



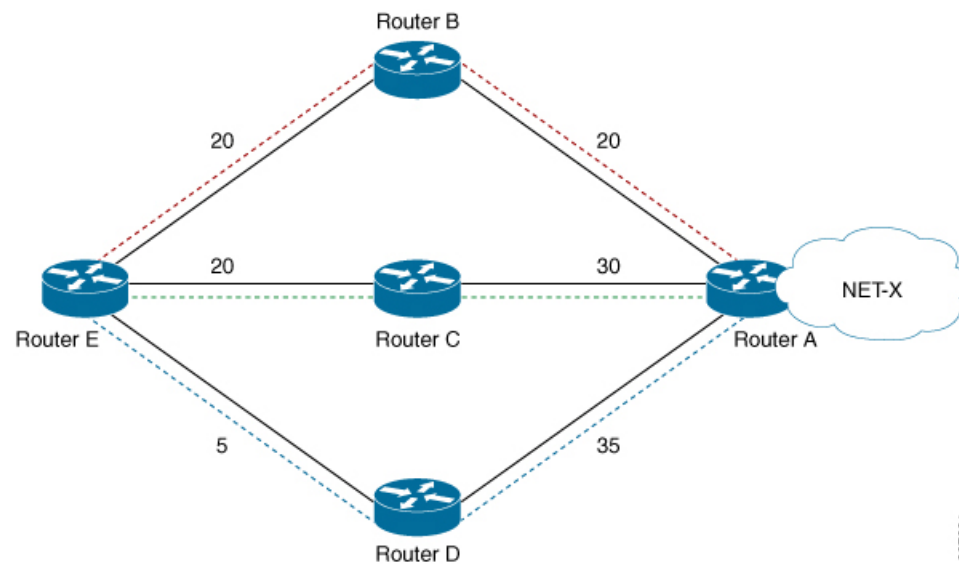
Implementing UCMP

The unequal cost multipath (UCMP) load-balancing provides the capability to load balance traffic proportionally across multiple paths, with different cost. Generally, higher bandwidth paths have lower Interior Gateway Protocol (IGP) metrics configured, so that they form the shortest IGP paths.

With the UCMP load-balancing enabled, protocols can use even lower bandwidth paths or higher cost paths for traffic, and can install these paths to the forwarding information base (FIB). These protocols still install multiple paths to the same destination in FIB, but each path will have a 'load metric/weight' associated with it. FIB uses this load metric/weight to decide the amount of traffic that needs to be sent on a higher bandwidth path and the amount of traffic that needs to be sent on a lower bandwidth path.

In the following example, there are 3 paths to get to Network X as follows:

Figure 1: Topology for UCMP



Paths	Cost from Router E to Net -X
E-B-A	40
E-C-A	50
E-D-A	40

IGP selects the lowest path links, i.e E-B-A and E-D-A. The path E-C-A is not considered for load balancing because of higher cost. The lowest path link E-D (5) is not a tie breaker, as the end to end cost to the Network X is considered.

More than 32 ECMP and UCMP paths are not supported for these features:

- LI
- GRE
- BVI
- NetFlow
- Satellite
- MCAST
- SPAN
- PWHE
- ABF
- P2MP
- MVPN
- VPLS
- L2TPv3
- LISP
- VIDMON
- PBR

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ECMP vs. UCMP Load Balancing

Load balancing is a forwarding mechanism that distributes traffic over multiple links based on certain parameters. Equal Cost Multi Path (ECMP) is a forwarding mechanism for routing packets along multiple paths of equal cost with the goal to achieve almost equally distributed link load sharing. This significantly impacts a router's next-hop (path) decision.

In ECMP, it is assumed that all links available are of similar speed which inherently means that the hash values that are computed are equally shared over the multiple paths available.

For instance, if we have two paths available, the buckets (which in the end identify the links to be chosen) will be assigned in a 50% / 50% loadsharing. This can be problematic when one path is say a 10G link and the other link is a 1G link. In this case, you probably want to assign a (near) 90/10 type deviation, but considering that BGP is not bandwidth aware, the 10G path is still chosen 50% of the time as much as the 1G link. In this scenario, not all paths are of equal cost path.

What UCMP does in this case is apply a *weight* to a path which means that we are giving more hash buckets to one path that has a higher weight. The weight applied is *static* in the sense that it is derived by the DMZ bandwidth extended community either assigned to a peer or as configured via the Route Policy Language (RPL) route manipulation functionality.

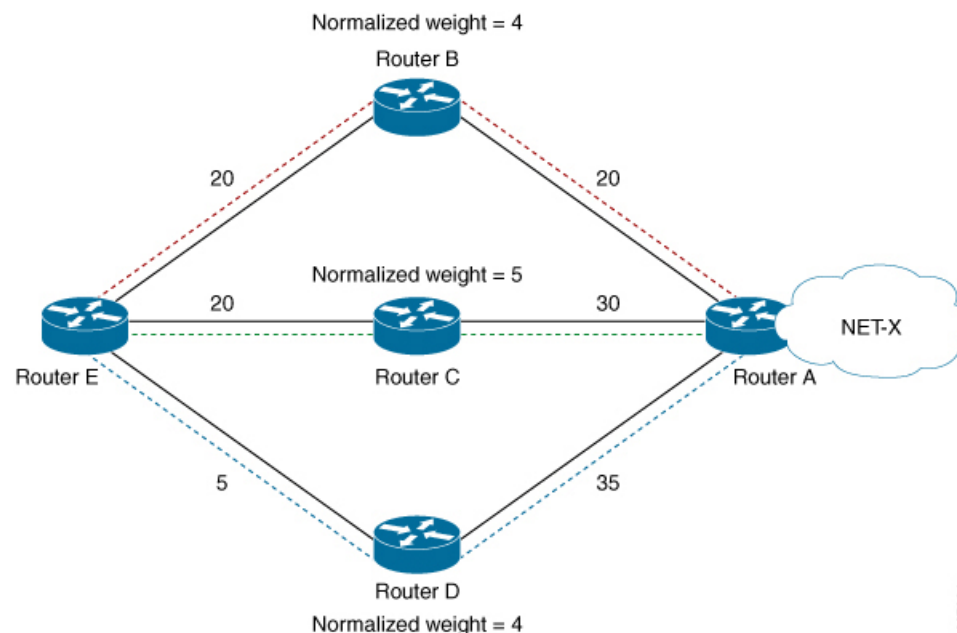
In general, a routing protocol decides a best path to a destination based on a metric. This metric is generally driven by the bandwidth of the circuit. When we have 3 paths available, say 1G/10G/100G, routing protocols generally discard the 1G/10G paths available. In defined cases, one may want to spread the load over the circuits based on the load they can carry. In this example, one may want to distribute traffic in a 1%/10%/89% fashion over the 1G/10G/100G paths available.

UCMP Minimum Integer Ratio

The UCMP Minimum Integer Ratio feature saves hardware resources when programming UCMP, by using optimized number of buckets.

To calculate the UCMP minimum integer ratio, find the greatest common divisor (GCD) and divide all the calculated normalized weights.

In the following Figure, we have three configured weights 40, 50, and 40, with GCD as 10. To calculate the normalized weight, divide the configured weight by GCD. In this example, we need to divide 40 by 10, 50 by 10, and 40 by 10, which is 4, 5, and 4 respectively. Therefore 4, 5, and 4 are the new normalized weights.



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New normalized weights are: $40/10 = 4$, $50/10 = 5$, and $40/10 = 4$

If GCD is 1, then Normalized Weight = (Path weight/Total weight) * Maximum bucket size

Configuring OSPF UCMP with Cost

The following example shows how to configure UCMP under OSPF default vrf with IPv4. The same can be done with IPv6.

R5 is advertising its two loopbacks with IP addresses 10.0.0.1 and 192.168.0.1 into OSPF. R1 learns these loopbacks through three directly connected next hops, R2, R3, and R4.

The metrics are as follows:

- Total link metric between R1 and R5 via R2 is 40.
- Total link metric between R1 and R5 via R3 is 50
- Total link metric between R1 and R5 via R4 is 40

Before

Based on the metrics, R1 installs two ECMP paths via R2 and R4 only. Path via R5 is not installed due to higher cost.

```
Router #show route 10.0.0.1/32
```

```
Routing entry for 10.0.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 19:09:21.399 for 03:57:18
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41
  No advertising protos.
```

```
Router #show route 192.168.0.1/32
```

```
Routing entry for 192.168.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 23:06:05.258 for 00:00:41
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41
```

Configuration

```
router ospf Procl
ucmp
```

Example

```
Router (config)#router ospf 0
Router (config-ospf)#ucmp
Router (config-ospf)#commit
```

Verification

Verify the installation of three paths by R1, to reach each of the R5 loopback IP addresses.

```
Router #show route 10.0.0.1/32
Routing entry for 10.0.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 23:15:13.495 for 00:02:01
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41, Wt is 4294967295
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41, Wt is 4294967295
    10.1.3.2, from 10.0.0.1, via GigabitEthernet0/0/0/1
      Route metric is 41, Wt is 3452816845
  No advertising protos.

Router #show ospf routes 10.0.0.1/32
Topology Table for ospf 0 with ID 172.16.0.1:

Codes: O - Intra area, O IA - Inter area
       O E1 - External type 1, O E2 - External type 2
       O N1 - NSSA external type 1, O N2 - NSSA external type 2

O      10.0.0.1/32, metric 41
       10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2, ifIndex 8, path-id 1
       10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0, ifIndex 6, path-id 2
       10.1.3.2, from 10.0.0.1, via GigabitEthernet0/0/0/1, path-id 3, (UCMP, metric 51)

Router #show route 192.168.0.1/32
Routing entry for 192.168.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 23:15:13.495 for 00:02:06
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41, Wt is 4294967295
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41, Wt is 4294967295
    10.1.3.2, from 10.0.0.1, via GigabitEthernet0/0/0/1
      Route metric is 41, Wt is 3452816845
  No advertising protos.

Router #show ospf routes 192.168.0.1/32
Topology Table for ospf 0 with ID 172.16.0.1:

Codes: O - Intra area, O IA - Inter area
       O E1 - External type 1, O E2 - External type 2
       O N1 - NSSA external type 1, O N2 - NSSA external type 2

O      192.168.0.1/32, metric 41
       10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2, ifIndex 8, path-id 1
       10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0, ifIndex 6, path-id 2
       10.1.3.2, from 10.0.0.1, via GigabitEthernet0/0/0/1, path-id 3, (UCMP, metric 51)
```

Configuring OSPF UCMP with Cost Only for Certain Prefixes

The following example shows how to configure UCMP under OSPF default VRF with IPv4 only for prefixes that match an access list. Ensure to follow the same procedure with IPv6.

R5 is advertising its two loopbacks with IP addresses 10.0.0.1 and 192.168.0.1 into OSPF. R1 learns these loopbacks via three directly connected next hops, R2, R3, and R4.

The metrics are as follows:

- Total link metric between R1 and R5 via R2 is 40
- Total link metric between R1 and R5 via R3 is 50
- Total link metric between R1 and R5 via R4 is 40

Before

Based on the metrics, R1 installs two ECMP paths via R2 and R4 only. Path via R5 is not installed due to higher cost.

```
Router #show route 10.0.0.1/32

Routing entry for 10.0.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 19:09:21.399 for 03:57:18
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41
  No advertising protos.

Router #show route 192.168.0.1/32

Routing entry for 192.168.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 23:06:05.258 for 00:00:41
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41
```

Configuration

```
router ospf Procl
ucmp prefix-list Acl1
```



Note OSPF UCMP prefix-list configuration should refer to an access list, not a prefix-set.

Example

Install UCMP only for prefix 192.168.0.1/32. Other prefixes will not be affected by the UCMP change.

```
Router (config)#ipv4 access-list foo
Router (config-ipv4-acl)#10 permit ipv4 host 192.168.0.1 any

Router (config)#router ospf 0
Router (config-ospf)#ucmp prefix-list foo
Router (config-ospf)#commit
```

Verification

Verify that R1 installs three paths to reach R5 loopback IP address 192.168.0.1/32.

```

Router #show route 192.168.0.1/32

Routing entry for 192.168.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 23:25:11.997 for 00:15:56
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41, Wt is 4294967295
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41, Wt is 4294967295
    10.1.3.2, from 10.0.0.1, via GigabitEthernet0/0/0/1
      Route metric is 41, Wt is 3452816845
  No advertising protos.

Router #show ospf routes 192.168.0.1/32

Topology Table for ospf 0 with ID 172.16.0.1:

Codes: O - Intra area, O IA - Inter area
       O E1 - External type 1, O E2 - External type 2
       O N1 - NSSA external type 1, O N2 - NSSA external type 2

O      192.168.0.1/32, metric 41
       10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2, ifIndex 8, path-id 1
       10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0, ifIndex 6, path-id 2
       10.1.3.2, from 10.0.0.1, via GigabitEthernet0/0/0/1, path-id 3, (UCMP, metric 51)

Router #show cef 192.168.0.1/32

192.168.0.1/32, version 186, internal 0x1000001 0x10 (ptr 0xe2ecc50) [1], 0x400 (0xe489c30),
0x0 (0x0)
Updated Aug  3 23:43:10.261
  remote adjacency to GigabitEthernet0/0/0/0
Prefix Len 32, traffic index 0, precedence n/a, priority 1
  gateway array (0xe2f2060) reference count 2, flags 0x0, source rib (7), 0 backups
    [3 type 3 flags 0x8401 (0xe3a2ca8) ext 0x0 (0x0)]
  LW-LDI[type=3, refc=1, ptr=0xe489c30, sh-ldi=0xe3a2ca8]
  gateway array update type-time 1 Aug  3 23:43:10.261
LDI Update time Aug  3 23:43:10.261
LW-LDI-TS Aug  3 23:43:10.261
  via 10.1.2.2/32, GigabitEthernet0/0/0/0, 6 dependencies, weight 4294967295, class 0
[flags 0x0]
  path-idx 0 NHID 0x0 [0xf4270b0 0x0]
  next hop 10.1.2.2/32
  remote adjacency
  via 10.1.4.2/32, GigabitEthernet0/0/0/2, 6 dependencies, weight 4294967295, class 0
[flags 0x0]
  path-idx 1 NHID 0x0 [0xf4271e0 0x0]
  next hop 10.1.4.2/32
  remote adjacency
  via 10.1.3.2/32, GigabitEthernet0/0/0/1, 6 dependencies, weight 3452816845, class 0
[flags 0x0]
  path-idx 2 NHID 0x0 [0xf427148 0x0]
  next hop 10.1.3.2/32
  remote adjacency

Weight distribution:
slot 0, weight 4294967295, normalized_weight 11, class 0
slot 1, weight 4294967295, normalized_weight 11, class 0
slot 2, weight 3452816845, normalized_weight 9, class 0
Load distribution: 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 (refcount
3)

```

Hash	OK	Interface	Address
0	Y	GigabitEthernet0/0/0/0	remote
1	Y	GigabitEthernet0/0/0/0	remote
2	Y	GigabitEthernet0/0/0/0	remote
3	Y	GigabitEthernet0/0/0/0	remote
4	Y	GigabitEthernet0/0/0/0	remote
5	Y	GigabitEthernet0/0/0/0	remote
6	Y	GigabitEthernet0/0/0/0	remote
7	Y	GigabitEthernet0/0/0/0	remote
8	Y	GigabitEthernet0/0/0/0	remote
9	Y	GigabitEthernet0/0/0/0	remote
10	Y	GigabitEthernet0/0/0/0	remote
11	Y	GigabitEthernet0/0/0/2	remote
12	Y	GigabitEthernet0/0/0/2	remote
13	Y	GigabitEthernet0/0/0/2	remote
14	Y	GigabitEthernet0/0/0/2	remote
15	Y	GigabitEthernet0/0/0/2	remote
16	Y	GigabitEthernet0/0/0/2	remote
17	Y	GigabitEthernet0/0/0/2	remote
18	Y	GigabitEthernet0/0/0/2	remote
19	Y	GigabitEthernet0/0/0/2	remote
20	Y	GigabitEthernet0/0/0/2	remote
21	Y	GigabitEthernet0/0/0/2	remote
22	Y	GigabitEthernet0/0/0/1	remote
23	Y	GigabitEthernet0/0/0/1	remote
24	Y	GigabitEthernet0/0/0/1	remote
25	Y	GigabitEthernet0/0/0/1	remote
26	Y	GigabitEthernet0/0/0/1	remote
27	Y	GigabitEthernet0/0/0/1	remote
28	Y	GigabitEthernet0/0/0/1	remote
29	Y	GigabitEthernet0/0/0/1	remote
30	Y	GigabitEthernet0/0/0/1	remote

Verify the installation of only two paths by R1, to reach R5 loopback IP address 10.0.0.1/32.

```
Router #show route 10.0.0.1/32
```

```
Routing entry for 10.0.0.1/32
  Known via "ospf 0", distance 110, metric 41, type intra area
  Installed Aug  3 23:25:11.897 for 00:16:11
  Routing Descriptor Blocks
    10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0
      Route metric is 41, Wt is 4294967295
    10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2
      Route metric is 41, Wt is 4294967295
  No advertising protos.
```

```
Router #show ospf routes 10.0.0.1/32
```

```
Topology Table for ospf 0 with ID 172.16.0.1:
```

```
Codes: O - Intra area, O IA - Inter area
       O E1 - External type 1, O E2 - External type 2
       O N1 - NSSA external type 1, O N2 - NSSA external type 2
```

```
O    10.0.0.1/32, metric 41
     10.1.4.2, from 10.0.0.1, via GigabitEthernet0/0/0/2, ifIndex 8, path-id 1
     10.1.2.2, from 10.0.0.1, via GigabitEthernet0/0/0/0, ifIndex 6, path-id 2
```

```
Router #show cef 10.0.0.1/32
```

```
10.0.0.1/32, version 199, internal 0x1000001 0x10 (ptr 0xe2ed3e8) [1], 0x400 (0xe4899f0),
0x0 (0x0)
Updated Aug  3 23:46:12.770
  remote adjacency to GigabitEthernet0/0/0/0
Prefix Len 32, traffic index 0, precedence n/a, priority 1
```



```

gateway array (0xe2f1838) reference count 1, flags 0x0, source rib (7), 0 backups
      [2 type 3 flags 0x8401 (0xe3a2948) ext 0x0 (0x0)]
LW-LDI[type=3, refc=1, ptr=0xe4899f0, sh-ldi=0xe3a2948]
gateway array update type-time 1 Aug  3 23:46:12.770
LDI Update time Aug  3 23:46:12.779
LW-LDI-TS Aug  3 23:46:12.779
  via 10.1.2.2/32, GigabitEthernet0/0/0/0, 8 dependencies, weight 4294967295, class 0
[flags 0x0]
  path-idx 0 NHID 0x0 [0xf4270b0 0x0]
  next hop 10.1.2.2/32
  remote adjacency
  via 10.1.4.2/32, GigabitEthernet0/0/0/2, 8 dependencies, weight 4294967295, class 0
[flags 0x0]
  path-idx 1 NHID 0x0 [0xf4271e0 0x0]
  next hop 10.1.4.2/32
  remote adjacency

Weight distribution:
slot 0, weight 4294967295, normalized_weight 1, class 0
slot 1, weight 4294967295, normalized_weight 1, class 0
Load distribution: 0 1 (refcount 2)

Hash OK Interface Address
0 Y GigabitEthernet0/0/0/0 remote
1 Y GigabitEthernet0/0/0/2 remote

```

Configuring IS-IS With Weight

The following example shows the IS-IS weight configuration with IPv4. The same can be done for IPv6, with or without SR.

```

CPU0:router(config)# router isis 1
RP/0/RSP0/CPU0:router(config-isis)# interface GigabitEthernet0/3/0/8
RP/0/RSP0/CPU0:router(config-isis-if)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-isis-if-af)# weight 200
RP/0/RSP0/CPU0:router(config-isis)# interface GigabitEthernet0/3/0/9
RP/0/RSP0/CPU0:router(config-isis-if)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-isis-if-af)# weight 300

```

Verification

The following example verifies CEF entry. Then, for two paths with weights of 200 and 300 respectively, and GCD of 100; the expected normalized weights are 2 and 3.

```

Router# show cef ipv4 97.0.0.0 detail

97.0.0.0/24, version 537, internal 0x1000001 0x0 (ptr 0x71bcaee0) [1], 0x0 (0x71b98870),
0x0 (0x0)
Updated Oct 16 06:34:46.197
remote adjacency to GigabitEthernet0/3/0/8
Prefix Len 24, traffic index 0, precedence n/a, priority 2
gateway array (0x71a6de10) reference count 13, flags 0x0, source rib (7), 0 backups
      [14 type 3 flags 0x8401 (0x71b02d90) ext 0x0 (0x0)]
LW-LDI[type=3, refc=1, ptr=0x71b98870, sh-ldi=0x71b02d90]
gateway array update type-time 1 Oct 16 06:34:46.196
LDI Update time Oct 16 06:34:46.197
LW-LDI-TS Oct 16 06:34:46.197
  via 1.0.0.2/32, GigabitEthernet0/3/0/8, 4 dependencies, weight 200, class 0 [flags 0x0]
  path-idx 0 NHID 0x0 [0x7244d2a4 0x0]
  next hop 1.0.0.2/32

```

```

remote adjacency
via 2.0.0.2/32, GigabitEthernet0/3/0/9, 4 dependencies, weight 300, class 0 [flags 0x0]
path-idx 1 NHID 0x0 [0x7244d2f8 0x0]
next hop 2.0.0.2/32
remote adjacency

```

```

Weight distribution:
slot 0, weight 200, normalized_weight 2, class 0
slot 1, weight 300, normalized_weight 3, class 0

```

```

Load distribution: 0 1 0 1 1 (refcount 14)

```

Hash	OK	Interface	Address
0	Y	GigabitEthernet0/3/0/8	remote
1	Y	GigabitEthernet0/3/0/9	remote
2	Y	GigabitEthernet0/3/0/8	remote
3	Y	GigabitEthernet0/3/0/9	remote
4	Y	GigabitEthernet0/3/0/9	remote

Configuring IS-IS With Metric

The following example shows IS-IS metric configuration with IPv4. The same can be done with IPv6.

```

Router# enable
RP/0/RSP0/CPU0:router(config)# router isis 1
RP/0/RSP0/CPU0:router(config-isis)# interface GigabitEthernet0/3/0/8
RP/0/RSP0/CPU0:router(config-isis-if)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-isis-if-af)# metric 1
RP/0/RSP0/CPU0:router(config-isis)# interface GigabitEthernet0/3/0/9
RP/0/RSP0/CPU0:router(config-isis-if)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-isis-if-af)# metric 100

```

Verification

The following example verifies CEF entry, and checks for the two paths with metric values of 1 and 100, respectively. In this example, the best path route metric is 21 and the UCMP path route metric is 120. Therefore, the calculation is as follows:

The best path route metric, 21 = (1 configured + 20 added by IS-IS), weight 0xFFFFFFFF (4294967295)

The UCMP path route metric, 120 = (100 + 20), weight = (21/120) * 4294967295 = 751619276

GCD is one. So Normalized Weight is:

$$(4294967295 * 64) / (4294967295 + 751619276) = 54$$

$$(751619276 * 64) / (4294967295 + 751619276) = 9$$

```

Router# show cef ipv4 97.0.0.0 detail

```

```

97.0.0.0/24, version 773, internal 0x1000001 0x0 (ptr 0x71bcaee0) [1], 0x0 (0x71b98870),
0x0 (0x0)
Updated Oct 16 06:36:08.632
remote adjacency to GigabitEthernet0/3/0/8
Prefix Len 24, traffic index 0, precedence n/a, priority 2
gateway array (0x71a6d9d0) reference count 2, flags 0x0, source rib (7), 0 backups
[3 type 3 flags 0x8401 (0x71b02b90) ext 0x0 (0x0)]
LW-LDI [type=3, refc=1, ptr=0x71b98870, sh-ldi=0x71b02b90]
gateway array update type-time 1 Oct 16 06:36:08.632
LDI Update time Oct 16 06:36:08.632

```

```

LW-LDI-TS Oct 16 06:36:08.632
  via 1.0.0.2/32, GigabitEthernet0/3/0/8, 14 dependencies, weight 4294967295, class 0
[flags 0x0]
  path-idx 0 NHID 0x0 [0x7244d2a4 0x0]
  next hop 1.0.0.2/32
  remote adjacency
  via 2.0.0.2/32, GigabitEthernet0/3/0/9, 14 dependencies, weight 751619276, class 0 [flags
0x0]
  path-idx 1 NHID 0x0 [0x7244d2f8 0x0]
  next hop 2.0.0.2/32
  remote adjacency

Weight distribution:
slot 0, weight 4294967295, normalized_weight 54, class 0
slot 1, weight 751619276, normalized_weight 9, class 0

```

Configuring BGP With Weights

The following example shows BGP configuration with weights.

```

RP/0/RSP0/CPU0:router(config)# route-policy BW1
RP/0/RSP0/CPU0:router(config-rpl)# set extcommunity bandwidth (2906:45750000)
RP/0/RSP0/CPU0:router(config-rpl)# end-policy
RP/0/RSP0/CPU0:router(config)# !
RP/0/RSP0/CPU0:router(config)# route-policy BW2
RP/0/RSP0/CPU0:router(config-rpl)# set extcommunity bandwidth (2906:47250000)
RP/0/RSP0/CPU0:router(config-rpl)# end-policy
RP/0/RSP0/CPU0:router(config)# !
RP/0/RSP0/CPU0:router(config)# route-policy pass-all
RP/0/RSP0/CPU0:router(config-rpl)# pass
RP/0/RSP0/CPU0:router(config-rpl)# end-policy
RP/0/RSP0/CPU0:router(config)# !
RP/0/RSP0/CPU0:router(config)# router bgp 1
RP/0/RSP0/CPU0:router(config-bgp)# bgp bestpath as-path multipath-relax
RP/0/RSP0/CPU0:router(config-bgp)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-bgp-af)# maximum-paths eibgp 64
RP/0/RSP0/CPU0:router(config-bgp-af)# !
RP/0/RSP0/CPU0:router(config-bgp-af)# neighbor 1.0.0.2
RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 2
RP/0/RSP0/CPU0:router(config-bgp-nbr)# ebgp-multihop 255
RP/0/RSP0/CPU0:router(config-bgp-nbr)# dmz-link-bandwidth
RP/0/RSP0/CPU0:router(config-bgp-nbr)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# multipath
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# route-policy BW1 in
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# route-policy pass-all out
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# !
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# neighbor 2.0.0.2
RP/0/RSP0/CPU0:router(config-bgp-nbr)# remote-as 2
RP/0/RSP0/CPU0:router(config-bgp-nbr)# ebgp-multihop 255
RP/0/RSP0/CPU0:router(config-bgp-nbr)# dmz-link-bandwidth
RP/0/RSP0/CPU0:router(config-bgp-nbr)# address-family ipv4 unicast
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# multipath
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# route-policy BW2 in
RP/0/RSP0/CPU0:router(config-bgp-nbr-af)# route-policy pass-all out

```

Verification

Step 1: Verify CEF entry:


```

next hop 200.0.0.1/32
local adjacency
via 200.0.0.1/32, tunnel-te5, 3 dependencies, weight 1, class 0 [flags 0x0]
path-idx 4 NHID 0x0 [0x7244d7e4 0x0]
next hop 200.0.0.1/32
local adjacency

Weight distribution:
slot 0, weight 8, normalized_weight 8, class 0
slot 1, weight 4, normalized_weight 4, class 0
slot 2, weight 1, normalized_weight 1, class 0
slot 3, weight 1, normalized_weight 1, class 0
slot 4, weight 1, normalized_weight 1, class 0

```

Policy-Based Tunnel Selection

Policy-Based Tunnel Selection (PBTS) provides a mechanism that lets you direct traffic into specific TE tunnels based on different criteria.

PBTS is a special case in UCMP calculation. It uses load share command to configure weight. The UCMP algorithm normalizes each class independently and it uses `max_path` from PD specific `max_tunnels_per_class`. UCMP with PBTS can have more total `_paths` (buckets) than the supported number of paths (buckets) for all Forwarding Classes (FCs).

All other XR platform sets 8 buckets per FC and 64 buckets for all 8 (0-7) FCs. After normalization, the total number buckets do not exceed platform limit.

Example

The `show cef ipv6` command displays the PBTS class information in the following output.

```

Router# show cef ipv6 97:: detail

97::/64, version 88177, internal 0x1000001 0x0 (ptr 0x980eef7c) [1], 0x0 (0x974366b8), 0xa28
(0x988842c0)
Updated Mar  7 05:44:46.875

Prefix Len 64, traffic index 0, precedence n/a, priority 2
gateway array (0x97e54770) reference count 11, flags 0x28, source rib (7), 0 backups
[12 type 1 flags 0x200401 (0x9799a3f8) ext 0x0 (0x0)]
LW-LDI[type=1, refc=1, ptr=0x974366b8, sh-ldi=0x9799a3f8]
gateway array update type-time 4 Mar  7 05:46:11.118
LDI Update time Mar  7 05:46:11.118
LW-LDI-TS Mar  7 05:46:11.118

via ::ffff:200.0.0.1/128, tunnel-te45, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 0 NHID 0x0 [0x97b51978 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te46, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 1 NHID 0x0 [0x97b51648 0x0]

```

```

next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te47, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 2 NHID 0x0 [0x97b51c20 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te48, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 3 NHID 0x0 [0x97b52308 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te49, 3 dependencies, weight 1, forward class 7 [flags
0x0]

path-idx 4 NHID 0x0 [0x97b518f0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te1, 3 dependencies, weight 3, forward class 1 [flags
0x0]

path-idx 5 NHID 0x0 [0x97b4f338 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te2, 3 dependencies, weight 500, forward class 1 [flags
0x0]

path-idx 6 NHID 0x0 [0x97b50328 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te3, 3 dependencies, weight 1, forward class 1 [flags
0x0]

path-idx 7 NHID 0x0 [0x97b4ede8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te4, 3 dependencies, weight 1, forward class 1 [flags
0x0]

path-idx 8 NHID 0x0 [0x97b4eb40 0x0]
next hop VRF - 'default', table - 0xe0000000

```

```
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te5, 3 dependencies, weight 1, forward class 1 [flags
0x0]

path-idx 9 NHID 0x0 [0x97b4fff8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te6, 3 dependencies, weight 1, forward class 1 [flags
0x0]

path-idx 10 NHID 0x0 [0x97b4f778 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te7, 3 dependencies, weight 1, forward class 1 [flags
0x0]

path-idx 11 NHID 0x0 [0x97b4f118 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te8, 3 dependencies, weight 1, forward class 1 [flags
0x0]

path-idx 12 NHID 0x0 [0x97b4ee70 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te9, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 13 NHID 0x0 [0x97b4f090 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te10, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 14 NHID 0x0 [0x97b4f448 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te11, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 15 NHID 0x0 [0x97b4faa8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
```

```

local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te12, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 16 NHID 0x0 [0x97b4f008 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te13, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 17 NHID 0x0 [0x97b50218 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te14, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 18 NHID 0x0 [0x97b4fbb8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te15, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 19 NHID 0x0 [0x97b4ed60 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te16, 3 dependencies, weight 1, forward class 2 [flags
0x0]

path-idx 20 NHID 0x0 [0x97b4fcc8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te17, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 21 NHID 0x0 [0x97b50190 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te18, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 22 NHID 0x0 [0x97b4f998 0x0]

```



```
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te19, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 23 NHID 0x0 [0x97b4fee8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te20, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 24 NHID 0x0 [0x97b505d0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te21, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 25 NHID 0x0 [0x97b4fc40 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te22, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 26 NHID 0x0 [0x97b50988 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te23, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 27 NHID 0x0 [0x97b50080 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te24, 3 dependencies, weight 1, forward class 3 [flags
0x0]

path-idx 28 NHID 0x0 [0x97b4fd50 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
```

```

labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te25, 3 dependencies, weight 1, forward class 4 [flags
0x0]

path-idx 29 NHID 0x0 [0x97b503b0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te26, 3 dependencies, weight 1, forward class 4 [flags
0x0]

path-idx 30 NHID 0x0 [0x97b507f0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te27, 3 dependencies, weight 1, forward class 4 [flags
0x0]

path-idx 31 NHID 0x0 [0x97b4ff70 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te28, 3 dependencies, weight 1, forward class 4 [flags
0x0]

path-idx 32 NHID 0x0 [0x97b50548 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te29, 3 dependencies, weight 1, forward class 4 [flags
0x0]

path-idx 33 NHID 0x0 [0x97b4fb30 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te30, 3 dependencies, weight 1, forward class 4 [flags
0x0]

path-idx 34 NHID 0x0 [0x97b506e0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}

```

```
via ::ffff:200.0.0.1/128, tunnel-te31, 3 dependencies, weight 1, forward class 4 [flags 0x0]
```

```
path-idx 35 NHID 0x0 [0x97b51208 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}
```

```
via ::ffff:200.0.0.1/128, tunnel-te32, 3 dependencies, weight 1, forward class 4 [flags 0x0]
```

```
path-idx 36 NHID 0x0 [0x97b502a0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}
```

```
via ::ffff:200.0.0.1/128, tunnel-te33, 3 dependencies, weight 1, forward class 5 [flags 0x0]
```

```
path-idx 37 NHID 0x0 [0x97b514b0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}
```

```
via ::ffff:200.0.0.1/128, tunnel-te34, 3 dependencies, weight 1, forward class 5 [flags 0x0]
```

```
path-idx 38 NHID 0x0 [0x97b50c30 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}
```

```
via ::ffff:200.0.0.1/128, tunnel-te35, 3 dependencies, weight 1, forward class 5 [flags 0x0]
```

```
path-idx 39 NHID 0x0 [0x97b50b20 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}
```

```
via ::ffff:200.0.0.1/128, tunnel-te36, 3 dependencies, weight 1, forward class 5 [flags 0x0]
```

```
path-idx 40 NHID 0x0 [0x97b50cb8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
labels imposed {ExpNullv6}
```

```
via ::ffff:200.0.0.1/128, tunnel-te37, 3 dependencies, weight 1, forward class 5 [flags 0x0]
```

```

path-idx 41 NHID 0x0 [0x97b51180 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te38, 3 dependencies, weight 1, forward class 5 [flags
0x0]

path-idx 42 NHID 0x0 [0x97b51428 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te39, 3 dependencies, weight 1, forward class 5 [flags
0x0]

path-idx 43 NHID 0x0 [0x97b51758 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te40, 3 dependencies, weight 1, forward class 5 [flags
0x0]

path-idx 44 NHID 0x0 [0x97b520e8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te41, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 45 NHID 0x0 [0x97b51538 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te42, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 46 NHID 0x0 [0x97b50dc8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te43, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 47 NHID 0x0 [0x97b51b10 0x0]
next hop VRF - 'default', table - 0xe0000000

```

```
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te44, 3 dependencies, weight 1, forward class 6 [flags
0x0]

path-idx 48 NHID 0x0 [0x97b516d0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te50, 3 dependencies, weight 1, forward class 7 [flags
0x0]

path-idx 49 NHID 0x0 [0x97b525b0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te51, 3 dependencies, weight 1, forward class 7 [flags
0x0]

path-idx 50 NHID 0x0 [0x97b52638 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te52, 3 dependencies, weight 1, forward class 7 [flags
0x0]

path-idx 51 NHID 0x0 [0x97b51f50 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te53, 3 dependencies, weight 1, forward class 7 [flags
0x0]

path-idx 52 NHID 0x0 [0x97b52060 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te54, 3 dependencies, weight 1, forward class 7 [flags
0x0]

path-idx 53 NHID 0x0 [0x97b527d0 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te55, 3 dependencies, weight 1, forward class 7 [flags
0x0]
```

```

path-idx 54 NHID 0x0 [0x97b52280 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te56, 3 dependencies, weight 1, forward class 7 [flags
0x0]

path-idx 55 NHID 0x0 [0x97b52d20 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te57, 3 dependencies, weight 1, class 0 [flags 0x0]

path-idx 56 NHID 0x0 [0x97b51ca8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te58, 3 dependencies, weight 1, class 0 [flags 0x0]

path-idx 57 NHID 0x0 [0x97b52858 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te59, 3 dependencies, weight 1, class 0 [flags 0x0]

path-idx 58 NHID 0x0 [0x97b52390 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te60, 3 dependencies, weight 1, class 0 [flags 0x0]

path-idx 59 NHID 0x0 [0x97b52a78 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te61, 3 dependencies, weight 1, class 0 [flags 0x0]

path-idx 60 NHID 0x0 [0x97b52c10 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

via ::ffff:200.0.0.1/128, tunnel-te62, 3 dependencies, weight 1, class 0 [flags 0x0]

path-idx 61 NHID 0x0 [0x97b52da8 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}

```

```
via ::ffff:200.0.0.1/128, tunnel-te63, 3 dependencies, weight 1, class 0 [flags 0x0]
```

```
path-idx 62 NHID 0x0 [0x97b52c98 0x0]
next hop VRF - 'default', table - 0xe0000000
next hop ::ffff:200.0.0.1/128
local adjacency
  labels imposed {ExpNullv6}
```

Weight distribution:

```
slot 0, weight 1, normalized_weight 1, class 0
slot 1, weight 1, normalized_weight 1, class 0
slot 2, weight 1, normalized_weight 1, class 0
slot 3, weight 1, normalized_weight 1, class 0
slot 4, weight 1, normalized_weight 1, class 0
slot 5, weight 1, normalized_weight 1, class 0
slot 6, weight 1, normalized_weight 1, class 0
slot 7, weight 1, normalized_weight 1, forward class 1
slot 8, weight 3, normalized_weight 1, forward class 1
slot 9, weight 500, normalized_weight 1, forward class 1
slot 10, weight 1, normalized_weight 1, forward class 1
slot 11, weight 1, normalized_weight 1, forward class 1
slot 12, weight 1, normalized_weight 1, forward class 1
slot 13, weight 1, normalized_weight 1, forward class 1
slot 14, weight 1, normalized_weight 1, forward class 1
slot 15, weight 1, normalized_weight 1, forward class 2
slot 16, weight 1, normalized_weight 1, forward class 2
slot 17, weight 1, normalized_weight 1, forward class 2
slot 18, weight 1, normalized_weight 1, forward class 2
slot 19, weight 1, normalized_weight 1, forward class 2
slot 20, weight 1, normalized_weight 1, forward class 2
slot 21, weight 1, normalized_weight 1, forward class 2
slot 22, weight 1, normalized_weight 1, forward class 2
slot 23, weight 1, normalized_weight 1, forward class 3
slot 24, weight 1, normalized_weight 1, forward class 3
slot 25, weight 1, normalized_weight 1, forward class 3
slot 26, weight 1, normalized_weight 1, forward class 3
slot 27, weight 1, normalized_weight 1, forward class 3
slot 28, weight 1, normalized_weight 1, forward class 3
slot 29, weight 1, normalized_weight 1, forward class 3
slot 30, weight 1, normalized_weight 1, forward class 3
slot 31, weight 1, normalized_weight 1, forward class 4
slot 32, weight 1, normalized_weight 1, forward class 4
slot 33, weight 1, normalized_weight 1, forward class 4
slot 34, weight 1, normalized_weight 1, forward class 4
slot 35, weight 1, normalized_weight 1, forward class 4
slot 36, weight 1, normalized_weight 1, forward class 4
slot 37, weight 1, normalized_weight 1, forward class 4
slot 38, weight 1, normalized_weight 1, forward class 4
slot 39, weight 1, normalized_weight 1, forward class 5
slot 40, weight 1, normalized_weight 1, forward class 5
slot 41, weight 1, normalized_weight 1, forward class 5
slot 42, weight 1, normalized_weight 1, forward class 5
slot 43, weight 1, normalized_weight 1, forward class 5
slot 44, weight 1, normalized_weight 1, forward class 5
slot 45, weight 1, normalized_weight 1, forward class 5
slot 46, weight 1, normalized_weight 1, forward class 5
slot 47, weight 1, normalized_weight 1, forward class 6
slot 48, weight 1, normalized_weight 1, forward class 6
slot 49, weight 1, normalized_weight 1, forward class 6
slot 50, weight 1, normalized_weight 1, forward class 6
slot 51, weight 1, normalized_weight 1, forward class 6
```

```

slot 52, weight 1, normalized_weight 1, forward class 6
slot 53, weight 1, normalized_weight 1, forward class 6
slot 54, weight 1, normalized_weight 1, forward class 6
slot 55, weight 1, normalized_weight 1, forward class 7
slot 56, weight 1, normalized_weight 1, forward class 7
slot 57, weight 1, normalized_weight 1, forward class 7
slot 58, weight 1, normalized_weight 1, forward class 7
slot 59, weight 1, normalized_weight 1, forward class 7
slot 60, weight 1, normalized_weight 1, forward class 7
slot 61, weight 1, normalized_weight 1, forward class 7
slot 62, weight 1, normalized_weight 1, forward class 7

```

PBTS class information:

```

class 0: 7 paths, offset 0

forward class 1: 8 paths, offset 7
forward class 2: 8 paths, offset 15
forward class 3: 8 paths, offset 23
forward class 4: 8 paths, offset 31
forward class 5: 8 paths, offset 39
forward class 6: 8 paths, offset 47
forward class 7: 8 paths, offset 55

```

```

Load distribution: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55
56 57 58 59 60 61 62 (refcount 12)

```

Hash	OK	Interface	Address
0	Y	tunnel-te57	point2point
1	Y	tunnel-te58	point2point
2	Y	tunnel-te59	point2point
3	Y	tunnel-te60	point2point
4	Y	tunnel-te61	point2point
5	Y	tunnel-te62	point2point
6	Y	tunnel-te63	point2point
7	Y	tunnel-te8	point2point
8	Y	tunnel-te1	point2point
9	Y	tunnel-te2	point2point
10	Y	tunnel-te3	point2point
11	Y	tunnel-te4	point2point
12	Y	tunnel-te5	point2point
13	Y	tunnel-te6	point2point
14	Y	tunnel-te7	point2point
15	Y	tunnel-te16	point2point
16	Y	tunnel-te9	point2point
17	Y	tunnel-te10	point2point
18	Y	tunnel-te11	point2point
19	Y	tunnel-te12	point2point
20	Y	tunnel-te13	point2point
21	Y	tunnel-te14	point2point
22	Y	tunnel-te15	point2point
23	Y	tunnel-te24	point2point
24	Y	tunnel-te17	point2point
25	Y	tunnel-te18	point2point
26	Y	tunnel-te19	point2point
27	Y	tunnel-te20	point2point
28	Y	tunnel-te21	point2point
29	Y	tunnel-te22	point2point
30	Y	tunnel-te23	point2point

31	Y	tunnel-te32	point2point
32	Y	tunnel-te25	point2point
33	Y	tunnel-te26	point2point
34	Y	tunnel-te27	point2point
35	Y	tunnel-te28	point2point
36	Y	tunnel-te29	point2point
37	Y	tunnel-te30	point2point
38	Y	tunnel-te31	point2point
39	Y	tunnel-te40	point2point
40	Y	tunnel-te33	point2point
41	Y	tunnel-te34	point2point
42	Y	tunnel-te35	point2point
43	Y	tunnel-te36	point2point
44	Y	tunnel-te37	point2point
45	Y	tunnel-te38	point2point
46	Y	tunnel-te39	point2point
47	Y	tunnel-te44	point2point
48	Y	tunnel-te45	point2point
49	Y	tunnel-te46	point2point
50	Y	tunnel-te47	point2point
51	Y	tunnel-te48	point2point
52	Y	tunnel-te41	point2point
53	Y	tunnel-te42	point2point
54	Y	tunnel-te43	point2point
55	Y	tunnel-te56	point2point
56	Y	tunnel-te49	point2point
57	Y	tunnel-te50	point2point
58	Y	tunnel-te51	point2point
59	Y	tunnel-te52	point2point
60	Y	tunnel-te53	point2point
61	Y	tunnel-te54	point2point
62	Y	tunnel-te55	point2point

Interior Gateway Protocol (IGP) Destination-based Load Balancing (DLB)

Currently, the router supports up to 2K labelled prefixes with Equal Cost Multi Path (ECMP). From Cisco IOS XR Software Release 7.1.1, with the introduction of the Interior Gateway Protocol (IGP) Destination-based Load Balancing (DLB) feature, the router can support higher scale of labelled prefixes.

If this feature is enabled, the software selects one path out of the available multipaths based on a software hash of the destination IP address and then programs the data plane with the selected single path. Thus, the traffic gets distributed on available paths by pre-selection of the path based on the per-prefix hash.

However, if Layer 2 Virtual Private Network (L2VPN) or Border Gateway Protocol (BGP) service uses a IGP DLB prefix for next-hop reachability, then the software removes DLB from that particular prefix and it behaves as if L2VPN or BGP runs on a non-DLB IGP.

Restrictions for IGP DLB

The following are the restrictions for IGP DLB:

- IGP DLB is not enabled in software, by default.

- ECMP resource utilization happens only on enabling BGP or L2 services for the DLB prefix. However disabling BGP or L2 services for the prefix does not release the ECMP resource immediately. ECMP resources get released only when the prefix is re-learned again or with a router reload.
- For the configuration command **hw-module fib dlb level-1 enable** to take effect, you should reload the LC.

Configuring IGP DLB

Without IGP DLB enabled, all prefixes consume ECMP hardware resources.

However, with IGP DLB enabled, DLB IP and labeled prefixes do not consume ECMP resources. Only BGP and L2VPN services over a DLB IGP prefix consume ECMP resources. This enables the router to handle higher prefix scale by the efficient use of the ECMP hardware resources.

The following example shows the ECMP software-based load-balancing configuration:

```
Router# config terminal
Router(config)# hw-module fib dlb level-1 enable
Router(config)# commit
Router(config)# end
Router# reload location all
Proceed with reload? [confirm]
```

Verification

In the below command, resource usage will be less when IGP DLB is enabled:

```
Router# show controllers npu resources ecmpfec location 0/3/CPU0
HW Resource Information
  Name                : ecmp_fec
  Asic Type            : Jericho Plus

NPU-0
OOR Summary
  Estimated Max Entries : 4096
  Red Threshold         : 95
  Yellow Threshold     : 80
  OOR State             : Green

Current Usage
  Total In-Use         : 3          (0 %)
  ipnhgroup            : 3          (0 %)
  ip6nhgroup           : 0          (0 %)

NPU-1
OOR Summary
  Estimated Max Entries : 4096
  Red Threshold         : 95
  Yellow Threshold     : 80
  OOR State             : Green

Current Usage
  Total In-Use         : 3          (0 %)
  ipnhgroup            : 3          (0 %)
```

```

        ip6nhgroup          : 0          (0 %)

```

NPU-2

OOR Summary

```

    Estimated Max Entries    : 4096
    Red Threshold            : 95
    Yellow Threshold         : 80
    OOR State                 : Green

```

Current Usage

```

    Total In-Use             : 3          (0 %)
    ipnhgroup                : 3          (0 %)
    ip6nhgroup               : 0          (0 %)

```

NPU-3

OOR Summary

```

    Estimated Max Entries    : 4096
    Red Threshold            : 95
    Yellow Threshold         : 80
    OOR State                 : Green

```

Current Usage

```

    Total In-Use             : 3          (0 %)
    ipnhgroup                : 3          (0 %)
    ip6nhgroup               : 0          (0 %)

```

```
Router# show cef 209.165.200.225 hardware egress detail location npu0
```

```
....
```

```
HW Walk:
```

```
LEAF:
```

```

    PI:0x308bec58b8 PD:0x308bec5958 rev:4910 type: IPV4 (0)
    LEAF location: LEM
    FEC key: 0x20e20000e0b

```

```
LWLDI:
```

```

    EOS0/1 LDI: ECD_MARKED SERVICE_MARKED # shows ECMP resource usage with IGP DLB
    LSP pattern:3

```

Increased ECMP Maximum Paths for BGP within VRF

Table 1: Feature History Table

Feature Name	Release Information	Description
Increased ECMP Maximum Paths for BGP within VRF	Release 7.11.1	<p>Introduced in this release on: NCS 5500 fixed port routers; NCS 5700 fixed port routers; NCS 5500 modular routers (NCS 5500 line cards; NCS 5700 line cards [Mode: Compatibility; Native])</p> <p>We have increased the maximum ECMP paths available for BGP within a VRF to 128. This increases the number of next hops that are added for ECMP in the Forwarding Information Base (FIB) table, which in turn ensures that the network is geared up to deal with sudden increase in bandwidth, without compromising on the load balancing and performance aspects.</p> <p>Previously, the maximum number of ECMP paths supported for IGP, BGP, and labeled paths was 64. With this release, the support is enhanced to 128 ECMP paths for IPv4 and IPv6 prefixes over iBGP and eBGP within a VRF.</p> <p>This feature modifies the maximum-paths command.</p>

ECMP is a mechanism to load balance the traffic associated with a destination prefix across the equal cost labeled or unlabeled paths. The destination prefix can be a recursive (from BGP) or a non-recursive (IGP) one. Based on the nature of the traffic, different components like ISIS, OSPF, BGP, and FIB associate the destination prefix with the available ECMP paths.

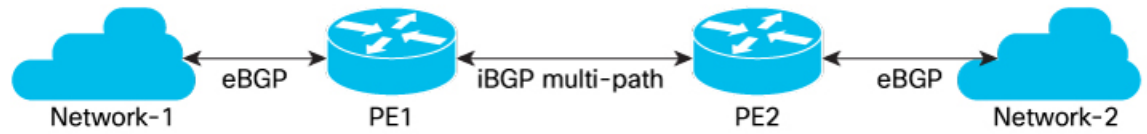
Previously, with the maximum number of ECMP paths for BGP in a Virtual Routing and Forwarding (VRF) context as 64, the number of equal-cost routes that BGP can install in the routing table for a given destination prefix was limited to 64. This resulted in limited path diversity and sub-optimal load balancing.

As the maximum number of ECMP paths for BGP within a VRF is now increased to 128, the BGP can now consider up to 128 equal-cost routes in the routing table for a given destination prefix. This improves path diversity and allows more efficient load balancing and redundancy.

Topology

The following figure depicts a sample topology, where two provider edge routers are connected over iBGP.

Figure 2: Sample Topology (iBGP)



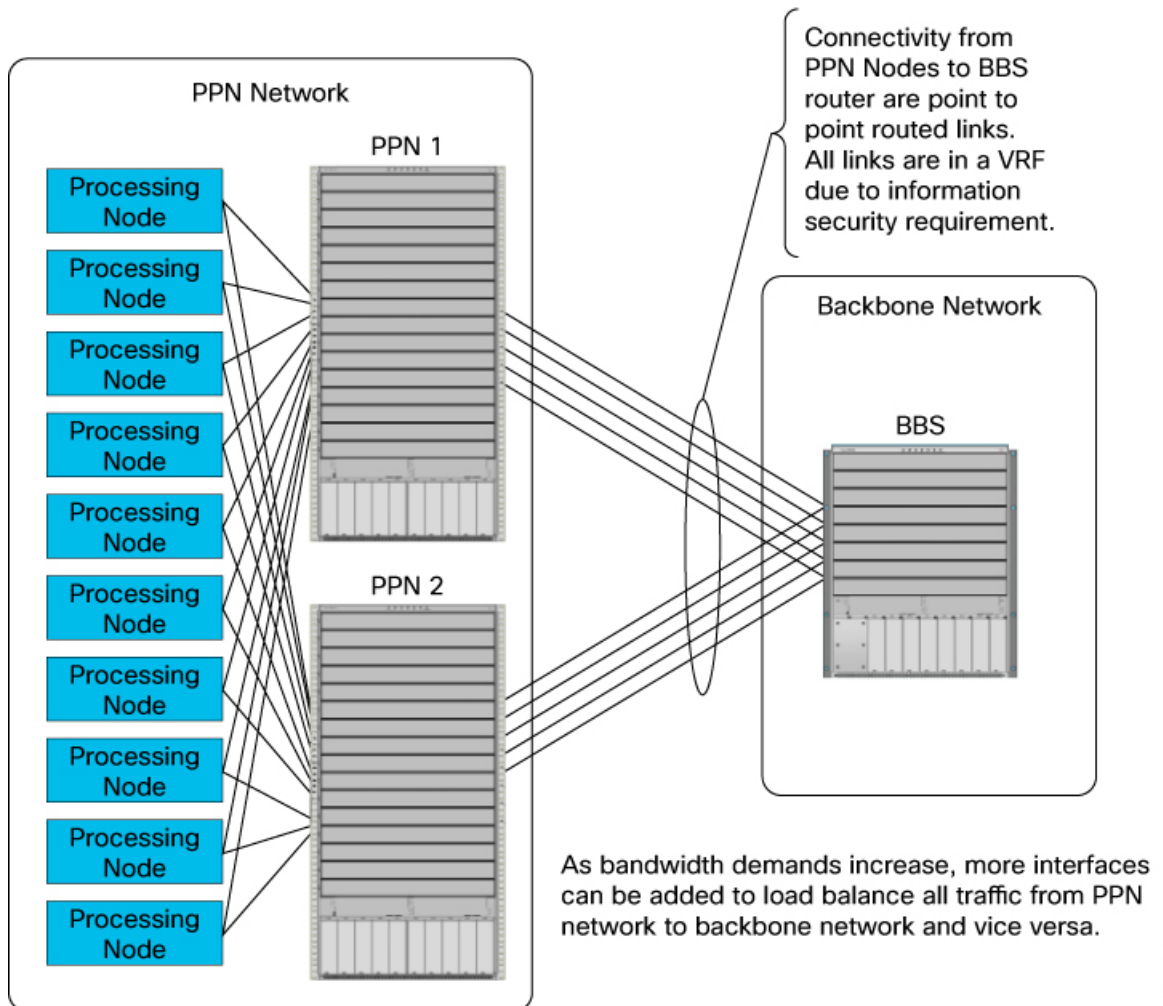
523394

In this topology,

- Network-1 and PE1 are connected using eBGP.
- Network-2 and PE2 are connected using eBGP.
- PE1 and PE2 exchange routes over iBGP multipaths.
- Out of the multiple iBGP sessions between PE1 and PE2, the available ECMP paths are used to forward the traffic between PE1 and PE2.

The following figure depicts a sample topology, where a packet processing node (PPN) network interacts with the backbone network over VRF links.

Figure 3: Sample Topology with VRF Links



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The number of ECMP paths for IPv4 and IPv6 prefixes over iBGP and eBGP within a VRF is increased from 64 to 128. The increase in number ECMP paths enable you to add more interfaces between backbone network system (BBS) and packet processing node (PPN) network. The extra interfaces thus added, can be used to load balance the traffic between PPN network and BBS. The additional ECMP paths also ensure better bandwidth aggregation over the interfaces and redundancy of each ECMP path. The benefits of having more paths will be more evident in large networks with high traffic loads.

Restrictions for Increased ECMP Maximum Paths for BGP within VRF

- The maximum number of ECMP paths over ISIS and OSPF remains unchanged and supports only 64 ECMP paths.
- The maximum number of ECMP paths over iBGP labeled paths remains unchanged and supports only 64 ECMP paths.
- The maximum number of PBTS supported remains unchanged and supports only 8 PBTS.

- The hardware continues to support the same number of FECs. When all 128 ECMP paths are utilized for redundancy, 128 FECs are allocated for primary paths and an additional 128 FECs for backup paths. As a result, the available number of FECs is reduced.

Configure Increased ECMP Maximum Paths for BGP within VRF

Configuration Example

This section describes how to configure the maximum number of supported ECMP paths within a VRF over eiBGP.

```
RP/0/RP0/CPU0:ios#configure
RP/0/RP0/CPU0:ios(config)#router bgp 200
RP/0/RP0/CPU0:ios(config-bgp)#bgp router-id 1.1.1.1
RP/0/RP0/CPU0:ios(config-bgp)#address-family ipv4 unicast
RP/0/RP0/CPU0:ios(config-bgp-af)#exit
RP/0/RP0/CPU0:ios(config-bgp)#address-family vpnv4 unicast
RP/0/RP0/CPU0:ios(config-bgp-af)#exit
RP/0/RP0/CPU0:ios(config-bgp)#vrf vrf_cel
RP/0/RP0/CPU0:ios(config-bgp-vrf)#address-family ipv4 unicast
RP/0/RP0/CPU0:ios(config-bgp-vrf-af)#maximum-paths eibgp 128
RP/0/RP0/CPU0:ios(config-bgp-vrf-af)#label mode per-vrf
RP/0/RP0/CPU0:ios(config-bgp-vrf-af)#commit
```

Running Configuration

```
RP/0/RP0/CPU0:ios#show running-config
router bgp 200
  bgp router-id 1.1.1.1
  address-family ipv4 unicast
  !
  address-family vpnv4 unicast
  !
  vrf vrf_cel
    rd 2001:1601
    address-family ipv4 unicast
      maximum-paths eibgp 128
      label mode per-vrf
    !
  !
end
```

Verification

Following is the **show** command output when 128 paths are enabled, truncated to show the relevant portions.

```
RP/0/RP0/CPU0:ios#show cef vrf vrf_cel 1.1.1.1/32 hardware egress detail location 0/rp0/CPU0
1.1.1.1/32, version 383, internal 0x1000001 0x30 (ptr 0x95a81348) [1], 0x0 (0x0), 0x0 (0x0)

Updated Sep 20 16:57:44.368
local adjacency to HundredGigE0/0/0/16.1

Prefix Len 32, traffic index 0, precedence n/a, priority 3
gateway array (0x958e1d38) reference count 10, flags 0x2010, source rib (7), 0 backups
[1 type 3 flags 0x48501 (0x99b2efd8) ext 0x0 (0x0)]
LW-LDI[type=0, refc=0, ptr=0x0, sh-ldi=0x0]
gateway array update type-time 1 Sep 20 16:57:44.367
LDI Update time Sep 20 16:57:44.947
```

```

via 47.1.1.1/32, 2 dependencies, recursive, bgp-ext, bgp-multipath [flags 0x60a0]
  path-idx 0 auto-bkup-idx 1 NHID 0x0 [0x95a7a088 0x0], Internal 0x99ccb048
  next hop 47.1.1.1/32 via 47.1.1.1/32
via 57.1.1.1/32, 2 dependencies, recursive, bgp-ext, bgp-multipath [flags 0x60a0]
  path-idx 1 auto-bkup-idx 2 NHID 0x0 [0x95a81238 0x0], Internal 0x99d4b048
  next hop 57.1.1.1/32 via 57.1.1.1/32

/* output truncated - extends for 128 paths */

via 57.128.1.1/32, 2 dependencies, recursive, bgp-ext, bgp-multipath [flags 0x60a0]
  path-idx 127 auto-bkup-idx 0 NHID 0x0 [0x95a7a198 0x0], Internal 0x9dbff048
  next hop 57.128.1.1/32 via 57.128.1.1/32

Show-data Print at RPLC

/* output truncated */

      SHLDI:
      PI:0x3099b2efd8 PD:0x3099b2f0e0 rev:2983 dpa-rev:7126 cbf_enabled:0 pbts_enabled:0
surpf_enable:0 flag:0x0
      FEC key: 0x21640001ae10 fec index: 0x20000040(64) num paths: 128 bkup paths:
128
      /* output truncated */
      Path:0 fec index: 0x20019bbe(105406) DSP:0x9 Dest fec index: 0x0(0)
      Path:1 fec index: 0x20019bc0(105408) DSP:0x9 Dest fec index: 0x0(0)
      /* output truncated */
      Path:254 fec index: 0x20019cb9(105657) DSP:0x9 Dest fec index: 0x0(0)
      Path:255 fec index: 0x20019cbb(105659) DSP:0x9 Dest fec index: 0x0(0)
/* output truncated */
Load distribution: 0 1 2 3 .. 127 (refcount 1)
  Hash OK Interface Address
    0 Y HundredGigE0/0/0/16.1 47.1.1.1
    1 Y HundredGigE0/0/0/16.2 57.1.1.1
/* output truncated */
127 Y HundredGigE0/0/0/16.128 57.128.1.1

```