DOCSIS Load Balancing Movements

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

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

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

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

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

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

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

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

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

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

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

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Hardware Compatibility Matrix for the Cisco cBR Series Routers

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

Table 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

Note Do not use DPICs (8X10G and 2x100G) to forward IP traffic, as it may cause buffer exhaustion, leading to line card reload.

The only allowed traffic on a DPIC interface is DEPI, UEPI, and GCP traffic from the Cisco cBR-8 router to Remote PHY devices. Other traffic such as DHCP, SSH, and UTSC should flow via another router, since DPICs cannot be used for normal routing.

Prerequisites

Prerequisites for Load Balancing

The Load Balancing feature has the following prerequisites:

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

Prerequisites for Dynamic Channel Change for Load Balancing

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

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

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

Restrictions

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

Restrictions for Load Balancing

The Load Balancing feature has the following restrictions:

- Load balancing can be done only on a per-line card basis—all interfaces in a load balancing group must be provided by the same line card.

- All downstreams and upstreams in a load balancing group must share physical connectivity to the same group of cable modems. All downstreams or all upstreams that have the same RF physical connectivity must be members of the same load balancing group.
- You can create a maximum of 256 load balancing groups on each line card.
- If an upstream port is operational, using the **no shutdown** command, and is not being used and not connected, load balancing attempts to use the port even though there are no cable modems registered on that port. When the upstream port is up, it is put into INIT state and load balancing includes this port as a potential target. However, if the load balancing sees multiple failures moving to this upstream, it is set to DISABLE state and the port is avoided later on in load balancing processes.
- The load balancing algorithms assume a relatively even distribution of usage among modems. In the situation where one cable modem creates the bulk of the load on an interface, the load balancing thresholds should be configured for a value above the load created by that single modem.
- You cannot select particular cable modems to be automatically moved for load balancing, although you can exclude cable modems from load balancing operations altogether on the basis of their MAC address or organization unique identifier (OUI). (You can use the **test cable load-balance** command to manually move a particular cable modem among upstreams, but this is done typically to test the configuration of the load balancing groups.)
- If you have configured upstream shared spectrum groups while doing downstream load balancing, the downstream in each MAC domain must not use overlapping upstream groups. For example, the downstream in one MAC domain could use an upstream spectrum band of 10 to 30 MHz, while the downstream in a second MAC domain could use an upstream spectrum band of 30 to 42 MHz. Each MAC domain has its own upstream shared spectrum group, allowing the load balancing group to contain the downstreams for both MAC domains.
- All upstream ports coming from the same splitter must be using different center frequencies that are separated by the channel width. For example, if the upstreams are using a channel width of 3.2 MHz, the center frequencies for all upstreams must be separated by at least 3.2 MHz.
- You can use four initialization techniques for Dynamic Channel Change (DCC).
- If you have configured load balancing, the provisioning system must not assign specific upstream channels or downstream frequencies to individual cable modems in their DOCSIS configuration files. Any cable modems requiring specific upstream channels or downstream frequencies must be excluded from load balancing operations (using the **cable load-balance exclude** command).
- Do not use the utilization method of load balancing on cable interfaces that have a small number of cable modems and where a single modem is responsible for the majority of the interface load. In this condition, the Cisco CMTS could end up continually moving cable modems from one interface to another in an endless attempt to load balance the interfaces. To avoid this, configure the utilization threshold to a value that is higher than what can be caused by any single cable modem.
- When deployed with channel restriction features, if the target upstream channel attribute masks are against that of the cable modem, then the cable modem on the higher load upstream will not be load balanced, as the current load balancing moves cable modems only to the target upstream. However, cable modems that do not have an attribute mask can still be load balanced. You should consider the following while deploying the load balancing groups: the target upstream will always be the upstream that has the lowest load. If some other upstreams have the same load, the upstream with the lowest index will be chosen as the target upstream.
- A TLV in a cable modem configuration file restricts dynamic load balancing on per modem basis.

- If you remove the last rule of a DOCSIS policy, the policy itself will be removed.
- The Cisco CMTS load balancing feature moves a cable modem based on the load of the channels in a load balancing group, without checking if the cable modem supports the extended frequency range (5Mhz-85Mhz). This may result in moving a cable modem that supports standard frequency range (5Mhz-65Mhz) to a channel that has extended frequency configured. To overcome such scenarios, operators should not mix upstreams that have standard and extended frequencies configured into the same load balancing group, unless all modems in the group support extended frequency range.

Restrictions for Dynamic Channel Change for Load Balancing

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

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

- The TCS and RCS assigned to the DOCSIS 3.0 cable modems are restricted by the upstream and downstream bonding groups configured by the Cisco CMTS.
- Load balancing and DCC are not supported for CMs that are enabled for Layer 2 VPN (L2VPN) support.
- When a DCC occurs, the cable modem US and DS counters are reset. The US and DS counters include counters such as data and throughput seen in the **show cable modem** (**mac-address**) **verbose** command output and packets and bytes seen in the **show cable modem (mac-address) counters** command output.

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

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

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

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

Restrictions for DOCSIS 3.0 Static Modem Count-Based Load Balancing

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

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

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

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

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

- The Cisco CMTS can use only DBC messaging to move modems within a MAC domain and applies only to cable modems operating in MTC mode or MRC-only mode without a primary downstream change.
- The Cisco CMTS moves the MRC-only cable modems with a primary channel change using DCC with initialization technique 0.
- The Cisco CMTS moves cable modems across MAC domains using only DCC with initialization technique 0.
- The Cisco CMTS must ensure minimum interruption to existing QoS services while considering an initialization technique that is suitable for the cable plant conditions.

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

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

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

Restrictions for MRC-Only Cable Modems

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

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

- cable modems are moved across upstream channels using DCC.

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

  However, if there is a change in the primary downstream channel also, DCC with init tech 0 is used to balance the cable modems.

- MRC-only modems are treated similar to cable modems operating in MTC mode, to move modems across downstream channels. For change in upstream channel, MRC-only cable modems are treated similar to single-channel NB cable modems.

Information on the Load Balancing on the Cisco CMTS

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

Feature Overview

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

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

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

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

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

Following are the general guidelines for the rules and policies:

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

Methods to Determine When Interfaces Are Balanced

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

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

See the following sections for more information about each method.

Modems Method

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

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

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

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

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

Utilization Method

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

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

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

Wideband Interface Average Utilization and Throughput

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

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

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

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

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

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

Load Balancing Parameters

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

- Number of active cable modems
- Channel bandwidth utilization

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

Configurable Minimum Threshold under Utilization Method

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

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

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

Single Channel Load Balancing

Error Handling of Channel Assignment

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

Downstream Load Balancing Distribution with Upstream Load Balancing

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

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

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

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

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

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

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

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

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

The enhancement enables the following advantages and behaviors:

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

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

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

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

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

Interaction with Spectrum Management

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

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

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

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

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

Using Dynamic Channel Change

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

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

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

Multiple Channel Load Balancing

Algorithm for Bonded Channel Cable Modem Load Balancing

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

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

DOCSIS 3.0 Static Modem Count-Based Load Balancing

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Primary Channel Load Display for Target RCS

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

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

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

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

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

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

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

Dynamic Load Balancing for DOCSIS 3.0 Cable Modems

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

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

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

Multiple Channel Load Balancing Operation

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

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

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

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

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

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

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

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

Table 2: Load Balancing Method to Move Bonded and Non-bonded CMs

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

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

Modem Mode	Load Balancing Method	Load Balancing Counters	Channels	Dynamic Service Charge (Initialization Technique)	
DOCSIS 2.0 /DOCSIS 1.1 CMs in NB mode	DOCSIS 2.0 dynamic MCBLB, dynamic utilization	NB	DS	DCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	DCC init tech 0
			US	UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	UCC
DOCSIS 1.0 in NB mode	DOCSIS 2.0 dynamic MCBLB, dynamic utilization	NB	DS	Force reinitialize CM **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	Force reinitialize CM
			US	UCC **Note** CM outside RLBG moves inside RLBG with DOCSIS 2.0 LB.	UCC

Table 3: Using DCC/DBC to Load Balance Bonded and Non-bonded Cable Modems

Channel	CM in MRC, MTC Mode	CM in MRC, non-MTC Mode	DOCSIS 1.1/2.0 CMs with Single US/DS	DOCSIS 1.0 CMs with Single US/DS
Upstream (US)	DBC	DCC	DCC	UCC

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

Using DBC for DOCSIS 3.0 Load Balancing Movement

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

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

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

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

Using DBC to Change the Receive Channel Set

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

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

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

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

Using DBC to Change the Transmit Channel Set

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

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

Using DBC to Change the Downstream ID

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

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

Using DBC to Change the Security Association for Encrypting Downstream Traffic

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

Using DBC to Change the Service Flow SID Cluster Assignments

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

Note Multiple actions can occur within a single DBC message.

Benefits of Load Balancing

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

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

Exclude Cable Modems from Load Balancing Groups

Load Balancing Process

The load balancing process has two phases.

- Assignment phase.

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

- Balancing phase.

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

Excluding Cable Modems from Load Balancing

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

- The **assignment** option:

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

- The **static** option:

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

- The **enforce** option:

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

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

- The **strict** option:

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

How to Configure Load Balancing

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

Enabling Single Channel Load Balancing

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

Configuring Dynamic Bonding Change for DOCSIS 3.0 Static Load Balancing

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

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

Before you begin

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

Excluding Cable Modems from a Load Balancing Group

This configuration is optional. This section describes how to exclude a particular cable modem, or all cable modems from a particular vendor, from participating in static or dynamic load balancing operations, and

optionally marking the modems for passive load balancing. This task is optional, because, by default, cable modems on an interface participate in whatever load balancing operations have been configured.

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

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

Support for Excluding Old Devices

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

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

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

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

Procedure

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

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

Distributing Downstream Load Balancing with Upstream Load Balancing

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

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

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

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

Procedure

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

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

How to Configure Dynamic Channel Change for Load Balancing

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

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

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

Configuring Dynamic Channel Change for Load Balancing

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

SUMMARY STEPS

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

DETAILED STEPS

Procedure

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

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

	Command or Action	Purpose

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

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

What to do next

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

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

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

Verifying Load Balancing Operations

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

Procedure

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

Example

This example shows the result of load balancing operations.

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

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

Current load:

DOCSIS load-balancing load
Interface           State   Group      Utilization     Rsvd NBCM  WB/UB Weight
                                                           Total Total
In8/0/0:0(411 MHz)  initial 1          0%(0%/0%)       0%   0     11    37
In8/0/0:0(411 MHz)  initial 2147631104 0%(0%/0%)       0%   0     11    37
Us8/0/0:0           initial 1          0%              0%   0     31    30.7
Us8/0/0:0           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:1           initial 1          0%              0%   0     31    30.7
Us8/0/0:1           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 1          0%              0%   0     31    30.7
Us8/0/0:3           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:3           initial 1          0%              0%   0     31    30.7
In8/0/0:4(435 MHz)  up      2147635201 0%(0%/0%)       0%   48    11    37
Us8/0/1:0           up      2147635201 0%              0%   15    0     30.7
Us8/0/1:1           up      2147635201 0%              0%   11    0     30.7
Us8/0/1:2           up      2147635201 0%              0%   11    0     30.7
Us8/0/1:3           up      2147635201 0%              0%   11    0     30.7
In8/0/0:8(459 MHz)  initial 1          0%(0%/0%)       0%   0     9     37
In8/0/0:8(459 MHz)  initial 2147631104 0%(0%/0%)       0%   0     9     37
Us8/0/0:0           initial 1          0%              0%   0     31    30.7
Us8/0/0:0           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:1           initial 1          0%              0%   0     31    30.7
Us8/0/0:1           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 1          0%              0%   0     31    30.7
Us8/0/0:3           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:3           initial 1          0%              0%   0     31    30.7
In8/0/0:12(483 MHz) down    2147635201 0%(0%/0%)       0%   0           0
In8/0/0:16(507 MHz) initial 2147631104 0%(0%/0%)       0%   0     11    37
In8/0/0:16(507 MHz) initial 1          0%(0%/0%)       0%   0     11    37
Us8/0/0:0           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:0           initial 1          0%              0%   0     31    30.7
Us8/0/0:1           initial 2147631104 0%              0%   0     31    30.7
```

```
Us8/0/0:1           initial 1          0%              0%   0     31    30.7
Us8/0/0:2           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:2           initial 1          0%              0%   0     31    30.7
Us8/0/0:3           initial 2147631104 0%              0%   0     31    30.7
Us8/0/0:3           initial 1          0%              0%   0     31    30.7
In8/0/0:20(531 MHz) down    2147635201 0%(0%/0%)       0%   0           0
In8/0/1:0(555 MHz)  initial 2147631618 0%(0%/0%)       0%   0     12    37
Us8/0/2:0           initial 2147631618 0%              0%   0     19    30.7
Us8/0/2:1           initial 2147631618 0%              0%   0     19    30.7
Us8/0/2:2           initial 2147631618 0%              0%   0     19    30.7
```

Troubleshooting Tips

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

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

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

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

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

Solution No action is required.

Examples

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

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

```
Router# show cable load-balance target

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

Router# show cable load-balance statistics

Statistics:

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

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

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

Router# show cable load-balance statistics

Statistics:

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

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

```
Router# show cable load-balance statistics

Statistics:

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

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

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

Router# show cable load-balance statistics

Statistics:
```

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

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

```
Router# show cable modem

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

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

Router# show cable modem

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

Configuration Examples for Load Balancing

This section provides the following configuration examples:

Example: Configuring Dynamic Channel Change for Load Balancing

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

Verify configuration:

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

Verify channel current load:

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

Verify channel overload and target:

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

Verify channel modem-list:

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

Verify QAM channel utilization:

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

Verify channel statistic movement:

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

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

```
Router# show cable load all

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

Current load:

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

Target assignments:

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

Statistics:

Target interface       State      Transfers
```

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

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

```
Router# show running configuration

Building configuration...
Current configuration : 11889 bytes
!
version 12.3
no service pad
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname Router
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$tEvV$8xICVVbFm10hx0hAB7DO90
enable password lab
!
no cable qos permission create
no cable qos permission update
cable qos permission modems
cable load-balance group 1 threshold load 75 enforce
cable load-balance group 1 threshold stability 75
cable load-balance group 1 policy ugs
cable load-balance group 1 threshold ugs 75
cable load-balance group 1 policy pcmm
cable load-balance group 1 threshold pcmm 75
no aaa new-model
ip subnet-zero
!
!
ip cef
no ip domain lookup
!
!
interface GigabitEthernet0/1
 ip address 10.14.1.130 255.255.0.0
 duplex auto
 speed auto
 media-type rj45
 no negotiation auto
!
interface GigabitEthernet0/2
```

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

```
Router# show cable load all

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

Current load:
```

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

Target assignments:

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

Statistics:

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

Pending:

Modem          Group  Source interface  Target interface     Retries
```

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

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

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

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

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

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

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

Additional References

Technical Assistance

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

Feature Information for DOCSIS Load Balancing Movements

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

Table 4: Feature Information for DOCSIS Load Balancing Groups

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