at the specified rate; these causes have high & low priority queues. In this case gleans are limited to 50 pps and “Source Verify Inconclusive” (100) is limited to 100 pps

Summary Statistics

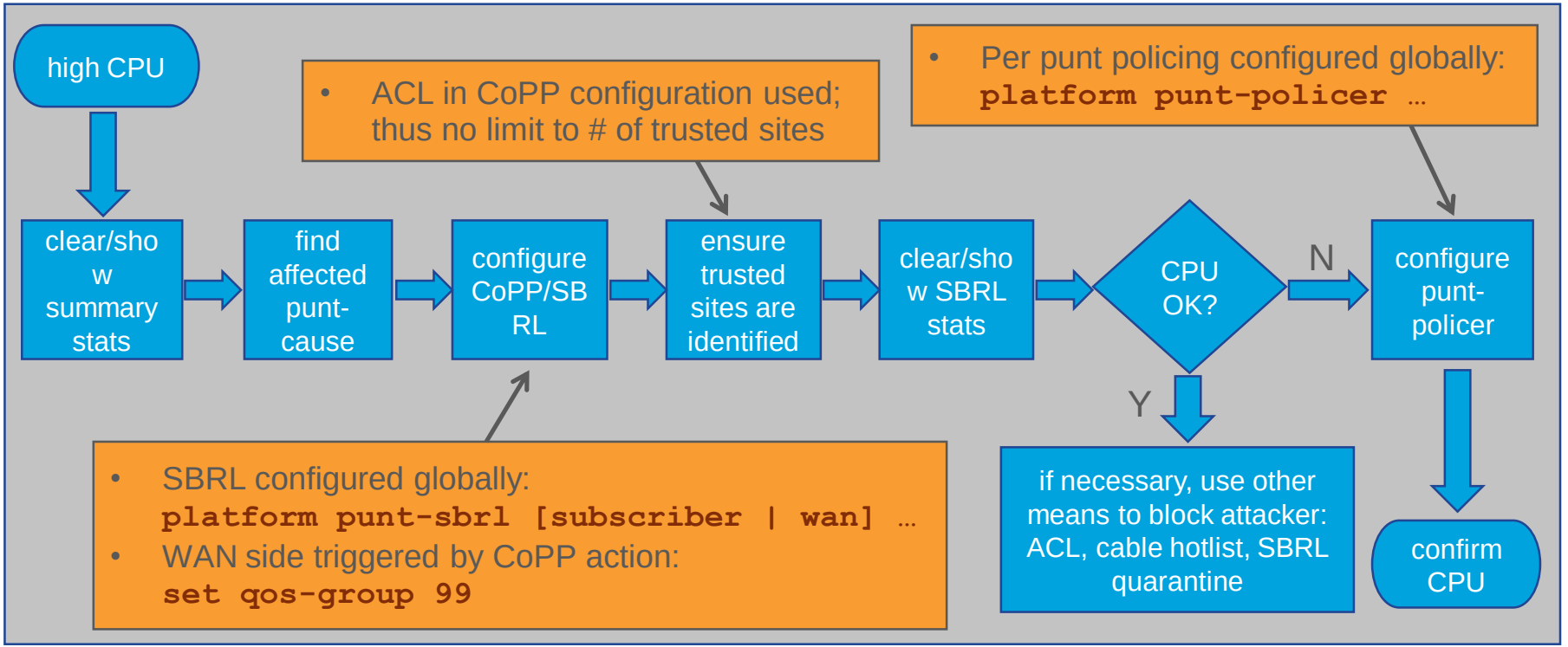
For Your Reference

```
CBR# show platform hardware qfp active infrastructure punt summary [clear] [threshold <T>]

CBR# show platform hardware qfp active infrastructure punt summary threshold 10
Punt Path Rate-Limiting summary statistics
Subscriber-side
ID   punt cause                CPP punt    CoPP drop    SBRL drop    per-cause       global
-------------------------------------------------------------------------------------------
017  IPv6 Bad hop limit              22            0            0            0            0
050  IPv6 packet                     13            0            0            0            0
080  CM not online                  335            0            0            0            0

WAN-side
ID   punt cause                CPP punt    CoPP drop    SBRL drop    per-cause       global
-------------------------------------------------------------------------------------------
017 IPv6 Bad hop limit              471            0            0            0            0
018 IPV6 Hop-by-hop Options       29901            0            0         1430            0
024 Glean adjacency              450911            0       308912            0            0
025 Mcast PIM signaling              19            0            0            0            0
050 IPv6 packet                      11            0            0            0            0
```

High number of SBRL drops for Gleans indicative of subnet scanning

- Clear & show the summary-stats to determine how to configure SBRL or punt-policer

(D)DoS Attack Mitigation Plan



Licensing States

The cBR-8 operates in two states:

- Communicating regularly with Cisco
- Not communicating regularly with Cisco

A cBR-8 That Communicates Regularly with Cisco Will NEVER Encounter License Enforcement!!!

- License enforcement does NOT impact existing services

For Your Reference

cBR-8 Licensing Procedure

- Setup a Cisco Smart Account (requires CCO ID) on Cisco Software Workspace
  - **https://software.cisco.com/#SmartLicensing-Inventory**
- Optionally create virtual accounts to organize licenses
- All licenses assigned to a customer and Smart Account when purchased
- Registration tokens generated on license portal (or satellite) must be configured on the product (i.e. cBR-8)
- Transfers between virtual account license pools supported

Licensing Configuration – Option 1 (Direct)

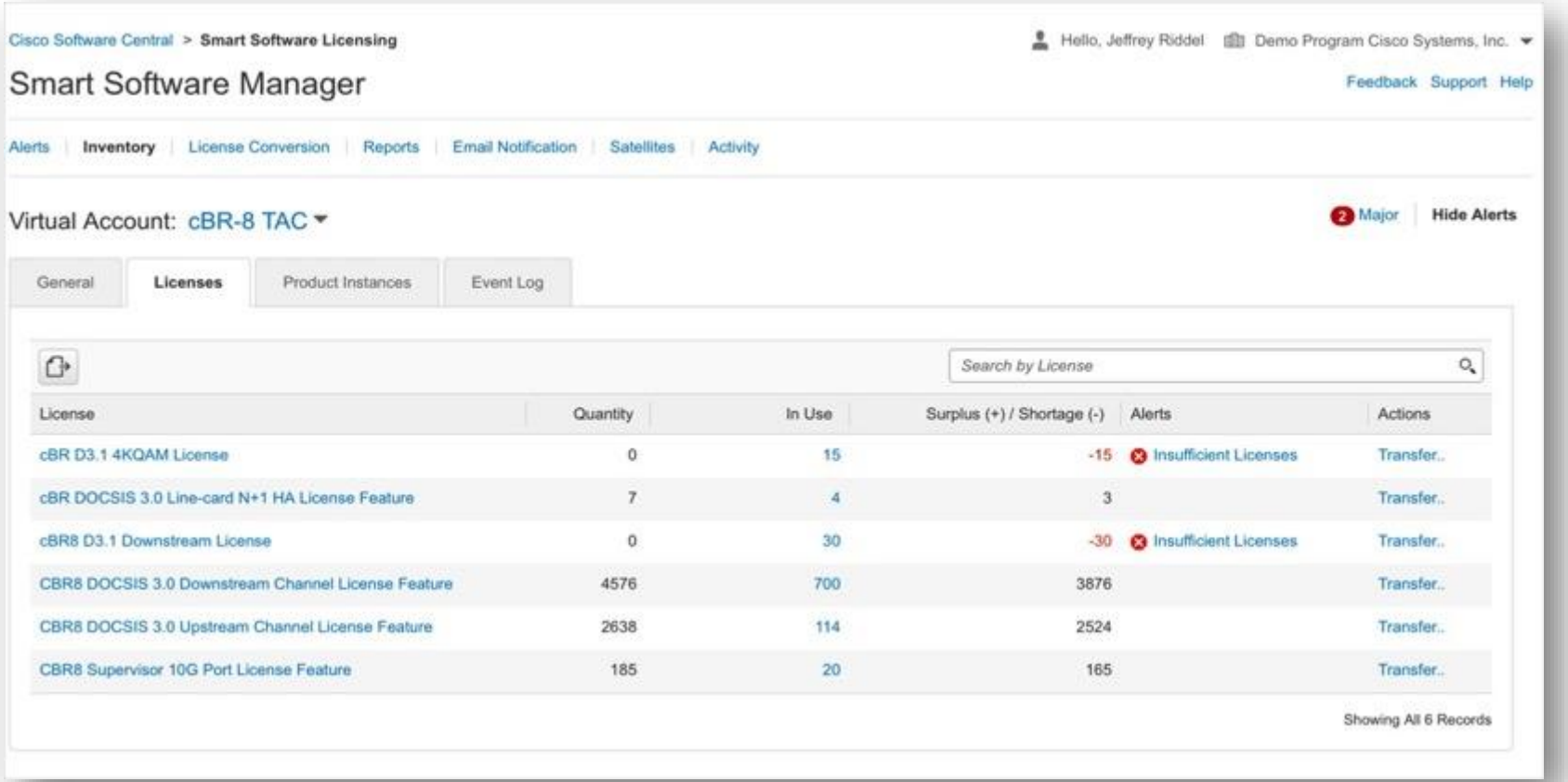
- Default configuration should work unless reaching the portal via an interface in a VRF (such as GigabitEthernet 0)
- If using GigabitEthernet 0; set this as the HTTP client source interface
- Make sure ***tools.cisco.com*** can be resolved by DNS or add a static host entry

```
ip host vrf Mgmt-intf tools.cisco.com 72.163.4.38

ip http client source-interface GigabitEthernet0

call-home
 source-ip-address "172.18.98.46"
 vrf Mgmt-intf
```

- Register CLI: `cBR8#license smart register idtoken <token from portal>`

Cisco Smart Licensing Portal

For Your Reference



Licensing Configuration – Option 2 (Proxy)

- If using the Cisco Transport Gateway as the proxy server make sure it's registered to Cisco.com and just change the destination HTTP address in the default profile to point to the proxy

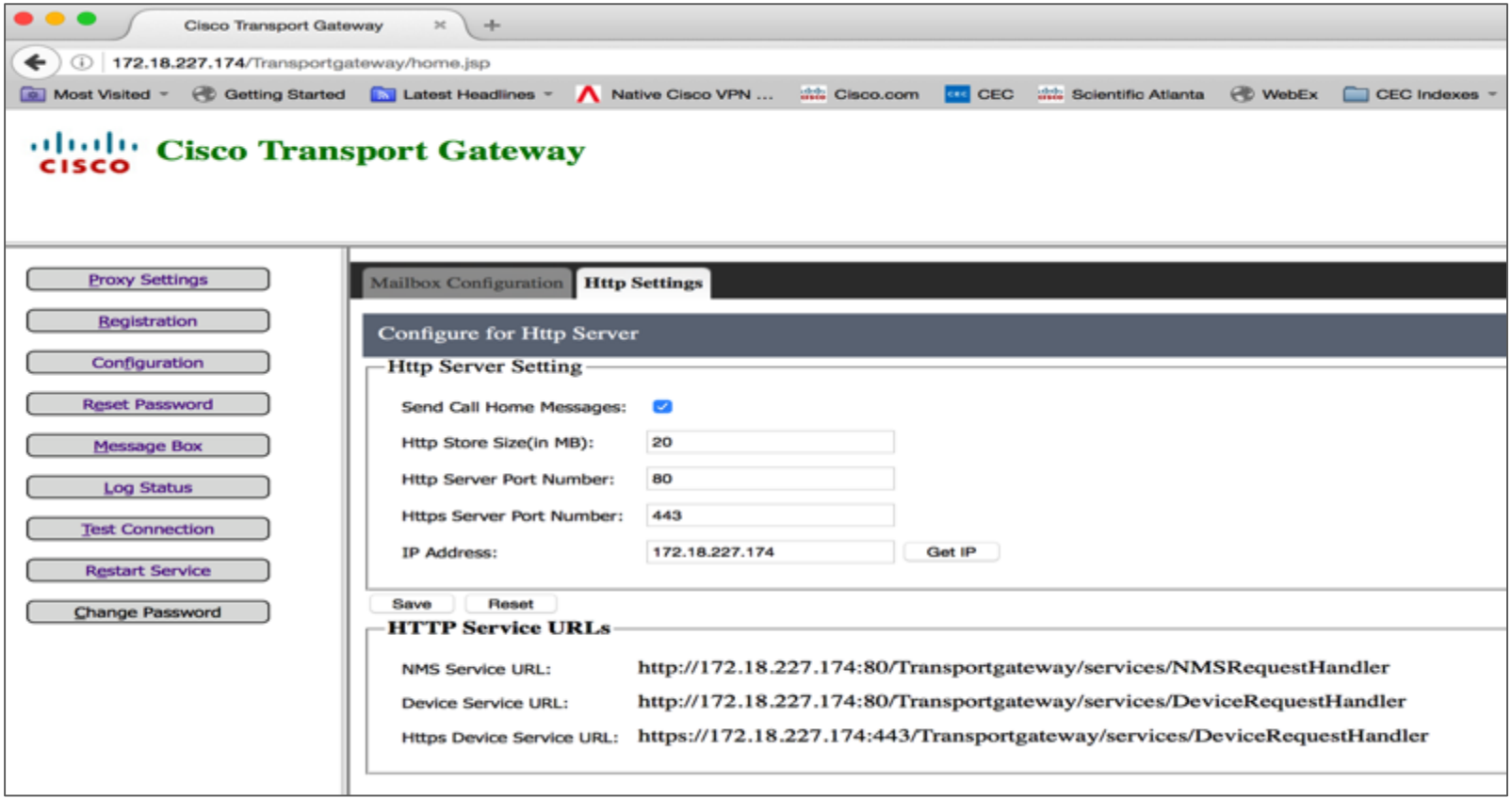
```
call-home
 profile "CiscoTAC-1"
  no reporting smart-call-home-data
  destination address http
http://172.18.227.174:80/Transportgateway/services/DeviceRequestHandler
  no destination address http
https://tools.cisco.com/its/service/oddce/services/DDCEService
```

- If using an "off-the-shelf" proxy; leave the destination HTTP address default and add the "http-proxy" option under the global "call-home" configuration.

```
CBR(config)#call-home
CBR(cfg-cal-home)#http-proxy <HTTP Proxy Server address>
```

Transport GW Configuration

For Your Reference



For Your Reference

Licensing Config – Options 3&4 (Satellite)

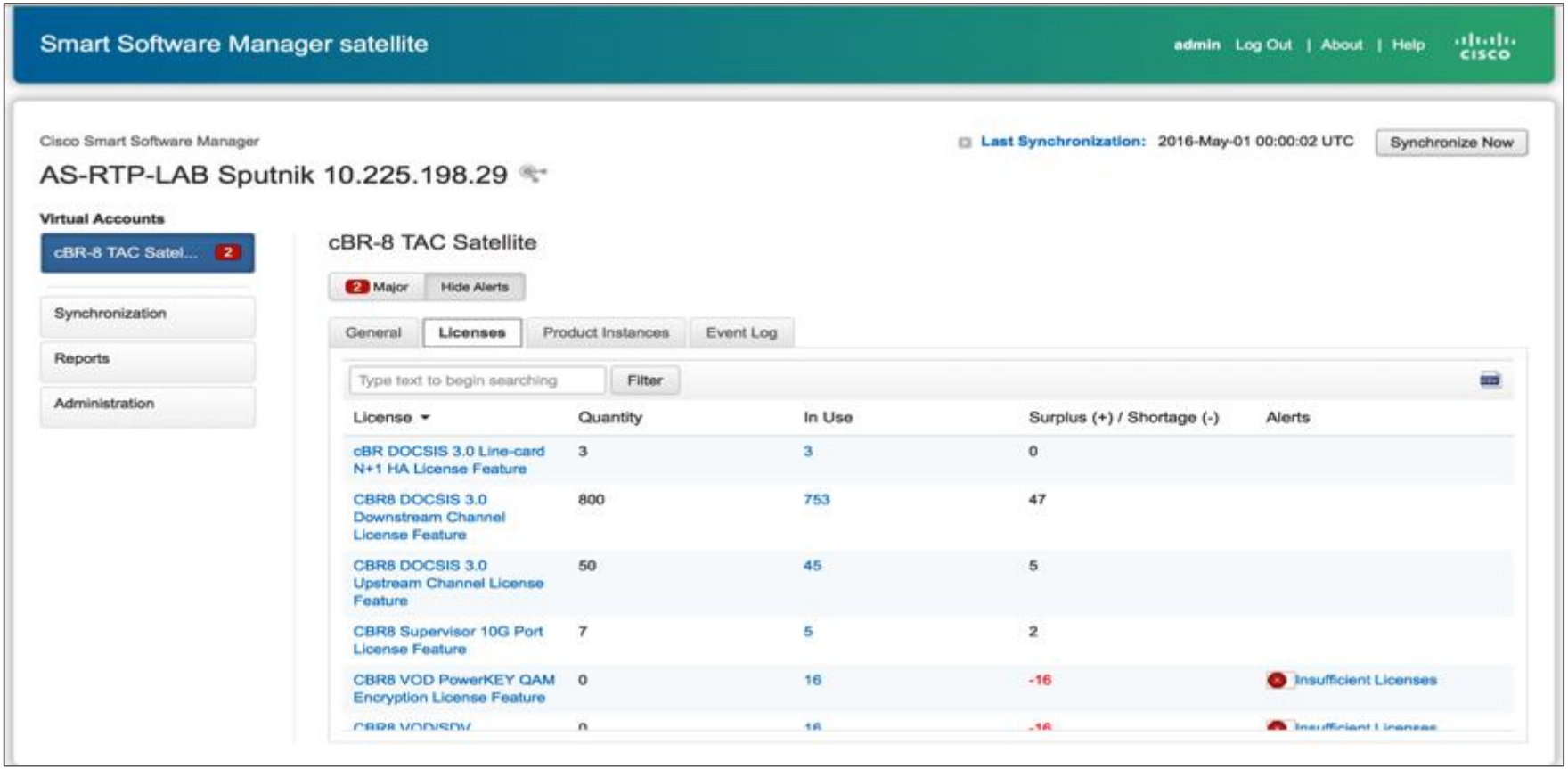
- Simplest solution is to just change the destination HTTP address in the default profile to point to the satellite

```
call-home
 profile "CiscoTAC-1"
  no reporting smart-call-home-data
  destination address http
https://10.225.198.29:443/Transportgateway/services/DeviceRequestHandler
   no destination address http
https://tools.cisco.com/its/service/oddce/services/DDCEService
```

- The satellite will periodically synchronize with the Cisco portal automatically; or can manually force synchronization
- Generate tokens directly on the satellite; licenses and product instance information can be seen on the satellite or on the portal (but may not be in sync)

Smart Software Manager Satellite

For Your Reference



For Your Reference

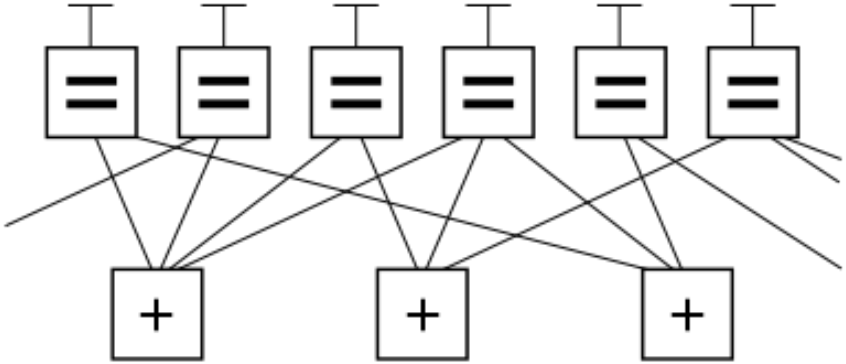
Sub-Package List

- cbrsup-cciomdsup
- cbrsup-clc-firmware
- cbrsup-clccontrol
- cbrsup-clcdocsis
- cbrsup-clcios
- cbrsup-clciosdb
- cbrsup-clcmipsbase
- cbrsup-clcvideo

- cbrsup-espx86base
- cbrsup-rp-firmware
- cbrsup-rpaccess
- cbrsup-rpbase
- cbrsup-rpcontrol
- cbrsup-rpios-universalk9
- cbrsup-rpvideo
- cbrsup-rprphy

- For Supervisor PIC
- For Cable LC
- For Supervisor FP
- For Supervisor RP

LDPC FEC



- FEC = Forward Error Correction
  - FEC adds redundant bits so that errored bits can be re-created
  - FEC requires an interleaver in order to be truly effective.
- LDPC = Low Density Parity Check
  - Invented by Robert Gallager in 1960
  - Could not be implemented in HW until recently
  - **More robust than Reed-Solomon. (4 – 5 dB gain)**
  - LDPC should allow two orders of modulation increase
  - Used in many standards including DVB-C2, WiMAX, MoCA, etc.

Next Codeword Pointer (NCP)

- Codewords are variable in size and can span multiple OFDM symbols
- Different codewords can use different data profiles
- NCP tells where a codeword starts and what data profile is used
- Each NCP block is 48 bits and can use QPSK, 16-QAM, or 64-QAM

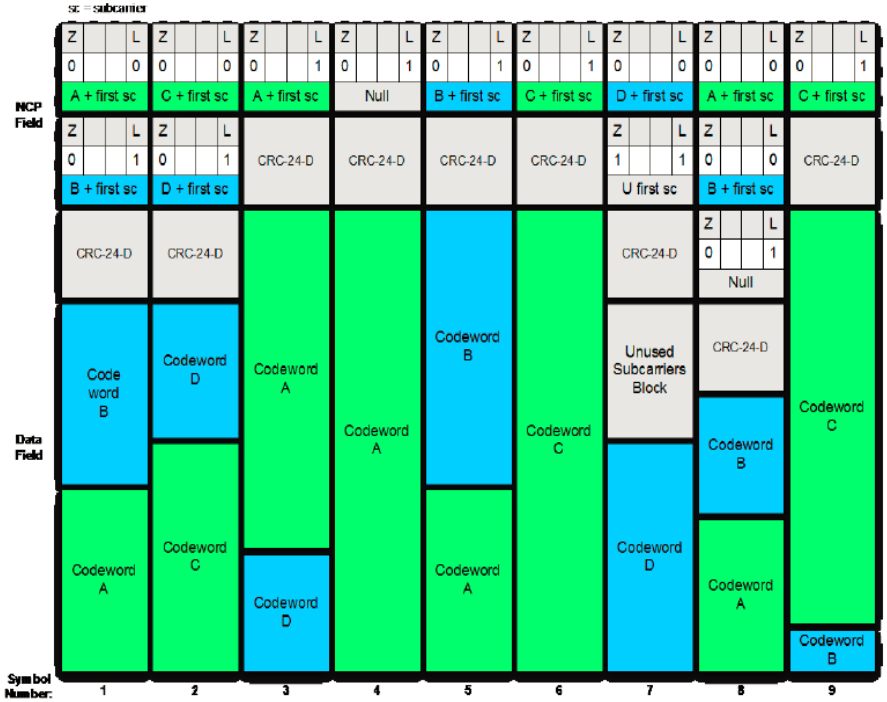


Figure 8-12 - NCP Examples

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

- 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`

Compare/Contrast to uBR10012

	uBR10012 (w/ 3G60)	cBR-8
Chassis size	18 RU	13 RU
Total DOCSIS Solution RUs	**~35 RU (M-CMTS)**	**13 RU (I-CCAP)**
# of Cable LCs	8	8
Total # DS Channels	**1,728 (w/ 6G SPA)**	**6,144 (5,376 w/ HA)**
Average # DS Chs/port	48 (RFGW-10 w/ DS-384)	96 (72 Annex A)
Total # US Channels	480	768 (512 @ R0)
Average # US Chs/port	3	6 (4 @ R0)
Total # SGs	varies (28-54 typical)	64 (56 w/ HA)
Line card HA	**Requires external RF switch**	**Integrated (mid-plane design)**
Backhaul Capacity	4 TGEs per PRE-5	8 TGEs per Sup PIC
Card Connectivity	**Directly on LCs**	**Separate PICs used**
Power Connectivity	**Directly to PEMs**	**To FPEM, not to modules**
Image size	~96 MB (SCJ2a)	~858 MB (3.18.1SP)

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