Cisco cBR Converged Broadband Routers Layer 2 and DOCSIS 3.0 Configuration Guide for Cisco IOS XE Bengaluru 17.6.x

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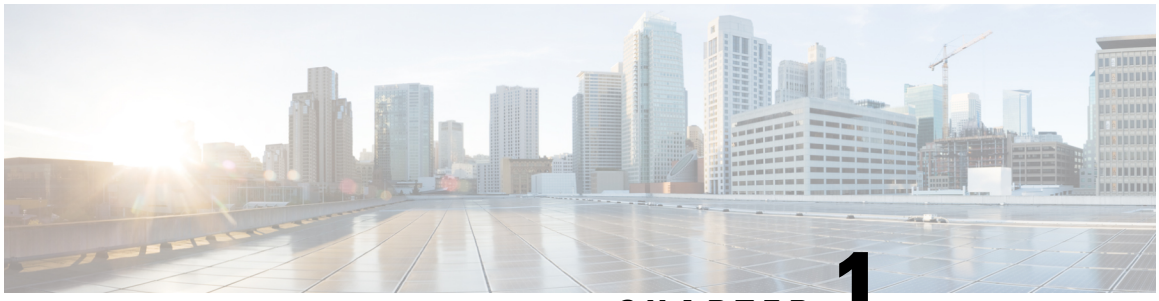


CHAPTER 1

Downstream Interface Configuration

This document describes how to configure the downstream interfaces on the Cisco cBR Series Converged Broadband Router.

- Finding Feature Information, on page 1
- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 1
- Information About Downstream Interface Configuration , on page 2
- How to Configure Downstream Interfaces, on page 5
- Configuration Examples, on page 9
- Additional References, on page 12
- Feature Information for Downstream Interface Configuration on the Cisco cBR Router, on page 12

Finding Feature Information

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 1: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Information About Downstream Interface Configuration

Overview

- Each downstream port requires port level configuration and channel level configuration. Port level configuration is optimized with a frequency profile that defines ranges of frequencies available on the port. Channel level configuration is optimized with a QAM profile and channel range configuration block that auto-increments frequency and duplicates annex, modulation, and interleaver.
- Each channel requires a set of parameters: frequency, annex, modulation, interleaver, and DOCSIS channel id.

- Configuration is done in 4 major blocks of configuration:
  - QAM Profile—Example: “cable downstream qam-profile 1”
  - Frequency Profile—Example: “cable downstream freq-profile 2”
  - Port/Controller—Example: “controller Integrated-Cable 3/0/0”
  - RF Channel block—Example: “rf-chan 0 31”

Downstream RF Port and Channel Management

The downstream RF port and channel management feature is responsible for the configuration and management of the downstream RF ports and channels. Each downstream RF channel can be provisioned either as a DOCSIS or traditional MPEG video QAM channel.

QAM Profile

A QAM profile describes the common downstream channel modulator settings, referred to as physical layer parameters. This includes QAM constellation, symbol rate, interleaver-depth, spectrum-inversion, and annex. The QAM profile is described by *CCAP DownPhyParams* object. Default QAM profiles are supported and customized for DOCSIS or MPEG Video, which are described as *DocsisPhyDefault* and *VideoPhyDefault* objects, respectively.

A maximum of 32 QAM profiles can be defined. There are six system-defined QAM profiles (0 to 5), which cannot be deleted or modified. You can define profiles 6 to 31.

The system defined profiles are:

- Profile 0 - default-annex-b-64-qam
  - interleaver-depth: I32-J4
  - symbol rate: 5057 kilo-symbol/second
  - spectrum-inversion: off
- Profile 1 - default-annex-b-256-qam
  - interleaver-depth: I32-J4
  - symbol rate: 5361 kilo-symbol/second
  - spectrum-inversion: off
- Profile 2 - default-annex-a-64-qam
  - interleaver-depth: I12-J17
  - symbol rate: 6952 kilo-symbol/second
  - spectrum-inversion: off
- Profile 3 - default-annex-a-256-qam
  - interleaver-depth: I12-J17
  - symbol rate: 6952 kilo-symbol/second

    - spectrum-inversion: off

- Profile 4 - default-annex-b-64-qam
    - interleaver-depth: I128-J1
    - symbol rate: 5057 kilo-symbol/second
    - spectrum-inversion: off
- Profile 5 - default-annex-b-256-qam
    - interleaver-depth: I128-J1
    - symbol rate: 5361 kilo-symbol/second
    - spectrum-inversion: off

Spectrum Inversion

Spectrum inversion happens as a result of mixing processes in RF or IF electronics. Spectrum inversion allows for the adaptation of older equipment with the new plant. The mixing of I and Q are used to create a quadrant profile. For some settops, the inversion of the quadrant profile is needed where the axis are flipped such that I represents the X and Q represents the Y-axis. Most modern equipment can detect and resolve the inversion split.

You can change this spectrum inversion configuration on a user-defined qam-profile. It cannot be changed on a system generated qam-profile from 0 to 5.

Frequency Profile

A frequency profile defines the ranges of frequencies available on a port. A maximum of 16 frequency profiles can be defined. There are four system-defined frequency profiles (0 to 3), which cannot be deleted or modified. You can define profiles 4 to 15.

The system defined profiles are:

- Profile 0 - annex-b-low, Frequency range (Hz): 90000000 - 863999999
- Profile 1 - annex-b-high, Frequency range (Hz): 234000000 - 1002999999
- Profile 2 - annex-a-low, Frequency range (Hz): 94000000 - 867999999
- Profile 3 - annex-a-high, Frequency range (Hz): 267000000 - 1002999999

The frequency ranges are defined using lanes and blocks:

- Four lanes per port, each lane can support 216 MHz range.
- Four blocks per lane, each block can support 54 MHz range.
- Lanes and blocks may have overlapping frequency ranges.

How to Configure Downstream Interfaces

This section contains the following:

Configuring the Cisco CMTS Manually Using Configuration Mode

Connect a console terminal to the console port on the I/O controller. When asked if you want to enter the initial dialog, answer **no** to go into the normal operating mode of the router. After a few seconds the user EXEC prompt (**Router>**) appears.

Configuring the QAM Profile on the Downstream Channels

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable downstream qam-profile** *Qam_Profile_ID* **Example:** `Router(config)# cable downstream qam-profile 3`	Defines or modifies a QAM profile.
Step 4	**annex** {**A** | **B** | **C**} **Example:** `Router(config-qam-prof)# annex A`	Defines the profile MPEG framing format. The default is Annex B.
Step 5	**description** *LINE* **Example:** `Router(config-qam-prof)# description qam1`	Name or description for this profile.
Step 6	**interleaver-depth** {**I12-J17** | **I128-J1** | **I128-J2** | **I128-J3** | **I128-J4** | **I128-J5** | **I128-J6** | **I128-J7** | **I128-J8** | **I16-J8** | **I32-J4** | **I64-J2** | **I8-J16**} **Example:** `Router(config-qam-prof)# interleaver-depth I64-J2`	Defines the interleaver depth. The default is I32 J4 for DOCSIS.
Step 7	**modulation** {**256** | **64**} **Example:** `Router(config-qam-prof)# modulation 64`	Defines the modulation. The default is 256QAM.

	Command or Action	Purpose
Step 8	**spectrum-inversion** {**off** | **on**} **Example:** `Router(config-qam-prof)# spectrum-inversion on`	Enables or disables spectrum inversion. Default is off.
Step 9	**symbol-rate** *value* **Example:** `Router(config-qam-prof)# symbol-rate 5057`	Defines the symbol rate. Value is in kilo-symbol/sec.
Step 10	**exit** **Example:** `Router(config-qam-prof)# exit`	Exits from the QAM profile configuration mode.

Configuring the Frequency Profile on the Downstream Channels

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable downstream freq-profile** *DS_frequency_profile_ID* **Example:** `Router(config)# cable downstream freq-profile 4`	Defines or modifies a frequency profile.
Step 4	**exit** **Example:** `Router(config)# exit`	Exits from the frequency lane configuration mode.

Configuring the Controller on the Downstream Channels

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.

	Command or Action	Purpose
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**controller integrated-cable** *slot/subslot/port* **Example:** `Router(config)#controller Integrated-Cable 3/0/0`	Enters the controller sub-mode.
Step 4	**base-channel-power** *value* **Example:** `Router(config-controller)#base-channel-power 26`	Sets the base channel power level. If not specified, the default value is calculated based on the number of carriers. Maximum limit is 34 dBmV DRFI. If you configure a value greater than the maximum specified by DRFI, the following message is displayed: Caution: RF Power above DRFI specification. May result in minor fidelity degradation.
Step 5	**freq-profile** *number* **Example:** `Router(config-controller)#freq-profile 0`	Specifies the frequency profile for the port.
Step 6	**max-carrier** *value* **Example:** `Router(config-controller)#max-carrier 1`	Specifies the maximum number of carriers.
Step 7	**mute** **Example:** `Router(config-controller)#mute`	Mutes the port. Use the **no** prefix to unmute the port. Default is "no mute".
Step 8	**rf-chan** *starting_Qam_ID ending_Qam_ID* **Example:** `Router(config-controller)#rf-chan 0 1`	Enters RF channel configuration sub-mode to configure an individual channel or a block of channels.
Step 9	**shutdown** **Example:** `Router(config-controller)#shutdown`	Changes the port administration state to down. Use the **no** prefix to change the port administration state to up.

Troubleshooting Tips

Shutting and No Shutting Downstream Controller Immediately

Problem Shutting down a downstream controller on a cable line card and bringing the controller back up immediately can cause a Queue ID Pending Drain event on the system. This results in traffic disruption to the modems or modems going offline.

Solution It is recommended that you wait for a few seconds (>30 secs) before issuing the no shut command on a shut downstream controller. The system also restricts the user from issuing the no shut command immediately by printing this message.

```
Config change could not be applied as a cleanup is pending following shut on
controller x/x/x. Please wait for the cleanup to complete before attempting to
no shut controller.
```

Configuring the RF Channel on a Controller

The RF channel submode is entered from the channel controller configuration submode using the **rf-chan** command as described in the previous section. If an individual channel was specified in the **rf-chan** command, only that channel configuration is changed. If a block of channels was specified in the **rf-chan** command, the configuration change is applied to all channels in the block.

Note If the user tries to add a video type RF channel to a cable interface, the following message appears to reject the configuration:

```
X/X/X rf-channel XX is video type channel, it can't be configured as primary DS
```

If a RF channel is configured under cable interface, when the user tries to change the channel type to video, the following message appears to reject the configuration:

```
X/X/X rf channel X can't be set to video type.
It is configured under Cable1/0/1.
Please remove the configuration before change the qam type
```

Step 1 **docsis-channel-id** *dcid*

Example:

```
Router(config-rf-chan)#docsis-channel-id 1
```

Changes the channel DOCSIS channel identifier. In block mode, the value is assigned to the first channel and incremented for successive channels.

Step 2 **frequency** *value*

Example:

```
Router(config-rf-chan)#frequency 93000000
```

Configures the channel's center frequency in Hz. The available frequency range is determined from the port's frequency profile, if configured. If not configured, the available range will be the full port spectrum. In block mode, the frequency will be assigned to the first channel. Successive channels will get the next center frequency for the annex specified in the QAM profile (+6 Hz for Annex B, +8 Hz for Annex A).

Step 3 **mute**

Example:

```
Router(config-rf-chan)#mute
```

Mutes the RF channel. Enter the **no** prefix to unmute the channel. Default is "no mute".

Step 4 **power-adjust** *pwr_adj_range*

Example:

```
Router(config-rf-chan)#power-adjust 8.0 -  0.0  dBmV
```

Adjusts the RF channel's power.

Step 5 **qam-profile** *qam_profile_number*

Example:

```
Router(config-rf-chan)#qam-profile 0
```

Specifies the QAM profile for this channel.

Step 6 **rf-output** *value*

Example:

```
Router(config-rf-chan)#rf-output normal
```

Changes the RF output mode to test the channel.

Step 7 **shutdown**

Example:

```
Router(config-rf-chan)#shutdown
```

Changes the channel administration state to down. Use the **no** prefix to change the channel administration state to up. The default is "no shut".

Step 8 **type** *value*

Example:

```
Router(config-rf-chan)#type video
```

Configures the channel QAM type. The default is DOCSIS.

Configuration Examples

Downstream Interface Configuration Example

The example below shows the configuration of:

- QAM Profile—The system defined QAM profile for Annex B and 256 QAM.
- Frequency Profile—The system defined frequency profile annex-b-low.
- Controller and RF channel—Port 0 on slot 3/0 with frequency profile 0; 96 channels with QAM profile 1 and center frequencies starting at 93 MHz.

```
cable downstream qam-profile 1
  annex B
  modulation 256
  interleaver-depth I32-J4
  symbol-rate 5361
  spectrum-inversion off
  description default-annex-b-256-qam
```

```
cable downstream freq-profile 0
  lane 1 start-freq 90000000
    block 1 start-freq 90000000
    block 2 start-freq 138000000
    block 3 start-freq 186000000
    block 4 start-freq 234000000
  lane 2 start-freq 282000000
    block 1 start-freq 282000000
    block 2 start-freq 330000000
    block 3 start-freq 378000000
    block 4 start-freq 426000000
  lane 3 start-freq 474000000
    block 1 start-freq 474000000
    block 2 start-freq 522000000
    block 3 start-freq 570000000
    block 4 start-freq 618000000
  lane 4 start-freq 666000000
    block 1 start-freq 666000000
    block 2 start-freq 714000000
    block 3 start-freq 762000000
    block 4 start-freq 810000000
controller Integrated-Cable 3/0/0
 max-carrier 128
 base-channel-power 34
 freq-profile 0
 rf-chan 0 95
  type DOCSIS
  frequency 93000000
  rf-output NORMAL
  power-adjust 0
  docsis-channel-id 1
  qam-profile 1
```

Show Command Examples for Displaying the State

Use the following commands to display the state of any QAM profile, Frequency profile, downstream controller or channel.

QAM Profile Configuration Example

```
Router#show cable qam-profile 0
QAM Profile ID 0: default-annex-b-64-qam
        annex: B
        modulation: 64
        interleaver-depth: I32-J4
        symbol rate: 5057 kilo-symbol/second
        spectrum-inversion: off
Router#
```

Frequency Profile Configuration Example

```
Router#show cable freq-profile 0
Frequency Profile ID 0 annex-b-low:
        Lane 1 start-freq 90000000hz
                Block 1 start-freq 90000000hz
                Block 2 start-freq 138000000hz
                Block 3 start-freq 186000000hz
                Block 4 start-freq 234000000hz
        Lane 2 start-freq 282000000hz
```

```
                Block 1 start-freq 282000000hz
                Block 2 start-freq 330000000hz
                Block 3 start-freq 378000000hz
                Block 4 start-freq 426000000hz
        Lane 3 start-freq 474000000hz
                Block 1 start-freq 474000000hz
                Block 2 start-freq 522000000hz
                Block 3 start-freq 570000000hz
                Block 4 start-freq 618000000hz
        Lane 4 start-freq 666000000hz
                Block 1 start-freq 666000000hz
                Block 2 start-freq 714000000hz
                Block 3 start-freq 762000000hz
                Block 4 start-freq 810000000hz
Router#
```

Controller Configuration Example

```
Router#show controller Integrated-Cable 3/0/0 rf-port
  Admin:  UP  MaxCarrier: 128  BasePower: 34 dBmV  Mode: normal
  Rf Module 0: UP
  Frequency profile: 0
  Free freq block list has 1 blocks:
    666000000 - 863999999
  Rf Port Status: UP
Router#
```

RF Channel Configuration Example

```
Router#show controller integrated-Cable 3/0/0 rf-channel 0-3 95
Chan State Admin Frequency  Type   Annex Mod  srate Interleaver  dcid  power  output
 0     UP   UP   93000000   DOCSIS  B    256   5361  I32-J4       1    34     NORMAL
 1     UP   UP   99000000   DOCSIS  B    256   5361  I32-J4       2    34     NORMAL
 2     UP   UP   105000000  DOCSIS  B    256   5361  I32-J4       3    34     NORMAL
 3     UP   UP   111000000  DOCSIS  B    256   5361  I32-J4       4    34     NORMAL
 95    UP   UP   663000000  DOCSIS  B    256   5361  I32-J4       96   34     NORMAL

Router# show controller integrated-Cable 3/0/0 rf-channel 0 verbose
Chan State Admin Frequency  Type   Annex Mod  srate Interleaver  dcid  power  output
 0     UP   UP   93000000   DOCSIS  B    256   5361  I32-J4       1    34     NORMAL
 Qam profile: 1
 Spectrum Inversion: Off
 Frequency Lane: 1  Block: 1  index: 1
 Resource status:   OK
 License: granted <02:00:04 EDT Jan 2 2012>
 JIB channel number: 0
Chan EnqQ  Pipe  RAF SyncTmr Vid Mac            Video Primary DqQ  TM Mpts Sniff
   0     0     0   4       0   0 0000.0000.0000     0       0    0  0    0 NO
Grp  Prio P  Prate Phy0-ctl Phy1-ctl Enable Tun-Id  L2TPv3_Ses_id
   0    0  0     1        1        0   TRUE       0      0
Chan  Qos-Hi Qos-Lo  Med-Hi Med-Lo  Low-Hi Low-Lo
   0  32774  16384   32768  16384   65536  32768
Chan  Med Low TB-neg Qos_Exc  Med_Xof  Low_Xof       Qdrops  Pos Qlen(Hi-Med-lo) Fl
    0   0   0      0       0        0        0            0  Y     0     0     0  0
DSPHY Info:
  DSPHY Register Local Copy: QPRHI = c0000163, QPRLO = e30d0
  DSPHY Register Local Copy Vaddr = 80000290, qam2max_mapping = 80000000
  DSPHY Register Local Copy: SPR ID = 0, SPR Mapping= c200000a
  Last read from HW: Mon Jan  2 02:02:04 2012
   QPRHI = c0000163, QPRLO = e30d0, SPR = c200000a SPRMAPING c0000000 Q2Max 80000000
  Last time read spr rate info from HW: Mon Jan  2 13:21:41 2012
    SPR ID 0, rate value in kbps 0, overflow count 0, underflow count 0
```

```
Router# sh controllers Integrated-Cable 7/0/0 counter rf-channel
Controller  RF    MPEG       MPEG        MPEG   Sync       MAP/UCD    User    QAM
            Chan  Packets    bps         Mbps   Packets    Packets    Mbps    Util
                             Tx                             Tx         Tx      Percentage
7/0/0       0     0          0           00.00  0          0          00.00   000.00
7/0/0       1     0          0           00.00  0          0          00.00   000.00
7/0/0       2     8239954    2475952     02.47  0          0          02.39   006.60
7/0/0       3     85927382   25769779    25.76  0          0          24.94   068.71
7/0/0       4     85927608   25769027    25.76  0          0          24.94   068.71
7/0/0       5     8239088    2474599     02.47  0          0          02.39   006.59
7/0/0       6     8210840    2463770     02.46  0          0          02.38   006.57
7/0/0       7     50103      15040       00.01  0          0          00.01   000.04
7/0/0       8     50103      15040       00.01  0          0          00.01   000.04

Router# show cable licenses ds
-------------------------------------------
Entitlement:  Downstream License
Consumed count: 672
Consumed count reported to SmartAgent: 672
Forced-Shut count: 0
Enforced state: No Enforcement

Router#
```

Additional References

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

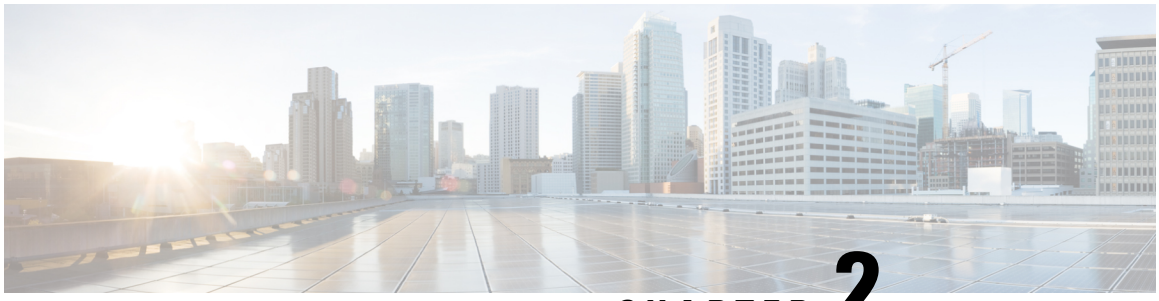
Feature Information for Downstream Interface Configuration on the Cisco cBR Router

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 2: Feature Information for Downstream Interface Configuration

Feature Name	Releases	Feature Information
Downstream Interface Configuration	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.
Display QAM Utillization Percentage using the **sh controllers Integrated-Cable 7/0/0 counter rf-channel**	Cisco IOS XE Gibraltar 16.10.1f	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 2

Upstream Interface Configuration

This document describes how to configure the upstream interfaces on the Cisco cBR Series Converged Broadband Router.

- Finding Feature Information, on page 15
- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 15
- Information About Upstream Interface Configuration, on page 16
- How to Configure Upstream Interfaces, on page 17
- Configuration Examples, on page 21
- Additional References, on page 22
- Feature Information for Upstream Interface Configuration on the Cisco cBR Router, on page 22

Finding Feature Information

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 3: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Information About Upstream Interface Configuration

The cable interface in the Cisco cBR router supports upstream signals and serves as the radio frequency (RF) interface. This chapter provides an overview of the upstream interfaces on the Cisco cBR Series Converged Broadband Router.

Cisco IOS XE Fuji 16.9.1 and later releases support 10 Gbps of upstream throughput on the following line cards on the Cisco cBR Series Converged Broadband Router:

- CBR-CCAP-LC-40G
- CBR-CCAP-LC-40G-R

Upstream Channel Management

Upstream Channel Management (UCM) is responsible for the physical (PHY) layer configuration and resource management of upstream channels in the Cisco cBR Series Converged Broadband Router.

Upstream Controller

An upstream port represents a physical upstream RF connector on a cable line card, connected to one or more fiber nodes. An upstream RF port is a container of upstream RF channels, which imposes constraints on both topology and spectrum for the group of RF channels contained in the physical port. An upstream RF port also represents the RF front-end hardware component on a cable line card including the connector, variable gain adjustment (VGA), and A/D converter. This is directly connected to a set of upstream physical channel receivers. The number of upstream physical channels per port is thus constrained by the number of receivers accessible to the port.

Upstream Channel

An upstream RF channel represents DOCSIS physical layer operation on a single upstream center frequency with a particular channel width. It is contained by a single physical port on the CMTS line card hardware.

Upstream Resource Management

The upstream resource management (URM) feature is primarily responsible for the maintenance of the relationship between a physical upstream connector on the line card and the upstream RF channels received on that connector.

How to Configure Upstream Interfaces

This section contains the following:

Configuring the Cisco CMTS Manually Using Configuration Mode

Connect a console terminal to the console port on the I/O controller. When asked if you want to enter the initial dialog, answer **no** to go into the normal operating mode of the router. After a few seconds the user EXEC prompt (**Router>**) appears.

Configuring the Modulation Profile and Assigning to an Upstream Channel

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

	Command or Action	Purpose
Step 3	**cable modulation-profile** *profile mode_of_oper qam_profile* **Example:** `Router(config)# cable modulation-profile 23 tdma qam-16`	Creates a preconfigured modulation profile, where the burst parameters are set to their default values for each burst type.
Step 4	**Controller Upstream-Cable** *slot/subslot/port* **Example:** `Router(config)# Controller Upstream-Cable 7/0/0`	Enters the controller interface configuration mode.
Step 5	**us-channel** *n* **modulation-profile** *primary-profile-number* [*secondary-profile-number*] [*tertiary-profile-number*] **Example:** `Router(config-if)#cable upstreamus-channel 0 modulation-profile 23`	Assigns up to three modulation profiles to an upstream port.
Step 6	**end** **Example:** `Router(config-controller)# end`	Exits controller configuration submode and returns to privileged EXEC mode.

Configuring the Upstream Channel with PHY Layer

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**controller upstream-cable** *slot/subslot/port* **Example:** `Router(config)# controller upstream-cable 1/0/0`	Specifies the controller interface line card and enters upstream controller config configuration submode.
Step 4	**us-channel** *rf-channel* **frequency** *freq-val* **Example:** `Router(config-controller)# us-channel 1 frequency 20000000`	Assigns frequency to an RF channel on a controller interface.

	Command or Action	Purpose
Step 5	**us-channel** *rf-channel* **docsis-mode** *mode* **Example:** `Router(config-controller)# us-channel 1 docsis-mode tdma`	Assigns DOCSIS mode to an RF channel on a controller interface.
Step 6	**us-channel** *rf-channel* **channel-width** *value* **Example:** `Router(config-controller)# us-channel 1 channel-width 3200000`	Assigns channel width in Hertz to an RF channel on a controller interface.
Step 7	**us-channel** *rf-channel* **modulation-profile** *profile* **Example:** `Router(config-controller)# us-channel 1 modulation-profile 21`	Assigns modulation profile to an RF channel on a controller interface.
Step 8	**no us-channel** *rf-channel* **shutdown** **Example:** `Router(config-controller)# no us-channel 1 shutdown`	Enables the upstream channel.
Step 9	**end** **Example:** `Router(config-controller)# end`	Exits upstream controller configuration submode and returns to privileged EXEC mode.

Associating Upstream Channels with a MAC Domain and Configuring Upstream Bonding

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** *slot/subslot/cable-interface-index* **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.

	Command or Action	Purpose
Step 4	**downstream integrated-cable** *slot*/*subslot*/*port* **rf-channel** *rf-chan* [**upstream** *grouplist*] **Example:** `Router(config-if)# downstream integrated-cable 7/0/0 rf-channel 3 upstream 3`	Associates a set of upstream channels to the integrated downstream channels.
Step 5	**upstream** *md-us-chan-id* **upstream-cable** *slot*/*subslot*/*port* **us-channel** *rf-channel* **Example:** `Router(config-if)# upstream 0 upstream-cable 7/0/0 us-channel 0`	Associates a set of physical upstream channels with the Mac Domain.
Step 6	**cable upstream bonding-group** *id* **Example:** `Router(config-if)# cable upstream bonding-group 200`	Creates the upstream bonding group on the specified cable interface and enters upstream bonding configuration submode.
Step 7	**upstream** *number* **Example:** `Router(config-upstream-bonding)# upstream 1`	Adds an upstream channel to the upstream bonding group. A maximum of 16 upstream channels can be configured for each MAC Domain, which are divided into two groups: • Group 1: upstream channel 0-7 • Group 2: upstream channel 8-15 The **upstream bonding-group** should include all the upstream channels either from Group 1 or Group 2 only.
Step 8	**attributes** *value* **Example:** `Router(config-upstream-bonding)# attributes eeeeeeee`	Modifies the attribute value for the specified upstream bonding group.
Step 9	**end** **Example:** `Router(config-upstream-bonding)# end`	Exits upstream bonding configuration submode and returns to privileged EXEC mode.

Configuring Upstream Channel Priority

Feature History

Table 4: Feature History

Feature Name	Release Information	Feature Description
Upstream Channel Priority	Cisco IOS XE Bengaluru 17.6.1w	This feature allows the cable modem to do the initial ranging on the upstream channel with the highest priority.

Starting from Cisco IOS XE Bengaluru 17.6.1w release, you can use the **cable upstream priority** command to configure the upstream channel with different priorities.

```
Router(config-if)# cable upstream 0 priority 1
```

You can also run this command for mac-domain profile.

```
Router(config-profile-md)# cable upstream 0 priority 2
```

Use **show cable mac-domain mdd | in MD-US** command to check the upstream channel priority.

```
Router#show cable mac-domain c3/0/1 mdd | in MD-US
        MD-US Chan ID/CM-STATUS:  1/0x0000
        MD-US Chan Priority:  3
        MD-US Chan DCID Binding:    9  10  11  12  13  14  15  16
        MD-US Chan ID/CM-STATUS:  2/0x0000
        MD-US Chan Priority:  4
        MD-US Chan DCID Binding:    9  10  11  12  13  14  15  16
        MD-US Chan ID/CM-STATUS:  3/0x0000
        MD-US Chan Priority:  5
        MD-US Chan DCID Binding:    9  10  11  12  13  14  15  16
        MD-US Chan ID/CM-STATUS:  4/0x0000
        MD-US Chan Priority:  0
```

Configuration Examples

Upstream Channel with PHY Layer Configuration Example

```
...
us-channel 0 frequency 20000000
us-channel 0 channel-width 3200000 3200000
us-channel 0 power-level 0
us-channel 0 docsis-mode tdma
us-channel 0 minislot-size 2
us-channel 0 modulation-profile 21
no us-channel 0 shutdown
...
```

Upstream Channels with a MAC Domain Configuration Example

```
...
interface Cable8/0/0
downstream Modular-Cable 8/0/0 rf-channel 0
upstream 0 Upstream-Cable 8/0/0 us-channel 0
upstream 1 Upstream-Cable 8/0/0 us-channel 1
cable mtc-mode
cable upstream bonding-group 1
  upstream 0
  upstream 1
  attributes 80000000

...
```

Additional References

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

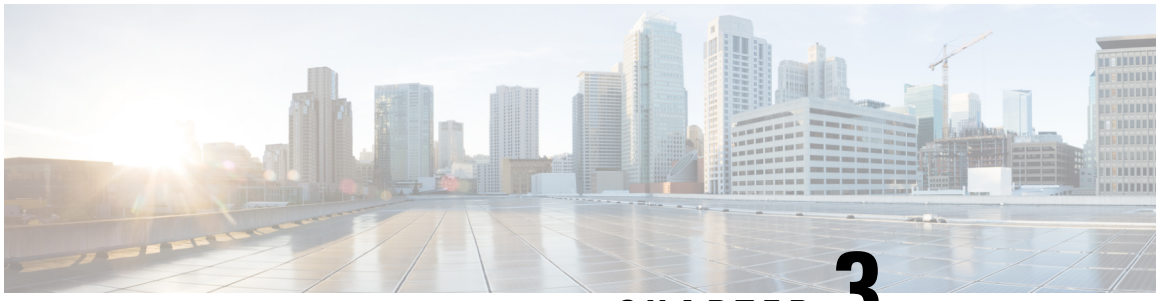
Feature Information for Upstream Interface Configuration on the Cisco cBR Router

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 5: Feature Information for Upstream Interface Configuration

Feature Name	Releases	Feature Information
Upstream Interface Configuration	Cisco IOS XE Fuji 16.7.1	This feature was integrated on theCisco cBR Series Converged Broadband Routers.



CHAPTER 3

DOCSIS Interface and Fiber Node Configuration

- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 23
- Overview of DOCSIS Interfaces and Fiber Node Configurations, on page 24
- Configuring DOCSIS Interfaces and Fiber Nodes, on page 26
- Configuring MAC Domain Service Groups, on page 32
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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 6: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Overview of DOCSIS Interfaces and Fiber Node Configurations

The Interface line card used in the Cisco cBR chassis is an integrated line card that has two downstream modules and one upstream module. The line cards support DOCSIS 3.0 features including downstream bonding groups, and upstream bonding groups.

Downstream Features

Physically, the downstream modules support eight physical connectors or ports. The downstream modules support the following features:

- The downstream modules support eight downstream integrated-cable controllers for these eight ports. Each downstream integrated-cable controller is associated with an RF port.
- Each downstream controller supports up to 128 downstream channels (0-127).
- Each downstream controller supports up to 128 integrated-cable interfaces. Therefore, each line card has 1024 integrated-cable interfaces.
- Each integrated-cable interface has a static mapping to an integrated-cable controller RF channel. For example, Integrated-Cable interface 3/0/0:0 is mapped to RF Channel 0 on Integrated-Cable controller 3/0/0.
- The following table lists the number of downstream DOCSIS channels different Cisco cBR-8 line cards support.

  This table lists the number of downstream DOCSIS channels different Cisco cBR-8 line cards support.

Table 7: Support for Downstream DOCSIS Channels

Line Card	Downstream DOCSIS Channels
CBR-CCAP-LC-40G	Up to 768
CBR-CCAP-LC-40G-R	Up to 1024
CBR-CCAP-LC-G2-R	Up to 1536

Note In Cisco IOS XE Amsterdam 17.3.x and earlier releases, CBR-CCAP-LC-G2-R line card supports up to 768 downstream DOCSIS channels.

- A total of 512 wideband-cable interfaces (downstream bonding groups) may be configured on each line card.
  - Each wideband-cable interface supports a maximum of 64 downstream channels.
  - 128 of the 512 wideband-cable interfaces (downstream bonding groups) may contain 33 or more channels.

Upstream Features

The Interface line card has one upstream module supporting 16 physical connectors or ports. The upstream features are as follows:

- The line card supports 16 upstream-cable controllers, each mapping to one upstream connector.
- 12 upstream channels can be configured per upstream controller.
- 12 upstream channels can be enabled per pair of upstream controllers.

For more details on the upstream features, see the *Downstream Upstream Guide*.

MAC Domains (Cable Interfaces)

1. 16 MAC domains (cable interfaces) may be configured per line card.

Note CBR-CCAP-LC-G2-R line card supports up to 32 MAC domains per line card.

2. Maximum of 16 upstream channels can be configured in each MAC domain.
3. A maximum of 255 downstream channels may be added to a MAC domain.
4. Maximum number of primary capable downstream channels per MAC Domain is 32. Non Primary downstream channels are added automatically to the MAC domains when the fiber nodes are configured.

Fiber Nodes

512 fiber nodes may be configured for each Cisco cBR-8 chassis.

Configuring DOCSIS Interfaces and Fiber Nodes

Configuring Upstream Channels

Verifying the Controller Configuration

Use the **show controllers upstream-cable** command to verify the configuration of the upstream channels in the controllers. Use the modifier **| include upstream** to see the administrative and operational state of the controllers.

```
Router#show controllers upstream-Cable 1/0/0 | include upstream
Controller 1/0/0 upstream 0  AdminState:UP OpState: UP
Controller 1/0/0 upstream 1  AdminState:UP OpState: UP
Controller 1/0/0 upstream 2  AdminState:UP OpState: UP
Controller 1/0/0 upstream 3  AdminState:UP OpState: UP
Controller 1/0/0 upstream 4  AdminState:DOWN Opstate: DOWN (Reason: Default)
Controller 1/0/0 upstream 5  AdminState:DOWN Opstate: DOWN (Reason: Default)
Controller 1/0/0 upstream 6  AdminState:DOWN Opstate: DOWN (Reason: Default)
Controller 1/0/0 upstream 7  AdminState:DOWN Opstate: DOWN (Reason: Default)
Router#
```

Binding Upstream Channels to MAC Domain

By default, a MAC domain does not contain any upstream channels. This section describes the configurations necessary to bind one or more upstream channels to a MAC domain. Each upstream channel is bound to only one MAC domain. The MAC domain and the upstream channel must reside on the same line card (same slot). If required, the upstream channels within the same upstream controller can be bound to different MAC domains.

Before you begin

Restrictions

- A maximum of 8 upstream channels may be bound to one MAC domain.

Note A maximum of 16 upstream channels may be configured in each MAC domain.

- The MAC domain and channels must share the same slot. That is, a MAC Domain may include channels from any controller on the same slot.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** **Example:** `Router#interface cable 1/0/0`	Enters MAC Domain configuration mode. Values for slot are 0-3 and 6-9, for subslot is always 0, for MD Index is 0-15.
Step 4	**upstream upstream-Cable us-channel** **Example:** `Router(config-if)#upstream 4 upstream-Cable 1/0/0 us-channel 7`	Binds the specified upstream channel to the MAC Domain.
Step 5	**end** **Example:** `Router# end`	Returns to privileged EXEC mode.

What to do next

To verify MAC Domain configurations for upstream, use the **show cable mac-domain** command with **cgd-associations** keyword.

The MD US Binding table shows the upstream channel binding.

```
Router#show cable mac-domain c1/0/0 cgd-associations
Load for five secs: 1%/0%; one minute: 2%; five minutes: 2%
Time source is NTP, *13:36:26.209 PST Fri Jan 20 2012
CGD Host  Resource  DS Channels           Upstreams    (ALLUS)   Active DS
Ca1/0/0   1/0/0     8                     0-1          Yes        8

                    16                    0-1          Yes        16
```

```
                    24                  0-1         Yes         24

                    32-33               0-1         Yes         32-33

                    40                  0-1         Yes         40


MD US binding:
Host    MD Controller US channel State
Ca1/0/0 U0 1/0/0      0          UP
Ca1/0/0 U1 1/0/0      1          UP
Ca1/0/0 U2 1/0/0      2          UP
Ca1/0/0 U3 1/0/0      3          UP
Ca1/0/0 U4 1/0/1      0          UP
Ca1/0/0 U5 1/0/1      1          UP
Ca1/0/0 U6 1/0/1      2          UP
Ca1/0/0 U7 1/0/1      3          UP

Router#
```

Configuring Primary Capable Downstream Channels

Verifying Downstream Configuration in Controller

Use the **show controller Integrated-Cable** command to verify the status of the downstream channels configured on an Integrated-cable controller.

```
Router# show controller Integrated-Cable 1/0/0 rf-channel 0-127
Chan State Admin Frequency Type   Annex Mod srate Interleaver dcid power output
0 UP UP    381000000       DOCSIS B     256 5361  I32-J4      1    32    NORMAL
1 UP UP    387000000       DOCSIS B     256 5361  I32-J4      2    34    NORMAL
2 UP UP    393000000       DOCSIS B     256 5361  I32-J4      3    34    NORMAL
3 UP UP    399000000       DOCSIS B     256 5361  I32-J4      4    34    NORMAL
```

Configuring Integrated-cable Interface

Configure an integrated-cable interface to prepare a downstream channel for inclusion within a MAC Domain as a primary-capable downstream channel. The interface configuration provides the following advantages:

- It enables the allocation of bandwidth to the downstream channel.
- It enables the control of the administrative state (shut/no shut) of the channel interface.

The time interval required between the shut and no shut administrative states for the same controller is approximately 30 seconds. You must not change the shut and no shut states rapidly without any delay in script or copy-paste. It can generate unexpected errors.

Each integrated-cable interface is mapped statically to an integrated-cable controller RF channel. For example, IC interface 1/0/0:0 is mapped to IC controller 1/0/0 RF channel 0. Similarly, IC interface 1/0/0:1 is mapped to IC controller 1/0/0 RF channel 1.

IC controllers are numbered 0-7 and RF Channels on each controller are numbered 0-127.

Before you begin

Determine the percentage of bandwidth to allocate to a channel. The bandwidth percentage configured is converted to a committed information rate (CIR) value for the interface. The value is used to admit non-bonded service flows on this channel. For more information, see the *Dynamic Bandwidth Sharing on the Cisco CMTS Router*.

Step 1 **enable**

Example:

```
Router> enable
```

Enables privileged EXEC mode.

Enter your password if prompted.

Step 2 **configure terminal**

Example:

```
Router# configure terminal
```

Enters global configuration mode.

Step 3 **interface integrated-cable**

Example:

```
Router(config)# interface integrated-cable 1/0/0:0
```

Enter the integrated-cable interface configuration mode for specified integrated-cable interface.

Step 4 **cable rf-bandwidth-percent** *percentage-number*

Example:

```
Router(config-if)# cable rf-bandwidth-percent 30
```

Configures the bandwidth allocation to the specified integrated-cable interface.

Step 5 **end**

Example:

```
Router# end
```

Returns to privileged EXEC mode.

What to do next

The following conditions are used to determine if an IC (Integrated-Cable) interface is up in current software.

- The IC interface is associated to a MD (MAC Domain) interface.
- The MD interface, which the IC interface associated to, is in UP state.
- The IC interface is not configured shut down.
- The IC interface is configured with bandwidth.

- The associated downstream channel within the IC controller is operationally up.

Use the **show interface Integrated-Cable controller** command to verify the status of the specified integrated-cable interface. The State info table provides information to diagnose issues affecting the operational state of the interface.

```
Router# show interface Integrated-Cable 1/0/0:0 controller
Integrated-Cable1/0/0:0 is up, line protocol is up
…
-----------------------------------------------
State info (DSNB if and its underlying states)
-----------------------------------------------
DSNB IF state : UP
RF Chan state : UP
RF Chan frequency : 381000000
Bandwidth configured on DSNB IF : YES
Inject Header/HW flow creation status : DSNB_IF_SM_UP
MD state (9/0/0) : UP
*DSNB i/f Line State : UP
-----------------------------------------------
```

Binding Primary Capable Downstream Channels to a MAC Domain

After a downstream channel has a properly configured Integrated-cable interface, it may be bound to a MAC Domain as a primary capable channel. The Channel Grouping Domain (CGD) configuration allows specified downstream channels to be bound to a MAC Domain as primary capable channels. Optionally, it also allows downstream channels to be associated with a subset of upstream channels within the MAC domain.

Before you begin

Restrictions

- The downstream channel and MAC domain must reside on the same line card (same slot)
- A maximum of 32 primary capable downstream channels may be bound to a single MAC domain.

Step 1 **enable**

Example:

```
Router> enable
```

Enables privileged EXEC mode.

Enter your password if prompted.

Step 2 **configure terminal**

Example:

```
Router# configure terminal
```

Enters global configuration mode.

Step 3 **interface cable**

Example:

```
Router#interface cable 1/0/0
```

Enters MAC domain configuration mode.

- *slot*—Specifies the chassis slot number of the interface line card. Valid values are 0-3 and 6-9
- *subslot*—Specifies the secondary slot number of the interface line card. Valid subslot is 0.
- *MD index*—Specifies the MAC Domain index number. Valid values are 0-15.

Step 4 **downstream Integrated-Cable** *slot/subslot/port* **rf-channels** *grouplist*

Example:

```
Router#downstream Integrated-Cable 1/0/0 rf-channels 1-6
```

Configures the downstream primary capable channels.

- *grouplist*—Specify the range of downstream rf-channels.

Step 5 **end**

Example:

```
Router# end
```

Returns to privileged EXEC mode.

What to do next

To verify the downstream primary capable channels, use the **show cable mac-domain** command with **cgd-associations** keyword.

```
Router#show cable mac-domain c1/0/0 cgd-associations
Load for five secs: 1%/0%; one minute: 2%; five minutes: 2%
Time source is NTP, *13:36:26.209 PST Fri Jan 20 2012
CGD Host  Resource  DS Channels           Upstreams    (ALLUS)   Active DS
Ca1/0/0   1/0/0     8                     0-1          Yes        8

                    16                    0-1          Yes        16

                    24                    0-1          Yes        24

                    32-33                 0-1          Yes        32-33

                    40                    0-1          Yes        40


MD US binding:
Host    MD Controller US channel State
Ca1/0/0 U0 1/0/0      0          UP
Ca1/0/0 U1 1/0/0      1          UP
Ca1/0/0 U2 1/0/0      2          UP
Ca1/0/0 U3 1/0/0      3          UP
Ca1/0/0 U4 1/0/1      0          UP
Ca1/0/0 U5 1/0/1      1          UP
Ca1/0/0 U6 1/0/1      2          UP
Ca1/0/0 U7 1/0/1      3          UP
```

```
Router#
```

Configuring MAC Domain Service Groups

Configuring the Fiber Nodes

A maximum of 512 fiber nodes may be configured per CMTS. A fiber node configured on the CMTS represents one or more matching physical fiber nodes in the HFC plant. The CMTS uses the fiber node configuration to identify the DOCSIS downstream service group (DS-SG) and DOCSIS upstream Service Group (US-SG) of the physical fiber nodes in the plant. The Service Group information is compared with MAC Domain channel configuration to automatically calculate the MAC Domain downstream and upstream service groups (MD-DS-SGs and MD-US-SGs respectively) within the MAC Domains.

The following is required to create a valid fiber node configuration.

- Each fiber node configuration must include at least one downstream controller and one upstream controller.
- Every MAC Domain and Wideband Interface including channels within the fiber node must use the same bundle interface.
- All downstream channels included within the fiber node must be assigned a unique frequency.
- All downstream channels associated with a particular MAC Domain must be assigned a unique DOCSIS channel ID.

If automatic DOCSIS channel ID allocation is preferred over manual DOCSIS channel ID configuration, the **cable downstream-channel-id automatic** command may be used to enable automatic DOCSIS channel ID allocation for the CMTS.

For details, see the *Cisco CMTS Cable Command Reference*.

Step 1 **enable**

Example:

```
Router> enable
```

Enables privileged EXEC mode.

Enter your password if prompted.

Step 2 **configure terminal**

Example:

```
Router# configure terminal
```

Enters global configuration mode.

Step 3 **cable fiber-node** *id*

Example:

```
Router(config)#cable fiber-node 1
Router(config-fiber-node)#
```

Enters cable fiber-node configuration mode to configure a fiber node

- *id*— cable fiber node ID. The valid range is 1-512.

Step 4 **downstream Integrated-Cable** *slot/subslot/port*

Example:

```
Router(config-fiber-node)#downstream Integrated-Cable 1/0/0
```

Adds the DOCSIS downstream channels within the controller to the fiber node.

Step 5 **upstream upstream-Cable** *slot/subslot/port*

Example:

```
Router(config-fiber-node)#upstream upstream-Cable 1/0/0
```

Adds the upstream channels within the controller to the fiber node.

Step 6 **end**

Example:

```
Router# end
```

Returns to privileged EXEC mode.

What to do next

To verify the fiber-node configuration use the **show cable fiber-node** command.

```
Router# show cable fiber-node 1
-------------------------------------------------------------------------------
--
Fiber-Node 1
Description: Feed Mac Domain: Cable1/0/0
Channel(s) : downstream Integrated-Cable 1/0/0: 0-3, 32-35, 64-67,
96-99
Channel ID(s): 1 2 3 4 33 34 35 36 65 66 67 68 97 98
99 100
Upstream-Cable 1/0/0
FN Config Status: Configured (status flags = 0x01)
MDD Status: Valid
Router#
```

The output shows the downstream channel IDs configured on a fiber node. It also shows the status of the upstream-cable configured on the fiber node. Further, it shows the status of MAC Domain Descriptor (MDD) messaging.

Verify MD-DS-SG Channel Membership

Once the fiber node is valid, the MD-DS-SGs within the associated MAC domains will be automatically populated with downstream channels. The MD-DS-SGs will include the active primary downstream channels within the MAC domain as well as non-primary downstream channels automatically associated with the MAC domain through the fiber node configuration. The non-primary channels must be properly configured within the controller (that are operationally up) to be included in MD-DS-SGs

Use the **show cable mac-domain** command with the **downstream-service-group** option to display the MD-DS-SG channel membership.

```
outer#show cable mac-domain c1/0/0 downstream-service-group
Cable MD-DS-SG RF
IF Id Resource Chan  Primary Chan
C1/0/0 5 1/0/0 0-3   0-3
               32-35 32-35
               64-67
               96-99
```

To verify that the primary downstream channels are transmitting MAC Management Messages (MMMs) use the **show controller Integrated-Cable counter rf-channel** command.

```
Router#sh controllers Integrated-Cable 7/0/0 counter rf-channel
Controller  RF    MPEG       MPEG        MPEG   Sync       MAP/UCD    User    QAM
            Chan  Packets    bps         Mbps   Packets    Packets    Mbps    Util
                             Tx                             Tx         Tx      Percentage
7/0/0       0     0          0           00.00  0          0          00.00   000.00
7/0/0       1     0          0           00.00  0          0          00.00   000.00
7/0/0       2     8239954    2475952     02.47  0          0          02.39   006.60
7/0/0       3     85927382   25769779    25.76  0          0          24.94   068.71
7/0/0       4     85927608   25769027    25.76  0          0          24.94   068.71
7/0/0       5     8239088    2474599     02.47  0          0          02.39   006.59
7/0/0       6     8210840    2463770     02.46  0          0          02.38   006.57
7/0/0       7     50103      15040       00.01  0          0          00.01   000.04
7/0/0       8     50103      15040       00.01  0          0          00.01   000.04
```

Verify MD-US-SG Channel Membership

Use the **show cable mac-domain** command with the **upstream-service-group** option to display the MD-US-SG channel membership.

```
Router#show cable mac-domain c1/0/0 upstream-service-group
Cable MD 1/0/0
US-SG-ID : 5 US-Chan : U0,1,2,3
Primary-DS: 1/0/0:0 US-SG-ID: 5
MDD US-List : U0,1,2,3
MDD Ambiguity : U0,1,2,3
Primary-DS: 1/0/0:1 US-SG-ID: 5
MDD US-List : U0,1,2,3
MDD Ambiguity : U0,1,2,3
Primary-DS: 1/0/0:2 US-SG-ID: 5
MDD US-List : U0,1,2,3
MDD Ambiguity : U0,1,2,3
Primary-DS: 1/0/0:3 US-SG-ID: 5
MDD US-List : U0,1,2,3
MDD Ambiguity : U0,1,2,3
```

Downstream Bonding Group Configuration

Configuring Wideband-cable Interface (Downstream Bonding Grouping)

A Wideband-Cable interface forwards bonded traffic in the downstream direction. A set of downstream RF channels is configured under the Wideband interface. Each line card will support up to 512 Wideband interfaces.

Although there is no real relationship between these wideband interfaces and the 8 controllers (ports), there is a convention of dividing the wideband interfaces into groups per controller.

The 512 wideband interfaces are divided among the 8 controllers - 64 interfaces per controller.

You can create a wideband-cable interface to define a downstream bonding group. A downstream bonding group bonds together a set of downstream RF channels. It can only contain the RF channels from the same line card.

Associations between bonding groups and MAC Domains are automatically created. Associations occur when a bonding group channel set is found to be a subset of a MAC Domain Downstream Service Group (MD-DS-SG) within a MAC Domain. The automatic associations will trigger the creation of an RCC that contains the bonding group's channel set within the MAC Domain.

Before you begin

Restrictions:

1. Included downstream channels must be a part of the same line card slot.
2. All the downstream channels must be from the integrated-cable controllers 0-3 or 4-7.

Step 1 **enable**

Example:

```
Router> enable
```

Enables privileged EXEC mode.

Enter your password if prompted.

Step 2 **configure terminal**

Example:

```
Router# configure terminal
```

Enters global configuration mode.

Step 3 **interface wideband-Cable**

Example:

```
Router(config)#interface wideband-Cable 1/0/0:1
Router(config-if)#
```

Enter the wideband-cable interface configuration mode for specified wideband-cable interface.

Step 4 **cable bundle** *id*

Example:

```
Router(config-if)#cable bundle 1
```

Configures the cable bundle id for this wideband-cable interface. The configured cable bundle id must match the cable bundle id configured in associated MAC domains.

- *Bundle number*— cable bundle number. The valid range is 1-255.

Step 5 **cable rf-channels channel-list** *grouplist* **bandwidth-percent** *percentage-bandwidth*

Example:

```
Router(config-if)#cable rf-channel channel-list 1-3 bandwidth-percent 10
```

Configures the bandwidth allocation for specified channel-list and includes the channels in the downstream bonding group. Range for channel numbers are 0-127 (<first channel num-last channel num>).

- *grouplist*—Specify the range of downstream rf-channels.

Step 6 **cable rf-channels controller** *controller number* **channel-list** *grouplist* **bandwidth-percent** *percentage-bandwidth*

Example:

```
Router(config-if)#cable rf-channel controller 1 channel-list 1-3 bandwidth-percent 10
```

Configures the bandwidth allocation for specified channel-list on downstream controllers and includes the channels in the downstream bonding group. Range for channel numbers are 0-127.

- *controller number*—Downstream controller number. The valid numbers are 0-7.
- *grouplist*—Specify the range of downstream rf-channels.

Step 7 **end**

Example:

```
Router# end
```

Returns to privileged EXEC mode.

What to do next

Verify the Bonding Group Interfaces.

Verifying the Bonding Group Interfaces

Use **wideband-channel** option of the **show controllers integrated-Cable** command to display bonding group interfaces:

```
Router# show controllers integrated-cable 1/0/0 wideband-channel
Load for five secs: 2%/0%; one minute: 2%; five minutes: 2%
```

```
Time source is NTP, *17:45:51.964 PST Thu Jan 12 2012
WB                      BG    Primary
channel                 ID    BG
Wideband-Cable1/0/0:0   12289 Yes
Wideband-Cable1/0/0:1   12290 Yes
Wideband-Cable1/0/0:2   12291 Yes
Wideband-Cable1/0/0:3   12292 Yes
Wideband-Cable1/0/0:4   12293 Yes
Wideband-Cable1/0/0:5   12294 Yes
Wideband-Cable1/0/0:6   12295 Yes
Wideband-Cable1/0/0:7   12296 Yes
Wideband-Cable1/0/0:8   12297 Yes
Wideband-Cable1/0/0:9   12298 Yes
Wideband-Cable1/0/0:10  12299 Yes
Wideband-Cable1/0/0:11  12300 Yes
Wideband-Cable1/0/0:12  12301 Yes
Wideband-Cable1/0/0:13  12302 Yes
Wideband-Cable1/0/0:14  12303 Yes
Wideband-Cable1/0/0:15  12304 Yes
Wideband-Cable1/0/0:16  12305 Yes
Wideband-Cable1/0/0:17  12306 Yes
Wideband-Cable1/0/0:18  12307 Yes
Wideband-Cable1/0/0:19  12308 Yes
Wideband-Cable1/0/0:20  12309 Yes
Wideband-Cable1/0/0:21  12310 Yes
Wideband-Cable1/0/0:22  12311 Yes
Wideband-Cable1/0/0:23  12312 Yes
Wideband-Cable1/0/0:24  12313 Yes
Wideband-Cable1/0/0:25  12314 Yes
```

- To display the RF-channel mapping to wideband channels, use **mapping wb-channel** option.

```
Router# show controllers Integrated-Cable 1/0/0 mapping wb-channel 0
Ctrlr    WB       RF         WB %   WB Rem
1/0/0    0        1/0/0:0    40     1
                  1/0/0:1    40     1
```

- To display the downstream MAC Domain service groups, use the **dsbg-associations** option of the **show cable mac-domain** command.

```
Router# show cable mac-domain c1/0/0 dsbg-associations
Wi1/0/0:0       Wi1/0/0:1
```

Use the **show interface Wideband-Cable controller** command to verify the bonding group configurations. The State info table shows the downstream bonding group state information.

```
Router#show interface Wideband-Cable 1/0/0:0 controller
Wideband-Cable1/0/0:0 is up, line protocol is up
  Hardware is CMTS WB interface, address is c414.3c17.1dcb (bia c414.3c17.1dcb)
  MTU 1500 bytes, BW 150000 Kbit/sec, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation MCNS, loopback not set
  Keepalive set (10 sec)
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/375/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: weighted fair
```

```
  Output queue: 0/1000/64/0 (size/max total/threshold/drops)
     Conversations  0/0/256 (active/max active/max total)
     Reserved Conversations 0/0 (allocated/max allocated)
     Available Bandwidth 112500 kilobits/sec
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts (0 multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     0 packets output, 0 bytes, 0 underruns
     0 output errors, 0 collisions, 3 interface resets
     0 unknown protocol drops
     0 output buffer failures, 0 output buffers swapped out


BG controller details
Wi1/0/0:0 BGID: 12289
Member RFIDs:
  Config RFIDs: 12288-12291 Count: 4
  Active RFIDs: 12288-12291 Count: 4
Attribute mask: 0x80000000
-----------------------------------------------
State info (DSBG if and its underlying states)
-----------------------------------------------
DSBG IF state               : UP
DSBG Member RF chan states  : UP (4 out of 4 chans are UP)
DSBG HWID(FCID)             : 0x3800
*DSBG i/f Line State        : UP
-----------------------------------------------
-----------------------------
DMP Resources
DMP handle     : 0x10000800
-----------------------------
DMP BG pool entry details
HW-id   BGid  BGSize  Enabled
-----------------------------
0     : 12289 4        1
-----------------------------
Bgid  BGecnt BGaddr Channels (1023 means invalid/Unused)
    0      0      0:   0    1    2    3 1023 1023 1023 1023
BG         Rate   Neg   Pos    LastTS  CurrCr  Pos
   0      25000 65535 65535         0       0   N

-----------------------------
RFID - JIB chan mapping for active RFIDs: [rfid:jib-chan-no]
[12288:0] [12289:1] [12290:2] [12291:3]

Router#
```

Upstream Bonding Group Configuration

Restrictions for Upstream Bonding Groups

- Upstream bonding groups are configured within the MAC Domain interface
- Upstream bonding groups consist of a set of upstream channels that are bonded together.

- A maximum of 16 upstream channels can be configured for each MAC Domain, which are divided into two groups:
  - Group 1: upstream channel 0-7
  - Group 2: upstream channel 8-15

  The **upstream bonding-group** should include all the upstream channels either from Group 1 or Group 2 only.

Configuring Upstream Bonding Groups

Before you begin

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** *slot/subslot/MD index* **Example:** `Router(config)# interface cable 1/0/0`	Enters MAC domain configuration mode. • *slot*—Specifies the chassis slot number of the interface line card. Valid values are 0-3 and 6-9 • *subslot*—Specifies the secondary slot number of the interface line card. Valid subslot is 0. • *MD index*—Specifies the MAC Domain index number. Valid values are 0-15.

Step 4	**cable upstream bonding-group**
	Example:
	`Router(config-if)#cable upstream bonding-group 7`
	`Router(config-upstream-bonding)#`
		Creates a static upstream bonding group on a MAC Domain.

Step 5	**upstream** **Example:** `Router(config-upstream-bonding)#upstream 7`	Add upstream channels to an upstream bonding group. A maximum of 16 upstream channels can be configured for each MAC Domain, which are divided into two groups: • Group 1: upstream channel 0-7 • Group 2: upstream channel 8-15

	Command or Action	Purpose
		The **upstream bonding-group** should include all the upstream channels either from Group 1 or Group 2 only.
Step 6	**end** **Example:** `Router# end`	Returns to privileged EXEC mode.

What to do next

Use the **show interface cable upstream bonding-group** command to display upstream bonding group information.

```
Router#show interface cable 1/0/0 upstream bonding-group
Load for five secs: 1%/0%; one minute: 2%; five minutes: 2%
Time source is NTP, *10:47:17.142 PST Thu Jan 12 2012

Cable1/0/0: Upstream Bonding Group 1
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 46080000 bits/sec
     Total Service Flows On This Bonding Group: 0
Cable1/0/0: Upstream Bonding Group 2
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 46080000 bits/sec
     Total Service Flows On This Bonding Group: 0
Cable1/0/0: Upstream Bonding Group 65536
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 15360000 bits/sec
     Total Service Flows On This Bonding Group: 0
Cable1/0/0: Upstream Bonding Group 65537
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 15360000 bits/sec
     Total Service Flows On This Bonding Group: 0

Router#
```

Verifying Upstream Bonding Groups

Use the **show cable upstream bonding-group** command.

```
Router#show interface cable 1/0/0 upstream bonding-group
Load for five secs: 1%/0%; one minute: 2%; five minutes: 2%
Time source is NTP, *10:47:17.142 PST Thu Jan 12 2012
```

```
Cable1/0/0: Upstream Bonding Group 1
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 46080000 bits/sec
     Total Service Flows On This Bonding Group: 0
Cable1/0/0: Upstream Bonding Group 2
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 46080000 bits/sec
     Total Service Flows On This Bonding Group: 0
Cable1/0/0: Upstream Bonding Group 65536
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 15360000 bits/sec
     Total Service Flows On This Bonding Group: 0
Cable1/0/0: Upstream Bonding Group 65537
     0 packets input, 0 octets input
     Segments: 0 valid, 0 discarded, 0 lost
     Reserved Bandwidth Max : 0 bits/sec
     Reserved Bandwidth     : 0 bits/sec
     Available Bandwidth    : 15360000 bits/sec
     Total Service Flows On This Bonding Group: 0

Router#
```

Additional References

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

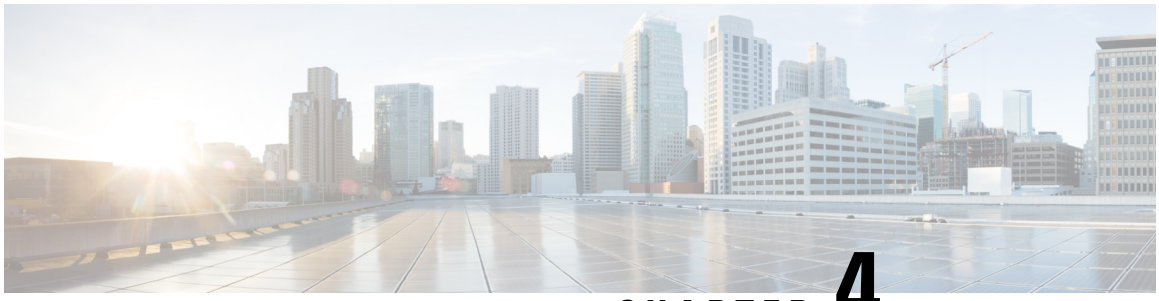
Feature Information for DOCSIS Interface and Fiber Node Configuration

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 8: Feature Information for DOCSIS Interface and Fiber Node Configuration

Feature Name	Releases	Feature Information
DOCSIS Interface and Fiber Node Configuration	Cisco IOS XE Everest 16.6.1	This feature was integrated into Cisco IOS XE Everest 16.6.1 on the cisco cBR Series Converged Broadband Routers.
Display QAM Utillization Percentage using the **sh controllers Integrated-Cable 7/0/0 counter rf-channel**	Cisco IOS XE Gibraltar 16.10.1f	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 4

Service Group Based Configuration of the Cisco cBR Router

- Service Group Profile Based Configuration, on page 43
- Service Profile Configuration for 16x8 with One MAC Domain, on page 45
- Service Profile Configuration for 16x8 with Two MAC Domains, on page 47
- MAC-Domain Split Configuration, on page 49

Service Group Profile Based Configuration

The DOCSIS Interface and Fiber Node Configuration guide describes the interface and fiber node configurations that are required to operationalize the Cisco cBR router. The steps described to accomplish the tasks involved in such configuration are complex.

To simplify and speed up the process of configuring the physical and logical interfaces required to deploy the Cisco cBR router quickly, a service group (SG) profile based approach is adopted. This document describes the simplified SG profile approach.

This approach provides the following advantages:

- Improves and simplifies the deployment of Cisco cBR router.
- Improves and simplifies the configuration of Cisco cBR Router by eliminating duplicate configurations.
- Improves and simplifies troubleshooting of Cisco cBR router.
- Supports faster Converged Cable Access Platform (CCAP) provisioning by using common and quick replication across nodes and regions.

To configure the interfaces and quickly operationalize the Cisco cBR router, a set of common profiles are created and are created and configured into global service group profiles. These global service group profiles may be applied to fiber node interfaces along with a mapping of the service group interfaces to the physical interfaces.

Common profiles are profiles which contain configurations for common service group (SG) interfaces like MAC domain, wideband-cable, and primary downstream

The common profiles and the global SG profiles may be independent of the topology of the network in which they are applied. The SG interface to physical interface mapping defines the behavior of the profiles in the topology that the SG profiles have been applied to.

Limitations:

- A common profile cannot be deleted if it is associated with the fiber nodes. It can be modified by entering the profile configuration mode using the **cable profile** command.
- A service-group profile cannot be deleted or modified if it is associated with the fiber nodes.
- To associate a new global SG profile to a fiber node, dissociate the currently associated global SG profile from the fiber node.
- To configure for a unique topology, use the full configuration approach provided in DOCSIS Interface and Fiber Node Configuration guide.
- When the secondary line card is in active mode, the following limitations apply:
  - A MAC domain, Wideband-Cable interface, downstream channel, and SG profile cannot be modified when they are associated with the fiber nodes.
  - SG profile cannot be dissociated from the fiber nodes.
  - A MAC domain, Wideband-Cable interface, downstream channel, and SG profile can be created but cannot be associated to the fiber node.
  - To enable the SG operation simplification feature, auto-reset feature must be enabled using the **cable wideband auto-reset** command.
- Do not support downgrade cBR-8 image from 16.7.x to previous image if the configuration includes mac domain split configuration.

Broadly, the following steps define and deploy the common profiles and the SG profiles:

1. Define and configure the Common profiles: The SG interface profiles or the common profiles contain configuration parameters common to a group of similar interfaces. For example, a profile may contain specific configuration parameters shared by multiple Wideband-Cable interfaces, associated across multiple line cards. A common profile is configured at the global or chassis level. All interfaces associated with a profile will inherit the configuration in the profile. Any common profile may be associated with any global SG profile. Use the **cable profile** *profile-type profile-name* command to define the following common profiles:
   - MAC Domain (MD) profile
   - Primary Downstream channel (DS) profile
   - Wideband-cable Interface (WB) profile
   - Global Service Group (SG) profile
2. Complete the following configurations to the fiber node interface using the **cable fiber-node** command:
   - Define the downstream and upstream ports. Map the appropriate interface-cable using the **downstream interface-cable** command. Map the appropriate upstream-cable interface using the **upstream upstream-cable** command.
   - Use the **downstream sg-channel** command to map the logical downstream SG channels to the physical RF channels and the **upstream sg-channel** command to map the logical upstream SG channels to the physical upstream channels.
   - Use the **service-group profile** to associate the global service group profile to the fiber node.

See the use case scenarios for configurations and examples.

Service Profile Configuration for 16x8 with One MAC Domain

This section describes the service group based configurations for a 16x8 service group with one MAC domain.

Step 1 **cable profile** *profile-type profile-name*

For MAC Domain profile, specify *profile-type* as **mac-domain**.

```
Router(config)#cable profile mac-domain MD1
Router(config-profile-md)#cable dynamic-secret mark
Router(config-profile-md)#cable shared-secret 0 cisco
Router(config-profile-md)#cable ip-init ipv4
Router(config-profile-md)#cable mtc-mode
Router(config-profile-md)#cable mrc-mode
Router(config-profile-md)#cable privacy mandatory
Router(config-profile-md)#cable privacy bpi-plus-policy
```

For Primary downstream profile, specify *profile-type* as **downstream**.

```
Router(config)#cable profile downstream DS1
Router(config-profile-ds)#cable rf-bandwidth-percent 20
Router(config-profile-ds)#cable attribute-mask 0x80000000
```

For wideband-cable interface profile, specify *profile-type* as **wideband-interface**.

```
Router(config)#cable profile wideband-interface BG1
Router(config-profile-wb)#cable downstream attribute-mask 0x80000000
```

For global service group profile, specify *profile-type* as service-group. In the service group profile, configure the cable bundle associated, mac-domain profile, and the wideband interface profile

```
Router(config)#cable profile service-group SG-16x8-1_1
Router(config-profile-sg)#cable bundle 71
Router(config-profile-sg)#mac-domain 0 profile md1
Router(config-profile-sg-md)#downstream sg-channel 0-7  profile ds1 upstream 0-3
Router(config-profile-sg-md)#upstream 0 sg-channel 0
Router(config-profile-sg-md)#upstream 1 sg-channel 1
Router(config-profile-sg-md)#upstream 2 sg-channel 2
Router(config-profile-sg-md)#upstream 3 sg-channel 3
Router(config-profile-sg-md)#upstream 4 sg-channel 4
Router(config-profile-sg-md)#upstream 5 sg-channel 5
Router(config-profile-sg-md)#upstream 6 sg-channel 6
Router(config-profile-sg-md)#upstream 7 sg-channel 7
Router(config-profile-sg-md)#us-bonding-group 1
Router(config-profile-sg-md-usbg)#upstream 0
Router(config-profile-sg-md-usbg)#upstream 1
Router(config-profile-sg-md-usbg)#upstream 2
Router(config-profile-sg-md-usbg)#upstream 3
Router(config-profile-sg-md-usbg)#upstream 4
Router(config-profile-sg-md-usbg)#upstream 5
Router(config-profile-sg-md-usbg)#upstream 6
```

```
Router(config-profile-sg-md-usbg)#upstream 7
Router(config-profile-sg-md-usbg)#attributes 8000000
Router(config-profile-sg-md-usbg)#exit
Router(config-profile-sg-md)#exit
Router(config-profile-sg)#

Router(config-profile-sg)#wideband-interface 1 profile BG1
Router(config-profile-sg-bg)#downstream sg-channel 0 15 rf-bandwidth-percent 10
Router(config-profile-sg-bg)#end
Router#
```

Step 2 **cable fiber-node**

Enter fiber-node configuration mode. Configure the following in fiber-node configuration mode:

- downstream port
- upstream port
- downstream sg-channels to rf-channels mapping
- upstream sg-channels to us-channels mapping
- global service group mapping
- managed MAC domain

```
Router(config)#cable fiber-node 1
Router(config-fiber-node)#downstream integrated-cable 3/0/0
Router(config-fiber-node)#upstream upstream-cable 3/0/0
Router(config-fiber-node)#downstream sg-channel 0 15 integrated-cable 3/0/0 rf-channel 0 15
Router(config-fiber-node)#upstream sg-channel 0 7 upstream-cable 3/0/0 us-channel 0 7
Router(config-fiber-node)#service-group profile SG-16X8-1_1
```

What to do next

Use the **show cable fiber-node** [*id*] **mapping** and the **show cable fiber-node** [*id*] **derived** commands to check the configuration of the interfaces.

```
Router#show cable fiber-node 1 mapping
Fiber-node 1:
Upstream:
Sg chan       Us-chan        Op state
0             3/0/0 0        Up
1             3/0/0 1        Up
2             3/0/0 2        Up
3             3/0/0 3        Up
4             3/0/0 4        Up
5             3/0/0 5        Up
6             3/0/0 6        Up
7             3/0/0 7        Up
Downstream:
Sg chan       Ds-rf-chan     Op state
0             3/0/0:0        Up
1             3/0/0:1        Up
2             3/0/0:2        Up
```

```
3             3/0/0:3        Up
4             3/0/0:4        Up
5             3/0/0:5        Up
6             3/0/0:6        Up
7             3/0/0:7        Up
8             3/0/0:8        Up
9             3/0/0:9        Up
10            3/0/0:10        Up
11            3/0/0:11        Up
12            3/0/0:12        Up
13            3/0/0:13        Up
14            3/0/0:14        Up
15            3/0/0:15        Up
```

```
Router#show cable fiber-node 1 derived
Fiber-node 1:
              interface                   Assoc successed
mac-domain 0   Cable3/0/0                  Y
Wideband 1     Wideband-Cable3/0/0:0       Y
Router#
```

Use the **show cable mac-domain fiber-node** command to verify the interface associations.

```
Router#show cable mac-domain fiber-node 1 md 0 downstream-service-group
Cable    MD-DS-SG              RF
IF       Id        Resource    Chan     Primary Chan
C3/0/0
Router#
```

```
Router#show cable mac-domain fiber-node 1 md 0 upstream-service-group
Cable MD 3/0/0
Router#
```

Service Profile Configuration for 16x8 with Two MAC Domains

This section describes the service group based configurations for a 16x8 service group with two MAC domains, split downstream and overlaid upstream channels.

Step 1 **cable profile** *profile-type profile-name*

For MAC Domain profile, specify *profile-type* as **mac-domain**.

```
Router(config)#cable profile mac-domain MD1
Router(config-profile-md)#cable dynamic-secret mark
Router(config-profile-md)#cable shared-secret 0 cisco
Router(config-profile-md)#cable ip-init ipv4
Router(config-profile-md)#cable mtc-mode
Router(config-profile-md)#cable mrc-mode
Router(config-profile-md)#cable privacy mandatory
Router(config-profile-md)#cable privacy bpi-plus-policy
```

For Primary downstream profile, specify *profile-type* as **downstream**.

```
Router(config)#cable profile downstream DS1
Router(config-profile-ds)#cable rf-bandwidth-percent 20
Router(config-profile-ds)#cable attribute-mask 0x80000000
```

For wideband-cable interface profile, specify *profile-type* as **wideband-interface**.

```
Router(config)#cable profile wideband-interface BG1
Router(config-profile-wb)#cable downstream attribute-mask  0x80000000
```

For global service group profile, specify *profile-type* as service-group. In the service group profile, configure the cable bundle associated, mac-domain profile, and the wideband interface profile

```
Router(config)#cable profile service-group SG-16x4-1_2
Router(config-profile-sg)#cable bundle 71
Router(config-profile-sg)#mac-domain 0 profile md1
Router(config-profile-sg-md)#downstream sg-channel 0-15  profile ds1 upstream 0-3
Router(config-profile-sg-md)#upstream 0 sg-channel 0
Router(config-profile-sg-md)#upstream 1 sg-channel 1
Router(config-profile-sg-md)#upstream 2 sg-channel 2
Router(config-profile-sg-md)#upstream 3 sg-channel 3
Router(config-profile-sg-md)#us-bonding-group 1
Router(config-profile-sg-md-usbg)#upstream 0
Router(config-profile-sg-md-usbg)#upstream 1
Router(config-profile-sg-md-usbg)#upstream 2
Router(config-profile-sg-md-usbg)#upstream 3
Router(config-profile-sg-md-usbg)#exit
Router(config-profile-sg-md)#exit
Router(config-profile-sg)#

Router(config-profile-sg)#wideband-interface 1 profile BG1
Router(config-profile-sg-bg)#downstream sg-channel 0 7 rf-bandwidth-percent 10
Router(config-profile-sg-bg)#exit
Router(config-profile-sg)#wideband-interface 2 profile BG1
Router(config-profile-sg-bg)#downstream sg-channel 8 15 rf-bandwidth-percent 10
Router#
```

Step 2 cable fiber-node

Enter fiber-node configuration mode. Configure the following in fiber-node configuration mode:

- downstream port
- upstream port
- downstream sg-channels to rf-channels mapping
- upstream sg-channels to us-channels mapping
- global service group mapping
- managed MAC domain

```
Router(config)#cable fiber-node 1
Router(config-fiber-node)#downstream integrated-cable 3/0/0
Router(config-fiber-node)#upstream upstream-cable 3/0/0
Router(config-fiber-node)#downstream sg-channel 0 7 integrated-cable 3/0/0 rf-channel 0 15
Router(config-fiber-node)#upstream sg-channel 0 3 upstream-cable 3/0/1 us-channel 0 3
```

```
Router(config-fiber-node)#service-group profile SG-16X4-1_2
Router(config-fiber-node)#exit
Router(config)#
```

```
Router(config)#cable fiber-node 2
Router(config-fiber-node)#downstream integrated-cable 3/0/0
Router(config-fiber-node)#upstream upstream-cable 3/0/1
Router(config-fiber-node)#downstream sg-channel 0 7 integrated-cable 3/0/0 rf-channel 8 15
Router(config-fiber-node)#downstream sg-channel 8 15 integrated-cable 3/0/0 rf-channel 0 7
Router(config-fiber-node)#upstream sg-channel 0 3 upstream-cable 3/0/1 us-channel 0 3
Router(config-fiber-node)#service-group profile SG-16X4-1_2
Router(config-fiber-node)#exit
Router(config)#
```

What to do next

Use the **show cable fiber-node** [*id*] **mapping** and the **show cable fiber-node** [*id*] **derived** commands to check the configuration of the interfaces.

MAC-Domain Split Configuration

This section describes the MAC-domain split configurations.

Note

- In MAC domain split scenario, we must configure upstream peer-node-us and managed MAC domain.
- After a fiber node managed MAC domain, we will reserve cable interface by **cable managed fiber-node** command.
- If a fiber-node has peer, we can not add managed MAC domain.
- If a fiber-node has peer, we can not modify the configuration of channel mapping and upstream peer-node-us
- If a fiber-node has managed MAC domain, we can not remove upstream peer-node-us.
- Only both two fiber-nodes are associated with service group profile, mac-domains and wideband interfaces will be generated.
- MAC domain and wideband interfaces will be removed as soon as one fiber-node is unassociated with service group profile.

Step 1 cable profile mac-domain

Define global common profiles for MAC-domain, bonding group, primary downstream.

```
Router(config)#cable profile mac-domain MD
```

```
Router(config-profile-md)#load-interval 30
Router(config-profile-md)#cable dynamic-secret mark
Router(config-profile-md)#cable shared-secret 0 cisco
Router(config-profile-md)#cable ip-init ipv4
Router(config-profile-md)#cable mtc-mode
Router(config-profile-md)#cable mrc-mode
Router(config-profile-md)#cable privacy mandatory
Router(config-profile-md)#cable privacy bpi-plus-policy
Router(config-profile-md)#cable privacy accept-self-signed-certificate
Router(config-profile-md)#cable privacy dsx-support
Router(config-profile-md)#cable privacy eae-policy capability-enforcement
Router(config-profile-md)#cable privacy kek life-time 300
Router(config-profile-md)#cable privacy retain-failed-certificates
Router(config-profile-md)#cable privacy skip-validity-period
Router(config-profile-md)#cable privacy tek life-time 180
Router(config-profile-md)#cable cm-status enable 3
Router(config-profile-md)#cable map-advance dynamic
Router(config-profile-md)#cable upstream 0 attribute-mask FFFFFFFF
Router(config-profile-md)#cable upstream 0 power-adjust continue 5
Router(config-profile-md)#cable upstream balance-scheduling
Router(config)#cable profile downstream DS
Router(config-profile-ds)#cable rf-bandwidth-percent 20
Router(config-profile-ds)#cable attribute-mask 0x80000000
Router(config)#cable profile wideband-interface BG
Router(config-profile-wb)#cable downstream attribute-mask 0x80000000
Router(config-profile-wb)#description BG
Router(config-profile-wb)#load-interval 30
```

Step 2 cable profile service-group

In the service group profile, configure the cable bundle associated, mac-domain profile, and the wideband interface profile.

```
Router(config)#cable profile service-group MD_SPLIT
Router(config-profile-sg)#cable bundle 1
Router(config-profile-sg)#mac-domain 0 profile MD
Router(config-profile-sg-md)#downstream sg-channel 0-15 profile DS
Router(config-profile-sg-md)#upstream 0 sg-channel 0
Router(config-profile-sg-md)#upstream 1 sg-channel 1
Router(config-profile-sg-md)#upstream 2 sg-channel 2
Router(config-profile-sg-md)#upstream 3 sg-channel 3
Router(config-profile-sg-md)#upstream 4 sg-channel 4
Router(config-profile-sg-md)#upstream 5 sg-channel 5
Router(config-profile-sg-md)#upstream 6 sg-channel 6
Router(config-profile-sg-md)#upstream 7 sg-channel 7
Router(config-profile-sg-md)#us-bonding-group 1
Router(config-profile-sg-md-usbg)#upstream 0
Router(config-profile-sg-md-usbg)#upstream 1
Router(config-profile-sg-md-usbg)#upstream 2
Router(config-profile-sg-md-usbg)#upstream 3
Router(config-profile-sg-md-usbg)#attributes 8000000
Router(config-profile-sg-md-usbg)#exit
Router(config-profile-sg-md)#us-bonding-group 2
Router(config-profile-sg-md-usbg)#upstream 4
Router(config-profile-sg-md-usbg)#upstream 5
Router(config-profile-sg-md-usbg)#upstream 6
Router(config-profile-sg-md-usbg)#upstream 7
Router(config-profile-sg-md-usbg)#attributes 8000000
Router(config-profile-sg-md-usbg)#exit
Router(config-profile-sg-md)#exit
Router(config-profile-sg)#wideband-interface 0 profile WB
Router(config-profile-sg-bg)#downstream sg-channel 0 7 rf-bandwidth-percent 1
Router(config-profile-sg-bg)#exit
Router(config-profile-sg)#wideband-interface 1 profile WB
```

```
Router(config-profile-sg-bg)#downstream sg-channel 8 15 rf-bandwidth-percent 1
```

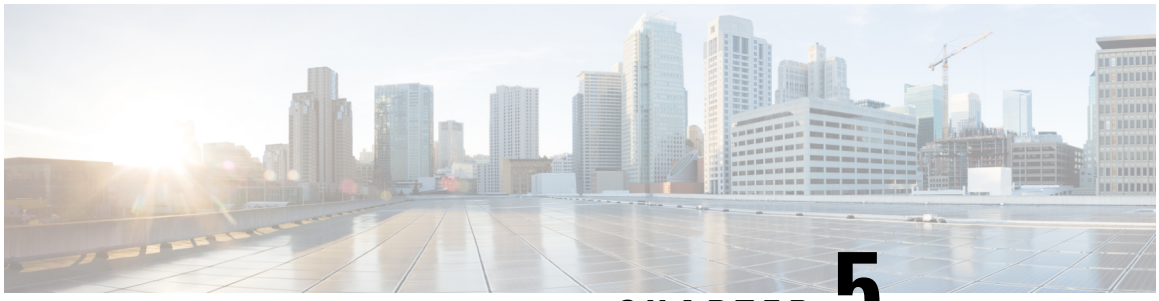
Step 3 **cable fiber-node**

Enter fiber-node configuration mode. Configure the following in fiber-node configuration mode:

- downstream port
- upstream port
- downstream sg-channels to rf-channels mapping
- upstream sg-channels to us-channels mapping
- abstract upstream channel
- managed MAC domain
- global service group mapping

```
Router(config)#cable fiber-node 67
Router(config-fiber-node)#downstream integrated-cable 6/0/6
Router(config-fiber-node)#upstream upstream-cable 6/0/6
Router(config-fiber-node)#downstream sg-channel 0 15 integrated-cable 6/0/6 rf-channel 0
15
Router(config-fiber-node)#upstream sg-channel 0 3 upstream-cable 6/0/6 us-channel 0 3
Router(config-fiber-node)#upstream sg-channel 4 7 peer-node-us
Router(config-fiber-node)#service-group managed md 0 cable6/0/6
Router(config-fiber-node)#service-group profile MD_SPLIT

Router(config)#cable fiber-node 69
Router(config-fiber-node)#downstream integrated-cable 6/0/6
Router(config-fiber-node)#upstream upstream-cable 6/0/1
Router(config-fiber-node)#downstream sg-channel 0 15 integrated-cable 6/0/6 rf-channel 0
15
Router(config-fiber-node)#upstream sg-channel 4 7 upstream-cable 6/0/1 us-channel 0 3
Router(config-fiber-node)#upstream sg-channel 0 3 peer-node-us
Router(config-fiber-node)#service-group managed md 0 cable6/0/6
Router(config-fiber-node)#service-group profile MD_SPLIT
```



CHAPTER 5

DOCSIS Load Balancing Groups

First Published: April 11, 2015

Support for the restricted load balancing group (RLBG)/general load balancing group (GLBG) is based on DOCSIS 3.0 specifications.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 9: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for DOCSIS Load Balancing Groups

DOCSIS Load Balancing Groups including Restricted/General Load Balancing groups with Downstream Dynamic Load Balancing feature has the following prerequisites:

- A RLBG and a DOCSIS 2.0 GLBG should have a load balancing group (LBG) ID.
- A LBG should have a default policy ID.
- During registration, a cable modem (CM) that has been assigned to a LBG must also be assigned a policy ID and priority, through Simple Network Management Protocol (SNMP), the cable modem configuration file, or Cisco Cable Modem Termination System (CMTS) configuration.

- The cable modem must send service type identifier (STID), service class name, and DOCSIS version and capability type/length/value (TLV) settings to the Cisco CMTS for registration if the fields are used by general tagging.

Restrictions for DOCSIS Load Balancing Groups

The DOCSIS Load Balancing Groups (LBG) including RLBG/GLBG Support with DLB Support feature has the following restrictions:

- A maximum of 256 DOCSIS policies and 256 rules per chassis are supported.
- Cross-line card (LC) configuration or moving of cable modems is not supported.
- When deployed with channel restriction features, if the target upstream channel attribute masks are against that of the cable modem, then the cable modem on the higher load upstream will not be load balanced, as the current load balancing moves cable modems only to the target upstream. However, cable modems that do not have an attribute mask can still be load balanced. You should consider the following while deploying the load balancing groups: the target upstream will always be the upstream that has the lowest load. If some other upstreams have the same load, the upstream with the lowest index will be chosen as the target upstream.
- We recommend all LBGs that share channels must use the same LB method.

The DOCSIS LBG with RLBG/GLBG Support and DLB Support feature have the following cross functional restrictions:

- Cable modems operating in the multiple transmit channel (MTC) mode do not register for a RLBG assignment, even if their configuration file contains relevant TLVs, such as STID and LBG ID. However, cable modems operating in the multiple receive channel (MRC) can register for a RLBG assignment.
- The Cisco CMTS can parse a specific TLV encoded in cable modem configuration file, and prohibit any DCC operation on the cable modems.
- DOCSIS MAC domain downstream service group (MD-DS-SG) channels in MDD messages are incorrect when a combination of channels from multiple line card types are placed in the same fiber node.

In a complex fiber node setup, with channels from more than one line card, or downstream channels of one MAC domain in more than one fiber node, some modems may not come w-online (wideband online). If a MAC domain has more than one MD-DS-SG, the MDD will contain more than one MD-DS-SG and cause the modem to perform downstream ambiguity resolution. When the modem analyzes the downstream channels from the other line card, it will not see MDD packets and disqualify the channel and the MD-DS-SG. The modem then sends a requested MD-DS-SG of 0 to the CMTS implying it will not participate in a bonding group.

Use the **show cable mac-domain downstream-service-group** command to see the channels in the same MD-DS-SG.

The DOCSIS LBG with RLBG/GLBG Support and DLB Support feature have the following scaling limitations:

- The total number of RLBGs and DOCSIS 2.0 GLBGs cannot exceed 256.
- The total number of tags in a Cisco CMTS cannot exceed 256.
- The total number of DOCSIS 3.0 GLBGs is bounded by free memory.
- A cable modem reset occurs if a CM moves from one cable interface to another because DCC init-tech 0 resets a cable modem during a LB move. A cable modem also resets if the two cable interfaces have been configured with a mismatched **cable ip-init** command.

Information About DOCSIS Load Balancing Groups

The DOCSIS 2.0 “Autonomous Load Balancing” specification is CM-centric, allowing a channel (US or DS) to be part of multiple RLBGs. Therefore, with the DOCSIS 2.0 specifications, you can decide on which channel the CM can be load balanced.

To configure the Restricted/General Load Balancing and Narrowband Dynamic Bandwidth Sharing with Downstream Dynamic Load Balancing feature, you should understand the following concepts:

Service-Based Load Balancing

Using the DOCSIS 3.0 modem-based load balancing specifications, you can manage the LB activity on a per-modem basis as follows:

1. Modem to RLBG association through STID
2. Modem to RLBG association through LBG ID
3. Per-modem LB policy assignment
4. Per-modem LB priority assignment
5. Per-modem channel restriction

Implementing the DOCSIS 3.0 modem-based LB specifications enables the Cisco CMTS to provide an advanced service-based LB. The service-based LB can be used to alleviate the burden for the modem-based provisioning and provide the operator an ability to selectively control LB activity based on modem service type. For example, for LB purposes modems can be classified based on:

- Device type
- DOCSIS version
- Service class

The results of the classification can then be used to selectively control the modem LB activity by mapping the modem to the following settings:

- LBG
- Policy

With the service-based LB enabled, existing service-based cable modem segregation features and channel restriction become special cases and can be handled within the same LB framework.

Functionality

The Cisco CMTS functions in the following ways for general tagging and service-based LB:

- The Cisco CMTS can classify some modems with user-defined modem classifiers using the STID, service class name, DOCSIS version and capability TLVs and MAC Organization Unique Identifier (OUI).
- Each modem classifier has a unique tag. The Cisco CMTS allows each modem to carry one tag. When multiple tags match one cable modem, the tag that has the least index gets applied on the cable modems.
- The Cisco CMTS classifies a CM and assigns a tag, and if a RLBG with that tag is configured, the CM gets assigned to that RLBG.
- The Cisco CMTS can match multiple tags to a RLBG and a DOCSIS policy.
- On the Cisco CMTS, a user can configure whether the general tagging overrides the RLBG or DOCSIS policy assignment using TLVs in the CM configuration file and SNMP when a conflict occurs.

- When doing autonomous LB, the Cisco CMTS ensures that the target channels are available to a specific CM with regard to admission control, the SF attribute masks, and CM attribute masks.
- The user can configure the number of times that a DCC fails a CM before the CM is removed from dynamic LB on the Cisco CMTS.
- The user can configure DCC initialization techniques or whether to use Upstream Channel Change (UCC) for a LBG or for a particular source and target pair on the Cisco CMTS. However, DCC is not issued to cable modems provisioned in DOCSIS 1.0 mode. By default, the UCC for a LBG is not configured and therefore, all channel changes are done through DCC.
- The Cisco CMTS supports LB on at least one logical channel on a physical US channel that has multiple logical US channels.
- As per the DOCSIS 3.0 specifications, a lower load balancing priority indicates a higher likelihood that a CM will be moved due to load balancing operations.
- You can create a policy to set the lower bandwidth for CMs. the LBG can only move cable modems with throughput that is above the threshold.

Compatibility

Both downstream and upstream autonomous load balancing is supported for single channel cable modems.

RLBG/GLBG Assignment

The user can configure one or more service type IDs for each RLBG. The user can also configure the Cisco CMTS, using CLI or SNMP, to restrict a particular cable modem to a certain STID and RLBG ID. However, if such a configuration is made, both the STID and RLBG ID in the configuration file are ignored by the Cisco CMTS.

When the STID is configured by CLI or SNMP or the STID is present in the cable modem configuration file, the Cisco CMTS selects an upstream and downstream channel, which offers the signaled service type, from a RLBG, if such channels exist. However, if an upstream and downstream channel do not exist that provide the signaled service type the Cisco CMTS assigns an upstream and downstream channel that does not offer the signaled service type.

When the LBG ID is configured by CLI or SNMP or the LBG ID is present in the cable modem configuration file, the Cisco CMTS examines the available choices for upstream and downstream channels and, if they include a channel pair associated with the signaled LBG, the Cisco CMTS assigns the cable modem to the signaled LBG. If these conditions are not met, the Cisco CMTS disregards the LBG ID.

If there are multiple upstream and downstream channels available that meet the requirements of the STID, if present, and the LBG ID, if present, the Cisco CMTS selects an upstream and/or downstream channel that meet the cable modem required and forbidden attribute masks requested in the configuration file. If upstream and downstream channels are not available that meet these criteria, the Cisco CMTS can disregard the cable modem attribute masks and select an alternative upstream and/or downstream channel.

In determining a target channel pair for a cable modem during registration time, the Cisco CMTS tries to find the target channel pair that can actually reach the cable modem by checking the current channel pair, the MD-DS-SG-ID (Media Access Control Domain Downstream Service Group Identifier) of cable modem (CM-DS-SG-ID) and the MD-US-SG-ID (Media Access Control Domain Upstream Service Group Identifier) of cable modem (CM-US-SG-ID), if present, and fiber node (FN) configurations. If the target channel pair is available to the cable modem and is different from the current channel pair, the Cisco CMTS is required to move the CM by means of DCC technique 0 or downstream frequency override (DFO).

When the Cisco CMTS identifies multiple candidate RLBGs for a CM, but cannot determine which fiber node configuration the cable modem is actually wired to, or cannot determine if the wired RLBG is unusable (when

interfaces in the load balance group are disabled or in an administratively down state), the Cisco CMTS assigns the cable modem to the RLBG with the lowest group index. This assignment causes the Cisco CMTS to attempt to move the cable modem to interfaces it is not physically connected to, resulting in service outages for the CM.

The Cisco CMTS enforces fiber node checking during RLBG assignment.

The Cisco CMTS follows the following RLBG assignment rules:

- If there is no fiber node configuration, there is no change in the candidate RLBG list. However, if the fiber node is configured, the fiber node must be configured correctly to reflect the real fiber node connection.
- If the cable modem is inside a fiber node, only those RLBGs that are inside that fiber node are selected.
- If the cable modem is not inside any fiber node, that is, the fiber node configuration does not cover all the channels, only those RLBGs that are not inside any fiber node are selected.
- If an RLBG spans across multiple fiber nodes, it is not considered to be inside any fiber node.
- If no candidate RLBG is found, cable modems are assigned to the GLBG, if the GLBG exists.

Channel Assignment

For cable modems operating in MRC mode, the registration request message can have multiple TLVs to influence the selection of upstream and downstream channels that the Cisco CMTS assigns. To avoid conflicts between the multiple TLVs, the Cisco CMTS follows the precedence order defined below:

1. TLV 56—Channel Assignment
2. TLV 43.11—Service Type Identifier
3. TLV 43.3—Load Balancing Group ID
4. TLVs 24/25.31-33—Service Flow Attribute Masks
5. TLV 43.9—CM Attribute Masks

The Cisco CMTS must follow this TLV precedence order for cable modems not operating in MRC mode:

1. TLV 43.11—Service Type Identifier
2. TLV 43.3—Load Balancing Group ID
3. TLV 43.9—CM Attribute Masks
4. TLVs 24/25.31-33—Service Flow Attribute Masks

Note When a target for the new receive channel configuration (RCC) and Transmit channel configuration (TCC) is selected, ensure that the service level for cable modems is not decreased. Target total RCCs and TCCs must not be less than the source total RCCs and TCCs so that cable modems can keep their service level unchanged. This may cause some unbalanced results when high capacity cable modems come online, later releases..

The Cisco CMTS also considers the DOCSIS 3.0 cable modem capabilities defined in the registration request message and assigns the maximum number of channels that the CM requests.

The tables below define the load balancing matrix for RLBG and GLBG assignment:

Table 10: RLBG Assignment for DOCSIS Cable Modems

Operational Mode	MAC Version				
	DOCSIS 3.0 CM	DOCSIS 2.x CM	DOCSIS 2.0 CM	DOCSIS 1.1 CM	DOCSIS 1.0 CM

Operational Mode	MAC Version				
Non-MRC mode (online)	Assigned	Assigned	Assigned	Assigned	Assigned
MRC mode only (w-online)	Assigned	Assigned	Assigned	NA	NA
MRC/MTC mode (UB-online)	Assigned	NA	NA	NA	NA
	DOCSIS 3.0 cable modems are assigned to the DOCSIS 3.0 RLBG	NA	NA	NA	NA

Table 11: GLBG Assignment for DOCSIS Cable Modems

Operational Mode	MAC Version				
	DOCSIS 3.0 CM	**DOCSIS 2.x CM**	**DOCSIS 2.0 CM**	**DOCSIS 1.1 CM**	**DOCSIS 1.0 CM**
Non-MRC mode (online)	Assigned to the DOCSIS 2.0 GLBG without MD-DS-SG-ID/MD-US-SG-ID				
	Assigned to the DOCSIS 3.0 GLBG with MD-DS-SG-ID/MD-US-SG-ID		NA	NA	NA
MRC mode only (w-online)	Assigned to the DOCSIS 2.0 GLBG without MD-DS-SG-ID/MD-US-SG-ID				
	Assigned to the DOCSIS 3.0 GLBG with MD-DS-SG-ID/MD-US-SG-ID		NA	NA	NA
MRC/MTC mode (UB-online)	Assigned	NA	NA	NA	NA
	DOCSIS 3.0 cable modems are assigned to the DOCSIS 3.0 GLBG	NA	NA	NA	NA

The tables below give a snapshot view of the load balancing methods and the operations used to "move" bonded and non-bonded CMs.

Table 12: Load Balancing Method to Move Bonded and Non-bonded cable modems

Modem Mode	Dynamic Service Charge (Initialization Technique)	
	Within MAC Domain	**Across MAC Domains**
DOCSIS 3.0 cable modems in MTC mode	NA	DCC initialization technique 0

Modem Mode	Dynamic Service Charge (Initialization Technique)	
DOCSIS 3.0/DOCSIS 2.x cable modems in MRC-only mode	DCC initialization technique 0 **Note** CM with primary DS outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC initialization technique 0
DOCSIS 3.0 cable modems in MRC-only mode	DCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC initialization technique 0
DOCSIS 2.x cable modems in MRC-only mode	DCC/UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC initialization technique 0
DOCSIS 2.0 /DOCSIS 1.1 cable modems in NB mode	DCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC initialization technique 0
	UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	UCC
DOCSIS 1.0 in NB mode	Force reinitialize CM **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	Force reinitialize CM
	UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	UCC

Table 13: Using DCC/DBC to Load Balance Bonded and Non-bonded Cable Modems

Channel	CM in MRC, non-MTC Mode	DOCSIS 1.1/DOCSIS 2.0 cable modems with Single US/DS	DOCSIS 1.0 cable modems with Single US/DS
Upstream (US)	DCC	DCC	UCC
Downstream (DS)	NA (within the same MAC domain)	DCC (within the same MAC domain).	Force reinitialize CM
	DCC with initialization technique 0 when moving cable modems across MAC domains.	DCC with initialization technique 0 when moving cable modems across MAC domains.	Force reinitialize CM

Error Handling of Channel Assignment

This restriction is modified. As long as the interface state of the channels is not "administratively down", all channels are available for LBG assignment. For other load balancing operations, such as moving modems

using DCC, UCC, or DBC, the interface state of the channels should be in "initial", "up", "suspicious", or "testing" states.

The following conditions apply when an LBG is disabled:

- cable modems that match all load balancing criteria can be assigned to an LBG.
- cable modem moves for load balancing are disabled, but cable modem moves from outside of the LBG to inside of the LBG are allowed.

Upstream Load Balancing for DOCSIS 3.0 Cable Modems in Single Upstream Mode

The upstream load balancing functionality enables the Cisco CMTS router to effectively handle upstream traffic for wideband and narrowband cable modems that are in single upstream mode. Single upstream mode (Mx1) means that the modems cannot send upstream traffic on multiple upstream channels. In the event of traffic overload on a single upstream channel of a wideband or narrowband cable modem, the Cisco CMTS router automatically moves the cable modem to another upstream channel in the same load balancing group.

Note A cable modem operating in single upstream mode is assigned to a load balancing group based on the primary channel of the modem. A cable modem in single upstream mode can support multiple receive channel (MRC) mode or narrowband mode. However, a cable modem in single upstream mode cannot support multiple transmit channel mode (MTC).

Auto-generate DOCSIS 2.0 GLBG

Cisco CMTS does not automatically implement DOCSIS 2.0 GLBG. DOCSIS 2.0 GLBG is configured manually after a new fiber node - MAC domain (FN-MD) pair is added.

This enhancement to automatically generate DOCSIS 2.0 GLBG after adding a new FN-MD pair and resolving a new combination of MAC domain, cable modem, and service group (MD-CM-SG). This enhancement is implemented through a new command **cable load-balance d20 GLBG auto-generate**. The command has options to renew and update DOCSIS 2.0 GLBGs for a fiber node configuration.

Independent Upstream/Downstream Throughput Rules

Currently, during upstream or downstream load balancing, to move modems in load balancing operations, Cisco CMTS applies the DOCSIS policy throughput rules to both upstream and downstream throughput to upstream or downstream load balancing operations. In other words, for downstream load balancing, both upstream and downstream sets of rules are applied and similarly for upstream load balancing both set of rules are applied. This prevents movement of modems with low upstream or high downstream throughput and high upstream or low downstream throughput.

Upstream or downstream throughput rules are checked independently to corresponding upstream or downstream load balancing operations. During upstream load balancing, only upstream throughput rules are checked, and during downstream load balancing, only downstream throughput rules are checked.

The following important points are implemented for independent upstream/downstream throughput rules:

- If DOCSIS 2.0 load balancing policy configured is **us-across-ds**, it is recommended to configure a maximum of 16 downstream channels and 8 upstream channels.
- If a load balancing operation involves a change only in the downstream channel of a cable modem without any change to the upstream channel, then only the downstream lower boundary rules are checked.
- If a load balancing operation involves a change only in the upstream channel of a cable modem without any change to the downstream channel, then only the upstream lower boundary rules are checked.
- If a load balancing operation involves a change in both the upstream and downstream channels of a cable modem, then the modem rule check must pass all the rules for that (upstream or downstream) load balancing.
- If the load balancing policy configured is **pure-ds-load**, then only the downstream rules are checked.
- If the load balancing policy configured is **us-across-ds** or both **us-across-ds** and **pure-ds-load**, then two types of target interfaces occur as follows:
  - Local interface—where the cable modem shares the upstream with the source. Only downstream load balancing operation occurs.
  - Remote interface—where the the cable modem does not share the upstream with the source. The upstream/downstream load balancing is triggered by upstream load.

  If the load balancing policy configured is neither us-across-ds nor pure-ds-load, then the load balancing is done based on Mac domain load.

How to Configure DOCSIS Load Balancing Groups

The Restricted/General Load Balancing and Narrowband Dynamic Bandwidth Sharing with Downstream Dynamic Load Balancing feature can be configured as follows:

- A user can configure a DOCSIS 2.0 general load balancing group (GLBG) on the Cisco CMTS according to DOCSIS specification. The Cisco CMTS creates a DOCSIS 3.0 GLBG for each Media Access Control Domain Cable Modem Service Group (MD-CM-SG) automatically and checks whether the GLBG contains both upstream and downstream channels.
- A cable modem that is not provisioned to any RLBG and cannot resolve its MD-CM-SG gets assigned to a DOCSIS 2.0 GLBG. However, if the cable modem resolves its MD-CM-SG, it gets assigned to a DOCSIS 3.0 GLBG.
- A user can configure RLBGs and any upstream or downstream channel into multiple RLBGs on the Cisco CMTS. The Cisco CMTS checks whether a RLBG contains both upstream and downstream channels. A RLBG can cross multiple MDs.
- A backward compatibility with existing Cisco LB schemes is maintained. The users can switch between the old and new DOCSIS 3.0 compliant LB schemes.

Note When the Cisco IOS system is upgraded, if the docsis-policy configuration of the DOCSIS load balancing groups, is missing in the output of the **show running-config** command, apply the docsis-policy to the DOCSIS load balancing groups using the **docsis-policy** *policy-id* command again.

The following sections describe how to create and configure DOCSIS load balancing groups to enable DOCSIS load balancing on the Cisco CMTS:

Configuring DOCSIS 3.0 and 2.0 RLBG and DOCSIS 2.0 GLBG

This section describes how to create and configure a DOCSIS load balancing group. There is a separate configuration mode for a DOCSIS load balancing group that is different from the legacy load balancing group.

Note UGS/PCMM policy and threshold do not apply on DOCSIS 3.0 LB.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance docsis-enable** **Example:** `Router(config)# cable load-balance docsis-enable`	Enables DOCSIS load balancing on the Cisco CMTS.
Step 4	**cable load-balance docsis-group** *docsis-group-id* **Example:** `Router(config)# cable load-balance docsis-group 1`	Creates a DOCSIS load balance group on the Cisco CMTS, with the following parameter: The router enters DOCSIS load balancing group configuration mode.
Step 5	**init-tech-list** *tech-list* [**ucc**] **Example:** `Router(config-lb-group)# init-tech-list 1 ucc`	Sets the DCC initialization techniques that the Cisco CMTS can use to load balance cable modems.
Step 6	**downstream** {**Cable** {*slot/subslot/port* | *slot/port*} | **Integrated-Cable** {*slot/subslot/bay* | *slot/port*} {**rf-channel** *group list*}|{| *slot/port*} {**rf-channel** *group list*}}	Sets the downstream RF channels.

	Command or Action	Purpose
	Example: `Router(config-lb-group)# downstream integrated-Cable 5/0/0 rf-channel 2`	
Step 7	**upstream Cable** {*slot/subslot/port* | *slot/port*} *upstream-list* **Example:** `Router(config-lb-group)# upstream Cable 1/0 2`	Sets upstream channels with the following parameters:
Step 8	**docsis-policy** *policy-id* **Example:** `Router(config-lb-group)# docsis-policy 0`	Assigns a policy to a group with the parameter that becomes the default policy assigned to the CM, if the CM does not choose a different policy.
Step 9	**restricted** **Example:** `Router(config-lb-group)# restricted`	Selects the restricted group type. By default, the general group type is selected.
Step 10	**init-tech-ovr Cable** {*slot/subslot/port* | *slot/port*} *upstream* **Cable** {*slot/subslot/port* } | *slot/port upstream* **init-tech-list** *0-4* [**ucc**] **Example:** `Router(config-lb-group)# init-tech-ovr Cable 8/1/0 0 Cable 8/1/1 1 init-tech-list 1 ucc`	Sets DCC initialization techniques that overrides the physical upstream channel pair. The **init-tech-ovr** command can also be used to determine whether the UCC can be used for modems during dynamic upstream load balancing. The following parameters override the physical upstream channel pair: **Note** The **init-tech-list** keyword accepts an upstream that is not added into the load balancing group. The upstream channel pair is invalid until the upstream is added. When the load balancing group is removed, all upstream channel pairs are also removed.
Step 11	**service-type-id** *string* **Example:** `Router(config-lb-group)# service-type-id commercial`	Adds a service type ID, with the following parameter, that is compared against the cable modem provisioned service type ID, to determine an appropriate restricted load balancing group (RLBG):
Step 12	**tag** *tag name* **Example:**	Adds a tag to the RLBG.

	Command or Action	Purpose
	`Router(config-lb-group)# tag t1`	
Step 13	**interval** *<1-1000>* **Example:** `Router(config-lb-group)# interval 60`	Sets the time interval, the Cisco CMTS waits before checking the load on an interface.
Step 14	**method** {**modems** | **service-flows** | **utilization**} {**us-method** {**modems** | **service-flows** | **utilization**}} **Example:** `Router(config-lb-group)# method modems us-method modems`	Selects the method the Cisco CMTS use to determine the load.

Step 15	**policy** {**pcmm** | **ugs** | **us-across-ds** | **pure-ds-load**}
	Example:
	`Router(config-lb-group)# policy us-across-ds`
	`Router(config-lb-group)# policy ugs`
	`Router(config-lb-group)# policy pure-ds-load`
		Selects the modems based on the type of service flow that are balanced.

Step 16	**threshold** {**load** {**minimum** *<1-100>* | *<1-100>*}| **pcmm** *<1-100>* | **stability** *<0-100>* | **ugs** *<1-100>*}
	Example:
	`Router(config-lb-group)# threshold load minimum 10`
	`Router(config-lb-group)# threshold pcmm 70`
	`Router(config-lb-group)# threshold load 10`
	`Router(config-lb-group)# threshold stability 50`
	`Router(config-lb-group)# threshold ugs 70`
		Selects the percentage of use beyond which load balancing occurs.

Step 17	**exit** **Example:** `Router# exit`	Exits DOCSIS LBG configuration.

Configuring DOCSIS 3.0 GLBG

The following sections describe how to configure a DOCSIS 3.0 GLBG and also how to configure default values of DOCSIS 3.0 certification for the DOCSIS 3.0 general group:

Note If a Cable interface on the line card is in "no shut down" state, the associated DOCSIS 3.0 GLBGs are restored in the running-configuration.

Configuring a DOCSIS 3.0 General Load Balancing Group

This section describes how to configure a DOCSIS 3.0 general load balancing group.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance docsis-enable** **Example:** `Router(config)# cable load-balance docsis-enable`	Enables DOCSIS load balancing on the Cisco CMTS.
Step 4	**cable load-balance docsis-group FN** *fn-id* **MD** *cable* {*slot/subslot/port* | *slot/port*} **Example:** `Router(config)# cable load-balance docsis-group FN 1 MD c5/0/0`	Enters the DOCSIS load balancing group configuration mode.
Step 5	**init-tech-list** *tech-list* [**ucc**] **Example:** `Router(config-lb-group)# init-tech-list 1 ucc`	Sets the DCC initialization technique list, with the following parameters.
Step 6	**disable** **Example:** `Router(config-lb-group)# disable`	Disables the load balance group.
Step 7	**docsis-policy** *policy-id* **Example:** `Router(config-lb-group)# docsis-policy 0`	Sets the load balance group policy.
Step 8	**interval** *1-1000* **Example:** `Router(config-lb-group)# interval 10`	Sets the interface polling interval.
Step 9	**method** {**modems** | **service-flows** | **utilization**} {**us-method** {**modems** | **service-flows** | **utilization**}} **Example:** `Router(config-lb-group)# method modems us-method modems`	Sets the load balancing type or method.

	Command or Action	Purpose
Step 10	**policy** {**pcmm** | **ugs** | **us-across-ds** | **pure-ds-load**} **Example:** `Router(config-lb-group)# policy us-across-ds`	Sets load balancing policy.
Step 11	**threshold** {**load** {**minimum** *1-100* | *1-100*} | **pcmm** *1-100* | **stability** *0-100* | **ugs** *1-100*} **Example:** `Router(config-lb-group)# threshold pcmm 70`	Sets the load balancing threshold in percentage.
Step 12	**exit** **Example:** `Router# exit`	Exits the DOCSIS load balancing group configuration mode.

Configuring Default Values of DOCSIS 3.0 Load Balancing Group

This section describes how to configure default values of DOCSIS 3.0 certification for a DOCSIS 3.0 general group on the Cisco CMTS. A DOCSIS 3.0 general group is automatically created for each MD-CM-SG derived from the fiber node (FN) configuration, and the group parameters are set as default values.

Note The configured default values of DOCSIS 3.0 certification are applicable to the new automatically created DOCSIS 3.0 GLBGs and do not affect the existing DOCSIS 3.0 GLBGs. When a DOCSIS 3.0 GLBG is removed and recreated, its group parameters do not change.

Note The default settings for interface polling interval, load balancing method, policy for modems selection, and threshold usage in percent, can be configured for DOCSIS 3.0 general group. For more information, see the Cisco CMTS Cable Command Reference.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance d30-ggrp-default disable** **Example:**	Disables the default values of the DOCSIS 3.0 general load balance group (GLBG).

	Command or Action	Purpose
	`Router(config)# cable load-balance d30-ggrp-default disable`	
Step 4	**cable load-balance d30-ggrp-default init-tech-list** *tech-list* **Example:** `Router(config)# cable load-balance d30-ggrp-default init-tech-list 1`	Sets the default DOCSIS 3.0 GLBGs DCC and dynamic bonding change (DBC) initialization techniques.
Step 5	**cable load-balance d30-ggrp-default docsis-policy** *0-0xffffffff* **Example:** `Router(config)# cable load-balance d30-ggrp-default docsis-policy 2`	Sets the default DOCSIS 3.0 GLBGs policy ID.
Step 6	**exit** **Example:** `Router# exit`	Exits the global configuration mode.

Configuring Cable Modems to RLBG or a Service Type ID

This section shows how to configure a list of cable modems that are statically provisioned at the Cisco CMTS to a RLBG or a service type ID.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance restrict modem** *index mac-addr* [*mac-mask*] {**docsis-group** *docsis-group-id* | **service-type-id** *string*} **Example:** `Router(config)# cable load-balance restrict modem 1 001a.c30c.7eee FFFF.FFFF.0000 docsis-group 100`	Assigns a modem or a group of modems with a common MAC mask to a load balancing group or a service type ID.
Step 4	**exit** **Example:** `Router# exit`	Exits the global configuration mode.

Configuring Rules and Policies

This section shows how to create and configure rules and DOCSIS policies to restrict the movement of modems during load balancing. Rules determine whether a modem can be moved and during which time periods. The time periods are measured in seconds with the start time being an offset from midnight measured in seconds. Rules are created individually and can be combined into policies. The user is able to create DOCSIS policies that consist of one or more rules. When more than one rule is part of a DOCSIS policy, all rules apply. Each group has a default DOCSIS policy.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance rule** *rule-id* **Example:** `Router(config)# cable load-balance rule 1`	Creates a rule to prevent the modem from being moved.
Step 4	**cable load-balance rule** rule-id {**enabled** | **disabled** | {**disable-period dis-start** *0-86400* **dis-period** <*0-86400*>**}** | **disable-throughput-lowerbound ds** | **us** *thrupt in kbps* | **vdoc-enabled}** **Example:** `Router(config)# cable load-balance rule 1 disable-period dis-start 40 dis-period 50`	Configures the rule. **Note** Static multicast groups should be configured on the appropriate bundle interface as well as on the correct forwarding interfaces to enable this rule. This feature will not be supported on load balancing groups which are derived from fiber node configuration and with multicast encryption.
Step 5	**cable load-balance docsis-policy** *policy-id* **rule** *rule-id* **Example:** `Router(config)# cable load-balance docsis-policy 2 rule 1`	Associates a particular rule with the DOCSIS policy with the following parameters:
Step 6	**exit** **Example:** `Router# exit`	Exits the global configuration mode.

Troubleshooting Tips

Problem When you disable load balancing and enable it for the next day using the **cable load-balance rule** *rule-id* **disable-period dis-start** *start-time* **dis-period** *disable-period* command, the load balancing is enabled at 12.00 am instead of the configured *disable-period*.

Possible Cause Load balancing rule cannot be disabled and enabled on the next day (that is, after 24 hours) using a single load balancing rule.

Solution Configure separate load balancing rules for disabling load balancing and enabling it on the next day. Configure the rule to disable load balancing using the **cable load-balance rule** *rule-id* **disable-period dis-start** *start-time* **dis-period 0** command. Configure the rule to enable load balancing using the **cable load-balance rule** *rule-id* **disable-period dis-start 0 dis-period** *disable-period* command to enable it for the next day.

Configuring Load Balancing Parameter for a Cable Modem Movement Failure

This section describes how to configure the number of times a CM can fail before the CM is removed from the dynamic load balancing group.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance modem max-failures** *0-100* **Example:** `Router(config)# cable load-balance modem max-failures 10`	Configures the number of times a CM can fail before the CM is removed from the dynamic load balancing group.
Step 4	**exit** **Example:** `Router# exit`	Exits the global configuration mode.

Creating and Configuring TLV type Tag

The tags for TLV type matching rule are created and configured in this section.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:**	Enters global configuration mode.

	Command or Action	Purpose
	`Router# configure terminal`	
Step 3	**cable tag** *1-1000* **Example:** `Router(config)# cable tag 1`	Creates a tag. Enters the cmts-tag configuration mode.
Step 4	**name** *tag name* **Example:** `Router(cmts-tag)# name CSCO`	Specifies the name of the tag.
Step 5	[**exclude**] **service-type-id** *service-type-id* **Example:** `Router(cmts-tag)# service-type-id HSD`	Configures the specified service type ID for the tag.
Step 6	[**exclude**]**service-class** *service-class-name* **Example:** `Router(cmts-tag)# service-class work`	Configures the specified service class name for the tag.
Step 7	[**exclude**] **docsis-version** *docsis version* **Example:** `Router(cmts-tag)# docsis-version docsis20`	Configures the specified DOCSIS version of the cable modem for the tag.
Step 8	**[exclude] oui** *oui of CM* **Example:** `Router(cmts-tag)# oui 00.1a.c3`	Configures the specified OUI of the cable modem for the tag.
Step 9	[**exclude**] **tlv** *type value* **Example:** `Router(cmts-tag)# tlv mrcs 4`	Configures the specified TLV type for the tag.
Step 10	**override** **Example:** `Router(cmts-tag)# override`	Overrides the TLV or SNMP during load balancing an RLBG.
Step 11	**exit** **Example:** `Router(cmts-tag)# exit`	Exits the cmts-tag configuration mode.
Step 12	**cable load-balance docsis-group** *docsis-group-id* **Example:** `Router(config)# cable load-balance docsis-group 1`	Creates a DOCSIS load balancing group on the Cisco CMTS. If the DOCSIS load balancing group is already present, the router enters the specified DOCSIS load balancing group configuration mode.

	Command or Action	Purpose
Step 13	**tag** *tag name* **Example:** `Router(config-lb-group)# tag CSCO`	Adds a tag to the load balancing group.
Step 14	**exit** **Example:** `Router(config-lb-group)# exit`	Exits the DOCSIS load balancing group configuration mode.
Step 15	**cable load-balance docsis-policy** *policy-id* **tag** *tag name* [**override**] **Example:** `Router(config)# cable load-balance docsis-policy 2 tag CSCO`	Creates a DOCSIS policy and associates a new rule or an existing rule with the policy.
Step 16	**exit** **Example:** `Router# exit`	Exits the global configuration mode.

Configuration Examples for DOCSIS Load Balancing Groups

This section describes a sample configuration example for configuring DOCSIS Load Balancing Groups including Restricted/General Load Balancing and downstream dynamic load balancing:

Example: Configuring a Tag

The following example shows how you can configure the tag to exclude a DOCSIS version, a MAC address, a service class name or a service type ID:

```
Router# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)# cable tag 1
Router(cmts-tag)# exclude ?
  docsis-version   set the match rule for docsis version
  oui              set the match rule for oui
  service-class    set the match rule for service class name
  service-type-id  set the match rule for service type id
Router(cmts-tag)# exclude docsis-version ?
  docsis10  Match docsis 1.0 modems
  docsis11  Match docsis 1.1 modems
  docsis20  Match docsis 2.0 modems
  docsis30  Match docsis 3.0 modems
Router(cmts-tag)# exclude docsis-version docsis10
Router(cmts-tag)# exclude oui ?
  WORD  OUI of the vendor in the format xx.xx.xx or xx:xx:xx
Router(cmts-tag)# exclude oui 00.1a.c3
Router(cmts-tag)# exclude service-class ?
  WORD  Service class name
Router(cmts-tag)# exclude service-class work
Router(cmts-tag)# exclude service-type-id ?
```

```
  WORD  Service Type ID
Router(cmts-tag)# exclude service-type-id commercial
```

Example: Disabling Load Balancing

Use the following commands to disable DOCSIS 3.0 GLBG:

```
Router(config)# cable load-balance docsis-group FN 1 MD cable 6/0/0
Router(config-lb-group)# disable
Router(config-lb-group)#
```

Use the following commands to disable DOCSIS 3.0 RLBG:

```
Router(config)# cable load-balance docsis-group 1
Router(config-lb-group)# disable
Router(config-lb-group)#
```

How to Configure Load Balancing with Operational Simplification

To configure Load Balancing Groups with Operational Simplification, complete the following steps:

SUMMARY STEPS

1. Define the global common Load Balancing profile. Specify the Load Balancing Group configure: method, interval, threshold, policy, and so on.
2. Define the Load Balancing Group under service-group profile. Associate the Load Balancing profile with Load Balancing group. Configure the DS and US channels.
3. Define the physical mapping info for US or DS channels under fiber-mode.
4. Define the service-group profile under Fiber-node.

DETAILED STEPS

	Command or Action	Purpose

Step 1	Define the global common Load Balancing profile. Specify the Load Balancing Group configure: method, interval, threshold, policy, and so on.
	Example:
	`cable profile load-balance lb_1`
	`disable`
	`method utilization primary-distributed us-method utilization`
	`threshold load 2`
	`policy pcmm`
	`interval 1`	

	Command or Action	Purpose

Step 2	Define the Load Balancing Group under service-group profile. Associate the Load Balancing profile with Load Balancing group. Configure the DS and US channels.
	Example:
	`cable profile service-group sg`
	`load-balance docsis-group 0 profile lb_1`
	`downstream sg-channel 0-7`
	`upstream 0 sg-channel 0`
	`upstream 1 sg-channel 1`	

Step 3	Define the physical mapping info for US or DS channels under fiber-mode.
	Example:
	`cable fiber-node 1`
	`downstream sg-channel 0 15 downstream-Cable 6/0/0`
	`rf-channel 0 15`
	`upstream sg-channel 0 3 Upstream-Cable 6/0/0`
	`us-channel 0 3`	

Step 4	Define the service-group profile under Fiber-node.
	Example:
	`cable fiber-node 1`
	`service-group profile sg`	

The Load Balancing Groups are auto-generated when the SG profile is applied.

Example

An example of the Load Balancing Groups Operational Simplification configuration, **show run** as is as follows:

```
cable profile load-balance lb
 method utilization primary-distributed us-method utilization
 threshold load 22
 threshold load lcmm 33
 policy lcmm
 policy pure-ds-load
 init-tech-list 1-3

cable profile service-group sg
    load-balance docs is-group 0 profile lb
    downstream sg-channel  0  15
    upstream 0  sg-channel  0
    upstream 1  sg-channel  1
    upstream 2  sg-channel  2
    upstream 3  sg-channel  3
load-balance docsis-group 2 profile RLBG_STB
     downstream sg-channel 0-3 8-11
     upstream 0 sg-channel  0
```

```
cable fiber-node 1
 downstream Downstream-Cable 6/0/0
 upstream Upstream-Cable 6/0/0
 downstream sg-channel 0 15 downstream-Cable downstream-Cable 6/0/0 rf-channel 0 15
        upstream sg-channel 0 3 Upstream-Cable 6/0/0 us-channel 0 3
 service-group profile sg
```

An example of the Load Balancing Groups Operational Simplification configuration, **show derived** as is as follows:

```
cable profile load-balance lb
 method utilization primary-distributed us-method utilization
 threshold load 22
 threshold load lcmm 33
 policy lcmm
 policy pure-ds-load
 init-tech-list 1-3

Cable profile service-group sg
   Load-balance docsis-group 0 profile lb
  downstream sg-channel  0  15
    upstream 0  sg-channel  0
    upstream 1  sg-channel  1
    upstream 2  sg-channel  2
    upstream 3  sg-channel  3
load-balance docsis-group 2 profile RLBG_STB
     downstream sg-channel 0-3 8-11
     upstream 0 sg-channel  0

Cable fiber-node 1
 downstream Downstream-Cable 6/0/0
 upstream Upstrea-CAble 6/0/0
 downstream sg-channel 0 15 downstream-Cable 6/0/0 rf-channel 0 15
 upstream sg-channel 0 3 Upstream-Cable 6/0/0 us-channel 0 3
 service-group profile sg

Cable load-balance docsis-group 2
 restricted
 downstream Downstream-Cable 6/0/0/ rf-channel 0 15
 upstream Upstream-Cable 6/0/0 us-channel 0-3
 method utilization primary-distributed
 threshold load 22
 threshold pcmm 33
 policy lcmm
 policy pure-ds-load
 init-tech-list 1-3
 cable managed fiber-node 1
 cable load-balance-profile lb
 cable load-balance docsis-group 3
 restricted
 downstream Downstream-Cable 6/0/0 rf-channel 0-3 8-11
Upstream Upstream-Cable 6/0/0 us-channel 0
Threshold load 55
Interval 5
Cable managed fiber-node 1
Cable load-balance-profile RLBG_STB
```

Load Balancing Groups with Operational Simplification

The Cisco IOS XE Gibraltar 16.10.1d supports simplified Load Balancing configuration in the Operational Simplification service group profile. Currently, CMTS supports auto creation of D30 GLBGs based on the existing configuration. Load Balancing would now support creation of RLBGs and D20 GLBGs.

Following are the salient features of the feature:

- For D20 GLBG created by Operational Simplification, the Group ID is in range [65024, 65535]. This follows legacy design.
- For RLBG created by Operational Simplification, the Group ID is related to the information of fiber-node id/us channel controller/docsis-group index in service group file. This also follows legacy range [1, 2147483647]. For example: RLBG ID: 12330208. Where '123' is the Fiber node ID, '302' is the Upstream-Cable 6/0/0, and '08' is the docsis-group index in service group profile.

```
cable profile service-group sg
  load-balance docsis-group 8 profile lb_1
  downstream sg-channel 0-7
  upstream 0 sg-channel 0
  upstream 1 sg-channel 1
```

- The default value of Load Balance profile are equal to the value of “cable load-balance d20-ggrp-default xxx”.
- For Load Balancing Groups that are created by Operational Simplification, the user cannot configure them with CLI.
- For one service group profile, a user is only allowed to configure one GLBG load balance.
- A user can configure a maximum of 20 tags into one load balance profile.
- A user can configure a maximum of 15 service-type-ids into one load balance profile.
- Load Balancing Groups by Operational Simplification supports fly modification.
- For Load Balancing Groups created by Operational Simplification, if a user changes the option of Load Balance profile, the OPS would update all the related LBGs automatically. However, the user cannot change the type of LBGs.

For the Load Balaning Groups created by Operational Simplification, the configuration of the groups would not be dispalyed for the **show run** or the **show run all** commands. The Load Balancing Groups would only be displayed using the **derived** command. This change can simplify the running configuration.

```
clab-cbr-S11K01#show derived-config | sec cable load
cable load-balance docsis-group 1
restricted
downstream Downstream-Cable 6/0/0 rf-channel 0-7
upstream Upstream-Cable 6/0/0 us-channel 0-1
method utilization primary-distributed
threshold load 2
cable managed fiber-node 1
cable load-balance-profile lb_1
```

Verifying DOCSIS Load Balancing Groups

This section describes how to use certain show commands to verify the configuration of the Restricted/General Load Balancing and Narrowband Dynamic Bandwidth Sharing with Downstream Dynamic Load Balancing feature.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.

Step 2	**show cable load-balance docsis-group** {*docsis-group-id* | **FN** *fn-id* **MD cable** {*slot/subslot/port* | *slot/port*}} [**all** | **load** | **pending** | **statistics** | **target** | **modem-list** | **primary-load**]
	Example:
	`Router# show cable load-balance docsis-group 1`
	`Router# show cable load-balance docsis-group fn 1 MD c8/1/4`
		Displays real-time configurational, statistical, and operational information of the load balancing operations on the router.

Step 3	**show cable fiber-node** *fiber-node-id* [**spectrum**] **Example:** `Router# show cable fiber-node 3`	Displays information about a fiber node.
Step 4	**show cable load-balance** [**group** *n*] | [**all** | **load** | **pending** | **statistics** | **target** | **fiber-node-validation**] **Example:** `Router# show cable load-balance group 1`	Displays real-time statistical and operational information for load balancing operations. If given without any options, this command displays information for the load balancing groups and each cable interface's current load and load balancing status.
Step 5	**show cable modem** [*ip-address* | *mac-address* | **cable** *slot/port* [**upstream** *port*] | **name** *fqdn*] [*verbose*] **Example:** `Router# show cable modem 40.3.160.15 verbose`	Displays information for the registered and unregistered CMs.

Examples

Use the **show cable load-balance docsis-group** command to see the DOCSIS group status and to see the list of modems in the group, use the **show cable fiber-node** command to see the information on fiber nodes, use the **show cable load-balance** command to see information on LBG and DOCSIS channels, and use the **show cable modem** command to see the information on all the CMs.

The following examples show the output of the **show cable load-balance docsis-group** command:

```
Router# show cable load-balance docsis-group 2
```

```
DOCSIS LB Enabled: Yes
DOCSIS     Group Status Interval DCC mask  Policy     Method Threshold
Group      Index                /UCC                  DS/US  M/E/U/P/S
2          82    RE 10       0xF8(0)/N 0          s/s    1/1/70/70/50
Router# show cable load-balance docsis-group 1 modem-list
US                    Group Index Mac Address      Priority
Mo1/0/0:0/U0          81          (1)
                                  0000.ca45.9898   0
Mo1/0/0:0/U1          81          (0)
Mo1/0/0:0/U2          81          (2)
                                  0013.711c.0820   0
                                  0016.924f.8300   0
```

The output of the **show cable load-balance docsis-group** command is modified to include an additional field MUPFXLR to display more status information on the modems in the DOCSIS groups. For more information, see the Cisco IOS CMTS Cable Command Reference.

The following example shows the modified output of the **show cable load-balance docsis-group** command:

```
Router#show cable load docsis-group fn 1 md c6/0/0 modem-list
Load for five secs: 1%/0%; one minute: 2%; five minutes: 1%
Time source is NTP, 13:39:31.300 PDT Thu Mar 28 2013
Codes: M - Multicast, U - UGS, P - PCMM, F - Max-Failures, X - eXcluded
       L - L2vpn, R - RSVP
Primary DS     Grp Idx MAC Address    RCC-ID Bad Rfid Priority MUPFXLR
In6/0/0:0/UB   40448   (6)
                       e448.c70c.98af 1              2        -------
                       e448.c70c.9b76 1              2        -------
                       e448.c70c.9c15 1              2        -------
                       e448.c70c.9a92 1              2        -------
                       e448.c70c.99e4 1              2        -------
                       e448.c70c.9a35 1              2        -------
In6/0/0:0/U0   40448   (0)
In6/0/0:0/U1   40448   (1)
                       e448.c70c.9915                2        -------
In6/0/0:0/U2   40448   (0)
In6/0/0:0/U3   40448   (0)
In6/0/0:1/UB   40448   (5)
                       e448.c70c.9abc 1              2        -------
                       e448.c70c.993f 1              2        -------
                       e448.c70c.9927 1              2        -------
                       e448.c70c.9b82 1              2        -------
                       4458.2945.2cb8 1              2        -------
In6/0/0:1/U0   40448   (0)
In6/0/0:1/U1   40448   (0)
In6/0/0:1/U2   40448   (0)
In6/0/0:1/U3   40448   (0)
In6/0/0:2/UB   40448   (5)
                       e448.c70c.9759 1              2        -------
                       e448.c70c.9a0e 1              2        -------
                       e448.c70c.992d 1              2        -------
                       e448.c70c.9a38 1              2        -------
                       0025.2ed9.9984 1              2        -----L-
In6/0/0:2/U0   40448   (0)
In6/0/0:2/U1   40448   (0)
In6/0/0:2/U2   40448   (0)
In6/0/0:2/U3   40448   (0)
In6/0/0:3/UB   40448   (5)
                       e448.c70c.9c00 1              2        -------
```

```
                      e448.c70c.99a5 1              2        -------
                      e448.c70c.9a5f 1              2        -------
                      e448.c70c.9a3b 1              2        -------
                      e448.c70c.96b1 1              2        -------
In6/0/0:3/U0   40448   (0)
In6/0/0:3/U1   40448   (0)
In6/0/0:3/U2   40448   (0)
In6/0/0:3/U3   40448   (0)
```

The following example shows the output of the **show cable fiber-node** command:

```
Router# show cable fiber-node
Fiber-Node         Config Status
Fiber-Node 1
       Modular-Cable 1/0/0:  0-1
    FN Config Status: Configured (status flags = 0x01)
    MDD Status: Valid
```

The following examples show the output of the **show cable load-balance** command:

```
Router#show cable load-balance
Group  Interval  Method        DCC Init   Threshold
                               Technique  Minimum  Static  Enforce  Ugs   PCMM
1      10        service-flows 1          1        2%      2%       ---   ---
2      10        modems        0          5        10%     ---      ---   ---

DOCSIS LB Enabled: No
Router# show cable load-balance load
Interface            State      Group  Utilization  Reserved Modems Flows Weight
                                Index
Cable5/0/3 (459 MHz) up         1      0%(0%/0%)       0%    7      7     37
Cable5/0/3/U0        up         1      0%              0%    2      2     1.2
Cable5/0/3/U1        up         1      0%              0%    2      2     1.2
Cable5/0/3/U2        up         1      0%              0%    2      2     1.2
Cable5/0/3/U3        up         1      0%              0%    1      1     1.2
Cable5/0/4 (465 MHz) up         1      0%(0%/0%)       0%    7      7     37
Cable5/0/4/U0        up         1      0%              0%    1      1     1.2
Cable5/0/4/U1        up         1      0%              0%    2      2     1.2
Cable5/0/4/U2        up         1      0%              0%    2      2     1.2
Cable5/0/4/U3        up         1      0%              0%    2      2     1.2
Mo1/0/0:0 (555 MHz)  down       1      0%(0%/0%)       0%    0      0     0
Router# show cable load-balance fiber-node-validation
DOCSIS LBG ID    Match    Channel    Fiber-node list
1                match    Ca5/0/0/U0 {1}
                          Ca5/0/0/U1 {1}
                          Ca5/0/0/U2 {1}
                          Ca5/0/0/U3 {1}
                          Mo1/0/0:0  {1}
                          Mo1/0/0:1  {1}
2                mismatch Ca5/0/0/U0 {1}
                          Ca5/0/0/U1 {1}
                          Ca5/0/0/U2 {1}
                          Ca5/0/0/U3 {1}
                          Ca5/0/0    {}
```

The following example shows the output of the **show cable modem** command:

```
Router# show cable modem 40.3.160.19 verbose
LB group ID assigned(index)        : 1(81)
LB group ID in config file(index)  : N/A(N/A)
LB policy ID  : 0
LB policy ID in config file        : 0
LB priority                        : 0
Tag                                :
```

DOCSIS 3.0 GLBG is generated dynamically by the fiber node configuration, if a valid fiber node is configured.

For example, if the fiber node configuration is:

```
cable fiber-node 2
 downstream Modular-Cable 1/0/0 rf-channel 0-3
 downstream Cable7/0/0
 upstream Cable 7/0 connector 0-3
!
```

The GLBG generated by this fiber node is similar to:

```
Router# show cable load-balance docsis-group fn 2 md cable 7/0/0
DOCSIS 3.0 General LB
MD       FN  Group S Intv DCC mask  Policy     Mtd MD-CM-SG Threshold
             Index        /UCC                 D/U          M/E/U/P/S
Ca7/0/0  2   48129 E 30   0xF8(0)/N 0          m/m 0x3C0101 5/10/70/70/50
```

```
Router# show cable load-balance docsis-group fn 2 md cable 7/0/0 all
DOCSIS 3.0 General LB
MD       FN  Group S Intv DCC mask  Policy     Mtd MD-CM-SG Threshold
             Index        /UCC                 D/U          M/E/U/P/S
Ca7/0/0  2   48129 E 30   0xF8(0)/N 0          m/m 0x3C0101 5/10/70/70/50
Current load:
DOCSIS load-balancing load
Interface            State   Group  Utilization Rsvd NBCM  WB/UB Flows Weight
                             Index                    Total Total
Cable7/0/0 (333 MHz) up      48129  0%(0%/0%)   0%   2     8     7     37
Cable7/0/0/U0        up      48129  0%          0%   22    7     29    7.6
Cable7/0/0/U1        up      48129  0%          0%   21    8     28    7.6
Cable7/0/0/U2        up      48129  0%          0%   21    8     28    7.6
Cable7/0/0/U3        up      48129  0%          0%   20    10    30    7.6
Mo1/0/0:0 (501 MHz)  up      48129  0%(0%/0%)   0%   2     63    2     36
Mo1/0/0:0/U0         up      48129  0%          0%   22    7     29    7.6
Mo1/0/0:0/U1         up      48129  0%          0%   21    8     28    7.6
Mo1/0/0:0/U2         up      48129  0%          0%   21    8     28    7.6
Mo1/0/0:0/U3         up      48129  0%          0%   20    10    30    7.6
Mo1/0/0:1 (507 MHz)  up      48129  0%(0%/0%)   0%   1     58    1     36
Mo1/0/0:1/U0         up      48129  0%          0%   22    7     29    7.6
Mo1/0/0:1/U1         up      48129  0%          0%   21    8     28    7.6
Mo1/0/0:1/U2         up      48129  0%          0%   21    8     28    7.6
Mo1/0/0:1/U3         up      48129  0%          0%   20    10    30    7.6
Mo1/0/0:2 (513 MHz)  up      48129  0%(0%/0%)   0%   2     59    2     36
Mo1/0/0:2/U0         up      48129  0%          0%   22    7     29    7.6
Mo1/0/0:2/U1         up      48129  0%          0%   21    8     28    7.6
Mo1/0/0:2/U2         up      48129  0%          0%   21    8     28    7.6
```

```
Mo1/0/0:2/U3          up      48129  0%          0%   20    10    30    7.6
Mo1/0/0:3 (519 MHz)   up      48129  0%(0%/0%)   0%   1     61    1     36
Mo1/0/0:3/U0          up      48129  0%          0%   22    7     29    7.6
Mo1/0/0:3/U1          up      48129  0%          0%   21    8     28    7.6
Mo1/0/0:3/U2          up      48129  0%          0%   21    8     28    7.6
Mo1/0/0:3/U3          up      48129  0%          0%   20    10    30    7.6
Target assignments:
Interface             State      Group   Target
                                 Index
Cable7/0/0 (333 MHz)  up         48129
Cable7/0/0/U0         up         48129
Cable7/0/0/U1         up         48129
Cable7/0/0/U2         up         48129
Cable7/0/0/U3         up         48129
Mo1/0/0:0 (501 MHz)   up         48129   Mo1/0/0:1 (507 MHz)
Mo1/0/0:0/U0          up         48129
Mo1/0/0:0/U1          up         48129
Mo1/0/0:0/U2          up         48129
Mo1/0/0:0/U3          up         48129
Mo1/0/0:1 (507 MHz)   up         48129
Mo1/0/0:1/U0          up         48129
Mo1/0/0:1/U1          up         48129
Mo1/0/0:1/U2          up         48129
Mo1/0/0:1/U3          up         48129
Mo1/0/0:2 (513 MHz)   up         48129
Mo1/0/0:2/U0          up         48129
Mo1/0/0:2/U1          up         48129
Mo1/0/0:2/U2          up         48129
Mo1/0/0:2/U3          up         48129
Mo1/0/0:3 (519 MHz)   up         48129
Mo1/0/0:3/U0          up         48129
Mo1/0/0:3/U1          up         48129
Mo1/0/0:3/U2          up         48129
Mo1/0/0:3/U3          up         48129
Statistics:
Target interface       State      Transfers
                                  Complete  Pending   Retries   Failures
Cable7/0/0 (333 MHz)   up         8         0         0         0
Cable7/0/0/U0          up         30        0         0         0
Cable7/0/0/U1          up         83        0         0         0
Cable7/0/0/U2          up         48        0         0         0
Cable7/0/0/U3          up         34        0         0         0
Mo1/0/0:0 (501 MHz)    up         19        0         0         0
Mo1/0/0:0/U0           up         33        0         0         0
Mo1/0/0:0/U1           up         46        0         0         0
Mo1/0/0:0/U2           up         22        0         0         0
Mo1/0/0:0/U3           up         22        0         0         0
Mo1/0/0:1 (507 MHz)    up         22        0         0         0
Mo1/0/0:1/U0           up         9         0         0         0
Mo1/0/0:1/U1           up         19        0         0         0
Mo1/0/0:1/U2           up         15        0         0         0
Mo1/0/0:1/U3           up         21        0         0         0
Mo1/0/0:2 (513 MHz)    up         21        0         0         0
Mo1/0/0:2/U0           up         4         0         0         0
Mo1/0/0:2/U1           up         3         0         0         0
Mo1/0/0:2/U2           up         6         0         0         0
Mo1/0/0:2/U3           up         7         0         0         0
Mo1/0/0:3 (519 MHz)    up         9         0         0         0
Mo1/0/0:3/U0           up         1         0         0         0
Mo1/0/0:3/U1           up         2         0         0         0
Mo1/0/0:3/U2           up         4         0         0         0
Mo1/0/0:3/U3           up         4         0         0         0
Pending:
Modem          Grp Idx Primary RF/RCC              MD/TCS        Action Active Retries
```

```
Src          Target       Src    Target        Time
```

Additional References

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

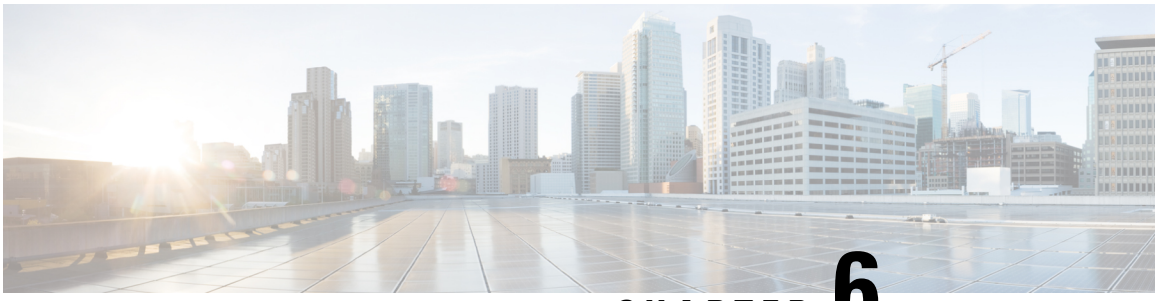
Feature Information for DOCSIS Load Balancing Groups

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 14: Feature Information for DOCSIS Load Balancing Groups

Feature Name	Releases	Feature Information
DOCSIS Load Balancing Groups	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the cisco cBR Series Converged Broadband Routers.
Load Balancing with Operational Simplification	Cisco IOS XE Gibraltar 16.10.1d.	This feature was integrated on the cisco cBR Series Converged Broadband Routers.



CHAPTER 6

DOCSIS Load Balancing Movements

Cisco CMTS supports static load balancing for MTC/MRC modems and dynamic load balancing for non-MTC and/or non-MRC modems. Support for configuration of load balancing groups (LBGs) that entail multiple interfaces, multiple load balancing policies, and the option to configure multiple additional load balancing parameters are also included.

The load balancing policies can be configured on the Cisco CMTS, indexed by an ID, to limit the movement of cable modems within a Load Balancing Group (LBG). The cable modem will forward TLV43.1in its registration request (REG-REQ) message, which is then parsed and stored in the Cisco CMTS. A policy defines whether and when cable modems can be moved within their load balancing groups.

During dynamic load balancing, the specified policy of the cable modem is checked to determine whether the cable modem is allowed to move.

Load balancing supports Dynamic Channel Change (DCC). DCC in DOCSIS 1.1, dynamically changes cable modem upstream or downstream channels without forcing a cable modem to go offline, and without re-registration after the change.

Load balancing distributes downstream load balancing with upstream channel loads in the same upstream load balancing group. This improves upon the prior load balancing limitation, in which load balancing was implemented on the basis of the entire downstream channel load.

Load balancing uses rules and policies to decide on moving the cable modems within their LB groups. These policies are created on the Cisco CMTS and chosen on a per-CM basis using type-length-value (TL V) portion (43.1,Policy ID) of REG-REQ. These policies prohibit a modem from being moved or restricted.

A policy contains a set of rules. When the policy is defined by multiple rules, all rules apply in combinations. A rule can be defined as "enabled" , "disabled" , or "disabled during time period. " Each rule can be used by more than one policy.

DOCSIS 3.0 static modem count-based load balancing uses the dynamic bonding change (DBC) to modify the following parameters of DOCSIS 3.0 cable modem with multiple transmit channel (MTC) mode or multiple receive channel(MRC) mode without primary channel change:

- Transmit channel set (TCS)
- Receive channel set (RCS)
- Downstream IDs (DSID) or DSID-associated attributes
- Security association for encrypting downstream traffic

These parameters and additional load balancing schemes are supported on the Cisco CMTS, and described in this document. This document describes all implementations of load balancing on the Cisco CMTS, dependent upon the Cisco IOS release installed and the desired parameters.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 84
- Prerequisites, on page 85
- Restrictions, on page 86
- Information on the Load Balancing on the Cisco CMTS, on page 91
- How to Configure Load Balancing, on page 106
- How to Configure Dynamic Channel Change for Load Balancing, on page 109
- Configuration Examples for Load Balancing, on page 115
- Additional References, on page 119
- Feature Information for DOCSIS Load Balancing Movements, on page 119

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 15: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites

Prerequisites for Load Balancing

The Load Balancing feature has the following prerequisites:

- Load balancing can be done only on upstreams and downstreams that share physical connectivity with the same group of cable modems.

Prerequisites for Dynamic Channel Change for Load Balancing

- DCC can be done only to a cable modem that is physically connected to both source and target upstream or downstream channels, or both.
- Upstreams and downstream channels that share the same physical connectivity must have different center frequencies separated by channel width.
- The difference between the physical layer parameters on the source and target DCC channels must be within the threshold required by the desired DCC initialization technique.
- DOCSIS 1.1 must be enabled for a modem to behave properly for the DCC operation. Note that not all DOCSIS 1.1 certified modems are DCC-capable, as the CableLabs DCC ATP tests need enhancement for complete coverage.

Prerequisites for Dynamic Bonding Change for DOCSIS 3.0 Static Modem Count-Based Load Balancing

- Initialization techniques 1 to 4, when used, require the Cisco CMTS to include the upstream channel descriptor (UCD) TLV (TLV46.5) in the DBC-REQ message.
- Bandwidth must be sufficient on the target bonding group to support DBC. This is determined by the admission control APIs.
- Fiber nodes must be configured before configuring DOCSIS 3.0 static modem count-based load balancing.

Restrictions

The following sections describe the restrictions applicable for the Load Balancing, Dynamic Channel Change, and Dynamic Bonding Change feature:

Restrictions for Load Balancing

The Load Balancing feature has the following restrictions:

- Load balancing can be done only on a per-line card basis—all interfaces in a load balancing group must be provided by the same line card.
- All downstreams and upstreams in a load balancing group must share physical connectivity to the same group of cable modems. All downstreams or all upstreams that have the same RF physical connectivity must be members of the same load balancing group.
- You can create a maximum of 256 load balancing groups on each line card.
- If an upstream port is operational, using the **no shutdown** command, and is not being used and not connected, load balancing attempts to use the port even though there are no cable modems registered on that port. When the upstream port is up, it is put into INIT state and load balancing includes this port as a potential target. However, if the load balancing sees multiple failures moving to this upstream, it is set to DISABLE state and the port is avoided later on in load balancing processes.

- The load balancing algorithms assume a relatively even distribution of usage among modems. In the situation where one cable modem creates the bulk of the load on an interface, the load balancing thresholds should be configured for a value above the load created by that single modem.
- You cannot select particular cable modems to be automatically moved for load balancing, although you can exclude cable modems from load balancing operations altogether on the basis of their MAC address or organization unique identifier (OUI). (You can use the **test cable load-balance** command to manually move a particular cable modem among upstreams, but this is done typically to test the configuration of the load balancing groups.)
- If you have configured upstream shared spectrum groups while doing downstream load balancing, the downstream in each MAC domain must not use overlapping upstream groups. For example, the downstream in one MAC domain could use an upstream spectrum band of 10 to 30 MHz, while the downstream in a second MAC domain could use an upstream spectrum band of 30 to 42 MHz. Each MAC domain has its own upstream shared spectrum group, allowing the load balancing group to contain the downstreams for both MAC domains.
- All upstream ports coming from the same splitter must be using different center frequencies that are separated by the channel width. For example, if the upstreams are using a channel width of 3.2 MHz, the center frequencies for all upstreams must be separated by at least 3.2 MHz.
- You can use four initialization techniques for Dynamic Channel Change (DCC).
- If you have configured load balancing, the provisioning system must not assign specific upstream channels or downstream frequencies to individual cable modems in their DOCSIS configuration files. Any cable modems requiring specific upstream channels or downstream frequencies must be excluded from load balancing operations (using the **cable load-balance exclude** command).
- Do not use the utilization method of load balancing on cable interfaces that have a small number of cable modems and where a single modem is responsible for the majority of the interface load. In this condition, the Cisco CMTS could end up continually moving cable modems from one interface to another in an endless attempt to load balance the interfaces. To avoid this, configure the utilization threshold to a value that is higher than what can be caused by any single cable modem.
- When deployed with channel restriction features, if the target upstream channel attribute masks are against that of the cable modem, then the cable modem on the higher load upstream will not be load balanced, as the current load balancing moves cable modems only to the target upstream. However, cable modems that do not have an attribute mask can still be load balanced. You should consider the following while deploying the load balancing groups: the target upstream will always be the upstream that has the lowest load. If some other upstreams have the same load, the upstream with the lowest index will be chosen as the target upstream.
- A TLV in a cable modem configuration file restricts dynamic load balancing on per modem basis.
- If you remove the last rule of a DOCSIS policy, the policy itself will be removed.
- The Cisco CMTS load balancing feature moves a cable modem based on the load of the channels in a load balancing group, without checking if the cable modem supports the extended frequency range (5Mhz-85Mhz). This may result in moving a cable modem that supports standard frequency range (5Mhz-65Mhz) to a channel that has extended frequency configured. To overcome such scenarios, operators should not mix upstreams that have standard and extended frequencies configured into the same load balancing group, unless all modems in the group support extended frequency range.

Restrictions for Dynamic Channel Change for Load Balancing

- The source and target upstreams and downstreams must share physical connectivity with the modem desired for a DCC transaction.
- Independent downstream change is not supported, and cross-MAC domain upstream changes must occur with the associated downstream changes.
- The source and target downstream interfaces must belong to the same virtual bundle and the same load balancing group if DCC is used for load balancing.
- For DCC initialization techniques 1 to 4, all the configuration variables of the cable modem must remain constant with the exception of the configuration variables that are explicitly changed by the Dynamic Channel Change request (DCC-REQ) messages encoding.
- DCC initialization techniques 2 to 4 must not be used if the propagation delay differences between the old and new channels exceeds the ranging accuracy requirement defined in DOCSIS, for example, ±0.25 usec plus ± symbol time.

  For example, for a symbol rate of 1.28 Msps, the timing offset difference between the source and target upstream channel is ± floor[(0.250 us + 0.5*0.781us)/(1/10.24)] = ± 6.
- The attenuation or frequency response differences between the old and new upstream channels causes the received power at the Cisco CMTS to change by more than 6 dB.
- DCC initialization technique 3 must not be used if the conditions for using technique 2 are not met.
- DCC initialization technique 4 must not be used if the conditions for using technique 2 cannot be met.
- Micro-reflections on the new upstream channel result in an unacceptable BER (greater than 1e-8) with pre-equalization coefficients set to the initial setting.
- DCC is used only for dynamic downstream load balancing on DOCSIS 1.1 and later CMs. Upstream Channel Change (UCC) is always used for dynamic upstream load balancing on DOCSIS 1.x CMs. For DOCSIS 2.x CMs, UCC is used when the *ucc* option is configured. For DOCSIS 3.x CMs, DCC is used irrespective of whether the *ucc* option is configured or not.
- Prolonged interruption of the multicast traffic is expected if the cable modem moved by DCC is the first one in a dynamic multicast group on the target interface. The downstream multicast service flow cannot be reestablished until the Cisco CMTS receives an Internet Group Management Protocol (IGMP) join message from the customer premises equipment (CPE) as the result of the Cisco CMTS IGMP query, where the IGMP query interval is set to one minute. This is an IGMPv2 limitation.
- Multiple statically-assigned IP addresses to a CPE can be pinged. However, this works only if all the security features, such as verification of IP addresses for cable modems and CPE devices on the upstream, and other security mechanism are disabled.
- The TCS and RCS assigned to the DOCSIS 3.0 cable modems are restricted by the upstream and downstream bonding groups configured by the Cisco CMTS.
- Load balancing and DCC are not supported for CMs that are enabled for Layer 2 VPN (L2VPN) support.
- When a DCC occurs, the cable modem US and DS counters are reset. The US and DS counters include counters such as data and throughput seen in the **show cable modem** (**mac-address**) **verbose** command output and packets and bytes seen in the **show cable modem (mac-address) counters** command output.

DCC Restrictions with N+1 Redundancy and Inter-Card Load Balancing

- Inter-card load balancing is not supported with cable interface line cards using N+1 redundancy. Refer to general DCC restrictions for additional information.
- Dynamic load balancing should not be used together with N+1 redundancy. Cable modems with outstanding DCC transactions go offline after a switchover event.

Note When cable modems go offline during a switchover event, the load balancing feature activates. Cable modems move in relation to the switchover event. When the cable modems return online, load balancing may need to initiate again.

To facilitate load balancing during a switchover, you can increase the dynamic load balance threshold, if a certain percentage of cable modems that reset during switchover is configured in the system. An alternate method is to use static load balancing with N+1 redundancy. For more information, see the Types of Load Balancing Operations.

Restrictions for DOCSIS 3.0 Static Modem Count-Based Load Balancing

- Static modem count-based load balancing is supported on MTC and MRC-only cable modems. Single-channel, narrowband cable modems will continue to be supported with dynamic load balancing. MRC-only modems are supported by dynamic load balancing on upstream channels.

Note DOCSIS 3.0 static modem count-based load balancing is not supported on:

- Multiple line cards.
- Load balancing groups and downstream channels shared across multiple line cards.

- DOCSIS 3.0 static modem count-based load balancing does not support service flow method of load balancing.

Restrictions for Dynamic Bonding Change for DOCSIS 3.0 Static Modem Count-Based Load Balancing

- The Cisco CMTS can use only DBC messaging to move modems within a MAC domain and applies only to cable modems operating in MTC mode or MRC-only mode without a primary downstream change.
- The Cisco CMTS moves the MRC-only cable modems with a primary channel change using DCC with initialization technique 0.
- The Cisco CMTS moves cable modems across MAC domains using only DCC with initialization technique 0.

- The Cisco CMTS must ensure minimum interruption to existing QoS services while considering an initialization technique that is suitable for the cable plant conditions.

Note DOCSIS 3.0 Static Load Balancing uses Initialization Technique 1 to move cable modems for DBC movement.

  - Initialization Technique 1—(Broadcast initial ranging) may result in a lengthy interruption of service, which is mitigated by the reservation of QoS resources on the new channel(s). The service interruption can be further reduced if the Cisco CMTS supplies the UCD TLV in the DBC request in addition to providing more frequent initial ranging opportunities on the new channel.
  - Initialization Technique 2—(Unicast ranging) offers the possibility of only a slight interruption of service. To use this technique, the Cisco CMTS must include the UCD TLV in the DBC message if the upstream channel is changing.
  - Initialization Technique 3—(Broadcast or unicast ranging) offers the possibility of only a slight interruption of service. Use this technique when there is uncertainty when the CM may execute the DBC command and thus a chance that it might miss station maintenance slots. However, the Cisco CMTS should not use this technique if the conditions for using techniques 1 and 2 are not completely satisfied.
  - Initialization Technique 4—(Use the new channel directly) results in the least interruption of service.

- For a DOCSIS 3.0 cable modem that in a DOCSIS 3.0 static load balancing group, the multicast join will be dropped before REG-HOLD time elapses.

Restrictions for MRC-Only Cable Modems

- MRC-only cable modems use single channel non-bonded upstreams (similar to narrowband (NB) modems) and multi-channel bonding groups on the downstream.

Note The following restrictions apply only to DOCSIS 2.0 and DOCSIS 3.0 cable modems in MRC-only mode.

- cable modems are moved across upstream channels using DCC.
- cable modems are moved to different downstream channels through DBC, if there is a change in the upstream channel and downstream channel bonding group, but not in the primary downstream channel and the upstream channel change is ignored.

  However, if there is a change in the primary downstream channel also, DCC with init tech 0 is used to balance the cable modems.
- MRC-only modems are treated similar to cable modems operating in MTC mode, to move modems across downstream channels. For change in upstream channel, MRC-only cable modems are treated similar to single-channel NB cable modems.

Information on the Load Balancing on the Cisco CMTS

This section describes the operation, concepts, and benefits of the Load Balancing on the Cisco CMTS feature:

Feature Overview

The Load Balancing on the Cisco CMTS feature allows service providers to optimally use both downstream and upstream bandwidth, enabling the deployment of new, high-speed services such as voice and video services. This feature also can help reduce network congestion due to the uneven distribution of cable modems across the cable network and due to different usage patterns of individual customers.

By default, the Cisco CMTS platforms use a form of load balancing that attempts to equally distribute the cable modems to different upstreams when the cable modems register

This feature has been enhanced to make use of DOCSIS policies and rules to limit the movement of cable modems within a Load Balancing Group. A policy defines whether and when cable modems can be moved within their load balancing groups.

A policy consists of a set of rules. Each rule can be defined as “enabled”, “disabled”, or “disabled during time period.” Multiple policies can share a single rule. However, if you remove the last rule of a policy, that will also remove the policy.

Each rule can be used in any number of policies. When it is defined by multiple rules, all rules apply in combinations. Each rule helps to prohibit load balancing using a particular cable modem and to prohibit load balancing using a particular cable modem during certain times of the day.

Following are the general guidelines for the rules and policies:

- The policy or rule is recognized by a 32-bit ID.
- Each cable modem can have one policy only.
- Each rule can be associated to one or more policies.
- Each policy is described by at least one rule, otherwise it cannot be created.
- The zero Policy ID is reserved by Cisco CMTS indicating “Do nothing to LB prohibition.”
- If the policy ID specified by the cable modem configuration file is not configured on Cisco CMTS, no LB prohibition is applied to that CM. However, after the policy with the matched ID is configured, LB prohibition takes effect immediately.

Methods to Determine When Interfaces Are Balanced

In addition to selecting how interfaces should be balanced (using the static, passive, or dynamic types of load balancing), you can also select one of the following methods that the Cisco CMTS should use to determine when interfaces are balanced:

- Modems Method—Uses the number of active cable modems on an interface.
- Utilization Method—Uses the current percentage of utilization of an interface.

See the following sections for more information about each method.

Modems Method

The modem method of load balancing uses the number of active cable modems on an interface to determine the current load. This is a form of distribution-based load balancing, in which the absolute numbers of modems are used to determine whether interfaces are load balanced.

This method does not take into account the amount of traffic flowing through the cable modems, but the system does take into account the relative bandwidth of the channels being used, so that channels with higher bandwidths are allocated higher numbers of cable modems. This means that when interfaces are using different channel widths or modulation profiles, the system can assign different numbers of cable modems to the interfaces to achieve a balanced load. For example:

- Channel widths— If two upstreams are being load balanced, and one upstream is configured with a channel width of 1.6 MHz and the other upstream is configured for a channel width of 3.2 MHz, the Cisco CMTS allocates twice as many cable modems to the second upstream because its channel width is twice as large as the first upstream channel width.
- Modulation profiles— If one downstream is configured for 64-QAM and the other downstream is configured for 256-QAM, the Cisco CMTS allocates a proportionately larger number of cable modems to the second downstream so as to achieve a balanced load.

When both the channel width and modulation profile are set differently on two interfaces, the system calculates a "weight" value to use as a guide to determine the relative bandwidths of the interfaces.

Tip In a system with balanced loads, the interfaces will contain the same number of cable modems only when the interfaces are configured with the same channel width and modulation parameters.

Utilization Method

Note Narrowband cable modems, multiple downstream modems and upstreams of MRC-only cable modems participate in the utilization method.

The utilization method uses an interface's current percentage of utilization to determine the current load. This method uses the amount of traffic being sent over an interface, in the form of the percentage of total bandwidth being used. The system takes into account the relative throughput and bandwidth (as determined by the modulation profiles and channel widths) of each interface when evaluating the load on those interfaces.

For example, if two upstreams are being load balanced using the utilization method, and the first upstream has twice the bandwidth of the second upstream, the two upstreams are considered balanced when they reach the same percentage of utilization. The first upstream is carrying more traffic than the second upstream because it has a larger capacity for traffic, but the percentage of utilization will be the same.

Wideband Interface Average Utilization and Throughput

The average utilization and average throughput between Wideband interfaces of the same size can be calculated by:

Average Utilization (WB) = $\sum^{n}_{i-1}$rfch - util(rf_i)/n

- n represents the size of the Wideband interface

- $\sum^{n}_{i-1}$rfch - util(rf_i) represents the sum of rfch - util of QAM channels in Wideband interface.

Average Throughput (WB) = AverageThroughput(WB)in last 30s/$\sum^{n}_{i=1}BW(rf_i)$

- Average Throughput (WB) represents the KB recorded in the last 30 seconds
- $\sum^{n}_{i=1}BW(rf_i)$ represents the total bandwidth of Wideband interface.

Note Use the **show cable load-balance load wideband** command to view the average utilization and average throughput between Wideband interfaces.

Load Balancing Parameters

You can determine which cable interfaces should participate in load balancing operations. You can also choose which of the following methods should be used to determine the current load on a cable interface, and therefore determine whether cable modems should be moved:

- Number of active cable modems
- Channel bandwidth utilization

You can also specify the threshold values that the Cisco CMTS should use to determine how to assign new cable modems to upstreams and downstreams for both types of load balancing. You can also configure whether cable modems with active Voice-over-IP (VoIP) calls should be moved, and if so, what thresholds should be used. You can also exclude certain cable modems from one or all of the different forms of load balancing.

Configurable Minimum Threshold under Utilization Method

The utilization method does not move cable modems for load balancing until the utilization of at least one of the interfaces reaches minimum threshold. This is done to avoid the unnecessary moving of cable modems due to temporary spikes in an interface's utilization rate.

Minimum utilization threshold can be configured under Utilization Method. The minimum utilization threshold may be configured in a range of 10 to 90 percent. As a result the cable modems will be moved only when the configured minimum utilization threshold is reached on an interface.

To configure the minimum threshold under the Utilization method, use the **cable load-balance method-utilization min-threshold** command in global configuration mode. For more information, refer to **cable load-balance method-utilization min-threshold** command reference.

Single Channel Load Balancing

Error Handling of Channel Assignment

As long as the interface state of the channels is not "administratively down", all channels are available for LBG assignment. For other load balancing operations, such as moving modems using DCC, or UCC, the interface state of the channels should be in "initial", "up", "suspicious", or "testing" states.

Downstream Load Balancing Distribution with Upstream Load Balancing

Downstream load balancing provides equalized load balancing with upstream group members. This enhancement synchronizes the “pending” statistic between different cable interface line cards in the load balancing group. The result is an alternative downstream load balancing scheme that makes use of per-upstream loads rather than total downstream loads.

This enhancement performs downstream load balancing that accounts for upstream channel loads in the same upstream load balancing group, rather than on the basis of the entire downstream channel load. Prior Cisco IOS releases may not have distributed cable modems evenly over individual upstream channels, nor in a way that accounted for downstream and upstream together.

The load balancing enhancement applies when downstream load balancing occurs on a headend system with separate upstream load balancing segments; the upstream segments are spread over multiple downstream segments.

The configuration and operation of making downstream load balancing decisions is enabled as follows:

- The target downstream segment is in the same downstream load balancing group as the source downstream segment.
- The upstream load balancing group can be set for the corresponding channel on which a cable modem is balanced.
- The Cisco CMTS automatically locates the upstream segment for a load balancing group and processes the upstream group status on the source interface that has the lowest load.
- The target downstream segment must have an upstream channel set in the upstream load balancing group.
- The highest target upstream segment must carry less load than any other potential target—the highest upstream segment on other interfaces.

For example, several upstream segments can be configured across multiple downstream segments as follows:

```
       U0      U1      U2      U3     Downstream
3/0    LB10    LB11    LB12    LB13      LB1
4/0    LB10    LB11    LB12    LB13      LB1
5/0    LB10    LB11    LB12    LB13      LB1
6/0    LB10    LB11    LB12    LB13      LB1
```

In this example, a cable modem that comes online on the interface cable 5/0 Upstream 2 could potentially come online on the following interfaces:

- cable 3/0 upstream 2
- cable 4/0 upstream 2
- cable 6/0 upstream 2

The enhancement enables the following advantages and behaviors:

- This enhancement adds support for synchronizing the “pending” statistic between different cable interface line cards and the network processing engine (NPE) so that a better decision can be made about where cable modems should be moved. This function can be used as a normal downstream load balancing implementation, if desired.
- This enhancement adds the **us-groups-across-ds** keyword to **cable load-balance group** command for configuring downstream load balancing groups with upstream resources.

Note You can use the **no cable load-balance docsis20-enable** command to disable DOCSIS 2.0 dynamic downstream and upstream load balance.

Upstream Load Balancing for DOCSIS 3.0 Cable Modems in Single Upstream Mode

The upstream load balancing functionality enables the Cisco CMTS router to effectively handle upstream traffic for wideband and narrowband cable modems that are in single upstream mode. Single upstream mode (Mx1) means that the modems cannot send upstream traffic on multiple upstream channels. In the event of traffic overload on a single upstream channel of a wideband or narrowband cable modem, the Cisco CMTS router automatically moves the cable modem to another upstream channel in the same load balancing group.

Note A cable modem operating in single upstream mode is assigned to a load balancing group based on the primary channel of the modem. A cable modem in single upstream mode can support multiple receive channel (MRC) mode or narrowband mode. However, a cable modem in single upstream mode cannot support multiple transmit channel mode (MTC).

Interaction with Spectrum Management

Cisco cable interface line cards support a number of features to maximize channel bandwidth and to minimize the impact of ingress noise on cable modem traffic. These features have the following impacts upon load balancing operations:

- Frequency hopping—Frequency hopping does not affect the load balancing algorithm, because it does not change either the bandwidth of a channel nor the number of cable modems on an interface.
- Dynamic modulation changes—The dynamic modulation feature affects the load balancing algorithm because it typically switches an interface from a higher-bandwidth modulation profile to a lower-bandwidth modulation profile in response to noise conditions on the interface.

  For example, if an upstream is configured for 16-QAM, sufficient noise levels could switch the upstream to a QPSK modulation profile. Depending on the load balancing configuration, this could then result in the movement of cable modems to other channels. Similarly, when the noise conditions improve, and the modulation is returned to the original, higher-bandwidth profile, the cable modems could be moved again to rebalance the upstream channels.
- Channel width changes—Cisco cable interface line cards support automatic changes to the channel width in response to noise conditions. Because changing the channel width affects the throughput of a channel, this also affects the load balancing algorithm.

  For example, if noise makes the current channel width unusable, the Cisco cable interface line card reduces the channel width until it finds a usable channel width. Because this reduces the available bandwidth on the channel, the load balancing algorithm moves cable modems to rebalance the upstreams.

  In addition, the Cisco cable interface line card does not automatically restore the original channel width when noise conditions improve. Instead, the card changes the channel width only when it performs a subsequent frequency hop, either in response to additional noise conditions or when an operator performs a manual frequency hop. When the hop occurs, the card then searches for the largest possible channel width, and this could result in another movement of cable modems to rebalance the channels.

Using Dynamic Channel Change

DCC in DOCSIS 1.1 dynamically changes cable modem upstream or downstream channels without forcing a cable modem to go offline, and without re-registration after the change. DCC supports five different initialization methods (0-4).

- Load balancing techniques allow for moving cable modems with DCC by using configurable initialization techniques.
- DCC allows line card channel changes across separate downstream channels in the same cable interface line card, with the DCC initialization techniques ranging from 0 to 4.
- DCC transfers cable modem state information from the originating downstream channel to the target downstream channel, and maintains synchronization of the cable modem information between the cable interface line card and the Network Processing Engine (NPE) or Route Processor (RP).
- Applications that are sensitive to delay , such as PacketCable (PC) and PacketCable Multi Media (PCMM), may use DCC initialization technique4 to retain services while the cable modem is performing DCC.
- If the channel is in mixed or ATDMA-only mode, the primary Service Identifier (SID) must be switched to ATDMA-only mode.

Note You can use the **no cable load-balance docsis20-enable** command to disable DOCSIS 2.0 dynamic downstream and upstream load balance.

Multiple Channel Load Balancing

Algorithm for Bonded Channel Cable Modem Load Balancing

During registration of the cable modem, the modem count-based method uses the number of active cable modems on the allowed RCS to determine the current load on each channel. After the modem is assigned an RCS, the Cisco CMTS does not move the cable modem even when traffic conditions change.

When a cable modem sends a registration request, modem count-based method of load balancing ranks the allowed receive channel sets (RCS) based on their modem count and assigns the set with the lowest number of CMs, to the ranging cable modem.

DOCSIS 3.0 Static Modem Count-Based Load Balancing

The static modem count-based load balancing supports the following:

- DOCSIS General and Restricted load balancing group assignment to include DOCSIS 3.0 cable modems in MTC and MRC-only modes.

Note DOCSIS 3.0 static modem count-based load balancing is not supported:

- Across multiple line cards.
- For load balancing groups and downstream channels shared across multiple line cards. However, autonomous load balancing-based CM steering and load balancing group assignment is supported across multiple line cards

- Use of DCC and DBC in load balancing.
- Use of DBC for MRC-only modems during downstream move.
- Use of DCC with init tech 0 if the primary downstream channel is changed for MRC-only CMs.
- Use of DBC for cable modems in MTC mode for all upstream and downstream modem move.
- Separate counters for NB and wideband (WB)/upstream bonding (UB) CMs. For more information, see the **show cable load-balance docsis-group** command in the Cisco IOS CMTS Cable Command Reference.
- Aggregate logical channels to physical channels for load balancing. Physical channel load is calculated by using average weights among all logical channels.
- Non-primary downstream channels load where utilization of SPA QAM is considered

Note When the CM counts across different WB interfaces are within predefined threshold levels, the load is always considered as balanced; no more CM move is initiated by the LB system. No service flow count, whether primary or secondary, is taken into consideration during this LB process.

Note The attributes considered for the forward interface for the service flow (SF) are attribute mask and available bandwidth, and *not* the number of service flows on each channel. If a channel is within the new RCS, then irrespective of the type of narrowband SF, (whether primary or secondary, or static or dynamic) the SF continues to use its current channel.

Note The US Phy Mode counters (scdma, atdma, and tdma) remain 0 for the UB interfaces.

DOCSIS 3.0 static modem count-based load balancing is based on legacy load balancing and supports any type of channel combination (upstream and downstream)—MxN, with 1x1 combination being the subset.

DOCSIS 3.0 static modem count-based load balancing controls dynamic changes to the set of downstream and upstream channels used by a registered CM. It supports the following:

- Multiple channel load balancing operation.
- Load balancing operation based on policies and priorities.

- Load balancing with multicast. DOCSIS 3.0 static modem count-based load balancing does not move any CM with active video sessions.

DOCSIS 3.0 static modem count-based load balancing supports the modem count-based load balancing in a hybrid deployment of DOCSIS 1.x, 2.0 and 3.0 cable modems.

Static modem count-based load balancing is supported only for DOCSIS 3.0 CMs. Single-channel, narrowband cable modems will continue to be supported with dynamic load balancing. MRC-only cable modems are supported by dynamic load balancing on upstream channels.

With DOCSIS 3.0 static modem count-based load balancing, when load balancing related configuration within the LBG is changed as follows, the cable modems are forced to re-register:

- Partial shut or no shut interfaces under the LBG domain
- MRC or MTC mode in cable modems is turned on or turned off
- Change in fiber node for GLBG
- Change in wideband configuration for downstream group
- Change in the upstream bonding group

Use the following commands to force cable modems to re-register:

- **clear cable modem delete**
- **clear cable load state**
- **clear cable load counters**

Primary Channel Load Display for Target RCS

This feature enables the bonded modems to be moved at the time of registration such that the primary channels are distributed evenly among the primary-capable channels apart from the load being balanced on the target DS channels. Modem method ranks the RCS based on their primary loads and assigns the set with the lowest primary load to the ranging cable modem.

An optional keyword **primary-load** has been added to the **show cable load-balance docsis-group** command to display the primary load of an RCS. For more information, see the Cisco CMTS Command Reference.

Although the modem count-based method distributes the cable modems fairly as they register, the following conditions may cause a system imbalance:

- A channel or groups of channels fail because of a planned (administrative shutdown) or unplanned event.
- While some cable modems may continue to operate in partial mode, some may re-register because of the failure and are reassigned to the channels that are active.
- When the failed channels become operational again, the cable modems do not re-register and the system is unbalanced.

In this case, the modem count-based method sends an SNMP trap to alert the operator, and the operator can choose to manually intervene to re-balance the cable modems by resetting the MAC domain to force all cable modems to re-register.

Note For cable modems in MRC and MTC modes, the modem count based load balancing method considers the number of active modems and service flows on the primary channels in the RCS and TCS of the cable modem.

Note Use **no cable load-balance docsis30-enable static** command to disable this feature.

Dynamic Load Balancing for DOCSIS 3.0 Cable Modems

The existing Load Balancing (LB) feature is enhanced to cope with the increase in the number of downstream and upstream channels by Multi-Service Operators (MSO) and wider deployment of 16-channel, 24-channel and multiple downstream channel Cable Modems (CMs). This enhancement allows the customer to better utilize their available bandwidth. The enhancements made to the existing LB feature include:

- Utilization based Dynamic downstream LB for DOCSIS 3.0
- Support for DOCSIS 3.0 LB statistics
- Enable or Disable DOCSIS 3.0 LB feature
- Distribute the CM on all the primary channels for the target interface when performing DOCSIS 3.0 LB dynamic movement. This feature is only used on DOCSIS 3.0 LB dynamic movement. It is disabled by default. Use **method utilization primary-distributed** command in the DOCSIS load balancing group mode to enable this feature. To disable this feature, use **no** form of this command or **method utilization us-method** command.

Note Use **cable load-balance docsis-enable** command to enable this feature. In addition, use **cable load-balance docsis30-enable** and **cable load-balance docsis30-enable dynamic downstream** command to enable dynamic and utilization based dynamic downstream LB for DOCSIS 3.0 Cable Modems.

Multiple Channel Load Balancing Operation

CMs load balance in MRC and MTC modes. The following rules apply while load balancing CMs operating in these modes:

- For CMs operating in MRC and MTC modes, DBC is used to move CMs across downstreams by changing the RCS of the CM within same MAC domain.

  CMs operating in MRC-only mode can be moved across upstreams only through a DCC request. However, the Cisco CMTS uses DCC with initialization technique 0 (reinitializing the MAC domain) when changing the downstream channel of a CM operating in MRC mode.

- During CM registration, the Cisco CMTS may send a multipart registration response (REG-RSP-MP) message to include a TCC TLV encoding to the CM. This CM is marked as TCC-capable.

  For CMs operating in MRC, non-MTC, non-TCC-capable mode, load balancing uses:

  - DBC to change RCS of the CM
  - DCC to change upstream channel of the CM

- For CMs operating in narrowband mode, DCC is used to move CMs within and across MAC domains.

The tables below provide a snapshot view of the load balancing methods and the operations used to move bonded and non-bonded CMs:

Table 16: Load Balancing Method to Move Bonded and Non-bonded CMs

Modem Mode	Load Balancing Method	Load Balancing Counters	Channels	Dynamic Service Charge (Initialization Technique)	
				Within MAC Domain	**Across MAC Domains**
DOCSIS 3.0 CM in MTC mode	DOCSIS 3.0 static modem count-based load balancing (MCBLB) DOCSIS 3.0 dynamic load balancing	WB/UB	DS	DBC **Note** When DOCSIS 3.0 LB is enabled, and the MTC CM is outside RLBG, CM is moved inside RLBG.	DCC init tech 0
	DOCSIS 3.0 static modem count-based load balancing (MCBLB)	WB/UB	US	DBC **Note** When DOCSIS 3.0 LB is enabled, and the MTC CM is outside RLBG, CM is moved inside RLBG.	DCC init tech 0

Modem Mode	Load Balancing Method	Load Balancing Counters	Channels	Dynamic Service Charge (Initialization Technique)	
DOCSIS 3.0/D2.x CMs in MRC-only mode	DOCSIS 3.0 static MCBLB DOCSIS 3.0 dynamic load balancing	WB/UB	No change to the primary DS channel	DBC **Note** When DOCSIS 3.0 LB is enabled and CM with all DSs is outside RLBG, CM is moved inside RLBG.	DCC init tech 0
			Change to the primary DS channel	DCC init tech 0 **Note** CM with primary DS outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC init tech 0
DOCSIS 3.0 CMs in MRC-only mode	DOCSIS 2.0 static and dynamic MCBLB, dynamic utilization	NB	US	DCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC init tech 0

Modem Mode	Load Balancing Method	Load Balancing Counters	Channels	Dynamic Service Charge (Initialization Technique)	
D2.x CMs in MRC-only mode	DOCSIS 2.0 static and dynamic MCBLB, dynamic utilization	NB	US	DCC/UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC init tech 0
DOCSIS 2.0 /DOCSIS 1.1 CMs in NB mode	DOCSIS 2.0 dynamic MCBLB, dynamic utilization	NB	DS	DCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC init tech 0
			US	UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	UCC

Modem Mode	Load Balancing Method	Load Balancing Counters	Channels	Dynamic Service Charge (Initialization Technique)	
DOCSIS 1.0 in NB mode	DOCSIS 2.0 dynamic MCBLB, dynamic utilization	NB	DS	Force reinitialize CM **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	Force reinitialize CM
			US	UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	UCC

Table 17: Using DCC/DBC to Load Balance Bonded and Non-bonded Cable Modems

Channel	CM in MRC, MTC Mode	CM in MRC, non-MTC Mode	DOCSIS 1.1/2.0 CMs with Single US/DS	DOCSIS 1.0 CMs with Single US/DS
Upstream (US)	DBC	DCC	DCC	UCC
Downstream (DS)	DBC (within the same MAC domain)	DBC (within the same MAC domain)	DCC (within the same MAC domain)	Force reinitialize CM
	DCC with initialization technique 0 when moving CMs across MAC domains	DCC with initialization technique 0 when moving CMs across MAC domains	DCC with initialization technique 0 when moving CMs across MAC domains	Force reinitialize CM

Using DBC for DOCSIS 3.0 Load Balancing Movement

As part of the DOCSIS 3.0 specifications, at any time after registration, the Cisco CMTS uses the DBC command to change any of the following parameters in a DOCSIS 3.0 CM:

- Receive channel set
- Transmit channel set

- DSID(s) or DSID associated attributes
- Security association(s) for encrypting downstream traffic
- Service Flow Cluster Assignments

Note Only RCS and TCS are used by the DOCSIS 3.0 load balancing.

Use the **show cable load-balance docsis-group** command to display the current, real-time statistics for load balancing operations. For more information, see the Cisco IOS CMTS Cable Command Reference.

Using DBC to Change the Receive Channel Set

The Cisco CMTS can add, delete, or change the channels in the RCS of a cable modem by including a RCC in the DBC-REQ.

If an RCS change affects the primary downstream channel of the cable modem, the cable modem is required to re-register on its upstream channels.

If channels are deleted from the RCS, the Cisco CMTS may stop sending traffic on the downstream channel to be removed, which may cause loss of traffic. The Cisco CMTS minimizes packet loss by duplicating traffic on the new and old RCS until it receives a DBC-RSP from the cable modem.

Note For cable modems in MRC-only mode, a downstream channel move is initiated by a DBC message. However, DCC initialization technique 0 is used if there is a change in the primary downstream channel.

Using DBC to Change the Transmit Channel Set

The Cisco CMTS can add, delete, or replace one or multiple channels in the TCS in a single DBC message. Whenever the TCS of the cable modem changes, the CMTS appropriately modifies the service identifiers (SIDs) associated with the affected service flows.

A change in the TCS is accompanied by a valid initialization technique.

Using DBC to Change the Downstream ID

Using DBC, the Cisco CMTS can change the following attributes of a downstream ID (DSID):

- Re-sequencing encodings:
  - Downstream re-sequencing channel list—The CMTS can add, delete, and replace channels in the DS re-sequencing channel list.
  - DSID re-sequencing wait time—The CMTS can indicate a change in skew due to network or configuration changes through DSID re-sequencing wait time.
- re-sequencing Warning Threshold
- CM-STATUS Hold-Off Timer for Out-of-range Events
- Multicast Encoding—The CMTS can initiate a DBC transaction to either add, deleted, or change attributes of an existing multicast DSID:

- Client MAC Address
- Multicast cable modem interface Mask
- Group MAC Address

Using DBC to Change the Security Association for Encrypting Downstream Traffic

- The CMTS can initiate a DBC transaction to add or delete Security Associations (SA) used to encrypt downstream traffic.
- The CMTS cannot send a DBC request to a cable modem that is not in the "Authorized" State.
- The CMTS can send a DBC request with an SA that uses a cryptographic suite unsupported by the cable modem. However, if the cable modem receives a DBC request with an SA that it is not capable of using, the cable modem rejects the DBC request.

Using DBC to Change the Service Flow SID Cluster Assignments

The Cisco CMTS uses the Service Flow SID Cluster Assignments TLV in the DBC request to assign new channels to a service flow, remove channels from a service flow, or replace one channel with another for a service flow.

Note Multiple actions can occur within a single DBC message.

Benefits of Load Balancing

The Load Balancing feature on the Cisco CMTS provides the following benefits to cable service providers and their partners and customers:

- Provides a method that service providers can use for efficient bandwidth utilization, especially when using multiple upstream channels per fiber node.
- Allows service providers to expand their networks in an efficient manner, avoiding the cost of having to install additional fiber optic equipment and further segmenting the physical plant.
- Load balancing on downstream channels enables efficient bandwidth usage when using multiple downstream channels per fiber node to enable Video over IP and other services that require high-bandwidth real-time streams.
- Load balancing of upstream and downstream channels does not require any change to the provisioning servers or to any DOCSIS configuration files.
- Load balancing of upstream and downstream channels does not require any administrator or user intervention (such as manually resetting cable interfaces or manually rebooting cable modems).
- Allows service providers to equally balance their downstreams as cable modems register, so that cable modems do not all attempt to register on the same downstream, resulting in many cable modems failing to register and having to search for a new downstream.
- Cable modems can be moved among downstream and upstream channels without having to change any network parameters in manual fashion, such as IP address.

- Allows service providers to stay ahead of customers' bandwidth demands by dynamically responding to current load-usage conditions.
- Allows service providers to optimize the load balancing parameters for critical services, such as Voice over IP (VoIP).

Exclude Cable Modems from Load Balancing Groups

Load Balancing Process

The load balancing process has two phases.

- Assignment phase.

  When a modem is coming online in the assignment phase, the modem is moved to the load balance group by assigning it a load balancing group (LBG) ID. The assignment phase occurs only when a modem is coming online.

- Balancing phase.

  In the balancing phase, a modem is re-assigned to an LBG to balance the load.

Excluding Cable Modems from Load Balancing

There are four options that are used to exclude cable modems from an LBG:

- The **assignment** option:

  The **assignment** option is used to exclude a modem during the assignment phase. The modem is not assigned an LBG and LBG ID is not displayed in the output of the **show cable modem verbose** command. The **assignment** option cannot be used when a modem is already online.

- The **static** option:

  The **static** option is used to exclude a modem during the Balancing phase. The modem is assigned to an LBG with an LBG ID. The **static** option is used to exclude a modem during static load balancing.

- The **enforce** option:

  The **enforce** option is similar to the **static** option, except that the **enforce** option is used to exclude a modem during dynamic load balancing.

When a cable modem is excluded from load balancing using the **assignment** option, the cable modem is not available for load balancing using the **static** or the **enforce** options.

- The **strict** option:

  The **strict** option excludes a modem in both the phases of load balancing. When a modem is online already, the **strict** option applies the **static** and the **enforce** options. It applies the **assignment** option only when the modem comes online again.

How to Configure Load Balancing

To configure load balancing groups, and to enable load balancing, refer to the configurations in the *DOCSIS Load Balancing Groups* document. Each task is marked as required or optional, as appropriate.

Enabling Single Channel Load Balancing

To configure Single Channel Load Balancing, see the *DOCSIS Load Balancing Groups guide*.

Configuring Dynamic Bonding Change for DOCSIS 3.0 Static Load Balancing

Use the **cable load-balance docsis30-enabled** command in the global configuration mode, to enable DOCSIS 3.0 Static Load Balancing.

Note DOCSIS 3.0 Static Load Balancing always uses Modem Count Method for load balancing.

Before you begin

Configure Load Balancing Groups. For more details, see the *DOCSIS Load Balancing Groups guide*.

Excluding Cable Modems from a Load Balancing Group

This configuration is optional. This section describes how to exclude a particular cable modem, or all cable modems from a particular vendor, from participating in static or dynamic load balancing operations, and optionally marking the modems for passive load balancing. This task is optional, because, by default, cable modems on an interface participate in whatever load balancing operations have been configured.

Note This step might be required for some cable modems that are not DOCSIS-compliant. Such cable modems can go offline for long periods of time when load balancing is attempted using DOCSIS MAC messages. If this is the case, use the **cable load-balance exclude** command to exclude such cable modems from load balancing operations until the modem can be upgraded to DOCSIS-compliant software.

Tip You must exclude cable modems that require specific upstream channels or downstream frequencies. Load balancing cannot be done when cable modems are assigned specific channels or frequencies in their DOCSIS configuration files.

Support for Excluding Old Devices

Load balancing for old cable devices like Set Top Boxes (STBs) which do not support load balancing, will fail. In the output for **show cable load-balance group** command, these devices will show as 'suspicious' and then as 'disabled'. This will disrupt normal operations of other modems in the load balancing group. To exclude these STBs, a **cable load-balance exclude** command is configured to exclude each STB.

Note You can configure the **cable load-balance exclude** command once to exclude all the STBs, that do not support load balancing, instead of configuring the command several times with matched MAC addresses. You can also move cable modems that were moved to a load balancing group in assignment phase.

The **cable load-balance exclude** modem command is modified to include the *mask* argument as an optional argument. The MAC address of a cable modem that belongs to the range specified by the MAC address mask, will be excluded by matching the "1" bit in mask. While configuring a new range rule using the *mask* argument, an existent rule with the same range is overwritten.

The **cable load-balance exclude** modem command is modified to include the **assignment** option. This option allows you to exclude a cable modem that was moved into a load balancing group in assignment phase.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance exclude** {**modem** *mac-address* [*mac-mask*] | **oui** *oui-value*} [**assignment** | **enforce** | **static** | **strict**] **Example:** `Router(config)# cable load-balance exclude oui 00:00:0c`	Specifies that one or more cable modems should be excluded from load balancing operations. By default, the cable modems are excluded from dynamic and static load balancing, but they continue to participate in passive load balancing. Use the following options to exclude the cable modems from others combinations of load balancing:
Step 4	**exit** **Example:** `Router(config)# exit`	Exits global configuration mode.

Distributing Downstream Load Balancing with Upstream Load Balancing

Two commands are used to configure or display the configuration and status of distributed load balancing on the Cisco CMTS:

- **cable load-balance group** *ds-lb-group-id* **policy** {**pcmm** | **ugs** | **us-groups-across-ds**}
- **show cable load all**

The optional configuration of making downstream load balancing decisions is enabled as follows:

- The target downstream segment is in the same downstream load balancing group as the source downstream segment. This feature finds the target frequency and interface based on the upstream loads within the same upstream group as the source.
- The upstream load balancing group can be set for the corresponding channel on which a cable modem is balanced on the downstream channels.
- The Cisco CMTS automatically locates the upstream segment for a load balancing group and processes the upstream group status on the source interface that has the lowest load.
- The target downstream segment must have an upstream channel set in the upstream load balancing group.
- The highest target upstream segment must carry less load than any other potential target—the highest upstream segment on other interfaces.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance group** *ds-lb-group-id* **policy** {**pcmm** | **ugs** | **us-groups-across-ds**} **Example:** `Router(config)# cable load-balance group 1 policy us-groups-across-ds`	Sets the type of service flow policy for use with Load Balancing. This command synchronizes the pending statistic between different cable interface line cards in the load balancing group. The result is an alternative downstream load balancing scheme that makes use of per-upstream loads rather than total downstream loads when making load balancing decisions.
Step 4	**exit** **Example:** `Router(config)# exit`	Exits global configuration mode.
Step 5	**show cable load all** **Example:** `Router# show cable load all`	Displays load balancing statistics and status of load balancing configurations on the Cisco CMTS, to include distributed upstream-to-downstream load balancing when configured.

How to Configure Dynamic Channel Change for Load Balancing

DCC in DOCSIS 1.1 dynamically changes cable modem upstream or downstream channels without forcing a cable modem to go offline, and without reregistration after the change. DCC supports five different initialization methods (0-4), instead of one, as in earlier DOCSIS support.

Dynamic Channel Change (DCC) and DCC for Load Balancing on the Cisco CMTS supports the following:

- Load balancing techniques allow for moving cable modems with DCC by using configurable initialization techniques.
- DCC allows line card channel changes across separate downstream channels in the same cable interface line card, with the DCC initialization techniques ranging from 0 to 4.
- DCC transfers cable modem state information from the originating downstream channel to the target downstream channel, and maintains synchronization of the cable modem information between the cable interface line card and the Network Processing Engine (NPE) or Route Processor (RP).
- Applications that are sensitive to delay, such as PacketCable (PC) and PacketCable MultiMedia (PCMM), may use DCC initialization technique 4 to retain services while the cable modem is performing DCC.
- If the channel is in mixed or ATDMA-only mode, the primary Service Identifier (SID) must be switched to ATDMA-only mode.

Configuring Dynamic Channel Change for Load Balancing

To configure the DCC feature for load balancing, use the following steps. Values indicated are sample values that may differ from your own.

SUMMARY STEPS

1. **enable**
2. **configure terminal**
3. **cable load-balance docsis-enable**
4. **cable load-balance docsis-group** *docsis-group-id*
5. **init-tech-list** *tech-list* [**ucc**]
6. **policy** {**pcmm** | **ugs** | **us-across-ds** | **pure-ds-load**}
7. **threshold** {**load** {**minimum** *<1-100>* | *<1-100>*}| **pcmm** *<1-100>* | **stability** *<0-100>* | **ugs** *<1-100>*}
8. **end**

DETAILED STEPS

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable load-balance docsis-enable** **Example:** `Router(config)# cable load-balance docsis-enable`	Enables DOCSIS load balancing on the Cisco CMTS.

	Command or Action	Purpose
Step 4	**cable load-balance docsis-group** *docsis-group-id* **Example:** `Router(config)# cable load-balance docsis-group 1`	Creates a DOCSIS load balance group on the Cisco CMTS, with the following parameter: The router enters DOCSIS load balancing group configuration mode.
Step 5	**init-tech-list** *tech-list* [**ucc**] **Example:** `Router(config-lb-group)# init-tech-list 1 ucc`	Sets the DCC initialization techniques that the Cisco CMTS can use to load balance cable modems.

Step 6	**policy** {**pcmm** | **ugs** | **us-across-ds** | **pure-ds-load**}
	Example:
	`Router(config-lb-group)# policy us-across-ds`
	`Router(config-lb-group)# policy ugs`
	`Router(config-lb-group)# policy pure-ds-load`
		Selects the modems based on the type of service flow that are balanced.

Step 7	**threshold** {**load** {**minimum** *<1-100>* | *<1-100>*}| **pcmm** *<1-100>* | **stability** *<0-100>* | **ugs** *<1-100>*}
	Example:
	`Router(config-lb-group)# threshold load minimum 10`
	`Router(config-lb-group)# threshold pcmm 70`
	`Router(config-lb-group)# threshold load 10`
	`Router(config-lb-group)# threshold stability 50`
	`Router(config-lb-group)# threshold ugs 70`
		Selects the percentage of use beyond which load balancing occurs.

Step 8	**end** **Example:** `Router# end`	Returns to privileged EXEC mode.

What to do next

To test and verify DCC for load balancing, use the following two commands:

- **test cable dcc**
- **show controllers cable**

These commands are described in the *Cisco CMTS Cable Command Reference* .

Verifying Load Balancing Operations

This section describes how to use certain test and show commands to verify the configuration and operation of the Load Balancing feature or Dynamic Channel Change feature on the Cisco CMTS.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**show cable load-balance** [**group** *n*] [**all** | **load** | **pending** | **statistics** | **target**] **Example:** `Router# show cable load-balance group 1`	Displays real-time statistical and operational information for load balancing operations. If given without any options, this command displays information for the load balancing groups and each cable interface's current load and load balancing status. You can also specify the following options:
Step 3	**test cable dcc** [*mac-addr* | *ip-addr* | *cable-if-src sid*] *cable-if-target uschan* {*ranging-tech* } **Example:** `Router# test cable dcc 0000.394e.4e59`	Tests Dynamic Channel Change (DCC) by moving a target cable modem, as specified by MAC address, IP address, or the primary service ID (SID) value. Applies to a cable modem on the source interface to an upstream channel on a target downstream interface using the initialization technique specified.

Example

This example shows the result of load balancing operations.

```
Router#show cable load all
DOCSIS 2.0 LB Enabled: Yes DOCSIS 3.0 LB Enabled: No
DOCSIS     Status Interval DCC mask  Policy     Method Threshold
Group                      /UCC                DS/US  M/E/U/P/S
1          RE     30       0xF8(0)/N 0         m/m    5/10/70/70/50
12345      GE     30       0xF8(0)/N 0         m/m    5/10/70/70/50
12346      RE     30       0xF8(0)/N 0         m/m    5/10/70/70/50
12347      RE     30       0xF8(0)/N 0         m/m    5/10/70/70/50
12348      RE     30       0xF8(0)/N 0         m/m    5/10/70/70/50
12349      RE     30       0xF8(0)/N 0         m/m    5/10/70/70/50

DOCSIS 3.0 General LB
MD       FN  Group ID   S Intv DCC mask  Policy     Mtd MD-CM-SG  Threshold
                                /UCC                D/U           M/E/U/P/S
Ca8/0/0  1   2147631104 E 30   0x30(2)/N 0         m/m 0x1200301 5/10/70/70/50
Ca8/0/1  3   2147631618 E 30   0x30(2)/N 0         m/m 0x1210301 5/10/70/70/50
Ca8/0/2  5   2147632132 E 30   0x30(2)/N 0         m/m 0x1220401 5/10/70/70/50
Ca8/0/2  6   2147632133 E 30   0x30(2)/N 0         m/m 0x1220402 5/10/70/70/50
Ca8/0/3  7   2147632646 E 30   0x30(2)/N 0         m/m 0x1230501 5/10/70/70/50
Ca8/0/3  8   2147632647 E 30   0x30(2)/N 0         m/m 0x1230502 5/10/70/70/50
Ca8/0/8  2   2147635201 E 30   0x30(2)/N 0         m/m 0x1280201 5/10/70/70/50
Ca8/0/9  4   2147635715 E 30   0x30(2)/N 0         m/m 0x1290201 5/10/70/70/50

Current load:

DOCSIS load-balancing load
Interface           State   Group      Utilization     Rsvd NBCM  WB/UB Weight
                                                           Total Total
In8/0/0:0(411 MHz)  initial 1          0%(0%/0%)       0%   0     11    37
In8/0/0:0(411 MHz)  initial 2147631104 0%(0%/0%)       0%   0     11    37
Us8/0/0:0           initial 1          0%              0%   0     31    30.7
Us8/0/0:0           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:1           initial 1          0%              0%   0     31    30.7
```

```
Us8/0/0:1           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 1          0%              0%   0     31    30.7
Us8/0/0:3           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:3           initial 1          0%              0%   0     31    30.7
In8/0/0:4(435 MHz)  up      2147635201 0%(0%/0%)       0%   48    11    37
Us8/0/1:0           up      2147635201 0%              0%   15    0     30.7
Us8/0/1:1           up      2147635201 0%              0%   11    0     30.7
Us8/0/1:2           up      2147635201 0%              0%   11    0     30.7
Us8/0/1:3           up      2147635201 0%              0%   11    0     30.7
In8/0/0:8(459 MHz)  initial 1          0%(0%/0%)       0%   0     9     37
In8/0/0:8(459 MHz)  initial 2147631104 0%(0%/0%)       0%   0     9     37
Us8/0/0:0           initial 1          0%              0%   0     31    30.7
Us8/0/0:0           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:1           initial 1          0%              0%   0     31    30.7
Us8/0/0:1           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 1          0%              0%   0     31    30.7
Us8/0/0:3           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:3           initial 1          0%              0%   0     31    30.7
In8/0/0:12(483 MHz) down    2147635201 0%(0%/0%)       0%   0           0
In8/0/0:16(507 MHz) initial 2147631104 0%(0%/0%)       0%   0     11    37
In8/0/0:16(507 MHz) initial 1          0%(0%/0%)       0%   0     11    37
Us8/0/0:0           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:0           initial 1          0%              0%   0     31    30.7
Us8/0/0:1           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:1           initial 1          0%              0%   0     31    30.7
Us8/0/0:2           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 1          0%              0%   0     31    30.7
Us8/0/0:3           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:3           initial 1          0%              0%   0     31    30.7
In8/0/0:20(531 MHz) down    2147635201 0%(0%/0%)       0%   0           0
In8/0/1:0(555 MHz)  initial 2147631618 0%(0%/0%)       0%   0     12    37
Us8/0/2:0           initial 2147631618 0%              0%   0     19    30.7
Us8/0/2:1           initial 2147631618 0%              0%   0     19    30.7
Us8/0/2:2           initial 2147631618 0%              0%   0     19    30.7
```

Troubleshooting Tips

Problem Packets are dropped when a cable modem moves from one channel to another.

Possible Cause When the **test cable dcc** command is used to move a cable modem from one channel to another with DCC initialization technique 3:

- If the pre-equalization coefficient is enabled, the cable modem moves and packet drop occurs for 5 seconds.
- If the pre-equalization coefficient is disabled, the cable modem moves and packet drop occurs for less than 1 second.

Possible Cause When the **test cable dcc** command is used to move a cable modem from one channel to another with DCC initialization technique 4:

- If the pre-equalization coefficient is enabled, the cable modem moves and packet drop occurs for less than 1 second.
- If the pre-equalization coefficient is disabled, the cable modem moves without any packet drop.

Solution No action is required.

Examples

Use the **show cable load-balance target** command to display the interfaces being used for load balancing, use the **test cable load-balance** command to test whether a cable modem can move between interfaces, and use the **show cable load-balance statistics** command to display the results of the test.

The following example shows how to test whether a specific cable modem responds to both a UCC request and to an upstream channel override to move from one upstream to another in its load balancing group:

```
Router# show cable load-balance target

Target assignments:
Interface            State      Group  Target
Cable1/0/0 (669 MHz) up         1
Cable1/0/0/U0        up         1      Cable1/0/0/U1 [enforce]
Cable1/0/0/U1        up         1

Router# show cable load-balance statistics

Statistics:

Target interface     State      Transfers
                                Complete  Pending   Retries   Failures
Cable1/0/0 (669 MHz) up         15        0         1         0
Cable1/0/0/U0        up         33        0         1         0
Cable1/0/0/U1        up         22        0         2         0

Router# test cable load-balance 0000.394e.4e59

Sending UCC request: Cable1/0/0/U0 --> U1
Waiting for test completion ........
Test results:
    UCC Response: 0.0s
    Initial Ranging: 8.5s
    Ranging Complete: failed.
    Modem replied to DOCSIS ping.
Test summary:
    UCC Response: success rate 100% min 0.0s max 0.0s avg 0.0s
    Initial Ranging: success rate 100% min 8.5s max 8.5s avg 8.5s
Testing US Channel Override: Cable1/0/0/U1 --> U0
Waiting for test completion ...........
Test results:
    Initial Ranging: 8.5s
    Ranging Complete: failed.
    Modem replied to DOCSIS ping.
Test summary:
    UCC Response: success rate 100% min 0.0s max 0.0s avg 0.0s
    Initial Ranging: success rate 100% min 8.5s max 8.5s avg 8.5s

Router# show cable load-balance statistics

Statistics:

Target interface     State      Transfers
                                Complete  Pending   Retries   Failures
Cable1/0/0 (669 MHz) up         15        0         1         0
Cable1/0/0/U0        up         34        0         1         0
Cable1/0/0/U1        up         23        0         2         0
```

The following example shows how to test whether a specific modem responds to a UCC request to move from one upstream to another in its load balancing group:

```
Router# show cable load-balance statistics

Statistics:

Target interface     State      Transfers
                                Complete  Pending   Retries   Failures
Cable1/0/0 (669 MHz) up         15        0         1         0
Cable1/0/0/U0        up         34        0         1         0
Cable1/0/0/U1        up         23        0         2         0

Router# test cable load-balance 0007.0e01.4129 ucc 1

Sending UCC request: Cable1/0/0/U0 --> U1
Waiting for test completion ........
Test results:
    UCC Response: 0.0s
    Initial Ranging: 10.3s
    Ranging Complete: 11.2s
    Modem replied to DOCSIS ping.
Test summary:
    UCC Response: success rate 100% min 0.0s max 0.0s avg 0.0s
    Initial Ranging: success rate 100% min 10.3s max 10.3s avg 10.3s
    Ranging Complete: success rate 100% min 11.2s max 11.2s avg 11.2s

Router# show cable load-balance statistics

Statistics:

Target interface     State      Transfers
                                Complete  Pending   Retries   Failures
Cable1/0/0 (669 MHz) up         15        0         1         0
Cable1/0/0/U0        up         35        0         1         0
Cable1/0/0/U1        up         24        0         2         0
```

The following example shows information when moving a cable modem to a different upstream channel using DCC initialization technique 1. This example moves the cable modem 0012.17ea.f563 from interface c7/1/0 upstream 1 to interface c7/1/1 upstream 0 using DCC initialization technique 1:

```
Router# show cable modem

MAC Address    IP Address      I/F       MAC         Prim RxPwr  Timing  Num BPI
                                         State       Sid  (dB)   Offset  CPE Enb
 State       Sid  (dB)   Offset  CPE Enb
0012.17ea.f563 12.0.0.2        C7/1/0/U1 online      4    0.00  2449     0   N

Router# test cable dcc 0012.17ea.f563 c7/1/1 0 1

Router# show cable modem

MAC Address    IP Address      I/F       MAC         Prim RxPwr  Timing  Num BPI
                                         State       Sid  (dB)   Offset  CPE Enb
0012.17ea.f563 12.0.0.2        C7/1/1/U0 online      3    0.00  2451     0   N
```

Configuration Examples for Load Balancing

This section provides the following configuration examples:

Example: Configuring Dynamic Channel Change for Load Balancing

The following examples illustrate the working of dynamic load balancing working process in DOCSIS 3.0 cable modems.

Verify configuration:

```
Router#  show cable load-balance docsis-group 1
DOCSIS LB Enabled: Yes
DOCSIS 2.0 LB Enabled: No
DOCSIS 3.0 LB Enabled: Yes
DOCSIS 3.0 Static LB Enabled: No
DOCSIS 3.0 Dynamic Downstream LB Enabled: Yes
DOCSIS Status Interval DCC mask Policy Method Threshold
Group /UCC DS/US M/E/U/P/S
1 RE 60 0x38(2)/N 0 u/u 1/10/70/70/50
```

Verify channel current load:

```
Router#  show cable load-balance docsis-group 1 load wideband
DOCSIS load-balancing wide band load
Interface Size Group Throughput(Kbps)/bw(Mbps) Avg-Util
Wi9/0/0:1 8 1 93324/300 36%
Wi9/0/0:2 8 1 37329/300 39%
Wi9/0/0:3 8 1 74659/300 31%
Wi9/0/0:4 8 1 0/300 13%
Wi9/0/0:5 8 1 9332/300 2%
```

Verify channel overload and target:

```
Router#  show cable load-balance docsis-group 1 target wideband
Interface Bg-Id State Group Target
Wi9/0/0:1 28674 up 1 Wi9/0/0:5 ...
Wi9/0/0:2 28675 up 1 Wi9/0/0:5 ...
Wi9/0/0:3 28676 up 1 Wi9/0/0:5 ...
Wi9/0/0:4 28677 up 1 Wi9/0/0:5
Wi9/0/0:5 28678 up 1
```

Verify channel modem-list:

```
Router#  show cable load-balance docsis-group 1 modem-list wideband
Codes: M - Multicast, U - UGS, P - PCMM, F - Max-Failures, X - eXcluded
L - L2vpn, R - RSVP
Primary WB MAC Address Primary DS RCC-ID Priority MUPFXLR State
Wi9/0/0:1 (10)
c8fb.26a6.c02c In9/0/0:4 1 0 ------- LB_CM_READY
c8fb.26a6.c62c In9/0/0:4 1 0 ------- LB_CM_READY
c8fb.26a6.c706 In9/0/0:4 1 0 ------- LB_CM_READY
c8fb.26a6.c0dc In9/0/0:4 1 0 ------- LB_CM_READY
c8fb.26a6.c53a In9/0/0:4 1 0 ------- LB_CM_READY
```

Verify QAM channel utilization:

```
Router#  show cable load-balance docsis-group 1 rfch-util
Interface Pstate Pending-In Pending-Out Throughput(Kbps) Util
In9/0/0:4 up No No 6517 17
In9/0/0:5 NA No No 6574 17
In9/0/0:6 NA No No 6520 17
In9/0/0:7 NA No No 6738 17
In9/0/0:8 up No No 8624 22
In9/0/0:9 NA No No 8482 22
In9/0/0:10 NA No No 8353 22
```

Verify channel statistic movement:

```
Router#  show cable load-balance docsis-group 1 statistics wideband
Target interface State Transfers
Complete Pending Total Failures Disabled
Wi9/0/0:1 up 0 0 0 0 0
Wi9/0/0:2 up 0 0 0 0 0
Wi9/0/0:3 up 3 0 3 0 0
Wi9/0/0:4 up 0 0 0 0 0
Wi9/0/0:5 up 9 0 9 0 0
```

The following example of the running configuration illustrates DCC for load balancing.

```
Router# show cable load all

*Nov 11 15:42:18.955: %SYS-5-CONFIG_I: Configured from console by conscable load all
Group  Interval  Method      DCC Init     Threshold
                           Technique    Minimum  Static  Enforce  Ugs   PCMM
1      10        modems      0             5        10%     ---     ---   ---

Current load:

Interface            State      Group Utilization  Reserved Modems Flows Weight
Cable3/0 (0 MHz)     initial    1     0%(0%/0%)    0%       0      0     26

Target assignments:

Interface            State      Group  Target
Cable3/0 (0 MHz)     initial    1

Statistics:

Target interface       State      Transfers
                                  Complete  Pending   Retries   Failures
Cable3/0 (0 MHz)       initial    0         0         0         0
Pending:
Modem          Group  Source interface  Target interface     Retries
```

The following example of the running configuration illustrates DCC for load balancing.

```
Router# show running configuration

Building configuration...
Current configuration : 11889 bytes
!
version 12.3
no service pad
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname Router
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$tEvV$8xICVVbFm10hx0hAB7DO90
enable password lab
!
no cable qos permission create
no cable qos permission update
cable qos permission modems
cable load-balance group 1 threshold load 75 enforce
cable load-balance group 1 threshold stability 75
cable load-balance group 1 policy ugs
cable load-balance group 1 threshold ugs 75
```

```
cable load-balance group 1 policy pcmm
cable load-balance group 1 threshold pcmm 75
no aaa new-model
ip subnet-zero
!
!
ip cef
no ip domain lookup
!
!
interface GigabitEthernet0/1
 ip address 10.14.1.130 255.255.0.0
 duplex auto
 speed auto
 media-type rj45
 no negotiation auto
!
interface GigabitEthernet0/2
```

The following example of the show cable load all command illustrates DCC for load balancing.

```
Router# show cable load all

*Nov 11 15:43:39.979: %SYS-5-CONFIG_I: Configured fromconf t
Group  Interval  Method      DCC Init     Threshold
                           Technique    Minimum  Static  Enforce  Ugs   PCMM
1      10        modems      0             5        75%     75%     75%   75%

Current load:

Interface            State      Group Utilization  Reserved Modems Flows Weight
Cable3/0 (0 MHz)     initial    1     0%(0%/0%)    0%       0      0     26

Target assignments:

Interface            State      Group  Target
Cable3/0 (0 MHz)     initial    1

Statistics:

Target interface       State      Transfers
                                  Complete  Pending   Retries   Failures
Cable3/0 (0 MHz)       initial    0         0         0         0

Pending:

Modem          Group  Source interface  Target interface     Retries
```

The following example illustrates a DCC load balancing group with the default DCC initialization technique. This command configures load balancing group 1:

```
Router(config)# cable load-balance group 1 threshold load 10 enforce
```

This configuration creates a dynamic load balancing group with the following default settings:

```
cable load-balance group 1 method modem
cable load-balance group 1 threshold load 10 enforce
cable load-balance group 1 interval 10
cable load-balance group 1 dcc-init-technique 0
```

The following example changes this DCC load balancing configuration to initialization technique 4:

```
Router# cable load-balance group 1 dcc-init-technique 4
```

Note By default, UGS and PCMM policies are not turned on, so that CMs with active voice calls or PCMM calls participate in load balancing.

Additional References

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

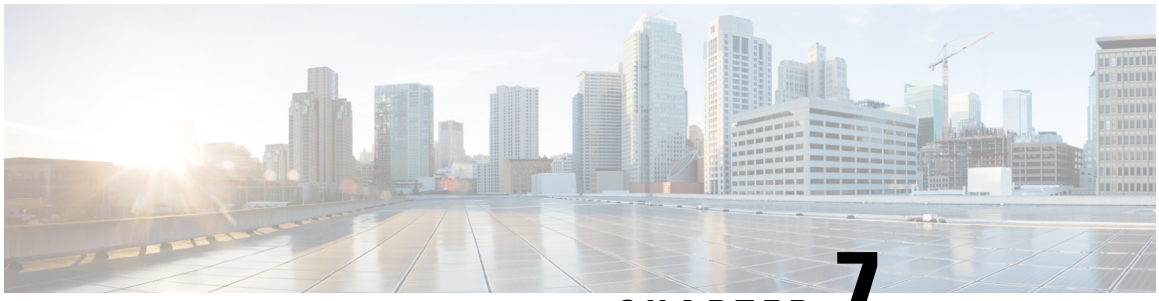
Feature Information for DOCSIS Load Balancing Movements

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 18: Feature Information for DOCSIS Load Balancing Groups

Feature Name	Releases	Feature Information
DOCSIS Load Balancing Movements	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 7

DOCSIS 3.0 Downstream Bonding

The DOCSIS 3.0 Downstream Bonding feature helps cable operators offer new, more bandwidth-intensive services by adding one or more additional downstream quadrature amplitude modulation (QAM) channels to the standard broadband DOCSIS system.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 121
- Information About DOCSIS 3.0 Downstream Bonding, on page 122
- How to Configure RCP and RCC Encoding, on page 124
- How to Configure Attribute Masks, on page 133
- How to Enable Service Flow Priority in Downstream Extender Header, on page 137
- Enabling Verbose Reporting for Receive Channel Profiles, on page 139
- Configuration Example for an RCC Template, on page 140
- Additional References, on page 141
- Feature Information for DOCSIS 3.0 Downstream Bonding, on page 141

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 19: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Information About DOCSIS 3.0 Downstream Bonding

DOCSIS 3.0 Downstream Bonding enables high-speed broadband access and helps cable operators offer more bandwidth-intensive services by adding one or more additional downstream quadrature amplitude modulation (QAM) channels to the standard broadband DOCSIS system. This new set of downstream channels is grouped into one larger channel, known as a bonded channel.

Channel bonding combines several RF channels into one virtual channel. Data rates in this virtual channel range from hundreds of megabits to potentially gigabits per second, creating more available bandwidth in the network.

Receive Channel Profile

An RCP is an encoding that represents the receive channels and receive modules of a cable modem. A cable modem communicates to the CMTS one or more RCP encodings within its registration request using either verbose description, which contains complete subtype encoding defined in DOCSIS 3.0, or simple description, which only contains RCP identifiers.

The cable modem reporting method is configurable within the MAC domain and communicated to cable modems via the MDD.

You must define an RCP-ID to describe the cable modem's capabilities for that RCP-ID and to input information about cable modems which are not defined on the system. Once configured the RCP-ID is available to the entire system since it is not meant to be card specific or mac-domain specific. The path selection module ensures that the RCP ID is accurately transmitted as part of the RCC profile.

The CableLabs MULPI specification defines standard RCPs which are automatically created by the CMTS.

Receive Channel Configuration

A cable modem reports its ability to receive multiple channels with one or more RCP encodings in a REG-REQ or REG-REQ-MP message. Each receive channel profile describes a logical representation of the cable modem’s downstream physical layer in terms of receive channels (RCs) and receive modules (RMs). The CMTS initially configures the cable modem’s receive channels and receive modules with an RCC encoding in the registration response.

This feature supports any arbitrary RCP ID configuration and receive channel configuration on a Cisco cBR Series Converged Broadband Router.

RCC Template

You can configure one or more RCC templates for an RCP. An RCC template configures the physical layer components described by an RCP, including receive modules and receive channels to specific downstream frequencies. The template also specifies the interconnections among receive modules, or between a receive module and a receive channel. An RCC template can be associated only to the cable interface (MAC domain).

A cable modem's RCP ID is matched with an RCC, when RCC templates are configured. A cable modem's RCP ID may be matched with an RCC generated by an RCC template when RCC templates are configured. The path selection module ensures that the RCP ID that is transmitted as part of the RCC profile is accurate.

At time of registration, if there are multiple valid RCCs that can be assigned to the CM after going through the sequence of checks outlined in the CableLabs MULPI specifications then the RCC with the most channels will be the one selected. If there are multiple valid RCCs of equal size then the RCC with the least amount of cable modems will be selected.

Channel Assignment

The CMTS assigns a receive channel configuration encoding to a DOCSIS 3.0-certified cable modem operating in a Multiple Receive Channel (MRC) mode during cable modem registration.

With the implementation of this feature, the DOCSIS 3.0-certified cable modem reports its receiving capabilities and characteristics using the receive channel profile type, length, value (TLV) list in the registration request message. Based on this report, the CMTS assigns an RCC encoding that is compatible with the reported RCP.

Cable modems operating in MRC mode are assigned an RCC encoding associated with an RCP. RCC encodings may be derived from RCC templates or from a wideband-cable interface configuration.

Downstream Traffic Forwarding

DOCSIS 3.0 introduces the concept of assigning downstream service flows of cable modems, which are operating in an MRC mode, to downstream (DS) channels or bonding groups. Forwarding interfaces assigned to service flows (SFs) can be either DS channel interfaces (integrated cable interfaces) or downstream bonding groups (wideband interfaces).

Note Valid interfaces that are available for SF assignment must be a subset of the cable modem's assigned RCC encoding.

Service Flow Priority in Downstream Extended Header

The purpose of the feature is to be able to reflect the traffic priority of downstream packets into the DOCSIS extended header. The priority is derived from the service flow that the packet is mapped to. Priority refers to the service flow priority specified in the CM configuration file, or the Cisco CMTS service class configuration.

The service flow priority can be set using cable modem configuration file, or dynamic configuration.

By default, this feature is disabled on Cisco cBR-8 router, user can use **cable service flow priority** command to enable this feature.

How to Configure RCP and RCC Encoding

The following tasks describe how to configure a receive channel profile and configuration encoding for a receive channel profile:

Configuring the RCP ID

You must configure the RCP IDs with the cable modem capabilities that are not defined in the CMTS. This is done to supplement the standard MULPI RCP IDs already created by the CMTS.

Before you begin

Restrictions

The configurations are subject to RCC Templates and RCP Interactions as follows:

- RCC templates can only be created for an RCP that is already defined on the system. By default the system will contain the RCPs that are specified in the MULPI spec.
- When defining RCC templates for a particular RCP, error checking will be done to ensure that the information being configured in the RCC template does not violate the corresponding RCP information. For example, if the RCP information indicates that there are 2 receive modules then the RCC template configuration will not allow the user to configure more than 2 modules.
- Once an RCP is included in an RCC template users will not be allowed to modify the RCP. Only an RCP which is not being used by any RCC template can be modified

- A valid RCP that can be applied to an rcc-template must contain the following;
  - center-frequency-spacing
  - At least one module which defines the minimum and maximum center frequency range.
  - Rules of inheritance.
  - rcc-template inherit definition from the associated user-defined RCP, such as center-frequency-spacing.
  - rcc-template channel frequencies must fall within the range of the minimum and maximum center frequency per the corresponding RCP module.
  - common-module definition is applicable to the rcc-template module referenced with the same index.
  - rcc-template module channel frequencies overrides the same channel from the corresponding common-module.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

Step 3	**cable rcp-id** *rcp-id*
	Example:
	`Router(config)#cable rcp-id 00 10 00 01 08`
	`Router(config-rcp)#`
		Defines the RCC template.
		• *rcp-id* - Specifies an RCP ID in Hex.
		This command changes the input mode to the RCC configuration mode.

Step 4	**name** *word* **Example:** `Router(config-rcp)# name rcp-id_1`	**name** —Assigns a name ro the RCP ID • *word*—Use a string to name the RCP ID. **Note** Do not include space between words in the name
Step 5	**center-frequency-spacing** *frequency* **Example:** `Router(config-rcp)#center-frequency-spacing 6`	Assigns a center frequency space to the RCP ID. The valid values are 6 and 8.

Step 6	**module** *module index* **minimum-center-frequency** *Hz* **maximum-center-frequency** *Hz*
	Example:
	`Router(config-rcp)# module 1`
	`minimum-center-frequency 120000000`
	`maximum-center-frequency 800000000`
		Configures a receive module configuration for the selected RCP.
		• *module index* - Specifies the module number for the receivemodule. The valid range is 1 to 12.
		• **minimum-center-frequency** - Specifies the minimum center frequency for the channels of the receivemodule channel.

	Command or Action	Purpose
		• *Hz*- Specifies the center frequency value in Hz. The valid range is from 111000000 to 999000000. • **maximum-center-frequency** - Specifies the maximum center frequency for the channels of the receive module channel.

Step 7	**module** *module index* **number-of-adjacent-channels** *Integrer*
	Example:
	`Router(config-rcp)#module 2`
	`number-of-adjacent-channels 10`
	`Router(config-rcp)#`
		Specifies the frequency band for the receive module. The valid values are 1-255.

Step 8	**module** *module index* **connected-module** *module index* **Example:** `Router(config-rcp)# module 1 connected-module 0`	Specifies a receive channel configuration for the selected RCP. • **connected-receive-module**— (Optional) Specifies a nested receive module in the RCC template. Generally, only one receive module is configured for an RCC template. • *module index*—Specifies the module number for the receive module. The valid range is 1 to 12.
Step 9	**number-of-channels** *Number of channel* **Example:** `Router (config-rcp)#number-of-channels 8`	Specifies the number of receive channels in the RCP ID.
Step 10	**primary-capable-channels** *Number of channel* **Example:** `Router(config-rcp)# primary-capable-channels 1`	Specifies the number of receive channels that are defined as primary capable channels.

What to do next

Verify RCP ID configurations using the **show cable rcps** command.

```
Router# show cable rcps
RCP ID  : 00 10 00 01 08
  Name  : rcp-id 1
  Center Frequency Spacing      : 6
  Max number of Channels        : 8
  Primary Capable Channel       : 1
  Number of Modules             : 2
   Module[1]:
     Number of Adjacent Channels: 10
     Minimum Center Frequency-Hz: 111000000
     Maximum Center Frequency-Hz: 999000000
   Module[2]:
     Number of Adjacent Channels: 10
```

```
     Minimum Center Frequency-Hz: 120000000
     Maximum Center Frequency-Hz: 800000000

RCP ID  : 00 10 00 00 02
  Name  : rcp-id 2
  Center Frequency Spacing      : 6
  Max number of Channels        : 2
  Primary Capable Channel       : 1
  Number of Modules             : 1
   Module[1]:
     Number of Adjacent Channels: 10
Minimum Center Frequency-Hz: 111000000
     Maximum Center Frequency-Hz: 867000000
     Connected Module           : 64
```

Configuring the RCC Templates

You must configure an RCC template with a unique RCP ID for a particular CMTS. A valid RCC template consists of a configured RCP ID, RMs, and RCs. There is dependency between the RCC templates and the RCP since information present in the RCP configuration is also present in RCC templates.

Each RCC encoding contains all operational DS channels with their channel parameters, including the frequency match RC attribute specified in the RCC template. An RCC template specifies the intended receive channel assignment in the available DS spectrum.

Note If an RCC template is removed from a MAC domain through configuration, the CMTS removes all RCC encodings derived from the RCC template, and all cable modems assigned to the RCC encoding are marked offline.

Before you begin

At least one RC must be configured as a primary Receive Channel (RC).

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

Step 3	**cable rcc-templates frequency-based** *id*
	Example:
	`Router(config)#cable rcc-templates frequency-based 1`
	`Router(config-rcc-freq-based)#`
		id—Specifies an RCC template. The valid range is 1-64.

	Command or Action	Purpose
Step 4	**rcp-id** *id* **Example:** `Router(config-rcc-freq-based)#rcp-id 00 10 00 01 08`	*id*—Specifies an RCP ID for the RCC template. The valid range is 00 00 00 00 00 to FF FF FF FF. By default, the RCP ID is set to 00 00 00 00 00.
Step 5	**common-module** *module-index* **channel** *grouplist* **start-frequency** *Hz* **Example:** `Router(config-rcc-freq-based)# common-module 1 channels 0-6 start-frequency 555000000`	Specifies module configurations that are common for a selected set of channels assigned to the selected RCP ID. • *Module-index*—Specifies the index value for the receive module. The valid range is 1 to 12. • **channels**—Specifies the list of channels to which the common configurations apply. • *grouplist*—Specifies the list of channels to which a specific list of configurations apply. The range of values are 1-64. • **start-frequency** —Specifies the start frequency value in Hz. • *Hz*—Specifies the frequency value for the start frequency for the common module. Thevalidrangeisfrom 111000000 to 999000000.
Step 6	**rcc-template** *Id* **Example:** `Router(config-rcc-freq-based)# rcc-template 1`	Specifies an RCC template ID to configure the selected RCC template. • *Id*—Specifies the ID of the RCC template. The valid range is from 1-8.
Step 7	**cm-attribute-mask** *value* **Example:** `Router (config-rcc-freq-based-tmplt)# cm-attribute-mask 1`	(Optional) Configured to be used to match against the cm attribute mask define in CM 's configuration file. • *value*—The valid range is 00 00 00 00 00 to FF FF FF FF.
Step 8	**module***module-index* **channel** *grouplist* **start-frequency** *Hz*. **Example:** `Router(config-rcc-freq-based)# common-module 1 channels 0-6 start-frequency 555000000`	Specifies module configurations that are common for a selected set of channels assigned to the selected RCP ID. • *Module-index*—Specifies the index value for the receive module. The valid range is 1 to 12. • **channels**—Specifies the list of channels to which the common configurations apply. • *grouplist*—Specifies the list of channels to which a specific list of configurations apply. The range of values are 1-64. • **start-frequency** —Specifies the start frequency value in Hz.

	Command or Action	Purpose
		• *Hz*—Specifies the frequency value for the start frequency for the common module. The valid range is from 111000000 to 999000000. Repeat Step 3 and Step 7 to configure other frequency based RCC templates.

What to do next

The following configuration examples show the cable rcc-template configuration:

```
cable rcc-templates frequency-based 2
  rcp-id 00 10 00 01 08
  common-module 1 channels 1-4 start-frequency 381000000
  rcc-template 1
  module 1 channels 5-8 start-frequency 501000000
  rcc-template 2
  module 1 channels 5-8 start-frequency 669000000
  rcc-template 3

cable rcc-templates frequency-based 1
  rcp-id 00 10 00 01 08
  rcc-template 1
  cm-attribute-mask 2
  module 1 channels 1-4 start-frequency 381000000
  module 2 channels 5-8 start-frequency 501000000
  rcc-template 2
  module 1 channels 1-4 start-frequency 381000000
  module 2 channels 5-8 start-frequency 669000000
  rcc-template 3
  module 1 channels 1-4 start-frequency 381000000
```

After defining an RCC template, you must assign the template to a cable interface.

Assigning an RCC Template to a MAC Domain (Cable Interface)

The CMTS derives an RCC or RCCs from the RCC template for each MAC Domain Downstream Service Group (MD-DS-SG).

The following information is required for RCC assignment to cable modems:

- RCC templates assigned to the MAC domain.
- DS channel physical parameters including frequency and connected-receive-module index .
- DS channel primary capable indicator.
- DS channel membership to the MD-DS-SG.
- Cable modem membership to the MD-DS-SG.

This section describes how to assign an RCC template to a MAC Domain.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** *slot*/*subslot*/*port* **Example:** `Router(config)# interface cable 1/0/0`	Enters MAC domain configuration mode. • *slot*—Specifies the chassis slot number of the interface line card. • *subslot*—Specifies the secondary slot number of the interface line card. Valid subslot is 0. • *MD index*—Specifies the MAC Domain index number. Valid values are 0-15.
Step 4	**cable rcc-template frequency-based** *Id* **Example:** `Router(config-if)# cable rcc-template frequency-based 1`	Assigns the RCC template to the specified cable interface. • *Id*—Specifies the template you want to assign to the cable interface. The valid range is from 1 to 64.

What to do next

Verify RCC template binding to MD.

The following example shows the RCC template binding using the **show cable mac-domain rcc**

```
Router#show cable mac-domain c1/0/0 rcc

RCC-ID   RCP               RCs MD-DS-SG CMs   WB/RCC-TMPL
1        00 00 00 00 00    4   0        2     WB (Wi1/0/0:0)
2        00 00 00 00 00    4   0        2     WB (Wi1/0/0:1)
3        00 00 00 00 00    4   0        0     WB (Wi1/0/1:2)
4        00 00 00 00 00    4   0        0     WB (Wi1/0/2:3)
8        00 10 00 01 08    8   5        0     RCC-TMPL (1:1)
9        00 10 00 01 08    8   5        0     RCC-TMPL (1:2)
10       00 10 00 01 08    4   5        0     RCC-TMPL (1:3)
14       00 10 00 01 08    8   5        0     RCC-TMPL (2:1)
15       00 10 00 01 08    8   5        0     RCC-TMPL (2:2)
16       00 10 00 01 08    4   5        0     RCC-TMPL (2:3)
```

The following example shows the RCC template binding using the **show cable mac-domain rcc** *id* command.

```
Router#show cable mac-domain c1/0/0 rcc 8
```

```
RCC ID                  : 8
RCP                     : 00 10 00 01 08
Created Via             : rcc-template - 1:1
CM attribute mask       : 0x2
Receive Channels        : 8
  Receive Channel       : 1
    Center Frequency    : 381000000
    Primary Capability  : YES
    Receive Module Conn : 1
  Receive Channel       : 2
    Center Frequency    : 387000000
    Primary Capability  : NO
    Receive Module Conn : 1
  Receive Channel       : 3
    Center Frequency    : 393000000
    Primary Capability  : NO
    Receive Module Conn : 1
  Receive Channel       : 4
    Center Frequency    : 399000000
    Primary Capability  : NO
    Receive Module Conn : 1
  Receive Channel       : 5
    Center Frequency    : 501000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 6
    Center Frequency    : 507000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 7
    Center Frequency    : 513000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 8
    Center Frequency    : 519000000
    Primary Capability  : NO
    Receive Module Conn : 2
Receive Modules         : 2
  Receive Module        : 1
    First Frequency     : 381000000
  Receive Module        : 2
    First Frequency     : 501000000


Router#show cable mac-domain c9/0/2 rcc 9

RCC ID                  : 9
RCP                     : 00 10 00 01 08
Created Via             : rcc-template - 1:2
CM attribute mask       : 0x0
Receive Channels        : 8
  Receive Channel       : 1
    Center Frequency    : 381000000
    Primary Capability  : YES
    Receive Module Conn : 1
  Receive Channel       : 2
    Center Frequency    : 387000000
    Primary Capability  : NO
    Receive Module Conn : 1
  Receive Channel       : 3
    Center Frequency    : 393000000
    Primary Capability  : NO
    Receive Module Conn : 1
  Receive Channel       : 4
```

```
    Center Frequency    : 399000000
    Primary Capability  : NO
    Receive Module Conn : 1
  Receive Channel       : 5
    Center Frequency    : 669000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 6
    Center Frequency    : 675000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 7
    Center Frequency    : 681000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 8
    Center Frequency    : 687000000
    Primary Capability  : NO
    Receive Module Conn : 2
Receive Modules         : 2
  Receive Module        : 1
    First Frequency     : 381000000
  Receive Module        : 2
    First Frequency     : 669000000

Router#show cable mac-domain c1/0/0 rcc 10

RCC ID                  : 10
RCP                     : 00 10 00 01 08
Created Via             : rcc-template - 1:3
CM attribute mask       : 0x0
Receive Channels        : 4
  Receive Channel       : 1
    Center Frequency    : 381000000
    Primary Capability  : YES
    Receive Module Conn : 2
  Receive Channel       : 2
    Center Frequency    : 387000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 3
    Center Frequency    : 393000000
    Primary Capability  : NO
    Receive Module Conn : 2
  Receive Channel       : 4
    Center Frequency    : 399000000
    Primary Capability  : NO
    Receive Module Conn : 2
Receive Modules         : 1
  Receive Module        : 2
    First Frequency     : 381000000
```

Verifying the RCC Configuration

To verify the runtime RCCs on a cable interface, use the **show cable mac-domain rcc** command.

```
Router#show cable mac-domain c1/0/0 rcc

RCC-ID   RCP                RCs MD-DS-SG CMs   WB/RCC-TMPL
1        00 00 00 00 00     4   0        2     WB (Wi1/0/0:0)
```

```
2         00 00 00 00 00       4    0         2      WB (Wi1/0/0:1)
3         00 00 00 00 00       4    0         0      WB (Wi1/0/1:2)
4         00 00 00 00 00       4    0         0      WB (Wi1/0/2:3)
8         00 10 00 01 08       8    5         0      RCC-TMPL (1:1)
9         00 10 00 01 08       8    5         0      RCC-TMPL (1:2)
10        00 10 00 01 08       4    5         0      RCC-TMPL (1:3)
14        00 10 00 01 08       8    5         0      RCC-TMPL (2:1)
15        00 10 00 01 08       8    5         0      RCC-TMPL (2:2)
16        00 10 00 01 08       4    5         0      RCC-TMPL (2:3)
```

Note A zero (0) value in the RCP or MD-DS-SG field indicates that the RCC encoding is configured directly through a wideband interface configuration and not through any RCC template.

How to Configure Attribute Masks

DOCSIS 3.0 introduces the concept of assigning service flows to channels or bonding groups based on binary attributes. The attribute masks configured on a cable, modular, integrated or wideband interface are called provisioned attribute masks.

The two types of attributes are as follows:

- Specification-defined attributes—Contain default values based on the characteristics of the channel or bonding group.
- Operator-defined attributes—Default to zero.

The operator can configure a provisioned attribute mask for each channel and provisioned bonding group to assign values to the operator-defined binary attributes. The operator can also assign new values to override the default values of the specification-defined attributes.

The operator can configure a required attribute mask and a forbidden attribute mask for a service flow in the cable modem configuration file. These required and forbidden attribute masks are optionally provided on the DOCSIS 3.0 service flows and are matched with the provisioned attribute masks of the interfaces.

Each service flow is optionally configured with the following TLV parameters:

- Service flow required attribute mask—To configure this, assign a service flow to a channel that has a 1-bit in all positions of its provisioned attribute mask corresponding to the 1-bit in the service flow required attribute mask.
- Service flow forbidden attribute mask—To configure this, assign a service flow to a channel that has a 0-bit in all positions of its provisioned attribute mask corresponding to the 1-bit in the service flow forbidden attribute mask.

Additionally, in a cable modem-initiated dynamic service request, the cable modem can include a required attribute mask and a forbidden attribute mask for a service flow. The CMTS assigns service flows to channels or bonding groups so that all required attributes are present and no forbidden attributes are present in the cable modem configuration file.

The table below lists the supported binary attributes for channels and bonding groups.

Table 20: Binary Attributes

Bit Position	Definition
Bit 0	Bonded—This bit is zero for all individual channel interfaces and one for all bonding groups.
Bit 1	Low latency—This bit is set when the interface can provide relatively low latency service. This bit is set to zero for all channels, and left up to the operator to define.
Bit 2	High availability—This bit is set to zero for all channels, and left up to the operator to define.
Bit 3:15	Reserved—Set to zero.
Bit 16:31	Operator defined—Set to zero by default.

You can configure provisioned attribute masks for cable, integrated cable, wideband cable, and modular cable interfaces.

Prerequisites

- To assign an interface to a wideband cable modem's service flow, the interface must be a subset of the cable modem's RCC.
- To assign a service flow to an integrated cable (IC) channel, the corresponding integrated cable interface must be configured and operational.

Restrictions

- The service flow from a narrowband cable modem is always assigned to the primary interface of the cable modem. No attribute checking is performed in this case.

This section describes the following:

Configuring Provisioned Attributes for an Integrated Cable Interface

The default provisioned attribute is zero for an integrated cable interface.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface integrated-cable** {*slot/port* | *slot/subslot/port*}*:rf-channel* **Example:**	Specifies the cable interface line card on a Cisco CMTS router: • *slot*—Chassis slot number of the cable interface line card.

	Command or Action	Purpose
	`Router(config)# interface integrated-cable 1/0/0:0`	• *subslot*—subslot number of the cable interface line card. Valid subslot is always 0. • *port*—Downstream port number. • *rf-channel*—RF channel number with a range of 0 to 3.
Step 4	**cable attribute-mask** *mask* **Example:** `Router(config-if)# cable attribute-mask 800000ff`	Specifies the mask for the interface.

Configuring Provisioned Attributes for a Wideband Cable Interface

The default provisioned attribute is 0x80000000 for a wideband cable interface, and the zero bit is automatically added to the wideband cable interface whenever an attribute is configured for that interface.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface wideband-cable** {*slot/port* | *slot/subslot/port*}:*wideband-channel* **Example:** `Router(config)# interface wideband-cable 1/0/1:4`	Specifies the wideband cable interface and enters interface configuration mode:
Step 4	**cable downstream attribute-mask** *mask* **Example:** `Router(config-if)# cable downstream attribute-mask 800000ff`	Specifies the mask for the interface.

Verifying the Attribute-Based Service Flow Assignments

To verify the attribute-based assignment of service flows on a cable interface, use the **show interface cable service-flow** or **show interface wideband-cable service-flow** command as shown in the following example:

```
Router# show interface cable 3/0 service-flow
```

```
Sfid  Sid   Mac Address     QoS  Param Index Type  Dir  Curr  Active  DS-ForwIf/
                           Prov Adm   Act             State Time    US-BG/CH
17    4     001c.ea37.9aac  3    3     3     P     US   act   13h21m  CH 3
18    N/A   001c.ea37.9aac  4    4     4     P     DS   act   13h21m  Wi3/0:0
21    6     001c.ea37.9b5a  3    3     3     P     US   act   13h21m  CH 4
22    N/A   001c.ea37.9b5a  4    4     4     P     DS   act   13h21m  Wi3/0:0
23    7     0016.925e.654c  3    3     3     P     US   act   13h21m  CH 3
24    N/A   0016.925e.654c  4    4     4     P     DS   act   13h21m  In3/0:0

Router# show interface wideband-cable 5/1:0 service-flow
Sfid  Sid   Mac Address     QoS Param Index Type  Dir Curr   Active  DS-ForwIf/
                           Prov  Adm  Act           State  Time    US-BG/CH
3     8193  ffff.ffff.ffff   3     3    3   S(s)  DS  act    2h06m   Wi5/1:0
```

The table below shows descriptions for the fields displayed by this command:

Table 21: show interface cable service-flow Field Descriptions

Field	Description
Sfid	Identifies the service flow identification number. **Note** Primary service flow IDs are displayed even for offline cable modems because they are needed for modem re-registration.
Sid	Identifies the service identification number (upstream service flows only).
Mac Address	Identifies the MAC address for the cable modem.
QoS Parameter Index Prov	Identifies the QoS parameter index for the provisioned state of this flow.
QoS Parameter Index Adm	Identifies the QoS parameter index for the Admitted state of this flow.
QoS Parameter Index Act	Identifies the QoS parameter index for the Active state of this flow.
Type	Indicates if the service flow is the primary flow or a secondary service flow. Secondary service flows are identified by an "S" (created statically at the time of registration, using the DOCSIS configuration file) or "D" (created dynamically by the exchange of dynamic service messages between the cable modem and CMTS).
Dir	Indicates if this service flow is DS or US.
Curr State	Indicates the current run-time state of the service flow.
Active Time	Indicates the length of time this service flow has been active.
DS-ForwIf/US-BG/CH BG/DS	Indicates the bonding group ID or the downstream RFID of the forwarding interface assigned to the downstream service flow.

How to Enable Service Flow Priority in Downstream Extender Header

The following tasks describe how to enable service flow priority in downstream extender header:

Enabling Service Flow Priority in Downstream Extender Header

This section describes how to enable service flow priority in downstream extender header on the Cisco cBR-8 routers:

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable service flow priority** **Example:** `Router(config)# cable service flow priority`	Enables the service flow priority in downstream extender header.

Verifying the Enablement of the Service Flow Priority in Downstream Extended Header

To verify the enablement of the service flow priority in downstream extended header, use the **show running-config | in service flow** or **show cable modem** [*ip-address* | *mac-address*] **verbose** command as shown in the following example:

```
Router# show running-config | in service flow
cable service flow priority

Router# show cable modem 100.1.2.110 verbose

MAC Address                     : 0025.2e2d.74f8
IP Address                      : 100.1.2.110
IPv6 Address                    : 2001:420:3800:909:7964:98F3:7760:ED2
Dual IP                         : Y
Prim Sid                        : 1
Host Interface                  : C3/0/0/U0
MD-DS-SG / MD-US-SG             : N/A / N/A
MD-CM-SG                        : 0x900000
Primary Downstream              : In3/0/0:32 (RfId : 12320, SC-QAM)
Wideband Capable                : Y
```

```
DS Tuner Capability                : 8
RCP Index                          : 6
RCP ID                             : 00 00 00 00 00
Downstream Channel DCID RF Channel : 191   3/0/0:32 (SC-QAM)
UDC Enabled                        : N
US Frequency Range Capability      : Standard (5-42 MHz)
Extended Upstream Transmit Power   : 0dB
Multi-Transmit Channel Mode        : N
Upstream Channel                   : US0
Ranging Status                     : sta
Upstream SNR (dB)                  : 39.8
Upstream Data SNR (dB)             : 36.12
Received Power (dBmV)              : -1.00
Timing Offset             (97.6 ns): 1799
Initial Timing Offset              : 1799
Rng Timing Adj Moving Avg(0.381 ns): 0
Rng Timing Adj Lt Moving Avg       : 0
Rng Timing Adj Minimum             : 0
Rng Timing Adj Maximum             : 0
Pre-EQ Good                        : 0
Pre-EQ Scaled                      : 0
Pre-EQ Impulse                     : 0
Pre-EQ Direct Loads                : 0
Good Codewords rx                  : 8468
Corrected Codewords rx             : 0
Uncorrectable Codewords rx         : 0
Phy Operating Mode                 : atdma
sysDescr                           :
Downstream Power                   : 0.00 dBmV (SNR = ----- dB)
MAC Version                        : DOC3.0
QoS Provisioned Mode               : DOC1.1
Enable DOCSIS2.0 Mode              : Y
Service Flow Priority              : N
Modem Status                       : {Modem= online, Security=disabled}
Capabilities                       : {Frag=Y, Concat=Y, PHS=Y}
Security Capabilities              : {Priv=, EAE=N, Key_len=}
L2VPN Capabilities                 : {L2VPN=N, eSAFE=N}
L2VPN type                         : {CLI=N, DOCSIS=N}
Sid/Said Limit                     : {Max US Sids=16, Max DS Saids=15}
Optional Filtering Support         : {802.1P=N, 802.1Q=N, DUT=N}
Transmit Equalizer Support         : {Taps/Symbol= 1, Num of Taps= 24}
CM Capability Reject              : {15,22,23,24,25,26,27,28,29,35,36,38}
Flaps                              : 3(Oct 8  16:22:23)
Errors                             : 0 CRCs, 0 HCSes
Stn Mtn Failures                   : 0 aborts, 2 exhausted
Total US Flows                     : 1(1 active)
Total DS Flows                     : 1(1 active)
Total US Data                      : 294 packets, 25903 bytes
Total US Throughput                : 143 bits/sec, 0 packets/sec
Total DS Data                      : 91 packets, 10374 bytes
Total DS Throughput                : 0 bits/sec, 0 packets/sec
LB group ID assigned               : 1
LB group ID in config file         : N/A
LB policy ID                       : 0
LB policy ID in config file        : 0
LB priority                        : 0
Tag                                : d30
Required DS Attribute Mask         : 0x0
Forbidden DS Attribute Mask        : 0x0
Required US Attribute Mask         : 0x0
Forbidden US Attribute Mask        : 0x0
Service Type ID                    :
Service Type ID in config file     :
Active Classifiers                 : 0 (Max = NO LIMIT)
```

```
CM Upstream Filter Group           : 0
CM Downstream Filter Group         : 0
CPE Upstream Filter Group          : 0
CPE Downstream Filter Group        : 0
DSA/DSX messages                   : permit all
Voice Enabled                      : NO
DS Change Times                    : 0
Boolean Services                   : 0
CM Energy Management Capable       : N
CM Enable Energy Management        : N
CM Enter Energy Management         : NO
Battery Mode                       : N
Battery Mode Status                :
Number of Multicast DSIDs Support  : 16
MDF Capability Mode                : 2
IGMP/MLD Version                   : MLDv2
FCType10 Forwarding Support        : Y
Features Bitmask                   : 0x0
Total Time Online                  : 6h00m   (6h00m    since last counter reset)
CM Initialization Reason           : POWER_ON
```

Enabling Verbose Reporting for Receive Channel Profiles

A receive channel profile is an encoding that represents the receive channels and receive modules of a cable modem. A cable modem communicates to the CMTS one or more RCP encodings within its registration request using either verbose description, which contains complete subtype encodings defined in DOCSIS 3.0, or simple description, which only contains RCP identifiers.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/port* | *slot/subslot/port*} **Example:** `Router(config)# interface cable7/0/0`	Specifies the cable interface line card on a Cisco CMTS router: • *slot*—Chassis slot number of the cable interface line card. • *subslot*—subslot number of the cable interface line card. Valid subslot is 0. • *port*—Downstream port number.
Step 4	**cable rcp-control verbose** **Example:** `Router(config-if)# cable rcp-control verbose`	Enables RCP reporting with verbose description.

Configuration Example for an RCC Template

The following sample shows an RCP ID configuration:

```
...
!
cable rcp-id 00 10 00 01 08
  center-frequency-spacing 6
  module 1 minimum-center-frequency 120000000 maximum-center-frequency 800000000 module 1
number-of-adjacent-channels 10
  module 2 minimum-center-frequency 120000000 maximum-center-frequency 800000000 module 2
 number-of-adjacent-channels 10
  number-of-channels 8
  primary-capable-channels 1
!
```

The following sample shows an RCC template configuration:

```
...
!
cable rcc-templates frequency-based 1
  rcp-id 00 10 00 01 08
  rcc-template 1
  cm-attribute-mask 2
  module 1 channels 1-4 start-frequency 381000000
  module 2 channels 5-8 start-frequency 501000000
  rcc-template 2
  module 1 channels 1-4 start-frequency 381000000
  module 2 channels 5-8 start-frequency 669000000
  rcc-template 3
  module 1 channels 1-4 start-frequency 381000000
!
```

The following sample shows an RCC template configuration using the **common-module** option:

```
...
!
cable rcc-templates frequency-based 2
   rcp-id 00 10 00 01 08
   common-module 1 channels 1-4 start-frequency 381000000
   rcc-template 1
   module 1 channels 5-8 start-frequency 501000000
   rcc-template 2
   module 1 channels 5-8 start-frequency 669000000
   rcc-template 3
!
```

The following sample shows the assignment of an RCC template to MAC Domain:

```
...
!
configure terminal
interface c1/0/0
 cable rcc-templates frequency-based 1
 end

...
```

Additional References

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

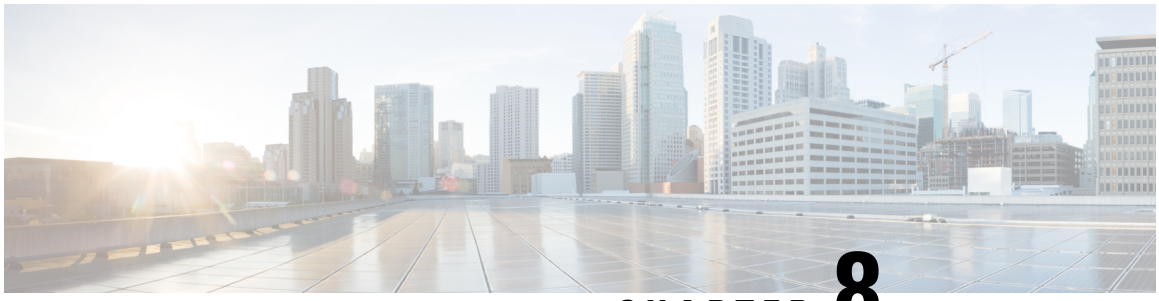
Feature Information for DOCSIS 3.0 Downstream Bonding

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 22: Feature Information for Downstream Interface Configuration

Feature Name	Releases	Feature Information
DOCSIS 3.0 Downstream Bonding	Cisco IOS XE Everest 16.6.1	This feature was integrated on the Cisco cBR Series Converged Broadband Router.
Service Flow Priority in Downstream Extended Header	Cisco IOS XE Everest 16.6.1	This feature was integrated on the Cisco cBR Series Converged Broadband Router.



CHAPTER 8

DOCSIS 2.0 A-TDMA Modulation Profiles

This document describes the DOCSIS 2.0 A-TDMA services feature, which provides support for DOCSIS 2.1 Advanced Time Division Multiple Access (A-TDMA) upstream modulation profiles on the router. This feature supplements the existing support for DOCSIS 1.0 and DOCSIS 1.1 Time Division Multiple Access (TDMA) modulation profiles.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 23: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for DOCSIS 2.0 A-TDMA Modulation Profiles

- The cable physical plant must be capable of supporting the higher-bandwidth DOCSIS 2.0 A-TDMA modulation profiles.
- Cable modems must be DOCSIS-compliant. If cable modems go offline, or appear to be online but do not pass traffic when in the mixed TDMA/A-TDMA mode, upgrade the modem software to a DOCSIS-compliant version.
- The following are required to support the DOCSIS 2.0 A-TDMA features:
    - Cable modems must be DOCSIS 2.0 capable.

  - The DOCSIS configuration file for a DOCSIS 2.0 cable modem must either omit the DOCSIS 2.0 Enable field (TLV 39), or it must set TLV 39 to 1 (enable). If you set TLV 39 to 0 (disable), a DOCSIS 2.0 CM uses the TDMA mode.
  - The upstream must be configured for either A-TDMA-only or mixed TDMA/A-TDMA mode. To use the 6.4 MHz channel width, the upstream must be configured for A-TDMA-only mode.
- Complete a basic configuration of the router; this includes, at a minimum, the following tasks:
  - Configure a host name and password for the router.
  - Configure the router to support Internet Protocol (IP) operations.
  - Install and configure at least one WAN adapter to provide backbone connectivity.
- Determine a channel plan for the router and all of its cable interfaces.
- Verify that your headend site includes all necessary servers to support DOCSIS and Internet connectivity, including DHCP, ToD, and TFTP servers.
- The system clock on the router should be set to a current date and time to ensure that system logs have the proper timestamp and to ensure that the BPI+ subsystem uses the correct timestamp for verifying cable modem digital certificates.

Restrictions for DOCSIS 2.0 A-TDMA Services

- Does not support virtual channels, as described in DOCSIS 2.0 specification.
- Does not support Synchronous Code Division Multiple Access (S-CDMA) channels.
- Changing the DOCSIS mode of an upstream takes all cable modems on that upstream offline, which forces the cable modems to reregister, so that the CMTS can determine the capabilities of the cable modems on the new channels.

Information About DOCSIS 2.0 A-TDMA Services

DOCSIS 2.0 A-TDMA services improve the maximum upstream bandwidth on existing DOCSIS 1.0 and DOCSIS 1.1 cable networks by providing a number of advanced PHY capabilities that have been specified by the new DOCSIS 2.0 specifications.

DOCSIS 2.0 A-TDMA services incorporate the following advantages and improvements of DOCSIS 2.0 networks:

- Builds on existing DOCSIS cable networks by providing full compatibility with existing DOCSIS 1.0 and DOCSIS 1.1 cable modems. (The registration response (REG-RSP) message contains the DOCSIS version number to identify each cable modem’s capabilities.)
- Upstreams can be configured for three different modes to support different mixes of cable modems:
  - An upstream can be configured for TDMA mode to support only DOCSIS 1.0 and DOCSIS 1.1 cable modems.
  - An upstream can be configured for A-TDMA mode to support only DOCSIS 2.0 cable modems.
  - An upstream can be configured for a mixed, TDMA/A-TDMA mode, to support both DOCSIS 1.0/DOCSIS 1.1 and DOCSIS 2.0 cable modems on the same upstream.

Note DOCSIS 2.0 A-TDMA cable modems will not register on a TDMA upstream if an A-TDMA or mixed upstream exists in the same MAC domain, unless the CMTS explicitly switches the cable modem to another upstream using an Upstream Channel Change (UCC) message. DOCSIS 1.0 and DOCSIS 1.1 cable modems cannot register on an A-TDMA-only upstream.

- A-TDMA mode defines new interval usage codes (IUC) of A-TDMA short data grants, long data grants, and Unsolicited Grant Service (UGS) grants (IUC 9, 10, and 11) to supplement the existing DOCSIS 1.1 IUC types.
- Increases the maximum channel capacity for A-TDMA upstreams to 30 Mbps per 6 MHz channel.
- A-TDMA and mixed modes of operation provide higher bandwidth on the upstream using new 32-QAM and 64-QAM modulation profiles, while retaining support for existing 16-QAM and QPSK modulation profiles. In addition, an 8-QAM modulation profile is supported for special applications.
- Supports a minislot size of 1 tick for A-TDMA operations.
- Increases channel widths to 6.4 MHz (5.12 Msymbol rate) for A-TDMA operations.
- A-TDMA and mixed modes of operation provide a more robust operating environment with increased protection against ingress noise and other signal impairments, using a number of new features:
  - Uses to a symbol (T)-spaced adaptive equalizer structure to increase the equalizer tap size to 24 taps, compared to 8 taps in DOCSIS 1.x mode. This allows operation in the presence of more severe multipath and microreflections, and can accommodate operation near band edges where group delay could be a problem.
  - Supports new QPSK0 and QPSK1 preambles, which provide improved burst acquisition by performing simultaneous acquisition of carrier and timing lock, power estimates, equalizer training, and constellation phase lock. This allows shorter preambles, reducing implementation loss.
  - Increases the forward error correction (FEC) T-byte size to 16 bytes per Reed Solomon block (T=16) with programmable interleaving.

Modes of Operation

Depending on the configuration, the DOCSIS 2.0 A-TDMA Service feature supports either DOCSIS or Euro-DOCSIS operation:

- DOCSIS cable networks are based on the ITU J.83 Annex B physical layer standard and Data-over-Cable Service Interface Specifications (DOCSIS, Annex B) specification, which use 6 MHz National Television Systems Committee (NTSC) channel plans. In this mode, the downstream uses a 6 MHz channel width in the 85 to 860 MHz frequency range, and the upstream supports multiple channel widths in the 5 to 42 MHz frequency range.
- EuroDOCSIS cable networks are based on the ITU J.112 Annex A physical layer standard and European DOCSIS (EuroDOCSIS, Annex A) specification, which use 8 MHz Phase Alternating Line (PAL) and Systeme Electronique Couleur Avec Memoire (SECAM) channel plans. In this mode, the downstream uses an 8 MHz channel width in the 85 to 860 MHz frequency range, and the upstream supports multiple channel widths in the 5 to 65 MHz frequency range.

Note The difference between DOCSIS and EuroDOCSIS is at the physical layer. To support a DOCSIS or EuroDOCSIS network requires the correct configuration of the DOCSIS 2.0 A-TDMA Service card, as well as upconverters, diplex filters, and other equipment that supports the network type.

The table below shows the maximum supported DOCSIS 1.1 data rates.

Table 24: Maximum DOCSIS 1.1 Data Rates

Upstream Channel Width	Modulation Scheme	Baud Rate Sym/sec	Maximum Raw Bit Rate Mbit/sec
3.2 MHz	16-QAM QPSK	2.56 M	10.24 5.12
1.6 MHz	16-QAM QPSK	1.28 M	5.12 2.56

The table below shows the maximum supported DOCSIS 2.0 (A-TDMA-mode) data rates.

Table 25: Maximum DOCSIS 2.0 (A-TDMA-mode) Data Rates

Upstream Channel Width	Modulation Scheme	Baud Rate Sym/sec	Maximum Raw Bit Rate Mbit/sec
6.4 MHz	64-QAM	5.12 M	30.72
	32-QAM		25.60
	16-QAM		20.48
	8-QAM		15.36
	QPSK		10.24
3.2 MHz	64-QAM	2.56 M	15.36
	32-QAM		12.80
	16-QAM		10.24
	8-QAM		7.68
	QPSK		5.12
1.6 MHz	64-QAM	1.28 M	7.68
	32-QAM		6.40
	16-QAM		5.12
	8-QAM		3.84
	QPSK		2.56

Modulation Profiles

To simplify the administration of A-TDMA and mixed TDMA/A-TDMA modulation profiles, the DOCSIS 2.0 A-TDMA Service feature provides a number of preconfigured modulation profiles that are optimized for different modulation schemes. We recommend using these preconfigured profiles.

Each mode of operation also defines a default modulation profile that is automatically used when a profile is not specifically assigned to an upstream. The default modulation profiles cannot be deleted. The table below lists the valid ranges according to cable interface and modulation type:

Table 26: Allowable Ranges for Modulation Profiles

Cable Interface	DOCSIS 1.X (TDMA)	Mixed DOCSIS 1.X/2.0	DOCSIS 2.0 (A-TDMA)
Cisco cBR-8 CCAP Line Cards	1 to 400 (default is 21)	1 to 400 (default 121)	1 to 400 (default 221)

Benefits

The DOCSIS 2.0 A-TDMA Service feature provides the following benefits to cable service providers and their partners and customers:

- Full compatibility with DOCSIS 1.0 and DOCSIS 1.1 cable modems (CMs) and cable modem termination systems (CMTS).
- Additional channel capacity in the form of more digital bits of throughput capacity in the upstream path.
- Increased protection against electronic impairments that occur in cable systems, allowing for a more robust operating environment.

How to Configure DOCSIS 2.0 A-TDMA Services

This section contains the following:

Creating Modulation Profiles

Cisco cable modem termination systems (CMTSs) can handle modulation profiles for the RF configuration of a voice and data cable modem plant. Cisco IOS® Software is designed with a default modulation profile that is optimal in most conditions. Therefore, do not change the default configuration. However, if the modulation needs are different for the customer plant, Cisco IOS Software has the ability to customize and to configure the modulation profiles to suit the customer needs.

Caution Only an expert, who understands modulation changes and Data-over-Cable Service Interface Specifications (DOCSIS), should modify these parameters. Otherwise, changes can cause disruption or the degradation of services because the commands affect the physical layer.

This section describes how to create modulation profiles for the different modes of DOCSIS operations, using the preconfigured modulation profile options.

Creating a TDMA Modulation Profile

This section describes how to create a modulation profile for the DOCSIS 1.0/DOCSIS 1.1 TDMA mode of operation, using one of the preconfigured modulation profiles.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

Step 3	**cable modulation-profile** *profile* **tdma** {**mix** | **qam-16** | **qpsk** | **robust-mix**}
	Example:
	`Router(config)# cable modulation-profile 3 tdma mix`
	`Router(config)# cable modulation-profile 4 tdma qpsk`
		Creates a preconfigured modulation profile, where the burst parameters are set to their default values for each burst type:
		Note You can also create custom modulation profiles with the **cable modulation-profile** command by configuring the values for the individual burst parameters. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer. We recommend using the preconfigured default modulation profiles for most cable plants.

Step 4	**exit** **Example:** `Router(config)# exit`	Exits global configuration mode.

Creating a Mixed Mode Modulation Profile

This section describes how to create a modulation profile for the mixed TDMA/A-TDMA mode of operation, using one of the preconfigured modulation profiles.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable modulation-profile** *profile* **mixed** {**mix-high** | **mix-low** | **mix-mid** | **mix-qam** | **qam-16** | **qpsk** | **robust-mix-high** | **robust-mix-mid** | **robust-mix-qam**}	Creates a preconfigured modulation profile, where the burst parameters are set to their default values for each burst type:

	Command or Action	Purpose

	Example:
	`Router(config)# cable modulation-profile 143 mixed mix-medium`
	`Router(config)# cable modulation-profile 144 mixed mix-high`
		Note The **robust-mix** profiles are similar to but more robust than the **mix** profiles, so that they are more able to deal with noise on the upstream.
		Note You can also create custom modulation profiles with the **cable modulation-profile** command by configuring the values for the individual burst parameters. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer. We recommend using the preconfigured default modulation profiles for most cable plants.

Step 4	**exit** **Example:** `Router(config)# exit`	Exits global configuration mode.

Creating an A-TDMA Modulation Profile

This section describes how to create a modulation profile for the DOCSIS 2.0 A-TDMA mode of operation, using one of the preconfigured modulation profiles.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

Step 3	**cable modulation-profile** *profile* **atdma** {**mix-high** | **mix-low** | **mix-mid** | **mix-qam** | **qam-8** | **qam-16** | **qam-32** | **qam-64** | **qpsk** | **robust-mix-high** | **robust-mix-low** | **robust-mix-mid**}
	Example:
	`Router(config)# cable modulation-profile 242 atdma qam-32`
	`Router(config)# cable modulation-profile 243 atdma qam-64`
	Example:
		Note For Cisco Remote PHY 220, preamble with QPSK modulation must have values—32x2^n (0, 1, 2, 3) bits.
		Preamble with 16-QAM modulation must have values—64x2^n (0, 1, 2,) bits.
		Note The **robust-mix** profiles are similar to but more robust than the **mix** profiles, so that they are more able to deal with noise on the upstream.

	Command or Action	Purpose
	cable modulation-profile 45 tdma request 0 16 0 22 qpsk scrambler 152 no-diff 64 fixed cable modulation-profile 45 tdma initial 5 34 0 48 16qam scrambler 152 no-diff 256 fixed cable modulation-profile 45 tdma station 5 34 0 48 16qam scrambler 152 no-diff 256 fixed cable modulation-profile 45 tdma short 3 76 12 22 16qam scrambler 152 no-diff 128 shortened cable modulation-profile 45 tdma long 9 232 0 22 16qam scrambler 152 no-diff 128 shortened cable modulation-profile 45 tdma initial 5 34 0 48 16qam scrambler 152 no-diff 256 fixed	**Note** You can also create custom modulation profiles with the **cable modulation-profile** command by configuring the values for the individual burst parameters. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer. We recommend using the preconfigured default modulation profiles for most cable plants. **Note** For Cisco Remote PHY 220, preamble with QPSK modulation must have values—32x2^n (0, 1, 2, 3) bits. Preamble with 16-QAM modulation must have values—64x2^n (0, 1, 2,) bits.
Step 4	**exit** **Example:** `Router(config)# exit`	Exits global configuration mode.

Configuring the DOCSIS Mode and Profile on an Upstream

This section describes how to configure an upstream for a DOCSIS mode of operation, and then to assign a particular modulation profile to that upstream.

Note By default, all upstreams are configured for ATDMA-only mode, using the default modulation profile.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**controller upstream-Cable** *slot/subslot/port* **Example:** `Router(config)# controller upstream-Cable 2/0/1`	Enters controller configuration mode for the interface.

	Command or Action	Purpose
Step 4	**us-channel** *n* **docsis-mode** {**atdma** | **tdma** | **tdma-atdma**} **Example:** `Router(config-controller)# us-channel 0 docsis-mode atdma`	Configures the upstream for the desired DOCSIS mode of operation.
Step 5	**us-channel** *n* **modulation-profile** *primary-profile-number* [*secondary-profile-number*] [*tertiary-profile-number*] **Example:** `Router(config-controller)# us-channel 0 modulation-profile 241`	Assigns up to three modulation profiles to the upstream port. **Note** The type of modulation profiles must match the DOCSIS mode configured for the upstream, using the **us-channel docsis-mode** command.
Step 6	**us-channel** *n* **equalization-coefficient** **Example:** `Router(config-controller)# us-channel 0 equalization-coefficient`	(Optional) Enables the use of a DOCSIS pre-equalization coefficient on the upstream port.
Step 7	**us-channel** *n* **ingress-noise-cancellation** *interval* **Example:** `Router(config-controller)# us-channel 0 ingress-noise-cancellation 400`	(Optional) Configures the interval, in milliseconds, for which the interface card should sample the signal on an upstream to correct any ingress noise that has appeared on that upstream.
Step 8	**us-channel** *n* **maintain-psd** **Example:** `Router(config-controller)# us-channel 0 maintain-psd`	(Optional) Requires DOCSIS 2.0 cable modems that are operating on an ATDMA-only upstream to maintain a constant power spectral density (PSD) after a modulation rate change. **Note** Repeat Step 3, on page 151 through Step 8, on page 152 for each upstream to be configured.
Step 9	**end** **Example:** `Router(config-controller)# end`	Exits controller configuration mode and returns to privileged EXEC mode.

Monitoring the DOCSIS 2.0 A-TDMA Services

This section contains the following:

Displaying Modulation Profiles

To display the modulation profiles that are currently defined on the CMTS, use the **show cable modulation-profile** command without any options:

```
Router# show cable modulation-profile

Mod Docsis  IUC     Type  Pre Diff FEC  FEC  Scrmb  Max Guard Last Scrmb Pre   Pre   RS
    -Mode               len enco T    k    seed   B   time  CW         offst Type
```

```
                                        BYTE BYTE        siz size  short
1   atdma   request 16qam 32  no    0x0  0x10 0x152  0   22    no   yes   0     qpsk1 no
1   atdma   initial 16qam 64  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk1 no
1   atdma   station 16qam 64  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk1 no
1   atdma   a-short 16qam 64  no    0x4  0x4C 0x152  7   22    yes  yes   0     qpsk1 no
1   atdma   a-long  16qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
1   atdma   a-ugs   16qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
2   atdma   request 16qam 32  no    0x0  0x10 0x152  0   22    no   yes   0     qpsk1 no
2   atdma   initial 16qam 64  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk1 no
2   atdma   station 16qam 64  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk1 no
2   atdma   a-short 16qam 64  no    0x4  0x4C 0x152  7   22    yes  yes   0     qpsk1 no
2   atdma   a-long  16qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
2   atdma   a-ugs   16qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
21  tdma    request qpsk  36  no    0x0  0x10 0x152  0   22    no   yes   0     qpsk  na
21  tdma    initial qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk  na
21  tdma    station qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk  na
21  tdma    short   qpsk  64  no    0x3  0x4C 0x152  12  22    yes  yes   0     qpsk  na
21  tdma    long    qpsk  64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk  na
121 mixed   request qpsk  36  no    0x0  0x10 0x152  0   22    no   yes   0     qpsk  na
121 mixed   initial qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk  na
121 mixed   station qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk  na
121 mixed   short   qpsk  64  no    0x3  0x4C 0x152  12  22    yes  yes   0     qpsk  na
121 mixed   long    qpsk  64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk  na
121 mixed   a-short 64qam 64  no    0x6  0x4C 0x152  6   22    yes  yes   0     qpsk1 no
121 mixed   a-long  64qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
121 mixed   a-ugs   64qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
221 atdma   request qpsk  36  no    0x0  0x10 0x152  0   22    no   yes   0     qpsk0 no
221 atdma   initial qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk0 no
221 atdma   station qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk0 no
221 atdma   a-short 64qam 64  no    0x6  0x4C 0x152  6   22    yes  yes   0     qpsk1 no
221 atdma   a-long  64qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
```

To display a specific modulation profile in detail, specify the profile number with the **show cable modulation-profile** command:

```
Router# show cable modulation-profile 221

Mod Docsis  IUC     Type  Pre Diff FEC  FEC  Scrmb  Max Guard Last Scrmb Pre   Pre   RS
    -Mode                 len enco T    k    seed   B   time  CW         offst Type
                                    BYTE BYTE        siz size  short
221 atdma   request qpsk  36  no    0x0  0x10 0x152  0   22    no   yes   0     qpsk0 no
221 atdma   initial qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk0 no
221 atdma   station qpsk  98  no    0x5  0x22 0x152  0   48    no   yes   0     qpsk0 no
221 atdma   a-short 64qam 64  no    0x6  0x4C 0x152  6   22    yes  yes   0     qpsk1 no
221 atdma   a-long  64qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
221 atdma   a-ugs   64qam 64  no    0x9  0xE8 0x152  0   22    yes  yes   0     qpsk1 no
```

Displaying Cable Modem Capabilities and Provisioning

To display the capabilities of the online cable modems and how the modems were provisioned, use the **show cable modem mac** command:

```
Router# show cable modem mac

MAC Address     MAC          Prim  Ver    QoS    Frag Concat PHS Priv DS    US
                State        Sid          Prov                        Saids Sids
1859.334d.7b4c  init(i)      145   DOC1.0 DOC1.0 no   no     no       0     0
1859.334d.fa8c  offline      146   DOC1.0 DOC1.0 no   no     no       0     0
1859.334d.fa02  offline      147   DOC1.0 DOC1.0 no   no     no       0     0
1859.334d.65b0  online(pt)   148   DOC3.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.6622  offline      149   DOC1.0 DOC1.0 no   no     no       0     0
```

```
1859.334d.7a50  init(i)      150   DOC1.0 DOC1.0 no   no     no       0     0
1859.334d.7a2e  offline      151   DOC1.0 DOC1.0 no   no     no       0     0
1859.334d.7d14  online(pt)   152   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.6636  online(pt)   153   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.7cf0  online(pt)   154   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.6742  online(pt)   155   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.7b2a  online(pt)   156   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.7e64  online(pt)   157   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.ede0  online(pt)   158   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.7b8a  online(pt)   159   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.6604  online(pt)   160   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.f93a  online(pt)   161   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.7bf0  online(pt)   162   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.596a  online(pt)   163   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.7d38  online(pt)   164   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.fc64  online(pt)   165   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.6434  online(pt)   166   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
1859.334d.f62a  online(pt)   167   DOC2.0 DOC1.1 yes  yes    yes BPI+ 15    16
!
```

To display how many cable modems of each DOCSIS type are online each upstream, use the **show cable modem mac summary** command:

```
Router# show cable modem mac summary

                              Cable Modem Summary
                              -------------------
                            Mac Version                          QoS Provision Mode
Interface        Total   DOC3.0  DOC2.0  DOC1.1  DOC1.0   Reg/Online   DOC1.1  DOC1.0
Cable3/0/1/U0    20      0       5       0       15       5            5       0
Cable3/0/1/U1    23      0       9       0       14       9            9       0
Cable3/0/1/U2    21      0       8       0       13       8            8       0
Cable3/0/1/U4    42      0       9       0       33       9            9       0
Cable3/0/1/U5    20      0       15      0       5        15           15      0
Cable3/0/1/U6    18      1       14      0       3        15           15      0
Cable3/0/2/U0    26      0       26      0       0        26           26      0
Cable3/0/2/U1    28      0       28      0       0        28           28      0
Cable3/0/2/U2    24      0       24      0       0        24           24      0
Cable3/0/2/U4    72      0       72      0       0        72           72      0
Cable3/0/3/U0    67      0       63      0       4        63           63      0
Cable3/0/3/U1    85      1       84      0       0        85           85      0
Cable3/0/3/U2    1       0       1       0       0        1            1       0
Cable3/0/4/U0    12      0       1       0       11       1            1       0
Cable3/0/4/U1    39      0       0       0       39       0            0       0
Cable3/0/4/U2    12      0       1       0       11       1            1       0
Cable3/0/4/U4    65      0       11      0       54       11           11      0
Cable3/0/4/U5    10      0       10      0       0        10           10      0
Cable3/0/4/U6    5       0       5       0       0        5            5       0
Cable3/0/5/U0    27      0       27      0       0        27           27      0
Cable3/0/5/U1    27      0       27      0       0        27           27      0
Cable3/0/5/U2    26      0       26      0       0        26           26      0
Cable3/0/5/U4    77      0       77      0       0        77           77      0
Cable3/0/6/U4    14      14      0       0       0        14           14      0
Cable3/0/6/U5    12      12      0       0       0        12           12      0
Cable3/0/6/U6    5       5       0       0       0        5            5       0
```

Configuration Examples for DOCSIS 2.0 A-TDMA services

This section contains the following:

Creating Modulation Profiles Examples

This section contains the following:

Example: DOCSIS 1.0/DOCSIS 1.1 TDMA Modulation Profiles

The following sample configurations show typical modulation profiles for the DOCSIS 1.0/DOCSIS 1.1 TDMA mode of operation:

- Profile 21 is the default profile for TDMA operations.
- Profiles 24 and 25 use the preconfigured 16-QAM and QPSK modulation profiles.
- Profile 26 is a typical QPSK modulation profile using some customized burst parameters.

```
cable modulation-profile 24 tdma qam-16
cable modulation-profile 25 tdma qpsk
cable modulation-profile 26 tdma request 0 16 0 8 qpsk scrambler 152 no-diff 68 fixed
cable modulation-profile 26 tdma initial 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed
cable modulation-profile 26 tdma station 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed
cable modulation-profile 26 tdma short 4 76 12 8 qpsk scrambler 152 no-diff 80 shortened
cable modulation-profile 26 tdma long 8 236 0 8 qpsk scrambler 152 no-diff 80 shortened
```

Example: Mixed TDMA/A-TDMA Modulation Profiles

The following sample configurations show typical modulation profiles for the DOCSIS 1.X/DOCSIS 2.0 mixed TDMA/A-TDMA mode of operation:

- Profile 121 is the default profile for mixed mode operations.
- Profiles 122 through 126 use the preconfigured mixed mode modulation profiles.
- Profile 127 is a typical mixed mode modulation profile some customized burst parameters.

```
cable modulation-profile 121 mixed request 0 16 0 8 qpsk scrambler 152 no-diff 64 fixed
cable modulation-profile 121 mixed initial 5 34 0 48 qpsk scrambler 152 no-diff 32 fixed
cable modulation-profile 121 mixed station 5 34 0 48 qpsk scrambler 152 no-diff 32 fixed
cable modulation-profile 121 mixed short 5 75 6 8 qpsk scrambler 152 no-diff 72 shortened
cable modulation-profile 121 mixed long 8 220 0 8 qpsk scrambler 152 no-diff 80 shortened
cable modulation-profile 121 mixed a-short 0 16 15 99 64qam scrambler 152 no-diff 128
shortened qpsk0 0 18
cable modulation-profile 121 mixed a-long 0 16 15 200 64qam scrambler 152 no-diff 128
shortened qpsk0 0 18

cable modulation-profile 122 mixed mix-high
cable modulation-profile 123 mixed mix-low
cable modulation-profile 124 mixed mix-medium
cable modulation-profile 125 mixed qam-16
cable modulation-profile 126 mixed qpsk

cable modulation-profile 127 mixed request 0 16 0 8 qpsk scrambler 152 no-diff 68 fixed
cable modulation-profile 127 mixed initial 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed
cable modulation-profile 127 mixed station 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed
cable modulation-profile 127 mixed short 6 76 7 8 16qam scrambler 152 no-diff 160 shortened

cable modulation-profile 127 mixed long 8 231 0 8 16qam scrambler 152 no-diff 160 shortened

cable modulation-profile 127 mixed a-short 9 76 6 8 32qam scrambler 152 no-diff 160 shortened
 qpsk1 1 2048
cable modulation-profile 127 mixed a-long 12 231 0 8 64qam scrambler 152 no-diff 132 shortened
 qpsk1 1 2048
```

Example: DOCSIS 2.0 A-TDMA Modulation Profiles

The following sample configurations show typical modulation profiles for the DOCSIS 2.0 A-TDMA mode of operation:

- Profile 221 is the default profile for A-TDMA mode operations.
- Profiles 222 through 226 use the preconfigured A-TDMA mode modulation profiles.
- Profile 227 is a typical A-TDMA mode modulation profile customized burst parameters.

```
cable modulation-profile 221 atdma request 0 16 0 8 qpsk scrambler 152 no-diff 64 fixed
qpsk0 0 18
cable modulation-profile 221 atdma initial 5 34 0 48 qpsk scrambler 152 no-diff 32 fixed
qpsk0 0 18
cable modulation-profile 221 atdma station 5 34 0 48 qpsk scrambler 152 no-diff 32 fixed
qpsk0 0 18
cable modulation-profile 221 atdma short 5 75 6 8 qpsk scrambler 152 no-diff 72 shortened
qpsk0 0 18
cable modulation-profile 221 atdma long 8 220 0 8 qpsk scrambler 152 no-diff 80 shortened
qpsk0 0 18
cable modulation-profile 221 atdma a-short 5 99 10 8 64qam scrambler 152 no-diff 128 shortened
 qpsk0 0 18
cable modulation-profile 221 atdma a-long 15 200 0 8 64qam scrambler 152 no-diff 128 shortened
 qpsk0 0 18

cable modulation-profile 222 atdma qam-8
cable modulation-profile 223 atdma qam-16
cable modulation-profile 224 atdma qam-32
cable modulation-profile 225 atdma qam-64
cable modulation-profile 226 atdma qpsk

cable modulation-profile 227 atdma request 0 16 0 8 qpsk scrambler 152 no-diff 68 fixed
qpsk0 1 2048
cable modulation-profile 227 atdma initial 0 16 0 0 qpsk no-scrambler no-diff 2 fixed qpsk1
 0 18
cable modulation-profile 227 atdma station 5 34 0 48 qpsk scrambler 152 no-diff 128 fixed
qpsk0 1 2048
cable modulation-profile 227 atdma a-short 9 76 6 8 32qam scrambler 152 no-diff 160 shortened
 qpsk1 1 2048
cable modulation-profile 227 atdma a-long 12 231 0 8 64qam scrambler 152 no-diff 132 shortened
 qpsk1 1 2048
cable modulation-profile 227 atdma a-ugs 3 231 0 8 16qam scrambler 152 no-diff 80 shortened
 qpsk1 1 2048
```

Assigning Modulation Profiles to Upstreams Examples

This section contains the following:

Example: Assigning DOCSIS 1.0/DOCSIS 1.1 TDMA Modulation Profiles

The following sample configuration shows DOCSIS 1.0/DOCSIS 1.1 TDMA modulation profiles being assigned to the upstreams. The TDMA modulation profile (profile 21) is assigned to the upstream controller 2/0/0.

```
controller Upstream-Cable 2/0/0
 us-channel 0 channel-width 1600000 1600000
 us-channel 0 docsis-mode tdma
 us-channel 0 minislot-size 4
 us-channel 0 modulation-profile 21
 no us-channel 0 shutdown
```

```
 us-channel 1 channel-width 1600000 1600000
 us-channel 1 docsis-mode tdma
 us-channel 1 minislot-size 4
 us-channel 1 modulation-profile 21
 no us-channel 1 shutdown
 us-channel 2 channel-width 1600000 1600000
 us-channel 2 docsis-mode tdma
 us-channel 2 minislot-size 4
 us-channel 2 modulation-profile 21
 no us-channel 2 shutdown
 us-channel 3 channel-width 1600000 1600000
 us-channel 3 docsis-mode tdma
 us-channel 3 minislot-size 4
 us-channel 3 modulation-profile 21
 no us-channel 3 shutdown
 !
```

Example: Assigning Mixed TDMA/A-TDMA Modulation Profiles

The following sample configuration shows mixed mode TDMA/A-TDMA modulation profiles being assigned to the upstreams. The mixed modulation profile (profile 121) is assigned to the upstream controller 2/0/15.

```
controller Upstream-Cable 2/0/15
 us-channel 0 channel-width 1600000 1600000
 us-channel 0 docsis-mode tdma-atdma
 us-channel 0 minislot-size 4
 us-channel 0 modulation-profile 121
 no us-channel 0 shutdown
 us-channel 1 channel-width 1600000 1600000
 us-channel 1 docsis-mode tdma-atdma
 us-channel 1 minislot-size 4
 us-channel 1 modulation-profile 121
 no us-channel 1 shutdown
 us-channel 2 channel-width 1600000 1600000
 us-channel 2 docsis-mode tdma-atdma
 us-channel 2 minislot-size 4
 us-channel 2 modulation-profile 121
 no us-channel 2 shutdown
 us-channel 3 channel-width 1600000 1600000
 us-channel 3 docsis-mode tdma-atdma
 us-channel 3 minislot-size 4
 us-channel 3 modulation-profile 121
 no us-channel 3 shutdown
!
```

Example: Assigning DOCSIS 2.0 A-TDMA Modulation Profiles

The following sample configuration shows DOCSIS 2.0 A-TDMA modulation profiles being assigned to the upstreams. The A-TDMA modulation profile (profile 221) is assigned to the upstream controller 2/0/10.

```
controller Upstream-Cable 2/0/10
 us-channel 0 channel-width 1600000 1600000
 us-channel 0 docsis-mode atdma
 us-channel 0 minislot-size 4
 us-channel 0 modulation-profile 221
 no us-channel 0 shutdown
 us-channel 1 channel-width 1600000 1600000
 us-channel 1 docsis-mode atdma
 us-channel 1 minislot-size 4
 us-channel 1 modulation-profile 221
 no us-channel 1 shutdown
 us-channel 2 channel-width 1600000 1600000
```

```
 us-channel 2 docsis-mode atdma
 us-channel 2 minislot-size 4
 us-channel 2 modulation-profile 221
 no us-channel 2 shutdown
 us-channel 3 channel-width 1600000 1600000
 us-channel 3 docsis-mode atdma
 us-channel 3 minislot-size 4
 us-channel 3 modulation-profile 221
 no us-channel 3 shutdown
 us-channel 4 channel-width 1600000 1600000
 us-channel 4 docsis-mode atdma
 us-channel 4 minislot-size 4
 us-channel 4 modulation-profile 221
 us-channel 4 shutdown
 us-channel 5 channel-width 1600000 1600000
 us-channel 5 docsis-mode atdma
 us-channel 5 minislot-size 4
 us-channel 5 modulation-profile 221
 us-channel 5 shutdown
!
```

Additional References

Related Documents

Related Topic	Document Title
Cisco CMTS Commands	*Cisco IOS CMTS Cable Command Reference* http://www.cisco.com/en/US/docs/ios/cable/command/reference/cbl_book.html

Standards

Standards	Title
SP-RFIv1.1-I09-020830	Data-over-Cable Service Interface Specifications Radio Frequency Interface Specification, version 1.1
SP-RFIv2.0-I03-021218	Data-over-Cable Service Interface Specifications Radio Frequency Interface Specification, version 2.0
SP-OSSIv2.0-I03-021218	Data-over-Cable Service Interface Specifications Operations Support System Interface Specification, version 2.0
SP-BPI+-I09-020830	Data-over-Cable Service Interface Specifications Baseline Privacy Plus Interface Specification, version 2.0
RFC 2233	DOCSIS OSSI Objects Support
RFC 2665	DOCSIS Ethernet MIB Objects Support
RFC 2669	Cable Device MIB

MIBs

MIBs	MIBs Link
• DOCS-BPI-PLUS-MIB • DOCS-CABLE-DEVICE-MIB (RFC 2669) • DOCS-CABLE-DEVICE-TRAP-MIB • DOCS-IF-EXT-MIB • DOCS-IF-MIB (RFC 2670) • DOCS-QOS-MIB • DOCS-SUBMGT-MIB • IGMP-STD-MIB (RFC 2933)	To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: http://www.cisco.com/go/mibs

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

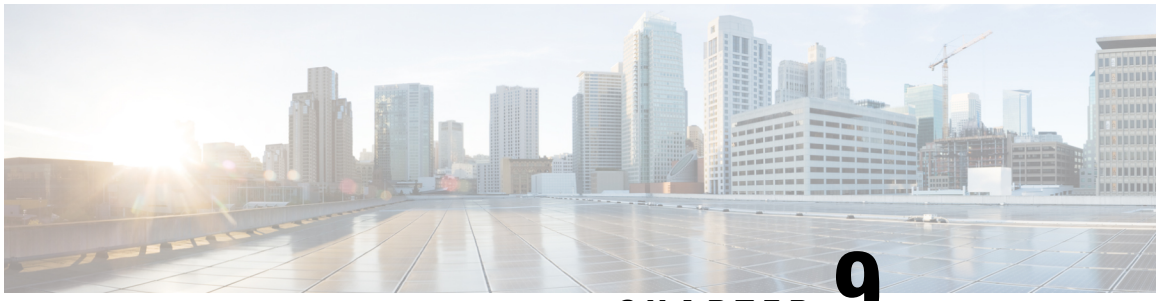
Feature Information for DOCSIS 2.0 A-TDMA Modulation Profile

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 27: Feature Information for DOCSIS 2.0 A-TDMA Modulation Profile

Feature Name	Releases	Feature Information
DOCSIS 2.0 A-TDMA Modulation Profile	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the cisco cBR Series Converged Broadband Routers.



CHAPTER 9

Downstream Resiliency Bonding Group

With more wideband (WB) modems being deployed in cable plants, WB modem resiliency is an important feature. When a comparatively smaller number of cable modems (CMs) observe an impairment on an RF channel, that RF channel stops working. It impacts all the CM using that RF channel, irrespective of whether they reported the impairment on that RF channel. Instead, the solution should be to communicate with the affected cable modems using the good RF channel, without affecting the other cable modems.

The Downstream Resiliency Bonding Group feature allows cable modems with multiple impaired RF channels to be allocated to a dynamically-created wideband interface, which ensures that the performance of the wideband cable modems is not drastically affected.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 28: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for Downstream Resiliency Bonding Group

- Set aside WB interfaces so that new WB interfaces can be dynamically created from the reserved list of WB interfaces.
- Free up RF bandwidth so that those RF channels can be added to a resiliency bonding group (RBG).
- Remove all existing RBG configuration from the WB interface.

Restrictions for the Downstream Resiliency Bonding Group

- If an existing wideband interface is reserved as a Resiliency Bonding Group (RBG) and later the RBG is removed (through the **no cable ds-resiliency** command), the modems using this RBG go offline and the RBG configuration itself is deleted. Therefore, it is highly recommended that users should not configure an existing BG as an RBG.
- This feature is enabled only when the number of cable modems observing an RF channel impairment is *below* the resiliency threshold. If the number of cable modems on an impaired RF channel is above the resiliency threshold, the impaired RF channel is temporarily removed from the bonding group.
- A cable modem is assigned to an RBG on a first-come-first-served basis. To handle this feature optimally, it is recommended to set aside more WB interfaces and RF channel bandwidth.
- The Cisco CMTS controls the freeing of unused RBGs, when there is no modem using the RGB. The freeing of the unused RGB may take some time and the RGB, which is not completely free cannot be used by the modems. Irrespective of the number of configured RBGs, if all the old RBGs are not completely set free and if the Cisco CMTS tries to move the cable modem to a new RBG, the Cisco CMTS moves the cable modem to the primary DS channel instead of RBG.
- Only SFs on the WB interface associated with the primary SF are moved to an RBG. SFs on other interfaces will not be moved.
- Static SFs are assigned to an RBG on a best effort quality of service (QoS).
- If the **resiliency rf-change-trigger** setting does not have the **secondary** keyword set, only the primary SF is moved to the RBG or a NB interface.
- If the Downstream Resiliency Bonding Group feature is not enabled to use an RBG, only cable modems with impairments on the primary WB interface are moved to the NB interface.
- SFs carrying multicast traffic are not moved.

There may not be enough reserved bonding groups to support all modems facing an impairment at any given time thus the following restrictions must be considered:

- Each RBG has at least two RF channels.
- RBG RF assignments are always a subset of the RF channel assignment of the parent WB interface.
- If an RBG is unavailable for a cable modem, the SF of the CM is moved to a NB interface.
- If a high percentage of cable modems experience an RF impairment and there are no more available bonding group IDs, the impaired RF itself may be removed from the bonding group. Removal of an

impaired RF from a parent bonding group is also reflected in the RBG. If an RBG drops to a single RF, all SFs are moved to the NB interface.

The Downstream Resiliency Bonding Group feature has the following cross-functional restrictions:

- All Dynamic service flows, whether they require a committed information rate (CIR) or not, typically voice flows, are created on the NB interface when an RF channel is impaired. Because all SFs assigned to an RBG are best effort only, voice calls may report a quality issue.
- Cable modems participating in the resiliency mode do not take part in load balancing.
- The Downstream Resiliency Bonding Group feature is only supported in the Dynamic Bandwidth Sharing (DBS) mode.

Information About Downstream Resiliency Bonding Group

You can set aside unused bonding groups as RBGs. Ensure that each RF channel is assigned at least 1% of the available bandwidth. Use the **cable rf-channel bandwidth-percent** command to configure the RF channel bandwidth.

Note If the bandwidth-percent is set to 100, the Cisco CMTS does not add any RFs to the RBG. In other words, this feature will not be enabled.

The Cisco CMTS controls the assignment and freeing of unused RBGs. If an RF channel is removed from a WB interface, it is also removed from any associated RBGs.

Note If the wideband interface is in standby mode, the Cisco CMTS does not assign or free up the unused downstream bonding group.

A suspended RF channel is restored for all affected wideband interfaces when a specified number of cable modems report (via CM-STATUS) that the channel connectivity is restored. The Wideband Modem Resiliency feature defines the specified number of cable modems as half of the configured count or percentage of rf-change-trigger, or both. For example, if the count is 20 and the percent is 10, then the number of cable modems reporting recovery should reduce the count to 10 and the percent to 5 for the suspended RF channel to be restored.

Finding a Best-Fit RBG for the Cable Modem

A bonding group is a list of channels that provide a means to identify the channels that are bonded together. The Cisco CMTS assigns a service flow (SF) to an RBG based on the attributes of the SF and the attributes of the individual channels of the bonding group.

In the Downstream Resiliency Bonding Group feature, when a line card receives a CM-STATUS message from the cable modem informing the line card that there is an RF channel impairment, the line card checks for the number of good RF channels and:

- Moves the cable modem to narrowband mode if there is only one available RF channel.

- Moves the cable modem to wideband mode if the cable modem reports all RF channels are in good state.
- Moves the cable modem to an RBG if there are two or more good RF channels, with at least one RF channel impaired, and if the Downstream Resiliency Bonding Group feature is enabled.

When the Cisco CMTS receives a message from the line card to move a cable modem to an RBG, the Cisco CMTS attempts to find an existing RBG or creates an RBG that satisfies the impairment.

Note If two or more RBGs are reserved for the same wideband controller, the Cisco CMTS creates one RBG for each cable modem.

Note The Cisco CMTS creates more than one RBG from a parent WB interface if the user has set aside more than one WB interface as the RBG and the RF bandwidth does not exceed 100%.

If a matching RBG is not found or cannot be created, the Cisco CMTS looks for an RBG with a subset of the required RF channels and if available, the cable modem is assigned to such an RBG.

However, if no such RBG exists, the Cisco CMTS instructs the line card to move the cable modem to NB mode.

How to Configure Downstream Resiliency Bonding Group

This section contains the following:

Enabling Downstream Resiliency Bonding Group

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable rf-change-trigger** {**percent** *value* | **count** *number*} [**secondary**] **Example:** `Router(config)# cable rf-change-trigger percent 50 count 1 secondary`	Specifies the amount of time an event must persist before it triggers an action for the reporting CM.

	Command or Action	Purpose
Step 4	**cable resiliency ds-bonding** **Example:** `Router(config)# cable resiliency ds-bonding`	Enables the downstream resiliency bonding group.
Step 5	**exit** **Example:** `Router(config)# exit`	Returns to the global configuration mode.

What to do next

Note The result of using the **cable rf-change-trigger** command with the **cable resiliency ds-bonding** command is different from using only the **cable rf-change-trigger** command. For more information, see Downstream Resiliency Narrowband Mode Versus Resiliency Bonding Group, on page 168.

Reserving a Resiliency Bonding Group for a Line Card

This section describes reserving a bonding group or a wideband interface for a line card per controller.

Restriction When you reserve a resiliency bonding group using the cable ds-resiliency command, the existing bundle and RF channel configurations on the wideband interface will be removed automatically. Other configurations like admission control, should be removed manually.

After downstream resiliency bonding group is configured, avoid other manual configurations.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface wideband-cable** *slot/subslot/port:wideband-channel* **Example:** `Router(config)# interface wideband-cable 1/0/0:7`	Configures a wideband cable interface.

	Command or Action	Purpose
Step 4	**cable ds-resiliency** **Example:** `Router(config-if)# cable ds-resiliency`	Reserves an individual bonding group or WB interface for usage on a line card, on a per controller basis.
Step 5	**exit** **Example:** `Router(config-if)# exit`	Returns to the global configuration mode.

Verifying Downstream Resiliency Bonding Group Configuration

This section contains the following:

Verifying the Downstream Resiliency Bonding Group

To verify if the Downstream Resiliency Bonding Group feature is enabled, use the **show cable modem resiliency** command as shown in the following example:

```
Router# show cable modem resiliency
                                Orig BG                 Curr BG
I/F     MAC Address    ID   I/F            RFs ID   I/F            RFs
------- -------------- ---- ---------------------- ----------------------
C7/0/0  0025.2eaf.843e 897  Wi7/0/0:0      4   898  Wi7/0/0:1      3
C7/0/0  0025.2eaf.8356 897  Wi7/0/0:0      4   899  Wi7/0/0:2      3
C7/0/0  0015.d176.5199 897  Wi7/0/0:0      4   720  In7/0/0:0
```

The **Current BG I/F** field indicates whether Downstream Resiliency Bonding Group feature is enabled and if the cable modems are assigned to a WB interface.

Verifying a Reserved Resiliency Bonding Group

To verify if a BG is reserved for a line card, use the **show cable resiliency** command as shown in the following example:

```
Router# show cable resiliency
              BG   Resil BG                                  RF
Resil BG I/F  ID   State          Count Time             Ctrl  Num
------------- ---- -------------- ----- ---------------- ----------
Wi1/0/0:10    10   Free
Wi1/0/0:20    20   Free
Wi7/0/0:1     1    Assigned       3     Nov 3  09:55:49 0     0
                                                              1
                                                              2
Wi7/0/0:2     2    Assigned       3     Nov 3  09:57:09 0     0
                                                              1
                                                              3
```

Downstream Resiliency Narrowband Mode Versus Resiliency Bonding Group

This section provides the sample outputs when using the **cable rf-change-trigger** command with the **cable resiliency ds-bonding** command and using only the **cable rf-change-trigger** command.

Table 29: Downstream Resiliency Narrowband Mode Versus Resiliency Bonding Group - Scenario 1

Effect on	Using only cable rf-change-trigger command (Downstream Resiliency NB Mode)		Using cable rf-change-trigger command with cable resiliency ds-bonding (Downstream Resiliency Bonding Group)	
	Below Threshold	**Above Threshold**	**Below Threshold**	**Above Threshold**
Primary Service Flow	Moves to the primary channel.	Remains on the original bonding group while the impaired downstream channels are not used and are reported as DOWN.	Moves to dynamic bonding group.	Remains on the original bonding group while the impaired downstream channels are not used and are reported as DOWN.
Secondary Service Flows	Remain on the original WB interface.	Remains on the original bonding group while the impaired downstream channels are not used and are reported as DOWN.	Remains on the original bonding group.	Remains on the original bonding group while the impaired downstream channels are not used and are reported as DOWN.

The following is a sample output for a cable modem when the **cable rf-change-trigger** command is used with the **cable resiliency ds-bonding** command and the number of cable modems observing an RF channel impairment is *below* the resiliency threshold:

```
Router# show cable modem

                                                                                D
MAC Address    IP Address     I/F           MAC           Prim RxPwr  Timing Num I
                                            State         Sid  (dBmv) Offset CPE P
0023.be83.1c9e 10.1.11.46     C5/0/0/UB     w-online      922  -0.50  1055   0   N
0023.be83.1caa 10.1.11.28     C5/0/0/UB     w-online      923  0.00   1043   0   N
0025.2ecf.f19c 10.1.11.53     C5/0/0/UB     w-online      925  0.00   1057   0   N
0022.3a30.9fc0 10.1.11.47     C5/0/0/UB     w-online      926  0.00   1055   0   N
001a.c3ff.e3d4 10.1.11.39     C5/0/0/UB     p-online      927  0.00   1307   0   N
0023.be83.1c9a 10.1.11.61     C5/0/0/UB     w-online      928  0.00   1057   0   N
0022.3a30.9fbc 10.1.11.60     C5/0/0/UB     p-online      929  -0.50  1055   0   N
0023.be83.1c8c 10.1.11.38     C5/0/0/UB     w-online      930  0.00   1061   0   N
001e.6bfb.1964 10.1.11.63     C5/0/0/UB     p-online      931  0.50   1305   0   N
0025.2ecf.f196 10.1.11.29     C5/0/0/UB     w-online      932  0.00   1057   0   N
0025.2ecf.f04e 10.1.11.54     C5/0/0/UB     w-online      933  0.00   1054   0   N
0022.3a30.9fc8 10.1.11.43     C5/0/0/UB     w-online      934  0.00   1056   0   N
0025.2ecf.f190 10.1.11.55     C5/0/0/UB     w-online      935  0.00   1059   0   N
0022.3a30.9fd0 10.1.11.52     C5/0/0/UB     p-online      936  0.00   1057   0   N
0022.ce97.8268 10.1.11.31     C5/0/0/UB     w-online      937  -0.50  1056   0   N
0022.ce97.8281 10.1.11.25     C5/0/0/UB     w-online      938  0.00   1058   0   N
001a.c3ff.e4ce 10.1.11.44     C5/0/0/UB     w-online      940  -0.50  1304   0   N
0022.ce9c.839e 10.1.11.32     C5/0/0/UB     w-online      941  -0.50  1305   0   N
0022.cea3.e768 10.1.11.41     C5/0/0/UB     w-online      942  -1.00  1305   0   N
0022.ce9c.8398 10.1.11.33     C5/0/0/UB     w-online      943  0.00   1306   0   N
001a.c3ff.e50a 10.1.11.59     C5/0/0/UB     w-online      944  0.00   1304   0   N
001a.c3ff.e3f8 10.1.11.57     C5/0/0/UB     w-online      945  -1.00  1306   0   N
001e.6bfb.1a14 10.1.11.37     C5/0/0/UB     w-online      946  0.00   1305   0   N
```

Note p-online indicates that cable modem has reported NP RF failure and it is in downstream partial service mode.

```
Router# show cable resiliency

              BG   Resil BG                                  RF
Resil BG I/F  ID   State           Count Time              Ctrl  Num
------------- ---- -------------- ----- ---------------- ----------
Wi5/0/0:2     2    Assigned       1     Mar 30 14:46:43 0     0
                                                               1
                                                               2
Wi5/0/0:3     3    Assigned       1     Mar 30 14:46:43 0     0
                                                               1
                                                               2
                                                         1     0
                                                               1
                                                               2
                                                               3
Wi5/0/0:4     4    Free           0
Wi5/0/0:5     5    Free           0

Router# show cable modem resiliency
                               Orig BG                Curr BG
I/F     MAC Address    ID   I/F            RFs ID   I/F            RFs
------- -------------- ---------------------- ----------------------
C5/0/0  001a.c3ff.e3d4 258  Wi5/0/0:1     4   259  Wi5/0/0:2     3 <- Dynamic Bonding Group
C5/0/0  0022.3a30.9fbc 257  Wi5/0/0:0     8   260  Wi5/0/0:3     7 <- Dynamic Bonding Group
C5/0/0  001e.6bfb.1964 258  Wi5/0/0:1     4   259  Wi5/0/0:2     3 <- Dynamic Bonding Group
C5/0/0  0022.3a30.9fd0 257  Wi5/0/0:0     8   260  Wi5/0/0:3     7 <- Dynamic Bonding Group
```

The following is a sample output for a cable modem under the following conditions:

- **cable rf-change-trigger** command is used with the **cable resiliency ds-bonding** command
- Number of cable modems observing an RF channel impairment is *below* the resiliency threshold
- There is no available WB interface for the resiliency bonding group:

```
Router# show cable modem
 0025.2ecf.f196 service-flow version

SUMMARY:
MAC Address    IP Address      Host          MAC           Prim  Num Primary    DS
                               Interface     State         Sid   CPE Downstream RfId
0025.2ecf.f196 10.1.11.29      C5/0/0/UB     p-online
      932   0   In5/0/0:0  240
Sfid  Dir Curr  Sid   Sched  Prio MaxSusRate  MaxBrst     MinRsvRate  Throughput
          State       Type
1867  US  act   932   BE     0    0           10000       0           294
1868  DS  act   N/A   N/A    0    0           3044        0           154

Router# show cable resiliency
              BG   Resil BG                                  RF
Resil BG I/F  ID   State           Count Time              Ctrl  Num
------------- ---- -------------- ----- ---------------- ----------
Wi5/0/0:2     2    Assigned       6     Mar 30 15:57:09 0     0
                                                               1
```

```
                                                                    2
                                                                    3
                                                              1     0
                                                                    2
                                                                    3
Wi5/0/0:3     3    Assigned       8     Mar 30 15:53:58 0      0
                                                                    1
                                                                    2
                                                              1     1
                                                                    2
                                                                    3
Wi5/0/0:4     4    Assigned       2     Mar 30 15:53:58 0      0
                                                                    1
                                                                    2
                                                                    3
                                                              1     1
                                                                    2
                                                                    3
Wi5/0/0:5     5    Assigned       2     Mar 30 15:58:35 0      0
                                                                    1
                                                                    2
                                                                    3
                                                              1     0
                                                                    1
                                                                    3
```

```
Router# show cable modem resiliency

                                Orig BG                 Curr BG
I/F     MAC Address    ID   I/F            RFs ID   I/F            RFs
------- -------------- ---- ---------------------- ----------------------
C5/0/0  0025.2ecf.f19c 257  Wi5/0/0:0      8   259  Wi5/0/0:2      7
C5/0/0  0025.2ecf.f196 257  Wi5/0/0:0      8   240  In5/0/0:0     <-- move NB for no available
 WB interface
C5/0/0  0025.2ecf.f04e 257  Wi5/0/0:0      8   262  Wi5/0/0:5      7
C5/0/0  0022.3a30.9fbc 257  Wi5/0/0:0      8   260  Wi5/0/0:3      6
C5/0/0  0022.3a30.9fd0 257  Wi5/0/0:0      8   261  Wi5/0/0:4      7
```

Table 30: Downstream Resiliency Narrowband Mode Versus Resiliency Bonding Group - Scenario 2

Effect on	Using only cable rf-change-trigger secondary command (Downstream Resiliency NB Mode)		Using cable rf-change-trigger secondary command with cable resiliency ds-bonding (Downstream Resiliency Bonding Group)	
	Below Threshold	**Above Threshold**	**Below Threshold**	**Above Threshold**
Primary Service Flow	Moves all service flows to the primary channel.	Remains on the original bonding group while the impaired downstream channels are not used and are reported as DOWN.	Moves all service flows to a dynamic bonding group.	Remains on the original bonding group while the impaired downstream channels are not used and are reported as DOWN.
Secondary Service Flows				

The following is a sample output for a cable modem when the **cable rf-change-trigger secondary** command is used with the **cable resiliency ds-bonding** command and the number of cable modems observing an RF channel impairment is *below* the resiliency threshold:

```
Router# show cable modem 0025.2ecf.f196 service-flow
```

```
SUMMARY:
MAC Address    IP Address      Host          MAC           Prim  Num Primary    DS
                               Interface     State         Sid   CPE Downstream RfId
0025.2ecf.f196 10.1.11.29      C5/0/0/UB     p-online      955   0   In5/0/0:0  240
Sfid  Dir Curr  Sid   Sched  Prio MaxSusRate  MaxBrst     MinRsvRate  Throughput
           State       Type
1913  US  act   955   BE     0    10000000    10000       0           425
1915  US  act   956   RTPS   7    0           3044        100000      0
1916  US  act   957   BE     0    0           3044        50000       0
1917  US  act   958   BE     4    0           3044        0           0
1914  DS  act   N/A   N/A    0    100000000   20000       0           0       <-- Primary
Service-Flow
1918  DS  act   N/A   N/A    0    0           3044        0           0       <-- Secondary
 Service-Flow
1919  DS  act   N/A   N/A    0    0           3044        0           0       <-- Secondary
 Service-Flow
1920  DS  act   N/A   N/A    4    4500000     3044        0           0       <-- Secondary
 Service-Flow
UPSTREAM SERVICE FLOW DETAIL:
SFID  SID   Requests   Polls      Grants     Delayed    Dropped    Packets
                                             Grants     Grants
1913  955   83         0          83         0          0          92
1915  956   0          0          0          0          0          0
1916  957   0          0          0          0          0          0
1917  958   0          0          0          0          0          0
DOWNSTREAM SERVICE FLOW DETAIL:
SFID  RP_SFID QID    Flg Policer              Scheduler              FrwdIF
                         Xmits      Drops      Xmits      Drops
1914  33210   131555     90         0          6          0          Wi5/0/0:3 <-- Dynamic
 Bonding Group
1918  33211   131556     0          0          0          0          Wi5/0/0:3
1919  33212   131557     0          0          0          0          Wi5/0/0:3
1920  33213   131558     0          0          0          0          Wi5/0/0:3
```

Troubleshooting the Downstream Resiliency Bonding Group Configuration

Use the following commands to get information on the WB interface, number of CMs in an impaired state, resiliency bonding groups, their associated bonding groups, available RF channels, and the number of CMS and service flows assigned to them:

- **debug cable wbcmts resiliency**
- **debug cable wbcmts resiliency report**
- **show cable resiliency**
- **show cable modem resiliency**
- **show cable modem wideband rcs-status**
- **show cable modem service-flow verbose**
- **show cable resil-rf-status**
- **show cable modem summary wb-rfs**

In case the CPU usage of the downstream resiliency process is high, use following commands to optimize the downstream resiliency bonding group configuration:

- **cable rf-change-up-multiplier** *value* - The default value is 2. Use this command to set the rf-channel up dampen time as an integer multiplier of the rf-channel down dampen time, in order to lengthen the recovery time to keep certain modems from falling back into DOWN state shortly after recovery.
- **cable resiliency free-interval** *seconds* - The recommended value is 360. Use this command to set the wait time before a created resiliency bonding group is freed/recycled, in order to hold the resiliency bonding group up long enough for it to be reused by impaired cable modems.

Configuration Examples for the Downstream Resiliency Bonding Group

The following is an example of the configuration of the Downstream Resiliency Bonding Group feature:

```
cable rf-change-trigger count 10 secondary
cable resiliency ds-bonding
!
controller Upstream-Cable 9/0/1
us-channel 0 frequency 13200000
us-channel 0 channel-width 6400000 6400000
us-channel 0 power-level -1
us-channel 0 docsis-mode atdma
us-channel 0 minislot-size 8
us-channel 0 modulation-profile 221
no us-channel 0 shutdown
us-channel 1 frequency 19600000
us-channel 1 channel-width 6400000 6400000
us-channel 1 power-level -1
us-channel 1 docsis-mode atdma
us-channel 1 minislot-size 8
us-channel 1 modulation-profile 221
no us-channel 1 shutdown
us-channel 2 frequency 26000000
us-channel 2 channel-width 6400000 6400000
us-channel 2 power-level -1
us-channel 2 docsis-mode atdma
us-channel 2 minislot-size 8
us-channel 2 modulation-profile 221
no us-channel 2 shutdown
us-channel 3 frequency 32400000
us-channel 3 channel-width 6400000 6400000
us-channel 3 power-level -1
us-channel 3 docsis-mode atdma
us-channel 3 minislot-size 8
us-channel 3 modulation-profile 221
no us-channel 3 shutdown
!
controller Integrated-Cable 9/0/1
max-carrier 128
base-channel-power 34
rf-chan 0
  type DOCSIS
  frequency 381000000
  rf-output NORMAL
  power-adjust -2
  docsis-channel-id 1
```

```
  qam-profile 1
rf-chan 1 3
  type DOCSIS
  frequency 387000000
  rf-output NORMAL
  power-adjust 0
  docsis-channel-id 2
  qam-profile 1
rf-chan 32 35
  type DOCSIS
  frequency 477000000
  rf-output NORMAL
  power-adjust 0
  docsis-channel-id 33
  qam-profile 1
rf-chan 64 67
  type DOCSIS
  frequency 501000000
  rf-output NORMAL
  power-adjust 0
  docsis-channel-id 65
  qam-profile 1
rf-chan 96 99
  type DOCSIS
  frequency 669000000
  rf-output NORMAL
  power-adjust 0
  docsis-channel-id 97
  qam-profile 1
!
interface Cable9/0/1
downstream Integrated-Cable 9/0/1 rf-channel 0-3
downstream Integrated-Cable 9/0/1 rf-channel 32-35
upstream 0 Upstream-Cable 9/0/1 us-channel 0
upstream 1 Upstream-Cable 9/0/1 us-channel 1
upstream 2 Upstream-Cable 9/0/1 us-channel 2
upstream 3 Upstream-Cable 9/0/1 us-channel 3
cable upstream bonding-group 1
  upstream 0
  upstream 1
  upstream 2
  attributes 80000000
cable upstream bonding-group 2
  upstream 0
  upstream 1
  attributes 80000000
cable upstream bonding-group 3
  upstream 1
  upstream 2
  attributes 80000000
cable upstream bonding-group 4
  upstream 0
  upstream 2
  attributes 80000000
cable upstream bonding-group 5
  attributes 80000000
cable bundle 1
no cable mtc-mode
cable privacy accept-self-signed-certificate
end
!
interface Integrated-Cable9/0/1:0
cable bundle 1
cable rf-bandwidth-percent 65
```

```
!
interface Wideband-Cable9/0/1:0
cable bundle 1
cable privacy accept-self-signed-certificate
cable rf-channels channel-list 0-3 bandwidth-percent 20
!
interface Integrated-Cable9/0/1:1
cable bundle 1
cable rf-bandwidth-percent 65
!
interface Wideband-Cable9/0/1:1
cable bundle 1
cable privacy accept-self-signed-certificate
cable rf-channels channel-list 32-35 bandwidth-percent 20
!
!
interface Wideband-Cable9/0/1:60
cable ds-resiliency
!
interface Wideband-Cable9/0/1:61
cable ds-resiliency
!
interface Wideband-Cable9/0/1:62
cable ds-resiliency
!
```

The following is a sample output for the **show cable modem** command to display impaired cable modems below the resiliency threshold value:

```
Router# show cable modem

MAC Address    IP Address      I/F           MAC           Prim  RxPwr  Timing Num I
                                             State         Sid   (dBmv) Offset CPE P
e448.c70c.96d5 80.17.150.6     C9/0/1/U2     p-online      1     0.00   1784   0   N
e448.c70c.96f3 80.17.150.14    C9/0/1/U1     w-online      2     -1.00  1797   0   N
68ee.9633.0699 80.17.150.31    C9/0/1/U0     w-online      3     -1.00  2088   1   N
e448.c70c.96e7 80.17.150.29    C9/0/1/U3     p-online      4     -0.50  1785   0   N
e448.c70c.982b 80.17.150.18    C9/0/1/U2     w-online      5     0.00   1780   0   N
e448.c70c.9804 80.17.150.13    C9/0/1/U3     w-online      6     -0.50  1788   0   N
e448.c70c.9819 80.17.150.30    C9/0/1/U0     w-online      7     -1.00  1782   0   N
e448.c70c.980d 80.17.150.17    C9/0/1/U0     w-online      8     -1.00  1787   0   N
```

Note p-online indicates that the cable modem has reported NP RF failure and it is in downstream partial service mode.

The following is a sample output when RBGs are created:

```
Router# show cable resiliency

              BG    Resil BG                                  RF
Resil BG I/F  ID    State          Count Time             Ctrl  Num
------------- ----- -------------- ----- ---------------- ----------
Wi9/0/1:60    28989 Assigned       1     Jan 9  07:35:08 1     0
                                                                1
                                                                2
Wi9/0/1:61    28990 Assigned       1     Jan 9  07:36:54 1     0
                                                                1
                                                                3
```

```
Wi9/0/1:62    28991 Free           0
```

The following is a sample output when cable modems service flows are assigned to RBGs:

```
Router# show cable modem resiliency

                              Orig BG                Curr BG
I/F     MAC Address    ID     I/F            RFs ID    I/F            RFs
------- -------------- ---------------------- ---------------------------
C9/0/1  e448.c70c.96d5 28929 Wi9/0/1:0      4   28989 Wi9/0/1:60     3
C9/0/1  e448.c70c.96e7 28929 Wi9/0/1:0      4   28990 Wi9/0/1:61     3
```

The following is a sample output of the **show cable modem** command when the impaired cable modems have recovered:

```
Router# show cable modem

MAC Address    IP Address      I/F           MAC           Prim  RxPwr  Timing Num I
                                             State         Sid   (dBmv) Offset CPE P
e448.c70c.96d5 80.17.150.6     C9/0/1/U2     w-online      1     0.00   1784   0   N
e448.c70c.96f3 80.17.150.14    C9/0/1/U1     w-online      2     -1.00  1797   0   N
68ee.9633.0699 80.17.150.31    C9/0/1/U0     w-online      3     -1.00  2088   1   N
e448.c70c.96e7 80.17.150.29    C9/0/1/U3     w-online      4     -0.50  1785   0   N
e448.c70c.982b 80.17.150.18    C9/0/1/U2     w-online      5     0.00   1780   0   N
e448.c70c.9804 80.17.150.13    C9/0/1/U3     w-online      6     -0.50  1788   0   N
e448.c70c.9819 80.17.150.30    C9/0/1/U0     w-online      7     -1.00  1782   0   N
e448.c70c.980d 80.17.150.17    C9/0/1/U0     w-online      8     -1.00  1787   0   N
```

The following is a sample output of the **show cable resiliency** command when the impaired cable modems have recovered:

```
Router# show cable resiliency

              BG    Resil BG                                  RF
Resil BG I/F  ID    State          Count Time              Ctrl  Num
------------- ----- -------------- ----- ---------------- ----------
Wi9/0/1:60    28989 Free           1     Jan 9  07:35:08
Wi9/0/1:61    28990 Free           1     Jan 9  07:36:54
Wi9/0/1:62    28991 Free           0
```

Additional References

Related Documents

Related Topic	Document Title
Cisco CMTS Command Reference	http://www.cisco.com/c/en/us/td/docs/cable/cmts/cmd_ref/b_cmts_cable_cmd_re

Technical Assistance

Description	Link
The Cisco Support and Documentation website provides online resources to download documentation, software, and tools. Use these resources to install and configure the software and to troubleshoot and resolve technical issues with Cisco products and technologies. Access to most tools on the Cisco Support and Documentation website requires a Cisco.com user ID and password.	http://www.cisco.com/cisco/web/support/index.html

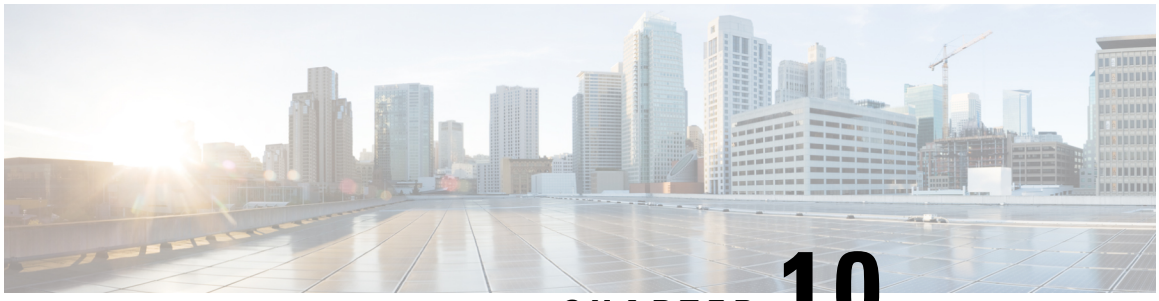
Feature Information for Downstream Resiliency Bonding Group

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 31: Feature Information for Downstream Resiliency Bonding Group

Feature Name	Releases	Feature Information
Downstream Resiliency Bonding Group	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.
Resiliency Bonding Group Enhancement	Cisco IOS XE Gibraltar 16.12.1y	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 10

Downstream Channel ID Assignment

First Published: April 17, 2015

The DOCSIS downstream channel ID (DCID) is defined as an 8-bit identifier for recognizing a Downstream Channel within a MAC Domain. All CMTS downstream channels are assigned a DCID by default that may be subsequently changed by configuration. It is used in most DOCSIS downstream packet headers and its valid range is from 1 to 255 (0 is reserved for network management purposes).

Note All downstream channels in a MAC domain must have a unique DCID within the MAC domain.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 32: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Information About Downstream Channel ID Assignment on the Cisco CMTS Routers

These are the downstream channel ID assignment features:

- Unique DCIDs are provided for all channels within a single controller by default.

Note DCID values for downstream channels in the same MAC Domain must be unique. If a MAC Domain only contains channels from a single controller, the default DCID values will be sufficient. If a MAC Domain contains channels from multiple controllers, DCID conflicts may be encountered within the MAC Domain. DCID conflicts may be resolved by changing the DCID value of the conflicting channels within the controller configuration or by enabling the automatic channel ID assignment feature.

- The default DCID value for each downstream channel within a controller is equivalent to rf-chan number plus one. For example, the default value for rf-chan 0 is 1, for rf-chan 1 is 2.

Manual Downstream Channel ID Assignment

When using the manual DCID provisioning feature, every downstream channel in the system is assigned a default DCID value equivalent to (controller QAM id + 1). The table below shows the default DCID ranges per downstream controller.

Table 33: Default Downstream Channel IDs Per Slot/Subslot/Controller

	0/0	1/0	2/0	3/0	6/0	7/0	8/0	9/0
DS Controller 0	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128
DS Controller 1	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128
DS Controller 2	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128
DS Controller 3	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128
DS Controller 4	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128
DS Controller 5	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128
DS Controller 6	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128

	0/0	1/0	2/0	3/0	6/0	7/0	8/0	9/0
DS Controller 7	1-128	1-128	1-128	1-128	1-128	1-128	1-128	1-128

The default DCID value can be replaced with a user configurable value. The configuration is available in the downstream controller per channel. The current DCID values for the channels within a downstream controller can be viewed in the dcid column of the **show controller Integrated-Cable rf-chan** command output. The example shows channels with default DCID values. When a DCID value is changed in the configuration, the new value appears in the output below.

```
Router#show controllers integrated-Cable 3/0/0 rf-channel 1-127
Chan State Admin Frequency  Type   Annex Mod  srate Interleaver  dcid  power  output
 1   NPRE   UP   99000000   DOCSIS  B    256   5361  I32-J4       2    37     NORMAL
 2   NPRE   UP   105000000  DOCSIS  B    256   5361  I32-J4       3    37     NORMAL
 3   NPRE   UP   111000000  DOCSIS  B    256   5361  I32-J4       4    37     NORMAL
 4   NPRE   UP   117000000  DOCSIS  B    256   5361  I32-J4       5    37     NORMAL
 5   NPRE   UP   123000000  DOCSIS  B    256   5361  I32-J4       6    37     NORMAL
 6   NPRE   UP   129000000  DOCSIS  B    256   5361  I32-J4       7    37     NORMAL
 7   NPRE   UP   135000000  DOCSIS  B    256   5361  I32-J4       8    37     NORMAL
 8   NPRE   UP   141000000  DOCSIS  B    256   5361  I32-J4       9    37     NORMAL
 9   NPRE   UP   147000000  DOCSIS  B    256   5361  I32-J4       10   37     NORMAL
 10  NPRE   UP   153000000  DOCSIS  B    256   5361  I32-J4       11   37     NORMAL
 11  NPRE   UP   159000000  DOCSIS  B    256   5361  I32-J4       12   37     NORMAL
 12  NPRE   UP   165000000  DOCSIS  B    256   5361  I32-J4       13   37     NORMAL
 13  NPRE   UP   171000000  DOCSIS  B    256   5361  I32-J4       14   37     NORMAL
 14  NPRE   UP   177000000  DOCSIS  B    256   5361  I32-J4       15   37     NORMAL
 15  NPRE   UP   183000000  DOCSIS  B    256   5361  I32-J4       16   37     NORMAL

Router#
```

Automatic Downstream Channel ID Assignment on the Cisco CMTS Routers

It is possible to automatically assign a unique set of downstream channel IDs to meet all DOCSIS requirements by enabling the Automatic DCID Assignment feature. When enabled, Downstream channel DCIDs will be automatically assigned when the channels are added to a fiber node and associated with a MAC Domain. Therefore, the use of fiber node configuration is a prerequisite for this feature.

Service Impact

Changing the DOCSIS downstream channel ID causes cable modems to re-register. Cable modems receive MAC Domain Descriptor (MDD) and Upstream Channel Descriptor (UCD) messages with a changed DCID in their headers.

- Enabling the automatic DCID assignment displays the following message:

```
WARNING: Enabling automatic DCID assignment will cause modems to flap and will apply
to all fiber nodes on this CMTS.
```

- Disabling the automatic DCID assignment displays the following message:

```
WARNING: Disabling automatic DCID assignment will no longer enforce channel-id uniqueness
 at fiber nodes. Channel ID changes may require manual verification to prevent conflicts.
```

- If there is a DCID conflict with another channel in the MAC Domain, the following error message is displayed:

```
ERROR: <slot>/<subslot>/<controller> rf-channel <channel>: The downstream channel id
conflicts with interface In<slot>/<subslot>/<controller>:channel. Downstream channel
id must be unique in a CGD.
```

- After automatic DCID assignment is configured, if there is a DCID conflict when a downstream channel that belongs to a fiber node is added to a MAC Domain, the automatic DCID feature tries to resolve the conflict by assigning another automatic DCID and the following message is displayed:

```
WARNING: The downstream channel id conflict for <slot>/<subslot>/<controller> rf-channel
 <channel> was resolved by Automatic DCID Assignment.
Please run "interface <md-slot>/<md-subslot>/<md-index>" followed by
"<slot>/<subslot>/<controller> rf-channel <channel>" again in order to add the channel.
```

  To add the channel, use this channel grouping domain (CGD) command again:

  cable downstream *x/y/z* **rf-channel** *channel*

- If automatic DCID is configured and the channel does not belong to a fiber node, or if automatic DCID cannot resolve the conflict, the following message is displayed:

```
WARNING: The downstream channel id conflict for <slot>/<subslot>/<controller> rf-channel
 <channel> could not be resolved by Automatic DCID Assignment.
```

  To resolve this issue, add the channel to a fiber node.

How to Configure Downstream Channel ID Assignment on the Cisco CMTS Routers

The following sections describe how to configure downstream channel ID assignment.

Configuring Manual Downstream Channel ID Assignment

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

	Command or Action	Purpose
Step 3	**interface controller integrated-Cable** *slot*/*subslot*/*port* **Example:** `Router(config)# interface controller integrated-Cable 1/0/1`	Enters controller configuration mode for the Channel Grouping Domain host line card.
Step 4	**rf-chan** *downstream QAM ID* • Alternatively, use the **rf-chan** *starting downstream QAM ID ending downstream QAM ID* command to set the range of downstream channel IDs. **Example:** `Router(config-controller)# rf-chan 0`	Enters the rf-channel configuration mode.
Step 5	**docsis-channel-id** *DCID* **Example:** `Router(config-rf-chan)#docsis-channel-id 1`	Configures the downstream channel's DCID to the specified value, for the RF channel. For the rf-channel range that was configured using the **rf-chan** *starting downstream QAM ID ending downstream QAM ID* command, the **docsis-channel-id** *DCID* command configures the DCIDs for the rf-channels in that range.

Configuring Automatic Downstream Channel ID Assignment

Automatic DCID assignment should be permanently configured. However, if you need to remove the feature, use the **no** or **default** commands.

Note The **no** or **default** form of the command is not written to startup-config file.

In this case, the DCIDs are retained as computed for all channels, and are not set to the defaults of the channels. Save the configuration containing the newly-assigned DCIDs to the startup-config file by using the **write memory** command.

When you enable automatic DCID assignment, any DCID conflict arising due to adding a channel to a MAC Domain is resolved automatically.

Restriction

- After running the **cable downstream-channel-id automatic** command in the configuration, manually editing the configuration file in an editor to add RF channels to the fiber nodes could cause DCID conflicts. The feature assumes all channels in fiber nodes have unique automatic DCIDs in global configuration mode. If the configuration is manually edited and the feature does not verify the unique DCIDs, the DCIDs of the newly-added channels may conflict with those of the existing channels. To fix any DCID conflicts, undo and re-apply the global automatic DCID configuration.

  Note Re-applying global automatic DCID configuration is a disruptiv operation.

  To avoid DCID conflicts, edit the configuration to configure the fiber nodes, then run the **cable downstream-channel-id automatic** command so all channels have unique automatic DCIDs.

  Make additions to the fiber nodes on the Cisco uBR10012 router command line interface with the automatic DCID configured.

- The **cable downstream-channel-id automatic** command should not be manually edited in to the startup-config file, since it does not guarantee unique DCIDs for channels in the fiber node.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable downstream-channel-id automatic** **Example:** `Router(config)# cable downstream-channel-id automatic`	Specifies automatic assignment of the DCIDs by the Cisco CMTS.

Example

This example displays the restriction on manually editing configurations:

```
Router# show run | include automatic
cable downstream-channel-id automatic

router# show cable fiber-node 3
------------------------------------------------------------------------------
Fiber-Node 3
```

```
Channel(s) : downstream Integrated-Cable 1/0/2: 0-3, 32-35, 64-67, 96-99
Channel ID(s): 1 2 3 4 33 34 35 36 65 66 67 68 97 98 99 100
Upstream-Cable 1/0/2
FN Config Status: Configured (status flags = 0x01)
MDD Status: Valid
Router#
```

If you manually edit the startup-config file in an editor to add a downstream controller, for example, 1/0/3, it causes a conflict.

```
Router> configure terminal
Router# cable fiber-node 3
Router# downstream integrated-Cable 1/0/3
```

If this downstream controller is added, the automatic DCID assignment feature automatically resolves it. However, since the startup-config file was manually edited to add the downstream controller, the automatic DCID assignment feature is unable to resolve it. This causes a DCID conflict when the edited startup-config file is loaded and invalidates the fiber node.

```
down Modular-Cable 5/0/0 rf-channel 0
DS frequency is not unique.
DS channel id is not unique.
Warning: D3.0 CMs cannot get w-online with an invalid fiber-node.
router#
```

What to do next

Run the **show cable fibernode** command to view DCIDs assigned to all the channels in the fiber node.

```
Router# show cable fiber-node 3
Fiber-Node 3
Channel(s) : downstream Integrated-Cable 1/0/2: 0-3, 32-35, 64-67,
96-99
Channel ID(s): 1 2 3 4 33 34 35 36 65 66 67 68 97 98
99 100
Upstream-Cable 1/0/2
FN Config Status: Configured (status flags = 0x01)
MDD Status: Valid
```

Additional References

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/cisco/web/support/index.html

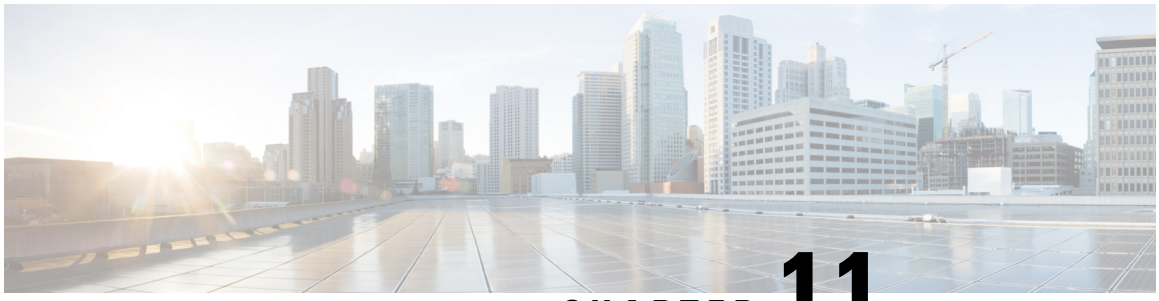
Feature Information for Downstream Channel ID Assignment

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 34: Feature Information for Downstream Channel ID Assignment

Feature Name	Releases	Feature Information
Downstream Channel ID Assignment	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Router.



CHAPTER 11

Upstream Channel Bonding

The Upstream Channel Bonding (USCB) feature helps cable operators offer higher upstream (US) bandwidth per cable modem (CM) user by combining multiple radio frequency (RF) channels to form a larger bonding group at the MAC layer.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 35: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for Upstream Channel Bonding

- Enable downstream channel bonding before configuring the Upstream Channel Bonding feature on a Cisco cable modem termination system (CMTS) router.
- Ensure that the CM is registered in Multiple Receive Channel (MRC) mode before configuring upstream channel bonding on a Cisco CMTS router.
- Ensure that the CM is DOCSIS 3.0 certified.

Restrictions for Upstream Channel Bonding

The following are the general restrictions for the Upstream Channel Bonding feature:

- Only the static bonding groups are supported.
- Only the upstream channels belonging to the same MAC domain can be added to an upstream bonding group.

Note A maximum of 16 upstream channels can be configured for each MAC Domain, which are divided into two groups:

- Group 1: upstream channel 0-7
- Group 2: upstream channel 8-15

The **upstream bonding-group** should include all the upstream channels either from Group 1 or Group 2 only.

- Committed information rate (CIR) oversubscription is not supported on USCB groups.

  Cisco CMTS allows oversubscription of the available bandwidth for individual upstream channels. However, oversubscription of bandwidth is not supported for USCB groups.

  An individual upstream may get oversubscribed due to static CIR service flows created for voice traffic. This may cause the DOCSIS 3.0 CMs with USCB to come online on single channel US bonding group (also known as default bonding group).

  This problem is mainly encountered in the voice deployments using static service flows. It is, therefore, recommended to choose from the following voice deployments such that the CIR is allocated (or released) when a voice call is attempted (or dropped):

  1. Dynamic Quality of Service (DQoS) Lite
  2. Packet Cable (PC) DQoS
  3. Packet Cable Multimedia (PCMM)

  These deployments avoid the individual upstream oversubscription and CMs come online on expected bonding groups.

Information About Upstream Channel Bonding

DOCSIS 3.0-based upstream channel bonding is a method for increasing upstream bandwidth up to a maximum of 120 Mbps raw throughput per CM user in a cable communications system that includes a Cisco CMTS router and multiple CMs. The upstream channel bonding method enables a CM to transmit data to a Cisco CMTS router on multiple upstream channels simultaneously.

Channel bonding is a method by which smaller bandwidth upstream channels are bonded together to create a larger upstream bonding group in the MAC domain. A MAC domain is a logical sub-component of a Cisco CMTS router and is responsible for implementing all DOCSIS functions on a set of downstream and upstream channels.

The Upstream Channel Bonding feature supports upstream traffic in Multiple Transmit Channel (MTC) mode for data and video services as these services require more bandwidth than voice-based services. Voice-based services either use the traditional single upstream channel or a single upstream channel bonding group configuration. Any traffic contract that exceeds 30 Mbps requires upstream channel bonding as the physical capacity of a single RF channel in DOCSIS cannot exceed 30 Mbps.

The Upstream Channel Bonding feature is supported on the Cisco cBR-8 router. Upstream data from the subscriber comes through the upstream ports (US0-US19) that are automatically configured on the cable interface line card. The cable interface line card processes the data and sends it across the backplane to the WAN card and out to the Internet.

The table below lists the downstream and upstream frequency supported on the cable interface line card.

Table 36: Downstream and Upstream Frequency

Line Card	Downstream Frequency	Upstream Frequency
Cisco cBR-8 CCAP	55-999 MHz[1]	The upstream frequency range for the Cisco cBR-8 CCAP line card is from 5 to 85 MHz irrespective of the region and Annexure configuration.

[1] This frequency range is subjected to the frequency restriction of the attached EQAM device.

Multiple Transmit Channel Mode

Multiple Transmit Channel mode is a CM capability that enables CMs to send upstream traffic on multiple upstream channels. You can enable the MTC mode on a cable interface line card:

- MTC mode for all CMs in a MAC domain—The MTC mode for all CMs in a MAC domain is enabled by default on an upstream bonding capable cable interface line card.

Multiple Receive Channel Mode

MRC mode is a CM capability that enables CMs to receive downstream traffic on multiple downstream channels. The MRC mode is enabled by default on an upstream bonding capable cable interface line card. You can enable or disable the MRC mode in the MAC domain during or after the CM registration using the **cable mrc-mode** command.

Dynamic Range Window and Transmit Power Levels for Upstream Channel Bonding

The dynamic range window functionality is based on the CableLabs DOCSIS 3.0 MAC and Upper Layer Protocols Interface Specification and DOCSIS 3.0 Specification. This requires a DOCSIS 3.0 CM to have upstream transmit channel power level within a 12 dB range for all channels in its transmit channel set (TCS).

DOCSIS 1.x or 2.0 CMs operating with a single upstream channel, in non-MTC mode, have a higher maximum transmit power level than DOCSIS 3.0 CMs operating in the MTC mode with two or more upstream channels. That is, the maximum transmit power level per channel is reduced in the MTC mode.

When the upstream attenuation exceeds the maximum transmit power level, a DOCSIS 3.0 CM attempting to register in the MTC mode may fail to come online, or register in partial mode. The CM fails to register when the transmit power level of all upstream channels in its TCS exceeds the maximum transmit power level.

If the CM has some upstream channels that are within the maximum transmit power level, the CM may come online in partial mode. However, the upstream channels that exceed the maximum transmit power level are marked as down and cannot be used for upstream traffic.

To verify the transmit power levels on a CM, use the show cable modem command with the verbose keyword. This command displays the following transmit power values for each assigned upstream channel:

- Reported Transmit Power—This is the reported transmit power level by the CM for each upstream channel.
- Minimum Transmit Power—This is the minimum transmit power level that the CM in the MTC mode could transmit at for the upstream channel.
- Peak Transmit Power—This is the maximum transmit power level that the CM in the MTC mode could transmit at for the upstream channel.

To support upstream channel bonding, the minimum transmit power must be less than or equal to the reported transmit power, and the reported transmit power must be less than or equal to the peak transmit power. The peak transmit power and minimum transmit power levels are derived from the CM TCS assignment and each individual upstream channel configuration.

If the minimum transmit power is higher than the reported transmit power, or the reported transmit power is higher than the peak transmit power, the CM may not come online or may register in partial mode.

You can troubleshoot this transmit power problem in the following two ways:

- Insert an additional amplifier to reduce the upstream attenuation so that the upstream transmit power falls within the allowed transmit power range (12 dB).
- Disable the MTC mode. To switch the CM from the MTC mode to non-MTC mode, disable the bonded-bit (bit-0) in type, length, value (TLV) 43.9.3 using the CM configuration file.

Extended Transmit Power

During the early deployment of DOCSIS 3.0 CMs, additional power is required from the CMs in order to compensate for the attenuation in the upstream path. CMs should transmit at extended power level than that defined in DOCSIS. This scenario is generally observed when USCB is enabled at the Cisco CMTS and the DOCSIS 3.0 CMs are operating in MTC mode.

Additional upstream power provides the operator with a power margin that helps overcome the upstream signal loss, reduces the cable plant operational cost, and enables rapid deployment of DOCSIS 3.0 CMs.

The Cisco CMTS supports the following features with which the CMs can transmit data at an extended power:

- Cisco Extended Transmit Power Feature
- DOCSIS Extended Transmit Power Feature

Cisco Extended Transmit Power Feature

The Cisco Extended Transmit Power feature supports DOCSIS 3.0 CMs operating in MTC mode to transmit at a higher power level than the power level specified in the *DOCSIS 3.0 Specification*. This feature is supported only with Cisco DPC3000 CMs.

The Cisco Extended Transmit Power feature enables cable operators to have better control on the cable modems that register in 4-channel or 2-channel MTC mode or in non-MTC mode to transmit at a higher power level than the DOCSIS-defined maximum power level. The cable operator can configure extended transmit power using the **cable tx-power-headroom** command in global configuration mode.

DOCSIS Extended Transmit Power Feature

The DOCSIS Extended Transmit Power feature supports extended upstream transmit power capability as defined in the DOCSIS3.0 Specification. This feature allows the CMs to transmit at a high extended power level to counter the attenuation in the US channel.

The table below lists the new TLVs supported by the DOCSIS Extended Transmit Power feature.

Table 37: TLVs for DOCSIS Extended Power Feature

TLV Name	Type	Length	Value
Extended Upstream Transmit Power Support	16	1	0—Extended Upstream Transmit Power Support Off 1—Extended Upstream Transmit Power Support On 2-255—Reserved
Extended Upstream Transmit Power CM Capability	5.40	1	0, 205-244 (units of one-quarter dB)

The Cisco CMTS sends TLV16 to inform the CM if the DOCSIS Extended Transmit Power feature is enabled. The CM in turn, sends TLV5.40 to the Cisco CMTS to communicate its extended power capability. After the negotiations are complete, the CM can transmit at an extended power.

DOCSIS Extended Transmit Power feature is enabled by default. Use the cable upstream ext-power command to enable or disable this feature. For more information on how to enable or disable DOCSIS Extended Power feature, see Configuring DOCSIS Extended Transmit Power Feature, on page 213.

Note DOCSIS Extended Transmit Power feature takes precedence, if both Cisco Extended Transmit Power feature and DOCSIS Extended Transmit Power feature are configured.

Reduced Transmit Channel Set

The Reduced Transmit Channel Set feature enables the Cisco CMTS router to reduce upstream channel set assignment based on the total power budget of the CM. For example, a reduction from four to two upstream channels gains 3 dB headroom. Further reduction from two channels to a single channel gains another 3 dB headroom, and the CM starts operating in non-MTC mode.

In order to take advantage of the reduced upstream channel set, the corresponding static bonding groups must be configured. For example, a MAC domain is configured with a bonding group having four channels. A CM with the reduced channel set of two is unable to match to the 4-channel bonding group, and can only be matched to a bonding group with two channels or less.

The Reduced Transmit Channel Set feature is helpful when a DOCSIS 3.0 CM is required to increase its total transmit power by 3 dB. For example, a DOCSIS 1.0 or 2.0 CM supports a maximum transmit power of 58 dBmV for Quadrature Phase Shift Keying (QPSK) modulation, while a DOCSIS 3.0 CM supports a maximum transmit power of 61 dBmV. In this case, the DOCSIS 3.0 CM operating in 4-channel MTC mode has a reduction in the maximum transmit power per upstream channel. This feature enables the Cisco CMTS router to support reduced input power level by 6 dB to prevent upstream path attenuation.

T4 Multiplier

T4 multiplier is the T4 timeout multiplier value of the default T4 timeout values as defined in for cable modems that are in the MTC mode. The default value is derived from the number of channels in the modem transmit channel set. You can change the default T4 multiplier value using the cable upstream ranging-poll command in cable interface configuration mode.

The T4 timeout multiplier values range is from 1 to 10. If the T4 multiplier value is equal to 1, the cable modem will T4 time out in 30 seconds (that is, 1 x 30 = 30). If you change the T4 multiplier to 4, then the new T4 timeout value will be 120 seconds (that is, 4 x 30 = 120).

Note If the T4 timeout multiplier is not configured from the range (1 - 10), then the CMTS uses the T4 timeout value of modem as T4 timeout value. For example, if the T4 timeout of the modem is 90 seconds, then the CMTS applies 3 as the T4 multiplier.

In the MTC mode, you can increase the T4 timeout value in order to reduce the router overhead associated with processing of ranging request (RNG-REQ) slots and ranging response messages. If an RNG-RSP message does not contain a T4 timeout multiplier value, then the CM uses the default T4 timeout value.

Fiber Node Configuration for Upstream Channel Bonding

The fiber node configuration on a Cisco CMTS router is used to define MAC domain downstream service groups (MD-DS-SGs) and MAC domain upstream service groups (MD-US-SGs) as defined in DOCSIS 3.0. Only the DOCSIS 3.0 certified modems use this information.

In hybrid fiber coaxial (HFC) networks, all CMs connected to the same coaxial segment of a fiber node reach the same set of downstream and upstream channels on one or more Cisco CMTS routers located at the headend.

A CM is physically connected to only one fiber node. The fiber node must include at least one primary-capable controller for the CM connected to the fiber node to be operational.

New TLVs for Upstream Channel Bonding

The table below lists the new CableLabs defined type, length, values (TLVs) for the Upstream Channel Bonding feature.

Table 38: New TLVs for Upstream Channel Bonding

TLV Name	Type	Length	Value
CM vendor ID	43.8	3	Per vendor definition
Cable modem attribute mask	43.9	n	Cable modem attribute mask subtype encodings

A Cisco CMTS can have multiple upstream channel bonding groups (USBG) configured. Each of these bonding groups can include upstream channels with different upstream frequencies. Some bonding groups can include channels with frequencies within the extended frequency range (see Table 36: Downstream and Upstream Frequency, on page 190). An HFC network consists of several types of CMs, each supporting standard or extended upstream frequencies.

When you register a CM, the Cisco CMTS does not assign bonding groups based on the upstream frequency range supported by that CM. The assignment of the bonding groups is done to balance the CM count on each of the bonding groups. This may lead to assignment of a bonding group, in the extended frequency range, to a CM that lacks the extended frequency support. As a result, the CM will not be able to register. This scenario is generally observed in the Cisco cBR-8 CCAP line card deployment (containing a mix of CMs), which supports frequency as high as 85MHz (see Table 36: Downstream and Upstream Frequency, on page 190).

If the Cisco CMTS assigns a USBG with a channel within the extended frequency range to a CM limited to the standard frequency range, that CM may not be able to register on that upstream bonding group. Use the TLV 43.9.3 (CM US Required Attribute Mask) or TLV 43.9.4 (CM US Forbidden Attribute Mask) as a workaround. These TLVs enable the Cisco CMTS to assign CM to a USBG, which is in the upstream frequency range supported by that CM.

The default attributes (in hexadecimal) on a CM Attribute Mask (TLV 43.9) are “80 00 00 00", which means by default the mask is all zeroes with the bonding bit enabled. The first four bytes are pre-defined while the last four bytes are user defined. In order to enable Cisco CMTS to assign bonding groups based on the frequency range supported by CMs, complete these steps:

1. Configure a mask, using TLV 43.9.3 or TLV 43.9.4, by modifying the last four bytes. The mask should be configured such that a unique attribute is assigned to each of the bonding groups.
2. Apply this mask to the CM configuration file. CMs supporting extended frequency, can register with any USBGs, irrespective of the configured frequency range of the USBG. CMs supporting standard frequency, can only register with USBGs that are configured with standard frequency range.

Apply the mask you have configured above, to the CMs that support standard or extended frequency ranges. However, the ONLY CMs that need to employ the attribute mask are the ones with the standard frequency range, since they will not be able to register with the USBG configured with extended upstream frequency range. No attribute mask on the extended frequency supporting CMs means that these modems will be assigned any USBG.

The Cisco CMTS uses this mask, received in the CM configuration file during registration, to decide which USBG should be assigned to the CM.

Upstream Weighted Fair Queuing

The upstream weighted fair queuing (WFQ) is a quality of service (QoS) feature that enables the Cisco CMTS router to allocate optimum bandwidth to upstream service flows based on the WFQ parameter configurations. To enable upstream WFQ, you must configure either the class-based or activity-based WFQ on a cable interface.

The following WFQ parameter configurations are supported:

Class-Based Weighted Fair Queuing

In the class-based weighted fair queuing configuration, allocation of available bandwidth is dependent on the service flows that are active in a service class. A service class is a group of queuing attributes configured on the Cisco CMTS router. The class must have at least one active service flow. The class receives its portion of the available bandwidth based on the weight of the class. By default, each class (0 to 7) has a weight of “class + 1.” For example, the class 0 has a weight of 1, and class 1 has a weight of 2.

Activity-Based Weighted Fair Queuing

In the activity-based weighted fair queuing configuration, allocation of available bandwidth is based on the service class and the total number of service flows that are active in a map for the service class. A service class with higher number of service flows receives the larger percentage of bandwidth.

Custom Weight for Service Flow Priorities

The weighted fair queuing functionality helps the Cisco CMTS router share the available bandwidth based on the weight of the service flow priorities specified for outstanding requests from an upstream service flow. Priority refers to the service flow priority specified in the CM configuration file, or the Cisco CMTS service class configuration. By default, the weight of a priority is equal to "priority+1." For example, priority 0 has a weight of 1, and priority 1 has a weight of 2. A higher priority provides more weight to the outstanding request. The custom weight can be specified for a total of eight priorities (0 to 7) in a service class.

The priority parameter refers to the priority of traffic in a service flow ranging from 0 (the lowest) to 7 (the highest). In the upstream traffic, all of the pending high priority service flows are scheduled for transmission before low priority service flows. You can configure the weight for priorities based on how much weight is appropriate per priority.

The table below lists the default weight for each service flow priority.

Table 39: Default Weight of Service Flow Priorities

Service Flow Priority	Default Weight
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8

Upstream Scheduler and Service Flows

A DOCSIS-qualified Cisco CMTS router can provide varied upstream scheduling modes for different packet streams or applications using upstream service flows. A service flow represents either an upstream or a downstream flow of data. A unique service flow ID (SFID) identifies each service flow. Each service flow can have its own quality of service (QoS) parameters, such as maximum throughput, minimum guaranteed throughput, and priority. In the case of upstream service flows, you can also specify a scheduling mode.

Scheduling is a process that enables the Cisco CMTS router to receive bandwidth requests and grant timeslots to CMs for the upstream traffic. The Cisco CMTS router periodically creates a grant map for each enabled upstream channel. The map grants individual timeslots to enable CMs to place packets on the upstream channels.

DOCSIS 3.0 describes a method by which a CM creates an upstream service flow. The following scheduling types enable the Cisco CMTS router to allocate bandwidth for upstream service flows:

- Unsolicited grant service (UGS)
- Solicited grant service

The unsolicited grant service is primarily used for voice. In the case of UGS, the CM does not have to explicitly request grants from the Cisco CMTS router whereas in the solicited grant service the CM has to explicitly request grants from the Cisco CMTS router. The solicited grant service is primarily used for best effort (BE) services.

Unlike DOCSIS 2.0, DOCSIS 3.0 allows multiple outstanding requests per service flow. For more information about the upstream scheduler, see the *Upstream Scheduler Mode for the Cisco CMTS Routers* feature guide at the following URL:

http://www.cisco.com/en/US/docs/ios/cable/configuration/guide/cmts_upstm_sch_md_ps2209_TSD_Products_Configuration_Guide_Chapter.html

Upstream Service Flow Fairness

The service flows in the same class receive approximately the same amount of bandwidth. Fairness resolves the bandwidth distribution disparity among various service flows including:

- non-bonded service flow vs bonded service flows
- Service flows on modems of different vendors, i.e Intel/TI vs Broadcom
- Service flows associated with different sized bonding groups, i.e. 1,2 4 channels

The upstream scheduler supports flow based queuing. When Upstream Service Flow Fairness is configured, the upstream scheduler determines the order and amount of BW a service flow should receive based on it's current consumption relative to other flows in the flows in the same class.

Use the **cable upstream qos fairness** command to configure the Upstream Service Flow Fairness feature. Use this command in interface configuration mode (or MAC Domain configuration mode).

Distribution of Traffic across all Channels in a USBG

When upstream channel bonding (USCB) is enabled, the Distribution of Traffic across all Channels in a USBG feature can be used to balance the bandwidth utilization across upstream channels on one upstream bonding group.

This feature balances the utilization only if there is one upstream channel bonding group configured per MAC domain.

Restrictions:

- This feature is supported only on one upstream bonding group under a MAC domain. When multiple upstream bonding groups are configured under a MAC domain, the utilization is unfair.
- All the channels must be configured in one upstream bonding group under the same MAC domain.
- This feature is used only for UB-online cable modems.

The USCB Balancing Scheduler may be enabled or disabled using the **cable upstream balance-scheduler** command in the interface (config-if) configuration mode.

DOCSIS 3.0 Load Balancing with USBG Smaller than Cable Modem Capabilities

When using USCB in a service group with USBGs containing fewer upstream channels than the total upstream channel set with DOCSIS 3.0 load balancing enabled, the CMTS can assign a Transmit Channel Set (TCS) to DOCSIS 3.0 cable modems for potential use which falls outside of the configured USBG. The CMTS will try to bind smaller UBGs and default single channel bonding groups into a bigger channel set in order to increase the cable modem services. For example, a DOCSIS 3.0 cable modem receiving the larger TCS can use these additional channels for dynamic service flow addition. The DOCSIS 3.0 Load Balancing feature can also move cable modems to upstream channels that are not explicitly configured with USBGs as a result of the larger TCS.

If you activate DOCSIS 3.0 Load Balancing while using upstream bonding, ensure that the upstream bonding group configuration is embedded and aligned by performing the following:

- Configure USBGs, which is matched to cable modem capabilities within the service group, such as a 4 channel USBG, 2 channel USBG, and 3 channel USBG as applicable.
- Ensure that configured USBGs are optimal for the upstream channel set based on modem capabilities within the service group. For example, if four upstream channels are available, channels 0+1 and 2+3 should each be an USBG to avoid dynamic TCS creating sub optimal bonding scenarios.
- Alternatively, you can choose to shut down any upstream channels that is not configured in USBGs which is not be used for bonding.

Cisco cBR-8 CCAP Line Card Rate Limiting

The rate limiting functionality enables you control the aggregated rate and CPU consumption of upstream traffic for DOCSIS 3.0 bonded service flows on the Cisco cBR-8 CCAP line card. The rate limiting functionality is configured by default on the Cisco cBR-8 CCAP line card. However, the default configuration can be modified using the **cable upstream rate-limit-ccf** command.

The rate limiting functionality uses the following two rate limiting methods:

- Aggregated rate limiting—This is based on Peripheral Component Interconnect (PCI) bus aggregated throughput. The throughput is per line card for all bonded service flows. You can modify the default throughput and burst rate configuration. The maximum allowed throughput is 115 Mbps.
- CPU-based rate limiting—This method controls the CPU consumed by Continuous Concatenation and Fragmentation (CCF) and ensures that the line card functions properly when traffic is overloaded with bonded service flows. The default configuration allocates 50 per cent of CPU to CCF. You can modify the default CPU threshold value and burst rate as required.

SID Tracking

The service ID (SID) tracking functionality enables you to track events related to upstream bandwidth requests and processing of grants. The SID tracker module can track events for a maximum of two service flows per MAC domain. The SID tracker module tracks up to 40,000 events per service flow on a cable interface line card.

You can enable SID tracking for the following types of events:

- DOCSIS 2.0 bandwidth request
- DOCSIS 3.0 bandwidth request
- Grant

- Pending grant (due to traffic congestion)
- Pending grant (due to shaping)

You can enable SID tracking using the **track keyword** along with the **debug cable interface sid** command. To verify SID tracking, use the **show interface cable upstream debug** command in privileged EXEC mode.

Service ID Clusters

A Cisco CMTS router can assign one or more service ID clusters to the upstream bonded service flows (upstream service flows assigned to an upstream bonding group) at the time of service flow creation. A SID cluster contains one SID per upstream in a bonding group. A CM uses one of the SIDs defined in the SID cluster for the upstream interface when the CM sends a bandwidth request. The CM chooses a SID or a SID cluster based on the SID cluster switching criteria.

For example, assume that a CM has ranged on upstream channels from 1 to 4. The Cisco CMTS router creates a bonded service flow and assigns a single SID cluster to each upstream channel. That is SID1 for UP1, SID2 for UP2, SID3 for UP3, and SID4 for UP4. Now, the CM can send a bandwidth request using any of the four upstream channels. That is, the CM can request bandwidth on any of the upstream interfaces in the SID cluster using the SID defined for the particular upstream. The Cisco CMTS router grants bandwidth to the CM using any combination of upstream channels.

How to Configure Upstream Channel Bonding

Note Before configuring the Upstream Channel Bonding feature, ensure that the fiber node is configured. The fiber node must be configured in accordance with the physical plant topology.

The following tasks describe how to configure Upstream Channel Bonding on the Cisco cBR-8 router:

Enabling MTC Mode on a Cisco CMTS Router

To section explains how to enable the MTC mode on a Cisco CMTS router.

Default MTC Mode Configuration on a Cisco CMTS Router

By default, the MTC mode is configured on a cable interface line card. With this default configuration, the Cisco CMTS router enables the MTC mode on a per MAC domain basis depending on the configuration file of each CM. When the CM configuration file has the bonded-bit (bit-0) enabled in TLV 43.9.3 (cable modem upstream required attribute mask), the Cisco CMTS router enables the CM to come online in the MTC mode. If the CM configuration file does not have the bonded-bit on, the CM comes online in non-MTC mode.

For more information on how to add the required attribute in the CM configuration file, see Example: Enabling MTC Mode for a Single CM Using the CM Configuration File, on page 215.

Enabling MTC Mode for All CMs

Note

- For DOCSIS 3.1 cable modems, the CMTS router must be configured to use MTC mode.
- This MTC mode configuration supersedes the default MTC mode configuration (per CM basis) with the required attribute. To disable the MTC mode for all CMs in a MAC domain, use the **no** form of the **cable mtc-mode** command. If the MTC mode is enabled and the forbidden mask of the upstream bonding in TLV 43.9.4 is disabled, the CM does not support the Upstream Channel Bonding feature.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable mtc-mode** **Example:** `Router(config-if)# cable mtc-mode`	Enables MTC mode at the MAC interface for all CMs.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring UCSB Required Attribute

If the CM configuration file has TLV 43.9.3 (CM upstream required attribute mask) configured and bonded bit is set to 1, then the modem comes UB-online on a MAC domain basis. If the CM configuration file has no TLV 43.9.3 or the bonded bit is not set to 1, then the modem comes online with a single upstream channel on a MAC domain basis.

Note Without this configuration, the modem comes UB-online on the MAC domain regardless of whether the TLV 43.9.3 is configured in the modem configuration file.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** { *slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable mtc-mode required-attribute** **Example:** `Router(config-if)# cable mtc-mode required-attribute`	Enable enforcement of required CM attribute on UCSB.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Creating a Bonding Group

An upstream bonding group is created by combining multiple upstream channels together on a cable interface line card.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*}	Specifies the cable interface line card on a Cisco CMTS router.

	Command or Action	Purpose
	Example: `Router(config)# interface cable 7/0/0`	
Step 4	**cable upstream bonding-group** *id* **Example:** `Router(config-if)# cable upstream bonding-group 200`	Creates the bonding group on the specified cable interface.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

What to do next

After creating an upstream bonding group, you must add upstream channels to the bonding group.

Adding Upstream Channels to a Bonding Group

Restriction DOCSIS 3.0-certified CMs support only four upstream channels on an upstream bonding group. These CMs do not accept additional upstream channels that are added to a bonding group.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream bonding-group** *id* **Example:** `Router(config-if)# cable upstream bonding-group 200`	Creates the bonding group on the specified interface.

	Command or Action	Purpose
Step 5	**upstream** *number* **Example:** `Router(config-upstream-bonding)# upstream 1`	Enters upstream bonding configuration submode and adds an upstream channel to the upstream bonding group. **Note** Upstream channel needs to be bonded to mac-domain first before adding it to the bounding group. For detailed configuration steps of the upstream channel bonding, please refer to Configuration Example for Upstream Channel Bonding A maximum of 16 upstream channels can be configured for each MAC Domain, which are divided into two groups: • Group 1: upstream channel 0-7 • Group 2: upstream channel 8-15 The **upstream bonding-group** should include all the upstream channels either from Group 1 or Group 2 only.
Step 6	**end** **Example:** `Router(config-upstream-bonding)# end`	Exits upstream bonding configuration submode and returns to privileged EXEC mode.

Adding Upstream Channel Ports to a Fiber Node

You must add upstream channel controllers to a fiber node in order to complete the basic upstream channel bonding configuration on a cable interface line card. The fiber node must contain all upstream and downstream controllers reached by the CMs.

Restriction

- Configuration of a fiber node is valid only if all upstream channels inside the fiber node have different upstream frequencies.
- For any two upstream channels mapped to the upstream cable controllers in the same fiber node where a spectrum group is assigned to one upstream channel, and a frequency is assigned to the other upstream channel, any overlap between any bands associated with the spectrum group of the upstream channel and the frequency of the upstream channel will result in an invalid fiber node configuration. That is a fixed frequency cannot overlap with another upstream channel's available spectrum group bands.

Note The fiber node configuration must be done in accordance with the physical plant topology.

Procedure

	Command or Action	Purpose
Step 1	**enable**	Enables privileged EXEC mode.

	Command or Action	Purpose
	Example: `Router> enable`	• Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable fiber-node** *fiber-node-id* **Example:** `Router(config)# cable fiber-node 2`	Enters fiber node configuration mode.
Step 4	**upstream Upstream-Cable** *slot*/*subslot*/*port* **Example:** `Router(config-fiber-node)# upstream Upstream-Cable 7/0/1`	Specifies the upstream channel ports for a fiber node.
Step 5	**end** **Example:** `Router(config-fiber-node)# end`	Exits fiber node configuration mode and returns to privileged EXEC mode.

Configuring the Class-Based Weighted Fair Queuing

In the case of a class-based configuration, allocation of available bandwidth is dependent on the service flows that are active in a service class.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream qos wfq class** **Example:**	Enables class-based weighted fair queuing.

	Command or Action	Purpose
	`Router(config-if)# cable upstream qos wfq class`	
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring the Activity-Based Weighted Fair Queuing

In the activity-based configuration, allocation of available bandwidth is based on the service class and the total number of service flows that are active in a map for the service class.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream qos wfq activity** **Example:** `Router(config-if)# cable upstream qos wfq activity`	Enables activity-based weighted fair queuing.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring Custom Weights for Service Flow Priorities

The WFQ functionality helps the Cisco CMTS router share the available bandwidth based on the weight of the service flow priorities specified for outstanding requests from an upstream service flow.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream qos wfq weights** *priority0-priority7* **Example:** `Router(config-if)# cable upstream qos wfq weights 10 20 30 40 50 60 70 80.`	Enables custom weight configuration for all the service flow priorities in a service class. **Note** You must specify custom weight values for all the eight service flow priorities (0 to 7) when you modify the default weights of priorities. The valid range is from 1 to 255.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring the SID Cluster

This section explains how to configure and assign SID cluster to an upstream bonded service flow.

To achieve desired upstream bonded speed, you can use the **cable sid-cluster-group num-of-cluster** to achieve desired upstream bonded speeds, and this takes precedence over **cable sid-cluster-group dynamic**. Alternatively you can use a large upstream Max Traffic burst value in the cable modem file (such as 30 kB). The Max Concat burst value in the cable modem file does not need change because DOCSIS 3.0 uses continuous concatenations and fragmentation (CCF), and can therefore use the default value of 3044 in the Max Concat field.

Note If the **cable sid-cluster-group** command is not used, the router accepts the default SID cluster configuration. By default, **dynamic sid-cluster assignment** is configured. Similarly, if the **cable sid-cluster-switching** command is not used, the router accepts the default SID cluster switchover criterion. That is, only one request can be made using the SID cluster.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.

Step 4	**cable sid-cluster-group** [**dynamic** [*max_rate_threshold*] **| req-multiplier** *value* **| num-of-cluster** *number*]
	Example:
	`Router(config-if)# cable sid-cluster-group dynamic`
	`Router(config-if)# cable sid-cluster-group dynamic 3000000000`
	`Router(config-if)# cable sid-cluster-group req-multiplier 12`
	`Router(config-if)# cable sid-cluster-group num-of-cluster 2`
		Creates a SID cluster group. Starting from Cisco IOS XE Gibraltar 16.12.1z release, you can configure a maximum rate threshold for the service flow, because the original threshold is not appropriate in some cases. If the maximum rate of the service flow is larger than the configured threshold, two SIDs will be allocated to the service flow instead of one SID.

Step 5	**cable sid-cluster-switching [max-outstanding-byte** *value* **| max-request** *value* **| max-time** *seconds* **| max-total-byte** *value***]**
	Example:
	`Router(config-if)# cable sid-cluster-switching max-outstanding-byte 4444`
	`Router(config-if)# cable sid-cluster-switching max-request 222`
	`Router(config-if)# cable sid-cluster-switching max-time 444`
	`Router(config-if)# cable sid-cluster-switching max-total-byte 67890`
		Specifies SID cluster switchover criteria.

Step 6	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

What to do next

Use the **show running-config all** command to verify the SID cluster configuration. Following is a sample output of the command:

```
Router# show running-config all
.
.
cable sid-cluster-group req-multiplier 4
```

Configuring the Channel Timeout for a Cable Modem

The channel timeout configuration allows you to specify the maximum time that a CM can spend performing initial ranging on the upstream channels described in the Registration Response (REG-RSP) and REG-RSP-MP messages. The default channel timeout value (60 seconds) is automatically configured.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable init-channel-timeout** *value* **Example:** `Router(config-if)# cable init-channel-timeout 160`	Specifies the maximum time that a CM can spend performing initial ranging on the upstream channels.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring Cable Upstream Resiliency

The cable upstream resiliency module ensures that a CM remains operational if one or more non-primary upstream service flows of the CM enter temporary or persistent error states. This module enables a Cisco CMTS router to handle various events and maintain the transmit channel set of each CM.

In the event of the primary upstream service flow failure, the upstream resiliency module forces the CM to go offline.

For a Multiple Transmit Channel (MTC) modem, the (NRTPS), Real-time Polling Service (RTPS), (UGS), and (UGS-AD) upstream service flows on an impaired upstream channel is moved to another good upstream channel in the cable modem without resetting the cable modem.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable upstream resiliency data-burst polling-interval** *number* **Example:** `Router(config)# cable upstream resiliency data-burst polling-interval 60`	Configures the polling interval for data-burst resiliency in seconds. The range is from 5 to 3600. The default configuration for polling-interval is 60.
Step 4	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.

Step 5	**cable upstream resiliency** {**channel-down-detect** *number* | **data-burst snr** *number* **ufec** *number* **cfec** *number* **hysteresis** *number* | **modem-offline-detect** *number* | **on-failure** {**disable-channel** | **extended-ranging** | **reset-modem**} | **sf-move** {**NRTPS** | **RTPS** | **UGS** | **UGS-AD**} }
	Example:
	`Router(config-if)# cable upstream resiliency channel-down-detect 68`
	`Router(config-if)# cable upstream resiliency modem-offline-detect 16`
	`Router(config-if)# cable upstream resiliency on-failure disable-channel`
	`Router(config-if)# cable upstream resiliency sf-move NRTPS`
	`Router(config-if)# cable upstream resiliency sf-move RTPS`
	`Router(config-if)# cable upstream resiliency sf-move UGS`
		Configures upstream resiliency for bonded upstream service flows.

	Command or Action	Purpose

	`Router(config-if)# cable upstream resiliency sf-move UGS-AD`
	
	`Router(config-if)# cable upstream resiliency data-burst snr 24 ufec 1 cfec 0 hysteresis 3`	

Step 6	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring Rate Limiting on the Cisco cBR-8 CCAP Line Card

The rate limiting functionality is configured by default on the Cisco cBR-8 CCAP line card. However, the default configuration can be modified using the cable upstream rate-limit-ccf command.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

Step 3	**cable upstream rate-limit-ccf** [**aggregated-burst** *value* | **aggregated-throughput** *value* | **cpu-burst** *value* | **cpu-threshold** *value*]
	Example:
	`Router(config)# cable upstream rate-limit-ccf aggregated-burst 25000`
	
	`Router(config)# cable upstream rate-limit-ccf aggregated-throughput 540000`
	
	`Router(config)# cable upstream rate-limit-ccf cpu-burst 30`
	
	`Router(config)# cable upstream rate-limit-ccf cpu-threshold 60`
		Configures rate limiting parameters for upstream bonded service flows on a cable interface line card.

Step 4	**end** **Example:** `Router(config)# end`	Exits global configuration mode and returns to privileged EXEC mode.

Enabling Upstream Related Events for CM Status Reports

You can enable upstream related CM status events only on a cable interface line card. You can enable the following upstream related CM status events per interface using the cable cm-status enable command:

- T4 time-out
- T3 re-tries exceeded
- Successful ranging after T3 re-tries exceeded

For details on how to enable upstream and downstream related CM status events, see the Wideband Modem Resiliency feature guide at the following URL:

http://www.cisco.com/en/US/docs/ios/cable/configuration/guide/ubr_wm_resiliency.html

Modifying the Bonding Group Attributes

Bonding group attributes are automatically configured for each upstream bonding group. You can modify them using the **attributes** command in upstream bonding configuration mode.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream bonding-group** *id* **Example:** `Router(config-if)# cable upstream bonding-group 200`	Creates the bonding group on the specified cable interface and enters the upstream bonding configuration mode.
Step 5	**attributes** *value* **Example:** `Router(config-upstream-bonding)# attributes eeeeeeee`	Modifies the attribute value for the specified bonding group.
Step 6	**end** **Example:**	Exits upstream bonding configuration mode and returns to privileged EXEC mode.

	Command or Action	Purpose
	`Router(config-upstream-bonding)# end`	

Modifying the Ranging Poll Interval on Upstream Channels

You can change the default ranging poll interval (20 seconds) on upstream channels using the cable upstream ranging-poll command in cable interface configuration mode. You can also specify the T4 timeout multiplier value using this command.

For information on T4 Multiplier, see T4 Multiplier, on page 193 .

Note We recommend that you do not modify the default ranging poll interval unless required. With the default configuration, a DOCSIS 2.0 CM in non-MTC mode performs ranging on one upstream channel every 20 seconds.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream ranging-poll** [**interval** *value* | **t4-multiplier** *timeout_value*] **Example:** `Router(config-if)# cable upstream ranging-poll interval 24000 t4-multiplier 4`	Specifies the ranging poll interval for upstream channels. **Note** If **t4-multiplier** *timeout_value* is not configured, then the CMTS uses the the T4 timeout of the modem. For example, if the T4 timeout of the modem is 90 seconds, then the CMTS will apply 3 as T4 multiplier for the modem.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring the Reduced Channel Set Assignment

You need to configure the transmit power offset budget to enable the Cisco CMTS router to reduce upstream channel set assignment based on the total power budget of the CM.

Note The threshold value specified for the power budget offset (max-channel-power-offset) must be less than the power threshold value (power-adjust continue) that determines the value of the Ranging Status field in the Ranging Response (RNG-RSP) messages that the Cisco CMTS router sends to the CM. You can specify the power threshold value using the **cable upstream power-adjust** command.

Before you begin

- Configure extended transmit power using the **cable tx-power-headroom** command in global configuration mode.
- Ensure that corresponding static bonding groups are configured.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream max-channel-power-offset** *dB-value* **Example:** `Router(config-if)# cable upstream max-channel-power-offset 2`	Specifies the power offset value for upstream channels.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits cable interface configuration mode and returns to privileged EXEC mode.

Configuring DOCSIS Extended Transmit Power Feature

The DOCSIS Extended Transmit Power feature is enabled by default on the Cisco CMTS. However, the default configuration can be modified using the cable upstream ext-power command.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** {*slot/subslot/port* | *slot/subslot/cable-interface-index* | *slot/port* | *slot/cable-interface-index*} **Example:** `Router(config)# interface cable 7/0/0`	Specifies the cable interface line card on a Cisco CMTS router.
Step 4	**cable upstream ext-power** **Example:** `Router(config-if)# cable upstream ext-power`	Enables the DOCSIS Extended Transmit Power feature on the Cisco CMTS. Using the **no** form of this command disables the DOCSIS Extended Transmit Power feature.
Step 5	**end** **Example:** `Router(config-if)# end`	Exits interface configuration mode and returns to privileged EXEC mode.

Troubleshooting Tips

The following debug commands help you troubleshoot an improper upstream channel bonding configuration and its related features:

- **debug cable cm-status**—Provide debugging information about CM status messages on the Cisco CMTS routers.
- **debug cable mdd**—Provides debugging information about MAC domain descriptor (MDD).
- **debug cable md-sg**—Provides information about service group debugging messages.
- **debug cable ubg**—Provides debugging information about upstream bonding groups.

Configuration Example for Upstream Channel Bonding

The following example shows how to configure the basic upstream channel bonding on the Cisco cBR-8 CCAP line card interface 7/0/0 on the Cisco cBR-8 router:

```
controller Upstream-Cable 7/0/0
us-channel 0 frequency 10000000
us-channel 0 channel-width 3200000 3200000
us-channel 0 ingress-noise-cancellation 50
us-channel 0 docsis-mode atdma
us-channel 0 minislot-size 2
us-channel 0 modulation-profile 221
us-channel 0 equalization-coefficient
no us-channel 0 shutdown
us-channel 1 frequency 16400000
us-channel 1 channel-width 6400000 6400000
us-channel 1 ingress-noise-cancellation 50
us-channel 1 docsis-mode atdma
us-channel 1 minislot-size 1
us-channel 1 modulation-profile 221
us-channel 1 equalization-coefficient
no us-channel 1 shutdown
us-channel 2 frequency 22800000
us-channel 2 channel-width 6400000 6400000
us-channel 2 docsis-mode atdma
us-channel 2 minislot-size 1
us-channel 2 modulation-profile 221
us-channel 2 equalization-coefficient
no us-channel 2 shutdown
us-channel 3 frequency 29200000
us-channel 3 channel-width 6400000 6400000
us-channel 3 docsis-mode atdma
us-channel 3 minislot-size 1
us-channel 3 modulation-profile 221
us-channel 3 equalization-coefficient
no us-channel 3 shutdown
us-channel 4 channel-width 1600000 1600000
us-channel 4 docsis-mode tdma
us-channel 4 minislot-size 4
us-channel 4 modulation-profile 21
us-channel 4 shutdown
us-channel 5 channel-width 1600000 1600000
us-channel 5 docsis-mode atdma
us-channel 5 minislot-size 4
us-channel 5 modulation-profile 221
us-channel 5 shutdown
!

interface Cable7/0/0
load-interval 30
downstream Integrated-Cable 7/0/0 rf-channel 0
downstream Integrated-Cable 7/0/0 rf-channel 8
downstream Integrated-Cable 7/0/0 rf-channel 16
upstream 0 Upstream-Cable 7/0/0 us-channel 0
upstream 1 Upstream-Cable 7/0/0 us-channel 1
upstream 2 Upstream-Cable 7/0/0 us-channel 2
upstream 3 Upstream-Cable 7/0/0 us-channel 3
no cable upstream 0 equalization-error-recovery
no cable upstream 1 equalization-error-recovery
no cable upstream 2 equalization-error-recovery
no cable upstream 3 equalization-error-recovery
cable upstream 7 attribute-mask 1FF
cable upstream bonding-group 1
upstream 0
upstream 1
upstream 2
attributes 80000000
cable bundle 1
```

```
cable map-advance static 2000
cable sync-interval 121
cable reduction-mode mta-battery enable
cable privacy accept-self-signed-certificate
end

cable fiber-node 1
description Feed Mac Domain: Cable7/0/0
downstream Integrated-Cable 7/0/0
upstream Upstream-Cable 7/0/0
```

Note Bonded channels are typically from the same connector; however, channels from different connectors in the same MAC domain can also be bonded together. A single MAC domain can support multiple channel bonding groups.

Note Up to 8 frequencies can be stacked to one upstream-cable controller. Once the upstream-cable controller has 8 frequencies stacked, no more frequency left for the adjacent upstream-cable controller.

Example: Enabling MTC Mode for a Single CM Using the CM Configuration File

The following example shows how to enable the MTC required attribute using the CM configuration file:

```
03 (Net Access Control) = 1
Unknown Type 005 = 01 01 01
18 (Maximum Number of CPE) = 4
24 (Upstream Service Flow Encodings)
   S01 (Service Flow Reference) = 1
   S06 (QoS Parameter Set Type) = 7
   S10 (Min Reserved Traffic Rate)= 500000
25 (Downstream Service Flow Encodings)
   S01 (Service Flow Reference) = 2
   S06 (QoS Parameter Set Type) = 7
   S10 (Min Reserved Traffic Rate) = 1000000
29 (Privacy Enable) = 0
43 (Vendor Specific Options)
   S08 (Vendor ID) = ff ff ff
   S009 (Unknown sub-type) = 03 04 80 00 00 00
```

Verifying the Upstream Channel Bonding Configuration

Use the following **show** commands to verify the upstream channel bonding configuration:

- **show cable mac-domain upstream-service-group**
- **show cable fiber-node**
- show interface cable upstream
- **show interface cable service-flow**
- **show cable modem**

To verify the runtime statistics of the upstream service group on a cable interface line card, use the **show cable mac-domain upstream-service-group** command.

To verify the configuration of a fiber node, use the **show cable fiber-node** command.

To verify the bonding groups configured on a cable interface line card, use the **show interface cable upstream** command.

To verify upstream bonding information on a cable interface line card, use the **show interface cable service-flow** command.

To verify the transmit power levels on a CM, use the **show cable modem** command.

Verifying Weighted Fair Queuing for Upstream Service Flows

To verify WFQ parameters configured for upstream service flows on a cable interface line card, use the **show interface cable mac-scheduler** command.

Verifying Rate Limiting for Upstream Bonded Service Flows

To verify the rate limiting criteria configured on the Cisco cBR8 CCAP line card for upstream bonded service flows, use the **show cable rate-limit-ccf** command.

Note The **show cable rate-limit-ccf** command is applicable only to the Cisco cBR8 CCAP cable interface line card.

Verifying Extended Power Transmission

To verify that a CM is transmitting at a higher power level, use the **show cable modem** command.

To list all the CMs that are transmitting at higher power level, use the **show cable modem extended-power** command.

Additional References

The following sections provide references related to the Upstream Channel Bonding feature.

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/techsupport

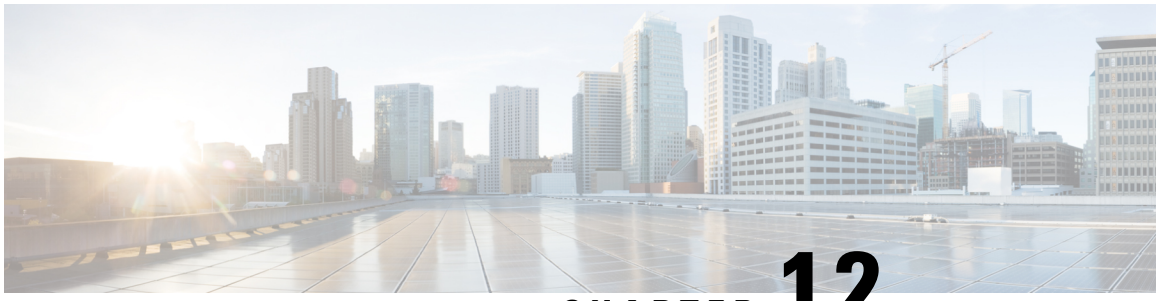
Feature Information for Upstream Channel Bonding

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 40: Feature Information for Upstream Channel Bonding

Feature Name	Releases	Feature Information
Upstream Channel Bonding	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Router.
User-Configurable Dynamic SID Cluster Threshold	Cisco IOS XE Gibraltar 16.12.1z	This feature was introduced on the Cisco cBR Series Converged Broadband Router.



CHAPTER 12

Dynamic Bonding Group

This document describes how to configure Dynamic Bonding Group that helps manage resource of all downstream bonding groups by automatically creating bonding groups.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 219
- Information About Dynamic Bonding Group, on page 220
- Overview of Dynamic Bonding Group, on page 220
- How to configure Dynamic Bonding Group, on page 221
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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 41: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Information About Dynamic Bonding Group

Dynamic Bonding Group (DBG) helps manage the resource of all downstream bonding groups, including automatically creating and reclaiming the downstream bonding groups.

Overview of Dynamic Bonding Group

To reduce the effort required in configuring and managing RCC, the DBG feature implements the automatic creating and reclaiming of the downstream bonding groups. DBG creates the bonding group automatically depending on the channel's load usage. With DBG, the modem is assigned the downstream bonding group

without any static RCC configuration. The load balancing feature leverages DBG to balance traffic among all channels. DBG also accommodates primary channel and CM capacity distributions automatically.

DBG also accommodates primary channel and CM capacity distributions automatically.

Dynamic Bonding Group supports the following:

- Support 896 bonding groups per CLC for CBR-CCAP-LC-40G and CBR-CCAP-LC-40G-R cards.
- Support creating DBGs and reclaiming DBG.
- Support DOCSIS 3.0 and DOCSIS 3.1 channel types.
- Support DOCSIS 3.0 and DOCSIS 3.1 load balance.
- Supports DBG interoperation — Modem registration and load balancing.
- Enhance dynamic load balance — Fixed primary channel movement.
- Enhance raider FPGA SQF — Fairness in channel utilization.

How to configure Dynamic Bonding Group

Enable Dynamic Bonding Group

Feature History

Table 42: Feature History

Feature Name	Release Information	Feature Description
Ability to create 8-channel DBG with contiguous frequency channels	Cisco IOS XE Bengaluru 17.6.1x	Some CMs change to downstream partial mode when moving on the DBG with disconnected frequency channels. This feature allows you to create 8-channel DBG with contiguous frequency channels for load balance purpose.

To enable DBG, run the following commands:

```
ROUTER# config t
Enter configuration commands, one per line. End with CNTL/Z.
ROUTER(config)# cable dynamic-bonding-group
ROUTER(config)# end
ROUTER#
ROUTER#
ROUTER# show run
ROUTER# show running-config | in dynamic-bonding
cable dynamic-bonding-group
```

Sometimes an 8-channel DBG is created with discontinuous frequency channels (such as 0-5 and 8-9) for load balance purpose. In this case, dual tuner 8-channel CM with BRCM3380 chipset may change to downstream partial mode when moving on the DBG with discontinuous frequency channels. To avoid this

issue, you can force the cBR-8 router to create 8-channel DBG with contiguous frequency channels using the following command:

```
ROUTER# config terminal
Enter configuration commands, one per line. End with CNTL/Z.
ROUTER(config)# cable dynamic-bonding-group eight-contiguous-channel
```

Enable DS-Resiliency and Configure Resiliency Bonding Group

To make sure that the modem remains w-online with maximum downstream capability when several rf channels are impaired, enable ds-resiliency feature by running the following commands:

```
Router# config t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)# cable resiliency ds-bonding
Router(config)# end
Router#
Router# show running-config | in resiliency
cable resiliency ds-bonding
Router#
Router# config t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)# interface wideband-Cable 3/0/1:30
Router(config-if)# cable ds-resiliency
Wideband-Cable3/0/1:30 is set to WB resiliency bonding group.
Remove any existing bundle and rf-channel configuration.
Router(config-if)#end
Router#
Router#show running-config interface wideband-Cable 3/0/1:30
Building configuration...
Current configuration : 61 bytes
!
interface Wideband-Cable3/0/1:30
cable ds-resiliency
end
```

Enable ACFE

Enable ACFE feature to make sure that modem registration is not blocked because of QoS failures:

```
Router# config t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)# cable acfe enable
Router(config)# end
Router# show running-config | in acfe
cable acfe enable
```

Configure Interface Mac-Domain and Fiber-Node

Note The recommended size of service group is 32 or 48. The recommended primary channel distribution is one primary channel for contiguous four channels, such as 0, 4, 8, 12, 16, 20, 24, 28 and so on.

To set up interface mac-domain and fiber-node, run the following commands:

```
Router# show running-config interface c3/0/1
```

```
Building configuration...
Current configuration : 963 bytes
!
interface Cable3/0/1
downstream Integrated-Cable 3/0/1 rf-channel 0
downstream Integrated-Cable 3/0/1 rf-channel 4
downstream Integrated-Cable 3/0/1 rf-channel 8
downstream Integrated-Cable 3/0/1 rf-channel 12
downstream Integrated-Cable 3/0/1 rf-channel 16
downstream Integrated-Cable 3/0/1 rf-channel 20
downstream Integrated-Cable 3/0/1 rf-channel 24
downstream Integrated-Cable 3/0/1 rf-channel 28
upstream 0 Upstream-Cable 3/0/1 us-channel 0
upstream 1 Upstream-Cable 3/0/1 us-channel 1
upstream 2 Upstream-Cable 3/0/1 us-channel 2
upstream 3 Upstream-Cable 3/0/1 us-channel 3
upstream 4 Upstream-Cable 3/0/1 us-channel 4
upstream 5 Upstream-Cable 3/0/1 us-channel 5
upstream 6 Upstream-Cable 3/0/1 us-channel 6
upstream 7 Upstream-Cable 3/0/1 us-channel 7
cable upstream bonding-group 1
upstream 0
upstream 1
attributes 80000002
cable upstream bonding-group 2
upstream 2
upstream 3
attributes 80000000
cable bundle 255
end

Router# show cab
Router# show cable fib
Router# show cable fiber-node 1
Fiber-Node 1
     Channel(s) : downstream Integrated-Cable 3/0/1: 0-31
     Channel ID(s): 1  2  3  4  5  6  7  8  9  10 11 12 13 14
                    15 16 17 18 19 20 21 22 23 24 25 26 27 28
                    29 30 31 32
     Upstream-Cable 3/0/1
         FN Config Status: Configured (status flags = 0x01)
         MDD Status: Valid
Router# show running-config | sec fiber-node 1
  cable fiber-node 1
   downstream Integrated-Cable 3/0/1
   upstream Upstream-Cable 3/0/1
```

Example of OFDM configured in the fiber node and added as part of the dynamic bonding group.

```
Router# show cable dynamic-bonding-group summary
Dynamic bonding group: Enable
BG ID BG Name      BG Size  CMs  ServFlows Create Time           Create Client        BG
State            RFid list
9219  Wi1/0/4:2    33       36   36        Nov 7  01:56:27.406   MODEM_ONLINE
OPERATIONAL          9216-9247, 9375
9220  Wi1/0/4:3    33       10   10        Nov 7  02:04:31.142   MODEM_ONLINE
OPERATIONAL          9248-9279, 9375
9221  Wi1/0/4:4    8        1    1         Nov 7  02:06:09.949   MODEM_ONLINE
OPERATIONAL          9248-9255

Router# show controller integrated-Cable 1/0/0 rf-channel 158
Load for five secs: 8%/1%; one minute: 8%; five minutes: 8%
Time source is NTP, *14:07:30.643 EST Fri Nov 17 2017
Chan State Admin Mod-Type  Start       Width     PLC        Profile-ID    dcid  power
```

```
output
                          Frequency
158 UP     UP   OFDM      258000000   48000000  279000000       100      159   34.0   NORMAL

Router# show cable fiber-node 10
Load for five secs: 9%/0%; one minute: 9%; five minutes: 8%
Time source is NTP, *13:59:39.571 EST Fri Nov 17 2017

--------------------------------------------------------------------------------

Fiber-Node 10
  Channel(s)   :  downstream Integrated-Cable 1/0/0:  0-63, 158
  Channel ID(s):   1   2   3   4   5   6   7   8   9  10  11  12  13  14
                  15  16  17  18  19  20  21  22  23  24  25  26  27  28
                  29  30  31  32  33  34  35  36  37  38  39  40  41  42
                  43  44  45  46  47  48  49  50  51  52  53  54  55  56
                  57  58  59  60  61  62  63  64 159
  Upstream-Cable 1/0/0
    FN Config Status: Configured (status flags = 0x01)
    MDD Status: Valid
```

Enable Load Balancing for DOCSIS 3.0 and DOCSIS 3.1

To enable DOCSIS load balancing, run the cable load-balance docsis-enable command. When DOCSIS load balancing is enabled, run the cable load-balance docsis30-enable command to enable load balancing for DOCSIS 3.0 and DOCSIS 3.1.

Note The **cable load-balance docsis30-enable** command enables load balancing for DOCSIS 3.0 and DOCSIS 3.1.

Enable DOCSIS 3.0 and DOCSIS 3.1 Static Load Balance

To balance the load of primary channels, enable static load balance by running the following commands:

```
ROUTER# config t
Enter configuration commands, one per line. End with CNTL/Z.
ROUTER(config)# cable load-balance docsis30-enable static
ROUTER(config)# end
ROUTER# show cable load-balance
DOCSIS LB Enabled: Yes
DOCSIS 2.0 LB Enabled: Yes
DOCSIS 3.0 LB Enabled: Yes
DOCSIS 3.0 Static LB Enabled: Yes
DOCSIS 3.0 Dynamic Downstream LB Enabled: No
```

Enable DOCSIS 3.0 and DOCSIS 3.1 General Load Balance Group

To enable general load balance group, run the following commands:

```
Router# config t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)# cable load-balance docsis-group fn 1 md c3/0/1
Router(config-lb-group)# no disable
```

```
Router(config-lb-group)# end
Router# show cable load-balance
DOCSIS LB Enabled: Yes
DOCSIS 2.0 LB Enabled: No
159
DOCSIS 3.0 LB Enabled: Yes
DOCSIS 3.0 Static LB Enabled: Yes
DOCSIS 3.0 Dynamic Downstream LB Enabled: Yes
DOCSIS 3.0 Dynamic Upstream LB Enabled: Yes
DOCSIS     Status Interval  DCC mask  Policy     Method Threshold

DOCSIS 3.0 General LB
MD       FN   Group ID         S Intv  DCC mask  Policy  Mtd     MD-CM-SG  Threshold
                                                          /UCC                        D/U
M/E/U/P/S
Ca3/0/1  1    2147557888 E 90   0xF8(0)/N 0           u/u        0x91010B   5/10/70/70/50
```

Enable Dynamic Load Balance and Fixed-Primary Channel Movement

Note To reduce service outage while enabling dynamic load balancing, enable fixed primary channel movement.

To balance the load of all of downstream channels based on utilization, enable dynamic load balance by running the following commands:

```
Router# config t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)# cable load-balance docsis30-enable dynamic downstream
Router(config)# end
Router#
Router# show cable load-balance
DOCSIS LB Enabled: Yes
DOCSIS 2.0 LB Enabled: No
DOCSIS 3.0 LB Enabled: Yes
DOCSIS 3.0 Static LB Enabled: Yes
DOCSIS 3.0 Dynamic Downstream LB Enabled: Yes
DOCSIS 3.0 Dynamic Upstream LB Enabled: Yes
DOCSIS     Status Interval  DCC mask  Policy     Method Threshold
Group                       /UCC                DS/US  M/E/U/P/S
1          GE     30        0xF8(0)/N 0          m/m    5/10/70/70/50

DOCSIS 3.0 General LB
MD       FN   Group ID   S Intv DCC mask  Policy    Mtd MD-CM-SG   Threshold
                                /UCC                D/U            M/E/U/P/S
Ca3/0/1  1    2147557888 E 90   0xF8(0)/N 0         u/u 0x91050A   5/10/70/70/50
Router#
Router# config t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)# cable load-balance fixed-primary-channel
Router(config)# end
Router#
Router# show run
Router# show running-config | in fixed
cable load-balance fixed-primary-channel
```

Verifying Dynamic Bonding Group Configuration

To verify that the DBGs are created:

Check the modem's primary wideband interface by using the **show cable modem wideband channel** command:

```
Router# show cable modem 4800.33ee.ebee wideband channel
MAC Address         IP Address         I/F          MAC         DSxUS     Primary
                                                    State               WB
4800.33ee.ebee      30.132.15.246      C3/0/1/UB    w-online    32x2      Wi3/0/1:3
Router# scm 4800.33ee.ebee ver
```

Check the modem's downstream tuner capability by using the **show cable modem verbose | in DS Tuner** command.

```
Router# show cable modem 4800.33ee.ebee verbose | in DS Tuner
DS Tuner Capability : 32
```

Check the related RCC by using the **show cable mac-domain rcc** command:

```
Router# show cable mac-domain c3/0/1 rcc
RCC-ID   RCP             RCs  MD-DS-SG  CMs  WB/RCC-TMPL       D3.0    D3.1
32 00 00 00 00 00  8    0         11   WB (Wi3/0/1:1)    Y       Y
33 00 00 00 00 00  32   0         6    WB (Wi3/0/1:3)    Y       Y
34 00 00 00 00 00  8    0         7    WB (Wi3/0/1:2)    Y Y
35 00 00 00 00 00  8    0         7    WB (Wi3/0/1:4)    Y Y
36 00 00 00 00 00  8    0         7    WB (Wi3/0/1:5)    Y Y
```

Check the dynamically created bonding groups, use the **show cable dynamic-bonding-group summary** command as shown in the example below:

```
Router# show cable dynamic-bonding-group summary
Dynamic bonding group: Enable
BG ID BG Name   BG Size CMs ServFlows Create Time         Create Client       BG State
RFid list
24834 Wi3/0/1:1 8       11  11        Sep 14 14:36:35.194 MODEM_ONLINE        OPERATIONAL
24832-24839
24836 Wi3/0/1:3 32      6    6        Sep 14 14:43:24.144 MODEM_ONLINE        OPERATIONAL
24832-24863
24835 Wi3/0/1:2 8       7    7        Sep 14 17:20:37.115 MODEM_ONLINE        OPERATIONAL
24840-24847
24837 Wi3/0/1:4 8       7    7        Sep 14 17:21:37.723 STATIC_LOAD_BALANCE OPERATIONAL
24856-24863
24838 Wi3/0/1:5 8       7    7        Sep 14 17:21:39.761 STATIC_LOAD_BALANCE OPERATIONAL
24848-24855
```

The following examples shows the DBG created with contiguous frequency channels for load balance purpose.

```
Router#show cable dynamic-bonding-group summary
 Dynamic bonding group: Enable
 DBG operation with Registration: Enable
 DBG operation with Load-Balance: Enable
 BG ID BG Name      BG Size  CMs  ServFlows Create Time           Create Client        BG
State             RFid list
 24578 Wi3/0/0:1    24       4    4         Sep 26 15:07:22.760   MODEM_ONLINE
OPERATIONAL          24576-24599
 24577 Wi3/0/0:0    8        17   17        Sep 26 16:35:01.240   MODEM_ONLINE
OPERATIONAL          24584-24591
 24579 Wi3/0/0:2    8        7    7         Sep 26 16:53:48.857   DYNAMIC_LOAD_BALANCE
OPERATIONAL          24577-24584
 24580 Wi3/0/0:3    8        6    6         Sep 26 16:56:49.790   DYNAMIC_LOAD_BALANCE
OPERATIONAL          24588-24595
```

```
Router#show derived-config interface wideband-Cable 3/0/0:3
Building configuration...

Derived configuration : 141 bytes
!
interface Wideband-Cable3/0/0:3
 cable bundle 255
 cable rf-channels channel-list 12-19 bandwidth-percent 1
 no snmp trap link-status
end

Router#show derived-config interface wideband-Cable 3/0/0:2
Building configuration...

Derived configuration : 139 bytes
!
interface Wideband-Cable3/0/0:2
 cable bundle 255
 cable rf-channels channel-list 1-8 bandwidth-percent 1
 no snmp trap link-status
end
```

Table 43: Dynamic Bonding Group States

CREATE_WAITING_SUP	Line card sends request to create DBG and waits for SUP to create the bonding group.
HOLD	DBG is created from SUP, or bonding group reverts from reclaim to ready for use.
OPERATIONAL	If modem is used on the bonding group after the HOLD state times out, the DBG state changes to OPERATIONAL.
RECLAIM_HOLD	Ready for reclaim. If no modem is used on the bonding group or match the reclaim in two minutes, the bonding group is reclaimed. The DBG state changes to RECLAIM_HOLD.
RECLAIM_MODEM_MOVING	Ready for reclaim. The modem is moved out of the bonding group.
RECLAIM_WAITING_SUP	Line card sends DBG reclaim request and waits for SUP to reclaim the BG.

To show the detailed channel list information of dynamic bonding group, use the **show derived-config interface wideband** command.

```
Router# show derived-config interface wideband-Cable 3/0/1:1
Building configuration...
Derived configuration: 113 bytes
!
interface Wideband-Cable3/0/1:1
  cable bundle 255
```

```
  cable rf-channels channel-list 0-7 bandwidth-percent 1
end
```

Check the usage of bonding group resource by using the **show cable dynamic-bonding-group quota summary | slot | controller** command.

```
Router# show cable dynamic-bonding-group quota controller 3/0/1
slot/subslot/ctrlr: 3/0/1
Total BG number: 128
Used BG number (static/dynamic): 6(1/5) Available BG number: 122
Available BG list port: 0, 6-29, 31-127
```

Note 128 BGs can be configured on one controller, but only 896 BGs are supported per CLC. All controllers share the 896 BG resources.

Check the reclaimed bonding group by using the **show cable dynamic-bonding-group reclaim-history summary** command:

```
Router# show cable dynamic-bonding-group reclaim-history summary
BG ID BG Name   BG Size Create Time     Create Client Reclaim Time    Reclaim Client RFid
list
24835 Wi3/0/1:2 16      Sep 14 14:40:27 MODEM_ONLINE  Sep 14 14:44:27 DBG_INTERNAL
24832-2484
```

Verifying Static Load Balancing Configuration

To verify if static load balancing is configured:

Check the load of all primary channels by using the **show cable load-balance docsis-group fn 1 md cable load | in In** command.

```
Router# show cable load-balance docsis-group fn 1 md c3/0/1 load | in In
Interface           State   Group      Utilization Rsvd NBCM WB/UB Weight
In3/0/1:0(573 MHz)  initial 2147557888 0%(0%/0%)   0%   0    17    37
In3/0/1:4(597 MHz)  initial 2147557888 0%(0%/0%)   0%   0    17    37
In3/0/1:8(621 MHz)  initial 2147557888 0%(0%/0%)   0%   0    13    37
In3/0/1:12(645 MHz) initial 2147557888 0%(0%/0%)   0%   0    13    37
In3/0/1:16(669 MHz) initial 2147557888 0%(0%/0%)   0%   0    13    37
In3/0/1:20(693 MHz) initial 2147557888 0%(0%/0%)   0%   0    13    37
In3/0/1:24(717 MHz) initial 2147557888 0%(0%/0%)   0%   0    13    37
In3/0/1:28(741 MHz) initial 2147557888 0%(0%/0%)   0%   0    13    37
```

This command output lists all primary channels and shows the number of cable modems used with these channels. NBCM is the number of narrow band modems used with a channel while WBCM (WB/UB) is the number of wideband modems used with a channel. The total number of WBCMs should be balanced among all the channels.

The difference between the total number of WBCMs used with any two channels is smaller or equal to the threshold load minimum. The default value of the threshold load minimum is 5.

Check the load of all rf channels by using the **show cable load-balance docsis-group fn 1 md rfch-util** command.

```
Router# show cable load-balance docsis-group fn 1 md c3/0/1 rfch-util
Interface  Pstate Pending-In Pending-Out Throughput(Kbps) Util NBCM WBCM
In3/0/1:0  up     No         No          0                0%   0    17
```

```
In3/0/1:1  NA     No          No          0                0%   0    17
In3/0/1:2  NA     No          No          0                0%   0    17
In3/0/1:3  NA     No          No          0                0%   0    17
In3/0/1:4  up     No          No          0                0%   0    17
In3/0/1:5  NA     No          No          0                0%   0    17
In3/0/1:6  NA     No          No          0                0%   0    17
In3/0/1:7  NA     No          No          0                0%   0    17
In3/0/1:8  up     No          No          0                0%   0    13
In3/0/1:9  NA     No          No          0                0%   0    13
In3/0/1:10 NA     No          No          0                0%   0    13
In3/0/1:11 NA     No          No          0                0%   0    13
In3/0/1:12 up     No          No          0                0%   0    13
In3/0/1:13 NA     No          No          0                0%   0    13
In3/0/1:14 NA     No          No          0                0%   0    13
In3/0/1:15 NA     No          No          0                0%   0    13
…….
Average: 0.0
Variance: 0.0
```

This command lists the load information about the primary and secondary channels. WBCM is the number of wideband modems used with a channel.

Check the cable modem's internal state in load balancing using the **show cable load-balance docsis-group fn 1 md modem-list wideband** command.

```
Router# show cable load-balance docsis-group fn 1 md c3/0/1 modem-list wideband
Codes: M - Multicast, U - UGS, P - PCMM, F - Max-Failures, X - eXcluded
       L - L2vpn, R - RSVP, S - DS-Resiliency
Primary WB   MAC Address            Primary DS   RCC-ID  Priority        MUPFXLRS State
Wi3/0/1:0    (3)
             c8fb.2631.0e56         In3/0/1:20   41      0        ------ LB_CM_HOLD_EXPIRE_IN
 36
             c8fb.26a6.c3dc         In3/0/1:16   41      0        ------ LB_CM_HOLD_EXPIRE_IN
 37
             c8fb.2631.0d7e         In3/0/1:16   41      0        ------ LB_CM_HOLD_EXPIRE_IN
 43
Wi3/0/1:1 (9)
             c8fb.2631.0c80         In3/0/1:0    32      0         ------ LB_CM_STATIC_MOVING

              c8fb.2631.0cae         In3/0/1:0    32      0         ------ LB_CM_STATIC_READY

             c8fb.2631.0db0         In3/0/1:24   42      0        ------ LB_CM_STATIC_MOVING

             c8fb.2631.0c10         In3/0/1:28   42      0        ------ LB_CM_STATIC_MOVING

             c8fb.2631.0d80         In3/0/1:16   41      0        ------ LB_CM_STATIC_MOVING

             c8fb.2631.0d26         In3/0/1:24   41      0        ------ LB_CM_STATIC_MOVING

             a4a2.4a2d.b4aa         In3/0/1:20   41      0        ------ LB_CM_STATIC_MOVING

             c8fb.2631.0e5c         In3/0/1:0    32      0        ------ LB_CM_STATIC_MOVING

             c8fb.2631.0cb0         In3/0/1:0    32      0        ------ LB_CM_STATIC_MOVING
Wi3/0/1:2 (3)
             c8fb.2631.0d2a         In3/0/1:12   34      0        ------ LB_CM_HOLD_EXPIRE_IN
 27
             c8fb.2631.0e5a         In3/0/1:12   34      0        ------ LB_CM_STATIC_MOVING

             c8fb.2631.0bfe         In3/0/1:8    34      0        ------ LB_CM_STATIC_MOVING
Wi3/0/1:3 (2)
             4800.33ea.54be         In3/0/1:28   33      0        ------ LB_CM_DYNAMIC_READY
```

```
            4800.33ee.ebe6         In3/0/1:20   33      0        ------ LB_CM_HOLD_EXPIRE_IN
 1
Wi3/0/1:4 (2)
            c8fb.2631.0e44         In3/0/1:24   42      0        ------ LB_CM_HOLD_EXPIRE_IN
 40
            c8fb.2631.0a44         In3/0/1:28   42      0        ------ LB_CM_HOLD_EXPIRE_IN
 42
```

Table 44: Cable Modem States

CM state	Description
LB_CM_STATIC_READY	Modem is ready for static load balance movement.
LB_CM_STATIC_MOVING	Modem is in movement triggered via static LB.
LB_CM_HOLD_EXPIRE_IN	Modem is in hold for the next movement. The default hold time is 600 seconds.
LB_CM_DYANMIC_READY	Modem is ready for dynamic load balance movement.
LB_CM_DYANMIC_MOVING	Modem is in movement triggered via dynamic LB.
LB_CM_DISABLED	Modem is not ready for movement. If the modem failure movement count reaches max-failure threshold, then set the modem in LB_CM_DISABLED to avoid further movement.

Verifying Dynamic Load Balancing Configuration

Check the utilization of all rf channels by using **show cable load-balance docsis-group fn 320 md rfch-util** command.

```
Router# show cable load-balance docsis-group fn 320 md c3/0/0 rfch-util
Interface Pstate   Pending-In   Pending-Out   Throughput(Kbps) Util   NBCM   WBCM
Do3/0/0:0  up      No           No            11754            31%    0      308
Do3/0/0:1  up      No           No            11754            31%    0      296
Do3/0/0:2  up      No           No            11754            31%    0      333
Do3/0/0:3  up      No           No            11754            31%    0      296
Do3/0/0:4  up      No           No            11754            31%    0      297
Do3/0/0:5  up      No           No            11754            31%    0      331
Do3/0/0:6  up      No           No            11754            31%    0      299
Do3/0/0:7  up      No           No            11753            31%    0      268
Do3/0/0:8  up      No           No            11754            31%    0      302
Do3/0/0:9  up      No           No            11754            31%    0      331
Do3/0/0:10 up      No           No            11753            31%    0      308
Do3/0/0:11 up      No           No            11754            31%    0      305
Do3/0/0:12 NA      No           No            12862            34%    0      258
Do3/0/0:13 NA      No           No            12862            34%    0      258
Do3/0/0:14 NA      No           No            12862            34%    0      258
…….
Average: 30.416
Variance: 1.701
```

The traffic among all rf channels is considered balanced when the difference between any two rf channel utilization is under the threshold load. The default value of threshold load is 10%.

To check the potential target bonding group for each of the source bonding group, use the **show cable load-balance docsis-group fn md cable target dbg** and the **show cable load-balance docsis-group fn md** target wide command.

```
Router# show cable load-balance docsis-group fn 320 md c3/0/0 target dbg
Interface    Bg-Id     Size     Group         Target
Wi3/0/0:0    24577     4        2147557695
Wi3/0/0:3    24580     4        2147557695
Wi3/0/0:4    24581     8        2147557695
Wi3/0/0:5    24582     8        2147557695
Wi3/0/0:6    24583     24       2147557695    33% [24576, 24584-24587, 24589-24607]
Wi3/0/0:7    24584     16       2147557695    30% [24576, 24586-24587, 24595-24607]
Wi3/0/0:8    24585     16       2147557695
Wi3/0/0:9    24586     32       2147557695
Wi3/0/0:10   24587     24       2147557695    33% [24576, 24584-24587, 24589-24607]
Wi3/0/0:11   24588     8        2147557695
Wi3/0/0:12   24589     8        2147557695    27% [24596-24603]
Wi3/0/0:13   24590     8        2147557695
Wi3/0/0:14   24591     4        2147557695
```

```
Router# show cable load-balance docsis-group fn 5 md c1/0/4 target wide
Interface     Bg-Id     State     Group         Target
Wi1/0/4:2     9219      up        2147510276    Wi1/0/4:4
Wi1/0/4:3     9220      up        2147510276
Wi1/0/4:4     9221      up        2147510276
```

If no target bonding groups are displayed, no bonding groups are created to balance traffic among rf channels.

A sample output with DOCSIS 3.1 modems with configured threshold of 14% is shown below. For utilization based load balancing to start on DOCSIS 3.1 modems, the OFDM channel must be 100% utilized and traffic must flow on SC-QAM. The utilization based load balancing balances the traffic flowing on the SC-QAM channels in a D31 modem.

```
Router# show cable load-balance docsis-group fn 5 md c1/0/4 rfch-util
Interface   Pstate Pending-In Pending-Out Throughput(Kbps) Util NBCM WBCM
In1/0/4:0   up     No         No          10632            28%  0    45
In1/0/4:1   NA     No         No          11226            29%  0    41
In1/0/4:2   NA     No         No          11225            29%  0    41
In1/0/4:3   NA     No         No          11225            29%  0    41
In1/0/4:4   down   No         No          11225            29%  0    41
In1/0/4:5   down   No         No          11225            29%  0    41
In1/0/4:6   down   No         No          11225            29%  0    41
In1/0/4:7   down   No         No          11225            29%  0    41
In1/0/4:8   up     No         No          10620            28%  0    43
....
....
In1/0/4:35   NA    No         No          6646             17%  0    6
In1/0/4:36   NA    No         No          6646             17%  0    6
In1/0/4:37   NA    No         No          6647             17%  0    6
In1/0/4:38   NA    No         No          6646             17%  0    6
In1/0/4:39   NA    No         No          6647             17%  0    6
In1/0/4:40   up    No         No          6088             16%  0    6
In1/0/4:41   NA    No         No          6648             17%  0    6
In1/0/4:42   NA    No         No          6647             17%  0    6
In1/0/4:43   NA    No         No          6647             17%  0    6
In1/0/4:44   NA    No         No          6646             17%  0    6
In1/0/4:45   NA    No         No          6646             17%  0    6
In1/0/4:46   NA    No         No          6647             17%  0    6
In1/0/4:47   NA    No         No          6648             17%  0    6
In1/0/4:48   NA    No         No          6648             17%  0    6
In1/0/4:49   NA    No         No          6648             17%  0    6
```

```
In1/0/4:50   NA    No          No          6646             17%  0    6
In1/0/4:51   NA    No          No          6648             17%  0    6
In1/0/4:52   NA    No          No          6647             17%  0    6
In1/0/4:53   NA    No          No          6648             17%  0    6
In1/0/4:54   NA    No          No          6647             17%  0    6
In1/0/4:55   NA    No          No          6648             17%  0    6
In1/0/4:56   NA    No          No          6647             17%  0    6
In1/0/4:57   NA    No          No          6647             17%  0    6
In1/0/4:58   NA    No          No          6646             17%  0    6
In1/0/4:59   NA    No          No          6645             17%  0    6
In1/0/4:60   NA    No          No          6646             17%  0    6
In1/0/4:61   NA    No          No          6646             17%  0    6
In1/0/4:62   NA    No          No          6647             17%  0    6
In1/0/4:63   NA    No          No          6647             17%  0    6
In1/0/4:159  NA    No          No          1819685          100% 0    47
```

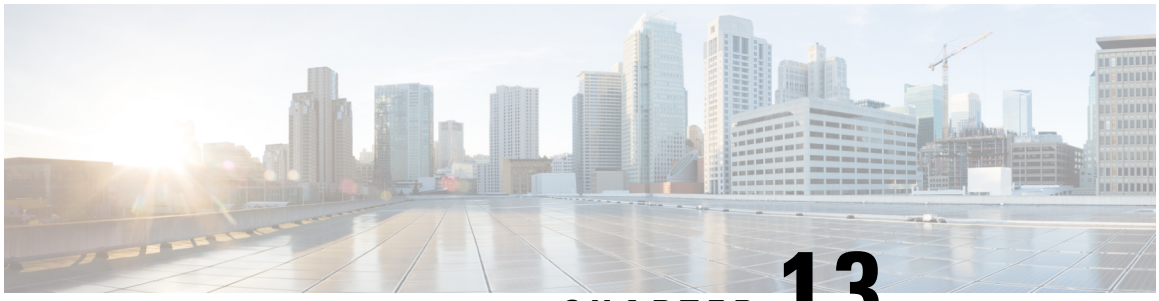
Feature Information for Dynamic Bonding Group

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 45: Feature Information for Dynamic Bonding Group

Feature Name	Releases	Feature Information
Dynamic Bonding Group	Cisco IOS XE Fuji 16.7.1	This feature was introduced on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 13

Spectrum Management and Advanced Spectrum Management

This chapter describes the spectrum management features supported for the Cisco Cable Modem Termination System (CMTS) routers. Spectrum management support is divided into two main groups:

- Guided and scheduled spectrum management features (supported in software)
- Intelligent and advanced spectrum management features (supported in hardware only on specific cable interfaces)

- Finding Feature Information, on page 233
- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 234
- Prerequisites for Spectrum Management, on page 235
- Restrictions for Spectrum Management, on page 235
- Information About Spectrum Management, on page 237
- How to Configure Spectrum Management, on page 253
- Monitoring Spectrum Management, on page 270
- Configuration Examples, on page 275
- Additional References, on page 282
- Feature Information for Spectrum Management and Advanced Spectrum Management, on page 283

Finding Feature Information

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 46: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for Spectrum Management

Ensure that your network is designed to support reliable broadband data transmission. At minimum, your network must include:

- A Dynamic Host Configuration Protocol (DHCP) server to assign IP addresses to cable modems or set-top boxes on the hybrid fiber-coaxial (HFC) network. This can be a Cisco CMTS router that has been configured to act as the DHCP server.
- If you are not using cable interface line cards with integrated upconverters, you must install the appropriate IF-to-RF external upconverter between the Cisco CMTS router and the combiner.

Note The term "combiner" refers to all cables, amplifiers, and taps at the headend or cable distribution center that connect the Cisco CMTS router to the HFC network.

- Diplex filters installed in the downstream RF path between the cable modems and the cable interface cards in the router. RG-59 headend coaxial cable with the maximum braid available (60 percent + 40 percent braid), double foil, and the correct connector for this cable.
- Avoid frequencies with known ingress problems such as amateur radio bands or short-wave bands.
- Avoid hostile spectrums below 20 MHz.
- When designing your channel plan, allow extra bands for frequency hopping.
- Use the receive power level setting to perform slight equalization adjustments.
- Due to the nature of CATV technology, upstream noise management is a significant issue. We recommend that you follow the rigorous North American plant maintenance procedures documented in the NCTA Supplement on Upstream Transport Issues (available from the National Cable and Telecommunications Association, https://www.ncta.com) to adjust return amplifiers and lasers.

Restrictions for Spectrum Management

This section describes the restrictions for the following spectrum management features:

Shared Spectrum Groups

- Advance spectrum management does not support inter-line-card shared spectrum groups.
- Guided spectrum management does support inter-line-card shared spectrum groups.

Dynamic Upstream Modulation

- The Cisco CMTS router has one preconfigured (primary) modulation profile that defines a typical profile for quadrature phase-shift keying (QPSK) modulation. To use the Dynamic Upstream Modulation feature,

you must create a secondary modulation profile that has a higher modulation scheme than the preconfigured profile. The Three Step Dynamic Modulation feature allows you to create and use a third modulation profile. However, the third modulation profile is optional.

- Upstream modulation profiles are assigned to upstream ports and affect all cable modems on those upstream ports.
- Modulation profiles affect the physical layer of the cable network, so only trained technicians who are familiar with the Data-over-Cable Service Interface Specifications (DOCSIS) specifications should create modulation profiles.
- When using the Dynamic Upstream Modulation feature with Voice over IP (VoIP) services, frequent changes to the upstream modulation or channel width could briefly impact the quality of voice calls.

Fixed-Frequency Spectrum Groups with Advanced Spectrum Management

Do the following to configure fixed-frequency spectrum groups:

```
Router(config)#controller upstream-cable 9/0/15
Router(config-controller)#us-channel 0 spectrum-group n
Router(config-controller)#us-channel 0 channel-width 1600000
```

Limitations on Upstream Modulation Parameters for PacketCable VoIP Calls

We recommend the use of a channel width that is 1.6Mhz, 3.2Mhz, or 6.4Mhz while configuring upstreams for PacketCable operations and VoIP calls. (All DOCSIS channel widths and upstream parameter combinations are supported, but not optimum when offering VoIP.)

N+1 Redundancy Support

N+1 redundancy requires the working and protect cable interface line cards to be identical. This ensures that the protect interface supports the same exact configuration as the working interface.

When protecting cards that support intelligent and advanced spectrum management, a switchover preserves the spectrum management configuration, and the protect interface initially uses the same upstream frequency as the working interface. The protect interface does not begin using the advanced spectrum management features until the system stabilizes to avoid any unnecessary frequency hops or channel width changes.

Intelligent and Advanced Spectrum Management Support

- Cable interfaces use standard DOCSIS, EuroDOCSIS, and the extended Japanese frequency ranges (5 to 85 MHz for upstream interfaces) to support the intelligent and advanced spectrum management features.
- Intelligent and advanced spectrum management features are supported only in the DOCSIS 1.0 and DOCSIS 1.1 Time Division Multiple Access (TDMA) mode of operation. These features cannot be used when a cable interface is operating in the DOCSIS 2.0 mixed, Advanced TDMA (A-TDMA), and Synchronous Code Division Multiple Access (S-CDMA) modes of operation. Similarly, these features are also not available when the cable interface is configured to use multiple logical channels. However, these restrictions do not apply for guided spectrum management.

- Upstream channels must meet the carrier-to-noise plus interference ratio (CNiR [CNR]), and carrier-to-ingress power ratio values given in the DOCSIS specifications. The minimum value for both parameters is 25 dB in the 5 to 65 MHz frequency range.
- The intelligent and advanced spectrum management features do not support inter-line card shared spectrum groups. Spectrum management features require that upstream ports on different line cards have their own RF domain (a unique set of non-overlapping frequencies).
- N+1 redundancy is not supported on any cable interface line card that has defined spectrum groups, which typically is the normal configuration for advanced spectrum management.
- The intelligent and advanced spectrum management feature is activated by assigning spectrum groups on cards with built-in spectrum analyzer.

Information About Spectrum Management

Spectrum management allows a Cisco Cable Modem Termination System (CMTS) to sense upstream plant impairments, report them to a management entity, and automatically correct them where possible. The spectrum management feature performs these functions without reducing throughput or latency and without creating additional packet overhead on the radio frequency (RF) plant.

In particular, because the cable interfaces on the router receive upstream packets, it can directly detect upstream transmission errors. The router can also indirectly monitor the condition of the plant by keeping a record of modem state changes, such as the number and frequency of cable modems that are “flapping” (modems that either miss a station maintenance message or that go offline and then come back online).

Note For more information about the cable modem flapping and how to monitor the cable modem flap list, see the Flap List Troubleshooting for the Cisco CMTS Routers .

Spectrum management can prevent long-term service interruptions caused by upstream noise events in the cable plant. It is also used for fault management and troubleshooting the cable network. When cable modems are detected to go online and offline by flap detectors, the cable operators can look at the flap list and spectrum tables to determine the possible causes.

Because of the nature of cable television (CATV) technology, upstream noise management is a significant issue. Frequency bands must have a sufficient CNR (CNiR) and carrier-to-ingress power ratio to support the transmission of QPSK and quadrature amplitude modulation (QAM) data. The DOCSIS sets the minimum value for both of these ratios to 25 dB in the 5 to 65 MHz frequency range. If the CNR (CNiR) drops below 25 dB on a particular channel due to noise, the cable modem on that channel degrades and can drop off the hybrid fiber-coaxial (HFC) network.

This overview contains the following subsections:

- Spectrum Management Measurements, on page 238—Provides an overview of fundamental concepts and terms that are used in spectrum management.
- Upstream Signal Channel Overview, on page 242—Describes how signals are sent and how changes occur in upstream channels.
- Upstream Segments and Combiner Groups, on page 243—Describes sparse and dense segments and combiner groups.

- Frequency Management Policy, on page 244—Describes the types of noise impairments and how to counteract ingress noise with spectrum groups and frequency hopping.
- Guided and Scheduled Spectrum Management, on page 246—Describes the following guided and scheduled spectrum management features: frequency hopping capabilities, dynamic upstream modulation (signal-to-noise ratio-based), and input power levels.
- Intelligent and Advanced Hardware-Based Spectrum Management, on page 250—Describes spectrum management features that are supported by a number of cable interface line cards that have onboard spectrum management hardware. These features include a real-time spectrum analyzer, CNR-based, proactive frequency hopping, and a more robust dynamic upstream modulation.
- Benefits, on page 251—Describes the spectrum management features provided on the Cisco CMTS router platforms.

Spectrum Management Measurements

Measuring the signal-to-noise ratio (SNR [MER]) and carrier-to-noise ratio (CNR [CNiR]) are the major ways of determining the quality of a downstream or upstream signal. The following sections provide an overview of these two ratios, as well as explaining the differences between them, and some additional values that might be useful:

Signal and Carrier Noise Ratios

Measuring the Modulation Error Ratio (MER [SNR]) and CNR (CNiR) of a downstream or upstream is the first step in determining the quality of the signal, and whether spectrum management needs to be performed to correct any errors. The following are brief descriptions of these two values:

- Modulation Error Ratio (MER [SNR])—This is an estimate of the signal strength on the upstream after ingress noise cancellation is performed. This means that the MER (SNR) takes into account a variety of modulation impairments, including frequency response distortions (such as in-channel amplitude tilt and ripple), group delay, microreflections, and phase noise. The MER (SNR) is a good gauge of the overall end-to-end quality of the cable network, because it includes the impact that the transmitter circuitry, receiver circuitry, and transmission media have on the upstream signal.
- Carrier-to-Noise Ratio (CNR)—This is an ratio of the measured modulated power, in dB, on the upstream (before ingress noise cancellation is done) that compares the channel power to the noise power.

  The term CNiR is part of the CableLabs nomenclature for the CNR measurement. Therefore these two terms, CNR and CNiR, can be used interchangeably.

  The CNR (CNiR) measurement is usually provided only by an external spectrum analyzer, but the cable interface line cards that support intelligent and advanced hardware spectrum management features also provide CNR (CNiR) measurement.

  The following two types of CNR (CNiR) measurements are supported on the Cisco CMTS:

  - CNR (CNiR) measured for a particular upstream—This is the overall CNR (CNiR) for all of the cable modems on an upstream, which is determined by measuring the RF power of the upstream receiver at the cable interface. This value is always just a snapshot in time for a particular upstream. The cable interface measures the RF power at a time when no bursts are expected from the cable modems, but it can be skewed by a small number of cable modems that are experiencing or creating signal problems.

- Per-modem CNR (CNiR)—This is the CNR (CNiR) for a particular cable modem, which is signal strength of the burst transmissions of the modem at the upstream receiver of the cable interface. The per-modem CNR (CNiR) measurement is a very accurate measure of a particular cable modem's signal, but you should not use a single modem's CNR (CNiR) to make assumptions about other cable modems on that upstream or about the upstream itself. However, you can get a good picture of the upstream's signal quality by polling the CNR (CNiR) for a number of cable modems over a representative time period.

Tip Changing the channel width has a direct impact on the CNR (CNiR). Doubling the channel width (for example, from 400 KHz to 800 KHz) decreases the CNR (CNiR) for an upstream by approximately 3 dB. Cutting the channel width in half (for example, from 3.2 MHz to 1.6 MHz) increases the CNR (CNiR) for an upstream by approximately 3 dB.

Differences Between the MER (SNR) and CNR (CNiR) Values

In a perfect network, such as a test lab where the only impairment is additive white Gaussian noise (AWGN), you can expect the CNR (CNiR) and MER (SNR) values to be comparable throughout all of the allowable power levels and frequency ranges. In a live network, however, it is expected that the MER (SNR) value should be a few dB lower than the CNR (CNiR) value, given that the MER (SNR) value takes into account noise impairments and distortions that are not accounted for by the CNR (CNiR) power measurements.

In general, when the CNR (CNiR) value is in the 15 to 25 dB range, you can expect the MER (SNR) value to have a comparable value. The difference between the MER (SNR) and CNR (CNiR) values is expected to be larger when the CNR (CNiR) value falls outside of the 15 to 25 dB range.

The table below provides a comparison between the MER (SNR) and CNR (CNiR) values, listing the major reasons for why the MER (SNR) and CNR (CNiR) values might diverge on an active network that is passing live traffic:

Table 47: Comparison of MER (SNR) and CNR (CNiR) in a DOCSIS Cable Network

Signal-to-Noise (SNR)	Carrier-to-Noise (CNR)
Post-detection measurement of the RF signal.	Pre-detection measurement of the RF signal.
Measurement of the baseband domain.	Measurement of the RF frequency domain.

Signal-to-Noise (SNR)	Carrier-to-Noise (CNR)
Includes the effect of signal distortions and impairments on the signal. These include: • Group delay in the channel such as occurs during operation near the diplexer band edge. • Channel amplitude variation and echoes. • Data collisions. • Microreflections. • Narrow band ingress in the channel. • Non-linearities in the cable plant. • Phase noise. • Poor selection of the preamble. • Poor symbol fidelity in the transmission of a a cable modem, despite a good MER (SNR) value. • Unrecoverable carrier offsets. • Unrecoverable symbol timing offsets.	Measures only the RF modulated carrier power versus noise power.
Provides an indication of overall, end-to-end network quality (what the transmitter, receiver, and transmission media are doing to the signal).	Provides an indication of network performance (what the transmission media or network is doing to the signal).
Average over time with current data traffic patterns, useful for tracking long-term trends in signal quality.	Real-time spectrum analysis.
Reflects the CNR (CNiR) value as part of its value.	Does not reflect the MER (SNR) value as part of its value.
Averaged over 10,000 symbols, and an accurate reading requires that short and long grants are being transferred.	Unaffected by the type of traffic being transmitted.
Does not use packets with uncorrectable FEC errors to determine its value. Bursts of uncorrectable errors, therefore, could result in a deceptively high MER (SNR) value.	Unaffected by uncorrectable FEC packet bursts.
DOCSIS specifications do not define any required MER (SNR) values for upstreams and downstreams.	Minimum downstream CNR of 35 dB in a 6-MHz band (44 dB in DOCSIS 2.0 for 8-MHz band) Minimum upstream CNR (CNiR) of 25 dB.

SNR Smoothing

Cisco cBR 16.12.1w and later, supports the following methods of easing the fluctuations in SNR:

- Cable Modem-based SNR

- US Channel-based SNR

Cable Modem-based SNR

The SNR error (2-Bytes) is decoded by US-PHY ASIC and calculated by using the SNR formula, 10 * log10 (power/error). For example:

- `error=7 SNR(db)=36.62db`
- `error=15 SNR(db)=33.22db`

The MIB is `docsIf3CmtsCmUsStatusSignalNoise`.

Use the **cable ranging cm packet** command to configure the number of ranging packets to get the CM-based SNR.

```
Router(config)# cable ranging cm packet <1-20>
```

The number of ranging packets can be 1 to 20. The default value is 1.

US Channel-based SNR

The SNR of a single US channel is calculated from the ranging packets of cable modems (CM) on that US channel. Cisco cBR-8 takes an average of every 10 SNR values from a CM to generate the SNR of the US channel. If a new CM SNR value is close to (within 3DB) the current US channel SNR, the Cisco cBR-8 router uses the new CM SNR to represent the current US channel SNR.

The MIB is `docsIfSigQSignalNoise`.

Use the **cable ranging upstream packet** command to configure the number of ranging packets to get the US channel-base SNR.

```
Router(config)# cable ranging upstream packet <10-80>
```

The default value is 10.

Use the **cable ranging upstream deviation** to configure the per upstream SNR deviation number.

```
Router(config)#cable ranging upstream deviation <1-3>
```

The default value is 3.

To display the cable ranging configuration, use the **show cable ranging setting** command. For example:

```
Router#show cable ranging setting
num_pkt_per_us:  20
num_pkt_per_cm:  5
snr_dev:         2
```

Additional Measurements

In addition to MER (SNR) and CNR (CNiR) values, you should be aware of and monitor the following indicators of signal quality:

- MER—This is the measure of RF signal quality, in dB, which is equivalent to SNR and similar to CNR (CNiR) under additive white Gaussian noise (AWGN) impairments. However, MER is preferred for data networks, because it also includes additional factors that affect the signal, such as analog-to-digital and digital-to- analog conversions, rounding errors, distortions, and signal impairments such as phase noise,

group delay, and jitter. For this reason, the DOCSIS 2.0 RF specification adds a requirement for the minimum MER value for a signal, supplementing the existing CNR (CNiR) minimum requirements.

A simple formula for calculating the MER value for an upstream is:

```
MER = 20 x log (RMS error magnitude / Average symbol magnitude)
```

You can also calculate the Error Vector Modulation (EVM) to find the equivalent value expressed as a percentage of noise on an upstream:

```
EVM = Average error magnitude / Max symbol magnitude * 100
```

See the DOCSIS 2.0 specification for more complete information on calculating and using the MER value.

- FEC Counters—These are counters that keep track of how many correctable and uncorrectable FEC errors occur on the upstream. The FEC error counters are useful for tracking fast transient errors such as impulse noise that are not usually reflected in MER (SNR) or CNR (CNiR) values.

  A correctable error count of more than 1 percent can be used as a warning sign of possible physical plant or cable modem problems that might be developed. An uncorrectable error count of more than 1 percent can indicate an existing problem that is blocking traffic on the upstream. Cable interface line cards that support the intelligent and advanced spectrum management features can use the FEC counters as one of the indicators to be monitored to determine whether an upstream must change frequencies so as to correct noise problems.

- Microreflections—Additional copies of a signal that arrive at the receiver, usually at different times and attenuated by different amounts, causing the receiver to misidentify the incoming signal's true phase and amplitude. Microreflections typically are caused by impedance mismatches in the physical cable plant, and can indicate either equipment that has been degraded by weather or other causes, or equipment that has not been installed correctly.

Upstream Signal Channel Overview

The upstream channel is characterized by many cable modems transmitting to the CMTS. These signals operate in a burst mode of transmission. Time in the upstream channel is slotted. The CMTS provides time slots and controls the usage for each upstream interval. The CMTS periodically broadcasts Upstream Channel Descriptor (UCD) messages to all cable modems. The UCD message contains the upstream frequency and transmission parameters associated with an upstream channel. These messages define upstream channel characteristics including the upstream frequencies, symbol rates and modulation schemes, forward error correction (FEC) parameters, and other physical layer values.

Cisco supports all DOCSIS error-correction encoding and modulation types and formats. Upstream signals are demodulated using QPSK or QAM. QPSK carries information in the phase of the signal carrier, whereas QAM uses both phase and amplitude to carry information.

Sending data reliably in the upstream direction is an issue. Because upstream spectrum varies greatly between cable plants, select upstream parameters based on your cable plant's return paths. Select or customize upstream profiles for the maximum trade-off between bandwidth efficiency and upstream channel robustness. For example, QAM-16 requires approximately 7 dB higher CNR (CNiR) to achieve the same bit error rate as QPSK, but it transfers information at twice the rate of QPSK.

Note The above specifications are based on predetermined sets of frequencies that may or may not have an adequate CNR (CNiR) at any given time.

Upstream frequencies can be assigned as follows:

- Fixed—Configuring a spectrum group disables the fixed upstream frequency setting.
- Single subband—The CMTS administrator can define a center frequency and symbol rate such that the boundaries of the upstream carrier stay within the subband. The frequency and symbol rate can change within the boundary in response to noisy line conditions, based on the defined upstream parameters.
- Multiple subbands—The data carrier can remain in a particular subband for a duration of time and then hop to another subband based on the defined upstream parameters.

Tip Measurement of noise power levels with a spectrum analyzer should be part of the procedure in initially selecting and setting up frequency allocations. We recommend having fixed frequency settings during early deployment, at least until amplifier cascade adjustments or plant repair have become infrequent enough that they no longer significantly affect the nodes connected to the upstream port.

Upstream Frequency Changes

As stated in the DOCSIS radio frequency interface (RFI) specification, RF channel migration or upstream frequency change occurs when a change in the UCD message is broadcast to all cable interfaces.

The speed of channel migration via the UCD message is typically less than 20 milliseconds (ms). During this time, upstream transmission is interrupted until the cable interface transmitter adjusts to its new frequency. Data is stored in the cable interface buffers during this time and is sent when the frequency hop is complete.

Station maintenance intervals are used to perform per modem keepalive polling. The CMTS polls each cable modem at least once every 30 seconds, with the default being once every 20 seconds. When ingress noise causes loss of keepalive messages from a configurable percentage of all cable interfaces, resulting in missed polls, a new frequency is selected from the allocation table and a UCD update is performed. The migration time is 2 msec for any upstream UCD update. After the UCD is updated, the hop occurs. The system must wait until a hop threshold time interval has elapsed before it can change the UCD a second time.

Upstream Segments and Combiner Groups

The Cisco routers divide a cable plant into downstream channels. Downstream channels contain upstream segments. Each upstream segment typically serves more than one fiber node. Upstream segments can be defined as one of the following:

- Sparse segment—Containing one upstream channel per upstream segment.
- Dense segment—Containing multiple upstream channels per upstream segment; frequencies must be different.

Note A cable interface line card can support sparse or dense segments, or both.

Defining sparse segments allows the cable operator to share upstream bandwidth among fiber nodes with fewer subscribers. Defining dense segments allows the cable operator to provide larger upstream bandwidth to fiber nodes with many subscribers.

The figure below illustrates sparse versus dense segments.

Figure 1: Sparse Versus Dense Segment Illustrations

As shown in the figure above, the downstream segment can contain multiple upstream segments. Two fiber nodes can be in one downstream segment but in different upstream segments.

The return path of several fiber nodes can be combined at a single point to form a single RF frequency domain called a combiner group. The CMTS software allows a frequency hop table called a spectrum group to be associated with a combiner group.

Note A combiner group refers to an RF topology point. A spectrum group refers to the frequency hop table associated with a combiner group.

Frequency Management Policy

Spectrum management applies a common frequency-management policy to a set of upstream ports to ensure that data is delivered reliably over the cable plant. Cable plant operators must make noise measurements and determine the cable plant's spectrum management policy. Different modulation schemes, upstream frequency techniques, and symbol rates are used based on the cable plant characteristics and the cable interface line card in the chassis.

See the following sections for more information about these topics:

Noise Impairments

Upstream noise impairments such as signal degradation on cable networks can negatively affect service to subscribers. Two-way digital data signals are more susceptible than one-way signals to stresses in the condition of the HFC network. Degradation in video signal quality might not be noticeable in one-way cable TV service, but when two-way digital signals share the network with video signals, digital signals can be hampered by:

- Impulse and electrical signal ingress—Noise can enter the network from electrical sources within a residence or from high-voltage lines that run near cable television cabling. Two types of ingress noise include broadband and narrowband. Broadband noise is generally of lower frequency (below 10 MHz) and results in harmonic rolloff. Narrowband noise is a more significant interference source. Cable equipment and infrastructure often pick up noise from amateur radio transmissions, citizen band radios, or high-power shortwave broadcast signals. Implement a signal leakage maintenance program to locate and repair areas of signal ingress.

- Amplifier noise—Amplifiers add noise to the HFC network that typically goes unnoticed in video signals, but degrades digital data signals if amplifiers are improperly configured. The larger the network, the higher the probability of amplifier noise affecting signals.
- Noise funneling—The upstream data path to the headend is susceptible to interference from the entire network. All upstream noise ultimately ends up at the headend because the cumulative nature of noise becomes concentrated at the headend. As a network serviced by a single RF receiver increases in size, the probability of noise funneling also increases.
- Variable transmit levels—Temperature affects signal loss over coaxial cable. This can cause variations of 6 to 10 dB per year.
- Clipping—The lasers in fiber-optic transmitters can stop transmitting light when input levels are excessive. Excessive input levels introduce bit errors in both the upstream and downstream transmissions. If a laser is overdriven as briefly as a fraction of a second, clipping can occur.

To adjust your return amplifiers and lasers, follow rigorous plant maintenance procedures documented in the NTSC Supplement on Upstream Transport Issues or appropriate cable plant standard.

Spectrum Groups and Frequency Hopping

We recommend that CMTS administrators configure upstream frequency hopping to counteract long-term, narrowband noise. Cisco CMTS routers support a combination of guided frequency hopping and time-scheduled frequency hopping.

The frequency hop to proactively avoid noise ingress is sometimes called frequency agility. Frequency agility is configured and activated using spectrum groups. Spectrum management supports the creation of a number of cable spectrum groups, allowing multiple upstream ports in a single spectrum group. Each spectrum group defines the table of frequencies to be used in a specific frequency plan. Upstream frequencies can be a fixed single frequency, a single continuous range of frequencies (band), or multiple ranges (or bands) of frequencies.

The cable interface does not operate until you assign a frequency to the upstream, which can be done either by configuring and assigning a spectrum group or assigning a fixed frequency. The spectrum group takes precedence, so if you configure both a spectrum group and a fixed frequency on an upstream, the spectrum group overrides the fixed upstream frequency setting.

From the interface point of view, a spectrum group also represents the set of upstreams connected to the same group of fiber nodes. The spectrum manager software in Cisco routers examines all the RF parameters that have been configured on an upstream to determine whether the upstream frequencies need to be managed together. For example, if you configure a spectrum group with several fixed frequencies, but those frequencies are all within the configured channel width, the spectrum manager software combines the frequencies into a single band.

The upstream ports use the spectrum group to determine which frequencies are available if frequency hopping is needed to deal with noise or other path impairments. The types of frequency hopping techniques are guided, time-scheduled, and combined guided and time-scheduled. See the Frequency Hopping Capabilities, on page 246 for more information on the types of frequency hopping techniques.

Note When each upstream port has its own RF domain, the group is called a nonshared spectrum group. When multiple upstream ports share the same RF domain, the group is called a shared spectrum group.

Guidelines for Spectrum Management

In general, when defining your spectrum, use the following guidelines:

- Avoid frequencies with known ingress problems, such as amateur radio bands or short-wave bands.
- Avoid a hostile spectrum below 20 MHz.
- Allow extra bands for frequency hopping.
- Take the possible channel widths into account when creating frequency bands. The range of frequencies being used must be able to hop between at least two different frequencies when using the channel width that is configured on the upstream.
- Place upstream ports in the same combiner group in a shared spectrum group.
- Use the receive power level setting to perform slight equalization adjustments.
- If you combine multiple upstream ports to provide increased bandwidth, you must avoid overlapping frequency bands. Each port should be using a discrete band of frequencies that does not overlap the bands being used by other ports in the group. We recommend adding at least 20 KHz between the ending frequency of one band and the starting frequency of the next band, to ensure that the bands do not overlap.

Guided and Scheduled Spectrum Management

Guided and scheduled spectrum management constitutes a set of basic features for all currently supported cable interface line cards. These features are considered basic because they are available for all cable interfaces, and constitute the elementary, cornerstone features upon which the intelligent and advanced spectrum management features are built.

See the following sections for more information about each feature:

Frequency Hopping Capabilities

Noise in the upstream transmission line, that is from the consumer to the service provider, can degrade data transmission from the subscriber's home. If the noise impairment is of substantial duration, it may cause the cable modem to temporarily lose communication with the headend facility. As a contingency plan, the multiple service operators (MSOs) can reserve multiple channels or upstream frequencies for their subscribers. If one channel suffers too much interference, the CMTS requests that the cable modems "hop" to another channel.

To provide frequency hopping capability, Cisco CMTS routers contain a spectrum manager that continuously monitors the noise in unused upstream channels. If the CNR (CNiR) reaches an unacceptable level on a particular channel, the spectrum manager automatically assigns a new upstream channel to the cable modem using that channel.

Cisco CMTS routers support the following techniques for upstream frequency hopping when the frequency band in use is not clean:

- Guided frequency hopping—In guided frequency hopping (also known as blind hopping), the spectrum manager automatically assigns a new upstream channel frequency when a configurable threshold of station maintenance (keepalive) messages fails. Failed station maintenance messages represent an impairment of the upstream channel due to noise, plant, or equipment failure. Explicit frequency subbands and associated input power levels are assigned in a spectrum group in guided frequency hopping.
- Time-scheduled frequency hopping—Frequency reassignment is scheduled by the time of day or by a specific day of the week.

- Combined guided and time-scheduled frequency hopping.

Note Frequency hopping is not effective against broadband noise phenomena such as impulse noise.

Time-scheduled and guided hopping techniques are independent concepts:

- The spectrum is controlled by a script, not a frequency table.
- The available spectrum is time-scheduled as an option.
- A guided hopping frequency is selected from the available spectrum at the current time.

You can configure and activate frequency hopping by using spectrum groups. You can create up to 40 cable spectrum groups, each containing multiple upstream ports. The configured channel width is used for each upstream frequency.

After you have created one or more spectrum groups for your cable network, you can add characteristics to them, providing you with more definitive control over frequency usage and frequency hopping.

You can configure hopping thresholds. For example, the frequency hop threshold percentage method prevents a single failing cable modem from affecting service to other working cable modems. As long as a high enough threshold is configured, the system does not hop endlessly due to a single cable modem failing to respond to 90 percent of its station maintenance (keepalive) messages.

You can also configure the minimum period between frequency hops, with a default setting of 30 seconds. If the destination channel is expected to be impaired, you can reduce the minimum period between frequency hops to a small value, such as 10 seconds. This allows the frequency hop to continue more rapidly until a clear channel is found. If excessive frequency hop is an issue, you can increase the minimum period between hops.

To configure different techniques of frequency hopping, see the Creating and Configuring Spectrum Groups, on page 253.

Note Spectrum management is not supported for one-way (telco return) cable modems, because spectrum management capabilities focus on the upstream path over an HFC network.

Note After the spectrum-band is changed, the spectrum management does not rearrange the frequency for each US channel if the previous frequency belongs to the range of new spectrum-band, which means that the US frequency will not be changed; if the previous frequceny is out of range of new spectrum-band, those US channels will not get frequencies.

Time-Scheduled Frequency Hopping

You can specify upstream channel frequency reassignment based on a configured time of every day or of a specific day of the week. If your cable plant has an upstream noise characteristic on a weekly cycle, use time-scheduled spectrum allocation. With a time-scheduled policy, a single frequency becomes valid at any given time.

Dynamic Upstream Modulation (MER [SNR]-Based)

This section describes the operation of this feature, which is based on evaluating the MER (SNR) of an upstream.

Note A more advanced version of dynamic upstream modulation, which uses the carrier-to-noise ratio (CNR [CNiR]), is supported on the cards that support intelligent and advanced spectrum management.

Feature Overview

Cisco cable interface line cards monitor the MER (SNR) values and the forward error correction (FEC) counters in the active return path of each upstream port. The Dynamic Upstream Modulation feature determines whether upstream channel signal quality can support the modulation scheme configured, and adjusts to the most robust modulation scheme when necessary. When return path conditions improve, this feature returns the upstream channel to the higher modulation scheme that includes the modulation profile.

A modulation profile is a collection of burst profiles that are sent out in a UCD message to configure modem transmit parameters for the upstream. The Dynamic Upstream Modulation feature adjusts the modulation profiles of an upstream channel based on upstream signal quality.

The Dynamic Upstream Modulation feature is configured on interfaces with fixed upstream frequencies or on interfaces with assigned spectrum groups.

The following examples show two different configurations of the Dynamic Upstream Modulation feature, using two and three modulation profiles.

Example Showing Dynamic Upstream Modulation Using Two Modulation Profiles

You can configure the Dynamic Upstream Modulation feature on the Cisco CMTS router using the following primary and secondary modulation profiles:

- The primary modulation profile uses 64-QAM or 16-QAM, which is a more bandwidth-efficient modulation scheme and has a higher throughput than a QPSK profile.
- The secondary modulation profile uses QPSK, which uses a more robust modulation scheme, but is not bandwidth-efficient.

We recommend that the primary profile use 64-QAM or 16-QAM modulation and the secondary use QPSK. However, this is optional as both modulation profiles can either be QPSK or QAM. It is not mandatory for one profile to be QAM and the other QPSK, but modulation profile switchover is tied to the QAM and QPSK thresholds.

Example Showing Dynamic Upstream Modulation Using Three Modulation Profiles

You can configure the Dynamic Upstream Modulation feature on the Cisco CMTS router using the following primary, secondary, and tertiary modulation profiles:

- The primary modulation profile uses 64-QAM, which is a more bandwidth-efficient modulation scheme and has a higher throughput than a 16-QAM profile.
- The secondary modulation profile uses 16-QAM, which is a more bandwidth-efficient modulation scheme and has a higher throughput than a QPSK profile.

- The tertiary modulation profile uses QPSK, which uses a more robust modulation scheme, but is not bandwidth-efficient.

We recommend that the primary profile use 64-QAM modulation, the secondary profile use 16-QAM, and the tertiary profile uses QPSK. However, this is optional as the modulation profiles can either be QPSK or QAM. It is not mandatory that one is QPSK and the other two are QAM, but modulation profile switchover is tied to the QAM and QPSK thresholds.

Criteria for Switching Modulation Profiles

The Dynamic Upstream Modulation feature uses the following criteria to determine whether it should switch from the primary modulation profile (the more bandwidth-efficient, but less robust profile) to the secondary modulation profile (more robust, but less bandwidth-efficient profile) or to the (optional) tertiary modulation profile (most robust, but less bandwidth-efficient profile):

The modulation switch from the primary profile (high performance) to the secondary profile (mid-level performance) uses the following criteria:

- The upstream MER (SNR) is less than or equal to MER (SNR) threshold one and the percentage of correctable FEC (cFEC) errors is greater than or equal to the correctable FEC error threshold or the percentage of uncorrectable FEC (uFEC) errors is greater than or equal to the uncorrectable FEC error threshold.

Before switching back to the primary profile from the secondary profile, the following criteria must be satisfied:

- The upstream MER (SNR) is greater than or equal to the sum of MER (SNR) threshold one and the hysteresis value and the percentage of correctable FEC errors is less than or equal to the correctable FEC error threshold and the percentage of uncorrectable FEC errors is less than or equal to the uncorrectable FEC error threshold and the hop period equals to the default value of 15 seconds.

The modulation switch from the secondary profile (mid-level performance) to the tertiary profile (most robust) uses the following criteria:

- The upstream MER (SNR) is less than or equal to MER (SNR) threshold two and the percentage of correctable FEC (cFEC) errors is greater than or equal to the correctable FEC error threshold or the percentage of uncorrectable FEC (uFEC) errors is greater than or equal to the uncorrectable FEC error threshold.

Before switching back to the secondary profile from the tertiary profile, the following criteria must be satisfied:

- The upstream MER (SNR) is greater than or equal to the sum of MER (SNR) threshold two and the hysteresis value and the percentage of correctable FEC errors is less than or equal to the correctable FEC error threshold and the percentage of uncorrectable FEC errors is less than or equal to the uncorrectable FEC error threshold.

The modulation switch from the primary profile to the tertiary profile uses the following criteria:

- The upstream MER (SNR) is less than or equal to MER (SNR) threshold two and the percentage of correctable FEC (cFEC) errors is greater than or equal to the correctable FEC error threshold or the percentage of uncorrectable FEC (uFEC) errors is greater than or equal to the uncorrectable FEC error threshold.

Before switching back to the primary profile from the tertiary profile, the following criteria must be satisfied:

- The modulation switch from the tertiary profile to the primary profile is a two-step process:

1. The modulation switch happens from tertiary profile to the primary profile, when the upstream MER (SNR) is greater than or equal to the sum of MER (SNR) threshold one and the hysteresis value.
2. After a 15-second (non-configurable) delay, the modulation switch occurs from secondary profile to the primary profile, when the upstream MER (SNR) remains greater than or equal to the sum of MER (SNR) threshold one and the hysteresis value.

If the only problem is that the upstream is experiencing a large number of uncorrectable errors, then a situation could occur where the router continues to switch back and forth between profiles. The uncorrectable errors occur with the primary profile, so the router switches to the secondary profile. The secondary profile does not experience any problems, so the router switches back to the primary profile. But the uncorrectable errors reoccur and the router switches back to the secondary profile, and this cycle continues indefinitely.

To avoid this problem, make sure that the cable plant is capable of supporting the modulation scheme being used in the primary profile (for example, 64-QAM). If you cannot guarantee successful operation on an upstream using this modulation scheme, then you should select a primary profile that uses a more bandwidth-efficient set of burst parameters (such as QPSK). The Cisco IOS software includes predefined modulation profiles that can be used for the primary, secondary, and tertiary profiles.

Input Power Levels

The input power level, *power-level-dBmV*, is an option in the **cable spectrum-group** command. The option allows you to specify the expected upstream input power levels on the upstream receivers on the CMTS when the cable modems are hopping from one fixed frequency to another or from one band to another. Each upstream channel width has an associated upstream input power level in dBmV. The power level is the modem transmit power that each spectrum group can use when an upstream frequency change is necessary. The input power level may be set at the time of the frequency hop.

Specifying an input power level is done so that the cable modems do not have to increase or decrease their transmit power with every hop. The cable operator can perform minor power equalizations as a function of frequency. The valid range is –10 to 10dBmV. The power level value should be changed only if you want to change the power level as part of spectrum management. Some cable plants may want to change only the input power level, and not the frequency, on a daily time schedule.

Intelligent and Advanced Hardware-Based Spectrum Management

Several cable interface line cards include hardware-based spectrum management features that provide enhancements to the basic features supported by the other Cisco cable interface line cards.

Intelligent Spectrum Management Enhancements

The following features are part of the intelligent spectrum management feature set:

- Integrates a DOCSIS cable interface line card with an onboard spectrum analyzer that continuously analyzes the upstream spectrum quality in the DOCSIS frequency range of 5 to 42 MHz.
- Includes hardware-assisted frequency hopping, providing for more intelligent and faster frequency selection than software-only solutions.
- Reduces the response time to ingress noise that could cause modems to drop offline.
- Eliminates blind frequency hopping by initiating frequency hops to known clean channels.

- Improves frequency agility to help eliminate dropped packets and thereby maintain full upstream data rates.
- Supports frequency agility in dense-mode combining environments across a shared spectrum.
- Restricts frequency hopping to a set of discrete fixed frequencies or to a range of frequencies, as desired.
- Allows frequency hop conditions to be customized for specific plant environments and requirements.
- Optionally schedules frequency hops to take advantage of known usage patterns or plant conditions.
- Optionally dynamically reduces channel width to allow cable modems to remain online, even in noisy upstream conditions.

Benefits

The spectrum management features provided on the Cisco CMTS router platforms provide several key system benefits:

- Improves response time to ingress noise impairments that appear in the upstream return path.
- Boosts the percentage of modems online.
- Mitigates the impact of ingress to subscriber services.
- Saves time and effort by MSO staff when troubleshooting minor plant outages.
- Increases cable plant reliability.
- Maximizes spectrum utilization.

Guided and Scheduled Spectrum Management Benefits

The following summarizes the specific benefits of the guided and scheduled spectrum management features that are supported for all Cisco CMTS router platforms.

Input Power Levels

Allows the cable plant operator to perform minor power level equalization as a function of frequency.

Frequency Hopping Capabilities

Proactively countermeasures upstream noise impairments by assigning a new upstream channel to the cable modem. MSOs can take advantage of this feature especially when they have less than an optimal carrier-to-noise ratio in the upstream frequencies or when their cable plants exhibit random bursts of ingress noise that affect reliability.

Dynamic Upstream Modulation

- Reduces the risk associated with transitioning to QAM-16 modulation in the return path and provides assurance that subscribers remain online and connected during return path impairments.
- Checks that the active upstream signal quality can support the configured modulation scheme and proactively adjusts to the more robust modulation scheme when necessary.

- Eliminates the necessity to hop channels for cable modems to stay online by automatically switching from the primary modulation profile to the secondary modulation profile.

Intelligent and Advanced Spectrum Management Benefits

The following summarizes the specific benefits of the advanced spectrum management features that are supported on Cisco CMTS routers using supported cable interface line cards.

Dynamic Channel Width Change

- Improves the DOCSIS upstream channel availability by finding the maximum possible channel width for an upstream when noise conditions make the current channel width unusable.
- Provides the maximum RF spectrum utilization efficiency for current plant conditions.
- Customizable range of channel widths that can be used to respond to noise problems.

Intelligent Frequency Hopping

- Proactively changes upstream frequency for an interface before noise conditions become severe enough to force cable modems offline.
- Dedicated hardware intelligent frequency hopping performs “look-ahead” to choose new upstream frequency to find a stable channel.
- Flexible priority configuration allows hopping decision criteria to be tailored to the individual cable plant environment.
- Improves responsiveness to ingress impairments, by matching the hopping decision criteria to the fluctuating plant conditions.
- Pinpoints CNR (CNiR) variations with per-modem accuracy to isolate problematic cable modems.
- Sustains or even improves subscriber online percentages through user-programmable proactive channel management techniques.

Dynamic Upstream Modulation

- Reduces the risk associated with switching between QPSK and QAM-16 modulation in the upstream to respond to ingress noise, so that subscribers remain online and connected.
- Checks the current upstream signal to ensure that it can support the configured modulation scheme, and proactively adjusts to the secondary more robust modulation scheme when necessary.
- Improves DOCSIS upstream channel availability and provides maximum RF spectrum utilization efficiency.
- Eliminates unnecessary frequency hopping by switching modulation profiles to one that allows cable modems to remain online while using the currently assigned upstream.
- Provides assurance that subscribers remain online and connected during periods of return path impairments.

SNMP Interface

- Provides a way to remotely obtain the current status of noise on an upstream. This information can then be inserted into third-party or custom reporting and graphing applications.
- Provides visibility to ingress and impulse noise under the carrier frequency on a per-port basis.
- Provides an easy-to-use, distributed method to remotely gather real-time display of the DOCSIS upstream spectrum for individual cable modems and set-top boxes (STBs).
- Reduces the reliance on costly spectrum analyzers at every headend or hub.
- Quickly provides spectrum views through an intuitive interface, without the complicated setup time of a spectrum analyzer.
- Allows the technician to troubleshoot the network remotely, as opposed to having to be physically present to connect and use a spectrum analyzer.

Default Hop Priority

For Intelligent and Advanced Spectrum Management feature, the default hop priority is as given below:

- Frequency, modulation, and channel width (when using spectrum groups on spectrum cards).
- Modulation, guided frequency hop, and channel width (when using analyzer cards with spectrum groups).
- Modulation only (when not using spectrum groups [fixed frequency]).

How to Configure Spectrum Management

This section describes the configuration tasks that are most commonly performed when using the spectrum management features on the Cisco CMTS platforms. See the following sections for the configuration tasks that are appropriate for your platform and cable interface line cards.

Guided and Scheduled Spectrum Management Configuration Tasks

The following tasks configure the guided and scheduled spectrum management features that are supported on all Cisco CMTS platforms:

Creating and Configuring Spectrum Groups

A spectrum group defines the frequencies that an upstream is allowed to use when frequency hopping is done, as well as other parameters that control the frequency hops. When creating and configuring spectrum groups, you can specify the following parameters:

- Frequencies that are assigned to the group. The cable interface uses these frequencies to determine what frequencies are available to use when frequency hopping is needed. You can specify either a list of fixed frequencies or a band of frequencies, or both. The Cisco CMTS uses the following rules when adding frequencies to a spectrum group:
  - When specifying a fixed frequency, the Cisco CMTS assumes it is a center frequency with a 6.4-MHz channel width to allow that frequency to operate at all possible channel widths. For example,

specifying a frequency of 17,700,000 Hz is equivalent to specifying a frequency band from 14,500,000 Hz to 20,900,000 Hz (a band that is 6.4 MHz wide).

- If you configure multiple fixed frequencies or bands of frequencies that overlap, the spectrum group combines them into one band. For example, if you specify a fixed frequency of 17,700,000 Hz and a band from 15,800,000 Hz to 25,200,000 Hz, the spectrum group is configured with one band from 14,500,000 Hz to 25,200,00 Hz.
- If you want more control over a spectrum group's frequencies, configure bands of frequencies with the same width as the desired channel width. For example, if you want to use a center frequency of 17,700,000 Hz with a 3.2-MHz channel width, specify a band that ranges from 16,100,000 Hz to 19,300,000 Hz. To ensure you configure non-overlapping bands, separate the bands by a minimum of 20 KHz.

- Upstream input power level—(Optional) Power level, in dBmV, that the upstream should use when hopping to a new frequency. (Some cable plants might want to change only the input power level, and not the frequency, on a daily time schedule.)
- Hop threshold—(Optional) Percentage of cable modems that start missing station maintenance messages before a frequency hop can occur. Configure the hop threshold percentage as needed to prevent a single failing cable interface from affecting service to other good cable interfaces. This ensures that the system does not hop endlessly because one cable modem is generating 90 percent of the errors and 90 percent of the traffic.
- Hop period—(Optional) Minimum time period that must elapse between frequency hops. This allows you to specify a time period long enough to allow an upstream to stabilize before another frequency hop can be performed.
- Scheduled hop time—(Optional) Time of day at which a frequency hop should be scheduled.

Tip Before adding a list of upstream frequencies (or frequency hop tables), start by determining which upstream ports are assigned to a combiner group. Refer to the Example: Determining the Upstream Ports Assigned to a Combiner Group, on page 276 for an example.

To create and configure a spectrum group, use the following procedure.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

	Command or Action	Purpose
Step 3	**cable spectrum-group** *group-number* **time**[*day hh:mm:ss*] **frequency** *up-freq-Hz* [*power-level-dBmV*] **Example:** `Router(config)# cable spectrum-group 4 time Monday 12:00:00 frequency 40000000`	Creates the spectrum group (if it does not already exist), and adds the specified fixed frequency to the group.
Step 4	**cable spectrum-group** *group-number* **time** [*day hh:mm:ss*] **band** *up-freq-Hz up-freq2-Hz [power-level-dBmV*] **Example:** `Router(config)# cable spectrum-group 4 band 20000000 24000000 13`	Creates the spectrum group (if it does not already exist), and adds the specified band of frequencies to the group. **Note** Repeat Step 4 and Step 6 as needed for each fixed frequency and frequency band that should be a member of this spectrum group. You must assign at least two fixed frequencies, or a frequency band that contains at least two center frequencies, to a spectrum group before frequency hopping can occur.
Step 5	**cable spectrum-group** *group-number* **hop period** *seconds* **Example:** `Router(config)# cable spectrum-group 4 hop period 60`	Specifies the minimum time, in seconds, between frequency hops. **Note** We recommend a configuration of 30 seconds when using a Cisco uBR-MC5X20S/U/H BPE.
Step 6	**cable spectrum-group** *group-number* **hop threshold** [*percent*] **Example:** `Router(config)# cable spectrum-group 4 hop threshold 25`	Specifies the frequency hop threshold for a spectrum group. • **percent**—(Optional) Frequency hop threshold as a percentage of station maintenance messages that are lost. Valid range is from 1 to 100 percent, with a default of 50 percent.
Step 7	**cable spectrum-group** *group-number* **Example:** `Router(config)# cable spectrum-group 4`	(Optional) Specifies that the upstream ports in a spectrum group should use a unique upstream frequency.
Step 8	**end** **Example:** `Router(config)# end`	Exits global configuration mode and returns to privileged EXEC mode.

Assigning a Spectrum Group to One or More Upstream Ports

After a spectrum group has been created and configured, you must assign it to one or more upstream ports before the group's frequency spectrum is used for frequency hopping.

To assign a spectrum group to one or all upstream ports on a controller interface, use the following procedure.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**controller upstream-cable** *slot/subslot/port* **Example:** `Router(config)# controller upstream-cable 9/0/15`	Enters controller configuration mode.
Step 4	**us-channel** *us -channel_num* **spectrum-group** *spectrum-group-num* **Example:** `Router(config-controller)# us-channel 0 spectrum-group 1`	Assigns the specified spectrum group as the default group for all upstream on this controller interface.
Step 5	**us-channel** *us -channel_num* **channel-width** *value* **Example:** `Router(config-controller)# us-channel 0 channel-width 1600000`	Configures the channel-width for the specified upstream channel spectrum group.
Step 6	**end** **Example:** `Router(config-controller)# end`	Exits controller interface configuration mode and returns to privileged EXEC mode.

What to do next

Tip To verify the spectrum group configuration, use the **show cable spectrum-group** command in privileged EXEC mode.

Configuring Shared Spectrum Groups (Fiber Node Groups) for DOCSIS 3.0

This feature supports shared spectrum groups that cross multiple cable interface line cards on the Cisco CMTS router, and shared spectrum groups within a single cable interface line card.

For additional information about configuring fiber node groups on the Cisco CMTS, see:

Configuring Dynamic Upstream Modulation (MER [SNR]-Based)

To use the Dynamic Upstream Modulation feature on cable interface line cards that support only the MER (SNR) version of this feature, you must do the following:

1. Create a primary modulation profile. This typically is a more bandwidth-efficient but a less robust profile.
2. Optionally create a secondary modulation profile. This typically is a less bandwidth-efficient but a moderately robust profile.
3. Optionally create a tertiary modulation profile. This typically is a less bandwidth-efficient but a more robust profile.
4. Assign the profiles to the desired cable interfaces and upstreams.

Tip When creating the modulation profiles, we recommend that you use the predefined modulation profiles, as opposed to manually specifying each burst parameter for each modulation profile.

Restriction

- The Dynamic Upstream Modulation feature is supported only for DOCSIS 1.0 or DOCSIS 1.1 TDMA-only modulation profiles for advanced spectrum management.
- The DOCSIS 2.0 mixed-mode or ATDMA-only mode modulation profiles are supported only for basic spectrum management (MER [SNR]-based) and not for advanced spectrum management.
- The Three Step Dynamic Modulation feature supports only basic spectrum management features. It does not support modulation profile changes based on CNR (CNiR) thresholds and CNR (CNiR) measurements.
- The Dynamic Upstream Modulation feature is not enabled for single modulation profile configurations.
- You can configure only two modulation profiles when an upstream is already assigned to a spectrum group for frequency hopping. The spectrum group here implies advanced spectrum management and/or the use of CNR (CNiR).
- A single profile is automatically removed from the configuration if three modulation profiles are assigned to an upstream interface before assigning spectrum group, based on the following conditions:
  - The robust profile is dropped if the upstream port is using a high performance profile.
  - The high performance profile is dropped if the upstream port is using a mid-level or robust profile.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.

	Command or Action	Purpose
Step 3	**cable modulation-profile** *profile* {**mixed** | **tdma** | **atdma** **Example:** `Router(config)# cable modulation-profile 3 mixed`	Creates the primary modulation profile for use on a DOCSIS 1.0 or DOCSIS 1.1 TDMA or A-TDMA upstream. **Note** Repeat this command to create the secondary and tertiary profile for use on a DOCSIS 1.0 or DOCSIS 1.1 TDMA or A-TDMA upstream. **Note** You can also create custom modulation profiles with the **cable modulation-profile** command by configuring the values for the individual burst parameters. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer. We recommend using the preconfigured default modulation profiles for most cable plants.
Step 4	**controller upstream-cable** *slot/subslot/port* **Example:** `Router(config)# controller upstream-cable 9/0/15`	Enters controller configuration mode.
Step 5	**us-channel** *n* **modulation-profile** *primary-profile-number* [*secondary-profile-number*] [*tertiary-profile-number*] **Example:** `Router(config-controller)# us-channel 0 modulation-profile 21 121 221`	Assigns a primary modulation profile, and the optional secondary and tertiary modulation profiles, to the specified upstream port.
Step 6	Use one of the following commands: • **us-channel** *n* **threshold snr-profiles** *threshold1-in-db threshold2-in-db* • **us-channel** *n m* **threshold snr-profiles** *threshold1-in-db threshold2-in-db* **Example:** `Router(config-controller)# us-channel 0 threshold snr-profiles 25 15`	(Optional) Specifies the MER (SNR) threshold in dB.
Step 7	Use one of the following commands: • **us-channel** *n* **threshold corr-fec** *corr-fec* • **us-channel** *n m* **threshold corr-fec** *corr-fec* **Example:** `Router(config-controller)# us-channel 0 threshold corr-fec 20`	(Optional) Specifies the allowable number of correctable FEC errors for the upstream.
Step 8	Use one of the following commands: • **us-channel** *n* **threshold uncorr-fec** *uncorr-fec*	(Optional) Specifies the allowable number of uncorrectable FEC errors for the upstream.

	Command or Action	Purpose
	• **us-channel** *n m* **threshold uncorr-fec** *uncorr-fec* **Example:** `Router(config-controller)# us-channel 0 threshold uncorr-fec 10`	
Step 9	**us-channel** *n* **threshold hysteresis** *hysteresis-in-db* **Example:** `Router(config-controller)# us-channel 0 threshold hysteresis 10`	(Optional) Specifies the hysteresis value to be used in conjunction with the dynamic modulation upgrade thresholds.
Step 10	**end** **Example:** `Router(config-controller)# end`	Exits controller interface configuration mode and returns to privileged EXEC mode.

What to do next

Tip See the Dynamic Upstream Modulation (MER [SNR]-Based), on page 248 for a complete description of the Dynamic Upstream Modulation feature.

Verifying Frequency Hopping

You can verify frequency hopping on the CMTS by using the command-line interface (CLI).

Verifying Frequency Hopping Using CLI Commands

To verify frequency hopping using CLI commands, use the following procedure:

Step 1 Verify that the interface being tested is up, using the **show interfaces cable** command in privileged EXEC mode. The first line of the output shows whether both the interface and line protocol are up.

Example:

```
Router# show interfaces cable 9/0/0

Hardware is CMTS MD interface, address is c414.3c16.cf8f (bia c414.3c16.cf8f)
MTU 1500 bytes, BW 26000 Kbit/sec, DLY 1000 usec,
reliability 255/255, txload 1/255, rxload 1/255
Encapsulation MCNS, loopback not set
```

Step 2 Verify that the upstream being tested is up, using the **show interfaces cable upstream** command. The first line shows whether the upstream is up.

Example:

```
Router# show interfaces cable 9/0/0 upstream 0

MAC domain upstream impairment report: 0x0
Cable9/0/0: Upstream 0 is up
```

```
Description: UC9/0/0:U0
Received 5 broadcasts, 0 multicasts, 26 unicasts
0 discards, 0 errors, 0 unknown protocol
31 packets input
Codewords: 348 good 0 corrected 0 uncorrectable
```

Step 3 Use the **show cable hop upstream-cable** command to display the frequency that the upstream is currently using:

Example:

```
Router# show cable hop upstream-cable 9/0/0

Upstream    Port       Poll Missed Min    Missed Hop   Hop     Corr    Uncorr
Port        Status     Rate Poll   Poll   Poll   Thres Period  FEC     FEC
                       (ms) Count  Sample Pcnt   Pcnt  (sec)   Errors  Errors
Cable6/0/U5 16.816 Mhz 1000 0      10         0%   20%  25     0       0
```

Step 4 Use the **show cable hop upstream-cable history** command to display the frequency change, modulation change, and channel width change action history of the upstreams:

Example:

```
Router# show cable hop upstream-cable 9/0/0 history

F = Frequency Hop, M = Modulation Change, C = Channel Width Change
Upstream     Action             Chg    Chg    Action
Port         Time          Code From   To     Reason
Ca7/0/0/U0   Sep 17 17:00:24 C  1.6    3.2    Configuration changed
             Sep 14 19:38:55 F  41.117 26.358 Interface state changed
             Sep 14 19:38:55 F   0.000 41.117 Interface state changed
             Sep 14 19:38:24 M  21     221    Configuration changed
```

Step 5 Use the **show cable hop upstream-cable threshold** command to display the user-defined thresholds and current CNR, MER (SNR), correctable FEC percentage, uncorrectable FEC percentage, and missed station maintenance percentage values of the upstreams:

Example:

```
Router# show cable hop upstream-cable 6/0/0 threshold

Upstream   SNR(dB)          CNR(dB)          CorrFEC%  UncorrFEC%       MissedSM%
Port       Val Thre1 Thre2 Val Thre1 Thre2 Pcnt Thre Pcnt Thre        Pcnt Thre

Ca6/0/0/U0 27   25   15    39   35   25    0    3    0    1           75   75
Ca6/0/0/U1 31   25   15    51   35   25    0    3    0    1           90   75
Ca6/0/0/U2 --   35   25    --   35   25    0    3    0    1           0    75
Ca6/0/0/U3 --   35   25    --   35   25    0    3    0    1           0    75
```

Step 6 Use the **test cable hop** command to force the desired upstream to perform a frequency hop. A few seconds after giving the command, a console message should appear informing you of the hop. Repeat the command as needed to verify that the upstream hops through all the frequencies that have been assigned to the upstream's spectrum group.

Example:

```
Router# test cable hop cable 6/0 upstream 5

2w0d: %UBR7200-5-USFREQCHG: Interface Cable6/0 Port U5, frequency changed to 15.760 MHz
```

```
Router# test cable hop cable 6/0 upstream 5

2w0d: %UBR7200-5-USFREQCHG: Interface Cable6/0 Port U5, frequency changed to 26.832 MHz
```

Step 7 Use the **test cable channel-width** command to force the desired upstream to perform a channel-width change. A few seconds after giving the test command, use the show cable hop command to verify the channel-width change.

Example:

```
Router# test cable channel-width cable 7/0/0 upstream 0

Channel width changed to 1600000 Hz for Cable7/0/0 U0

Router# *Sep 17 17:06:46.882: %UBR10000-5-USCWCHG: Interface Cable7/0/0 U0, channel width changed to
 1600 kHz SLOT 7/0: Sep 17 17:06:46.898: %UBR10000-5-USCWCHG: Interface Cable7/0/0 U0, channel width
 changed to 1600 kHz

Router# Sep 17 17:06:46.898: %Interface Cable7/0/0 U0 With channel width 1600 kHz, the minislot size
 is now changed to 4 ticks.

Router# show cable hop cable 7/0/0 upstream 0 history


F = Frequency Hop, M = Modulation Change, C = Channel Width Change
Upstream     Action             Chg    Chg    Action
Port         Time          Code From   To     Reason
Ca7/0/0/U0   Sep 17 17:06:46 C  3.2    1.6    Test command enforced
             Sep 17 17:06:02 M  222    221    SNR 36>=28 CFEC 0<=3 UnCFEC 0<=1
             Sep 17 17:06:00 M  221    222    Test command enforced
             Sep 17 17:03:21 M  222    221    SNR 36>=28 CFEC 0<=3 UnCFEC 0<=1
             Sep 17 17:03:19 M  221    222    Test command enforced
             Sep 17 17:01:44 F  26.358 19.742 Test command enforced
             Sep 17 17:01:17 F  21.528 26.358 Test command enforced
             Sep 17 17:00:24 C  1.6    3.2    Configuration changed
             Sep 14 19:38:55 F  41.117 21.528 Interface state changed
             Sep 14 19:38:55 F   0.000 41.117 Interface state changed
             Sep 14 19:38:24 M  21     221    Configuration changed
Router#
```

Step 8 Use the **test cable freq-hop** command to force the desired upstream to perform a dynamic frequency change. A few seconds after giving the test command, use the **show cable hop** command to verify the frequency change.

Example:

```
Router# test cable freq-hop cable 7/0/0 upstream 0

SLOT 7/0: Sep 17 17:01:44.650: %UBR10000-5-USFREQCHG: Interface Cable7/0/0 U0, changed to Freq 19.742
 MHz

Router# show cable hop cable 7/0/0 upstream 0 history

F = Frequency Hop, M = Modulation Change, C = Channel Width Change
Upstream     Action             Chg    Chg    Action
Port         Time          Code From   To     Reason
Ca7/0/0/U0   Sep 17 17:01:44 F  26.358 19.742 Test command enforced
             Sep 17 17:00:24 C  1.6    3.2    Configuration changed
             Sep 14 19:38:55 F  41.117 26.358 Interface state changed
             Sep 14 19:38:55 F   0.000 41.117 Interface state changed
             Sep 14 19:38:24 M  21     221    Configuration changed
```

Step 9 Use the **test cable modulation-change** command to force the desired upstream to perform a dynamic modulation change. A few seconds after giving the test command, use the **show cable hop** command to verify the modulation change.

Example:

```
Router# test cable modulation-change cable 7/0/0 upstream 0

SLOT 7/0: Sep 17 17:03:19.038: %UBR10000-5-USMODCHANGE: Interface Cable7/0/0 U0, dynamic modulation
 changed to QPSK
SLOT 7/0: Sep 17 17:03:19.038: %UBR10000-6-PREAMLENADJUST: request burst's preamble length in mod
profile 222 is adjusted to 38 bits.
SLOT 7/0: Sep 17 17:03:19.038: %UBR10000-6-PREAMLENADJUST: initial burst's preamble length in mod
profile 222 is adjusted to 100 bits.
SLOT 7/0: Sep 17 17:03:19.038: %UBR10000-6-PREAMLENADJUST: station burst's preamble length in mod
profile 222 is adjusted to 100 bits.

Router# show cable hop cable 7/0/0 upstream 0 history

F = Frequency Hop, M = Modulation Change, C = Channel Width Change
Upstream     Action             Chg    Chg    Action
Port         Time          Code From   To     Reason
Ca7/0/0/U0   Sep 17 17:03:19 M  221    222    Test command enforced
             Sep 17 17:01:44 F  26.358 19.742 Test command enforced
             Sep 17 17:01:17 F  21.528 26.358 Test command enforced
             Sep 17 17:00:24 C  1.6    3.2    Configuration changed
             Sep 14 19:38:55 F  41.117 21.528 Interface state changed
             Sep 14 19:38:55 F   0.000 41.117 Interface state changed
             Sep 14 19:38:24 M  21     221    Configuration changed
```

Troubleshooting Spectrum Group Characteristics

To troubleshoot the configuration, make sure that you entered a valid spectrum group number, time, frequency, and input power level. Also, when defining your spectrum, use the following guidelines:

- Avoid frequencies with known ingress problems, such as amateur radio bands or short-wave bands.
- Avoid a hostile spectrum below 20 MHz.
- Allow extra bands for frequency hopping.
- Place upstream ports in the same combiner group in a shared spectrum group.
- Use the receive power level setting to perform slight equalization adjustments.

Intelligent and Advanced Spectrum Management Configuration Tasks

The following sections describe the configuration tasks that are needed to configure a Cisco uBR7200 series or Cisco uBR10012 universal broadband router for the intelligent and advanced spectrum management features that are available with the Cisco cable interface line cards.

Configuring and Assigning Spectrum Groups

You must create and configure a spectrum group before you can use the intelligent and advanced spectrum management features. These procedures are the same as those used for guided and scheduled spectrum management, which are given in the following sections:

After the spectrum groups have been configured and assigned to upstreams, the Cisco IOS software automatically uses the advanced frequency hopping algorithms on the cable interface line cards that support it.

Note For efficient use of the intelligent and advanced spectrum management features, we recommend configuring only frequency bands, and not fixed frequencies, when creating spectrum groups. A spectrum group must contain a frequency band that is wide enough for the cable interface to find at least two center frequencies at the configured channel width, before frequency hopping can occur.

Configuring Dynamic Upstream Modulation (CNR-Based)

Configuring the CNR-based version of the Dynamic Upstream Modulation feature is similar to configuring the MER (SNR)-version of this feature:

1. Create a primary modulation profile. This typically is a more bandwidth-efficient but a less robust profile.
2. Create a secondary modulation profile. This typically is a less bandwidth-efficient but a more robust profile.

   Tip When creating the modulation profiles, we recommend that you use the predefined modulation profiles, as opposed to manually specifying each burst parameter for each modulation profile.
3. Assign the profiles to the desired cable interfaces and upstreams.

After the modulation profiles have been created and assigned to upstreams, the Cisco IOS software automatically uses the advanced CNR-based version of the Dynamic Upstream Modulation feature on the cable interface line cards that support it.

Restriction

- The Dynamic Upstream Modulation feature is supported only for DOCSIS 1.0 or DOCSIS 1.1 TDMA-only modulation profiles. It is not supported for DOCSIS 2.0 mixed-mode or A-TDMA-only mode modulation profiles.
- Three Step Dynamic Modulation is not supported on the CNR-based version of dynamic upstream modulation.
- The CNR-based Dynamic Upstream Modulation feature does not support A-TDMA modulation profiles. However, A-TDMA is supported in the MER (SNR)-based Dynamic Upstream Modulation feature.

To assign the primary and secondary profiles to an upstream, use the following procedure.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.

	Command or Action	Purpose
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable modulation-profile** *profile* {**mix** | **qam-16** | **qpsk** | **robust-mix**} **Example:** `Router(config)# cable modulation-profile 3 mix`	Creates the primary modulation profile for use on a DOCSIS 1.0 or DOCSIS 1.1 TDMA upstream. Typically, the primary profile is either **qam-16** or **mix**. **Note** Repeat this command to create the secondary profile for use on a DOCSIS 1.0 or DOCSIS 1.1 TDMA upstream. Typically, the secondary profile is either **robust-mix** or **qpsk**. **Note** You can also create custom modulation profiles with the **cable modulation-profile** command by configuring the values for the individual burst parameters. These parameters, however, should not be modified unless you are thoroughly familiar with how changing each parameter affects the DOCSIS MAC layer. We recommend using the preconfigured default modulation profiles for most cable plants.
Step 4	**controller upstream-cable** *slot/subslot/port* **Example:** `Router(config)# controller upstream-cable 9/0/15`	Enters controller configuration mode.
Step 5	**cable upstream** *n* **modulation-profile** *primary-profile-number secondary-profile-number* **Example:** `Router(config-controller)# cable upstream 0 modulation-profile 3 4`	Assigns a primary modulation profile, and an optional secondary modulation profile, to the specified upstream port.
Step 6	**end** **Example:** `Router(config-controller)# end`	Exits controller interface configuration mode and returns to privileged EXEC mode.

Configuring Proactive Channel Management

The cable interface line cards that support the advanced spectrum management features can be configured with the following parameters to fine-tune the operation of proactive channel management on the upstreams of the cards:

- Priority of the corrective actions to be taken when noise on an upstream exceeds the threshold for its modulation profile.
- CNR (CNiR) and MER (SNR) threshold and FEC values for the upstream and its two modulation profiles.

- Allowable range of channel widths that can be used if frequency hopping or modulation switching cannot avoid the upstream problems.

These parameters all have default settings, so you do not need to perform this procedure unless you want to change these parameters to better match the characteristics of your physical plant.

To configure the parameters, use the following procedure.

Configuring Proactive Channel Management

You can configure two logical channels on a single physical port of the Cisco CMTS router. When you configure logical channels, the upstream related commands are categorized into two groups: physical port level and logical channel level.

Physical Port Level

Physical port level commands use the format of **cable upstream** *n*, where *n* denotes the physical port number.

Logical Channel Level

Logical channel level commands use the format of **cable upstream** *n m* , where *n* denotes the physical port number, and *m* denotes the logical channel index number of 0 or 1.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**controller upstream-cable** *slot/subslot/port* **Example:** `Router(config)# controller upstream-cable 9/0/0`	Enters controller configuration mode.
Step 4	**us-channel** *n* **hop modulation frequency channel-width** **Example:** `Router(config-controller)# us-channel 0 hop modulation frequency channel-width`	Specifies the priority of the three types of corrective actions (**modulation**, **frequency**, and **channel-width**) to be taken when the noise for the upstream exceeds the threshold specified for the current modulation profile. The default priority is **frequency**, **modulation**, and **channel-width**. **Note** The **channel-width** option must always appear after the **frequency** option.
Step 5	**cable upstream** *n* **threshold cnr-profiles** *threshold1-in-db threshold2-in-db* **Example:**	(Optional) Specifies the CNR (CNiR) threshold and FEC values for the upstream and its two modulation profiles.

	Command or Action	Purpose
	`Router(config-controller)# cable upstream 2 threshold cnr-profiles 23 14`	**Note** To bypass both the primary and secondary CNR (CNiR) thresholds, set the first parameter (*threshold1-in-db*) to 0. This disallows the second parameter (*threshold2-in-db*), enabling you to bypass both the CNR (CNiR) thresholds.
Step 6	Use one of the following commands: • **cable upstream n upstream threshold snr-profiles** *threshold1-in-db threshold2-in-db* • • **cable upstream** *n m* **upstream threshold snr-profiles** *threshold1-in-db threshold2-in-db* • **Example:** `Router(config-controller)# cable upstream 2 threshold snr-profiles 23 14`	(Optional) Specifies the MER (SNR) threshold and FEC values for the upstream and its two modulation profiles. **Note** You can bypass the primary MER (SNR) threshold (*threshold1-in-db*) by setting it to 0. However, you must enter the second parameter (*threshold2-in-db*).
Step 7	**cable upstream** *n* **threshold hysteresis** *hysteresis-in-db* **Example:** `Router(config-controller)# cable upstream 2 threshold hysteresis 3`	(Optional) Specifies the hysteresis value to be used in conjunction with the dynamic modulation upgrade thresholds. **Note** You can bypass the **hysteresis** threshold by setting the value to 0.
Step 8	Use one of the following commands: • **cable upstream** *n* **threshold corr-fec** *corrfec-threshold* • **cable upstream** *n m* **threshold corr-fec** *corrfec-threshold* **Example:** `Router(config-controller)# cable upstream 5 threshold corr-fec 5`	(Optional) Specifies the CNR (CNiR) threshold and FEC values for the upstream and its two modulation profiles. **Note** You can bypass the **corr-fec** threshold by setting the value to 0.
Step 9	Use one of the following commands: • **cable upstream** *n* **threshold uncorr-fec** *uncorrfec-threshold* • **cable upstream** *n m* **threshold uncorr-fec** *uncorrfec-threshold* **Example:** `Router(config-controller)# cable upstream 5 threshold uncorr-fec 1`	(Optional) Specifies the CNR (CNiR) threshold and FEC values for the upstream and its two modulation profiles. **Note** You can bypass the un**corr-fec** threshold by setting the value to 0. **Note** For normal plant use, we recommend that the uncorrectable FEC threshold remain at its default of 1 percent to avoid an unacceptable number of errors on the channel.
Step 10	**cable upstream** *n* **channel-width** *first-choice-width* [*last-choice-width*] **Example:**	

	Command or Action	Purpose
	`Router(config-controller)# cable upstream 0 channel-width 800000 800000`	
Step 11	**end** **Example:** `Router(config-controller)# end`	Exits controller interface configuration mode and returns to privileged EXEC mode.

Verifying the Spectrum Management Configuration

Follow the steps given below to verify the spectrum management configuration.

Step 1 To check the value of the settings you have entered, use the **show running-config** command in privileged EXEC mode:

Example:

```
Router# show running-config
```

Step 2 To display the configuration for each modulation profile, use the **show cable modulation-profile** command in privileged EXEC mode:

Example:

```
Router# show cable modulation-profile
```

To display the configuration for a specific modulation profile, add the profile number to the **show cable modulation-profile** command in privileged EXEC mode:

Example:

```
Router# show cable modulation-profile 6
```

Step 3 To display the status and configuration of each upstream, use the **show controllers cable upstream** command in privileged EXEC mode. The following example displays information for upstreams 0 on a cable line card:

Example:

```
Router# show controller cable 8/1/14 upstream 0

 Cable8/1/14 Upstream 0 is up
  Frequency 19.504 MHz, Channel Width 3.200 MHz, Symbol Rate 2.560 Msps
  Modulations (64-QAM) - A-short 64-QAM, A-long 64-QAM, A-ugs 64-QAM
  Mapped to shared connector 18 and receiver 56
  Spectrum Group 8
  MC3Gx60  CNR measurement : 30 dB
  US phy MER(SNR)_estimate for good packets - 32.5530 dB
  Nominal Input Power Level 0 dBmV, Tx Timing Offset 1547
  Ranging Backoff Start 3, Ranging Backoff End 6
  US timing offset adjustment type 0, value 0
  Ranging Insertion Interval automatic (60 ms)
  US throttling off
  Tx Backoff Start 3, Tx Backoff End 5
  Modulation Profile Group 221
  Concatenation is enabled
  Fragmentation is enabled
  part_id=0x3142, rev_id=0xC0, rev2_id=0x00
  nb_agc_thr=0x0000, nb_agc_nom=0x0000
```

```
Range Load Reg Size=0x58
Request Load Reg Size=0x0E
Minislot Size in number of Timebase Ticks is = 2
Minislot Size in Symbols = 32
Bandwidth Requests = 0xEE3AF
Piggyback Requests = 0x6A24F
Invalid BW Requests= 0x76
Minislots Requested= 0xC33362
Minislots Granted  = 0x158609
Minislot Size in Bytes = 24
Map Advance (Dynamic) : 2581 usecs
Map Count Internal = 330309891
No MAP buffer= 0x0   No Remote MAP buffer= 0x0
Map Counts: Controller 8/1/0 = 1321230158
UCD Counts:
  Controller 8/1/0:0 = 336057
  Controller 8/1/0:1 = 336057
  Controller 8/1/0:2 = 336057
  Controller 8/1/0:3 = 336057

UCD procedures on lch 0
UCD ucd-succeeds(5) ucd-shut(0) init-state-err(0)
UCD init-tss-err(0) init-timeout(0) init-start-err(0)
UCD ucd-ccc-time(0) ucd-timeout(0) ucd-tss-err(0)
UCD ucd-state-err(0) ucd-process(0) ucd-retries(0)
UCD stale-tss(0)
ATDMA mode enabled
PHY: us errors 0  us recoveries 0 (enp 0)
MAC PHY TSS: tss error start 0  tss error end 0
MAC PHY Status: bcm3140 status 0  lookout status 0
PHY: TSS late 0  discontinuous 0
PHY: TSS mis-match 0  not-aligned 0
PHY: TSS missed snapshots from phy 0
MAP/UCD Replication Instructions:
  Controller 8/1/0 index = 477, bitmap = 0x000F
Dynamic Services Stats:
DSA: 0  REQs  0 RSPs  0 ACKs
0 Successful DSAs  0 DSA Failures
DSC: 0  REQs  0 RSPs  0 ACKs
0 Successful DSCs  0 DSC Failures
DSD:  0 REQs  0 RSPs
0 Successful DSDs  0 DSD Failures
Dropped MAC messages: (none)
```

Step 4 To display the hop period and hop threshold values for each upstream, use the **show cable hop** command in privileged EXEC mode:

Example:

```
Router# show cable hop

 Upstream    Port       Poll Missed Min    Missed Hop   Hop     Corr    Uncorr
 Port        Status     Rate Poll   Poll   Poll   Thres Period  FEC     FEC
                        (ms) Count  Sample Pcnt   Pcnt  (sec)   Errors  Errors
Cable3/0/U0 20.800 Mhz 105  0      20         0%   25%  45     1       4
Cable3/0/U1 20.800 Mhz 105  0      48         0%   25%  45     2       19
Cable3/0/U2 23.120 Mhz 105  0      45         0%   25%  45     0       5
Cable3/0/U3 22.832 Mhz 105  0      26         0%   25%  45     0       6
Cable3/0/U4 22.896 Mhz 105  0      43         0%   25%  45     0       7
Cable3/0/U5 23.040 Mhz 105  0      54         0%   25%  45     1       3
Cable4/0/U0 22.896 Mhz 117  0      26         0%   25%  45     0       2
Cable4/0/U1 23.168 Mhz 117  0      87         0%   25%  45     4       2
Cable4/0/U2 22.896 Mhz 117  0      23         0%   25%  45     1       0
Cable4/0/U3 20.800 Mhz 117  0      54         0%   25%  45     0       0
```

```
Cable4/0/U4 22.928 Mhz 117  0      22         0%   25%  45     0       1
Cable4/0/U5 22.960 Mhz 117  0      0       -----   25%  45     0       0
```

Step 5 To display changes from one state to another, at any time and for any reason, for frequency, modulation, and channel width, use the **history** option of the **show cable hop** command.

Example:

```
Router# show cable hop c8/1/1 u0 history

F = Frequency Hop, M = Modulation Change, C = Channel Width Change
Upstream   Action             Chg    Chg    Action
Port       Time          Code From   To     Reason
C8/1/1 U0  Feb 20 12:21:29 M  142    141    SNR 28>=28 CFEC 0<=3 UnCFEC 0<=1
           Feb 20 12:09:08 F   0.000 24.000 Configuration changed
```

Step 6 To display thresholds for MER (SNR), CNR (CNiR), and FEC, use the **threshold** option of the **show cable hop** command.

Example:

```
Router# show cable hop c8/1/1 u0 threshold

Upstream   SNR(dB)         CNR(dB)         CorrFEC%  UncorrFEC%       MissedSM%
Port       Val Thre1 Thre2 Val Thre1 Thre2 Pcnt Thre Pcnt Thre        Pcnt Thre
C8/1/1 u0  33   23   14    60   25   15    0    1    0    2           0    50
```

Step 7 To display the assignment of each spectrum group, use the **show cable spectrum-group** command in privileged EXEC mode:

Example:

```
Router# show cable spectrum-group

Group  Frequency      Upstream      Weekly Scheduled          Power   Shared
No.    Band           Port          Availability              Level   Spectrum
       (MHz)                        From Time:    To Time:    (dBmV)
1      42.967 [3.20]  UC2/0/4:U0                               -1     No
1      83.400 [3.20]  UC2/0/4:U1                               -1     No
1      80.200 [3.20]  UC2/0/4:U2                               -1     No
1      42.922 [3.20]  UC2/0/4:U3                               -1     No
1      17.677 [3.20]  UC2/0/5:U0                               -1     54
1      10.603 [3.20]  UC2/0/5:U1                               -1     54
```

In the above example,

- No—Fiber node is not configured
- 54—ID of the fiber node

Step 8 To display the current CNR (CNiR) value for a particular cable modem, use the **show cable modem cnr** command in privileged EXEC mode:

Example:

```
Router# show cable modem 5.100.1.94 cnr

MAC Address    IP Address      I/F         MAC         Prim  snr/cnr
                                           State       Sid   (dB)
```

```
0018.689c.17b8 5.100.1.94      C7/0/0/U1   online      428   36.12
```

Monitoring Spectrum Management

You can either use Cisco CLI commands or SNMP to monitor spectrum management activity on the Cisco CMTS.

See the following sections for more information:

Using CLI Commands

The following commands provide information on the spectrum condition of an upstream:

Command	Purpose
Router# **show cable hop**[**cable***x/y*] [**upstream** *usport*]	Displays the hop period and hop threshold values, as well as the FEC error counters, for all upstreams in the router, all upstreams on one cable interface line card, or a single upstream.
Router# **show cable hop** [**cable** *x/y[z]*] [**upstream** *n*][*thresholds*]	Displays the configured and current value of MER (SNR) in dB, CNR (CNiR) in dB, CorrFEC in percentage, UncorrFEC in percentage, and missed station maintenance in percentage for a specified upstream.
Router# **show cable hop history**	1. With the **show cable hop history** command for entire CMTS, the most recent change of each action is displayed. 2. With the **show cable hop history** command for a MAC domain, the most recent three changes of each action are displayed. 3. With the **show cable hop history** command for a specific upstream, the last ten changes of each action are displayed. Changes are sorted by time with the most recent at the top.
Router# **show cable hop** [**cable** *x/y[z]*] [**upstream** *n*][**summary**	Displays hourly, daily, weekly, 30 days running average, and average since the system was brought up for each specified upstream.
Router# **show cable hop** [**cable** *x/y[z]*] [**upstream** *n*] **[history]**	Displays changes from one state to another, at any time and for any reason, for frequency, modulation, and channel width.
Router# **show cable modem** [*ip-address* | *interface* | *mac-address*] [*options*]	Displays information, including MER (SNR) values, for the registered and unregistered cable modems.
Router# **show cable modulation-profile** [*num*] [**initial** | **long** | **reqdata** | **request** | **short** | **station**]	Displays the configuration for all modulation profiles, for a particular modulation profile, or for a specific burst type for a particular modulation profile.

Command	Purpose
`Router# show cable spectrum-group[groupnum] [detail]`	Displays information about the spectrum groups that have been configured.
`Router# show controllers cable x/y upstream n [ip-address | mac-address] start-freq end-freq res-freq`	Displays the upstream status, including the current frequency, channel width, modulation rate, and spectrum groups.
`Router# show controllers cable x/y upstream n spectrum [ip-address | mac-address] start-freq end-freq res-freq`	Displays the noise levels for a particular cable modem or displays the background noise for an entire upstream.

Note The **show cable flap-list** command displays the flap list of the CMTS router, which provides additional information about whether cable modems on an upstream are experiencing problems, and if so, what type of problems are occurring. For more information about the cable modem flapping and how to monitor the cable modem flap list, see the Flap List Troubleshooting for the Cisco CMTS Routers .

Using SNMP

You can use SNMP to monitor the spectrum management activity. The SNMP manager can be a graphically-based SNMP manager such as CiscoView or the Cable Broadband Troubleshooter (Release 3.0 or later).

The CISCO-CABLE-SPECTRUM-MIB has been enhanced to provide this SNMP support using the following MIB attributes:

ccsSNRRequestTable

The table below lists the attributes in the ccsSNRRequestTable table, which contains the CNR (CNiR) measurements that are made for individual cable modems on an upstream.

Table 48: ccsSNRRequestTable Attributes

Attribute	Type	Description
ccsSNRRequestIndex	Integer32	Arbitrary index to uniquely identify each table entry.
ccsSNRRequestMacAddr	MacAddress	MAC address of the remote online cable modem being reported on.
ccsSNRRequestSNR	Integer32	MER (SNR) value, in dB, that has been measured. This value is 0 when the Operation State is “running.”
ccsSNRRequestOperation	CCSRequestOperation	Sets the current operation: start, pending, running, or cancel.
ccsSNRRequestOperState	CCSRequestOperState	Reports on the current operation state: idle, pending, running, noError, canceled, notOnLine, invalidMac, timeOut, fftBusy, fftFailed, others.

Attribute	Type	Description
ccsSNRRequestStartTime	TimeStamp	Contains the time when the MER (SNR) measurement operation starts.
ccsSNRRequestStoppedTime	TimeStamp	Contains the time when the MER (SNR) measurement stops.
ccsSNRRequestStatus	RowStatus	Controls the modification, creation, and deletion of table entries.

ccsSpectrumRequestTable

The table below lists the attributes for each entry in the ccsSpectrumRequestTable table, which is used to obtain the spectrum profile for a particular cable modem or to obtain the background MER (SNR) for an entire upstream.

Table 49: ccsSpectrumRequestTable Attributes

Attribute	Type	Description
ccsSpectrumRequestIndex	Integer32	Arbitrary index to uniquely identify each table entry.
ccsSpectrumRequestIfIndex	InterfaceIndexOrZero	Interface identifying the upstream.
ccsSpectrumRequestMacAddr	MacAddress	MAC address to specify an MER (SNR) value for a particular cable modem, or 0000.0000.0000 to indicate background noise for the entire spectrum.
ccsSpectrumRequestUpperFreq	CCSFrequency	Upper frequency for the frequency range to be monitored (5000 to 42000 KHz, with a default of 42000 KHz).
ccsSpectrumRequestLowFreq	CCSFrequency	Lower frequency (in KHz) for the frequency range to be monitored (5000 to 42000 KHz, with a default of 5000 KHz).
ccsSpectrumRequestResolution	Integer32	Requested resolution to determine how the frequency range should be sampled (12 to 37000 KHz, with a default of 60 KHz).
ccsSpectrumRequestStartTime	TimeStamp	Time when the spectrum measurement began.
ccsSpectrumRequestStoppedTime	TimeStamp	Time when the spectrum measurement finished.
ccsSpectrumRequestOperation	CCSRequestOperation	Starts a new spectrum management request or cancels the current one.
ccsSpectrumRequestOperState	CCSRequestOperState	Provides the operational state of the current spectrum management request.
ccsSpectrumRequestStatus	RowStatus	Controls the modification, creation, and deletion of table entries.

ccsSpectrumDataTable

The table below lists the attributes in each entry of the ccsSpectrumDataTable table, which contains the results for a spectrum request.

Table 50: ccsSpectrumDataTable Attributes

Attribute	Type	Description
ccsSpectrumDataFreq	CCSMeasuredFrequency	Frequency in KHz for which this power measurement was made.
ccsSpectrumDataPower	INTEGER	Measured received power for the given frequency (–50 to 50 dBmV).

Note The ccsSpectrumRequestTable and ccsSpectrumDataTable tables provide the same information as that provided by the **show controllers cable upstream spectrum** command.

ccsUpSpecMgmtTable

The table below lists the attributes in the ccsUpSpecMgmtTable table, which provides an entry describing each frequency hop.

Table 51: ccsUpSpecMgmtEntry Attributes

Attribute	Type	Description
ccsUpSpecMgmtHopPriority	INTEGER	Specifies the priority of frequency, modulation profile, and channel width in determining corrective action for excessive noise on the upstream (default is frequency, modulation profile, and channel width).
ccsUpSpecMgmtSnrThres1	Integer32	Specifies the upper MER (SNR) threshold for modulation profile 1 (5 to 35 dB, default of 25).
ccsUpSpecMgmtSnrThres2	Integer32	Specifies the upper MER (SNR) threshold for modulation profile 2 (5 to 35 dB, default of 13, and must be lower than that specified for ccsUpSpecMgmtSnrThres1).
ccsUpSpecMgmtFecCorrectThres1	Integer32	Specifies the FEC correctable error threshold for modulation profile 1 (1 to 20 percent)
ccsUpSpecMgmtFecCorrectThres2	Integer32	Zero (0). Deprecated and no longer used.

Attribute	Type	Description
ccsUpSpecMgmtFecUnCorrecfThres1	Integer32	Specifies the FEC uncorrectable error threshold for modulation profile 1 (1 to 20 percent).
ccsUpSpecMgmtFecUnCorrecfThres2	Integer32	Deprecated and no longer used.
ccsUpSpecMgmtSnrPollPeriod	Integer32	Deprecated and no longer used.
ccsUpSpecMgmtHopCondition	INTEGER	Reports the condition that triggers a frequency hop (MER [SNR] value or percentage of modems going offline).
ccsUpSpecMgmtFromCenterFreq	CCSFrequency	Provides the center frequency (in KHz) before the latest frequency hop.
ccsUpSpecMgmtToCenterFreq	CCSFrequency	Provides the current center frequency (in KHz) after the latest frequency hop.
ccsUpSpecMgmtFromBandWidth	CCSFrequency	Provides the channel width (in KHz) before the latest frequency hop.
ccsUpSpecMgmtToBandWidth	CCSFrequency	Provides the current channel width (in KHz) after the latest frequency hop.
ccsUpSpecMgmtFromModProfile	Integer32	Provides the modulation profile number before the latest frequency hop.
ccsUpSpecMgmtToModProfile	Integer32	Provides the current modulation profile number after the latest frequency hop.
ccsUpSpecMgmtSNR	Integer32	Provides the current MER (SNR) value (in dB) for the upstream.
ccsUpSpecMgmtCnrThres1	Integer32	Specifies the upper CNR (CNiR) threshold for modulation profile 1 (5 to 35 dB, default of 25).
ccsUpSpecMgmtCnrThres2	Integer32	Specifies the upper CNR (CNiR) threshold for modulation profile 2 (5 to 35 dB, default of 13, and must be lower than that specified for ccsUpSpecMgmtCnrThres1).
ccsUpSpecMgmtCNR	Integer32	Provides the current CNR (CNiR) value (in dB) for the upstream.
ccsUpSpecMgmtMissedMaintMsgThres	Integer32	Provides the frequency hop threshold, as a percentage of station maintenance messages that are lost for a spectrum group.

Attribute	Type	Description
ccsUpSpecMgmtHopPeriod	Integer32	Provide the minimum time, in seconds, between frequency hops.

ccsHoppingNotification

The table below describes the attributes contained in the notification that is sent after each frequency hop.

Table 52: ccsHoppingNotification Attributes

Attribute	Type	Description
ccsUpSpecMgmtHopCondition	INTEGER	Reports the condition that triggers a frequency hop (MER [SNR] value or percentage of modems going offline).
ccsUpSpecMgmtFromCenterFreq	CCSFrequency	Provides the center frequency (in KHz) before the latest frequency hop.
ccsUpSpecMgmtToCenterFreq	CCSFrequency	Provides the current center frequency (in KHz) after the latest frequency hop.
ccsUpSpecMgmtFromBandWidth	CCSFrequency	Provides the channel width (in KHz) before the latest frequency hop.
ccsUpSpecMgmtToBandWidth	CCSFrequency	Provides the current channel width (in KHz) after the latest frequency hop.
ccsUpSpecMgmtFromModProfile	Integer32	Provides the modulation profile number before the latest frequency hop.
ccsUpSpecMgmtToModProfile	Integer32	Provides the current modulation profile number after the latest frequency hop.

Configuration Examples

This section provides the following configuration examples:

Spectrum Group and Combiner Group Examples

The following examples help you to determine whether spectrum group and combiner groups are configured and activated.

Example: Verifying Spectrum Group Creation

To verify that a spectrum group has been created, enter the **show cable spectrum-group** command:

```
Router# show cable spectrum-group
spectrum-group 1
spectrum-group 2
spectrum-group 3
```

Example: Time-Scheduled Spectrum Group

If your cable plant has an upstream noise characteristic on a weekly cycle, use time-scheduled spectrum allocation.

```
Router(config)# cable spectrum-group 1 time Mon 08:00:00 frequency 21600000
```

Deletion is performed using the **delete** keyword:

```
Router(config)# cable spectrum-group 1 time Mon 18:00:00 delete frequency 21600000
```

Example: Verifying Spectrum Group Configuration

To verify if spectrum groups have been configured and activated, enter the **show cable spectrum-group** command. This command displays each spectrum group, the frequencies assigned to it, the upstream port to which it has been assigned, whether a schedule exists for it, the currently measured power level, and whether it is a shared spectrum group.

```
Router# show cable spectrum-group

22:07:46: %SYS-5-CONFIG_I: Configured from console by console
Group  Frequency      Upstream     Weekly Scheduled            Power   Shared
No.    Band           Port         Availability                Level   Spectrum
       (Mhz)                       From Time:    To Time:      (dBmV)
1       5.000-15.000                                           0       Yes
1      12.000                                                  0       Yes
1      22.000         Cable6/0 U5                             7       Yes
2      29.000         Cable6/0 U4                             6       No
2      26.000                                                  0       No
3      35.000-41.000                                          0       No
3      16.000-19.000  Cable6/0 U3                             5       No
5*      5.000-10.000               Thu 21:50:00  Thu 21:45:00  0       Yes
```

Example: Determining the Upstream Ports Assigned to a Combiner Group

Following is a sample topology for a CMTS with combiner groups designated A through J. Combiner groups C and E have multiple upstream ports that should be configured in a shared spectrum group. The other upstreams should be configured in a nonshared spectrum group.

In this example, ten combiner groups are served with frequency hop tables from three spectrum groups:

```
Cable3/0
DS +-----+ Upconverter +----- laser group 1
U0 +----- combiner group A
U1 +----- combiner group B
U2 +------combiner group C
U3 +------combiner group C
U4 +----- combiner group D
U5 +------combiner group E
Cable4/0
DS +-----+ Upconverter +----- laser group 2
U0 +------combiner group E
U1 +----- combiner group F
U2 +----- combiner group G
U3 +----- combiner group H
U4 +----- combiner group I
U5 +----- combiner group J
```

The *laser group* term refers to the set of fiber nodes that share the same downstream signal. An optical splitter is often used to create individual feeds per node.

In the downstream direction, two 6-MHz channel slots are assigned. All fiber nodes in combiner groups A through E should have a channel slot containing the downstream signal from Cable3/0. Combiner groups A through E are said to belong to laser group 1.

All fiber nodes in combiner groups E through J should have a channel slot containing the downstream signal from Cable4/0. Combiner groups E through J are said to belong to laser group 2.

Because combiner group E belongs to two laser groups, there should be two different downstream channel slots for Cable3/0 and Cable4/0.

Example: Combiner Group

The following example enables spectrum management for all upstream ports, where all combiner groups use the frequency band from 20 to 26 MHz:

```
CMTS01(config)# cable spectrum-group 1 band 20000000 26000000
CMTS01(config)# cable spectrum-group 2 shared
CMTS01(config)# cable spectrum-group 2 band 20000000 26000000
CMTS01(config)# cable spectrum-group 3 shared
CMTS01(config)# cable spectrum-group 3 band 20000000 26000000
CMTS01(config)# controller upstream-Cable 9/0/0
CMTS01(config-controller)# cable spectrum-group 1
CMTS01(config-controller)# cable upstream 2 spectrum-group 2
CMTS01(config-controller)# cable upstream 3 spectrum-group 2
CMTS01(config-controller)# cable upstream 5 spectrum-group 3
CMTS01(config-controller)# exit
CMTS01(config)# controller upstream-Cable 9/0/1
CMTS01(config-controller)# cable spectrum-group 1
CMTS01(config-controller)# cable upstream 0 spectrum-group 3
```

A description of the spectrum groups 1 through 3 follows:

- Spectrum group 1—This group is nonshared. Upstream RF domains exist for each member upstream port.

```
Upstream Port   RF Domain
Cable3/0 U0     combiner group A
Cable3/0 U1     combiner group B
Cable3/0 U4     combiner group D
Cable4/0 U1     combiner group F
Cable4/0 U2     combiner group G
Cable4/0 U3     combiner group H
Cable4/0 U4     combiner group I
Cable4/0 U5     combiner group J
```

- Spectrum group 2—This group is shared. A single upstream RF domain exists.

```
Upstream Port   RF Domain
Cable3/0 U2     combiner group C
Cable3/0 U3     combiner group C
```

- Spectrum group 3—This group is shared. A single upstream RF domain exists.

```
Upstream Port   RF Domain
Cable3/0 U5     combiner group E
Cable4/0 U0     combiner group E
```

For the 20- to 26-MHz band of each RF domain, the spectrum is channelized according to the channel width settings of each member port. For example, if the ports U2 and U3 of Cable3/0 are set to 3.2 MHz and 1.6 MHz channel widths, respectively, then spectrum group 2 uses the following channelization:

```
> Channel Width Start Stop Center
>           (Mhz) (Mhz) (Mhz) (Mhz)
> 1        3.2    20.0 23.2 21.6
> 2*       1.6    20.0 21.6 20.8
> 3*       1.6    21.6 23.2 22.4
> 4        1.6    23.2 24.8 24.0
```

Note Channels 2 and 3 are not available when channel 1 is in use.

Because the group is shared, ports U2 and U3 will be assigned channels 1 and 4, respectively, to prevent overlap.

Note There are no alternate frequency assignments for either port, and bandwidth is wasted from 24.8 to 26.0 MHz. To create alternate channels, increase the upper boundary from 26.0 to 28.0 MHz.

```
> Channel  Width  Start Stop  Center
>           (Mhz)  (Mhz) (Mhz) (Mhz)
>  1        3.2    20.0  23.2  21.6
>  2        3.2    23.2  26.4  24.8
>  3        1.6    20.0  21.6  20.8
>  4        1.6    21.6  23.2  22.4
>  5        1.6    23.2  24.8  24.0
>  6        1.6    24.8  26.4  25.6
>  7        1.6    26.4  28.0  27.4
```

Try to reduce the spectrum allocation when it is used with small channel widths. Otherwise, there will be a large number of upstream channel slots, and the frequency hopping may require several minutes to find a clean slot.

Example: Other Spectrum Management Configurations

To configure differing spectrum groups, refer to the following examples:

- Use the following example to configure spectrum group 3 with an upstream band of 12,000,000 to 18,000,000 Hz and default power level of 0 dBmV:

  ```
  Router(config)# cable spectrum-group 3 band 12000000 18000000
  ```

- Use the following example to add the upstream band 20,000,000 to 24,000,000 Hz to the list of valid bands with a change in the power level of 13 dBmV for spectrum group 3:

  ```
  Router(config)# cable spectrum-group 3 band 20000000 24000000 13
  ```

- Use the following example to configure a continuous band between 5,000,004 and 40,000,000 Hz for scheduled spectrum group 4 with a default power level of 0 dBmV. The band is available to the spectrum group starting at 12:00 p.m. local time each Monday:

```
Router(config)# cable spectrum-group 4 time Monday 12:00:00 band 5000004 40000000
```

- Use the following example to add the upstream frequency 9,500,000 Hz to the list of valid frequencies and change the nominal power level to 5 dBmV. The spectrum manager adjusts frequencies and power levels on this group at 2:00 a.m. local time each day:

```
Router(config)# cable spectrum-group 3 time 02:00:00 frequency 9500000 5
```

- Use the following example to configure the minimum period before which a frequency hop can occur in seconds:

```
Router(config)# cable spectrum-group 3 hop period 800
```

- Use the following example to configure the threshold value (expressed as a percentage) of the number of "offline" modems identified before the router initiates an automatic frequency hop:

```
Router(config)# cable spectrum-group 3 hop threshold 40
```

- Use the following example to configure a particular spectrum group as a shared RF spectrum group. Specifying a given spectrum group as "shared" tells the router that you want to be sure that upstream frequencies assigned to upstream ports are not assigned to additional upstream ports:

```
Router(config)# cable spectrum-group 3 shared
```

- Use the following example to remove a specified spectrum group from your configuration:

```
Router(config)# no cable spectrum-group 3
```

Dynamic Upstream Modulation Examples

The following examples describe how to display modulation profile information with the **show cable modulation-profile** command and to define a modulation profile with the **cable modulation-profile** command.

Verifying Your Settings

Step 1 To check the value of the settings you have entered, enter the **show running-config** command in privileged EXEC mode:

Example:

```
Router# show running-config
```

To review changes you make to the configuration, use the **show startup-config** command in privileged EXEC mode to display the information stored in NVRAM.

Step 2 To display modulation profile group information, use the **show cable modulation-profile** command in privileged EXEC mode:

Example:

```
Router# show cable modulation-profile[profile][iuc-code]
```

This command uses the following syntax:

- *profile*—(Optional) Profile number. Valid values are from 1 to 8.
- *iuc-code*—(Optional) Internal usage code.

  Valid options are:

  - **initial**—Initial ranging burst
  - **long**—Long grant burst
  - **request**—Request burst
  - **short**—Short grant burst
  - **station**—Station ranging burst

Example: Modulation Profiles

The Cisco CMTS has one preconfigured modulation profile resident in memory, which defines a typical profile for QPSK modulation. To use the Dynamic Upstream Modulation feature, a second profile must be created that is unique from the first profile, and typically provides a higher, more robust modulation scheme.

The following example is a modulation profile for QAM-16, in which the initial, request, and station maintenance messages are sent as QPSK, and the short and long data packets are sent as QAM-16. The QAM-16 modulation is more bandwidth-efficient than QPSK, but QPSK is more robust than QAM-16.

Note The upstream request and station maintenance messages use less time on the cable network when configured in QPSK for symbol rates of 640K, 1280K, and 2560K symbols/sec. Thus, these messages are actually more efficient when used in QPSK mode and they ensure a more reliable modem connection. The upstream initial maintenance message takes exactly the same amount of time on the cable network, no matter how it is configured. Modems connect more quickly and experience fewer cycles of power adjustment during initial maintenance if the system is set for QPSK.

```
Router# configure terminal
Router(config)# cable modulation-profile 2 request 0 16 1 8 qpsk scrambler 152 no-diff 64
fixed uw16
Router(config)# cable modulation-profile 2 initial 5 34 0 48 qpsk scrambler 152 no-diff 128
 fixed uw16
Router(config)# cable modulation-profile 2 station 5 34 0 48 qpsk scrambler 152 no-diff 128
 fixed uw16
Router(config)# cable modulation-profile 2 short 6 75 6 8 16qam scrambler 152 no-diff 72
fixed uw16
Router(config)# cable modulation-profile 2 long 8 220 0 8 16qam scrambler 152 no-diff 160
fixed uw16
```

In the following example, all message types are carried with QAM-16 modulation. Although QAM-16 modulation offers a consistent modulation scheme for all five types of messages, the added length of the QAM-16 preamble offsets the increased bandwidth efficiency of the MAC data message for the station maintenance messages and bandwidth request messages.

```
Router# configure terminal
Router(config)# cable modulation-profile 2 request 0 16 1 8 16qam scrambler 152 no-diff 128
 fixed uw16
```

```
Router(config)# cable modulation-profile 2 initial 5 34 0 48 16qam scrambler 152 no-diff
256 fixed uw16
Router(config)# cable modulation-profile 2 station 5 34 0 48 16qam scrambler 152 no-diff
256 fixed uw16
Router(config)# cable modulation-profile 2 short 5 75 6 8 16qam scrambler 152 no-diff 144
fixed uw16
Router(config)# cable modulation-profile 2 long 8 220 0 8 16qam scrambler 152 no-diff 160
fixed uw16
```

Note When using DOCSIS concatenation with a 16-QAM or mixed symbol rate, configure the CMTS for Unique Word 16 ("uw16") in the preamble for both short and long data burst profiles.

Add the **cable upstream** *port-number* **modulation-profile** *primary profile-number secondary profile-number* command to the appropriate interfaces. In this example, modulation profile 2 is for QAM-16 modulation and profile 1 is for QPSK modulation.

```
Router# configure terminal
Router(config)# controller upstream-Cable 6/0/0
Router(config-controller)# cable upstream 0 modulation-profile 2 1
```

Example: Input Power Level

In the following example, the modem transmit power at 24.8 MHz is adjusted upstream by 1 dBmV and the modem transmit power at 28.0 MHz is adjusted upstream by 2 dBmV.

```
CMTS01(config)# cable spectrum-group 1 frequency 21600000
CMTS01(config)# cable spectrum-group 1 frequency 24800000 1
CMTS01(config)# cable spectrum-group 1 frequency 28000000 2
```

Advanced Spectrum Management Configuration Examples

This section provides the following typical configurations:

Example: Advanced Spectrum Management for the Cisco cBR Series Routers

This section provides an excerpt from a typical configuration example for a Cisco cBR Series router using a cable interface line card. This configuration does the following:

- Configures four spectrum groups with a hop period of 30 seconds.
- Creates a QPSK modulation profile and assigns it to four upstreams on the Cisco cable interface line card in slot 6/1/0.
- Assigns a spectrum group to each of the four upstreams.
- Configures each upstream for the default CNR (CNiR) and FEC thresholds.

```
cable modulation-profile 21 qpsk
interface Cable6/1/0
cable bundle 1
cable downstream annex B
cable downstream modulation 256qam
```

```
cable downstream interleave-depth 32
! upstream 0
cable upstream 0 spectrum-group 1
cable upstream 0 modulation-profile 21
cable upstream 0 threshold cnr-profiles 16 0
cable upstream 0 threshold Corr-Fec 3
cable upstream 0 threshold Uncorr-Fec 1
no cable upstream 0 shutdown ! upstream 1
cable upstream 1 spectrum-group 2
cable upstream 1 modulation-profile 21
cable upstream 1 threshold cnr-profiles 16 0
cable upstream 1 threshold Corr-Fec 3
cable upstream 1 threshold Uncorr-Fec 1
no cable upstream 1 shutdown ! upstream 2
cable upstream 2 spectrum-group 3
cable upstream 2 modulation-profile 21
cable upstream 2 threshold cnr-profiles 16 0
cable upstream 2 threshold Corr-Fec 3
cable upstream 2 threshold Uncorr-Fec 1
no cable upstream 2 shutdown ! upstream 3
cable upstream 3 spectrum-group 4
cable upstream 3 modulation-profile 21
cable upstream 3 threshold cnr-profiles 16 0
cable upstream 3 threshold Corr-Fec 3
cable upstream 3 threshold Uncorr-Fec 1
no cable upstream 3 shutdown
```

Additional References

The following sections provide references related to Spectrum Management and Advanced Spectrum Management for the Cisco CMTS routers.

Related Documents

Related Topic	Document Title
CMTS Command Reference	Cisco Broadband Cable Command Reference Guide.

Standards and RFCs

Standards	Title
SP-RFIv1.1-I09-020830	Data-over-Cable Service Interface Specifications Radio Frequency Interface Specification, version 1.1
SP-RFIv2.0-I03-021218	Data-over-Cable Service Interface Specifications Radio Frequency Interface Specification, version 2.0
SP-OSSIv2.0-I03-021218	Data-over-Cable Service Interface Specifications Operations Support System Interface Specification, version 2.0
SP-BPI+-I09-020830	Data-over-Cable Service Interface Specifications Baseline Privacy Plus Interface Specification, version 2.0

MIBs

MIBs	MIBs Link
CISCO-CABLE-SPECTRUM-MIB	To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: https://www.cisco.com/go/mibs

Technical Assistance

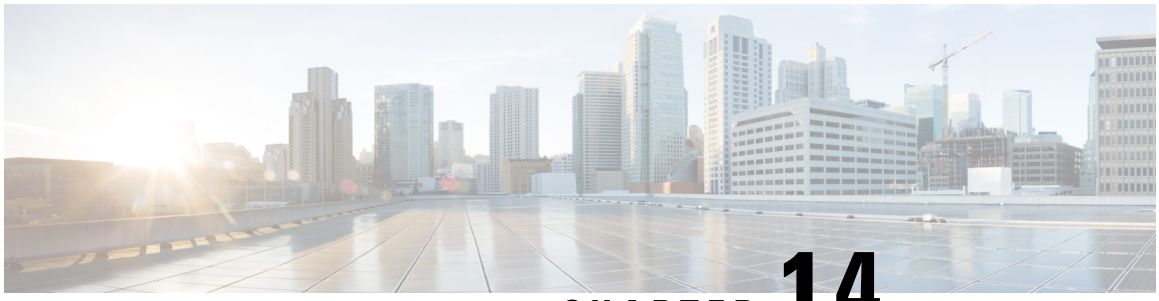
Description	Link
The Cisco Support and Documentation website provides online resources to download documentation, software, and tools. Use these resources to install and configure the software and to troubleshoot and resolve technical issues with Cisco products and technologies. Access to most tools on the Cisco Support and Documentation website requires a Cisco.com user ID and password.	https://www.cisco.com/cisco/web/support/index.html

Feature Information for Spectrum Management and Advanced Spectrum Management

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Feature Name	Releases	Feature Information
Spectrum Management and Advanced Spectrum Management	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 14

Upstream Scheduler Mode

This document describes how to configure optional upstream (US) scheduler modes.

With this feature, you can select Unsolicited Grant Services (UGS), Real Time Polling Service (rtPS) or Non-Real Time Polling Service (nrtPS) scheduling types, as well as packet-based or Time Division Multiplex (TDM) based scheduling. Low latency queuing (LLQ) emulates a packet-mode-like operation over the TDM infrastructure of DOCSIS. As such, the feature provides the typical trade-off between packets and TDM. With LLQ, you have more flexibility in defining service parameters for UGS, rtPS or nrtPS, but with no guarantee (other than statistical distribution) regarding parameters such as delay and jitter.

- Finding Feature Information, on page 285
- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 285
- Restrictions for Upstream Scheduler Mode, on page 286
- Information About Upstream Scheduler Mode for the Cisco CMTS Routers, on page 287
- How to Configure Upstream Scheduler Modes, on page 287
- Additional References, on page 288
- Feature Information for Upstream Scheduler Mode, on page 289

Finding Feature Information

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 53: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Restrictions for Upstream Scheduler Mode

- To ensure proper operation, Interface-based Admission Control must be enabled. When the LLQ option is enabled, it is possible for the upstream path to be filled with so many calls that it becomes unusable, making voice quality unacceptable. Interface-based admission control must be used to limit the number of calls to ensure acceptable voice quality, as well as to ensure traffic other than voice traffic.
- Even if Interface-based admission control is not enabled, the default (DOCSIS)scheduling mode blocks traffic after a certain number of calls.
- UGS with Activity Detection (UGS-AD) is not supported by the LLQ scheduler mode but remains supported by the default DOCSIS scheduler mode.

Information About Upstream Scheduler Mode for the Cisco CMTS Routers

With UGS, a service flow is created that enables a cable modem to transmit fixed-size bursts of data at a guaranteed rate and with a guaranteed level of jitter by providing periodic transmission opportunities to the cable modem for fixed-sized frames. This kind of service flow is particularly suitable for VoIP applications.

With rtPS, a service flow is created that provides a periodic opportunity for a cable modem to request permission to transmit data by polling a single cable modem for a bandwidth request, rather than all the cable modems. This satisfies applications that have a requirement for real-time data transmission, and enables the cable modem to transmit data bursts of varying length. This kind of service flow is particularly suitable for MPEG VoIP.

The rtPS requests, by default, are internally treated as priority 7—the highest priority for all Best Effort traffic. This high priority reduces the latency of rtPS traffic under congestion.

With nrtPS, a service flow is created that provides a periodic opportunity for a cable modem to request permission to transmit data by polling a single cable modem for a bandwidth request, rather than all the cable modems. The data bursts may be of varying length. This kind of service flow is particularly suitable for non-interactive services such as file transfers.

How to Configure Upstream Scheduler Modes

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	Use one the following commands: • **interface cable** *slot/subslot/port* • **interface cable** *slot/port* **Example:** `Router(config)# interface cable 7/0/1`	Enters interface configuration mode for the specified cable interface.
Step 4	**cable upstream** *n* **scheduling type ugs mode** [**llq** | **docsis**] **Example:**	Enables LLQ-type (packet-based) scheduling for UGS services.

	Command or Action	Purpose
	`Router(config-if)# cable upstream 4 scheduling type ugs mode llq`	**Note** Any combination of **ugs**, **rtps**, **nrtps**, **llq**, and **docsis** is allowed. The only default value is **docsis** .
Step 5	**cable upstream** *n* **scheduling type rtps mode** [**llq** | **docsis**] **Example:** `Router(config-if)# cable upstream 4 scheduling type rtps mode docsis`	Enables standard DOCSIS (TDM-based) scheduling for rtPS services. **Note** Any combination of **ugs**, **rtps**, **nrtps**, **llq**, and **docsis** is allowed. The only default value is **docsis** .
Step 6	**end** **Example:** `Router(config-if)# end`	Exits interface configuration mode and returns to privileged EXEC mode.

What to do next

To confirm whether the scheduler is operating in DOCSIS mode, use the **show interface cable mac-scheduler** command.

```
Router# show interface cable 7/0/1 mac-scheduler 0
     DOCSIS 1.1 MAC scheduler for Cable7/0/1/U0 : rate 30720000
     wfq:None
     us_balance:OFF
     fairness:OFF
     Queue[Rng Polls] flows 0
     Queue[CIR Grants] flows 0
     Queue[BE(07) Grants] flows 0
     Queue[BE(06) Grants] flows 0
     Queue[BE(05) Grants] flows 0
     Queue[BE(04) Grants] flows 0
     Queue[BE(03) Grants] flows 0
     Queue[BE(02) Grants] flows 0
     Queue[BE(01) Grants] flows 0
     Queue[BE(00) Grants] flows 0
     Req Slots 2601578997, Req/Data Slots 4484512
     Init Mtn Slots 38265829, Stn Mtn Slots 78753
     Short Grant Slots 0, Long Grant Slots 0
     Adv Phy Short Grant Slots 412, Adv Phy Long Grant Slots 5519087
     Adv Phy UGS Grant Slots 0
     Avg upstream channel utilization : 1%
     Avg percent contention slots : 98%
     Avg percent initial ranging slots : 1%
     Avg percent minislots lost on late MAPs : 0%

     MAP TSS: lch_state 9, init_retries 0
              late_initial_maps 0, late_ucd_maps 0
              mac-phy tss errors 0, missed ccc 0
```

Additional References

The following sections provide references related to the Cisco CMTS routers.

Related Documents

Related Topic	Document Title
Cisco CMTS command reference	*Cisco CMTS Cable Command Reference* http://www.cisco.com/c/en/us/td/docs/cable/cmts/cmd_ref/b_cmts_cable_cmd_ref.

Standards

Standard	Title
DOCSIS	Data-Over-Cable Service Interface Specifications, DOCSIS 2.0, Radio Frequency Interface Specification, CM-SP-RFIv2.0-I08-050408

Technical Assistance

Description	Link
The Cisco Support and Documentation website provides online resources to download documentation, software, and tools. Use these resources to install and configure the software and to troubleshoot and resolve technical issues with Cisco products and technologies. Access to most tools on the Cisco Support and Documentation website requires a Cisco.com user ID and password.	http://www.cisco.com/cisco/web/support/index.html

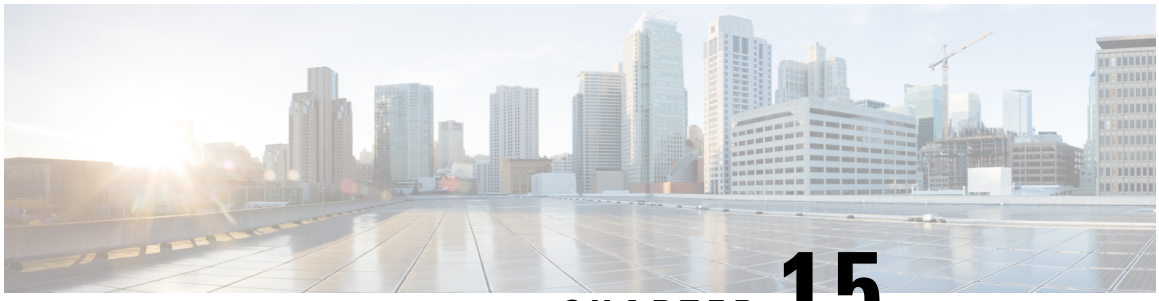
Feature Information for Upstream Scheduler Mode

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 54: Feature Information for Upstream Scheduler Mode

Feature Name	Releases	Feature Information
Upstream Scheduler Mode	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 15

Generic Routing Encapsulation

This document describes the Generic Routing Encapsulation (GRE) feature. This feature is a tunneling protocol that enables the encapsulation of a wide variety of protocol packet types inside IP tunnels, creating a virtual point-to-point link to Cisco routers at remote points over an IP internetwork.

- Finding Feature Information, on page 291
- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 292
- Restrictions for Implementing Tunnels, on page 292
- Restrictions for GRE IPv6 Tunnels, on page 293
- Information About Implementing Tunnels, on page 293
- Information About IPv6 over IPv4 GRE Tunnels, on page 295
- Information About GRE IPv6 Tunnels, on page 297
- How to Implement Tunnels, on page 298
- Configuration Examples for Implementing Tunnels, on page 305
- How to Configure IPv6 over IPv4 GRE Tunnels, on page 307
- Configuration Examples for IPv6 over IPv4 GRE Tunnels, on page 309
- How to Configure GRE IPv6 Tunnels, on page 310
- Configuration Examples for GRE IPv6 Tunnels, on page 311
- Additional References, on page 312
- Feature Information for Generic Routing Encapsulation , on page 314

Finding Feature Information

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 55: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Restrictions for Implementing Tunnels

- It is important to allow the tunnel protocol to pass through a firewall and access control list (ACL) check.

- Multiple point-to-point tunnels can saturate the physical link with routing information if the bandwidth is not configured correctly on a tunnel interface.
- A tunnel looks like a single hop link, and routing protocols may prefer a tunnel over a multihop physical path. The tunnel, despite looking like a single hop link, may traverse a slower path than a multihop link. A tunnel is as robust and fast, or as unreliable and slow, as the links that it actually traverses. Routing protocols that make their decisions based only on hop counts will often prefer a tunnel over a set of physical links. A tunnel might appear to be a one-hop, point-to-point link and have the lowest-cost path, but the tunnel may actually cost more in terms of latency when compared to an alternative physical topology. For example, in the topology shown in the figure below, packets from Host 1 will appear to travel across networks w, t, and z to get to Host 2 instead of taking the path w, x, y, and z because the tunnel hop count appears shorter. In fact, the packets going through the tunnel will still be traveling across Router A, B, and C, but they must also travel to Router D before coming back to Router C.

Figure 2: Tunnel Precautions: Hop Counts

- A tunnel may have a recursive routing problem if routing is not configured accurately. The best path to a tunnel destination is via the tunnel itself; therefore recursive routing causes the tunnel interface to flap. To avoid recursive routing problems, keep the control-plane routing separate from the tunnel routing by using the following methods:
  - Use a different autonomous system number or tag.
  - Use a different routing protocol.
  - Ensure that static routes are used to override the first hop (watch for routing loops).

  The following error is displayed when there is recursive routing to a tunnel destination:

```
%TUN-RECURDOWN Interface Tunnel 0
temporarily disabled due to recursive routing
```

Restrictions for GRE IPv6 Tunnels

- GRE tunnel keepalive packets are not supported.
- Multipoint GRE (mGRE) IPv6 tunneling is not supported.

Information About Implementing Tunnels

Tunneling Versus Encapsulation

To understand how tunnels work, you must be able to distinguish between concepts of encapsulation and tunneling. Encapsulation is the process of adding headers to data at each layer of a particular protocol stack. The Open Systems Interconnection (OSI) reference model describes the functions of a network. To send a data packet from one host (for example, a PC) to another on a network, encapsulation is used to add a header in front of the data packet at each layer of the protocol stack in descending order. The header must contain a data field that indicates the type of data encapsulated at the layer immediately above the current layer. As the

packet ascends the protocol stack on the receiving side of the network, each encapsulation header is removed in reverse order.

Tunneling encapsulates data packets from one protocol within a different protocol and transports the packets on a foreign network. Unlike encapsulation, tunneling allows a lower-layer protocol and a same-layer protocol to be carried through the tunnel. A tunnel interface is a virtual (or logical) interface. Tunneling consists of three main components:

- Passenger protocol—The protocol that you are encapsulating. For example, IPv4 and IPv6 protocols.
- Carrier protocol—The protocol that encapsulates. For example, generic routing encapsulation (GRE) and Multiprotocol Label Switching (MPLS).
- Transport protocol--The protocol that carries the encapsulated protocol. The main transport protocol is IP.

Tunnel ToS

Tunnel type of service (ToS) allows you to tunnel network traffic and group all packets in the same ToS byte value. The ToS byte values and Time-to-Live (TTL) hop-count value can be set in the encapsulating IP header of tunnel packets for an IP tunnel interface on a router. Tunnel ToS feature is supported for Cisco Express Forwarding (formerly known as CEF), fast switching, and process switching.

The ToS and TTL byte values are defined in RFC 791. RFC 2474, and RFC 2780 obsolete the use of the ToS byte as defined in RFC 791. RFC 791 specifies that bits 6 and 7 of the ToS byte (the first two least significant bits) are reserved for future use and should be set to 0.

Path MTU Discovery

Path MTU Discovery (PMTUD) can be enabled on a GRE or IP-in-IP tunnel interface. When PMTUD (RFC 1191) is enabled on a tunnel interface, the router performs PMTUD processing for the GRE (or IP-in-IP) tunnel IP packets. The router always performs PMTUD processing on the original data IP packets that enter the tunnel. When PMTUD is enabled, packet fragmentation is not permitted for packets that traverse the tunnel because the Don’t Fragment (DF) bit is set on all the packets. If a packet that enters the tunnel encounters a link with a smaller MTU, the packet is dropped and an Internet Control Message Protocol (ICMP) message is sent back to the sender of the packet. This message indicates that fragmentation was required (but not permitted) and provides the MTU of the link that caused the packet to be dropped.

Note PMTUD on a tunnel interface requires that the tunnel endpoint be able to receive ICMP messages generated by routers in the path of the tunnel. Ensure that ICMP messages can be received before using PMTUD over firewall connections.

Use the **tunnel path-mtu-discovery** command to enable PMTUD for the tunnel packets and use the **show interfaces tunnel** command to verify the tunnel PMTUD parameters. PMTUD works only on GRE and IP-in-IP tunnel interfaces.

QoS Options for Tunnels

A tunnel interface supports various quality of service (QoS) features as a physical interface. QoS provides a way to ensure that mission-critical traffic has an acceptable level of performance. QoS options for tunnels include support for applying generic traffic shaping (GTS) directly on the tunnel interface and support for class-based shaping using the modular QoS CLI (MQC). Tunnel interfaces also support class-based policing, but they do not support committed access rate (CAR).

GRE tunnels allow the router to copy the IP precedence bit values of the ToS byte to the tunnel or the GRE IP header that encapsulates the inner packet. Intermediate routers between the tunnel endpoints can use the IP precedence values to classify packets for QoS features such as policy routing, weighted fair queueing (WFQ), and weighted random early detection (WRED).

When packets are encapsulated by tunnel or encryption headers, QoS features are unable to examine the original packet headers and correctly classify the packets. Packets that travel across the same tunnel have the same tunnel headers, so the packets are treated identically if the physical interface is congested. Tunnel packets can, however, be classified before tunneling and encryption can occur when a user applies the QoS preclassify feature on the tunnel interface or on the crypto map.

Note Class-based WFQ (CBWFQ) inside class-based shaping is not supported on a multipoint interface.

For examples of how to implement some QoS features on a tunnel interface, see the section "Configuring QoS Options on Tunnel Interfaces Examples, on page 306".

Information About IPv6 over IPv4 GRE Tunnels

Overlay Tunnels for IPv6

Overlay tunneling encapsulates IPv6 packets in IPv4 packets for delivery across an IPv4 infrastructure (a core network or the figure below). By using overlay tunnels, you can communicate with isolated IPv6 networks without upgrading the IPv4 infrastructure between them. Overlay tunnels can be configured between border devices or between a border device and a host; however, both tunnel endpoints must support both the IPv4 and IPv6 protocol stacks. IPv6 supports the following types of overlay tunneling mechanisms:

- Manual
- Generic routing encapsulation (GRE)
- IPv4-compatible
- 6to4
- Intrasite Automatic Tunnel Addressing Protocol (ISATAP)

Figure 3: Overlay Tunnels

Note Overlay tunnels reduce the maximum transmission unit (MTU) of an interface by 20 octets (assuming that the basic IPv4 packet header does not contain optional fields). A network that uses overlay tunnels is difficult to troubleshoot. Therefore, overlay tunnels that connect isolated IPv6 networks should not be considered a final IPv6 network architecture. The use of overlay tunnels should be considered as a transition technique toward a network that supports both the IPv4 and IPv6 protocol stacks or just the IPv6 protocol stack.

Use the table below to help you determine which type of tunnel that you want to configure to carry IPv6 packets over an IPv4 network.

Table 56: Suggested Usage of Tunnel Types to Carry IPv6 Packets over an IPv4 Network

Tunneling Type	Suggested Usage	Usage Notes
Manual	Simple point-to-point tunnels that can be used within a site or between sites.	Can carry IPv6 packets only.
GRE- and IPv4-compatible	Simple point-to-point tunnels that can be used within a site or between sites.	Can carry IPv6, Connectionless Network Service (CLNS), and many other types of packets.
IPv4- compatible	Point-to-multipoint tunnels.	Uses the ::/96 prefix. We do not recommend using this tunnel type.
6to4	Point-to-multipoint tunnels that can be used to connect isolated IPv6 sites.	Sites use addresses from the 2002::/16 prefix.
6RD	IPv6 service is provided to customers over an IPv4 network by using encapsulation of IPv6 in IPv4.	Prefixes can be from the SP's own address block.
ISATAP	Point-to-multipoint tunnels that can be used to connect systems within a site.	Sites can use any IPv6 unicast addresses.

Individual tunnel types are discussed in detail in this document. We recommend that you review and understand the information about the specific tunnel type that you want to implement. When you are familiar with the type of tunnel you need, see the table below for a summary of the tunnel configuration parameters that you may find useful.

Table 57: Tunnel Configuration Parameters by Tunneling Type

Tunneling Type	Tunnel Configuration Parameter			
Tunnel Mode	**Tunnel Source**	**Tunnel Destination**	**Interface Prefix or Address**	

Tunneling Type	Tunnel Configuration Parameter			
Manual	ipv6ip	An IPv4 address, or a reference to an interface on which IPv4 is configured.	An IPv4 address.	An IPv6 address.
GRE/IPv4	gre ip		An IPv4 address.	An IPv6 address.
IPv4- compatible	ipv6ip auto-tunnel		Not required. These are all point-to-multipoint tunneling types. The IPv4 destination address is calculated, on a per-packet basis, from the IPv6 destination.	Not required. The interface address is generated as ::*tunnel-source*/96.
6to4	ipv6ip 6to4			An IPv6 address. The prefix must embed the tunnel source IPv4 address.
6RD	ipv6ip 6rd			An IPv6 address.
ISATAP	ipv6ip isatap			An IPv6 prefix in modified eui-64 format. The IPv6 address is generated from the prefix and the tunnel source IPv4 address.

GRE IPv4 Tunnel Support for IPv6 Traffic

IPv6 traffic can be carried over IPv4 GRE tunnels using the standard GRE tunneling technique that is designed to provide the services to implement any standard point-to-point encapsulation scheme. As in IPv6 manually configured tunnels, GRE tunnels are links between two points, with a separate tunnel for each link. The tunnels are not tied to a specific passenger or transport protocol but, in this case, carry IPv6 as the passenger protocol with the GRE as the carrier protocol and IPv4 or IPv6 as the transport protocol.

The primary use of GRE tunnels is for stable connections that require regular secure communication between two edge devices or between an edge device and an end system. The edge devices and the end systems must be dual-stack implementations.

Information About GRE IPv6 Tunnels

Overview of GRE IPv6 Tunnels

The GRE IPv6 Tunnels feature enables the delivery of packets from other protocols through an IPv6 network and allows the routing of IPv6 packets between private networks across public networks with globally routed IPv6 addresses.

For point-to-point GRE tunnels, each tunnel interface requires a tunnel source IPv6 address and a tunnel destination IPv6 address when being configured. All packets are encapsulated with an outer IPv6 header and a GRE header.

How to Implement Tunnels

Determining the Tunnel Type

Before configuring a tunnel, you must determine the type of tunnel you want to create.

SUMMARY STEPS

1. Determine the passenger protocol. A passenger protocol is the protocol that you are encapsulating.
2. Determine the **tunnel mode** command keyword, if appropriate.

DETAILED STEPS

Step 1 Determine the passenger protocol. A passenger protocol is the protocol that you are encapsulating.

Step 2 Determine the **tunnel mode** command keyword, if appropriate.

The table below shows how to determine the appropriate keyword to be used with the **tunnel mode** command.

Table 58: Determining the tunnel mode Command Keyword

Keyword	Purpose
dvmrp	Use the **dvmrp** keyword to specify that the Distance Vector Multicast Routing Protocol encapsulation will be used.
gre ip	Use the **gre** and **ip** keywords to specify that GRE encapsulation over IP will be used.
gre ipv6	Use the **gre** and **ipv6** keywords to specify that GRE encapsulation over IPv6 will be used.
ipip [**decapsulate-any**]	Use the **ipip** keyword to specify that IP-in-IP encapsulation will be used. The optional **decapsulate-any** keyword terminates any number of IP-in-IP tunnels at one tunnel interface. Note that this tunnel will not carry any outbound traffic; however, any number of remote tunnel endpoints can use a tunnel configured as their destination.
ipv6	Use the **ipv6** keyword to specify that generic packet tunneling in IPv6 will be used.
ipv6ip	Use the **ipv6ip** keyword to specify that IPv6 will be used as the passenger protocol and IPv4 as both the carrier (encapsulation) and transport protocol. When additional keywords are not used, manual IPv6 tunnels are configured. Additional keywords can be used to specify IPv4-compatible, 6to4, or ISATAP tunnels.
mpls	Use the **mpls** keyword to specify that MPLS will be used for configuring traffic engineering (TE) tunnels.

Configuring an IPv4 GRE Tunnel

Perform this task to configure a GRE tunnel. A tunnel interface is used to pass protocol traffic across a network that does not normally support the protocol. To build a tunnel, you must define a tunnel interface on each of the two routers, and the tunnel interfaces must reference each other. At each router, the tunnel interface must be configured with a Layer 3 address. The tunnel endpoints, tunnel source, and tunnel destination must be defined, and the type of tunnel must be selected. Optional steps can be performed to customize the tunnel.

Remember to configure the router at each end of the tunnel. If only one side of a tunnel is configured, the tunnel interface may still come up and stay up (unless keepalive is configured), but packets going into the tunnel will be dropped.

GRE Tunnel Keepalive

Keepalive packets can be configured to be sent over IP-encapsulated GRE tunnels. You can specify the rate at which keepalives are sent and the number of times that a device will continue to send keepalive packets without a response before the interface becomes inactive. GRE keepalive packets may be sent from both sides of a tunnel or from just one side.

Before you begin

Ensure that the physical interface to be used as the tunnel source in this task is up and configured with the appropriate IP address. For hardware technical descriptions and information about installing interfaces, see the hardware installation and configuration publication for your product.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface** *type number* **Example:** `Router(config)# interface tunnel 0`	Specifies the interface type and number, and enters interface configuration mode. • To configure a tunnel, use **tunnel** for the *type* argument.
Step 4	**bandwidth** *kb/s* **Example:** `Router(config-if)# bandwidth 1000`	Sets the current bandwidth value for an interface and communicates it to higher-level protocols. • Specifies the tunnel bandwidth to be used to transmit packets. • Use the *kb/s* argument to set the bandwidth, in kilobits per second (kb/s).

	Command or Action	Purpose
		Note This is only a routing parameter; it does not affect the physical interface. The default bandwidth setting on a tunnel interface is 9.6 kb/s. You should set the bandwidth on a tunnel to an appropriate value.
Step 5	**keepalive** [*period* [*retries*]] **Example:** `Router(config-if)# keepalive 3 7`	(Optional) Specifies the number of times the device will continue to send keepalive packets without response before bringing the tunnel interface protocol down. • GRE keepalive packets may be configured either on only one side of the tunnel or on both. • If GRE keepalive is configured on both sides of the tunnel, the *period* and *retries* arguments can be different at each side of the link. **Note** This command is supported only on GRE point-to-point tunnels. **Note** The GRE tunnel keepalive feature should not be configured on a VRF tunnel. This combination of features is not supported.
Step 6	**tunnel source** {*ip-address* | *interface-type interface-number*} **Example:** `Router(config-if)# tunnel source TenGigabitEthernet 4/1/0`	Configures the tunnel source. **Note** The tunnel source IP address and destination IP addresses must be defined on two separate devices.
Step 7	**tunnel destination** {*hostname* | *ip-address*} **Example:** `Router(config-if)# tunnel destination 10.0.2.1`	Configures the tunnel destination. **Note** The tunnel source and destination IP addresses must be defined on two separate devices.
Step 8	**tunnel key** *key-number* **Example:** `Router(config-if)# tunnel key 1000`	(Optional) Enables an ID key for a tunnel interface. **Note** This command is supported only on GRE tunnel interfaces. We do not recommend relying on this key for security purposes.
Step 9	**tunnel mode gre** { **ip** | **multipoint**} **Example:** `Device(config-if)# tunnel mode gre ip`	Specifies the encapsulation protocol to be used in the tunnel.
Step 10	**ip mtu** *bytes* **Example:**	(Optional) Sets the MTU size of IP packets sent on an interface.

	Command or Action	Purpose
	`Device(config-if)# ip mtu 1400`	• If an IP packet exceeds the MTU set for the interface, the Cisco software will fragment it unless the DF bit is set. • All devices on a physical medium must have the same protocol MTU in order to operate. • For IPv6 packets, use the **ipv6 mtu** command. **Note** If the **tunnel path-mtu-discovery** command is enabled do not configure this command.
Step 11	**ip tcp mss** *mss-value* **Example:** `Device(config-if)# ip tcp mss 250`	(Optional) Specifies the maximum segment size (MSS) for TCP connections that originate or terminate on a router.
Step 12	**tunnel path-mtu-discovery** [**age-timer** {*aging-mins* | **infinite**}] **Example:** `Device(config-if)# tunnel path-mtu-discovery`	(Optional) Enables PMTUD on a GRE or IP-in-IP tunnel interface. • When PMTUD is enabled on a tunnel interface, PMTUD will operate for GRE IP tunnel packets to minimize fragmentation in the path between the tunnel endpoints.
Step 13	**end** **Example:** `Device(config-if)# end`	Exits interface configuration mode and returns to privileged EXEC mode.

What to Do Next

Proceed to the "Verifying Tunnel Configuration and Operation" section.

Configuring 6to4 Tunnels

Before you begin

With 6to4 tunnels, the tunnel destination is determined by the border-router IPv4 address, which is concatenated to the prefix 2002::/16 in the format 2002:*border-router-IPv4-address* ::/48. The border router at each end of a 6to4 tunnel must support both the IPv4 and IPv6 protocol stacks.

Note The configuration of only one IPv4-compatible tunnel and one 6to4 IPv6 tunnel is supported on a router. If you choose to configure both of these tunnel types on the same router, Cisco recommends that they not share the same tunnel source.

A 6to4 tunnel and an IPv4-compatible tunnel cannot share the same interface because both of them are NBMA "point-to-multipoint" access links, and only the tunnel source can be used to reorder the packets from a multiplexed packet stream into a single packet stream for an incoming interface. When a packet with an IPv4 protocol type of 41 arrives on an interface, the packet is mapped to an IPv6 tunnel interface on the basis of the IPv4 address. However, if both the 6to4 tunnel and the IPv4-compatible tunnel share the same source interface, the router cannot determine the IPv6 tunnel interface to which it should assign the incoming packet.

Manually configured IPv6 tunnels can share the same source interface because a manual tunnel is a "point-to-point" link, and both IPv4 source and the IPv4 destination of the tunnel are defined.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface tunnel** *tunnel-number* **Example:** `Router(config)# interface tunnel 0`	Specifies a tunnel interface and number and enters interface configuration mode.
Step 4	**ipv6 address** *ipv6-prefix/prefix-length* [**eui-64**] **Example:** `Router(config-if)# ipv6 address 2002:c0a8:6301:1::1/64`	Specifies the IPv6 address assigned to the interface and enables IPv6 processing on the interface. • The 32 bits following the initial 2002::/16 prefix correspond to an IPv4 address assigned to the tunnel source. **Note** See the "Configuring Basic Connectivity for IPv6" module for more information on configuring IPv6 addresses.
Step 5	**tunnel source** {*ip-address* | *interface-type interface-number*} **Example:** `Router(config-if)# tunnel source TenGigabitEthernet 4/1/0`	Specifies the source IPv4 address or the source interface type and number for the tunnel interface. **Note** The interface type and number specified in the **tunnel source** command must be configured with an IPv4 address.

	Command or Action	Purpose
Step 6	**tunnel mode ipv6ip 6to4** **Example:** `Router(config-if)# tunnel mode ipv6ip 6to4`	Specifies an IPv6 overlay tunnel using a 6to4 address.
Step 7	**exit** **Example:** `Router(config-if)# exit`	Exits interface configuration mode and returns to global configuration mode.
Step 8	**ipv6 route** *ipv6-prefix* / *prefix-length* **tunnel** *tunnel-number* **Example:** `Router(config)# ipv6 route 2002::/16 tunnel 0`	Configures a static route to the specified tunnel interface. **Note** When configuring a 6to4 overlay tunnel, you must configure a static route for the IPv6 6to4 prefix 2002::/16 to the 6to4 tunnel interface. • The tunnel number specified in the **ipv6 route** command must be the same tunnel number specified in the **interface tunnel** command.
Step 9	**end** **Example:** `Router(config)# end`	Exits global configuration mode and returns to privileged EXEC mode.

What to Do Next

Proceed to the “Verifying Tunnel Configuration and Operation” section.

Verifying Tunnel Configuration and Operation

The **show** and **ping** commands in the steps below can be used in any sequence. The following commands can be used for GRE tunnels, IPv6 manually configured tunnels, and IPv6 over IPv4 GRE tunnels.

Step 1 **enable**

Enables privileged EXEC mode. Enter your password if prompted.

Example:

```
Device> enable
```

Step 2 **show interfaces tunnel** *number* [**accounting**]

Two routers are configured to be endpoints of a tunnel. Device A has TenGigabit Ethernet interface 4/1/0 configured as the source for tunnel interface 0 with an IPv4 address of 10.0.0.1 and an IPv6 prefix of 2001:0DB8:1111:2222::1/64. Device B has TenGigabit Ethernet interface 4/1/0 configured as the source for tunnel interface 1 with an IPv4 address of 10.0.0.2 and an IPv6 prefix of 2001:0DB8:1111:2222::2/64.

To verify that the tunnel source and destination addresses are configured, use the **show interfaces tunnel** command on Device A.

Example:

```
Device A# show interfaces tunnel 0

Tunnel0 is up, line protocol is up
  Hardware is Tunnel
  MTU 1514 bytes, BW 9 Kbit, DLY 500000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation TUNNEL, loopback not set
  Keepalive not set
  Tunnel source 10.0.0.1 (TenGigabitEthernet4/1/0), destination 10.0.0.2, fastswitch TTL 255
  Tunnel protocol/transport GRE/IP, key disabled, sequencing disabled
  Tunnel TTL 255
  Checksumming of packets disabled,  fast tunneling enabled
  Last input 00:00:14, output 00:00:04, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue :0/0 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     4 packets input, 352 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     8 packets output, 704 bytes, 0 underruns
     0 output errors, 0 collisions, 0 interface resets
     0 output buffer failures, 0 output buffers swapped out
```

Step 3 **ping** [*protocol*] *destination*

To check that the local endpoint is configured and working, use the **ping** command on Device A.

Example:

```
DeviceA# ping 2001:0DB8:1111:2222::2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:0DB8:1111:2222::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/20/20 ms
```

Step 4 **show ip route** [*address* [*mask*]]

To check that a route exists to the remote endpoint address, use the **show ip route** command.

Example:

```
DeviceA# show ip route 10.0.0.2

Routing entry for 10.0.0.0/24
  Known via "connected", distance 0, metric 0 (connected, via interface)
  Routing Descriptor Blocks:
  * directly connected, via TenGigabitEthernet4/1/0
      Route metric is 0, traffic share count is 1
```

Step 5 **ping** [*protocol*] *destination*

To check that the remote endpoint address is reachable, use the **ping** command on Device A.

Note The remote endpoint address may not be reachable using the **ping** command because of filtering, but the tunnel traffic may still reach its destination.

Example:

```
DeviceA# ping 10.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/21/28 ms
```

To check that the remote IPv6 tunnel endpoint is reachable, use the **ping** command again on Device A. The note regarding filtering earlier in step also applies to this example.

Example:

```
DeviceA# ping 2001:0DB8:1111:2222::2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 1::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/20/20 ms
```

These steps may be repeated at the other endpoint of the tunnel.

Configuration Examples for Implementing Tunnels

Example: Configuring a GRE IPv4 Tunnel

The following example shows a simple configuration of GRE tunneling. Note that TenGigabit Ethernet interface 4/1/0 is the tunnel source for Router A and the tunnel destination for Router B. TenGigabit Ethernet interface 4/1/1 is the tunnel source for Router B and the tunnel destination for Router A.

Router A

```
interface Tunnel 0
 ip address 10.1.1.2 255.255.255.0
 tunnel source TenGigabitEthernet 4/1/0
 tunnel destination 192.168.3.2
 tunnel mode gre ip
!
interface TenGigabitEthernet 4/1/0
 ip address 192.168.4.2 255.255.255.0
```

Router B

```
interface Tunnel 0
 ip address 10.1.1.1 255.255.255.0
 tunnel source TenGigabitEthernet 4/1/1
 tunnel destination 192.168.4.2
 tunnel mode gre ip
!
interface TenGigabitEthernet 4/1/1
 ip address 192.168.3.2 255.255.255.0
```

The following example configures a GRE tunnel running both IS-IS and IPv6 traffic between Router A and Router B:

Router A

```
ipv6 unicast-routing
clns routing
!
interface Tunnel 0
 no ip address
 ipv6 address 2001:0DB8:1111:2222::1/64
 ipv6 router isis
 tunnel source TenGigabitEthernet 4/1/0
 tunnel destination 10.0.0.2
 tunnel mode gre ip
!
interface TenGigabitEthernet 4/1/0
 ip address 10.0.0.1 255.255.255.0
!
router isis
 network 49.0000.0000.000a.00
```

Router B

```
ipv6 unicast-routing
clns routing
!
interface Tunnel 0
 no ip address
 ipv6 address 2001:0DB8:1111:2222::2/64
 ipv6 router isis
 tunnel source TenGigabitEthernet 4/1/0
 tunnel destination 10.0.0.1
 tunnel mode gre ip
!
interface TenGigabitEthernet 4/1/0
 ip address 10.0.0.2 255.255.255.0
!
router isis
 network 49.0000.0000.000b.00
 address-family ipv6
 redistribute static
 exit-address-family
```

Configuring QoS Options on Tunnel Interfaces Examples

The following sample configuration applies GTS directly on the tunnel interface. In this example, the configuration shapes the tunnel interface to an overall output rate of 500 kb/s.

```
interface Tunnel 0
 ip address 10.1.2.1 255.255.255.0
 traffic-shape rate 500000 125000 125000 1000
 tunnel source 10.1.1.1
 tunnel destination 10.2.2.2
```

The following sample configuration shows how to apply the same shaping policy to the tunnel interface with the MQC commands:

```
policy-map tunnel
 class class-default
 shape average 500000 125000 125000
!
interface Tunnel 0
 ip address 10.1.2.1 255.255.255.0
 service-policy output tunnel
 tunnel source 10.1.35.1
 tunnel destination 10.1.35.2
```

Policing Example

When an interface becomes congested and packets start to queue, you can apply a queueing method to packets that are waiting to be transmitted. Logical interfaces--tunnel interfaces in this example--do not inherently support a state of congestion and do not support the direct application of a service policy that applies a queueing method. Instead, you must apply a hierarchical policy. Create a "child" or lower-level policy that configures a queueing mechanism, such as low-latency queueing, with the **priority** command and CBWFQ with the **bandwidth** command.

```
policy-map child
 class voice
 priority 512
```

Create a "parent" or top-level policy that applies class-based shaping. Apply the child policy as a command under the parent policy because admission control for the child class is done according to the shaping rate for the parent class.

```
policy-map tunnel
 class class-default
 shape average 2000000
 service-policy child
```

Apply the parent policy to the tunnel interface.

```
interface tunnel 0
 service-policy tunnel
```

In the following example, a tunnel interface is configured with a service policy that applies queueing without shaping. A log message is displayed noting that this configuration is not supported.

```
Router(config)# interface tunnel1
Router(config-if)# service-policy output child
Class Based Weighted Fair Queueing not supported on this interface
```

How to Configure IPv6 over IPv4 GRE Tunnels

Configuring GRE on IPv6 Tunnels

GRE tunnels can be configured to run over an IPv6 network layer and to transport IPv4 and IPv6 packets in IPv6 tunnels.

Before you begin

When GRE IPv6 tunnels are configured, IPv6 addresses are assigned to the tunnel source and the tunnel destination. The tunnel interface can have either IPv4 addresses or IPv6 addresses assigned (this is not shown in the task). The host or device at each end of a configured tunnel must support both the IPv4 and IPv6 protocol stacks.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Device# configure terminal`	Enters global configuration mode.
Step 3	**interface tunnel** *tunnel-number* **Example:** `Device(config)# interface tunnel 0`	Specifies a tunnel interface and number, and enters interface configuration mode.
Step 4	Enter one of the following commands: • **ipv6 address** {*ipv6-address*/*prefix-length* | *prefix-name sub-bits*/*prefix-length*} • **ipv6 address** *ipv6-prefix*/*prefix-length* [**eui-64**] **Example:** `Device(config-if)# ipv6 address 3ffe:b00:c18:1::3/127`	Specifies the IPv6 network assigned to the interface and enables IPv6 processing on the interface. • If you specify the **eui-64** keyword, the software configures an IPv6 address for an interface and enables IPv6 processing on the interface using an EUI-64 interface ID in the low-order 64 bits of the address.
Step 5	**tunnel source** {*ip-address* | *ipv6-address* | *interface-type interface-number*} **Example:** `Device(config-if)# tunnel source Tengigabitethernet 4/1/0`	Specifies the source IPv4 address, IPv6 address, or the source interface type and number for the tunnel interface. • If an interface is specified, the interface must be configured with an IPv4 address.
Step 6	**tunnel destination** {*hostname* | *ip-address* | *ipv6-address*} **Example:** `Device(config-if)# tunnel destination 2001:DB8:1111:2222::1/64`	Specifies the destination IPv4 address, IPv6 address, or hostname for the tunnel interface.
Step 7	**tunnel mode** {**aurp** | **cayman** | **dvmrp** | **eon** | **gre** | **gre multipoint** | **gre ipv6** | **ipip** [**decapsulate-any**] | **iptalk** | **ipv6** | **mpls** | **nos**}	Specifies a GRE IPv6 tunnel.

	Command or Action	Purpose
	Example: `Device(config-if)# tunnel mode gre ipv6`	**Note** The **tunnel mode gre ipv6** command specifies GRE as the encapsulation protocol for the tunnel.
Step 8	**end** **Example:** `Device(config-if)# end`	Returns to privileged EXEC mode.

Configuration Examples for IPv6 over IPv4 GRE Tunnels

Example: GRE Tunnel Running IS-IS and IPv6 Traffic

The following example configures a GRE tunnel running both IS-IS and IPv6 traffic between Router A and Router B:

Router A Configuration

```
ipv6 unicast-routing
clns routing
!
interface tunnel 0
 no ip address
 ipv6 address 3ffe:b00:c18:1::3/127
 ipv6 router isis
 tunnel source TenGigabitEthernet 4/1/0
 tunnel destination 2001:DB8:1111:2222::1/64
 tunnel mode gre ipv6
!
interface TenGigabitEthernet4/1/0
 ip address 10.0.0.1 255.255.255.0
!
router isis
 net 49.0000.0000.000a.00
```

Router B Configuration

```
ipv6 unicast-routing
clns routing
!
interface tunnel 0
 no ip address
 ipv6 address 3ffe:b00:c18:1::2/127
 ipv6 router isis
 tunnel source TenGigabitEthernet 4/1/0
 tunnel destination 2001:DB8:1111:2222::2/64
 tunnel mode gre ipv6
!
interface TenGigabitEthernet4/1/0
 ip address 10.0.0.2 255.255.255.0
!
router isis
```

```
net 49.0000.0000.000b.00
address-family ipv6
redistribute static
exit-address-family
```

Example: Tunnel Destination Address for IPv6 Tunnel

```
Router(config)#interface Tunnel0
Router(config-if)#ipv6 address 2001:1:1::1/48
Router(config-if)#tunnel source TenGigabitEthernet 4/1/0
Router(config-if)#tunnel destination 10.0.0.2
Router(config-if)#tunnel mode gre ipv6
Router(config-if)#exit
!
Router(config)#interface TenGigabitEthernet4/1/0
Router(config-if)#ip address 10.0.0.1 255.255.255.0
Router(config-if)#exit
!
Router(config)#ipv6 unicast-routing
Router(config)#router isis
Router(config)#net 49.0000.0000.000a.00
```

How to Configure GRE IPv6 Tunnels

Configure CDP Over GRE IPv6 Tunnels

Perform this task to configure a GRE tunnel on an IPv6 network. GRE tunnels can be configured to run over an IPv6 network layer and transport IPv6 and IPv4 packets through IPv6 tunnels.

Note You must enable IPv6 or configure IPv6 MTU size more than 1500 on a tunnel's exit interface to avoid receiving warning messages.

Before you begin

When GRE IPv6 tunnels are configured, IPv6 addresses are assigned to the tunnel source and the tunnel destination. The tunnel interface can have either IPv4 or IPv6 addresses. The host or device at each end of the configured tunnel must support both IPv4 and IPv6 protocol stacks.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Device> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:**	Enters global configuration mode.

	Command or Action	Purpose
	`Device# configure terminal`	
Step 3	**interface tunnel** *tunnel-number* **Example:** `Device(config)# interface tunnel 0`	Specifies a tunnel interface and number and enters interface configuration mode.
Step 4	**CDP enable** **Example:** `Device(config)# CDP enable`	Enables Cisco Discovery Protocol on the interface.
Step 5	**tunnel source** {*ipv6-address* | *interface-type* |*interface-number* } **Example:** `Device(config-if)# tunnel source ethernet 0`	Specifies the source IPv6 address or the source interface type and number for the tunnel interface. • If an interface type and number are specified, the interface must be configured with an IPv6 address. **Note** For more information on the tunnel source command, refer to the IPv6 command reference guide.
Step 6	**tunnel destination** *ipv6-address* **Example:** `Device(config-if)# tunnel destination 2001:0DB8:0C18:2::300`	Specifies the destination IPv6 address for the tunnel interface. **Note** For more information on the tunnel destination command, refer to the IPv6 command reference guide.
Step 7	**tunnel mode gre ipv6** **Example:** `Device(config-if)# tunnel mode gre ipv6`	Specifies a GRE IPv6 tunnel. **Note** The **tunnel mode gre ipv6** command specifies GRE as the encapsulation protocol for the tunnel interface. Only the syntax used in this context is displayed. For more details, see the IPv6 Command Reference.
Step 8	**end** **Example:** `Device(config-if)# end`	Exits interface configuration mode and returns to privileged EXEC mode.

Configuration Examples for GRE IPv6 Tunnels

Example: Configuring CDP Over GRE IPv6 Tunnels

The following example shows how to configure a GRE tunnel over an IPv6 transport. In this example, Ethernet0/0 has an IPv6 address, and this is the source address used by the tunnel interface. The destination IPv6 address of the tunnel is specified directly. In this example, the tunnel carries both IPv4 and IS-IS traffic.

```
interface Tunnel0
 ip address 10.1.1.1 255.255.255.0
 ip router isis
 tunnel source Ethernet0/0
 tunnel destination 2001:DB8:1111:2222::1
 tunnel mode gre ipv6
!
interface Ethernet0/0
 no ip address
 ipv6 address 2001:DB8:1111:1111::1/64
!
router isis
 net 49.0001.0000.0000.000a.00
```

The following example shows how to configure CDP on GRE IPv6 P2P Tunnel Interface.

```
interface Tunnel1
  cdp enable
  ipv6 address 20::1/64
  tunnel source Ethernet0/0
  tunnel mode gre ipv6
  tunnel destination 10::2
end
```

The following example shows how to configure CDP on GRE IPv6 Multipoint Tunnel Interface.

```
interface Tunnel1
   ipv6 address 172::2/64
   ipv6 nhrp map 172::1/64 192::1
   ipv6 nhrp map multicast 192::1
    ipv6 nhrp network-id 1
   ipv6 nhrp nhs 172::1
   llp nhrp map multicast 192::1
   tunnel source 2000::1
   tunnel mode gre multipoint ipv6
end
```

The following show example displays the CDP neighbor tunnels that are configured in a device.

```
Router#show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone,
                  D - Remote, C - CVTA, M - Two-port Mac Relay

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
Router           Tunnel1           179               R    Linux Uni Tunnel1
```

Additional References

The following sections provide references related to the GRE feature.

Related Documents

Related Topic	Document Title
CMTS Command Reference	Cisco CMTS Cable Command Reference, at the following URL: http://www.cisco.com/c/en/us/td/docs/cable/cmts/cmd_ref/b_cmts_cable_cmd_ref.html

Related Topic	Document Title
Configuring GRE Tunnel over Cable	Configuring GRE Tunnel over Cable, at the following URL: http://www.cisco.com/en/US/tech/tk86/tk89/technologies_configuration_example09186a008011520d.sht

Standards

Standard	Title
SP-RFIv1.1-I09-020830	Data-over-Cable Service Interface Specifications Radio Frequency Interface Specification, version 1.1 (http://www.cablemodem.com)

MIBs

MIB	MIBs Link
No new or modified MIBs are supported by this feature.	To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: http://tools.cisco.com/ITDIT/MIBS/servlet/index

RFCs

RFC	Title
RFC 1701	Generic Routing Encapsulation (GRE)
RFC 1702	Generic Routing Encapsulation over IPv4 networks
RFC 1853	IP in IP Tunneling
RFC 2003	IP Encapsulation within IP
RFC 2784	Generic Routing Ecapsulation (GRE)
RFC 2890	Key and Sequence Number Extensions to GRE

Technical Assistance

Description	Link
The Cisco Technical Support & Documentation website contains thousands of pages of searchable technical content, including links to products, technologies, solutions, technical tips, and tools. Registered Cisco.com users can log in from this page to access even more content.	http://www.cisco.com/cisco/web/support/index.html

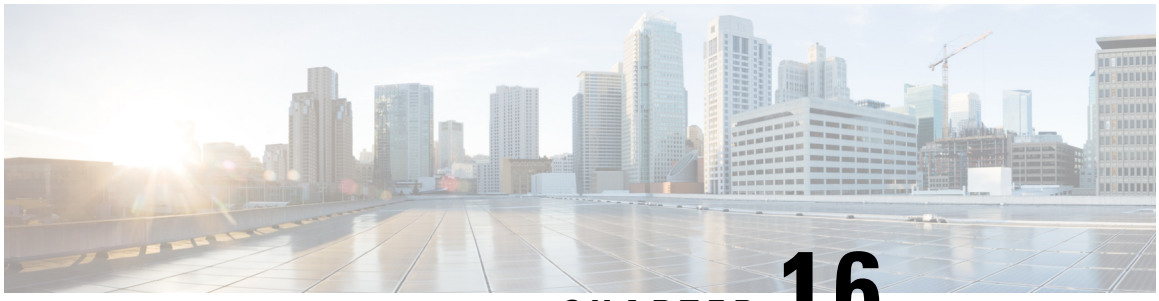
Feature Information for Generic Routing Encapsulation

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 59: Feature Information for Generic Routing Encapsulation

Feature Name	Releases	Feature Information
Generic Routing Encapsulation	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 16

Transparent LAN Service over Cable

This document describes the Transparent LAN Service (TLS) over Cable feature, which enhances existing Wide Area Network (WAN) support to provide more flexible Managed Access for multiple Internet service provider (ISP) support over a hybrid fiber-coaxial (HFC) cable network. This feature allows service providers to create a Layer 2 tunnel by mapping an upstream service identifier (SID) to an IEEE 802.1Q Virtual Local Area Network (VLAN).

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

Contents

- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 315
- Prerequisites for Transparent LAN Service over Cable, on page 316
- Restrictions for Transparent LAN Service over Cable, on page 317
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Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 60: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for Transparent LAN Service over Cable

- You must know the hardware (MAC) addresses of the cable modems that are to be mapped to IEEE 802.1Q VLANs.
- You must create a bridge group for each separate customer on the Layer 2 bridge aggregator, so that traffic from all of the Customer Premises Equipment (CPE) devices for the customer is grouped together into the same 802.1Q tunnel.

Restrictions for Transparent LAN Service over Cable

- Configuring 802.1Q for a particular cable modem removes any previous cable modem configuration on the router.
- We strongly recommend that TLS over Cable only be used when Baseline Privacy Interface (BPI) is enabled in the environment. If BPI is not enabled when using the TLS feature, traffic can flow between multiple virtual private networks (VPNs), and become vulnerable to denial-of-service attacks or snooping. We also recommend that remote networks be isolated with a gateway or firewall router when BPI is not enabled.

When the TLS feature is used with Layer 2 VPNs, the participating cable modems *must* have the Baseline Privacy Interface security feature (BPI) enabled. Otherwise, the Cisco CMTS drops such Layer 2 traffic in the upstream or downstream.

- Packets are mapped to their Layer 2 tunnel only on the basis of Layer 2 information (the cable modem's MAC address and primary SID). Layer 3 services, such as access lists, IP address source-verify, and IP QoS, are not supported as packets are sent through the tunnel.
- All traffic from a cable modem is mapped to the same Layer 2 tunnel. It is not possible to differentiate traffic from different customer premises equipment (CPE) devices behind the cable modem.
- CPE learning is not available when using the Transparent LAN Service over Cable feature. When a cable modem is mapped to a Layer 2 tunnel, the **show interface cable modem** command shows that the IP addresses for its CPE devices are "unavailable."
- DOCSIS QoS is supported across the Layer 2 tunnel only on the primary SID. Traffic using secondary services uses the same Layer 2 tunnel as the primary SID.
- The Spanning Tree Protocol (STP) cannot be used with devices (cable modems, their CPE devices, and the endpoint CPE devices) that are using this feature. In particular, Spanning Tree Protocol cannot be used between the VLAN bridge aggregator and the endpoint customer devices.
- The following restrictions apply to Layer 2 tunnels over an Ethernet IEEE 802.1Q VLAN interface:
  - IEEE 802.1Q tunnels are supported only on Ten Gigabit Ethernet interfaces.
  - The Cisco CMTS router supports a maximum of 4095 VLAN IDs, but the switches acting as the bridge aggregator might support a lower number of VLAN IDs. If this is the case, the Cisco CMTS should be configured only for the maximum number of VLANs that are supported by the bridge aggregator switches.

Information About Transparent LAN Service over Cable

This section contains the following:

Feature Overview

The Transparent LAN Service over Cable feature enables service providers to provide Layer 2 tunnels for traffic to and from cable modems. This allows customers to create their own virtual local area network (VLAN) using any number of cable modems in multiple sites.

On the Cisco CMTS, you map each cable modem (on the basis of its MAC address) to the appropriate VLAN. The CMTS then creates an internal database of this one-to-one mapping of cable modems to VLANs, and uses it to encapsulate packets for the appropriate VLAN.

The CMTS encapsulates the CPE traffic from mapped cable modems using the following method:

- IEEE 802.1Q Mapping—The cable modem's MAC address is mapped to an IEEE 802.1Q VLAN on a specific Ten Gigabit Ethernet interface, so that all traffic from the cable modem is tagged with the specified VLAN ID.

Traffic to and from this group of cable modems is bridged into a single logical network (the VLAN) by the bridge aggregator, creating a secure Virtual Private Network (VPN) for that particular group of cable modems. Traffic in one VLAN cannot be sent into another VLAN, unless specifically done so by an external router.

The switch acting as the Layer 2 Bridge Aggregator uses the VLAN tagging to forward the traffic to the appropriate destination. This frees up service providers from needing to know the addressing, routing, and topological details of the customer's network.

Transparent LAN Service and Layer 2 Virtual Private Networks

In addition, service providers can provide a Layer 2 VPN with only minimal configuration changes on the provider's routers. The service subscriber does not need to make any changes to their private network or cable modems, nor does the service provider have to provide any special DOCSIS configuration files to enable this feature.

For the TLS feature with Layer 2 VPNs:

- When the TLS feature is used with Layer 2 VPNs, the participating cable modems must have the Baseline Privacy Interface security feature (BPI) enabled. Otherwise, the Cisco CMTS drops such Layer 2 traffic in the upstream or downstream.
- Information about Customer Premises Equipment (CPE) does not display in the output of the **show cable modem** command.

IEEE 802.1Q Mapping

This section describes the mapping of cable modems to an IEEE 802.1Q VLAN, as it is available in the Transparent LAN Service over Cable feature:

Overview

The Transparent LAN Service over Cable feature enables service providers to provide Layer 2 tunnels over an Ethernet network, using IEEE 802.1Q standard tags. This allows customers to create their own virtual network using any number of cable modems in different sites.

On the Cisco CMTS, you map each cable modem (on the basis of its MAC address) to the appropriate VLAN. The CMTS then creates an internal database of this one-to-one mapping of cable modems to VLANs, and uses it to encapsulate packets for the appropriate VLAN.

The CMTS encapsulates the CPE traffic from mapped cable modems using VLAN tags, as defined in IEEE 802.1Q-1993, IEEE Standards for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks . The switch acting as the Layer 2 Bridge Aggregator uses the VLAN tagging to forward the packets to the appropriate destination.

Traffic to and from this group of cable modems is bridged into a single logical network by the bridge aggregator, creating a secure Virtual Private Network (VPN) for that particular group of cable modems. Traffic in one VLAN cannot be sent into another VLAN, unless specifically done so by an external router.

Details of IEEE 802.1Q Mapping

To implement the Transparent LAN Service over Cable feature using IEEE 802.1Q VLANs, a service provider must perform the following configuration steps:

1. Identify the cable modems and their MAC addresses that should be mapped to the IEEE 802.1Q VLANs.
2. Create the required VLANs on the router that is acting as the bridge aggregator.
3. Enable Layer 2 mapping on the Cisco CMTS, and then map each cable modem on that Cisco CMTS to the appropriate VLAN.

After the Transparent LAN Service over Cable feature has been enabled and configured to use IEEE 802.1Q mappings, the Cisco CMTS immediately begins mapping traffic between the associated cable modems and VLANs. For efficient mapping, the Cisco CMTS maintains an internal database that links each cable modem's primary service flow ID (SFID) and service ID (SID) to the appropriate VLAN and Ethernet interface. This ensures that all service flows from the cable modem are routed properly.

When the Cisco CMTS receives a packet on an upstream, it looks up its SID to see if it is mapped to a VLAN. If so, and if the packet's source MAC address is not the cable modem's MAC address, the Cisco CMTS inserts the appropriate IEEE 802.1Q VLAN tag into the packet's header and forwards the packet to the appropriate Ethernet interface. If the packet is not being mapped, or if the packet originated from the cable modem, the Cisco CMTS routes the packet using the normal Layer 3 processes.

When the Cisco CMTS receives a packet from a WAN interface that is encapsulated with an IEEE 802.1Q VLAN tag, it looks up the packet's SID to see if it belongs to a cable modem being mapped. If so, the Cisco CMTS strips off the VLAN tag, adds the proper DOCSIS header, and transmits the packet on the appropriate downstream interface. If the packet is not being mapped, the Cisco CMTS continues with the normal Layer 3 processing.

Benefits

The Transparent LAN Service over Cable feature provides the following benefits to cable service providers and their partners and customers:

- Provides Layer 2 level mapping, which is transparent to Layer 3 protocols and services. This means that service providers do not need to know the details of their customers' network topologies, routing protocols, or IP addressing.
- Allows service providers to maximize the use of their existing Ethernet WAN networks. Multiple customers can be combined on the same outgoing interface, while still ensuring that each customer's network is kept private while it is transmitted over the tunnel.
- Provides a highly flexible and scalable solution for multiple customers. The service provider needs to create only one bridge group for each VPN, and then only one VLAN mapping for each cable modem should participate in that VPN tunnel.
- Customers retain full control over their private networks, while service providers retain full control over cable modems and the rest of the cable and WAN networks. Only the CPE traffic from the cable modems is mapped into the L2VPN tunnel, while traffic originating at the cable modem continues to be processed as normal by the service provider's network.
- Allows service providers to mix tunneled and non-tunneled cable modems on the same DOCSIS cable network.

- Allows customers to create a single, secure virtual network with Ethernet Layer 2 connectivity for multiple sites.
- Allows multiple tunnels from different customers and endpoints to be aggregated into a single bridge, so as to maximize the use of bandwidth and other network resources.
- Supports the tunneling of multiple Layer 3, non-IP protocols, and not just IP Layer 3 services, as is the case with Layer 3 solutions, such as Multiprotocol Label Switching (MPLS) VPNs.
- All DOCSIS services, including BPI+ encryption and authentication, continue to be supported for all cable modems.

How to Configure the Transparent LAN Service over Cable

This section contains the following:

Configuring IEEE 802.1Q VLAN Mapping

This section describes how to enable Layer 2 mapping on the Cisco CMTS, and then to map particular cable modems to an IEEE 802.1Q VLAN.

Enabling and Configuring Layer 2 Tunneling for IEEE 802.1Q Mapping

This section describes how to enable Layer 2 mapping on the Cisco CMTS, and then to map particular cable modems to IEEE 802.1Q VLANs on a Ten Gigabit Ethernet interface.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable l2-vpn-service xconnect nsi dot1q** **Example:** `Router(config)# cable l2-vpn-service xconnect nsi dot1q`	Enables Layer 2 tunneling for IEEE 802.1Q VLAN mapping. **Note** It is not required to configure VLAN trunking on the Cisco CMTS. Though VLAN trunking is supported, be aware of additional impact of VLAN trunking on the Cisco CMTS.
Step 4	**cable dot1q-vc-map** *mac-address ethernet-interface vlan-id* [*cust-name*] **Example:**	Maps the specified MAC address of a cable modem to the indicated VLAN and Ten Gigabit Ethernet interface. **Note** Repeat this command for each cable modem that is to be mapped to an IEEE 802.1Q VLAN.

	Command or Action	Purpose
	`Router(config)# cable dot1q-vc-map 0000.0C04.0506 TenGigabitEthernet4/1/0 10`	
Step 5	**end** **Example:** `Router(config)# end`	Exits global configuration mode and returns to privileged EXEC mode.

Creating the IEEE 802.1Q VLAN Bridge Group

This section describes the minimum configuration needed to configure a Cisco router, which is acting as an IEEE 802.1Q VLAN bridge aggregator, so that it can terminate the VLANs being used with the Transparent LAN Service over Cable feature.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal` **Example:**	Enters global configuration mode.
Step 3	**interface TenGigabitEthernet** *slot/subslot/port* **Example:** `Router(config)# interface TenGigabitEthernet4/1/0`	Enters interface configuration mode for the Ten Gigabit Ethernet interface.
Step 4	**ip address** *ip-address mask* **Example:** `Router(config-if)# ip address 10.10.10.85 255.255.255.0`	Configures the interface with the specified IP address and subnet mask.
Step 5	**exit** **Example:** `Router(config-if)# exit`	Exits interface configuration and returns to global configuration mode.
Step 6	**interface TenGigabitEthernet** *slot/subslot/port.y* **Example:**	Creates a subinterface on the Ten Gigabit Ethernet interface.

	Command or Action	Purpose
	`Router(config)# interface TenGigabitEthernet4/1/0.10`	**Note** To simplify network management, set the subinterface number to the same value as the VLAN ID that will use this subinterface (which in this case is 10). **Note** The steps to create a subinterface is not essential for dot1q tagging of frames, but it is recommended.
Step 7	**bridge group** *number* **Example:** `Router(config-if)# bridge group 20`	Configures this subinterface to belong to the specified bridge group. **Note** Repeat steps Step 5 through Step 7 for each subinterface to be created and bridged.
Step 8	**end** **Example:** `Router(config-if)# end`	Exits interface configuration mode and returns to privileged EXEC mode.

Configuration Examples for Transparent LAN Service over Cable

This section lists sample configurations for the Transparent LAN Service over Cable feature on a CMTS router and on a Cisco router acting as a bridge aggregator:

Example: Configuring IEEE 802.1Q VLAN Mapping

The following partial configuration shows a typical configuration that shows a number of cable modems being mapped to two different IEEE 802.1Q VLANs.

```
cable l2-vpn-service xconnect nsi dot1q
! Customer 1
cable dot1q-vc-map 000C.0e03.69f9 TenGigabitEthernet 4/1/0 10 Customer1
cable dot1q-vc-map 0010.7bea.9c95 TenGigabitEthernet 4/1/0 11 Customer1
cable dot1q-vc-map 0010.7bed.81c2 TenGigabitEthernet 4/1/0 12 Customer1
cable dot1q-vc-map 0010.7bed.9b1a TenGigabitEthernet 4/1/0 13 Customer1
! Customer 2
cable dot1q-vc-map 0002.fdfa.137d TenGigabitEthernet 4/1/0 20 Customer2
cable dot1q-vc-map 0006.28f9.9d19 TenGigabitEthernet 4/1/0 21 Customer2
cable dot1q-vc-map 000C.7b6b.58c1 TenGigabitEthernet 4/1/0 22 Customer2
cable dot1q-vc-map 000C.7bed.9dbb TenGigabitEthernet 4/1/0 23 Customer2
cable dot1q-vc-map 000C.7b43.aa7f TenGigabitEthernet 4/1/0 24 Customer2
cable dot1q-vc-map 0050.7302.3d83 TenGigabitEthernet 4/1/0 25 Customer2
...
```

Example: Configuring IEEE 802.1Q Bridge Aggregator

The following example shows a router being used as a bridge aggregator to transmit VLANs across the same Ten Gigabit Ethernet interface, using IEEE 802.1Q tagging.

```
!
interface TenGigabitEthernet4/1/0
 ip address 10.10.10.31 255.255.255.0
 duplex full
 speed auto
!
interface TenGigabitEthernet4/1/0.10
 description Customer1-site10
 encapsulation dot1Q 10
 bridge-group 200
interface TenGigabitEthernet4/1/0.11
 description Customer1-site11
 encapsulation dot1Q 11
 bridge-group 200
interface TenGigabitEthernet4/1/0.12
 description Customer1-site12
 encapsulation dot1Q 12
 bridge-group 200
interface TenGigabitEthernet4/1/0.13
 description Customer1-site13
 encapsulation dot1Q 13
 bridge-group 200
!-----------------------------------
interface TenGigabitEthernet4/1/0.20
 description Customer2-site20
 encapsulation dot1Q 20
 bridge-group 201
interface TenGigabitEthernet4/1/0.21
 description Customer2-site21
 encapsulation dot1Q 21
 bridge-group 201
interface TenGigabitEthernet4/1/0.22
 description Customer2-site22
 encapsulation dot1Q 22
 bridge-group 201
interface TenGigabitEthernet4/1/0.23
 description Customer2-site23
 encapsulation dot1Q 23
 bridge-group 201
interface TenGigabitEthernet4/1/0.24
 description Customer2-site24
 encapsulation dot1Q 24
 bridge-group 201
interface TenGigabitEthernet4/1/0.25
 description Customer2-site25
 encapsulation dot1Q 25
 bridge-group 201
!
bridge 200 protocol ieee
bridge 201 protocol ieee
...
```

Verifying the Transparent LAN Service over Cable Configuration

- **show cable l2-vpn xconnect dot1q-vc-map** —Displays the mapping information of the cable modems to IEEE 802.1Q VLANs.

  Following is a sample output of the command:

```
Router# show cable l2-vpn xconnect dot1q-vc-map

MAC Address    Ethernet Interface      VLAN ID   Cable Intf  SID  Customer Name/VPNID
38c8.5cac.4a62 TenGigabitEthernet4/1/2     56    Cable3/0/0  4    Customer2
38c8.5cfe.f6fa TenGigabitEthernet4/1/2     34    Cable3/0/0  3    Customer1
602a.d083.2e1c TenGigabitEthernet4/1/4     43    Cable3/0/0  5    Customer3
```

- **show cable l2-vpn xconnect dot1q-vc-map customer** *name*—Displays the mapping information of the cable modems to IEEE 802.1Q VLANs for the specified customer name.

  Following is a sample output of the command.

```
Router# show cable l2-vpn xconnect dot1q-vc-map customer Customer1

MAC Address    Ethernet Interface      VLAN ID   Cable Intf  SID  Customer Name/VPNID
38c8.5cfe.f6fa TenGigabitEthernet4/1/2     34    Cable3/0/0  3    Customer1
```

- **show cable l2-vpn xconnect dot1q-vc-map** *mac-address*—Displays the mapping information of the cable modems to IEEE 802.1Q VLANs for the specified MAC address.

  Following is a sample output of the command:

```
Router# show cable l2-vpn xconnect dot1q-vc-map 38c8.5cac.4a62

MAC Address    Ethernet Interface      VLAN ID   Cable Intf  SID  Customer Name/VPNID
38c8.5cac.4a62 TenGigabitEthernet4/1/2     56    Cable3/0/0  4    Customer2
```

- **show cable l2-vpn xconnect dot1q-vc-map** *mac-address* **verbose**—Displays additional information about the Layer 2 mapping, including the number of packets and bytes received on the upstream and downstream.

  Following is a sample output of the command:

```
Router# show cable l2-vpn xconnect dot1q-vc-map 38c8.5cac.4a62 verbose

MAC Address                    : 38c8.5cac.4a62
Customer Name                  : Customer2
Prim Sid                       : 4
Cable Interface                : Cable3/0/0
Ethernet Interface             : TenGigabitEthernet4/1/2
DOT1Q VLAN ID                  : 56
Total US pkts                  : 1
Total US bytes                 : 342
Total DS pkts                  : 4
Total DS bytes                 : 512
```

Additional References

Standards

Standards	Title
SP-RFIv1.1-I08-020301	Data-over-Cable Service Interface Specifications Radio Frequency Interface Specification

Standards	Title
IEEE 802.1Q, 1998 Edition	IEEE Standards for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks

RFCs

RFCs[2]	Title
RFC 1163	A Border Gateway Protocol
RFC 1164	Application of the Border Gateway Protocol in the Internet
RFC 2233	DOCSIS OSSI Objects Support
RFC 2283	Multiprotocol Extensions for BGP-4
RFC 2665	DOCSIS Ethernet MIB Objects Support
RFC 2669	Cable Device MIB

[2] Not all supported RFCs are listed.

Technical Assistance

Description	Link
Technical Assistance Center (TAC) home page, containing 30,000 pages of searchable technical content, including links to products, technologies, solutions, technical tips, and tools. Registered Cisco.com users can log in from this page to access even more content.	http://www.cisco.com/cisco/web/support/index.html

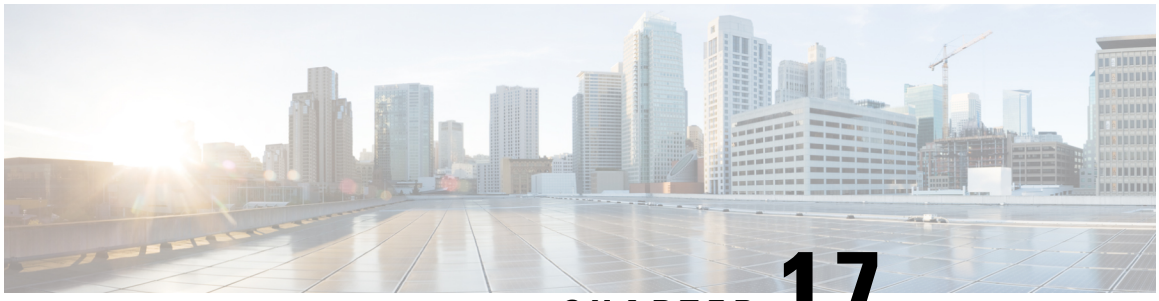
Feature Information for Transparent LAN Service over Cable

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 61: Feature Information for Upstream Channel Bonding

Feature Name	Releases	Feature Information
Transparent LAN Service over Cable	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Router.



CHAPTER 17

Downgrading Channel Bonding in Battery Backup Mode

Cisco CMTS supports downgrading the channel bonding for cable modems and media terminal adapters (MTAs) in battery backup mode.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

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- How to Configure Downgrading Channel Bonding in Battery Backup Mode, on page 330
- Verifying the Configuration for Channel Bonding Downgrade in Battery Backup Mode, on page 332
- Additional References, on page 335
- Feature Information for Downgrading Channel Bonding in Battery Backup Mode, on page 336

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 62: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for Downgrading Channel Bonding in Battery Backup Mode

- The cable modem must be DOCSIS3.0-compliant with battery backup capability.
- At last one free Downstream Resilient Bonding Group (RBG) must be available.

Note For information about how to reserve RBG and verify reserved RBG, refer to Downstream Resiliency Bonding Group , on page 161

Restrictions for Downgrading Channel Bonding in Battery Backup Mode

- If the cable modem does not support the CM-STATUS events 9 and 10, channel bonding is not downgraded for the cable modem in battery backup mode.

Note We recommend that you configure separate dynamic bonding groups for each primary channel in a MAC domain.

- If the cable modem has an active voice call, channel bonding is not downgraded for the cable modem in battery backup mode.
- If the cable modem is working on the protect line card, channel bonding is not downgraded if its primary channel is not included in the dynamic bonding group.
- If the line card switches over when the cable modem is entering or exiting the battery backup mode, the cable modem may go offline.

Information About Downgrading Channel Bonding in Battery Backup Mode

When this feature is enabled and the cable modem enters the battery backup mode, channel bonding is downgraded to one downstream and one upstream channels (battery backup 1x1 mode). This feature reduces the power usage when the cable modem is running on battery backup. When the cable modem returns to the AC power mode, the channel bonding is returned to its original configuration. You can configure this feature globally and for each MAC domain.

Note We recommend that you enable this feature globally and for each MAC domain.

The cable modem uses the following CM-STATUS events to indicate its power status to the Cisco CMTS:

- 9—Indicates that the cable modem is operating in battery backup mode.
- 10—Indicates that the cable modem has returned to AC power mode.

When this feature is disabled, cable modem cannot downgrade the channel bonding even if it is running on battery backup.

How to Configure Downgrading Channel Bonding in Battery Backup Mode

This section contains the following:

Configuring Channel Bonding Downgrade in Battery Backup Mode Globally

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**cable reduction-mode mta-battery enable** **Example:** `Router(config)# cable reduction-mode mta-battery enable`	Enables the channel bonding downgrade for cable modems in battery backup mode.
Step 4	**cable reduction-mode mta-battery dampen-time** *seconds* **Example:** `Router(config)# cable reduction-mode mta-battery dampen-time 40`	(Optional) Configures the dampen time, in seconds, to defer the cable modems from entering or exiting the channel bonding downgrade 1x1 mode.
Step 5	**cable reduction-mode mta-battery ranging-init-technique** *us-ranging-init-technique* **Example:** `Router(config)# cable reduction-mode mta-battery ranging-init-technique 3`	(Optional) Configures the init-ranging technique.
Step 6	**cable reduction-mode mta-battery dynamic-channel-percent** *percent* **Example:** `Router(config)# cable reduction-mode mta-battery dynamic-channel-percent 10`	(Optional) Configures the maximum and first try percentage of dynamic channel bandwidth in battery backup mode. **Note** Ensure to leave enough bandwidth for primary channel so that it can allocate dynamic channel bandwidth when it joins a newly created dynamic bonding group.
Step 7	**exit** **Example:** `Router(config)# exit`	Returns to the privileged EXEC mode.

Configuring Channel Bonding Downgrade in Battery Backup Mode for MAC Domain

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface wideband-cable** *slot/subslot/port:wideband-channel* **Example:** `Router(config)# interface wideband-cable 1/0/0:7`	Configures a wideband cable interface.
Step 4	**cable ds-resiliency** **Example:** `Router(config-if)# cable ds-resiliency`	Reserves a resiliency bonding group or WB interface for usage on a line card, on a per controller basis.
Step 5	**exit** **Example:** `Router(config-if)# exit`	Returns to the global configuration mode.
Step 6	**interface cable** *slot/subslot/port* **Example:** `Router(config)# interface cable 9/0/0`	Specifies the cable interface on the router and enters the interface configuration mode.
Step 7	**cable reduction-mode mta-battery enable** **Example:** `Router(config-if)# cable reduction-mode mta-battery enable`	Enables the channel bonding downgrade for cable modems in battery backup mode for each MAC domain.
Step 8	**cable cm-status enable 9** **Example:** `Router(config-if)# cable cm-status enable 9`	Enables the CM-STATUS event 9 for the MAC domain. The value 9 indicates that the cable modem is operating in battery backup mode.
Step 9	**cable cm-status enable 10** **Example:** `Router(config-if)# cable cm-status enable 10`	Enables the CM-STATUS event 10 for the MAC domain. The value 10 indicates that the cable modem has returned to AC power mode.

	Command or Action	Purpose
Step 10	**end** **Example:** `Router(config-if)# end`	Returns to the privileged EXEC mode.

Verifying the Configuration for Channel Bonding Downgrade in Battery Backup Mode

- **show cable modem**—Displays information if the cable modem is running in battery backup mode.

  Following is a sample output of the command:

```
Router# show cable modem

 D
MAC Address    IP Address      I/F           MAC               Prim  RxPwr  Timing Num
 I                                           State             Sid   (dBmv) Offset CPE
 P
f45f.d4a1.b75a ---             C6/1/0/UB     p-online(pt)      846  !-3.50  1475   0
 N
c427.9551.3489 30.154.1.12     C6/1/0/UB     w-online(pt)      930   -0.50  1579   2
 Y
f45f.d4a1.b762 30.55.223.253   C6/1/0/UB     w-online          1770  0.00   1503   0
 Y
0016.925e.661a 30.55.230.136   C6/1/0/U0     online(pt)        825   -0.50  1467   1
 N
4458.2945.458a 30.0.7.72       C6/1/0/UB     w-online          3916  0.00   1511   2
 Y
4458.2945.401e ---             C6/1/0/UB     w-online(pt)      847   -0.50  1473   1
 N
4458.2945.20c6 ---             C6/1/0/UB     w-online(pt)(bm)  895   0.00   1481   0
 N
```

- **show cable modem reduction-mode mta-battery**—Displays the channel bonding downgrade information for cable modems in battery backup mode.

  Following is a sample output of the command:

```
Router# show cable modem reduction-mode mta-battery

                              Orig BG                        Curr BG
I/F     MAC Address    ID      I/F       RFs     ID          I/F        Upstream
------- -------------- ------------------------------------------------------------
C7/0/0  0025.2eaf.843e 897  Wi7/0/0:0     4      252         Wi7/0/0:1      US0
C7/0/0  0025.2eaf.8356 897  Wi7/0/0:0     4      252         Wi7/0/0:1      US0
C7/0/0  0015.d176.5199 897  Wi7/0/0:0     4      252         Wi7/0/0:1      US0
```

  Following is a sample output of the command for a cable modem when the MAC address is specified:

```
Router# show cable modem 0025.2eaf.843e reduction-mode mta-battery

                              Orig BG                        Curr BG
I/F     MAC Address    ID      I/F       RFs     ID          I/F        Upstream
------- -------------- ------------------------------------------------------------
```

```
C7/0/0  0025.2eaf.843e 897  Wi7/0/0:0     4      252        Wi7/0/0:1      US0
```

Following is a sample output of the command for a cable modem when the IP address is specified:

```
Router# show cable modem 90.18.0.9 reduction-mode mta-battery

                              Orig BG                      Curr BG
I/F     MAC Address    ID      I/F       RFs     ID          I/F        Upstream
------- -------------- ------------------------------------------------------------
C7/0/0  0025.2eaf.843e 897  Wi7/0/0:0     4      252        Wi7/0/0:1      US0
```

Following is a sample output of the command for a cable modem when the IPv6 address is specified:

```
Router# show cable modem 2001:18::9 reduction-mode mta-battery

                              Orig BG                      Curr BG
I/F     MAC Address    ID      I/F       RFs     ID          I/F        Upstream
------- -------------- ------------------------------------------------------------
C7/0/0  0025.2eaf.843e 897  Wi7/0/0:0     4      252        Wi7/0/0:1      US0
```

- **show cable modem verbose**—Displays the detailed information for the cable modem.

  Following is a sample output of the command:

```
Router# show cable modem 54d4.6ffb.30fd verbose

MAC Address                      : 54d4.6ffb.30fd
IP Address                       : 40.4.58.14
IPv6 Address                     : 2001:40:4:58:741A:408D:7E4B:D7C8
Dual IP                          : Y
Prim Sid                         : 9
Host Interface                   : C7/0/0/UB
MD-DS-SG / MD-US-SG              : 1 / 1
MD-CM-SG                         : 0x3C0101
Primary Wideband Channel ID      : 897 (Wi7/0/0:0)
Primary Downstream               : In7/0/0:2 (RfId : 722)
Wideband Capable                 : Y
RCP Index                        : 3
RCP ID                           : 00 10 00 00 08
Downstream Channel DCID RF Channel : 99    7/0/0:2
Downstream Channel DCID RF Channel : 97    7/0/0:0
Downstream Channel DCID RF Channel : 98    7/0/0:1
Downstream Channel DCID RF Channel : 100   7/0/0:3
Multi-Transmit Channel Mode      : Y
Extended Upstream Transmit Power : 0dB
Upstream Channel                 : US0        US1
Ranging Status                   : sta        sta
Upstream SNR (dB)                : 36.12      32.55
Upstream Data SNR (dB)           : --         --
Received Power (dBmV)            : 0.00       0.00
Reported Transmit Power (dBmV)   : 25.25      26.00
Peak Transmit Power (dBmV)       : 54.00      54.00
Phy Max Power (dBmV)             : 54.00      54.00
Minimum Transmit Power (dBmV)    : 24.00      24.00
Timing Offset            (97.6 ns): 1226       1226
Initial Timing Offset            : 1229       973
Rng Timing Adj Moving Avg(0.381 ns): -1         0
Rng Timing Adj Lt Moving Avg     : -7         0
Rng Timing Adj Minimum           : -768       0
Rng Timing Adj Maximum           : 0          64768
Pre-EQ Good                      : 0          0
Pre-EQ Scaled                    : 0          0
Pre-EQ Impulse                   : 0          0
```

```
Pre-EQ Direct Loads                : 0          0
Good Codewords rx                  : 515        472
Corrected Codewords rx             : 0          0
Uncorrectable Codewords rx         : 0          0
Phy Operating Mode                 : atdma*     atdma*
sysDescr                           :
Downstream Power                   : 0.00 dBmV (SNR = ----- dB)
MAC Version                        : DOC3.0
QoS Provisioned Mode               : DOC1.1
Enable DOCSIS2.0 Mode              : Y
Modem Status                       : {Modem= w-online, Security=disabled}
Capabilities                       : {Frag=N, Concat=N, PHS=Y}
Security Capabilities              : {Priv=, EAE=Y, Key_len=}
L2VPN Capabilities                 : {L2VPN=N, eSAFE=N}
Sid/Said Limit                     : {Max US Sids=16, Max DS Saids=15}
Optional Filtering Support         : {802.1P=N, 802.1Q=N, DUT=N}
Transmit Equalizer Support         : {Taps/Symbol= 1, Num of Taps= 24}
Number of CPE IPs                  : 0(Max CPE IPs = 16)
CFG Max-CPE                        : 200
Flaps                              : 0()
Errors                             : 0 CRCs, 0 HCSes
Stn Mtn Failures                   : 0 aborts, 0 exhausted
Total US Flows                     : 1(1 active)
Total DS Flows                     : 1(1 active)
Total US Data                      : 7 packets, 2006 bytes
Total US Throughput                : 0 bits/sec, 0 packets/sec
Total DS Data                      : 5 packets, 1202 bytes
Total DS Throughput                : 0 bits/sec, 0 packets/sec
LB group ID assigned (index)       : 2151416065 (48131)
LB group ID in config file (index) : N/A (N/A)
LB policy ID                       : 0
LB policy ID in config file        : 0
LB priority                        : 0
Tag                                :
Required DS Attribute Mask         : 0x0
Forbidden DS Attribute Mask        : 0x0
Required US Attribute Mask         : 0x0
Forbidden US Attribute Mask        : 0x0
Service Type ID                    :
Service Type ID in config file     :
Active Classifiers                 : 2 (Max = NO LIMIT)
CM Upstream Filter Group           : 0
CM Downstream Filter Group         : 0
CPE Upstream Filter Group          : 0
CPE Downstream Filter Group        : 0
DSA/DSX messages                   : permit all
Voice Enabled                      : NO
CM Energy Management Capable       : Y
CM Enable Energy Management        : Y
CM Enter Energy Management         : No
Battery Mode                       : Yes
Battery Mode Status                : BATTERY_MODE / AC_POWER_MODE
DS Change Times                    : 0
Boolean Services                   : 2
Number of Multicast DSIDs Support  : 16
MDF Capability Mode                : 2
IGMP/MLD Version                   : MLDv2
FCType10 Forwarding Support        : Y
Features Bitmask                   : 0x0
Total Time Online                  : 2h12m   (2h12m    since last counter reset)
CM Initialization Reason           : NO_PRIM_SF_USCHAN
CFG Max IPv6 CPE Prefix            : 16 (-1 used)
```

Note *Battery Mode* indicates if the cable modem is in battery backup mode or AC power mode.

Battery Mode Status indicates the status of the cable modem:

- When the cable modem is in AC_POWER_MODE/BATTERY_MODE status, it is in stable state.
- When the cable modem is in AC_POWER_PENDING/BATTERY_PENDING status, it is in transfer state.
- When the cable modem is in AC_POWER_HOLD/BATTERY_HOLD status, it is updating status of the last event received until the dampen time expires.

- **show cable modem cm-status**—Displays the cable modem CM-STATUS event information.

  Following is a sample output of the command:

```
Router# show cable modem e448.c70c.9d80 cm-status

I/F       MAC Address    Event              TID   Count Error Dups  Time
C6/0/3/UB e448.c70c.9d80 Battery backup     14     1     0     0     Apr 2 22:17:29
          e448.c70c.9d80 A/C power          1      1     0     0     Apr 2 22:43:52
```

Additional References

Related Documents

Related Topic	Document Title
CMTS commands	Cisco CMTS Cable Command Reference

Standards and RFCs

Standard/RFC	Title
CM-SP- MULPIv3.1-I01-131029	Data-Over-Cable Service Interface Specifications, DOCSIS 3.1, MAC and Upper Layer Protocols Interface Specification

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

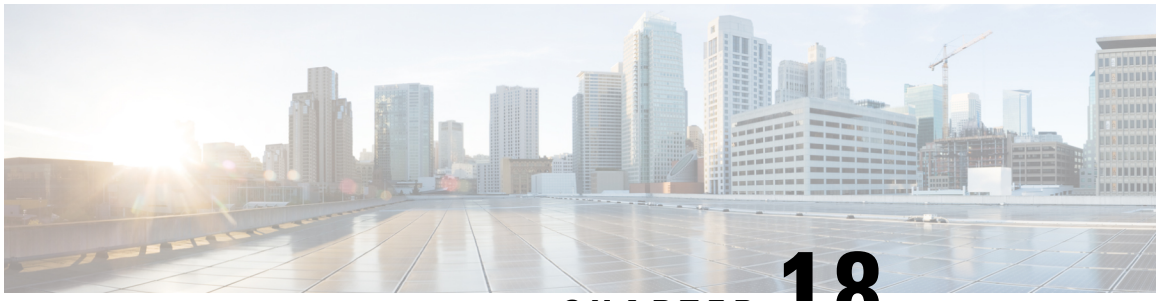
Feature Information for Downgrading Channel Bonding in Battery Backup Mode

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 63: Feature Information for Downgrading Channel Bonding in Battery Backup Mode

Feature Name	Releases	Feature Information
Battery Backup 1x1 Mode	Cisco IOS XE Everest 16.6.1	This feature was introduced in the Cisco IOS XE Everest 16.6.1 on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 18

Upstream Bonding Support for D-PON

The DOCSIS Passive Optical Network (D-PON) architecture, also known as RF over Glass (RFoG), helps the cable operators enter fiber-to-home market space and utilize the DOCSIS infrastructure effectively.

- Hardware Compatibility Matrix for the Cisco cBR Series Routers, on page 337
- Prerequisites for Upstream Bonding Support for D-PON, on page 338
- Restrictions for Upstream Bonding Support for D-PON, on page 339
- Information About Upstream Bonding Support for D-PON, on page 339
- How to Configure Upstream Bonding Support for D-PON , on page 341
- Verifying the Upstream Bonding Support for D-PON, on page 342
- Additional References, on page 342
- Feature Information for Upstream Bonding Support for D-PON, on page 343

Hardware Compatibility Matrix for the Cisco cBR Series Routers

Note The hardware components that are introduced in a given Cisco IOS-XE Release are supported in all subsequent releases unless otherwise specified.

Table 64: Hardware Compatibility Matrix for the Cisco cBR Series Routers

Cisco CMTS Platform	Processor Engine	Interface Cards
Cisco cBR-8 Converged Broadband Router	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 Supervisor: • PID—CBR-SUP-250G • PID—CBR-CCAP-SUP-160G	**Cisco IOS-XE Release 16.5.1 and Later Releases** Cisco cBR-8 CCAP Line Cards: • PID—CBR-LC-8D30-16U30 • PID—CBR-LC-8D31-16U30 • PID—CBR-RF-PIC • PID—CBR-RF-PROT-PIC • PID—CBR-CCAP-LC-40G • PID—CBR-CCAP-LC-40G-R • PID—CBR-CCAP-LC-G2-R • PID—CBR-SUP-8X10G-PIC • PID—CBR-2X100G-PIC Digital PICs: • PID—CBR-DPIC-8X10G • PID—CBR-DPIC-2X100G Cisco cBR-8 Downstream PHY Module: • PID—CBR-D31-DS-MOD Cisco cBR-8 Upstream PHY Modules: • PID—CBR-D31-US-MOD

Prerequisites for Upstream Bonding Support for D-PON

- DOCSIS 3.0 cable modems (CMs)
- DOCSIS 2.0 capable set-top boxes (STBs)
- You should configure the **cable upstream ranging-init-technique 2** command to prevent the use of additional broadcast initial ranging opportunities for the non D-PON reference upstream channels.

Restrictions for Upstream Bonding Support for D-PON

- Multiple CMs cannot work at the same time. Each CM must get a separate time slot for upstream data transmission. Configuring D-PON ensures that the upstream scheduler allows only a single CM to transmit at a particular time.
- Cisco cBR-8 does not support Upstream Bonding for D-PON on Remote-PHY.
- It is possible to enable or disable D-PON for individual Mac domain.
- When you enable D-PON on a MAC domain, you must manually shut down and enable the MAC domain using **shutdown** and **no shutdown** command.
- When enabling D-PON on a MAC domain, the D-PON is not supported with upstream balance-scheduling. Remove the upstream balance scheduling using the following command:

  ```
  no cable upstream balance-scheduling
  ```

- All frequencies in a MAC domain must have the same configuration for:
  - minislot size
  - channel-width
  - modulation profile
- Supports only ATDMA DOCSIS mode.
- The following features are not supported in MAC domains configured for D-PON:
  - Load balancing
  - Spectrum management
  - Upstream configuration (to change upstream configuration, you should shut down the MAC domain)
  - S-CDMA logical channels
  - Lower modulations profiles (D-PON uses only 16 QAM and 64 QAM modulation profiles)
  - Channel-width other than 3.2 MHz and 6.4 MHz
  - In-service Software Upgrade (ISSU)
  - Mixing of D-PON and HFC on the same MAC domain
  - Software licensing

Information About Upstream Bonding Support for D-PON

D-PON is a type of networking that allows the CMTS to transmit RF signals over the optical network. This technology enables the cable operators to use the RF technologies in a Hybrid Fiber-Coaxial (HFC) network.

The downstream data from the CMTS is combined with other RF signals at the hub and is sent to the transmitter. The signal from the transmitter is intended for multiple PONs. Each PON serves 32 homes from a single fiber.

The upstream data from the Optical Network Terminal (ONT) is combined at the splitter and sent to the hub, which is then routed to the optical receiver (RX). Upstream data from multiple optical receivers are combined and sent to the CMTS.

The upstream data to the CMTS contains signals from multiple PONs. Each upstream optical receiver is dedicated to a PON that can have multiple DOCSIS upstream sources (multiple modems and DSG terminals).

A PON can be configured in different ways, depending on the coaxial network. These configurations broadly fall under the following categories:

- Internal Control Configuration—In this configuration, the internal CM of the ONT controls the laser. Upstream signals go to the Ethernet interface of the CM allowing the ONT to control upstream timing. The device that uses this type of configuration is the Digital Audio Visual Council (DAVIC) set top terminal (STT).
- External Control Configuration—In this configuration, the presence of the RF at the ONT upstream input activates the laser. The device that uses this type of configuration is the DOCSIS Set-top Gateway (DSG) device.
- Dual Control Configuration—In this configuration, the home that contains an ONT with and internal CM and other DOCSIS upstream sources, like DSG devices. The RF presence detector or the internal CM control line detects the upstream signal and activates the upstream laser.

D-PON on Upstream Scheduling

In D-PON implementation, the native upstream scheduling software of the CMTS controls the timing of the upstream data transmission. Only one PON Receiver Domain (PRD) is allowed to transmit upstream data at any given point of time, irrespective of the upstream frequency allocation. The reason for this is that two lasers from the ONT of a PRD cannot work simultaneously as it leads to an Optical Beat Interference (OBI). Moreover, the use of a frequency modulation (FM) for and upstream signal transmission results in PHY errors when multiple ONTs within a PON transmits simultaneously.

Initial maintenance regions are scheduled on all upstream channels to prevent the DOCSIS 3.0 CMs in a D-PON environment from failing initial ranging on any upstream channel. When a ranging request is received within a MAC domain configured for D-PON, the CM receives an upstream channel override to the D-PON reference channel (US0).

In this implementation of D-PON, a DOCSIS device within a PRD is given a timeslot to transmit the upstream data, irrespective of the upstream frequency. Therefore, there is no benefit in having more than one upstream in a MAC domain without using the upstream channel bonding feature.

The D-PON feature supports the following service types:

- Best effort (BE) 3.0 using up to four frequencies concurrently
- BE 2.0 using only a single frequency
- Unsolicited grant service (UGS) using only a single frequency
- Real-time polling service (RTPS) using only a single frequency
- Non-real-time polling service (nRTPS) using only a single frequency

How to Configure Upstream Bonding Support for D-PON

This section describes how to enable D-PON for a MAC domain on the Cisco cBR router. The bonding group must include a reference channel which is default to the upstream channel 0.

Note The USCB can support a maximum of 4 US channels in a RFOG MAC domain in the following combination:

- US0
- US0, US1
- US0, US1, US2
- US0, US1, US2, US3

All US channels must be configured to have the same number of minislots, channel width (only 3.2 and 6.4 MHz supported), DOCSIS mode (only ATDMA supported) and modulation profile.

When enabling DPON on a MAC Domain, remove the command "cable upstream balance-scheduling? as DPON is not supported with upstream balance-scheduling.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**interface cable** *slot/subslot/cable-interface-index* **Example:** `Router(config)# interface cable 8/0/0`	Enters interface configuration mode for the specified cable interface.
Step 4	**cable upstream dpon** **Example:** `Router(config-if)# cable upstream dpon`	Enables D-PON for a MAC domain.
Step 5	**shutdown** **Example:** `Router(config-if)# shutdown`	Shuts down the interface.
Step 6	**no shutdown** **Example:**	Enables the interface.

	Command or Action	Purpose
	`Router(config-if)# no shutdown`	
Step 7	**end** **Example:** `Router(config-if)# end`	Exits interface configuration mode and returns to the privileged EXEC mode.

Verifying the Upstream Bonding Support for D-PON

To verify the upstream scheduler output for a MAC domain configured with D-PON, use the **show interface cable mac-scheduler** command.

Note The D-PON reference channel US0 (US channel-id 1) MAP serves as a template for producing other MAPs within the MAC domain. Therefore, some of the statistics related to upstream scheduling is not relevant for other channels, except for the D-PON reference channel.

```
Router# show interface cable 8/0/0 mac-scheduler 1
     DOCSIS 1.1 MAC scheduler for Cable8/0/0/U1 : rate 30720000
     wfq:None
     us_balance:OFF
     dpon_mode:ON
     fairness:OFF
     Queue[Rng Polls] flows 0
     Queue[CIR Grants] flows 0
     Queue[BE(07) Grants] flows 0
     Queue[BE(06) Grants] flows 0
     Queue[BE(05) Grants] flows 0
     Queue[BE(04) Grants] flows 0
     Queue[BE(03) Grants] flows 0
     Queue[BE(02) Grants] flows 0
     Queue[BE(01) Grants] flows 0
     Queue[BE(00) Grants] flows 0
     Req Slots 1824595508, Req/Data Slots 10640906
     Init Mtn Slots 89924653, Stn Mtn Slots 989543
     Short Grant Slots 0, Long Grant Slots 0
     Adv Phy Short Grant Slots 538, Adv Phy Long Grant Slots 219831
     Adv Phy UGS Grant Slots 0
     Avg upstream channel utilization : 0%
     Avg percent contention slots : 98%
     Avg percent initial ranging slots : 1%
     Avg percent minislots lost on late MAPs : 0%
     MAP TSS: lch_state 9, init_retries 0
     late_initial_maps 0, late_ucd_maps 0
     mac-phy tss errors 0, missed ccc 0
```

Additional References

The following sections provide references related to the Upstream Bonding Support for D-PON feature.

Related Documents

Related Topic	Document Title
Prisma D-PON	Cisco Prisma D-PON

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/support

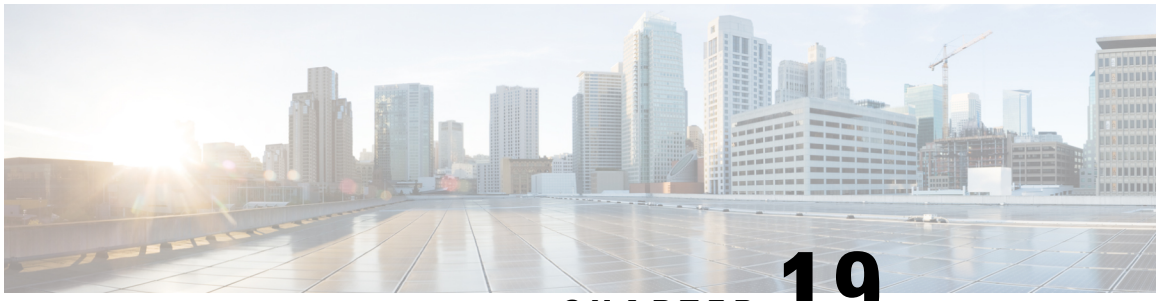
Feature Information for Upstream Bonding Support for D-PON

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 65: Feature Information for Upstream Bonding Support for D-PON

Feature Name	Releases	Feature Information
Upstream Bonding Support for D-PON	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 19

Energy Management Mode

Data-over-Cable Service Interface Specifications (DOCSIS) cable modems (CM) and CMTS support a low power energy mode referred to as the Energy Management 1x1 (EM) mode. During idle times, when the data rate demand of a user is met by the available capacity on a single upstream and downstream channel pair to which it is assigned, the CM switches to the Energy Management 1x1 mode. When the CM requires a higher data rate than that can be reliably provided on the single channel pair, the CMTS instructs the CM to return to the larger transmit and receive channel set.

Contents

- Information About Energy Management Mode, on page 345
- Prerequisites for Energy Management Mode, on page 347
- Restrictions for the Energy Management Mode, on page 348
- How to Configure the Energy Management Mode, on page 350
- Verifying the Energy Management Mode, on page 352
- Feature Information for Energy Management Mode, on page 354

Information About Energy Management Mode

The following sections provide more information about the Energy Management mode.

Note DOCSIS 3.1 CM's do not support the Energy Management mode in cBR-8 routers.

Dynamic Downstream Bonding Group

To support the Energy Management 1x1 (EM) mode feature, CMTS selects an upstream and a downstream channel pair for CM. The downstream and upstream channel assigned to the CMs should be available. If CMTS selects a channel that is not available, the downstream bonding channel might fail.

To simplify the process, CMTS chooses the 1x1 bonding group for the CM according to the following rules:

- For upstream, it chooses the highest actual amiable bandwidth channel from the upstream channels currently used by the CM.
- For downstream, CMTS chooses the current primary downstream channel used by the CM.

- If the CM is online with channel bonding 1xN or Nx1, and requests to enter into the EM mode, CMTS does not change the upstream and the downstream channel if the original channel bonding is 1 and the Quality of Service (QoS) parameter is not updated.
- CMTS checks the existing dynamic bonding groups (DBG), for an exact match in the target channel.
  - If found, CMTS uses this bonding group to instruct the CM to enter into EM mode.
  - If there is no available DBG and there is an unused DBG, CMTS adds the primary channel into the unused DBG and instructs the CM to enter the EM mode.
  - If there is no available DBG and no unused DBG, CMTS logs a warning to notify you that a new DGB should be configured.

Flow Chart of the CM Power State

The following figure shows the flow chart of the CM power state:

Figure 4: Flow Chart for the Power State of the Cable Modem

Interaction with the Battery Mode

Energy management mode is similar to battery mode as they both enter the 1x1 mode to save power. But, both have a different purpose to enter the 1x1 mode, so there are some differences in their behavior. The purpose of EM mode is to save power when the traffic is low, and it has minimum impact on the normal service. The purpose of the battery mode is try to guarantee the voice service, especially the 911 call service, for which it may drop other services, if necessary.

The table below describes the behavior difference between energy management mode and battery mode.

	Energy Management (EM) Mode	Battery Mode (BM)
QoS	Minimum reserved rate service up to 200k.	No minimum reserved rate.
Multicast	• IGMP request is guaranteed. • If the CM has joined the Internet Group Management Protocol (IGMP) groups, CMTS rejects the EM request to enter the EM mode and keeps the CM in the IGMP groups. • If the CM is in the EM mode and IGMP join request is received, CMTS instructs the CM to leave the EM mode.	• If the CM has joined IGMP groups and CMTS receives a CM-STATUS event with code 9, CMTS lets the CM leave the IGMP group. • If the CM is in the BM, CMTS rejects the IGMP join request from the CM.

BM has higher priority than the EM mode. If a CM is already in EM mode and a power off occurs, CM enters into the BM. After the power is restored, the CM returns to the normal mode, and if the traffic is lower than the threshold, it re-enters the EM mode. The CM does not directly transfer from the BM to the EM mode.

The interaction between the battery mode and the energy management mode is illustrated in the figure below:

Figure 5: Interaction Between the BM and the EM Modes

1. When the CM is in normal mode and CMTS receives a request to enter the EM mode, CMTS instructs the CM to enter the EM mode with downstream bonding channel (DBC).
2. When the CM is in EM mode and CMTS receives a request to leave the EM mode, CMTS instructs the CM to leave the EM mode to normal mode with DBC.
3. When the CM is in normal mode and CMTS receives a message: CM operating on battery backup, CMTS instructs the CM to enter the BM mode with DBC.
4. When the CM is in BM mode and CMTS receives a message: CM operating on AC power, CMTS instructs the CM to leave the BM mode to normal mode with DBC.
5. When the CM is in EM mode and CMTS receives a message: CM operating on battery backup, CMTS instructs the CM to enter the BM mode with service flow re-admin.
6. When the CM is in BM mode and CMTS receives a request to enter EM mode, CMTS waits until it receives the message: CM operating on AC power. It then instructs the CM to return to normal mode.

Handling Energy Management Request Load

When many CMs send EM requests at the same time, such as at the beginning or end of work hours, the traffic soars or slumps in a very short period and causes heavy load for CMTS. A throttle mechanism is adopted to avoid such load surge for CMTS.

The line card EM process defines a variable that indicates the current transactions handled by the process. When an energy management request is received and the maximum number of transactions is not met, CMTS handles this request and updates the counter of current transactions. When the maximum number of transactions is met, CMTS sends a temporary reject response. After a transaction is over or a CM goes offline, the counter of current transactions is updated.

Supervisor High Availability and Line Card Switchover

Energy Management feature supports supervisor high availability and line card switchover with limitations.

The active supervisor or line card syncs the EM mode data of a CM to the standby SUP or protected line card when the CM enters a stable EM status. When a CM enters or leaves the EM mode with an ongoing DBC process, the supervisor high availability or line card switchover causes the CM to enter into an offline or online status.

Prerequisites for Energy Management Mode

To enable the energy management mode, you must configure resiliency bonding group (RBG) and dynamic bonding group.

Restrictions for the Energy Management Mode

Restrictions for CMTS High Availability

- If there is no DBG available, CMTS cannot create a new DBG on the protected line card and CMs cannot enter the EM mode.
- Line card switchover is not supported when the CM enters the EM mode from the normal mode or exits the EM mode to the normal mode.
- To reduce the operation of the EM mode, the information about the EM status is not synced with the protected line card. Hence, the EM status is cleared after the line card high availability.

Restrictions for Dynamic Bonding Group

To support the EM feature, CMTS configures separate DBG for each primary channel in each MAC domain. For example, if a MAC domain has eight primary channels, it will create eight DBGs for the MAC domain. This ensures that the EM does not fail due to lack of DBGs.

Restrictions for Interaction of CMTS with Other Features

The following sections describe the restrictions for CMTS interaction with other features.

Voice

If a voice call is in progress, CMTS does not instruct the CM to enter into the EM mode.

When the CM is in the EM mode, and it receives a voice call, it adds a dynamic Unsolicited Grant Service (UGS) or Unsolicited Grant Service with activity detection (UGS-AD) service flow. During the voice call, the CM does not exit from the EM mode irrespective of the flow of traffic. Voice service is given the highest priority

Dynamic Bonding Change and Dynamic Channel Change and Related Applications

In D2.0 and D3.0 load-balance (static and dynamic), CM is not moved by load-balance when it is in EM mode.

For RF-adapt, CM is not relocated to an alternate logical channel by the RF-adapt when it is in EM mode.

Multicast

- When the CM is in a multicast group, CMTS would reject the EM request for both bonded and non bonded multicast cases.
- When the CM is in EM state and a multicast join request is received, CMTS discards this join request and forces the CM to exit the EM mode.
- When the CM is in EM state and a voice call is in progress, and a new multicast join request is received, CMTS discards this join request and does not force the CM to exit the EM mode since the voice call is in progress.

- There is a threshold for currently handled transactions. When there is multicast join request and the maximum transaction threshold has been reached, CMTS cannot instruct the CM to exit the EM mode. The multicast join is also be denied until the CM can exit the EM mode.
- When the CM is in EM mode and needs to join PacketCable Multimedia (PCMM) multicast, you should send a GateSet request twice, so that the gate can be setup successfully. The first GateSet request only forces the modem to exit the EM mode, but does not set up the gate

Committed Information Rate

If the QoS is defined by the Minimum Reserved Rate service flow QoS parameter in excess of 200 kbps, when the CM enters into the EM mode, CMTS only provides 200 kbps as the minimum reserved rate. If the minimum reserved rates is less than 200 kbps, CMTS schedules the minimum reserved rate according to the service flow configuration when the CM enters into the EM mode.

CMTS records the Minimum Reserved Rate service flow QoS parameter when the CM enters into the EM mode. When the CM exits the EM mode, CMTS uses the original parameter.

When the CM enters the EM mode, it selects one of the CM upstream channels. If the service flow is completely on that upstream channel, the service flow parameter is not changed. This behavior is because the service flow is not moved into the DBC operation, and the change of the service flow parameter has no benefit

Admission Control

When a request is received to exit the EM mode and recovery to the original wideband interface is restricted due to an admission control failure, CMTS forces the CM to go offline and re-register to prevent it from getting stuck in the EM mode. In such a case, CMTS logs a warning message.

Battery Mode

When CMTS receives the status of the CM as operating on battery power, CMTS instructs the CM to enter into the BM. If the CM rejects the instruction received, CMTS keeps the modem in normal status.

When the CM is in BM and CMTS receives the status of the CM as operating on A/C power, CMTS instructs the CM to exit the BM. If the CM rejects the instruction received, CMTS forces the CM to go offline to prevent it from getting stuck in the battery mode. In such a case, CMTS logs a warning message.

Attribute Mask

When selecting an upstream or a downstream channel pair for energy management mode, CMTS selects channels that meet the requirements of the attribute masks for the existing service flows for the corresponding CM.

In some cases, adherence to the service flow attribute-based assignment may not be possible when selecting an upstream and downstream channel pair for energy management mode of operation. To resolve this conflict, CMTS supports one or both of the following approaches:

1. CMTS may require strict adherence to the required and forbidden attribute masks and thus deny entry into the EM mode if these masks cannot be met by the available individual channels in the MD-CM-SG.
2. CMTS may allow the CM to enter the EM mode while not meeting all the criteria for the attribute masks. In this case, CMTS logs a warning event notifying that the attribute masks are not maintained.

For the following case, CMTS supports approach two:

When the CM is instructed to enter into the EM mode and the selected target upstream and downstream channels do not adhere to the service flow attribute mask. For this conflict CMTS instructs the modem to enter into the EM mode. CMTS also logs a warning message to notify this conflict.

Dynamic Service Addition

When the CM is in EM mode, DSA request can still be set up even if the requested attributes can not be met with a single channel. In order to not effect voice services, the CM is not forced to exit the EM mode.

Restrictions for Configuration Change and Interface Shutdown

1. **Shutdown of the upstream channel**—Shutdown of the upstream channel recalculates the MD-US-SG-ID and assigns a new MD-US-SG-ID. In this case, the CM is not offline and internal data structure of the CM instance is not updated. DBC operation checks the MD-US-SG-ID, so when the CM enters into the EM mode there is a mismatch between the MD-US-SD-ID on the CM and the new MD-US-SG-ID. Hence, DBC fails and the CM cannot get into the EM mode.
2. **Change in Upstream Service Group makes the CM in EM mode go offline**—The US-SG configuration change blocks the DBC behavior and the CM gets stuck in the EM mode. To avoid this scenario, when there is a change in the Upstream Service Group (US-SG), such as shutdown or no shutdown of the upstream channels, CMTS makes the CM go offline. The CM should re-register as a normal CM with the wideband channel bonding including multiple channels.
3. **Modify the original wideband interface**—When the CM is in EM mode, change in the original wideband interface channels on the CM makes the CM go offline and re-register as a normal CM.
4. **Disable or enable feature**— When you disable this feature, CMTS does not force CMs to exit from the EM mode unless CMs sends a request. CMTS does not accept EM requests after the EM feature is disabled from the CLI.

How to Configure the Energy Management Mode

This section describes how to configure the energy management feature on the Cisco cBR-8.

Contents

Enabling Energy Management Mode

To enable the energy management mode, complete the following procedure:

```
configure terminal
cable reduction-mode energy-management enable
```

Verifying the Energy Management Mode

- To verify if the CM is in EM mode, use the **show cable modem** command. If the cable modem is working in energy management mode, the MAC state is displayed with an "em" flag.

  ```
  show cable modem
  ```

D

```
MAC Address    IP Address      I/F                 MAC               Prim  RxPwr
 Timing Num   I
                                                                        State
         Sid   (dBmv) Offset  CPE    P
7cb2.1b0f.ea72 40.4.58.4       C7/0/0/UB     w-online(em)              2      0.00
    1231     1         Y
54d4.6ffb.2f6b 40.4.58.24      C7/0/0/UB     w-online                  3     -0.50
   1241     0         Y
0025.2ed9.9a22 40.4.58.3       C7/0/0/UB     w-online                  4      0.50
   1240     0         Y
```

- To verify which CM is in EM mode and to get the original wideband and upstream channel information, use the **show cable modem reduction-mode energy-management-mode** command.

  show cable modem reduction-mode energy-management-mode

```
                                Orig BG     Orig US                    Curr BG
I/F     MAC Address    ID       I/F        bitmap   RFs     ID          I/F
Upstream
------- -------------- ---------------- -------- ----------------------------------------
C7/0/0  0025.2eaf.843e 897  Wi7/0/0:0     0x3B     4      252        Wi7/0/0:1      US0
C7/0/0  0025.2eaf.8356 897  Wi7/0/0:0     0x3B     4      252        Wi7/0/0:1      US0

C7/0/0  0015.d176.5199 897  Wi7/0/0:0     0x3B     4      252        Wi7/0/0:1      US0
```

Enabling Energy Management Mode per MAC Domain

CMTS supports the EM feature when enabled both globally and per MAC domain. Use the following procedure to enable energy management feature per MAC domain.

To enable the EM mode per MAC domain, complete the following procedure:

```
configure terminal
interface cable slot/subslot/cable-interface-index

cable reduction-mode energy-management enable
```

Configuring Initialization Ranging Technique in Dynamic Bonding Channel

The default value for the technique in init-ranging is set to 1 and the valid range is 1-4.

To configure the technique in init-ranging, complete the following procedure:

```
configure terminal
cable reduction-mode energy-management ranging-init-technique value
```

Configuring the Percentage for the Dynamic Channel Bandwidth

Make sure that you leave enough bandwith for the primary channel so that it can allocate dynamic channel bandwidth when it joins to a newly created DBG. The default percentage value is set to 5 and the valid range is 1-96.

To configure the percentage of dynamic channel bandwidth, complete the following procedure:

```
configure terminal
cable reduction-mode energy-management dynamic-channel-percent value
```

Configuring the Queue Size for Energy Management

The default value for the queue size is set to 150 and the valid range is 50-10000.

To set the queue size of the energy management requests, complete the following procedure:

```
configure terminal
cable reduction-mode energy-management process-queue-size value
```

-

Verifying the Energy Management Mode

This section describes how to verify the EM mode.

Contents

Viewing the Basic Statistics for Energy Management Receive Request

To view the basic statistics for all energy management receive request events for a specific CM, use the **show cable modem <cable if | mac_addr | ip_addr> reduction-mode energy-management-status** command.

```
show cable modem c8/0/0 reduction-mode energy-management-status
```

```
I/F    MAC Address    Event          TID Count Error Dups   Time
C8/0/0 54d4.6ffb.2e21 Enter EM mode   1   1     0     1    Jul 16 21:38:18
                      Exit EM mode    1   1     0     0    Jul 16 21:38:39
C8/0/0 602a.d07c.4ec6 Enter EM mode   1   1     0     0    Jul 16 21:40:57
                      Exit EM mode    1   1     0     0    Jul 16 21:41:17
```

To clear the basic receive statistics for all EM_REQ events for a specified CM, use the **clear cable modem <cable if | mac_addr | ip_addr> em-status** command.

Verifying the Configuration Parameters

To verify the configuration parameters used in the CM configuration file, use the **show cable modem <mac address> reduction-mode energy-management-param** command.

```
show cable modem 54d4.6ffb.2e21 reduction-mode energy-management-param
```

```
Energy Management feature enable : Y
DS entry bitrate threshold(bps)  : 100000
DS entry time threshold(s)       : 120
DS exit bitrate threshold(bps)   : 200000
DS exit time threshold(s)        : 2
US entry bitrate threshold(bps)  : 100000
US entry time threshold(s)       : 120
US exit bitrate threshold(bps)   : 200000
US exit time threshold(s)        : 2
cycle period(s)                  : 300
```

Viewing Information Regarding a Cable Modem

To view all the information regarding a CM, use the **show cable modem** *mac address* **verbose** command.

show cable modem *54d4.6ffb.30fd* **verbose**

```
MAC Address                          : 54d4.6ffb.30fd
IP Address                           : 40.4.58.14
IPv6 Address                         : 2001:40:4:58:741A:408D:7E4B:D7C8
Dual IP                              : Y
Prim Sid                             : 9
Host Interface                       : C7/0/0/UB
MD-DS-SG / MD-US-SG                  : 1 / 1
MD-CM-SG                             : 0x3C0101
Primary Wideband Channel ID          : 897 (Wi7/0/0:0)
Primary Downstream                   : In7/0/0:2 (RfId : 722)
Wideband Capable                     : Y
RCP Index                            : 3
RCP ID                               : 00 10 00 00 08
Downstream Channel DCID RF Channel : 99    7/0/0:2
Downstream Channel DCID RF Channel : 97    7/0/0:0
Downstream Channel DCID RF Channel : 98    7/0/0:1
Downstream Channel DCID RF Channel : 100   7/0/0:3
Multi-Transmit Channel Mode          : Y
Extended Upstream Transmit Power     : 0dB
Upstream Channel                     : US0        US1
Ranging Status                       : sta        sta
Upstream SNR (dB)                    : 36.12      32.55
Upstream Data SNR (dB)               : --         --
Received Power (dBmV)                : 0.00       0.00
Reported Transmit Power (dBmV)       : 25.25      26.00
Peak Transmit Power (dBmV)           : 54.00      54.00
Phy Max Power (dBmV)                 : 54.00      54.00
Minimum Transmit Power (dBmV)        : 24.00      24.00
Timing Offset              (97.6 ns): 1226       1226
Initial Timing Offset                : 1229       973
Rng Timing Adj Moving Avg(0.381 ns): -1          0
Rng Timing Adj Lt Moving Avg         : -7         0
Rng Timing Adj Minimum               : -768       0
Rng Timing Adj Maximum               : 0          64768
Pre-EQ Good                          : 0          0
Pre-EQ Scaled                        : 0          0
Pre-EQ Impulse                       : 0          0
Pre-EQ Direct Loads                  : 0          0
Good Codewords rx                    : 515        472
Corrected Codewords rx               : 0          0
Uncorrectable Codewords rx           : 0          0
Phy Operating Mode                   : atdma*     atdma*
sysDescr                             :
Downstream Power                     : 0.00 dBmV (SNR = ----- dB)
MAC Version                          : DOC3.0
QoS Provisioned Mode                 : DOC1.1
Enable DOCSIS2.0 Mode                : Y
Modem Status                         : {Modem= w-online(em), Security=disabled}
Capabilities                         : {Frag=N, Concat=N, PHS=Y}
Security Capabilities                : {Priv=, EAE=Y, Key_len=}
L2VPN Capabilities                   : {L2VPN=N, eSAFE=N}
Sid/Said Limit                       : {Max US Sids=16, Max DS Saids=15}
Optional Filtering Support           : {802.1P=N, 802.1Q=N, DUT=N}
Transmit Equalizer Support           : {Taps/Symbol= 1, Num of Taps= 24}
Number of CPE IPs                    : 0(Max CPE IPs = 16)
CFG Max-CPE                          : 200
Flaps                                : 0()
```

```
Errors                              : 0 CRCs, 0 HCSes
Stn Mtn Failures                    : 0 aborts, 0 exhausted
Total US Flows                      : 1(1 active)
Total DS Flows                      : 1(1 active)
Total US Data                       : 7 packets, 2006 bytes
Total US Throughput                 : 0 bits/sec, 0 packets/sec
Total DS Data                       : 5 packets, 1202 bytes
Total DS Throughput                 : 0 bits/sec, 0 packets/sec
LB group ID assigned (index)        : 2151416065 (48131)
LB group ID in config file (index)  : N/A (N/A)
LB policy ID                        : 0
LB policy ID in config file         : 0
LB priority                         : 0
Tag                                 :
Required DS Attribute Mask          : 0x0
Forbidden DS Attribute Mask         : 0x0
Required US Attribute Mask          : 0x0
Forbidden US Attribute Mask         : 0x0
Service Type ID                     :
Service Type ID in config file      :
Active Classifiers                  : 2 (Max = NO LIMIT)
CM Upstream Filter Group            : 0
CM Downstream Filter Group          : 0
CPE Upstream Filter Group           : 0
CPE Downstream Filter Group         : 0
DSA/DSX messages                    : permit all
Voice Enabled                       : NO
DS Change Times                     : 0
Boolean Services                    : 2
CM Energy Management Capable        : Y
CM Enable Energy Management         : Y
CM Enter Energy Management          : YES
Number of Multicast DSIDs Support   : 16
MDF Capability Mode                 : 2
IGMP/MLD Version                    : MLDv2
FCType10 Forwarding Support         : Y
Features Bitmask                    : 0x0
Total Time Online                   : 2h12m   (2h12m    since last counter reset)
CM Initialization Reason            : NO_PRIM_SF_USCHAN
CFG Max IPv6 CPE Prefix             : 16 (-1 used)
```

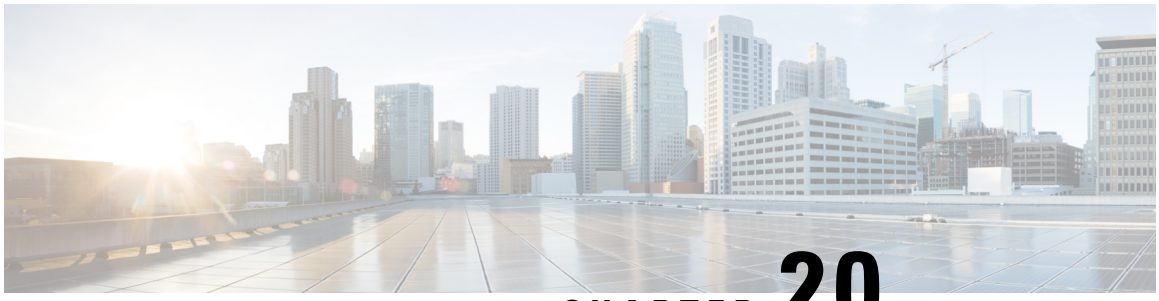
Feature Information for Energy Management Mode

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 66: Feature Information for Downgrading Channel Bonding in Battery Backup Mode

Feature Name	Releases	Feature Information
Energy Management Mode	Cisco IOS XE Fuji 16.7.1	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 20

Cable Modem Steering

The cable modem steering feature helps to redirect or steer cable modems to multiple CMTS routers. A configurable string is used to bond the cable modem to the proper CMTS. Once the bonding is done, the CMTS can move the cable modem within itself for load balancing.

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- Prerequisites for Cable Modem Steering, on page 358
- Restrictions for Cable Modem Steering, on page 358
- Information About Cable Modem Steering, on page 358
- How to Configure Cable Modem Steering on the CMTS Router, on page 360
- Verifying and Troubleshooting Cable Modem Steering, on page 362
- Additional References, on page 364
- Feature Information for Cable Modem Steering, on page 365

Cable Modem Steering on the Cisco cBR Series Converged Broadband Routers

First Published: July 13, 2016

The cable modem steering feature helps to redirect or steer cable modems to multiple CMTS routers. A configurable string is used to bond the cable modem to the proper CMTS. Once the bonding is done, the CMTS can move the cable modem within itself for load balancing.

Your software release may not support all the features that are documented in this module. For the latest feature information and caveats, see the release notes for your platform and software release. The Feature Information Table at the end of this document provides information about the documented features and lists the releases in which each feature is supported.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to http://tools.cisco.com/ITDIT/CFN/. An account on http://www.cisco.com/ is not required.

Contents

Prerequisites for Cable Modem Steering

DOCSIS 3.0-defined type, length, values (TLVs) are required to aid channel selection. All TLVs encoded as general extension information in cable modem configuration files are backward compatible with DOCSIS 1.1 and DOCSIS 2.0 cable modems.

Note The hardware components introduced in a given Cisco IOS Release are supported in all subsequent releases unless otherwise specified.

Restrictions for Cable Modem Steering

The Cable Modem Steering feature has the following general restrictions:

- To restrict the cable modem on the exact downstream on the target CMTS, the redirection must be configured on the target CMTS.
- You must manually execute the **clear cable modem service-type** command to clear the cable modem service type identifier stored at the CMTS during registration.
- You must manually execute the **clear cable modem attribute-masks** command to clear the cable modem attribute masks stored at the CMTS during registration. These attribute masks are used to restrict usage of upstream channels during ranging time.
- Cable modem steering supports only upstream masks.
- Channel steering does not take place when the cable modem fails in initial ranging.
- The cable modem will take more time to come online when channel steering is deployed. The time taken is proportional to the number of modems, and the downstreams and upstreams that the cable modem can reach.
- A modem cannot be load balanced to any upstream channel with attributes that conflict with attribute masks of the modem.
- Do not configure to use UCC in DOCSIS LBG.

Information About Cable Modem Steering

Cable modem steering allows you to redirect or steer the cable modems to one or more CMTS routers using downstream frequency overrides. Once a cable modem registers on a downstream on the proper CMTS router, the CMTS router can move the cable modem to any location for load balancing.

The DOCSIS 3.0-compliant Service Type Identifier used as the configurable string in the cable modem configuration file is backward-compatible with DOCSIS 1.1 and DOCSIS 2.0 cable modems.

The CMTS router can also impose restrictions on the number of channels a cable modem can use. DOCSIS 3.0 defines several TLVs to aid the channel selection.

The following TLVs are used in cable modem steering:

- TLV 43.9 (Cable Modem Attribute Masks) limits the set of channels the CMTS router can assign to the cable modem by allowing or forbidding certain binary attributes. The cable modem attribute masks have four sub-TLVs and cable modem steering makes use of two sub-TLVs, which are listed below:
  - TLV 43.9.3—Cable Modem Upstream Required Attribute Mask (C.1.1.18.1.8.3 of CM-SP-MULPIv3.0-I07-080215). It is a 32-bit mask representing the set of binary upstream channel attributes required for the cable modem.
  - TLV 43.9.4—Cable Modem Upstream Forbidden Attribute Mask (C.1.1.18.1.8.4 of CM-SP-MULPIv3.0-I07-080215). It is a 32-bit mask representing the set of binary upstream channel attributes forbidden for the cable modem.
- TLV 43.11 is used for a redirection action based on the service type identifier field. The cable modem sends the TLV 43.11 in the REG-REQ MAC message. The DOCSIS 1.1 and DOCSIS 2.0 modems will also send this file ID when doing the registration.
- TLV43.1, defined as Policy ID in DOCSIS 2.0 and DOCSIS 3.0, is parsed and stored in the cable modem during registration. Before moving the cable modem during load balancing (LB), the CMTS router checks whether the cable modem has a preconfigured policy with the same Policy ID. If the policy does exist, the CMTS router disables LB for this cable modem and moves to the next cable modem. If the policy does not exist on the CMTS router, or the Policy ID is missing from the cable modem configuration file, LB prohibition is not performed.

The following TLVs are supported in cable modem steering:

- TLV 43.11 (Service type identifier) from section C.1.1.18.1.10 in CM-SP-MULPIv3.0-I07-080215.
- Cable modem attribute masks (TLV 43.9) from C.1.1.18.1.8.3 and C.1.1.18.1.8.4 of CM-SP-MULPIv3.0-I07-080215.
- TLV portion (43.1, Policy ID) of REQ-REQ
- TLV 18--- Ranging Hold-off Priority Field
- TLV 19---Channel Class ID

Upstream Channel Descriptor TLV for Ranging Hold-off

The Upstream Channel Descriptor (UCD) TLV for Ranging Hold-off feature, enables the Cisco cBR Series Converged Broadband router to hold off a cable modem from initial ranging based on TLV 18 and 19 specified in the upstream channel descriptor (UCD) messages. The router can hold off a cable modem from initial ranging only for 5 minutes. This default value cannot be changed. This feature is supported with DOCSIS 2.0 and later releases cable modems using upstream logical channels.

Ranging Class ID

The CMTS enables UCD TLV for ranging hold-off after detecting the TLVs from the cable modem registration request (REG-REQ) or multipart registration request (REG-REQ-MP), and saves these TLVs as a cable modem ranging class ID.

By default, DOCSIS load balance is supported for all cable modems with all types of ranging class IDs. In the event of DOCSIS load balance, a cable modem moves to the target upstream channel only if the ranging class ID matches with the upstream channel class ID.

Cable Modem Exclusion for DOCSIS Load Balance

You can exclude a cable modem or a group of cable modems from DOCSIS load balance based on their device type, MAC address, and Organizational Unique Identifier (OUI) using the **cable load-balance exclude** command in global configuration mode.

How to Configure Cable Modem Steering on the CMTS Router

This section describes the following required and optional procedures:

Configuring an Upstream Channel Class ID

This configuration is optional. A channel class ID must be configured for an upstream logical channel if you want to configure UCD TLV ranging hold-off on the CMTS router.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**controller upstream-cable** *slot/subslot/controller-port-number* **Example:** `Router(config)# controller Upstream-Cable 3/0/0`	Specifies the cable interface and enters cable interface configuration mode. Arguments for this command may vary depending on the CMTS router, line card, and Cisco IOS software release. For details, see the Cisco IOS CMTS Cable Command Reference . • *Slot*— Slot where the interface card resides. The valid range is from 0 to 3 and 6 to 9 on the Cisco cBR-8 router. • *Subslot*—Subslot where the interface card resides. The valid value is 0 on the Cisco cBR-8 router. • *controller-port-number*—Controller port number. The valid values are from 0 to 7 on the Cisco cBR-8 router.
Step 4	**us-channel** *us-channel-id* **chan-class-id** *id* **Example:** `Router(config-controller)# us-channel 3 chan-class-id ff`	Configures the channel class ID for an upstream logical channel. • *us-channel-id*—Specifies the upstream channel id. • *id*—Channel class ID for the logical upstream channel in the hexadecimal format. The valid range is from 0 to ffffffff. The default value is 0.
Step 5	**end** **Example:** `Router(config-controller)# end`	Returns to privileged EXEC mode.

Configuring an Upstream Ranging Hold-off Priority Value

This configuration is optional

Maximum time that a cable modem can inhibit transmissions on an upstream channel in response to its ranging class ID matching a bit value in the Ranging Hold-off Priority field in the cable modem configuration file is 300 seconds (five minutes) per *DOCSIS 3.0 MAC and Upper Layer Protocols Interface Specification* . This default timer value cannot be changed.

Procedure

	Command or Action	Purpose
Step 1	**enable** **Example:** `Router> enable`	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	**configure terminal** **Example:** `Router# configure terminal`	Enters global configuration mode.
Step 3	**controller upstream-cable** *slot/subslot/controller-port-number* **Example:** `Router(config)# controller upstream-cable 3/0/0`	Specifies the cable interface and enters cable interface configuration mode. Arguments for this command may vary depending on the CMTS router, line card, and Cisco IOS software release. For details, see the Cisco IOS CMTS Cable Command Reference . • *Slot*—Slot where the interface card resides. The valid range is from 0 to 3 and 6 to 9 on the Cisco cBR-8 router. • *Subslot*—Subslot where the interface card resides. The valid value is 0 on the Cisco cBR-8 router. • *controller-port-number*—Controller port number. The valid values are from 0 to 7 on the Cisco cBR-8 router.
Step 4	**us-channel** *us-channel-id* **rng-holdoff** *priority* **Example:** `Router(config-controller)# us-channel 3 rng-holdoff 1`	Configures the ranging hold-off priority value for an upstream logical channel. • *us-channel-id*—Specifies the upstream channel id. • **rng-holdoff** *priority*—Specifies the ranging hold-off priority value in the hexadecimal format. The valid range is from 0 to ffffffff. The default value is 0.
Step 5	**end** **Example:** `Router(config-controller)# end`	Returns to privileged EXEC mode.

Verifying and Troubleshooting Cable Modem Steering

This section provides the verification and troubleshooting information:

Verifying an Upstream Ranging Class ID Configuration

To verify an upstream ranging class ID of a cable modem, use the **show cable modem** command with the **verbose** keyword.

Following is a sample output of the **show cable modem verbose** command:

```
Router# show cable modem 68b6.fcfe.22e5 verbose

MAC Address                          : 68b6.fcfe.22e5
IP Address                           : 192.168.0.8
IPv6 Address                         : 2001:DB8:10:1:9951:1972:33F9:9867
Dual IP                              : Y
Prim Sid                             : 8
Host Interface                       : C8/0/0/UB
MD-DS-SG / MD-US-SG                  : 1 / 2
MD-CM-SG                             : 0x5A0102
Primary Wideband Channel ID          : 3073 (Wi8/0/0:0)
Primary Downstream                   : Mo8/0/0:0 (RfId : 2304)
Wideband Capable                     : Y
RCP Index                            : 3
RCP ID                               : 00 10 00 00 18
Downstream Channel DCID RF Channel : 45    8/0/0:0
Downstream Channel DCID RF Channel : 46    8/0/0:1
Downstream Channel DCID RF Channel : 47    8/0/0:2
Downstream Channel DCID RF Channel : 48    8/0/0:3
Downstream Channel DCID RF Channel : 49    8/0/0:4
Downstream Channel DCID RF Channel : 50    8/0/0:5
Downstream Channel DCID RF Channel : 51    8/0/0:6
Downstream Channel DCID RF Channel : 52    8/0/0:7
Downstream Channel DCID RF Channel : 53    8/0/0:8
Downstream Channel DCID RF Channel : 54    8/0/0:9
Downstream Channel DCID RF Channel : 55    8/0/0:10
Downstream Channel DCID RF Channel : 56    8/0/0:11
Downstream Channel DCID RF Channel : 57    8/0/0:12
Downstream Channel DCID RF Channel : 58    8/0/0:13
Downstream Channel DCID RF Channel : 59    8/0/0:14
Downstream Channel DCID RF Channel : 60    8/0/0:15
Downstream Channel DCID RF Channel : 61    8/0/0:16
Downstream Channel DCID RF Channel : 62    8/0/0:17
Downstream Channel DCID RF Channel : 63    8/0/0:18
Downstream Channel DCID RF Channel : 64    8/0/0:19
Downstream Channel DCID RF Channel : 65    8/0/0:20
Downstream Channel DCID RF Channel : 66    8/0/0:21
Downstream Channel DCID RF Channel : 67    8/0/0:22
Downstream Channel DCID RF Channel : 68    8/0/0:23
UDC Enabled                          : N
Extended Upstream Transmit Power     : 61dB
Multi-Transmit Channel Mode          : Y
Number of US in UBG                  : 8
Upstream Channel                     : US0        US1        US2        US3
Ranging Status                       : sta        sta        sta        sta
Upstream SNR (dB)                    : 30.62      32.32      18.25      24.26
Upstream Data SNR (dB)               : --         --         --         --
Received Power (dBmV)                : 0.50       0.00       -0.50      -0.50
Reported Transmit Power (dBmV)       : 30.75      30.75      29.25      29.25
```

```
Peak Transmit Power (dBmV)          : 61.00      61.00      61.00      61.00
Phy Max Power (dBmV)                : 48.00      48.00      48.00      48.00
Minimum Transmit Power (dBmV)       : 21.00      21.00      21.00      21.00
Timing Offset              (97.6 ns): 1800       1800       1800       1800
Initial Timing Offset               : 1544       1544       1544       1544
Rng Timing Adj Moving Avg(0.381 ns): -1          0          -1         -1
Rng Timing Adj Lt Moving Avg        : -7         0          -7         -7
Rng Timing Adj Minimum              : -256       0          -256       -256
Rng Timing Adj Maximum              : 65536      65536      65536      65536
Pre-EQ Good                         : 0          0          0          0
Pre-EQ Scaled                       : 0          0          0          0
Pre-EQ Impulse                      : 0          0          0          0
Pre-EQ Direct Loads                 : 0          0          0          0
Good Codewords rx                   : 1201       1262       833        656
Corrected Codewords rx              : 0          0          169        117
Uncorrectable Codewords rx          : 0          0          205        335
Phy Operating Mode                  : atdma*     atdma*     atdma*     atdma*
Upstream Channel                    : US4        US5        US6        US7
Ranging Status                      : sta        sta        sta        sta
Upstream SNR (dB)                   : 15.53      31.62      31.1       31.87
Upstream Data SNR (dB)              : --         --         --         --
Received Power (dBmV)               : 0.00       0.00       -0.50      0.50
Reported Transmit Power (dBmV)      : 29.25      30.75      30.75      30.75
Peak Transmit Power (dBmV)          : 61.00      61.00      61.00      61.00
Phy Max Power (dBmV)                : 48.00      48.00      48.00      48.00
Minimum Transmit Power (dBmV)       : 21.00      21.00      21.00      21.00
Timing Offset              (97.6 ns): 1800       1800       1800       1800
Initial Timing Offset               : 1544       1800       1544       1544
Rng Timing Adj Moving Avg(0.381 ns): -1          -1         46         0
Rng Timing Adj Lt Moving Avg        : -7         -7         104        0
Rng Timing Adj Minimum              : -256       -256       0          0
Rng Timing Adj Maximum              : 65536      256        65536      65536
Pre-EQ Good                         : 0          0          0          0
Pre-EQ Scaled                       : 0          0          0          0
Pre-EQ Impulse                      : 0          0          0          0
Pre-EQ Direct Loads                 : 0          0          0          0
Good Codewords rx                   : 718        1328       1173       1252
Corrected Codewords rx              : 110        0          0          0
Uncorrectable Codewords rx          : 298        0          0          0
Phy Operating Mode                  : atdma*     atdma*     atdma*     atdma*
sysDescr                            : DOCSIS 3.0 Cable Modem Router
Downstream Power                    : 7.40 dBmV (SNR = 43.30 dB)
MAC Version                         : DOC3.0
QoS Provisioned Mode                : DOC1.1
Enable DOCSIS2.0 Mode               : Y
Modem Status                        : {Modem= w-online, Security=disabled}
Capabilities                        : {Frag=N, Concat=N, PHS=Y}
Security Capabilities               : {Priv=, EAE=Y, Key_len=}
L2VPN Capabilities                  : {L2VPN=Y, eSAFE=Y}
Sid/Said Limit                      : {Max US Sids=8, Max DS Saids=64}
Optional Filtering Support          : {802.1P=N, 802.1Q=N, DUT=Y}
Transmit Equalizer Support          : {Taps/Symbol= 1, Num of Taps= 24}
Number of CPE                       : 0(Max CPE = 16)
Number of CPE IPs                   : 0(Max CPE IPs = 16)
Number of CPE IPv6                  : 0(Max CPE IPv6 = 16)
CFG Max-CPE                         : 16
Flaps                               : 19(Oct 11 04:00:25)
Errors                              : 0 CRCs, 0 HCSes
Stn Mtn Failures                    : 0 aborts, 12 exhausted
Total US Flows                      : 1(1 active)
Total DS Flows                      : 1(1 active)
Total US Data                       : 3294 packets, 577031 bytes
Total US Throughput                 : 0 bits/sec, 0 packets/sec
Total DS Data                       : 2263 packets, 200777 bytes
```

```
Total DS Throughput                : 0 bits/sec, 0 packets/sec
LB group ID assigned (index)       : 2153382146 (55810)
LB group ID in config file (index) : N/A (N/A)
LB policy ID                       : 0
LB policy ID in config file        : 0
LB priority                        : 0
Tag                                :
Required DS Attribute Mask         : 0x0
Forbidden DS Attribute Mask        : 0x0
Required US Attribute Mask         : 0x0
Forbidden US Attribute Mask        : 0x0
Service Type ID                    :
Service Type ID in config file     :
Ranging Class ID                   : 0x2
Active Classifiers                 : 0 (Max = NO LIMIT)
CM Upstream Filter Group           : 0
CM Downstream Filter Group         : 0
CPE Upstream Filter Group          : 0
CPE Downstream Filter Group        : 0
DSA/DSX messages                   : permit all
Voice Enabled                      : NO
DS Change Times                    : 0
Boolean Services                   : 2
Number of Multicast DSIDs Support  : 63
MDF Capability Mode                : 2
IGMP/MLD Version                   : MLDv2
FCType10 Forwarding Support        : Y
Features Bitmask                   : 0x0
Total Time Online                  : 9h27m   (9h27m    since last counter reset)
CM Initialization Reason           : BAD_DHCP_ACK
CFG Max IPv6 CPE Prefix            : 16 (-1 used)
```

Additional References

The following sections provide references related to the Cable Modem Steering feature.

Related Documents

Related Topic	Document Title
CMTS cable commands	Cisco IOS CMTS Cable Command Reference

Standards and RFCs

Standard	Title
CM-SP-MULPIv3.0-I07-080215	DOCSIS 3.0 MAC and Upper Layer Protocols Interface Specification
CM-SP-MULPIv3.0-I18-120329	DOCSIS 3.0 MAC and Upper Layer Protocols Interface Specification
CM-SP-RFI2.0-I13-080215	DOCSIS 2.0 Radio Frequency Interface Specification

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/cisco/web/support/index.html

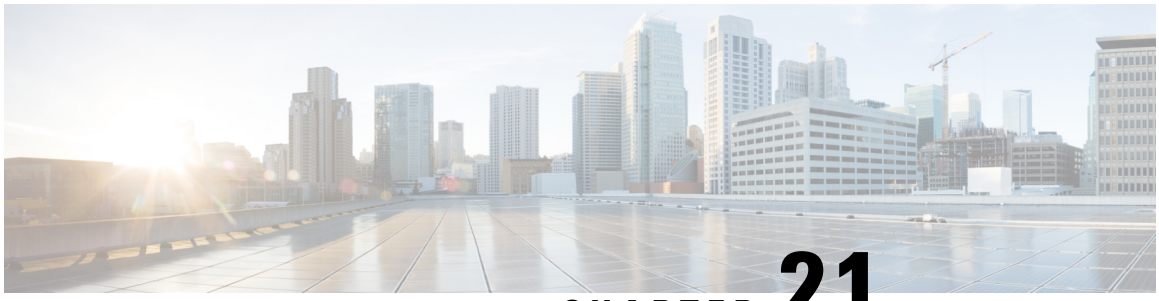
Feature Information for Cable Modem Steering

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 67: Feature Information for Cable Modem Steering on the Cisco CMTS Routers

Feature Name	Releases	Feature Information
Cable Modem Steering	Cisco IOS XE Everest 16.6.1	This feature was integrated into Cisco IOS XE Everest 16.6.1 on the Cisco cBR Series Converged Broadband Routers.



CHAPTER 21

DOCSIS Predictive Scheduler

This chapter describes how to configure the DOCSIS Predictive Scheduler (DPS) on the Cisco cBR Series Converged Broadband Router.

- Information about DOCSIS Predictive Scheduler, on page 367
- Configuring DPS on Cable Interface, on page 368
- Displaying DPS Grants on Upstream Channel, on page 368
- Displaying DPS Grants for Cable Modem, on page 368
- Displaying Upstream Utilization, on page 369
- Displaying Upstream Capacity Reserved for Contention Minislot, on page 371
- DOCSIS Predictive Scheduler Best Practices, on page 371
- Feature Information for DOCSIS Predictive Scheduler, on page 372

Information about DOCSIS Predictive Scheduler

DOCSIS Predictive Scheduler (DPS) is a scheduling technique to reduce the DOCSIS upstream latency by predictively allocating unsolicited grants to active service flows.

When enabled, DPS provides benefits to bonded service flows with scheduling service of type Real-Time Polling Service (rtPS), Non-Real-Time Polling Service (nrtPS), and Best Effort (BE).

DPS automatically identifies:

- service flows to which to issue predictive grants
- size of the grants to send
- when to send the grants

Predictive grants are sent after honoring all bandwidth requests received by the CMTS. DPS relies on unallocated MAP capacity to issue predictive grants. Therefore, the less upstream capacity is utilized, the more predictive grants that DPS can issue, and vice-versa.

The upstream latency improvements depend on several factors, such as the difference between the service flow's upstream bitrate and its max-rate, the congestion in the upstream channels, and the predictability of the traffic. In the best-case scenario, latency reductions of 66% are achievable due to a reduction of the request-grant delay from approximately three times the one-way propagation delay to one times the one-way propagation delay. Reductions on the upstream latency translate into upper layer performance improvements depending on the upper layer protocols. For example, reducing the upstream latency in the DOCSIS link may improve the TCP upstream and downstream throughput.

DPS is enabled on per MAC domain basis, and should be configured to issue predictive grants only on the SCQAM channels.

Configuring DPS on Cable Interface

Use the following steps to configure DPS on a MAC domain:

```
enable
configure terminal
interface cable slot/subslot/interface
cable upstream dps scqam-only
```

DPS configuration is also supported within a MAC domain profile. If you want to configure the number of reserved minislots for contention, use the **cable upstream min-bwreq-ops** command on a per MAC domain basis.

This is a configuration example:

```
Router> enable
Router# configure terminal
Router(config)# interface Cable 7/0/1
Router(config-if)# cable upstream dps scqam-only
Router(config-if)# cable upstream min-bwreq-ops scqam 5 0
```

Displaying DPS Grants on Upstream Channel

To view the number of bytes granted by DPS on an upstream channel, use the **show controller cable** *slot/subslot/interface* **upstream** *upstream* command as shown in the following example:

```
Router# show controller Cable 1/0/5 upstream 0 | include DPS
DPS Bytes Granted = 27595485909
```

Note DPS related counters are only displayed when DPS is configured.

Displaying DPS Grants for Cable Modem

DPS grants are issued on a per service flow basis. While a service flow may be allocated with more than one SID, DPS always grants on the SID from the first SID cluster. To determine the service flows and the corresponding SIDs for a given CM, use the **show cable modem** *mac-address* **qos** command as shown in the following example:

```
Router# show cable modem 0000.0020.01c0 qos
Sfid  Dir Curr  Sid   Sched  Prio MaxSusRate  MaxBrst     MinRsvRate  Throughput
          State       Type
173   US  act   89    BE     6    64000       3044        0           0
2538  US  act   1447  BE     1    120000000   50000       0           0
2539  US  act   1449  BE     1    2200000     50000       0           0
174   DS  act   N/A   N/A    6    64000       96000       0           0
2540  DS  act   N/A   N/A    1    0           65536       0           0
```

```
2541  DS  act   N/A   N/A    1    99000000    10000000    0           0
2542  DS  act   N/A   N/A    1    17600000    65536       0           0
```

To display the number of grants and granted bytes on a per service flow basis, use the **show interface cable** *slot/subslot/interface* **sid** *sid* **counter verbose** command as shown in the following example (for SFID 173):

```
Router# show interface cable 1/0/5 sid 89 counter verbose
Sid                             : 89
Request polls issued            : 0
BWReqs {Cont,Pigg,RPoll,Other} : 523, 10, 0, 0
Grants issued                   : 533
Packets received                : 1066
Bytes received                  : 180576
Queue-indicator bit statistics : 0 set, 0 granted
Total Codewords rx              : 2073
Good Codewords rx               : 2073
Corrected Codewords rx          : 0
Uncorrectable Codewords rx      : 0
Concatenated headers received   : 0
Fragmentation headers received : 0
Fragmentation headers discarded: 0

DPS grants                      : 0
DPS bytes granted               : 0
```

Note Two DPS related counters are only displayed when DPS is configured.

Displaying Upstream Utilization

There are three utilization metrics that can be used to assess the behavior of DPS:

- **%data bytes** (upstream capacity utilization by traffic): If t_1 bytes were sent in the upstream, and the upstream channel capacity was c_1 bytes, then this term refers to t_1/c_1.
- **%dps grants** (upstream grants scheduled by dps): If g_1 total grant opportunities exist within a map interval, and d_1 grants are issued by DPS, then this term refers to d_1/g_1.
- **%data grants** (total upstream grants scheduled): If g_1 total grant opportunities exist within a map interval, d_1 grants are issued by DPS and b_1 grants are issued due to bandwidth requests, then this term refers to $(d_1 + b_1)/g_1$.

To display the utilization rates on a per upstream channel basis for all three metrics above, use the **show interface cable** *slot/subslot/interface* **mac-scheduler** command as shown in the following example.

```
Router# show interface cable 1/0/2 mac-scheduler
     DOCSIS 1.1 MAC scheduler for Cable1/0/2/U0 : rate 30720000
     wfq:None
     us_balance:OFF
     dps:ON - SCQAM only
     dpon_mode:OFF
     fairness:OFF
     Queue[Rng Polls] flows 0
     Queue[CIR Grants] flows 0
<snip>
     Adv Phy Short Grant Slots 128066, Adv Phy Long Grant Slots 29214
     Adv Phy UGS Grant Slots 0
     Avg upstream channel utilization(%data bytes)   : 0%
```

```
     Avg upstream channel utilization(%dps grants) : 46%
     Avg upstream channel utilization(%data grants) : 46%
     Avg upstream channel utilization in 30 sec : 0%
     Avg percent contention slots : 53%
     Avg percent initial ranging slots : 1%
     Avg percent minislots lost on late MAPs : 0%
     Avg percent guardband slots : 0%
<snip>

     DOCSIS 1.1 MAC scheduler for Cable1/0/2/U1 : rate 30720000
     wfq:None
     us_balance:OFF
     dps:ON - SCQAM only
     dpon_mode:OFF
     fairness:OFF
     Queue[Rng Polls] flows 0
     Queue[CIR Grants] flows 0
<snip>
     Short Grant Slots 0, Long Grant Slots 0
     Adv Phy Short Grant Slots 121745, Adv Phy Long Grant Slots 28446
     Adv Phy UGS Grant Slots 0
     Avg upstream channel utilization(%data bytes)  : 0%
     Avg upstream channel utilization(%dps grants) : 40%
     Avg upstream channel utilization(%data grants) : 40%
     Avg upstream channel utilization in 30 sec : 0%
     Avg percent contention slots : 58%
     Avg percent initial ranging slots : 1%
     Avg percent minislots lost on late MAPs : 0%
     Avg percent guardband slots : 0%

Ruoter#show interface cable 1/0/2 mac-scheduler | incl utilization|rate
     DOCSIS 1.1 MAC scheduler for Cable1/0/2/U0 : rate 30720000
     Avg upstream channel utilization(%data bytes)  : 0%
     Avg upstream channel utilization(%dps grants) : 95%
     Avg upstream channel utilization(%data grants) : 95%
     Avg upstream channel utilization in 30 sec : 93%
     DOCSIS 1.1 MAC scheduler for Cable1/0/2/U1 : rate 30720000
     Avg upstream channel utilization(%data bytes)  : 75%
     Avg upstream channel utilization(%dps grants) : 95%
     Avg upstream channel utilization(%data grants) : 95%
     Avg upstream channel utilization in 30 sec : 93%
     DOCSIS 1.1 MAC scheduler for Cable1/0/2/U6 : rate 195592784
     IUC: 5  rate: 195592784
     IUC: 6  rate: 175962768
     IUC: 9  rate: 156332752
     IUC: 10  rate: 136702736
     IUC: 11  rate: 117072712
     IUC: 12  rate: 97442704
     IUC: 13  rate: 77989528
     Avg upstream channel utilization(%data bytes)  : 0%
     Avg upstream channel utilization(%dps grants) : 0%
     Avg upstream channel utilization(%data grants) : 1%
     Avg upstream channel utilization in 30 sec : 0%
     DOCSIS 1.1 MAC scheduler for Cable1/0/2/U7 : rate 219982848
     IUC: 5  rate: 0
     IUC: 6  rate: 0
     IUC: 9  rate: 0
     IUC: 10  rate: 219982848
     IUC: 11  rate: 202211312
     IUC: 12  rate: 179636656
     IUC: 13  rate: 135928256
     Avg upstream channel utilization(%data bytes)  : 0%
     Avg upstream channel utilization(%dps grants) : 0%
     Avg upstream channel utilization(%data grants) : 0%
     Avg upstream channel utilization in 30 sec : 0%
```

Note Data grants based utilization is calculated every 0.5 second, whereas the data bytes based utilization is calculated every 5 seconds for SCQAM channels and every 10 seconds for OFDMA channels.

Displaying Upstream Capacity Reserved for Contention Minislot

When DPS is enabled, some of the MAP capacity that was previously allocated for contention minislots is now used to issue predictive grants.

To display how much of the upstream capacity is reserved for contention minislots, use the **show interface cable** *slot/subslot/interface* **mac-scheduler** *upstream* **map-stats | inc bwr** command as shown in the following example:

```
Router#show interface cable 8/0/2 mac-schedulder 0 map-stats | inc bwr
     min_bwr_ops_pct 5.0, min_bwreq_mslot 8 sched min_bwreq_mslot 8
```

min_bwr_ops_pct represents the percent of the upstream capacity reserved for the contention minislots. **min_bwreq_mslot** represents the equivalent number of minislots reserved for the contention minislots.

DOCSIS Predictive Scheduler Best Practices

MIBs

The CMTS derives the following two MIBs from the data grants allocated in MAPs:

- MIB **docsIf31CmtsUsOfdmaChanUtilization**: Recalculated every 5 seconds
- MIB **docsIfCmtsChannelUtUtilization**: Recalculated every 5 seconds

Both MIBs include DPS related grants.

Load Balancing

Load balancing uses data grant-based average calculated over a 30-second interval. This average includes the DPS grants.

Contention Based Bandwidth Requests

Without DPS, as the CMTS adds more data grants in a MAP, the number of bandwidth request opportunities in a MAP decreases. During busy times, this reduction can lead to an increase in upstream latency, either due to collisions, a much larger back-off window (in time), or both.

DPS issues data grants in a MAP at the expense of bandwidth request opportunities. The worst case is when an upstream channel is at full data grants, at which point there is only a single bandwidth request per MAP. To avoid this situation's potential negative effects, we recommend setting the minimum percentage of contention-based bandwidth request opportunities to a non-zero value, e.g., 5%. Tuning may still be needed.

This is a configuration example for SC-QAM:

```
Router> enable
Router# configure terminal
Router(config)# interface Cable 7/0/1
Router(config-if)# cable upstream min-bwreq-ops scqam 5 0
```

This is a configuration example for OFDMA:

```
Router> enable
Router# configure terminal
Router(config)# interface Cable 7/0/1
Router(config-if)# cable upstream min-bwreq-ops ofdma 5 0
```

MAP Advance Time

The use of DPS increases the MAP build time by up to 50 microseconds per MAP. This additional build time accumulates for each MAP in a MAC domain (a maximum of 16) such that the last MAP can be transmitted as much as 800 microseconds later (than without DPS). Thus, when using DPS, we recommend increasing the MAP Advance parameter. Otherwise, some CMs may transition into partial mode due to late MAPs at the CM, even though the same MAPs would arrive on time at the PHY.

When using dynamic MAP advance, increasing the safety factor from 1200 to 2000 microseconds and the maximum MAP advance from 2000 to 2800 microseconds mitigated the extra MAP build time. Tuning may still be needed.

This is a configuration example:

```
Router> enable
Router# configure terminal
Router(config)# interface Cable 7/0/1
Router(config-if)# cable map-advance dynamic 2000 2800
```

Cable Modem Interoperability

DOCSIS 3.0 and above CMs are candidates for DPS granting. Some DOCSIS 3.0 CMs do not take advantage of the DPS grants.

TaFDM

TaFDM and DPS are mutually exclusive and not supported together, since both of them strive to reuse unused upstream capacity on the allocated spectrum.

Feature Information for DOCSIS Predictive Scheduler

Use Cisco Feature Navigator to find information about the platform support and software image support. Cisco Feature Navigator enables you to determine which software images support a specific software release, feature set, or platform. To access Cisco Feature Navigator, go to the https://cfnng.cisco.com/ link. An account on the Cisco.com page is not required.

Note The following table lists the software release in which a given feature is introduced. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Table 68: Feature Information for DOCSIS Predictive Scheduler

Feature Name	Releases	Feature Information
DOCSIS Predictive Scheduler	Cisco IOS XE Amsterdam 17.3.1w	This feature was integrated on the Cisco cBR Series Converged Broadband Routers.

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