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)

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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

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 6—Provides an overview of fundamental concepts and terms that are used in spectrum management.
- Upstream Signal Channel Overview, on page 10—Describes how signals are sent and how changes occur in upstream channels.
- Upstream Segments and Combiner Groups, on page 11—Describes sparse and dense segments and combiner groups.

- Frequency Management Policy, on page 12—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 14—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 19—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 19—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 2: 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:

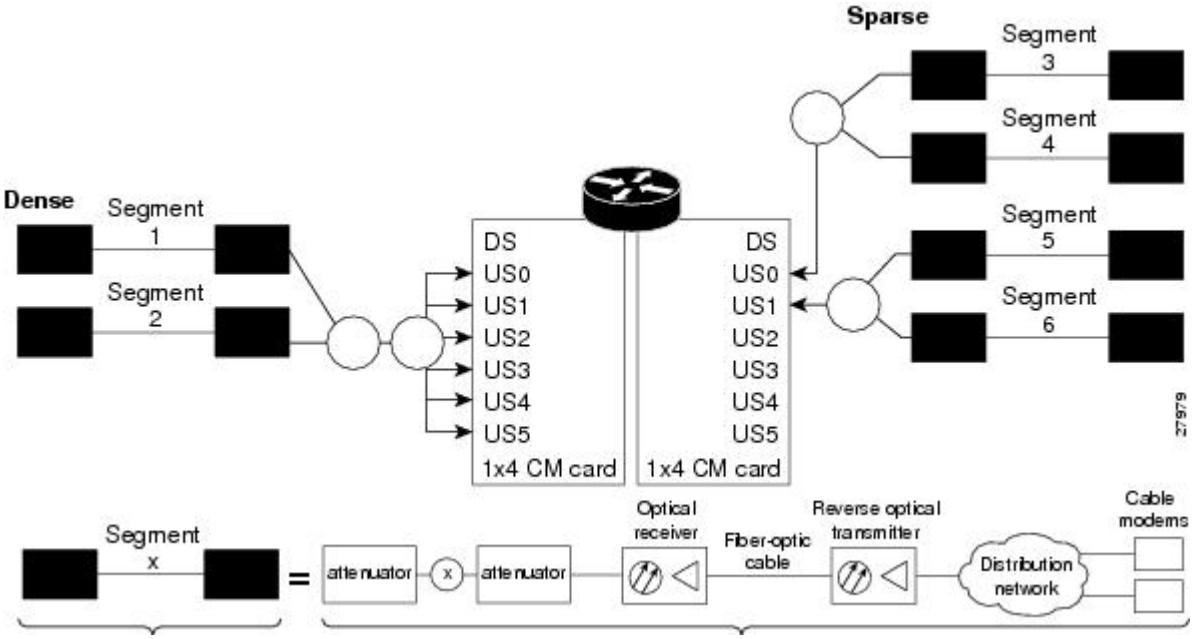
- Sparse segment—Containing one upstream channel per upstream segment.
- Dense segment—Containing multiple upstream channels per upstream segment; frequencies must be different.

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 14 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 22.

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 45 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.
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:**	Exits global configuration mode and returns to privileged EXEC mode.

	Command or Action	Purpose
	`Router(config)# end`	

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.
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.

	Command or Action	Purpose
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* • **us-channel** *n m* **threshold uncorr-fec** *uncorr-fec* **Example:** `Router(config-controller)# us-channel 0 threshold uncorr-fec 10`	(Optional) Specifies the allowable number of uncorrectable FEC errors for the upstream.
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 16 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.
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.

	Command or Action	Purpose
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.

	Command or Action	Purpose
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:** `Router(config-controller)# cable upstream 2 threshold cnr-profiles 23 14`	(Optional) Specifies the CNR (CNiR) threshold and FEC values for the upstream and its two modulation profiles. **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*	(Optional) Specifies the CNR (CNiR) threshold and FEC values for the upstream and its two modulation profiles.

	Command or Action	Purpose
	• **cable upstream** *n m* **threshold corr-fec** *corrfec-threshold* **Example:** `Router(config-controller)# cable upstream 5 threshold  corr-fec 5`	**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:** `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.

Command	Purpose
`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.
`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 3: 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 abort.
ccsSNRRequestOperState	CCSRequestOperState	Reports on the current operation state: idle, pending, running, noError, aborted, notOnLine, invalidMac, timeOut, fftBusy, fftFailed, others.
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 4: 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.

Attribute	Type	Description
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 5: 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 6: 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.
ccsUpSpecMgmtFecUnCorrectThres1	Integer32	Specifies the FEC uncorrectable error threshold for modulation profile 1 (1 to 20 percent).
ccsUpSpecMgmtFecUnCorrectThres2	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.

Attribute	Type	Description
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.
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 7: 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.

Attribute	Type	Description
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.