



# CHAPTER 13

## Configuring Cisco Express Forwarding

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This module contains information about Cisco Express Forwarding and describes the required and optional tasks for configuring a load-balancing scheme for Cisco Express Forwarding traffic. Load-balancing allows you to optimize resources by distributing traffic over multiple paths.

Cisco Express Forwarding is an advanced Layer 3 IP switching technology. It optimizes network performance and scalability for all kinds of networks: those that carry small amounts of traffic and those that carry large amounts of traffic in complex patterns, such as the Internet and networks characterized by intensive web-based applications or interactive sessions.

The following sections describe Cisco Express Forwarding:

- [Information About Cisco Express Forwarding, page 13-1](#)
- [Configuring Cisco Express Forwarding, page 13-6](#)
- [Configuration Examples for Configuring a Load-Balancing Scheme for Cisco Express Forwarding Traffic, page 13-11](#)

### Information About Cisco Express Forwarding

Before using Cisco Express Forwarding or distributed Cisco Express Forwarding, you should understand the following:

- [Cisco Express Forwarding Benefits—Improved Performance, Scalability, and Resilience, page 13-1](#)
- [Media Supported by Cisco Express Forwarding, page 13-2](#)
- [Main Components of Cisco Express Forwarding Operation, page 13-3](#)
- [FIB Overview, page 13-3](#)
- [Cisco Express Forwarding Adjacency Tables Overview, page 13-4](#)
- [Cisco Express Forwarding Operation Modes—Central and Distributed, page 13-5](#)

### Cisco Express Forwarding Benefits—Improved Performance, Scalability, and Resilience

Cisco Express Forwarding offers the following benefits:

- **Improved performance**—Cisco Express Forwarding is less CPU-intensive than fast switching route caching. As a result, more CPU processing power can be dedicated to Layer 3 services such as quality of service (QoS) and encryption.

- Scalability—Cisco Express Forwarding offers full switching capacity at each line card when distributed Cisco Express Forwarding mode is active. Distributed Cisco Express Forwarding is a distributed switching mechanism that scales linearly with the number of interface cards and the bandwidth installed in the router.

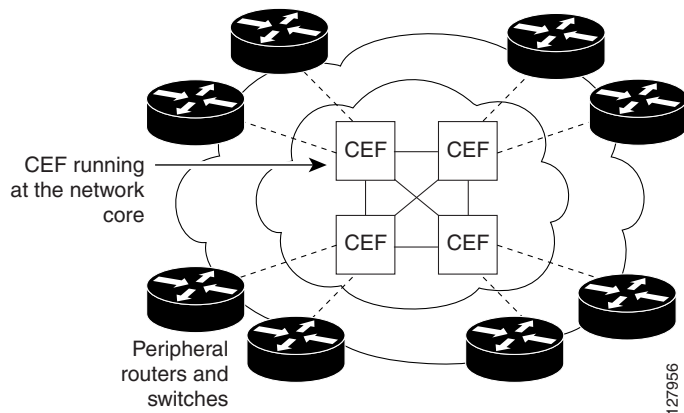
**Note**

Distributed Cisco Express Forwarding is not currently supported on the Cisco MWR 2941.

- Resilience—Cisco Express Forwarding offers an unprecedented level of switching consistency and stability in large dynamic networks. In dynamic networks, fast-switched cache entries are frequently invalidated by routing changes. These changes can cause traffic to be process-switched through use of the routing table, rather than fast switched through use of the route cache. Because the forwarding information base (FIB) lookup table contains all known routes that exist in the routing table, it eliminates the need for route cache maintenance and the steps involved with fast-switch or process-switch forwarding. Cisco Express Forwarding can switch traffic more efficiently than typical demand caching schemes.

You can use Cisco Express Forwarding in any part of a network. For example, [Figure 13-1](#) shows Cisco Express Forwarding being run on Cisco 12000 Series Internet routers at aggregation points at the core of a network where traffic levels are high and performance is critical.

**Figure 13-1 Cisco Express Forwarding Example**



In a typical high-capacity Internet service provider (ISP) environment, Cisco 12000 Series Internet routers function as aggregation devices at the core of the network and support links to Cisco 7500 series routers or other feeder devices. Cisco Express Forwarding in these platforms at the network core provides the performance and scalability that networks need to respond to continued growth and steadily increasing network traffic. Cisco Express Forwarding is a distributed switching mechanism that scales linearly with the number of interface cards and the bandwidth installed in the router.

## Media Supported by Cisco Express Forwarding

Cisco Express Forwarding currently supports the following media:

- ATM/AAL5snap, ATM/AAL5mux, and ATM/AAL5nlpid
- Ethernet
- FDDI

- Frame Relay
- High-Level Data Link Control (HDLC)
- PPP
- Spatial Reuse Protocol (SRP)
- TokenRing
- Tunnels

## Main Components of Cisco Express Forwarding Operation

Information conventionally stored in a route cache is stored in several data structures for Cisco Express Forwarding switching. The data structures provide optimized lookup for efficient packet forwarding. The two main components of Cisco Express Forwarding operation are the forwarding information base (FIB) and the adjacency tables.

The FIB is conceptually similar to a routing table or information base. A router uses this lookup table to make destination-based switching decisions during Cisco Express Forwarding operation. The FIB is updated when changes occur in the network and contains all routes known at the time. For more information, see the [“FIB Overview” section on page 13-3](#).

Adjacency tables maintain Layer 2 next-hop addresses for all FIB entries. For more information, see the [“Cisco Express Forwarding Adjacency Tables Overview” section on page 13-4](#).

This separation of the reachability information (in the Cisco Express Forwarding table) and the forwarding information (in the adjacency table), provides a number of benefits:

- The adjacency table can be built separately from the Cisco Express Forwarding table, allowing both to be built without any packets being process switched.
- The MAC header rewrite used to forward a packet is not stored in cache entries, so changes in a MAC header rewrite string do not require invalidation of cache entries.

## FIB Overview

Cisco Express Forwarding uses a FIB to make IP destination prefix-based switching decisions.

The FIB contains the prefixes from the IP routing table structured in a way that is optimized for forwarding. When routing or topology changes occur in the network, the IP routing table is updated, and those changes are reflected in the FIB. The FIB maintains next-hop address information based on the information in the IP routing table.

Because there is a one-to-one correlation between FIB entries and routing table entries, the FIB contains all known routes and eliminates the need for the route cache maintenance that is associated with switching paths such as those used in fast switching and optimum switching.

## Cisco Express Forwarding FIB and Load Balancing

Several paths can lead to a destination prefix. This occurs, for example, when a router is configured for simultaneous load balancing and redundancy. For each resolved path, the FIB contains a pointer for the adjacency corresponding to the next hop interface for that path.

## Cisco Express Forwarding Adjacency Tables Overview

A node is said to be adjacent to another node if the node can be reached with a single hop across a link layer (Layer 2). Cisco Express Forwarding stores forwarding information (outbound interface and MAC header rewrite) for adjacent nodes in a data structure called the adjacency table. Cisco Express Forwarding uses adjacency tables to prepend Layer 2 addressing information to packets. The adjacency tables maintain Layer 2 next-hop addresses for all FIB entries.

The following sections provide additional information about adjacencies:

- [Adjacency Discovery, page 13-4](#)
- [Adjacency Types That Require Special Handling, page 13-4](#)
- [Unresolved Adjacency, page 13-5](#)

### Adjacency Discovery

Each adjacency table is populated as adjacencies are discovered. Adjacencies are added to the table either through indirect manual configuration or dynamically—discovered through a mechanism like Address Resolution Protocol (ARP) or added through the use of a routing protocol, such as Border Gateway Protocol (BGP) or Open Shortest Path First (OSPF), which forms neighbor relationships. Each time an adjacency entry is created, a link-layer header for that adjacent node is computed and stored in the adjacency table.

The adjacency information is subsequently used for encapsulation during Cisco Express Forwarding switching of packets.

### Adjacency Types That Require Special Handling

In addition to adjacencies associated with next hop interfaces (host-route adjacencies), other types of adjacencies are used to expedite switching when certain exception conditions exist. Prefixes requiring exception processing or special handling are cached with one of the special adjacencies listed in [Table 13-1](#).

**Table 13-1** Adjacency Types That Require Special Handling

Packets of This Adjacency Type	Receive This Processing
Null adjacency	Packets destined for a Null0 interface are dropped. Null adjacency can be used as an effective form of access filtering.
Glean adjacency	When a router is connected to a multiaccess medium, the FIB table on the router maintains a prefix for the subnet rather than for the individual host prefixes. The subnet prefix points to a glean adjacency. A glean adjacency entry indicates that a particular next hop should be directly connected, but there is no MAC header rewrite information available. When the router needs to forward packets to a specific host on a subnet, Cisco Express Forwarding requests an ARP entry for the specific prefix, ARP sends the MAC address, and the adjacency entry for the host is built.
Punt adjacency	The router forwards packets that require special handling or packets sent by features that are not yet supported in conjunction with Cisco Express Forwarding switching paths to the next higher switching level for handling.

**Table 13-1 Adjacency Types That Require Special Handling (continued)**

Packets of This Adjacency Type	Receive This Processing
Discard adjacency	The router discards the packets.
Drop adjacency	The router drops the packets.

## Unresolved Adjacency

When a link-layer header is prepended to a packet, the FIB requires the prepended header to point to an adjacency corresponding to the next hop. If an adjacency was created by the FIB and not discovered through a mechanism such as ARP, the Layer 2 addressing information is not known and the adjacency is considered incomplete or unresolved. Once the Layer 2 information is known, the packet is forwarded to the RP, and the adjacency is determined through ARP. Thus, the adjacency is resolved.

## Cisco Express Forwarding Operation Modes—Central and Distributed

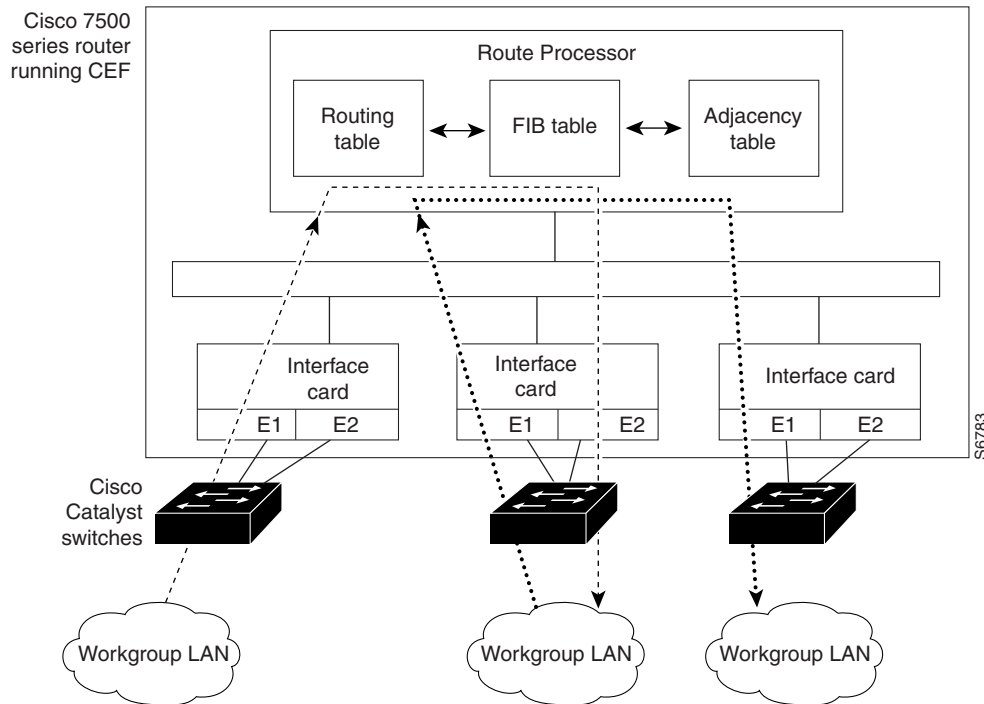
Cisco Express Forwarding can be enabled in Central or Distributed mode. The Cisco MWR 2941 supports Central mode but does not support Distributed mode.

### Central Cisco Express Forwarding Mode Operation

You can use central Cisco Express Forwarding mode when line cards are not available for Cisco Express Forwarding switching, when you need to use features not compatible with distributed Cisco Express Forwarding switching, or when you are running on a nondistributed platform. When central Cisco Express Forwarding mode is enabled, the Cisco Express Forwarding FIB and adjacency tables reside on the RP, and the RP performs the express forwarding.

[Figure 13-2](#) shows the relationship between the routing table, the FIB, and the adjacency table during central Cisco Express Forwarding mode operation. The Catalyst switches forward traffic from workgroup LANs to a Cisco 7500 series router on the enterprise backbone running central Cisco Express Forwarding. The RP performs the express forwarding.

Figure 13-2 Central Cisco Express Forwarding Mode Operation



## Configuring Cisco Express Forwarding

Cisco Express Forwarding load balancing is based on a combination of source and destination packet information; it allows you to optimize resources by distributing traffic over multiple paths.

You can configure load balancing on a per-destination or per-packet basis. Because load-balancing decisions are made on the outbound interface, load balancing must be configured on the outbound interface.



### Note

The Cisco MWR 2941 does not currently support per-packet load balancing.

The following sections describe how to configure Cisco Express Forwarding.

- [Supported Features, page 13-7](#)
- [How to Configure a Load-Balancing Scheme for Cisco Express Forwarding Traffic, page 13-7](#)
- [Enabling or Disabling Cisco Express Forwarding Per-Destination Load Balancing, page 13-8](#)
- [Selecting a Cisco Express Forwarding Load-Balancing Algorithm, page 13-8](#)
- [Selecting a Cisco Express Forwarding Load-Balancing Algorithm: Example, page 13-11](#)

## Supported Features

Cisco IOS Release 15.0(1)MR supports the following CEF features:

- [Per-Destination Load Balancing for Cisco Express Forwarding Traffic](#)
- [Load-Balancing Algorithms for Cisco Express Forwarding Traffic](#)

### Per-Destination Load Balancing for Cisco Express Forwarding Traffic

Per-destination load balancing allows the router to use multiple paths to achieve load sharing across multiple source-destination host pairs. Packets for a given source-destination host pair are guaranteed to take the same path, even if multiple paths are available. Traffic streams destined for different pairs tend to take different paths.

Per-destination load balancing is enabled by default when you enable Cisco Express Forwarding. To use per-destination load balancing, you do not perform any additional tasks once Cisco Express Forwarding is enabled. Per-destination is the load-balancing method of choice for most situations.

Because per-destination load balancing depends on the statistical distribution of traffic, load sharing becomes more effective as the number of source-destination host pairs increases.

You can use per-destination load balancing to ensure that packets for a given host pair arrive in order. All packets intended for a certain host pair are routed over the same link (or links).

Typically, you disable per-destination load balancing when you want to enable per-packet load balancing.

### Load-Balancing Algorithms for Cisco Express Forwarding Traffic

The following load-balancing algorithms are provided for use with Cisco Express Forwarding traffic. You select a load-balancing algorithm with the **ip cef load-sharing algorithm** command.

- **Universal algorithm**—The universal load-balancing algorithm allows each router on the network to make a different load sharing decision for each source-destination address pair, which resolves load-sharing imbalances. The router is set to perform universal load sharing by default.
- **Include-ports algorithm**—The include-ports algorithm allows you to use the Layer 4 source and destination ports as part of the load-balancing decision. This method benefits traffic streams running over equal cost paths that are not load shared because the majority of the traffic is between peer addresses that use different port numbers, such as Real-Time Protocol (RTP) streams.

**Note**

Cisco IOS Release 15.0(1)MR does not support the **original** or **tunnel** algorithms.

## How to Configure a Load-Balancing Scheme for Cisco Express Forwarding Traffic

Perform the following tasks to configure and fine-tune load balancing for Cisco Express Forwarding:

- [Enabling or Disabling Cisco Express Forwarding Per-Destination Load Balancing, page 13-8](#) (optional)
- [Selecting a Cisco Express Forwarding Load-Balancing Algorithm, page 13-8](#) (optional)

## Enabling or Disabling Cisco Express Forwarding Per-Destination Load Balancing

Perform this task to enable or disable Cisco Express Forwarding per-destination load balancing.


**Note**

The Cisco MWR 2941 router does not support per-packet load balancing.

Cisco Express Forwarding per-destination load balancing is enabled by default on the Cisco MWR 2941; therefore no configuration is required to use this feature.


**Note**

You cannot disable per-destination load balancing.

To display information about CEF sessions, use the **show ip cef exact-route** command.

## Selecting a Cisco Express Forwarding Load-Balancing Algorithm

Perform one of the following tasks to elect a Cisco Express Forwarding load-balancing algorithm.

- [Selecting a Tunnel Load-Balancing Algorithm for Cisco Express Forwarding Traffic, page 13-8](#)
- [Selecting an Include-Ports Layer 4 Load-Balancing Algorithm for Cisco Express Forwarding Traffic, page 13-9](#)

The router is set to perform universal load sharing by default.

## Selecting a Tunnel Load-Balancing Algorithm for Cisco Express Forwarding Traffic

Perform the following task to select a tunnel load-balancing algorithm for Cisco Express Forwarding traffic. Select the tunnel algorithm when your network environment contains only a few source and destination pairs.

	Command or Action	Purpose
Step 1	<b>enable</b>  <b>Example:</b> Router> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> <li>• Enter your password if prompted.</li> </ul>
Step 2	<b>configure terminal</b>  <b>Example:</b> Router# configure terminal	Enters global configuration mode.



	Command or Action	Purpose
Step 3	<pre>ip cef load-sharing algorithm {universal [id] include-ports {source [id]   [destination] [id]   source [id] destination [id]}}</pre> <p><b>Example:</b> Router(config)# ip cef load-sharing algorithm universal 111</p>	<p>Selects a Cisco Express Forwarding load-balancing algorithm.</p> <ul style="list-style-type: none"> <li>• The <b>universal</b> keyword sets the load-balancing algorithm to one that uses a source and destination and an ID hash.</li> <li>• The <b>include-ports source</b> keyword sets the load-balancing algorithm to one that uses the source port.</li> <li>• The <i>id</i> argument is a fixed identifier.</li> <li>• The <b>include-ports destination</b> keyword sets the load-balancing algorithm to one that uses the destination port.</li> <li>• The <b>include-ports source destination</b> keyword sets the load-balancing algorithm to one that uses the source and destination ports.</li> </ul>
Step 4	<pre>end</pre> <p><b>Example:</b> Router(config)# end</p>	Exits to privileged EXEC mode.
Step 5	<pre>show ip cef [vrf vrf-name] exact-route [platform] source-address destination-address</pre>	(Optional) Displays the exact route for a CEF session. You can use the <b>platform</b> keyword to display the exact route for a hardware session.

## Selecting an Include-Ports Layer 4 Load-Balancing Algorithm for Cisco Express Forwarding Traffic

Perform the following task to select an include-ports load-balancing algorithm for Cisco Express Forwarding traffic. Select the include-port algorithm when your network environment contains traffic running over equal-cost paths that is not load shared because the majority of the traffic is between peer addresses with different port numbers, such as RTP streams.

### Prerequisites

Your system must be using Cisco IOS Release 15.0(1)MR or a later release.

## Restrictions

The Layer 4 load-balancing algorithm applies to software switched packets.

For platforms that switch traffic using a hardware forwarding engine, the hardware load-balancing decision might be different from the software load-balancing decision for the same traffic stream. You might want to override the configured algorithm.

	Command or Action	Purpose
Step 1	<p><b>enable</b></p> <p><b>Example:</b> Router&gt; enable</p>	<p>Enables privileged EXEC mode.</p> <ul style="list-style-type: none"> <li>Enter your password if prompted.</li> </ul>
Step 2	<p><b>configure terminal</b></p> <p><b>Example:</b> Router# configure terminal</p>	<p>Enters global configuration mode.</p>
Step 3	<p><b>ip cef load-sharing algorithm</b> {<b>universal</b> [<i>id</i>] <b>include-ports</b> {<b>source</b> [<i>id</i>]   [<b>destination</b>] [<i>id</i>]   <b>source</b> [<i>id</i>] <b>destination</b> [<i>id</i>]}}</p> <p><b>Example:</b> Router(config)# ip cef load-sharing algorithm universal 111</p>	<p>Selects a Cisco Express Forwarding load-balancing algorithm.</p> <ul style="list-style-type: none"> <li>The <b>universal</b> keyword sets the load-balancing algorithm to one that uses a source and destination and an ID hash.</li> <li>The <b>include-ports source</b> keyword sets the load-balancing algorithm to one that uses the source port.</li> <li>The <i>id</i> argument is a fixed identifier.</li> <li>The <b>include-ports destination</b> keyword sets the load-balancing algorithm to one that uses the destination port.</li> <li>The <b>include-ports source destination</b> keyword sets the load-balancing algorithm to one that uses the source and destination ports.</li> </ul>
Step 4	<p><b>end</b></p> <p><b>Example:</b> Router(config)# end</p>	<p>Exits to privileged mode.</p>

# Configuration Examples for Configuring a Load-Balancing Scheme for Cisco Express Forwarding Traffic

This section provides the following examples for configuring a load-balancing scheme for Cisco Express Forwarding traffic.

## Selecting a Cisco Express Forwarding Load-Balancing Algorithm: Example

The router is set to perform universal load balancing by default.

The following examples show how to select a different Cisco Express Forwarding load-balancing algorithm:

- [Selecting a Tunnel Load-Balancing Algorithm for Cisco Express Forwarding Traffic: Example, page 13-11](#)
- [Selecting an Include-Ports Layer 4 Load-Balancing Algorithm for Cisco Express Forwarding Traffic: Example, page 13-11](#)

## Selecting a Tunnel Load-Balancing Algorithm for Cisco Express Forwarding Traffic: Example

The following example shows how to select a tunnel load-balancing algorithm for Cisco Express Forwarding:

```
configure terminal
!
ip cef load-sharing algorithm universal 111
end
```

The following example shows how to disable the tunnel load-balancing algorithm:

```
configure terminal
!
no ip cef load-sharing algorithm universal 111
end
```

## Selecting an Include-Ports Layer 4 Load-Balancing Algorithm for Cisco Express Forwarding Traffic: Example

The following example shows how to select an include-ports Layer 4 load-balancing algorithm for Cisco Express Forwarding traffic:

```
configure terminal
!
ip cef load-sharing algorithm include-ports source
end
```

This example sets up load sharing that includes the source port in the load-balancing decision.

To disable the include-ports Layer 4 load-balancing algorithm and return to the default universal mode, enter the following commands:

```
configure terminal
!
no ip cef load-sharing algorithm
end
```

