Introduction

This document clarifies how Cisco IOS® Software implements Layer 3 load balancing across multiple parallel links when using Cisco Express Forwarding.

What Is Load Balancing?

Load balancing describes the ability of a router to transmit packets to a destination IP address (also known as an IP prefix) over more than one path.

When discussing load balancing, we first need to define the following terms.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefix</td>
<td>Describes a destination IP network, such as 192.168.10.0/24. Cisco IOS adds a destination IP prefix to the routing table using information obtained from exchanging messages using a dynamic routing protocol or by manual configuration of static routes.</td>
</tr>
<tr>
<td>Path</td>
<td>Describes a valid route to reach a destination prefix. Cisco IOS assigns a cost to each path. A set of active paths to a destination prefix may have equal or unequal costs.</td>
</tr>
</tbody>
</table>
Describes a unidirectional communication flow between two IP nodes. All packets in a session use the same source and destination IP address.

For additional information, see How Does Load Balancing Work?

Before Cisco Express Forwarding - Collecting Multiple Paths or Routes

Cisco Express Forwarding uses the path information in the IP routing table to balance traffic over multiple links. For this reason, confirming proper Cisco Express Forwarding load balancing begins with confirming the contents of the IP routing table.

In the following topology, two routers, Router A and Router B, connect back-to-back over three serial interfaces with high-level data link control (HDLC) encapsulation.

<table>
<thead>
<tr>
<th>Router A</th>
<th>Router B</th>
</tr>
</thead>
<tbody>
<tr>
<td>interface Ethernet 0</td>
<td>interface Serial1</td>
</tr>
<tr>
<td>ip address 192.168.20.1 255.255.255.0</td>
<td>ip address 10.10.10.2 255.255.255.0</td>
</tr>
<tr>
<td>interface Serial1</td>
<td>clockrate 2000000</td>
</tr>
<tr>
<td>ip address 10.10.10.1 255.255.255.0</td>
<td></td>
</tr>
<tr>
<td>interface Serial2</td>
<td></td>
</tr>
<tr>
<td>ip address 20.20.20.1 255.255.255.0</td>
<td></td>
</tr>
<tr>
<td>interface Serial3</td>
<td></td>
</tr>
<tr>
<td>ip address 30.30.30.1 255.255.255.0</td>
<td></td>
</tr>
<tr>
<td>ip ospf cost 100</td>
<td></td>
</tr>
<tr>
<td>router ospf 1</td>
<td></td>
</tr>
<tr>
<td>network 10.10.10.0 0.0.0.255 area 0</td>
<td>network 10.10.10.0 0.0.0.255 area 0</td>
</tr>
<tr>
<td>network 20.20.20.0 0.0.0.255 area 0</td>
<td>network 20.20.20.0 0.0.0.255 area 0</td>
</tr>
<tr>
<td>network 30.30.30.0 0.0.0.255 area 0</td>
<td>network 30.30.30.0 0.0.0.255 area 0</td>
</tr>
<tr>
<td>network 192.168.20.0 0.0.0.255 area 0</td>
<td>maximum-paths 1</td>
</tr>
</tbody>
</table>

Let's look at how Router B selects one or more paths to reach Router A's Ethernet interface IP network 192.168.20.0.

•  By default, Open Shortest Path First (OSPF) supports four equal cost paths to a destination. In this scenario Router B is configured with maximum-paths equal to one. Hence Router B will choose only one path amongst the possible equal paths based on which one it received first. Router B starts by selecting Serial 2 as the single path to the 192.168.20.0 network. Use the show ip cef and show ip route commands to view the current path set.

RouterB# show ip cef 192.168.20.0
192.168.20.0/24, version 59, cached adjacency to Serial2
0 packets, 0 bytes
via 20.20.20.1, Serial2, 0 dependencies
next hop 20.20.20.1, Serial2
valid cached adjacency

RouterB# show ip route 192.168.20.0
Routing entry for 192.168.20.0/24
Known via "ospf 1", distance 110, metric 74, type intra area
Redistributing via ospf 1
Last update from 20.20.20.1 on Serial2, 00:03:58 ago
Routing Descriptor Blocks:
  * 20.20.20.1, from 204.204.204.1, 00:03:58 ago, via Serial2
  Route metric is 74, traffic share count is 1

•  Use the maximum-paths command under OSPF to allow more than one path to the routing table. OSPF allows only equal cost load balancing. To configure unequal cost load sharing, configure Enhanced Interior Gateway Routing Protocol (EIGRP) as your Interior Gateway Protocol (IGP). See How Does Unequal Cost Path Load Balancing (Variance) Work in OSPF and EIGRP? for further information.

RouterB(config-router)# maximum-paths 3

•  Use the show ip route command to confirm that the routing table contains two paths to 192.168.20.0.

RouterB# show ip route 192.168.20.0
Routing entry for 192.168.20.0/24
Known via "ospf 1", distance 110, metric 74, type intra area
Redistributing via ospf 1
Last update from 10.10.10.1 on Serial1, 00:00:11 ago
Routing Descriptor Blocks:
  * 20.20.20.1, from 204.204.204.1, 00:00:11 ago, via Serial2
  Route metric is 74, traffic share count is 1
  10.10.10.1, from 204.204.204.1, 00:00:11 ago, via Serial1
  Route metric is 74, traffic share count is 1

--- The route metric is 74 for both paths.

•  Although we configured OSPF to support three equal cost paths, only two active paths are displayed in the output of show ip route. We can use the show ip ospf interface command to determine the reason. Serial 3 has a higher cost than Serial 1 and Serial 2, and is therefore unequal.

RouterB# show ip ospf interface s1
Serial1 is up, line protocol is up
Internet Address 10.10.10.4/24, Area 0
Process ID 1, Router ID 100.100.100.1, Network Type POINT_TO_POINT, Cost: 64
RouterB#show ip ospf interface s2
Serial2 is up, line protocol is up
Internet Address 20.20.20.2/24, Area 0
Process ID 1, Router ID 100.100.100.1, Network Type POINT_TO_POINT, Cost: 64
RouterB#show ip ospf interface s3
Serial3 is up, line protocol is up
Internet Address 30.30.30.2/24, Area 0
Process ID 1, Router ID 100.100.100.1, Network Type POINT_TO_POINT, Cost: 100
Use the `show run` command to confirm whether Serial 3 is configured with the `ip ospf cost 100` command. Use the `no ip ospf cost 100` sub-interface command to remove it from the configuration and make the costs on all three serial links equal.

```
RouterB#show run interface s3
Building configuration...
Current configuration:
!
interface Serial3
ip address 30.30.30.2 255.255.255.0
no ip directed-broadcast
ip ospf cost 100
ip ospf interface-retry 0
```

The `show ip route` command now displays three equal cost paths to the 192.168.20.0 network.

```
RouterB#show ip route 192.168.20.0
Routing entry for 192.168.20.0/24
Known via "ospf 1", distance 110, metric 74, type intra area
Redistributing via ospf 1
Last update from 10.10.10.1 on Serial1, 00:00:01 ago
Routing Descriptor Blocks:
* 20.20.20.1, from 204.204.204.1, 00:00:01 ago, via Serial2
  Route metric is 74, traffic share count is 1
30.30.30.1, from 204.204.204.1, 00:00:01 ago, via Serial3
  Route metric is 74, traffic share count is 1
10.10.10.1, from 204.204.204.1, 00:00:01 ago, via Serial1
  Route metric is 74, traffic share count is
```

Now let’s look at how Cisco Express Forwarding load balancing uses the information in the routing table to forward packets.

Configuring Cisco Express Forwarding Load Sharing

Cisco Express Forwarding accomplishes load balancing through use of the loadshare table. As with all other load balancing solutions on Cisco routers, the load balancing decision is made on outbound interfaces. Unlike other switching methods, Cisco Express Forwarding tracks paths based on both the source and destination address of the path. To simplify this, you could say that the path is an IP session and each session is logically identified as a unique source-destination address pair.

In order to understand how the load balance takes place, you must first see how the tables relate. The Cisco Express Forwarding table points to 16 hash buckets (load share table), which point to the adjacency table for parallel paths. See the Cisco Express Forwarding Load Sharing Internal Mechanisms section for more details. Each packet to be switched is broken up into the source and destination address pair and checked against the loadshare table.

Note: There are two main types of Cisco Express Forwarding switching, per-destination and per-packet. If both types are in use on a router, each type has its own loadshare table.

Per-destination load balancing allows the router to use multiple paths to achieve load sharing. Per-destination load balancing is enabled by default when you enable Cisco Express Forwarding, and it 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 pairs increase.

Per-packet load balancing allows the router to send successive data packets over paths without regard to individual hosts or user sessions. It uses the round-robin method to determine which path each packet takes to the destination. Per-packet load balancing ensures balancing over multiple links. Path utilization with per-packet load balancing is good, but packets for a given source-destination host pair might take different paths which could cause reordering of packets. For this reason, per-packet load balancing is inappropriate for certain types of data traffic, such as VoIP, that depend on packets arriving at the destination in sequence. Use per-packet load balancing to help ensure that a path for a single source-destination pair does not become overloaded.

Use the `ip load-sharing` command to change between the per-packet and per-destination methods.

```
7200-1.3(config)#interface fast 0/0
7200-1.3(config-if)#ip load-sharing?
  per-destination  Deterministic distribution
  per-packet       Random distribution
7200-1.3(config-if)#ip load-sharing per-packet
```

Use the `show cef interface` command to confirm your changes.

```
7200-1.3#show cef interface fast 0/0
FastEthernet0/0 is up (if_number 3)
  Corresponding hwidb fast_if_number 3
  Corresponding hwidb firstsw->if_number 3
  Internet address is 172.16.81.13/24
  ICMP redirects are always sent
Per packet load-sharing is enabled
IP unicast RPF check is enabled
Inbound access list is not set
Outbound access list is not set
IP policy routing is disabled
```
Hardware idb is FastEthernet0/0
Fast switching type 1, interface type 18
IP CEF switching enabled
IP Feature Fast switching turbo vector
IP Feature CEF switching turbo vector
Input fast flags 0x0, Output fast flags 0x0
ifindex 1(1)
Slot 0 Slot unit 0 VC -1
Transmit limit accumulator 0x0 (0x0)
IP MTU 1500

Cisco Express Forwarding Load Balancing Internal Mechanisms

Let's start by breaking down the internal mechanism behind Cisco Express Forwarding load balancing.

- Each session (see the table above) is assigned to an active path.
- The session-to-path assignment is done using a hash function that takes the source and destination IP addresses and, in recent releases of Cisco IOS, a unique hash ID that randomizes the assignment across the end-to-end path.
- Active paths are assigned internally to several of 16 hash buckets. The path-to-bucket assignment varies with the type of load balancing and the number of active paths.
- The result of the hash function is used to pick one of the enabled buckets, and thus which path to use for the session.
- For all sessions being forwarded by the router, each active path carries the same number of sessions.

Let's look at an example of these Cisco Express Forwarding internals.
1. Use the `maximum-paths` command to reduce to two the number of active paths for the destination prefix.

   ```
   RouterB(config)#router ospf 1
   RouterB(config-router)#maximum-paths 2
   ```

2. Use the `show ip cef {prefix} internal` command to view the path-to-bucket assignment.

   ```
   RouterB#show ip cef 192.168.20.0 internal
   192.168.20.0/24, version 66, per-destination sharing
   0 packets, 0 bytes
   via 20.20.20.1, Serial2, 0 dependencies
   traffic share 1
   next hop 20.20.20.1, Serial2
   valid adjacency
   via 30.30.30.1, Serial3, 0 dependencies
   traffic share 1
   next hop 30.30.30.1, Serial3
   valid adjacency
   0 packets, 0 bytes switched through the prefix
   Load distribution: 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 (refcount 1)
   !!! The load distribution line summarizes how each path is assigned to the hash buckets.
   ```

<table>
<thead>
<tr>
<th>Hash</th>
<th>OK</th>
<th>Interface</th>
<th>Address</th>
<th>Packets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
</tbody>
</table>

The 16 hash buckets are set up depending on the type of load balancing and the number of active paths. The simple case is for an even number of paths. The 16 buckets are evenly filled with the active paths. If 16 isn't divisible by the number of active paths, the last few buckets that represent the remainder are disabled. The following table shows how the hash buckets look for two and three active paths.

<table>
<thead>
<tr>
<th>Bucket/Paths</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

In the following example, we have three paths to the destination. Notice how Cisco Express Forwarding has removed hash bucket 16 and how the three serial links are assigned evenly to hash buckets 1 through 15.

   ```
   RouterB#show ip cef 192.168.20.0 interface
   192.168.20.0/24, version 64, per-destination sharing
   0 packets, 0 bytes
   via 20.20.20.1, Serial2, 0 dependencies
   traffic share 1
   next hop 20.20.20.1, Serial2
   valid adjacency
   via 30.30.30.1, Serial3, 0 dependencies
   traffic share 1
   next hop 30.30.30.1, Serial3
   valid adjacency
   via 10.10.10.1, Serial1, 0 dependencies
   ```
traffic share 1
next hop 10.10.10.1, Serial1
valid adjacency
0 packets, 0 bytes switched through the prefix
Load distribution: 0 1 2 0 1 2 0 1 2 0 1 2 (refcount 1)
!--- The active paths are assigned to hash buckets in a
!--- round-robin pattern.

<table>
<thead>
<tr>
<th>Hash</th>
<th>OK</th>
<th>Interface</th>
<th>Address</th>
<th>Packets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>Serial12</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>Serial13</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>Serial11</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>Serial12</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>Serial13</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Y</td>
<td>Serial11</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Y</td>
<td>Serial12</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Y</td>
<td>Serial13</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Y</td>
<td>Serial11</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Y</td>
<td>Serial12</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Y</td>
<td>Serial13</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Y</td>
<td>Serial11</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>Y</td>
<td>Serial12</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Y</td>
<td>Serial13</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>Serial11</td>
<td>point2point</td>
<td>0</td>
</tr>
</tbody>
</table>

!--- Hash bucket 16 has been removed.

Note: Although they select a single path for a destination, the Cisco Express Forwarding per-destination and fast switching mechanisms differ in how they select that path. Cisco Express Forwarding considers both the source and destination IP addresses, while fast switching considers only the destination IP address.

Verifying Cisco Express Forwarding Load Balancing

Use the following steps to verify Cisco Express Forwarding load balancing on your router.

1. Confirm that Cisco Express Forwarding is enabled globally on the router.

   S3-4K-2# show ip cef
   %CEF not running

   Prefix Next Hop Interface
   !--- This output shows Cisco Express Forwarding is not enabled.
   !--- Use ip cef command in global configuration to enable it.

2. Confirm per-packet or per-destination switching is enabled on the particular outbound interfaces. The default is per-destination.

   RouterA# show cef interface s1
   Serial1 is up (if_number 3)
   Internet address is 10.10.10.1/24
   ICMP redirects are always sent
   Per packet loadbalancing is disabled
   IP unicast RPF check is disabled
   Inbound access list is not set
   Outbound access list is not set
   Interface is marked as point to point interface
   Hardware idb is Serial1
   Fast switching type 4, interface type 40
   IP CEF switching enabled
   !--- Cisco Express Forwarding is enabled on the interface.

   IP CEF Fast switching turbo vector
   Input fast flags 0x0, Output fast flags 0x0
   ifindex 5(5)
   Slot 0 Slot unit 1 VC -1
   Transmit limit accumulator 0x0 (0x0)
   IP MTU 1500

3. Confirm that the routing table and the Cisco Express Forwarding Table contain all parallel paths using the show ip route command.

   RouterB# show ip route 192.168.20.0
   Routing entry for 192.168.20.0/32, 1 known subnets
   0 192.168.20.1 [110/65] via 20.20.20.1, 00:06:54, Serial1
   [110/65] via 10.10.10.1, 00:06:54, Serial2
   [110/65] via 30.30.30.1, 00:06:54, Serial3

4. Check the Cisco Express Forwarding FIB using the show ip cef command.

   RouterB# show ip cef 192.168.20.0
   192.168.20.0/24, version 16, per-destination sharing
   0 packets, 0 bytes
   via 30.30.30.1, Serial3, 0 dependencies
traffic share 1
next hop 30.30.30.1, Serial3
valid adjacency
via 20.20.20.1, Serial2, 0 dependencies
traffic share 1
next hop 20.20.20.1, Serial2
valid adjacency
via 10.10.10.1, Serial1, 0 dependencies
traffic share 1
next hop 10.10.10.1, Serial1
valid adjacency
0 packets, 0 bytes switched through the prefix
tmstats: external 0 packets, 0 bytes
internal 0 packets, 0 bytes

RouterB# show ip cef 192.168.20.0 internal
192.168.20.0/24, version 18, per-destination sharing
0 packets, 0 bytes
via 30.30.30.1, Serial3, 0 dependencies
traffic share 1
next hop 30.30.30.1, Serial3
valid adjacency
via 20.20.20.1, Serial2, 0 dependencies
traffic share 1
next hop 20.20.20.1, Serial2
valid adjacency
via 10.10.10.1, Serial1, 0 dependencies
traffic share 1
next hop 10.10.10.1, Serial1
valid adjacency
0 packets, 0 bytes switched through the prefix
tmstats: external 0 packets, 0 bytes
internal 0 packets, 0 bytes

Load distribution: 0 1 2 0 1 2 0 1 2 0 1 2 (refcount 1)
Hash OK Interface Address Packets
1 Y Serial3 point2point 0
2 Y Serial2 point2point 0
3 Y Serial1 point2point 0
4 Y Serial3 point2point 0
5 Y Serial2 point2point 0
6 Y Serial1 point2point 0
7 Y Serial3 point2point 0
8 Y Serial2 point2point 0
9 Y Serial1 point2point 0
10 Y Serial3 point2point 0
11 Y Serial2 point2point 0
12 Y Serial1 point2point 0
13 Y Serial3 point2point 0
14 Y Serial2 point2point 0
15 Y Serial1 point2point 0

Note: The loadshare table above shows load distribution 0 1 2 0 1 2 . . . , and traffic share is 1 for each route. This means an equal cost per-destination load sharing among three equal cost routes.

5. Check Cisco Express Forwarding adjacencies.

6. Confirm the expected Cisco Express Forwarding load-balancing mechanism is configured on all the outbound interfaces.

RouterB# show adjacency detail
Protocol Interface Address
IP Serial1 point2point(11)
0 packets, 0 bytes
0F000800
CEF expires: 00:02:31
refresh: 00:00:31
IP Serial2 point2point(11)
0 packets, 0 bytes
0F000800
CEF expires: 00:02:31
refresh: 00:00:31
IP Serial3 point2point(11)
0 packets, 0 bytes
0F000800
CEF expires: 00:02:31
refresh: 00:00:31

6. Confirm the expected Cisco Express Forwarding load-balancing mechanism is configured on all the outbound interfaces.

RouterB# show ip cef 192.168.20.0
192.168.20.0/24, version 89, per-destination sharing
0 packets, 0 bytes
via 10.10.10.1, Serial1, 0 dependencies
traffic share 1
next hop 10.10.10.1, Serial1
valid adjacency

7. Enable hash bucket accounting to collect statistics to better understand Cisco Express Forwarding patterns in your network. For example, you might want to collect information such as the number of packets and bytes switched to a destination or the number of packets switched through a destination. Use the following command:
The following steps describe how Cisco Express Forwarding load-balancing information updates after a change in the number of active paths to a destination prefix. The selected bucket may or may not be the same as the one used previously.

After a change in the routing table, Cisco Express Forwarding deletes and then rebuilds the load balancing structures that assign active paths to the hash buckets. During the rebuilding process, some packets may be lost, and the output of the `show ip cef {prefix} internal` command indicates load sharing information due for deletion.

Note: Per-destination load sharing becomes more effective as the number of source-destination pairs increases.

### Load Sharing after a Link Change

When a routing table change adjusts the number of active paths to a destination, Cisco Express Forwarding updates the load balance structures that assign active paths to the hash buckets. Depending on the statistical distribution of traffic and becomes more effective as the number of source-destination pairs increase.

### Load Sharing Information Due for Deletion

After a change in the routing table, Cisco Express Forwarding deletes and then rebuilds the load balancing structures that assign active paths to the hash buckets. During the rebuilding process, some packets may be lost, and the `show ip cef {prefix} internal` command indicates load sharing information due for deletion.

```
Router(config)# ip cef accounting load-balance-hash
```

Verify the packet flow by observing the values under the Packet field.

```
Router# show ip cef 192.168.20.0 internal

Load distribution: 0 1 2 0 1 2 0 1 2 0 1 2 (refcount 1)

<table>
<thead>
<tr>
<th>Hash</th>
<th>OK</th>
<th>Interface</th>
<th>Address</th>
<th>Packets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>Serial1</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>Serial1</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>35</td>
</tr>
<tr>
<td>6</td>
<td>Y</td>
<td>Serial1</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>Y</td>
<td>Serial1</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Y</td>
<td>Serial1</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>Y</td>
<td>Serial3</td>
<td>point2point</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Y</td>
<td>Serial2</td>
<td>point2point</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>Y</td>
<td>Serial1</td>
<td>point2point</td>
<td>0</td>
</tr>
</tbody>
</table>

125 packets flowed through Serial 2. If you use `ping` to generate traffic, ensure that `ping` packets must transit the Cisco Express Forwarding-switched router. In other words, `ping` packets must enter from one Cisco Express Forwarding-switched interface, be Cisco Express Forwarding-switched and leave from another Cisco Express Forwarding-switched interface.

Note: Per-destination load sharing becomes more effective as the number of source-destination pairs increases.

### Load Sharing

With Cisco Express Forwarding per-destination load balancing, you can determine to which path a session is assigned with the following command. Add the keyword `internal` to display which hash bucket is used.

```
show ip cef exact-route {source-ip-address} {dest-ip-address} [internal]
```

```
Router# show ip cef exact-route 40.50.50.2 192.168.20.1 internal

Hash OK Interface Address Packets 
1 Y Serial1 point2point 0 
2 Y Serial2 point2point 2 
3 Y Serial3 point2point 0 
4 Y Serial1 point2point 0 
5 Y Serial2 point2point 35 
6 Y Serial1 point2point 0 
7 Y Serial3 point2point 0 
8 Y Serial2 point2point 60 
9 Y Serial1 point2point 0 
10 Y Serial3 point2point 0 
11 Y Serial2 point2point 0 
12 Y Serial1 point2point 0 
13 Y Serial3 point2point 0 
14 Y Serial2 point2point 30 
15 Y Serial1 point2point 0
```

9. With Cisco Express Forwarding per-destination load balancing, you can determine to which path a session is assigned with the following command. Add the keyword `internal` to display which hash bucket is used.

```
show ip cef exact-route {source-ip-address} {dest-ip-address} [internal]
```

```
Router# show ip cef exact-route 40.50.50.2 192.168.20.1 internal

50.50.50.2 -> 192.168.20.1 : Serial9/0 (next hop 20.20.20.1)
Bucket 4 from 15, total 3 paths
```

```
Router# show ip cef exact-route 5.5.5.1 192.168.20.1 internal

5.5.5.1 -> 192.168.20.1 : Serial9/0 (next hop 20.20.20.1)
Bucket 7 from 15, total 3 paths
```

```
Router# show ip cef exact-route 6.6.6.1 192.168.20.1 internal

6.6.6.1 -> 192.168.20.1 : Serial9/0 (next hop 20.20.20.1)
Bucket 7 from 15, total 3 paths
```

```
Router# show ip cef exact-route 8.8.8.1 192.168.20.1 internal

8.8.8.1 -> 192.168.20.1 : Serial9/0 (next hop 20.20.20.1)
Bucket 13 from 15, total 3 paths
```

10. If the output appears uneven, consider the following:

- The number of unique source and destination address pairs or sessions traversing the parallel links.
- The number and size of packets in each session. Does one session have a large number of packets? Per-destination load balancing depends on the statistical distribution of traffic and becomes more effective as the number of source-destination pairs increase.

Load Sharing Information Due for Deletion

After a change in the routing table, Cisco Express Forwarding deletes and then rebuilds the load balancing structures that assign active paths to the hash buckets. During the rebuilding process, some packets may be lost, and the `show ip cef {prefix} internal` command indicates load sharing information due for deletion.

```
router# show ip cef 10.10.128.0 int
```

```
10.10.128.0/28, version 63, per-destination sharing
0 packets, 0 bytes
via 10.8.0.31, 0 dependencies, recursive
next hop 10.8.2.49, POS0/0
valid adjacency
```

```
Load sharing information due for deletion
```
Changes implemented through Cisco bug ID CSCdm87127 minimize packet loss during a change in the number of active paths for the default 0.0.0.0 route. Specifically, Cisco Express Forwarding now allocates an FIB entry with space for the maximum possible active paths for this route.

Known Issues

Cisco Express Forwarding load balancing is not equal on four paths. For further details, refer to CSCdm87756 (registered customers only).

In Cisco IOS versions earlier than 12.0(16)B, entering the show ip cef exact-route command may cause the Route Processor (RP) in a Cisco 12000 series Internet router or a Cisco 7500/RSP series router to reload. This situation occurs when the destination prefix is recursive and the router is load-sharing to the next hop. For further details refer to CSCdt80914 (registered customers only), which resolves this issue.

In 6500 series platform CEF per-packet load-balancing is not supported. This is due to the hardware limitation and it is only possible to have per-destination load balancing currently. Therefore the only option is to use Distributed Multilink Point-to-Point Protocol (dMLPPP) or Layer 4 flow load-sharing.

Hardware Support for Cisco Express Forwarding Load Balancing

Cisco Express Forwarding per-packet load balancing originally was supported in platforms that use software-based forwarding. Such platforms include the 2600, 3600, and 7200 series. Per-packet load balancing is now supported in hardware using Parallel Express Forwarding (PXF) on the 7200 series with a NSSE-1 and 10600 series. On the Catalyst 6500 series, the Cisco IOS Cisco Express Forwarding ip load-sharing per-packet, ip cef accounting per-prefix, and ip cef accounting non-recursive commands on the MSFC2 apply only to traffic that is Cisco Express Forwarding-switched in software on the MSFC2. The commands do not affect traffic that is hardware Layer 3-switched on the PFC2 or on DFC-equipped switching modules. See Configuring IP Unicast Layer 3 Switching on Supervisor Engine 2 for more information.

Note: A Cisco 7300 router with an NSE-100 processor card does not support CEF per-packet load balancing in PXF. The PXF only supports per-destination load balancing. However, it appeared that they have support because the configuration commands were available in the CLI of the router. This is corrected and recorded in Cisco bug ID CSCdx63389.

On the 12000 series, per-packet load balancing is available on all Layer 3 forwarding engines except engines 3 and 4. Each line card makes independent forwarding decisions. To view the exact route for each IP flow, use the exec slot X show ip hardware-cef exact-route src dst command on line cards which use hardware-based Cisco Express Forwarding tables.

Related Information

- Cisco Express Forwarding Configuration Guide, Release 12.1
- Cisco Express Forwarding
- Load Balancing with Cisco Express Forwarding
- IP Routing Support
- Technical Support & Documentation - Cisco Systems

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