驗證Catalyst 9000交換器上的MPLS

目錄

簡介

本文說明如何在Catalyst 9000系列交換器上設定和驗證多重協定標籤交換(MPLS)第3層虛擬私人網路(VPN)。

必要條件

需求

思科建議您瞭解以下主題：

- IP轉送
- 邊界閘道通訊協定(BGP)

- MPLS

採用元件

本文中的資訊係根據以下軟體和硬體版本：

- Cisco IOS® XE 16.12.4上的C9500
- Cisco IOS® XE 16.12.4上的C9300
- Cisco IOS® XE 16.9.6上的C3850

本文中的資訊是根據特定實驗室環境內的裝置所建立。文中使用到的所有裝置皆從已清除（預設）的組態來啟動。如果您的網路運作中，請確保您瞭解任何指令可能造成的影響。

背景資訊

MPLS第3層VPN(L3VPN)使用使用BGP來分發VPN相關資訊的對等模型。MPLS VPN包含一組通過MPLS提供商核心網路互連的站點。在每個客戶地點，一個或多個客戶邊緣(CE)裝置連線到一個或多個提供邊緣(PE)裝置。

在常規的第3層路由中，當資料包經過網路時，每台交換機都會從第3層報頭提取轉發資料包的相關資訊。然後將此資訊用作路由表查詢的索引，以確定資料包的下一跳。

在大多數情況下，報頭中唯一的相關欄位是目的地址欄位，但在某些情況下，其他報頭欄位也可能相關。因此，在資料包通過的每台交換機上必須單獨進行報頭分析。此外，還必須在每台交換機上執行複雜的表查詢。

在標籤交換中，第3層報頭的分析僅執行一次。然後，第3層報頭對映到一個固定長度的非結構化值，稱為**alabel**。

許多不同的報頭可以對映到相同的標籤，只要這些報頭始終導致相同的下一跳選擇。實際上，標籤代表**轉發等價類**(FEC)，即一組資料包，無論它們如何不同，都可能被轉發函式所區分。

標籤的初始選擇不需要完全基於第3層資料包報頭的內容；例如，在後續躍點轉發資料包的決策也可能基於其他因素。

標籤分配後，第3層資料包的前面會新增一個短標籤報頭。此報頭作為資料包的一部分在網路中傳輸。在網路中通過每個MPLS交換機的後續跳時，標籤交換和決策通過為資料包報頭中攜帶的標籤進行MPLS轉發表查詢來完成。因此，在封包通過網路傳輸期間，不需要重新評估封包標頭。由於標籤具有固定長度和非結構化，因此MPLS轉發表查詢過程既簡單又快速。

網路中的每個標籤交換路由器(LSR)都會做出獨立的本地決策，決定使用哪個標籤值來表示轉發等價類。此關聯稱為標籤繫結。每個LSR向其鄰居通知它進行的標籤繫結。以下協定有助於鄰居交換機感知標籤繫結：

- 標籤分發協定(LDP) — 使MPLS網路中的對等LSR能夠交換標籤資訊，以支援MPLS網路中的逐跳轉發
- 邊界閘道通訊協定(BGP) — 用於支援MPLS虛擬私人網路(VPN)

當標籤資料包從LSR A傳送到LSR B時，IP資料包攜帶的標籤值是LSR B分配的標籤值，用於表示資料包的轉發等價類。因此，標籤值會隨著IP資料包穿越網路而改變。

如何使用本指南

本指南分為兩個場景，文檔末尾顯示硬體擴展驗證部分：

- mpls核心中的單跳鄰接關係
- MPLS核心中的等價多路徑(ECMP)鄰接關係
- 如何檢查TCAM使用率以發現擴展問題

每個場景都包含驗證每個MPLS裝置的字首和標籤。

技術

MPLS	多重通訊協定標籤交換	一種高效能資料包轉發技術，將資料鏈路層（第2層）交換的效能和流量管理與網路層（第3層）路由的可擴充性、靈活性和效能整合在一起。
PE	提供商邊緣（交換機/路由器）	從客戶CE接收IP字首並將它們傳遞到MPLS雲的提供商網路的邊緣裝置。
CE	客戶邊緣（交換機/路由器）	連線到服務提供商IP/MPLS網路的提供商邊緣路由器的客戶端裝置。
LDP	標籤發現協定	LDP是一種協定，可在路由器之間自動生成和交換標籤。每台路由器在本地為其字首的標籤，然後將標籤值通告給鄰居。
LSPA	標籤交換機路徑陣列	到達特定MPLS目標的標籤集。在典型的L3VPN中 — 可以有IGP + VPN標籤果存在TE通道，則您有TE標籤+ IGP + VPN。 Catalyst 9000最多可以支援籤，該標籤陣列稱為LSPA。
標籤堆疊ID	標籤堆疊ID	A 標識標籤堆疊的唯一索引(a)允許LSPA共用)。
標籤	標籤	用於查詢的MPLS標籤。 多個標籤組成標籤堆疊。
字首ID	字首識別符號	Catalyst 9000為每個字首建立一個全域性資源（在按字首標籤分配的情況下首ID與路由數量相同）。
EM	完全匹配	雜湊記憶體中一個為1:1匹配項（主機路由、直連主機）的條目。
LPM	最長字首匹配	任何路由是/31或更短（/32路由是EM型別）。
TCAM	三重內容可定址儲存器	一種儲存器，用於儲存和查詢具有三個不同輸入的條目：0、1和X。當同一的匹配項可能有多個時，並且每個條目的雜湊結果不唯一，則必須使用此型內**存。此表包含一個掩碼或「X」值，它可知道它是否與此條目的匹配或不**
CAM	內容可定址儲存器	硬體記憶體(Hash/TCAM)的一般術語。
RIB	路由資訊庫	「show ip route」中顯示的路由表
FIB	轉發資訊庫	帶有由RIB和ARP表新增字首的簡化表，帶有指向ADJ表的指標
直接連線	直連路由	本地連線的主機字首（ARP相鄰）
間接連線	間接連線路由	通過遠端下一跳到達的路由
ADJ	鄰接關係（表）	儲存用於資料包重寫的下一跳資訊
EM	完全匹配	連線的主機，間接/32主機字首
TCAM	三重內容可定址儲存器	間接字首/31或更短
美聯儲	轉發引擎驅動程式	ASIC（硬體）層
FMAN-FP	轉發管理器 —	FMAN-FP管理新增、刪除或修改FED資訊的軟體對象

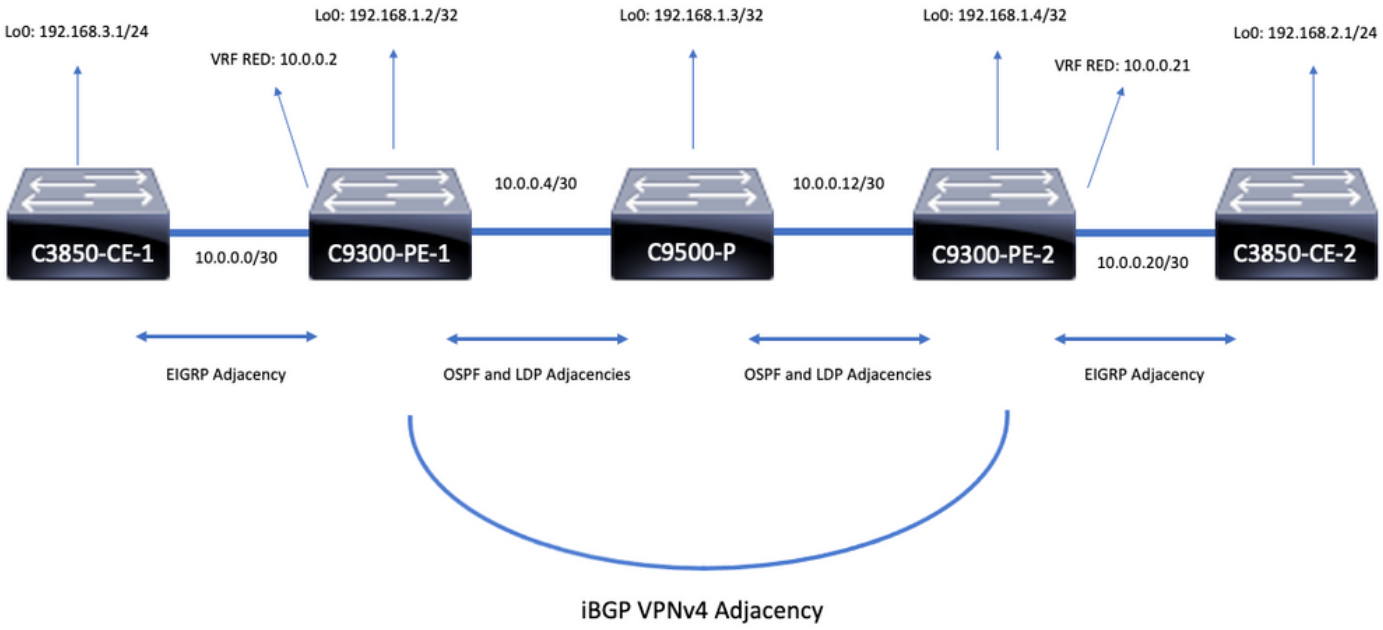
	轉發平面	
SI	站台索引	站台索引 = 資料包重寫資訊（RI =重寫索引）和出站介面資訊（DI =目標索
RI	重寫索引	第3層轉發到下一跳鄰接的MAC地址重寫資訊
DI	目標索引	指向出站介面的索引

設定和驗證

案例1. MPLS核心中具有單躍點鄰接關係的L3VPN

參考拓撲

在本示例中，Catalyst 9300交換機充當PE裝置，Stackwise虛擬中的Catalyst 9500充當P裝置，Catalyst 3850交換機充當CE裝置。



配置詳細資訊

C3850-CE-1的配置

```
hostname C3850-CE-1
!
interface Loopback0
ip address 192.168.3.1 255.255.255.0
!
interface TenGigabitEthernet1/0/1
no switchport
ip address 10.0.0.1 255.255.255.252
!
router eigrp 420
network 10.0.0.0 0.0.0.3
network 192.168.3.0 0.0.0.255
```

```
eigrp stub connected summary
!
ip route 0.0.0.0 0.0.0.0 10.0.0.2
```

C9300-PE-1的組態

```
hostname C9300-PE-1
!
ip vrf RED
rd 69:69
route-target export 69:69
route-target import 69:69
!
mpls ldp explicit-null
!
interface Loopback0
ip address 192.168.1.2 255.255.255.255
!
interface GigabitEthernet1/0/1
no switchport
ip vrf forwarding RED
ip address 10.0.0.2 255.255.255.252
!
interface GigabitEthernet1/0/2
no switchport
ip address 10.0.0.5 255.255.255.252
!
router eigrp 420
!
address-family ipv4 vrf RED
network 10.0.0.0 0.0.0.3
autonomous-system 420
exit-address-family
!
router ospf 420
network 0.0.0.0 255.255.255.255 area 0
mpls ldp autoconfig
!
router bgp 69420
bgp log-neighbor-changes
neighbor 192.168.1.4 remote-as 69420
neighbor 192.168.1.4 update-source Loopback0
!
address-family vpnv4
neighbor 192.168.1.4 activate
neighbor 192.168.1.4 send-community extended
exit-address-family
!
address-family ipv4 vrf RED
redistribute eigrp 420
exit-address-family
```

C9500-P的組態

```
hostname C9500-P
!
interface Loopback0
ip address 192.168.1.3 255.255.255.255
!
interface TenGigabitEthernet1/0/1
no switchport
ip address 10.0.0.6 255.255.255.252
```

```
!
interface TenGigabitEthernet1/0/2
no switchport
ip address 10.0.0.13 255.255.255.252
!
router ospf 420
network 0.0.0.0 255.255.255.255 area 0
mpls ldp autoconfig
```

C9300-CE-2的配置

```
hostname C9300-PE-2
!
ip vrf RED
rd 69:69
route-target export 69:69
route-target import 69:69
!
mpls ldp explicit-null
!
interface Loopback0
ip address 192.168.1.4 255.255.255.255
!
interface GigabitEthernet2/0/1
no switchport
ip vrf forwarding RED
ip address 10.0.0.21 255.255.255.252
!
interface GigabitEthernet2/0/2
no switchport
ip address 10.0.0.14 255.255.255.252
!
router eigrp 400
!
address-family ipv4 vrf RED
network 10.0.0.20 0.0.0.3
autonomous-system 400
exit-address-family
!
router ospf 420
network 0.0.0.0 255.255.255.255 area 0
mpls ldp autoconfig
!
router bgp 69420
bgp log-neighbor-changes
neighbor 192.168.1.2 remote-as 69420
neighbor192.168.1.2 update-source Loopback0
!
address-family vpnv4
neighbor 192.168.1.2 activate
neighbor 192.168.1.2 send-community extended
exit-address-family
!
address-family ipv4 vrf RED
redistribute eigrp 400
exit-address-family
```

C3850-CE-2的配置

```
hostname C3850-CE-2
!
interface Loopback0
```

```
ip address 192.168.2.1 255.255.255.0
!
interface TenGigabitEthernet2/0/1
no switchport
ip address 10.0.0.22 255.255.255.252
!
router eigrp 400
network 10.0.0.20 0.0.0.3
network 192.168.2.0 0.0.0.255
eigrp stub connected summary
!
ip route 0.0.0.0 0.0.0.0 10.0.0.21
```

基本驗證

在驗證MPLS程式設計之前，需要驗證基本要求：

- 驗證是否存在PE到PE連線
- 驗證PE之間的標籤交換路徑(LSP)
- 驗證PE之間的BGPv4鄰接關係
- 驗證VPNv4和LDP標籤
- 驗證MPLS轉發表

驗證PE到PE的連線

您可以從本地環回對遠端PE環回和源執行ping操作，但這並不能確認MPLS標籤交換路徑(LSP)是否正常，因為環回IP地址是在底層中通告的。

> **注意**:PE到PE MP-BGP VPNv4鄰接通過它們各自的Loopback0介面實現。

```
C9300-PE-1#ping 192.168.1.4 source 192.168.1.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.4, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.2
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms C9300-PE-1#show ip route
192.168.1.4
Routing entry for 192.168.1.4/32
Known via "ospf 420", distance 110, metric 3, type intra area
Last update from 10.0.0.10 on GigabitEthernet1/0/3, 00:55:58 ago
Routing Descriptor Blocks:
* 10.0.0.6, from 192.168.1.4, 00:55:58 ago, via GigabitEthernet1/0/2
Route metric is 3, traffic share count is 1
```

驗證LSP

您可以從PE到PE環回使用MPLS路徑來驗證路徑上的LSP和所有MPLS LDP標籤。

> **註**：此MPLS traceroute僅施加一個標籤，即LDP標籤，並不能證明來自CE的流量是成功的，因為該流量是使用2個標籤施加的，即VPNv4（內部）標籤和LDP（外部）標籤。

```
C9300-PE-1#traceroute mpls ipv4 192.168.1.4/32 source 192.168.1.2
Tracing MPLS Label Switched Path to 192.168.1.4/32, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
```

```
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
  0 10.0.0.5 MRU 1500 [Labels: 17 Exp: 0]
L 1 10.0.0.6 MRU 1500 [Labels: explicit-null Exp: 0] 8 ms
! 2 10.0.0.14 2 ms
```

如果您無法訪問CE或CE後面的裝置，並且希望證明存在成功的VPNv4和LDP標籤實施/處置，可以嘗試從PE上VRF中面向CE的介面ping遠端PE上VRF中面向CE的另一介面。

```
C9300-PE-1#ping vrf RED 10.0.0.21 source 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.21, timeout is 2 seconds:
Packet sent with a source address of 10.0.0.2
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/2 ms
```

驗證PE之間的BGP VPNv4鄰接關係

```
C9300-PE-1#show bgp vpnv4 unicast all neighbors 192.168.1.4
BGP neighbor is 192.168.1.4, remote AS 69420, internal link
BGP version 4, remote router ID 192.168.1.4
BGP state = Established, up for 00:57:37
Last read 00:00:41, last write 00:00:41, hold time is 180, keepalive interval is 60 seconds
Neighbor sessions:
1 active, is not multisession capable (disabled)
Neighbor capabilities:
Route refresh: advertised and received(new)
Four-octets ASN Capability: advertised and received
Address family IPv4 Unicast: advertised and received
Address family VPNv4 Unicast: advertised and received
Enhanced Refresh Capability: advertised and received
Multisession Capability:
Stateful switchover support enabled: NO for session 1
Message statistics:
InQ depth is 0
OutQ depth is 0

Sent Rcvd
Opens: 1 1
Notifications: 0 0
Updates: 6 6
Keepalives: 62 63
Route Refresh: 0 0
Total: 69 70
Do log neighbor state changes (via global configuration)
Default minimum time between advertisement runs is 0 seconds
<snip>

C9300-PE-2#show bgp vpnv4 unicast all neighbors 192.168.1.2
BGP neighbor is 192.168.1.2, remote AS 69420, internal link
BGP version 4, remote router ID 192.168.1.2
BGP state = Established, up for 01:01:00
Last read 00:00:13, last write 00:00:37, hold time is 180, keepalive interval is 60 seconds
```

```
Neighbor sessions:
1 active, is not multisession capable (disabled)
Neighbor capabilities:
Route refresh: advertised and received(new)
Four-octets ASN Capability: advertised and received
Address family IPv4 Unicast: advertised and received
Address family VPNv4 Unicast: advertised and received
Enhanced Refresh Capability: advertised and received
Multisession Capability:
Stateful switchover support enabled: NO for session 1
Message statistics:
InQ depth is 0
OutQ depth is 0

Sent Rcvd
Opens: 1 1
Notifications: 0 0
Updates: 6 6
Keepalives: 67 66
Route Refresh: 0 0
Total: 74 73
Do log neighbor state changes (via global configuration)
Default minimum time between advertisement runs is 0 seconds
```

遠端PE VPNv4鄰接已啟動，且已收到字首

```
C9300-PE-1#show bgp vpnv4 unicast all summary
BGP router identifier 192.168.1.2, local AS number 69420
BGP table version is 7, main routing table version 7
4 network entries using 1024 bytes of memory
4 path entries using 544 bytes of memory
4/4 BGP path/bestpath attribute entries using 1216 bytes of memory
4 BGP extended community entries using 1000 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 3784 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs
4 networks peaked at 16:19:10 Jun 1 2021 UTC (01:32:00.716 ago)

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.1.4     4        69420     108     108        7    0    0 01:34:52        2

C9300-PE-2#show bgp vpnv4 unicast all summary
BGP router identifier 192.168.1.4, local AS number 69420
BGP table version is 7, main routing table version 7
4 network entries using 1024 bytes of memory
4 path entries using 544 bytes of memory
4/4 BGP path/bestpath attribute entries using 1216 bytes of memory
4 BGP extended community entries using 1000 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 3784 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs
4 networks peaked at 16:18:31 Jun 1 2021 UTC (01:37:30.404 ago)

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.1.2     4        69420     114     114        7    0    0 01:40:22        2
```

驗證特定VRF中交換的字首是什麼

```
C9300-PE-1#show ip bgp vpnv4 vrf RED
```

```
BGP table version is 10, local router ID is 192.168.1.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
              t secondary path, L long-lived-stale,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 69:69 (default for vrf RED)
 *>   10.0.0.0/30      0.0.0.0                  0         32768 ?
 *>i  10.0.0.20/30     192.168.1.4              0    100      0 ?
 *>   192.168.1.0      10.0.0.1            130816         32768 ?
 *>i  192.168.2.0      192.168.1.4         130816    100      0 ?

C9300-PE-2#show ip bgp vpnv4 vrf RED
BGP table version is 9, local router ID is 192.168.1.4
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
              t secondary path, L long-lived-stale,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 69:69 (default for vrf RED)
 *>i  10.0.0.0/30      192.168.1.2              0    100      0 ?
 *>   10.0.0.20/30     0.0.0.0                  0         32768 ?
 *>i  192.168.1.0      192.168.1.2         130816    100      0 ?
 *>   192.168.2.0      10.0.0.22           130816         32768 ?
```

驗證VPNv4和LDP標籤：

驗證用於到達VRF中字首的VPNv4標籤

```
C9300-PE-1#show ip bgp vpnv4 vrf RED labels
   Network          Next Hop      In label/Out label
Route Distinguisher: 69:69 (RED)
   10.0.0.0/30      0.0.0.0         20/nolabel(RED)
   10.0.0.20/30     192.168.1.4     nolabel/20
   192.168.1.0      10.0.0.1        21/nolabel
   192.168.2.1/32   192.168.1.4     nolabel/21 <-- VPNv4 label that is imposed to reach
192.168.2.0

C9300-PE-1#show ip route vrf RED 192.168.2.1
Routing Table: RED
Routing entry for 192.168.2.0/24
Known via "bgp 69420", distance 200, metric 130816, type internal
Last update from 192.168.1.4 01:31:56 ago
Routing Descriptor Blocks:
* 192.168.1.4 (default), from 192.168.1.4, 01:31:56 ago
Route metric is 130816, traffic share count is 1
AS Hops 0
MPLS label: 21 <-- VPNv4 label that matches the previous output
MPLS Flags: MPLS Required
C9300-PE-2#show ip bgp vpnv4 vrf RED labels
   Network          Next Hop      In label/Out label
Route Distinguisher: 69:69 (RED)
   10.0.0.0/30      192.168.1.2     nolabel/20
   10.0.0.20/30     0.0.0.0         20/nolabel(RED)
   192.168.1.0      192.168.1.2     nolabel/21
```

```
   192.168.2.0.     10.0.0.22       21/nolabel <-- VPNv4 label that is advertised to reach
192.168.2.0

C9300-PE-2#show ip route vrf RED 192.168.2.1

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "eigrp 400", distance 90, metric 130816, precedence routine (0), type internal
  Redistributing via eigrp 400, bgp 69420
  Advertised by bgp 69420
  Last update from 10.0.0.22 on GigabitEthernet2/0/1, 01:34:42 ago
  Routing Descriptor Blocks:
  * 10.0.0.22, from 10.0.0.22, 01:34:42 ago, via GigabitEthernet2/0/1 <-- CE-facing interface in
the VRF
      Route metric is 130816, traffic share count is 1
      Total delay is 5010 microseconds, minimum bandwidth is 1000000 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 1
```

驗證使用的LDP標籤

```
C9300-PE-1#show mpls forwarding-table 192.168.1.4
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
19         17         192.168.1.4/32   0             Gi1/0/2    10.0.0.6 <-- 17 is the LDP label
imposed to reach PE at 192.168.1.4 through Gi1/0/2

C9300-PE-2#show mpls forwarding-table 192.168.1.2
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
17         16         192.168.1.2/32   0             Gi2/0/2    10.0.0.13 <-- 16 is the LDP
label imposed to reach PE at 192.168.1.4 through Gi2/0/2
```

驗證MPLS轉發表

```
C9300-PE-1#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi1/0/2    10.0.0.6
17         Pop Label  10.0.0.16/30     0             Gi1/0/2    10.0.0.6
18         Pop Label  10.0.0.12/30     0             Gi1/0/2    10.0.0.6
19         17         192.168.1.4/32   0             Gi1/0/2    10.0.0.6
20         No Label   10.0.0.0/30[V]   1982          aggregate/RED
21         No Label   192.168.3.0/24[V]   \
                                       0             Gi1/0/1    10.0.0.1

C9300-PE-2#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi2/0/2    10.0.0.13
           Pop Label  192.168.1.3/32   0             Gi2/0/3    10.0.0.17
17         16         192.168.1.2/32   164           Gi2/0/2    10.0.0.13
           16         192.168.1.2/32   1224          Gi2/0/3    10.0.0.17
18         Pop Label  10.0.0.4/30      0             Gi2/0/2    10.0.0.13
           Pop Label  10.0.0.4/30      0             Gi2/0/3    10.0.0.17
20         No Label   10.0.0.20/30[V]  0             aggregate/RED
21         No Label   192.168.2.0/24[V]   \
                                       1440          Gi2/0/1    10.0.0.22
```

確認用於到達VRF中每個給定字首的內部(VPNv4)和外部(LDP)標籤

```
C9300-PE-1#show ip cef vrf RED 192.168.2.0/24 detail
192.168.2.1/32, epoch 0, flags [rib defined all labels]
  recursive via 192.168.1.4 label 21 <-- VPNv4 label
    nexthop 10.0.0.6 GigabitEthernet1/0/2 label 17-(local:19) <-- 17 is the LDP label that is be
imposed to reach the remote PE,
19 is the local LDP label advertised to the P router

C9300-PE-2#show ip cef vrf RED 192.168.3.0/24 detail
192.168.1.1/32, epoch 0, flags [rib defined all labels]
  recursive via 192.168.1.2 label 22 <-- VPNv4 label
    nexthop 10.0.0.13 GigabitEthernet2/0/2 label 16-(local:17) <-- 16 is the LDP label that is
be imposed to reach the remote PE,
                                                                    17 is the local LDP label
advertised to the P router
```

驗證Object-Manager統計資訊

在理想情況下，沒有掛起對象

```
C9300-PE-1#show platform software object-manager switch active f0 statistics
Forwarding Manager Asynchronous Object Manager Statistics

Object update: Pending-issue: 0, Pending-acknowledgement: 0
Batch begin:   Pending-issue: 0, Pending-acknowledgement: 0
Batch end:     Pending-issue: 0, Pending-acknowledgement: 0
Command:       Pending-acknowledgement: 0
Total-objects: 491
Stale-objects: 0
Resolve-objects: 0
Childless-delete-objects: 0
Error-objects: 0
Paused-types: 0
9500-P#show platform software object-manager switch active f0 statistics
Forwarding Manager Asynchronous Object Manager Statistics

Object update: Pending-issue: 0, Pending-acknowledgement: 0
Batch begin:   Pending-issue: 0, Pending-acknowledgement: 0
Batch end:     Pending-issue: 0, Pending-acknowledgement: 0
Command:       Pending-acknowledgement: 0
Total-objects: 491
Stale-objects: 0
Resolve-objects: 0
Childless-delete-objects: 0
Error-objects: 0
Paused-types: 0
C9300-PE-2#show platform software object-manager switch active f0 statistics
Forwarding Manager Asynchronous Object Manager Statistics

Object update: Pending-issue: 0, Pending-acknowledgement: 0
Batch begin:   Pending-issue: 0, Pending-acknowledgement: 0
Batch end:     Pending-issue: 0, Pending-acknowledgement: 0
Command:       Pending-acknowledgement: 0
Total-objects: 482
Stale-objects: 0
Resolve-objects: 0
Childless-delete-objects: 0
Error-objects: 0
Paused-types: 0
```

首碼程式設計

下一節將介紹MPLS路由器C9300-PE-1、C9500-P和C9300-PE-2上的字首程式設計。

C9300-PE-1首碼程式

```
***Software Prefix Programming***
C9300-PE-1#show ip route vrf RED 192.168.2.1

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "bgp 69420", distance 200, metric 130816, type internal
  Last update from 192.168.1.4 20:21:40 ago
  Routing Descriptor Blocks:
  * 192.168.1.4 (default), from 192.168.1.4, 20:21:40 ago <-- Remote PE reachable in the global
routing table
      Route metric is 130816, traffic share count is 1
      AS Hops 0
      MPLS label: 21 <-- VPNv4 label
      MPLS Flags: MPLS Required

C9300-PE-1#show ip route 192.168.1.4
Routing entry for 192.168.1.4/32
Known via "ospf 420", distance 110, metric 3, type intra area
Last update from 10.0.0.6 on GigabitEthernet1/0/2, 21:27:11 ago
Routing Descriptor Blocks:
* 10.0.0.6, from 192.168.1.4, 21:27:11 ago, via GigabitEthernet1/0/2 <-- Next-hop 10.0.0.6 via
Gi1/0/2 to reach
Route metric is 3, traffic share count is 1

***FMAN RP Prefix Programming***
C9300-PE-1#show ip vrf detail
VRF RED (VRF Id = 2); default RD 69:69; default VPNID <-- VRF ID is important in subsequent
command
  Old CLI format, supports IPv4 only
  Flags: 0xC
  Interfaces:
    Gi1/0/1
Address family ipv4 unicast (Table ID = 0x2):
  Flags: 0x0
  Export VPN route-target communities
    RT:69:69
  Import VPN route-target communities
    RT:69:69
  No import route-map
  No global export route-map
  No export route-map
  VRF label distribution protocol: not configured
  VRF label allocation mode: per-prefix
C9300-PE-1#show platform software ip switch active r0 cef table index 2 prefix 192.168.2.0/24 <
- Index value is the VRF ID from previous command
Forwarding Table

Prefix/Len                     Next Object      Index
-----------------------------------------------------------------
192.168.2.0/24                 OBJ_LABEL        0x14

C9300-PE-1#show platform software mpls switch active r0 label index 0x14 <-- Utilize the Index
value from previous command


Label OCE 0x14 -> OBJ_LABEL (0x17) <-- Utilized in next command
```

```
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x15
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480636fb0

C9300-PE-1#show platform software mpls switch active r0 label index 0x17 <-- Utilize the
OBJ_LABEL value from previous command


Label OCE 0x17 -> OBJ_ADJACENCY (0x46) <-- Utilized in next command
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x348062f858

C9300-PE-1#show platform software adjacency switch active r0 index 0x46 <-- Utilize the
OBJ_ADJACENCY value from previous command
Number of adjacency objects: 6

Adjacency id: 0x46 (70)
  Interface: GigabitEthernet1/0/2, IF index: 54, Link Type: MCP_LINK_TAG <-- Egress interface
  Encap: d4:ad:71:b5:dd:e4:a0:f8:49:11:d1:d6:88:47 <-- MAC ending in DDE4 is the DMAC, MAC
ending in D1D6 is SMAC, 8847 is MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.6 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x3480636280

***FMAN FP Prefix Programming***
C9300-PE-1#show ip vrf detail
VRF RED (VRF Id = 2); default RD 69:69; default VPNID <-- VRF ID is important in subsequent
command
  Old CLI format, supports IPv4 only
  Flags: 0xC
  Interfaces:
    Gi1/0/1
Address family ipv4 unicast (Table ID = 0x2):
  Flags: 0x0
  Export VPN route-target communities
    RT:69:69
  Import VPN route-target communities
    RT:69:69
  No import route-map
  No global export route-map
  No export route-map
  VRF label distribution protocol: not configured
  VRF label allocation mode: per-prefix

C9300-PE-1#show platform software ip switch active f0 cef table index 2 prefix 192.168.2.0/24
detail <-- Index value is the VRF ID from previous command
Forwarding Table

192.168.2.0/24 -> OBJ_LABEL (0x14), urpf: 15 <-- Utilized in next command
Prefix Flags: unknown
aom id: 648, HW handle: (nil) (created)

C9300-PE-1#show platform software mpls switch active f0 label index 0x14 <-- Utilize the
OBJ_LABEL value from the previous command
```

```
Label OCE 0x14 -> OBJ_LABEL (0x17) <-- Utilized in next command
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x15
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 647, CPP handle: 0xdeadbeef (created)

C9300-PE-1#show platform software mpls switch active f0 label index 0x17 <-- Utilize the
OBJ_LABEL value from the previous command


Label OCE 0x17 -> OBJ_ADJACENCY (0x46) <-- Utilized in next command
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 664, CPP handle: 0xdeadbeef (created)


C9300-PE-1#show platform software adjacency switch active f0 index 0x46 <-- Utilize the
OBJ_ADJACENCY value from the previous command
Number of adjacency objects: 6

Adjacency id: 0x46 (70)
  Interface: GigabitEthernet1/0/2, IF index: 54, Link Type: MCP_LINK_TAG <-- Egress interface
  Encap: d4:ad:71:b5:dd:e4:a0:f8:49:11:d1:d6:88:47 <-- MAC ending in DDE4 is the DMAC, MAC
ending in D1D6 is SMAC, 8847 is MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.6 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 522, HW handle: (nil) (created)

***FED Prefix Programming***
C9300-PE-1#show platform software fed switch active ip route vrf-name RED 192.168.2.0/24
vrf   dest                                      htm            flags   SGT   DGID MPLS Last-
modified
---   ----                                      ---            -----   ---   ---- ---- -----
-------------------
2     192.168.2.0/24                            0x7feeeca12bb8 0x0     0     0   lspa0x2
2021/06/14 17:13:59.644 <-- HTM value significant for next command
  FIB: prefix_hdl:0x5000002a, mpls_ecr_prefix_hdl:0
  ========== OCE chain =====
  LABEL:objid:20 link_type:MPLS local_label:1048577 outlabel:(21, 0) <-- VPNv4 Label
      flags:0x1:(REAL,) pdflags:0x80:(INSTALL_HW_OK,RECIR_ADJ,) adj_handle:0x5100003d <--
adj_handle and local_adj_hdl values must match
      unsupported recursion:0 olbl_changed 0 local_adj:1 modify_cnt:1
      bwalk_cnt:0 subwalk_cnt:1 collapsed_oce:0
      AAL: id:1358954557 lbl:19 smac:0000.0000.0000 dmac:0000.0000.0000 <-- Label 19 matches the
local transport label
           sub_type:0 link_type:0 adj_flags:0x10 label_type:0 rewrite_type:PSH2(121)
           vlan_id:0 vrf_id:0 ri:0x7feeeca9acf8, ri_id:0x46 phdl:0, ref_cnt:2 <-- ri_id and
ri_idx values must match
           si:0x7feeeca6ab98, si_id:0xb6, di_id:0x5013
  LABEL:objid:23 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Label 19 is the local
transport label, Label 17 is the LDP label
      flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x50000034
      unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
      bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
      AAL: id:1342177332 lbl:0 smac:a0f8.4911.d1d6 dmac:d4ad.71b5.dde4 <-- Matches the next-hop
information to reach 192.168.2.0/24
           sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
           vlan_id:0 vrf_id:0 ri:0x7feeecd6d238, ri_id:0x3e phdl:0x9f00004b, ref_cnt:1
```

```
          si:0x7feeecd706d8, si_id:0x4013, di_id:0x535f <-- di_id utilized in subsequent
commands
  ADJ:objid:70 {link_type:MPLS ifnum:0x36, si:0x94000021, }
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0, mpls_lspa_hdl:0xab000003
    AAL:LSPA: id:2868903939 num_path:1 prefix_id:0x2 delete_hw_hdl_cnt:0
         cookie[64]:
150000000000000000000000000000000000000000000000000000000000000000000460000000000000000000000000
00000000000000000000000000000000 status:ok
          vpn_lbl:21 local_adj_hdl:0x5100003d hw_hdl:0x7feeecab2d48 ri_idx:0x46 <-- vpn_lbl
matches the VPNv4 label,adj_handle and local_adj_hdl values must match,ri_id and ri_idx values
must match
  ===============

C9300-PE-1#show platform hardware fed switch active fwd-asic abstraction print-resource-handle
0x7feeeca12bb8 1 <-- Utilize HTM value from previous command
Handle:0x7feeeca12bb8 Res-Type:ASIC_RSC_HASH_TCAM Res-Switch-Num:0 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_IPV4_L3_UNICAST ref_count:1
priv_ri/priv_si Handle: (nil)Hardware Indices/Handles: handle [ASIC: 0]: 0x7feeeca2af28
Features sharing this resource:Cookie length: 12
01 02 a8 c0 00 00 02 d0 07 00 00 00

Detailed Resource Information (ASIC# 0)
----------------------------------------
Number of HTM Entries: 1

Entry 0: (handle 0x7feeeca2af28)

Absolute Index: 66036
Time Stamp: 160003
KEY - vrf:2 mtr:0 prefix:192.168.2.0 rcp_redirect_index:0x0
MASK - vrf:0 mtr:0 prefix:0.0.0.255 rcp_redirect_index:0x0
FWD-AD = afd_label_flag:0 icmp_redir_enable:1 lvx_smr_enabled:0, dstNatType:0 priority:5
afdLabelOrDestClientId:0 SI:182 destined_to_us:0 hw_stats_idx:0 stats_id:0
redirectSetRouterMac:0 dgtIdx:0 destModIndex:0 dstNatTypeOrVpnPrefixPtrMsb:0 vpnPrefixPtr:0x2
SRC-AD = learning_violation:0 need_to_learn:0  locally_connected:0 staticentryViolation:0
rpfValid:1 rpfLe:0 rpfLePointer:0 rpfForcePass:0 rpfForceFail:0 reachableviaSome:0
rpfCheckIncomplete:0 defaultRoute:0 ChainPtrValid:0 ChainPtrOrPortLeIndex:72 UseRpfmatchTable:0
rpfIncomplete:0 is_src_ce:0 sgtValid:0 sgt:0 src_rloc_trusted:0,sgtCacheControl1 = 0,
sgtCacheControl0 = 0
port_label:0x0 port_mask:0x0 vlan_label:0x0 vlan_mask:0x0 l3if_label:0x0 l3if_mask:0x0
group_label:0x0 group_mask:0x0


==============================================================

C9300-PE-1#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x535f 0x535f <-- Utilize the di_id from the previous command
ASIC#0:

index = 0x535f
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
```

```
copySeg = 0
ASIC#1:

index = 0x535f
pmap = 0x00000000 0x00000002 <-- Looking at 0x00000002, in binary that is 0000 0000 0000 0000
0000 0000 0000 0010 = Port 1 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9300-PE-1#show plat soft fed switch active ifm mappings
Interface                IF_ID    Inst Asic Core Port SubPort Mac  Cntx LPN  GPN  Type Active
GigabitEthernet1/0/2     0x36       1   0   1    1      0      6    7    2    2    NIF  Y    <-
- Port 1 is the egress port, Gi1/0/2
```

C9500-P首碼程式

```
***Software Prefix Programming***
C9500-P#show ip route 192.168.1.4
Routing entry for 192.168.1.4/32
  Known via "ospf 420", distance 110, metric 2, type intra area
  Last update from 10.0.0.14 on TenGigabitEthernet1/0/2, 1d21h ago
  Routing Descriptor Blocks:
  * 10.0.0.14, from 192.168.1.4, 1d21h ago, via TenGigabitEthernet1/0/2 <-- Next-hop to reach
192.168.1.4
      Route metric is 2, traffic share count is 1

C9500-P#show ip cef 192.168.1.4 detail
192.168.1.4/32, epoch 4
  dflt local label info: global/17 [0x3]
  nexthop 10.0.0.14 TenGigabitEthernet1/0/2 label explicit-null-(local:17)

***FMAN RP Prefix Programming***
C9500-P#show platform software ip switch active r0 cef prefix 192.168.1.4/32
Forwarding Table

Prefix/Len                     Next Object      Index
----------------------------------------------------------------
192.168.1.4/32                 OBJ_LABEL        0x16 <-- Value used in next command

C9500-P#show platform software mpls switch active r0 label index 0x16 <-- Utilize the OBJ_LABEL
value from previous command


Label OCE 0x16 -> OBJ_ADJACENCY (0x49) <-- Value used in next command
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x34806492f0

C9500-P#show platform software adjacency switch active r0 index 0x49 <-- Utilize OBJ_ADJACENCY
value from previous command
```

```
Number of adjacency objects: 8

Adjacency id: 0x49 (73)
  Interface: TenGigabitEthernet1/0/2, IF index: 66, Link Type: MCP_LINK_TAG
  Encap: 70:d3:79:be:ae:71:d4:ad:71:b5:dd:d6:88:47 <-- MAC ending in AE71 is the DMAC, MAC
ending in DDD6 is the SMAC, 8847 is MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.14 <-- Next-hop IP
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x3480647760

***FMAN FP Prefix Programming***
C9500-P#show platform software ip switch active f0 cef prefix 192.168.1.4/32 detail
Forwarding Table

192.168.1.4/32 -> OBJ_LABEL (0x16), urpf: 21 <-- Used in subsequent command
Prefix Flags: unknown
aom id: 567, HW handle: (nil) (created)

C9500-P#show platform software mpls switch active f0 label index 0x16 <-- Utilize the OBJ_LABEL
value from previous command


Label OCE 0x16 -> OBJ_ADJACENCY (0x49) <-- Used in subsequent command
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 589, CPP handle: 0xdeadbeef (created)

C9500-P#show platform software adjacency switch active f0 index 0x49 <-- Utilize the
OBJ_ADJACENCY from previous command
Number of adjacency objects: 8

Adjacency id: 0x49 (73)
  Interface: TenGigabitEthernet1/0/2, IF index: 66, Link Type: MCP_LINK_TAG
  Encap: 70:d3:79:be:ae:71:d4:ad:71:b5:dd:d6:88:47 <-- MAC ending in AE71 is the DMAC, MAC
ending in DDD6 is the SMAC, 8847 is MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.14 <-- Next-hop IP
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 535, HW handle: (nil) (created)

*** FED Prefix Programming***
C9500-P#show platform software fed switch active ip route 192.168.1.4/32
vrf   dest                                      htm            flags   SGT   DGID MPLS Last-
modified
---   ----                                      ---            -----   ---   ---- ---- -----
------------------
0     192.168.1.4/32                            0x7f790c4cf0e8 0x0     0     0
2021/06/14 22:10:54.150 <-- HTM value significant for next command
  FIB: prefix_hdl:0x6a000020, mpls_ecr_prefix_hdl:0
  ========== OCE chain =====
  LABEL:objid:22 link_type:MPLS local_label:17 outlabel:(0, 0) <-- Label 17 is the local
transport label
      flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xb9000037
      unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
```

```
      bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
      AAL: id:3103785015 lbl:0 smac:d4ad.71b5.ddd6 dmac:70d3.79be.ae71 <-- Matches the next-hop
information to reach 192.168.1.4/32
           sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
           vlan_id:0 vrf_id:0 ri:0x7f790c4cdfd8, ri_id:0x38 phdl:0x76000058, ref_cnt:1
           si:0x7f790c4c22f8, si_id:0x400b, di_id:0x2 <-- di_id utilized in subsequent commands
  ADJ:objid:73 {link_type:MPLS ifnum:0x42, si:0x2d000027, }
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0, mpls_lspa_hdl:0
  ===============

C9500-P#show platform hardware fwd-asic abstraction print-resource-handle 0x7f790c4cf0e8 1 <--
Utilize the HTM value from previous command
Handle:0x7f790c4cf0e8 Res-Type:ASIC_RSC_HASH_TCAM Res-Switch-Num:0 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_IPV4_L3_UNICAST ref_count:1
priv_ri/priv_si Handle: (nil)Hardware Indices/Handles: handle [ASIC: 0]: 0x7f790c4cf2f8
Features sharing this resource:Cookie length: 12
04 01 a8 c0 00 00 00 d0 07 00 00 00

Detailed Resource Information (ASIC# 0)
---------------------------------------
Number of HTM Entries: 1

Entry 0: (handle 0x7f790c4cf2f8)

Absolute Index: 126650
Time Stamp: 40
KEY - vrf:0 mtr:0 prefix:192.168.1.4 rcp_redirect_index:0x0
MASK - vrf:0 mtr:0 prefix:0.0.0.0 rcp_redirect_index:0x0
FWD-AD = afd_label_flag:0 icmp_redir_enable:1 lvx_smr_enabled:0, dstNatType:0 priority:5
afdLabelOrDestClientId:0 SI:16395 destined_to_us:0 hw_stats_idx:1 stats_id:0
redirectSetRouterMac:0 dgtIdx:0 destModIndex:0 dstNatTypeOrVpnPrefixPtrMsb:0 vpnPrefixPtr:0
SRC-AD = learning_violation:0 need_to_learn:0  locally_connected:0 staticentryViolation:0
rpfValid:1 rpfLe:38 rpfLePointer:0 rpfForcePass:0 rpfForceFail:0 reachableviaSome:1
rpfCheckIncomplete:0 defaultRoute:0 ChainPtrValid:0 ChainPtrOrPortLeIndex:72 UseRpfmatchTable:0
rpfIncomplete:0 is_src_ce:0 sgtValid:0 sgt:0 src_rloc_trusted:0,sgtCacheControl1 = 0,
sgtCacheControl0 = 0
port_label:0x0 port_mask:0x0 vlan_label:0x0 vlan_mask:0x0 l3if_label:0x0 l3if_mask:0x0
group_label:0x0 group_mask:0x0


==============================================================

C9500-P#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x2 0x2 <-- Utilize the di_id value from the previous command
ASIC#0:

index = 0x2
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:
```

```
index = 0x2
pmap = 0x00000000 0x00000002 <-- 0x00000002 in binary is 0000 0000 0000 0000 0000 0000 0000 =
Port 1 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9500-P#show platform software fed switch active ifm mappings
Interface                IF_ID    Inst Asic Core Port SubPort Mac  Cntx LPN  GPN  Type Active
TenGigabitEthernet1/0/2  0x42       1   0   1    1      0      10   1    2    2    NIF  Y    <-
- Port 1 is the egress port, TenGig1/0/2
```

C9300-PE-2首碼程式

```
***Software Prefix Programming***
C9300-PE-2#show ip route vrf RED 192.168.2.1

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "eigrp 400", distance 90, metric 130816, precedence routine (0), type internal
  Redistributing via eigrp 400, bgp 69420
  Advertised by bgp 69420
  Last update from 10.0.0.22 on GigabitEthernet2/0/1, 1d21h ago
  Routing Descriptor Blocks:
  * 10.0.0.22, from 10.0.0.22, 1d21h ago, via GigabitEthernet2/0/1 <-- Next-hop reachable in the
VRF
      Route metric is 130816, traffic share count is 1
      Total delay is 5010 microseconds, minimum bandwidth is 1000000 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 1

C9300-PE-2#show ip route vrf RED 10.0.0.22

Routing Table: RED
Routing entry for 10.0.0.20/30
  Known via "connected", distance 0, metric 0 (connected, via interface)
  Redistributing via eigrp 400, bgp 69420
  Advertised by bgp 69420
  Routing Descriptor Blocks:
  * directly connected, via GigabitEthernet2/0/1 <-- Next-hop directly connected
      Route metric is 0, traffic share count is 1

C9300-PE-2#show ip cef vrf RED 192.168.2.0/24 detail
192.168.2.0/24, epoch 0
  QOS: Precedence routine (0)
  dflt local label info: other/21 [0x2]
  nexthop 10.0.0.22 GigabitEthernet2/0/1

***FMAN RP Prefix Programming***
C9300-PE-2#show ip vrf detail
VRF RED (VRF Id = 2); default RD 69:69; default VPNID <-- VRF ID is important in subsequent
command
```

```
  Old CLI format, supports IPv4 only
  Flags: 0xC
  Interfaces:
    Gi2/0/1
Address family ipv4 unicast (Table ID = 0x2):
  Flags: 0x0
  Export VPN route-target communities
    RT:69:69
  Import VPN route-target communities
    RT:69:69
  No import route-map
  No global export route-map
  No export route-map
  VRF label distribution protocol: not configured
  VRF label allocation mode: per-prefix

C9300-PE-2#show platform software ip switch active r0 cef table index 2 prefix 192.168.2.0/24
Forwarding Table

Prefix/Len                      Next Object      Index
-----------------------------------------------------------------
192.168.2.0/24                  OBJ_ADJACENCY    0x19

C9300-PE-2#show platform software adjacency switch active r0 index 0x19 <-- Utilize the Index
value from previous command
Number of adjacency objects: 6

Adjacency id: 0x19 (25)
  Interface: GigabitEthernet2/0/1, IF index: 53, Link Type: MCP_LINK_IP
  Encap: 0:72:78:c8:c9:c2:70:d3:79:be:ae:42:8:0 <-- MAC ending in C9C2 is DMAC, MAC ending in
AE42 is SMAC, 0x800 is the IP ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: no-l3-inject
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.22
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x348062f118

***FMAN FP Prefix Programming***
C9300-PE-2#show platform software ip switch active f0 cef table index 2 prefix 192.168.2.0/24
detail
Forwarding Table

192.168.2.0/24 -> OBJ_ADJACENCY (0x19), urpf: 30 <-- Utilized in next command
Prefix Flags: unknown
aom id: 665, HW handle: (nil) (created)
QPPB precedence: 0

C9300-PE-2#show platform software adjacency switch active f0 index 0x19 <-- Utilize the
OBJ_ADJACENCY from previous command
Number of adjacency objects: 6

Adjacency id: 0x19 (25)
  Interface: GigabitEthernet2/0/1, IF index: 53, Link Type: MCP_LINK_IP
  Encap: 0:72:78:c8:c9:c2:70:d3:79:be:ae:42:8:0
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: no-l3-inject
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.22
  IP FRR MCP_ADJ_IPFRR_NONE 0
```

```
  aom id: 659, HW handle: (nil) (created)

***FED Prefix Programming***
C9300-PE-2#show platform software fed switch active ip route vrf-name RED 192.168.2.0/24
vrf   dest                                        htm            flags   SGT   DGID MPLS Last-
modified
---   ----                                        ---            -----   ---   ---- ---- -----
------------------
2     192.168.2.0/24                              0x7f7fb4a25648 0x0     0     0
2021/06/14 17:04:13.460 <-- HTM value significant for next command
  FIB: prefix_hdl:0x6e00002a, mpls_ecr_prefix_hdl:0
  ========== OCE chain =====
  ADJ:objid:25 {link_type:IP ifnum:0x35, si:0x3300003e, IPv4:       10.0.0.22 }
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0, mpls_lspa_hdl:0


  ===============

C9300-PE-2#show platform hardware fed switch active fwd-asic abstraction print-resource-handle
0x7f7fb4a25648 1 <-- Utilize HTM value from previous command
Handle:0x7f7fb4a25648 Res-Type:ASIC_RSC_HASH_TCAM Res-Switch-Num:0 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_IPV4_L3_UNICAST ref_count:1
priv_ri/priv_si Handle: (nil)Hardware Indices/Handles: handle [ASIC: 0]: 0x7f7fb4a10e58
Features sharing this resource:Cookie length: 12
01 02 a8 c0 00 00 02 d0 07 00 00 00

Detailed Resource Information (ASIC# 0)
---------------------------------------
Number of HTM Entries: 1

Entry 0: (handle 0x7f7fb4a10e58)

Absolute Index: 66036
Time Stamp: 164911
KEY - vrf:2 mtr:0 prefix:192.168.2.0 rcp_redirect_index:0x0
MASK - vrf:0 mtr:0 prefix:0.0.0.255 rcp_redirect_index:0x0
FWD-AD = afd_label_flag:0 icmp_redir_enable:1 lvx_smr_enabled:0, dstNatType:0 priority:5
afdLabelOrDestClientId:0 SI:182 destined_to_us:0 hw_stats_idx:1 stats_id:0
redirectSetRouterMac:0 dgtIdx:0 destModIndex:0 dstNatTypeOrVpnPrefixPtrMsb:0 vpnPrefixPtr:0
SRC-AD = learning_violation:0 need_to_learn:0  locally_connected:0 staticentryViolation:0
rpfValid:1 rpfLe:37 rpfLePointer:0 rpfForcePass:0 rpfForceFail:0 reachableviaSome:1
rpfCheckIncomplete:0 defaultRoute:0 ChainPtrValid:0 ChainPtrOrPortLeIndex:72 UseRpfmatchTable:0
rpfIncomplete:0 is_src_ce:0 sgtValid:0 sgt:0 src_rloc_trusted:0,sgtCacheControl1 = 0,
sgtCacheControl0 = 0
port_label:0x0 port_mask:0x0 vlan_label:0x0 vlan_mask:0x0 l3if_label:0x0 l3if_mask:0x0
group_label:0x0 group_mask:0x0


=============================================================

C9300-PE-2#show platform software fed switch active ip adj
IPV4 Adj entries
dest            if_name                dst_mac          si_hdl         ri_hdl         pd_flags
adj_id  Last-modified
----            -------                -------          ------         ------         --------
-----   ------------------------
10.0.0.22       GigabitEthernet2/0/1    0072.78c8.c9c2   0x7f7fb4a44048 0x7f7fb4b089d8 0x0
0x19       2021/06/14 16:59:43.447 <-- si_hdl used in next command

C9300-PE-2#show platform hardware fed switch active fwd-asic abstraction print-resource-handle
0x7f7fb4a44048 1 <-- Utilize the si_hdl value from previous command
Handle:0x7f7fb4a44048 Res-Type:ASIC_RSC_SI Res-Switch-Num:255 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_INVALID ref_count:1
```

```
priv_ri/priv_si Handle: 0x7f7fb4b089d8Hardware Indices/Handles: index0:0xb6
mtu_index/l3u_ri_index0:0x0  index1:0xb6  mtu_index/l3u_ri_index1:0x0
Features sharing this resource:66 (1)]
Cookie length: 56
00 00 00 00 00 00 00 00 25 00 00 00 00 00 00 00 00 00 00 08 00 00 72 78 c8 c9 c2 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Detailed Resource Information (ASIC# 0)
---------------------------------------


Station Index (SI) [0xb6]
RI = 0x2b
DI = 0x5338
stationTableGenericLabel = 0
stationFdConstructionLabel = 0x7
lookupSkipIdIndex = 0
rcpServiceId = 0
dejaVuPreCheckEn = 0
Replication Bitmap: CD

Detailed Resource Information (ASIC# 1)
---------------------------------------


Station Index (SI) [0xb6]
RI = 0x2b
DI = 0x5338
stationTableGenericLabel = 0
stationFdConstructionLabel = 0x7
lookupSkipIdIndex = 0
rcpServiceId = 0
dejaVuPreCheckEn = 0
Replication Bitmap: LD

==============================================================

C9300-PE-2#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x5338 0x5338 <-- Utilize the DI value from previous command
ASIC#0:

index = 0x5338
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x5338
pmap = 0x00000000 0x00000001 <-- 0x00000001 in binary is 0000 0000 0000 0000 0000 0000 0000 0001
= Port 0 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
```

```
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9300-PE-2#show platform software fed switch active ifm map
Interface                IF_ID    Inst Asic Core Port SubPort Mac  Cntx LPN  GPN  Type Active
GigabitEthernet2/0/1     0x35       1   0   1    0      0      26   6    1    97   NIF  Y    <-
- Port 0 is the egress port, Gi2/0/1
```

VPNv4標籤程式設計

下一節將介紹MPLS PE路由器（C9300-PE-1和C9300-PE-2）上的VPNv4標籤程式設計。C9500不會在VPNv4標籤上轉發，因此沒有來自C9500的輸出。

C9300-PE-1 VPNv4標籤程式設計：

檢查PE的本地字首，而不是遠端字首。

```
***Software VPNv4 Label Programming***
C9300-PE-1#show ip cef vrf RED 192.168.3.0/24 detail
192.168.3.0/24, epoch 0
  QOS: Precedence routine (0)
  dflt local label info: other/22 [0x2] <-- VPNv4 label associated with the local prefix
  nexthop 10.0.0.1 GigabitEthernet1/0/1

*** FMAN RP VPNv4 Label Programming***
C9300-PE-1#show platform software mpls switch active r0 eos index 24 <-- Utilize the objid from
the FED command


EOS Choice 0x18, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x17
  OM handle: 0x3480631760

***FMAN FP VPNv4 Label Programming***
C9300-PE-1#show platform software mpls switch active f0 eos index 24 <-- Utilize the objid from
the FED command


EOS Choice 0x18, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x17
  aom id: 5748, CPP handle: 0xdeadbeef (created), flags: 0 <-- Utilized in subsequent command

C9300-PE-1#show platform software object-manager switch active f0 object 5748 <-- Utilize the
aom id from previous command
Object identifier: 5748
  Description: EOS Choice 0x18
  Status: Done, Epoch: 0, Client data: 0x63150908

C9300-PE-1#show platform software object-manager switch active f0 object 5748 parents <--
Utilize the aom id
```

```
Object identifier: 7
  Description: Special Object adj_drop
  Status: Done

Object identifier: 5746
  Description: label 0x17
  Status: Done
```

```
***FED VPNv4 Label Programming***
C9300-PE-1#show platform software fed switch active mpls forwarding label 22 detail
 LENTRY:label:22 nobj:(EOS, 24) lentry_hdl:0x800000a
   modify_cnt:1 backwalk_cnt:0
   lspa_handle:0
   AAL: id:134217738 lbl:22
        eos0:[adj_hdl:0, hw_hdl:0x7fa4c4d72e08]
        eos1:[adj_hdl:0x6e00003e, hw_hdl:0x7fa4c4d72c58]
        deagg_vrf_id = 0 lspa_handle:0
   EOS:objid:24 local_label:0 flags:0:() pdflags:0 <-- Utilized in previous commands
      nobj0:(ADJ SPECIAL,DROP 0), nobj1:(LABEL, 23) modify:0 bwalk:0
      LABEL:objid:23 link_type:IP local_label:22 outlabel:(1048577, 0)
          flags:0xc:(UHP,POP,) pdflags:0x2:(INSTALL_HW_OK,) adj_handle:0x6e00003e
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1845493822 lbl:0 smac:a0f8.4911.d1e4 dmac:0072.78c8.06e4
               sub_type:0 link_type:0 adj_flags:0x2 label_type:1 rewrite_type:POP2IP(135)
               vlan_id:0 vrf_id:0 ri:0x7fa4c4a81af8, ri_id:0x44 phdl:0xf1000024, ref_cnt:1
               si:0x7fa4c4d83da8, si_id:0x4012, di_id:0x5338
      ADJ:objid:113 {link_type:IP ifnum:0x35, si:0x2000003a, IPv4:        10.0.0.1 }
```

驗證C9300-PE-2 VPNv4標籤：

檢查PE的本地字首，而不是遠端字首

```
***Software VPNv4 Label Programming***
C9300-PE-2#show ip cef vrf RED 192.168.2.0/24 detail
192.168.2.0/24, epoch 0
  QOS: Precedence routine (0)
  dflt local label info: other/21 [0x2] <-- VPNv4 label associated with local prefix
  nexthop 10.0.0.22 GigabitEthernet2/0/1
```

```
*** FMAN RP VPNv4 Label Programming***
C9300-PE-2#show platform software mpls switch active r0 eos index 61 <-- Use the objid from the
FED command


EOS Choice 0x3d, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x3b
  OM handle: 0x348063f2f8
```

```
*** FMAN FP VPNv4 Label Programming***
C9300-PE-2#show platform software mpls switch active f0 eos index 61 <-- Use the objid from the
FED command


EOS Choice 0x3d, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x3b
  aom id: 3541, CPP handle: 0xdeadbeef (created), flags: 0 <-- Utilized in subsequent command

C9300-PE-2#show platform software object-manager switch active f0 object 3541 <-- Use the aom id
```

```
from previous command
Object identifier: 3541
  Description: EOS Choice 0x3d
  Status: Done, Epoch: 0, Client data: 0x11079188

C9300-PE-2#show platform software object-manager switch active f0 object 3541 parents <-- Use
the aom id from previous command
Object identifier: 7
  Description: Special Object adj_drop
  Status: Done

Object identifier: 3540
  Description: label 0x3b
  Status: Done

*** FED VPNv4 Label Programming***
C9300-PE-2#show platform software fed switch active mpls forwarding label 21 detail
 LENTRY:label:21 nobj:(EOS, 61) lentry_hdl:0x69000009
   modify_cnt:3 backwalk_cnt:0
   lspa_handle:0
   AAL: id:1761607689 lbl:21
        eos0:[adj_hdl:0, hw_hdl:0x7fe8f8a71bd8]
        eos1:[adj_hdl:0x49000040, hw_hdl:0x7fe8f8a72458]
        deagg_vrf_id = 0 lspa_handle:0
   EOS:objid:61 local_label:0 flags:0:() pdflags:0 <-- Utilized in previous commands
      nobj0:(ADJ SPECIAL,DROP 0), nobj1:(LABEL, 59) modify:0 bwalk:0
      LABEL:objid:59 link_type:IP local_label:21 outlabel:(1048577, 0)
          flags:0xc:(UHP,POP,) pdflags:0x2:(INSTALL_HW_OK,) adj_handle:0x49000040
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1224736832 lbl:0 smac:70d3.79be.ae42 dmac:0072.78c8.c9c2
               sub_type:0 link_type:0 adj_flags:0x2 label_type:1 rewrite_type:POP2IP(135)
               vlan_id:0 vrf_id:0 ri:0x7fe8f8a8ab98, ri_id:0x44 phdl:0xf1000024, ref_cnt:1
               si:0x7fe8f8a6ae08, si_id:0x4006, di_id:0x5338
      ADJ:objid:25 {link_type:IP ifnum:0x35, si:0x800003e, IPv4:       10.0.0.22 }
```

LDP標籤程式設計

下一節將介紹MPLS路由器C9300-PE-1、C9500-P和C9300-PE-2上的LDP標籤程式設計。

LDP（外部）標籤是MPLS網路標籤交換資料包的方式。驗證通告到遠端PE的本地LDP標籤，不要驗證遠端LDP標籤。

C9300-PE-1 LDP標籤程式設計：

驗證向遠端PE通告的本地LDP標籤，不要驗證遠端LDP標籤。從FED的角度檢查標籤，然後回溯至FMAN RP和FMAN FP。

```
***Software LDP Label Programming***
C9300-PE-1#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi1/0/2    10.0.0.6
18         Pop Label  10.0.0.12/30     0             Gi1/0/2    10.0.0.6
19         17         192.168.1.4/32   0             Gi1/0/2    10.0.0.6 <-- LDP Label 19 is
advertised to Remote PE 192.168.1.4, validate LDP label 19
20         No Label   10.0.0.0/30[V]   1890          aggregate/RED
22         No Label   192.168.3.0/24[V]   \
                                       1982          Gi1/0/1    10.0.0.1
```

```
***FMAN RP LDP Label Programming***
C9300-PE-1#show platform software mpls switch active r0 label index 59


Label OCE 0x3b -> OBJ_ADJACENCY (0x46)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x34805f3dc8

***FMAN FP LDP Label Programming***
C9300-PE-1#show platform software mpls switch active f0 label index 59


Label OCE 0x3b -> OBJ_ADJACENCY (0x46)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 7065, CPP handle: 0xdeadbeef (created)

C9300-PE-1#show platform software object-manager switch active f0 object 7065
Object identifier: 7065
  Description: label 0x3b
  Status: Done, Epoch: 0, Client data: 0x63152218


C9300-PE-1#show platform software object-manager switch active f0 object 7065 parents
Object identifier: 511
  Description: adj 0x46, Flags None
  Status: Done

***FED LDP Label Programming***
C9300-PE-1#show platform software fed switch active mpls forwarding label 19 detail
 LENTRY:label:19 nobj:(LABEL, 59) lentry_hdl:0xef000007
   modify_cnt:7 backwalk_cnt:0
   lspa_handle:0
   AAL: id:4009754631 lbl:19
        eos0:[adj_hdl:0x91000056, hw_hdl:0x7fa4c4d6cae8]
        eos1:[adj_hdl:0x91000056, hw_hdl:0x7fa4c4d6c8e8]
        deagg_vrf_id = 0 lspa_handle:0
   LABEL:objid:59 link_type:MPLS local_label:19 outlabel:(17, 0)
       flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x91000056
       unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
       bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
       AAL: id:2432696406 lbl:0 smac:a0f8.4911.d1d6 dmac:d4ad.71b5.dde4
            sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
            vlan_id:0 vrf_id:0 ri:0x7fa4c4d75fa8, ri_id:0x26 phdl:0x9f00004b, ref_cnt:1
            si:0x7fa4c4d5f6c8, si_id:0x4013, di_id:0x535f
   ADJ:objid:70 {link_type:MPLS ifnum:0x36, si:0x25000021, }
```

C9500 LDP標籤程式設計：

驗證向遠端PE通告的本地LDP標籤，不要驗證遠端LDP標籤。從FED的角度檢查標籤，然後回溯至FMAN RP和FMAN FP。

```
***Software LDP Label Programming***
C9500-P#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         explicit-n 192.168.1.2/32   23409         Te1/0/1    10.0.0.5  <-- LDP label 16 is
```

advertised to reach PE 192.168.1.2
17 explicit-n 192.168.1.4/32 23345 Te1/0/2 10.0.0.14 **<-- LDP label 17 is advertised to reach PE 192.168.1.4**

*****FMAN RP LDP Label Programming*****
C9500-P#**show platform software mpls switch active r0 label index 23 <-- Use the obj id from the FED command**

```
Label OCE 0x17 -> OBJ_ADJACENCY (0x3f)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480645150
```

*****FMAN FP LDP Label Programming*****
C9500-P#**show platform software mpls switch active f0 label index 23 <-- Use the obj id from the FED command**

```
Label OCE 0x17 -> OBJ_ADJACENCY (0x3f)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 654, CPP handle: 0xdeadbeef (created)
```

C9500-P#**show platform software object-manager switch active f0 object 654 <-- Use the aom id from the previous command**

```
Object identifier: 654
  Description: label 0x17
  Status: Done, Epoch: 0, Client data: 0x4b41c08
```

C9500-P#**show platform software object-manager switch active f0 object 654 parents <-- Use the aom id from the previous command**

```
Object identifier: 515
  Description: adj 0x3f, Flags None
  Status: Done
```

*****FED LDP Label Programming*****
C9500-P#**show platform software fed switch active mpls forwarding label 16 detail**

```
 LENTRY:label:16 nobj:(LABEL, 23) lentry_hdl:0xec000004
   modify_cnt:6 backwalk_cnt:0
   lspa_handle:0
   AAL: id:3959422980 lbl:16
        eos0:[adj_hdl:0xc3000055, hw_hdl:0x7f28944be3c8]
        eos1:[adj_hdl:0xc3000055, hw_hdl:0x7f28944be1b8]
        deagg_vrf_id = 0 lspa_handle:0
   LABEL:objid:23 link_type:MPLS local_label:16 outlabel:(0, 0) <-- Utilized in previous commands
       flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xc3000055
       unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
       bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
       AAL: id:3271557205 lbl:0 smac:d4ad.71b5.dde4 dmac:a0f8.4911.d1d6
            sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
            vlan_id:0 vrf_id:0 ri:0x7f289449bf88, ri_id:0x44 phdl:0xe9000057, ref_cnt:1
            si:0x7f2894489b58, si_id:0x4009, di_id:0x1
   ADJ:objid:63 {link_type:MPLS ifnum:0x41, si:0x57000023, }
```

*****Software LDP Label Programming*****
C9500-P#**show mpls forwarding-table**

```
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         explicit-n 192.168.1.2/32   23409         Te1/0/1    10.0.0.5
17         explicit-n 192.168.1.4/32   23345         Te1/0/2    10.0.0.14
```

```
***FMAN RP LDP Label Programming***
C9500-P#show platform software mpls switch active r0 label index 64 <-- Use the obj id from the
FED command


Label OCE 0x40 -> OBJ_ADJACENCY (0x49)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480641d08

***FMAN FP LDP Label Programming***
C9500-P#show platform software mpls switch active f0 label index 64 <-- Use the obj id from the
FED command


Label OCE 0x40 -> OBJ_ADJACENCY (0x49)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 657, CPP handle: 0xdeadbeef (created)

C9500-P#show platform software object-manager switch active f0 object 657 <-- Use the aom id
value from previous command
Object identifier: 657
  Description: label 0x40
  Status: Done, Epoch: 0, Client data: 0x4b523f8


C9500-P#show platform software object-manager switch active f0 object 657 parents<-- Use the aom
id value from previous command
Object identifier: 535
  Description: adj 0x49, Flags None
  Status: Done

***FED LDP Label Programming***
C9500-P#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LABEL, 64) lentry_hdl:0x8d000005
   modify_cnt:6 backwalk_cnt:0
   lspa_handle:0
   AAL: id:2365587461 lbl:17
        eos0:[adj_hdl:0xcc000037, hw_hdl:0x7f2894480438]
        eos1:[adj_hdl:0xcc000037, hw_hdl:0x7f2894480228]
        deagg_vrf_id = 0 lspa_handle:0
   LABEL:objid:64 link_type:MPLS local_label:17 outlabel:(0, 0) <-- Utilized in previous
commands
       flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xcc000037
       unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
       bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
       AAL: id:3422552119 lbl:0 smac:d4ad.71b5.ddd6 dmac:70d3.79be.ae71
            sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
            vlan_id:0 vrf_id:0 ri:0x7f2894498008, ri_id:0x38 phdl:0x76000058, ref_cnt:1
            si:0x7f2894498478, si_id:0x400b, di_id:0x2
   ADJ:objid:73 {link_type:MPLS ifnum:0x42, si:0x3d000027, }
```

C9300-PE-2 LDP標籤程式設計：

驗證向遠端PE通告的本地LDP標籤，不要驗證遠端LDP標籤。從FED的角度檢查標籤，然後回溯至FMAN RP和FMAN FP。

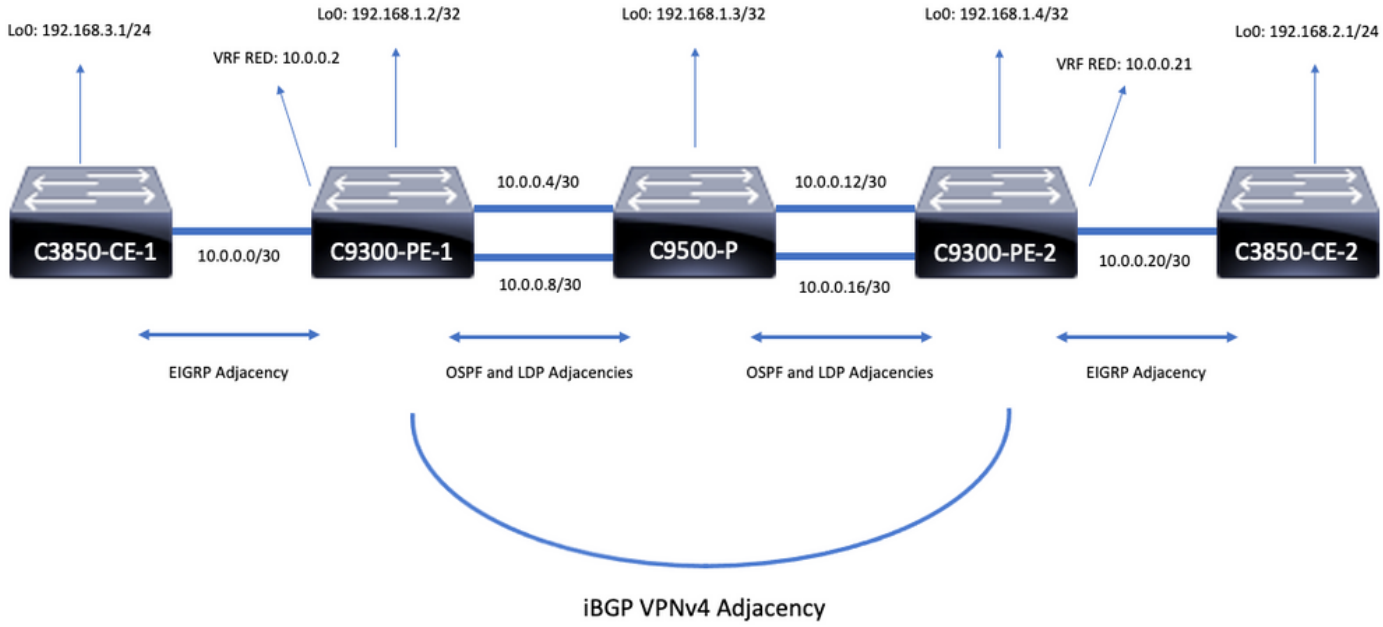
```
***Software LDP Label Programming***
C9300-PE-2#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi2/0/2    10.0.0.13
17         16         192.168.1.2/32   630           Gi2/0/2    10.0.0.13 <-- LDP label 17 is
advertised to Remote PE 192.168.1.2
18         Pop Label  10.0.0.4/30      0             Gi2/0/2    10.0.0.13
20         No Label   10.0.0.20/30[V]  1260          aggregate/RED
21         No Label   192.168.2.0/24[V]   \
                                       2070          Gi2/0/1    10.0.0.22

C9300-PE-2#show platform software mpls switch active r0 label index 82 <-- Utilize the obj id
value from the FED Command


Label OCE 0x52 -> OBJ_ADJACENCY (0x46)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x10
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x348063ad00


C9300-PE-2#show platform software mpls switch active f0 label index 82 <-- Utilize the obj id
value from the FED Command


Label OCE 0x52 -> OBJ_ADJACENCY (0x46)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x10
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 3624, CPP handle: 0xdeadbeef (created) <-- Used in next commands

C9300-PE-2#show platform software object-manager switch active f0 object 3624 <-- Utilize the
aom id value
Object identifier: 3624
  Description: label 0x52
  Status: Done, Epoch: 0, Client data: 0x11071668


C9300-PE-2#show platform software object-manager switch active f0 object 3624 parents <--
Utilize the aom id value
Object identifier: 496
  Description: adj 0x46, Flags None
  Status: Done

C9300-PE-2#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LABEL, 82) lentry_hdl:0x44000005
   modify_cnt:6 backwalk_cnt:0
   lspa_handle:0
   AAL: id:1140850693 lbl:17
        eos0:[adj_hdl:0x5f000032, hw_hdl:0x7fe8f8a52798]
        eos1:[adj_hdl:0x5f000032, hw_hdl:0x7fe8f8a52588]
        deagg_vrf_id = 0 lspa_handle:0
   LABEL:objid:82 link_type:MPLS local_label:17 outlabel:(16, 0) <-- Used in previous commands
       flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x5f000032
       unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
       bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
       AAL: id:1593835570 lbl:0 smac:70d3.79be.ae71 dmac:d4ad.71b5.ddd6
            sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
            vlan_id:0 vrf_id:0 ri:0x7fe8f8a93c78, ri_id:0x3a phdl:0x9f00004b, ref_cnt:1
            si:0x7fe8f8a91188, si_id:0x4011, di_id:0x535f
```

```
ADJ:objid:70 {link_type:MPLS ifnum:0x36, si:0xaa000021, }
```

案例2. PE和P路由器之間具有ECMP的L3VPN

參考拓撲

在本例中，Catalyst 3850交換機充當CE裝置，Catalyst 9300交換機充當PE裝置，Stackwise Virtual中的Catalyst 9500充當P裝置。EIGRP在CE和PE裝置之間運行，在MPLS核心中運行OSPF和LDP鄰接關係，在PE裝置之間運行iBGP VPNv4鄰接關係。在MPLS核心中，PE和P裝置之間存在ECMP。



配置詳細資訊

C3850-CE-1的配置

```
hostname C3850-CE-1
!
interface Loopback0
ip address 192.168.3.1 255.255.255.0
!
interface TenGigabitEthernet1/0/1
no switchport
ip address 10.0.0.1 255.255.255.252
!
router eigrp 420
network 10.0.0.0 0.0.0.3
network 192.168.3.0
eigrp stub connected summary
!
ip route 0.0.0.0 0.0.0.0 10.0.0.2
```

C9300-PE-1的組態

```
hostname C9300-PE-1
!
ip vrf RED
```

```
rd 69:69
route-target export 69:69
route-target import 69:69
!
mpls ldp explicit-null
!
interface Loopback0
ip address 192.168.1.2 255.255.255.255
!
interface GigabitEthernet1/0/1
no switchport
ip vrf forwarding RED
ip address 10.0.0.2 255.255.255.252
!
interface GigabitEthernet1/0/2
no switchport
ip address 10.0.0.5 255.255.255.252
!
interface GigabitEthernet1/0/3
no switchport
ip address 10.0.0.9 255.255.255.252
!
router eigrp 420
!
address-family ipv4 vrf RED
network 10.0.0.0 0.0.0.3
autonomous-system 420
exit-address-family
!
router ospf 420
network 0.0.0.0 255.255.255.255 area 0
mpls ldp autoconfig
!
router bgp 69420
bgp log-neighbor-changes
neighbor 192.168.1.4 remote-as 69420
neighbor 192.168.1.4 update-source Loopback0
!
address-family vpnv4
neighbor 192.168.1.4 activate
neighbor 192.168.1.4 send-community extended
exit-address-family
!
address-family ipv4 vrf RED
redistribute eigrp 420
exit-address-family
```

C9500-P的組態

```
hostname C9500-P
!
interface Loopback0
ip address 192.168.1.3 255.255.255.255
!
interface TenGigabitEthernet1/0/1
no switchport
ip address 10.0.0.6 255.255.255.252
!
interface TenGigabitEthernet1/0/2
no switchport
ip address 10.0.0.13 255.255.255.252
!
interface TenGigabitEthernet2/0/1
```

```
no switchport
ip address 10.0.0.10 255.255.255.252
!
interface TenGigabitEthernet2/0/2
no switchport
ip address 10.0.0.17 255.255.255.252
!
router ospf 420
network 0.0.0.0 255.255.255.255 area 0
mpls ldp autoconfig
```

C9300-PE-2的組態

```
hostname C9300-PE-2
!
ip vrf RED
rd 69:69
route-target export 69:69
route-target import 69:69
!
mpls ldp explicit-null
!
interface Loopback0
ip address 192.168.1.4 255.255.255.255
!
interface GigabitEthernet2/0/1
no switchport
ip vrf forwarding RED
ip address 10.0.0.21 255.255.255.252
!
interface GigabitEthernet2/0/2
no switchport
ip address 10.0.0.14 255.255.255.252
!
interface GigabitEthernet2/0/3
no switchport
ip address 10.0.0.18 255.255.255.252
!
router eigrp 400
!
address-family ipv4 vrf RED
network 10.0.0.20 0.0.0.3
autonomous-system 400
exit-address-family
!
router ospf 420
passive-interface GigabitEthernet2/0/24
network 0.0.0.0 255.255.255.255 area 0
mpls ldp autoconfig
!
router bgp 69420
bgp log-neighbor-changes
neighbor 192.168.1.2 remote-as 69420
neighbor 192.168.1.2 update-source Loopback0
!
address-family vpnv4
neighbor 192.168.1.2 activate
neighbor 192.168.1.2 send-community extended
exit-address-family
!
address-family ipv4 vrf RED
redistribute eigrp 400
exit-address-family
```

C3850-CE-2的配置

```
hostname C3850-CE-2
!
interface Loopback0
ip address 192.168.2.1 255.255.255.0
!
interface TenGigabitEthernet2/0/1
no switchport
ip address 10.0.0.22 255.255.255.252
!
router eigrp 400
network 10.0.0.20 0.0.0.3
network 192.168.2.0
eigrp stub connected summary
!
ip route 0.0.0.0 0.0.0.0 10.0.0.21
```

基本驗證

在驗證MPLS程式設計之前，需要驗證基本要求：

- 驗證是否存在PE到PE連線
- 驗證PE之間的標籤交換路徑(LSP)
- 驗證PE之間的BGPv4鄰接關係
- 驗證VPNv4和LDP標籤
- 驗證MPLS轉發表

驗證PE到PE的連線

您可以從本地環回對遠端PE環回和源執行ping操作，但這並不能確認MPLS標籤交換路徑(LSP)是否正常，因為環回IP地址是在底層中通告的。

> **注意**:PE到PE MP-BGP VPNv4鄰接通過它們各自的Loopback0介面實現。

```
C9300-PE-1#ping 192.168.1.4 source 192.168.1.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.4, timeout is 2 seconds:
Packet sent with a source address of 192.168.1.2
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms

C9300-PE-1#show ip route 192.168.1.4
Routing entry for 192.168.1.4/32
  Known via "ospf 420", distance 110, metric 3, type intra area
  Last update from 10.0.0.10 on GigabitEthernet1/0/3, 18:39:30 ago
  Routing Descriptor Blocks:
    10.0.0.10, from 192.168.1.4, 18:39:30 ago, via GigabitEthernet1/0/3
      Route metric is 3, traffic share count is 1
  * 10.0.0.6, from 192.168.1.4, 18:39:30 ago, via GigabitEthernet1/0/2
      Route metric is 3, traffic share count is 1
```

驗證LSP

您可以從PE到PE環回使用MPLS路徑來驗證路徑上的LSP和所有MPLS LDP標籤。

註：此MPLS traceroute僅施加一個標籤，即LDP標籤，並不能證明來自CE的流量是成功的，因為該流量是使用2個標籤施加的，即VPNv4（內部）標籤和LDP（外部）標籤。

```
C9300-PE-1#traceroute mpls ipv4 192.168.1.4/32 source 192.168.1.2
Tracing MPLS Label Switched Path to 192.168.1.4/32, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'l' - Label switched with FEC change, 'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
  0 10.0.0.5 MRU 1500 [Labels: 17 Exp: 0]
L 1 10.0.0.6 MRU 1500 [Labels: explicit-null Exp: 0] 7 ms
! 2 10.0.0.18 1 ms
```

如果您無法訪問CE或CE後面的裝置，並且希望證明存在成功的VPNv4和LDP標籤實施/處置，可以嘗試從PE上VRF中面向CE的介面ping遠端PE上VRF中面向CE的另一介面。

```
C9300-PE-1#ping vrf RED 10.0.0.21 source 10.0.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.21, timeout is 2 seconds:
Packet sent with a source address of 10.0.0.2
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

驗證PE之間的BGP VPNv4鄰接關係

```
C9300-PE-1#show bgp vpnv4 unicast all neighbors 192.168.1.4
BGP neighbor is 192.168.1.4,  remote AS 69420, internal link
  BGP version 4, remote router ID 192.168.1.4
  BGP state = Established, up for 18:40:49
  Last read 00:00:40, last write 00:00:47, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Address family VPNv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                4          4
    Keepalives:          1237       1233
    Route Refresh:          0          0
    Total:               1242       1238
```

```
  Do log neighbor state changes (via global configuration)
  Default minimum time between advertisement runs is 0 seconds
<snip>
C9300-PE-2#show bgp vpnv4 unicast all neighbors 192.168.1.2
BGP neighbor is 192.168.1.2,  remote AS 69420, internal link
  BGP version 4, remote router ID 192.168.1.2
  BGP state = Established, up for 18:41:36
  Last read 00:00:42, last write 00:00:32, hold time is 180, keepalive interval is 60 seconds
  Neighbor sessions:
    1 active, is not multisession capable (disabled)
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    Four-octets ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
    Address family VPNv4 Unicast: advertised and received
    Enhanced Refresh Capability: advertised and received
    Multisession Capability:
    Stateful switchover support enabled: NO for session 1
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                         Sent       Rcvd
    Opens:                  1          1
    Notifications:          0          0
    Updates:                4          4
    Keepalives:          1234       1238
    Route Refresh:          0          0
    Total:               1239       1243
  Do log neighbor state changes (via global configuration)
  Default minimum time between advertisement runs is 0 seconds
```

遠端PE VPNv4鄰接已啟動，且已收到字首

```
C9300-PE-1#show bgp vpnv4 unicast all summary
BGP router identifier 192.168.1.2, local AS number 69420
BGP table version is 7, main routing table version 7
4 network entries using 1024 bytes of memory
4 path entries using 544 bytes of memory
4/4 BGP path/bestpath attribute entries using 1216 bytes of memory
4 BGP extended community entries using 1000 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 3784 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs
4 networks peaked at 18:49:56 Jun 23 2021 UTC (18:41:06.070 ago)

Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.1.4     4        69420    1240    1244        7    0    0 18:41:59        2

C9300-PE-2#show bgp vpnv4 unicast all summary
BGP router identifier 192.168.1.4, local AS number 69420
BGP table version is 7, main routing table version 7
4 network entries using 1024 bytes of memory
4 path entries using 544 bytes of memory
4/4 BGP path/bestpath attribute entries using 1216 bytes of memory
4 BGP extended community entries using 1000 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 3784 total bytes of memory
BGP activity 4/0 prefixes, 4/0 paths, scan interval 60 secs
4 networks peaked at 18:49:37 Jun 23 2021 UTC (18:41:06.851 ago)
```

```
Neighbor        V           AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.1.2     4        69420    1244    1240        7    0    0 18:42:17        2
```

驗證特定VRF中交換的字首是什麼

```
C9300-PE-1#show ip bgp vpnv4 vrf RED
BGP table version is 7, local router ID is 192.168.1.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
              t secondary path, L long-lived-stale,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 69:69 (default for vrf RED)
 *>   10.0.0.0/30      0.0.0.0                  0         32768 ?
 *>i  10.0.0.20/30     192.168.1.4              0    100      0 ?
 *>i  192.168.2.0      192.168.1.4         130816    100      0 ?
 *>   192.168.3.0      10.0.0.1            130816         32768 ?

C9300-PE-2#show ip bgp vpnv4 vrf RED
BGP table version is 7, local router ID is 192.168.1.4
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
              t secondary path, L long-lived-stale,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 69:69 (default for vrf RED)
 *>i  10.0.0.0/30      192.168.1.2              0    100      0 ?
 *>   10.0.0.20/30     0.0.0.0                  0         32768 ?
 *>   192.168.2.0      10.0.0.22           130816         32768 ?
 *>i  192.168.3.0      192.168.1.2         130816    100      0 ?
```

驗證VPNv4和LDP標籤

```
C9300-PE-1#show ip bgp vpnv4 vrf RED labels
   Network          Next Hop      In label/Out label
Route Distinguisher: 69:69 (RED)
   10.0.0.0/30      0.0.0.0         20/nolabel(RED)
   10.0.0.20/30     192.168.1.4     nolabel/20
   192.168.2.0      192.168.1.4     nolabel/21 <-- VPNv4 label that is be imposed to reach
192.168.20
   192.168.3.0      10.0.0.1        21/nolabel

C9300-PE-1#show ip route vrf RED 192.168.2.1

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "bgp 69420", distance 200, metric 130816, type internal
  Last update from 192.168.1.4 18:41:56 ago
  Routing Descriptor Blocks:
  * 192.168.1.4 (default), from 192.168.1.4, 18:41:56 ago
      Route metric is 130816, traffic share count is 1
```

```
      AS Hops 0
      MPLS label: 21 <-- VPNv4 label that matches the previous output
      MPLS Flags: MPLS Required

C9300-PE-2#show ip bgp vpnv4 vrf RED labels
   Network          Next Hop      In label/Out label
Route Distinguisher: 69:69 (RED)
   10.0.0.0/30      192.168.1.2     nolabel/20
   10.0.0.20/30     0.0.0.0         20/nolabel(RED)
   192.168.2.0      10.0.0.22       21/nolabel <-- VPNv4 label that is advertised to reach
192.168.2.0
   192.168.3.0      192.168.1.2     nolabel/21


C9300-PE-2#show ip route vrf RED 192.168.2.1

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "eigrp 400", distance 90, metric 130816, precedence routine (0), type internal
  Redistributing via eigrp 400, bgp 69420
  Advertised by bgp 69420
  Last update from 10.0.0.22 on GigabitEthernet2/0/1, 18:45:04 ago
  Routing Descriptor Blocks:
  * 10.0.0.22, from 10.0.0.22, 18:45:04 ago, via GigabitEthernet2/0/1 <-- CE-facing interface in
the VRF
      Route metric is 130816, traffic share count is 1
      Total delay is 5010 microseconds, minimum bandwidth is 1000000 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 1
```

驗證使用的LDP標籤

```
C9300-PE-1#show mpls forwarding-table 192.168.1.4
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
19         17         192.168.1.4/32   0             Gi1/0/2    10.0.0.6  <-- 17 is the LDP
label imposed to reach PE at 192.168.1.4 through Gi1/0/2
           17         192.168.1.4/32   0             Gi1/0/3    10.0.0.10 <-- 17 is the LDP
label imposed to reach PE at 192.168.1.4 through Gi1/0/3

C9300-PE-2#show mpls forwarding-table 192.168.1.2
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
17         16         192.168.1.2/32   0             Gi2/0/2    10.0.0.13 <-- 16 is the LDP
label imposed to reach PE at 192.168.1.2 through Gi2/0/2
           16         192.168.1.2/32   0             Gi2/0/3    10.0.0.17 <-- 16 is the LDP
label imposed to reach PE at 192.168.1.2 through Gi2/0/3
```

驗證MPLS轉發表

```
C9300-PE-1#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi1/0/2    10.0.0.6
           Pop Label  192.168.1.3/32   0             Gi1/0/3    10.0.0.10
17         Pop Label  10.0.0.16/30     0             Gi1/0/2    10.0.0.6
           Pop Label  10.0.0.16/30     0             Gi1/0/3    10.0.0.10
18         Pop Label  10.0.0.12/30     0             Gi1/0/2    10.0.0.6
           Pop Label  10.0.0.12/30     0             Gi1/0/3    10.0.0.10
19         17         192.168.1.4/32   0             Gi1/0/2    10.0.0.6
```

```
          17         192.168.1.4/32   0              Gi1/0/3    10.0.0.10
20        No Label   10.0.0.0/30[V]   630            aggregate/RED
21        No Label   192.168.3.0/24[V]   \
                                      0              Gi1/0/1    10.0.0.1

C9300-PE-2#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi2/0/2    10.0.0.13
           Pop Label  192.168.1.3/32   0             Gi2/0/3    10.0.0.17
17         16         192.168.1.2/32   0             Gi2/0/2    10.0.0.13
           16         192.168.1.2/32   0             Gi2/0/3    10.0.0.17
18         Pop Label  10.0.0.4/30      0             Gi2/0/2    10.0.0.13
           Pop Label  10.0.0.4/30      0             Gi2/0/3    10.0.0.17
19         Pop Label  10.0.0.8/30      0             Gi2/0/2    10.0.0.13
           Pop Label  10.0.0.8/30      0             Gi2/0/3    10.0.0.17
20         No Label   10.0.0.20/30[V]  630           aggregate/RED
21         No Label   192.168.2.0/24[V]   \
                                      0              Gi2/0/1    10.0.0.22
```

確認用於到達VRF中每個給定字首的內部(VPNv4)和外部(LDP)標籤

```
C9300-PE-1#show ip cef vrf RED 192.168.2.0/24 detail
192.168.2.0/24, epoch 0, flags [rib defined all labels]
  recursive via 192.168.1.4 label 21 <-- VPNv4 label
    nexthop 10.0.0.6 GigabitEthernet1/0/2 label 17-(local:19) <-- 17 is the LDP label that is
imposed to reach the remote PE, 19 is the local LDP label advertised to the P router
    nexthop 10.0.0.10 GigabitEthernet1/0/3 label 17-(local:19)<-- 17 is the LDP label that is
imposed to reach the remote PE, 19 is the local LDP label advertised to the P router

C9300-PE-2#show ip cef vrf RED 192.168.3.0/24 detail
192.168.3.0/24, epoch 0, flags [rib defined all labels]
  recursive via 192.168.1.2 label 21 <-- VPNv4 label
    nexthop 10.0.0.13 GigabitEthernet2/0/2 label 16-(local:17) <-- 16 is the LDP label that is
imposed to reach the remote PE, 17 is the local LDP label advertised to the P router
    nexthop 10.0.0.17 GigabitEthernet2/0/3 label 16-(local:17) <-- 16 is the LDP label that is
imposed to reach the remote PE, 17 is the local LDP label advertised to the P router
```

驗證Object-Manager統計資訊：

在理想情況下，沒有掛起對象

```
C9300-PE-1#show platform software object-manager switch active f0 statistics
Forwarding Manager Asynchronous Object Manager Statistics

Object update: Pending-issue: 0, Pending-acknowledgement: 0
Batch begin:   Pending-issue: 0, Pending-acknowledgement: 0
Batch end:     Pending-issue: 0, Pending-acknowledgement: 0
Command:       Pending-acknowledgement: 0
Total-objects: 491
Stale-objects: 0
Resolve-objects: 0
Childless-delete-objects: 0
Error-objects: 0
Paused-types: 0
9500-P#show platform software object-manager switch active f0 statistics
Forwarding Manager Asynchronous Object Manager Statistics

Object update: Pending-issue: 0, Pending-acknowledgement: 0
```

```
Batch begin:   Pending-issue: 0, Pending-acknowledgement: 0
Batch end:     Pending-issue: 0, Pending-acknowledgement: 0
Command:       Pending-acknowledgement: 0
Total-objects: 491
Stale-objects: 0
Resolve-objects: 0
Childless-delete-objects: 0
Error-objects: 0
Paused-types: 0
C9300-PE-2#show platform software object-manager switch active f0 statistics
Forwarding Manager Asynchronous Object Manager Statistics

Object update: Pending-issue: 0, Pending-acknowledgement: 0
Batch begin:   Pending-issue: 0, Pending-acknowledgement: 0
Batch end:     Pending-issue: 0, Pending-acknowledgement: 0
Command:       Pending-acknowledgement: 0
Total-objects: 482
Stale-objects: 0
Resolve-objects: 0
Childless-delete-objects: 0
Error-objects: 0
Paused-types: 0
```

首碼程式設計

下一節將介紹MPLS路由器C9300-PE-1、C9500-P和C9300-PE-2上的字首程式設計。

C9300-PE-1首碼程式

```
***Software Prefix Programming***
C9300-PE-1#show ip route vrf RED 192.168.2.1

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "bgp 69420", distance 200, metric 130816, type internal
  Last update from 192.168.1.4 19:21:45 ago
  Routing Descriptor Blocks:
  * 192.168.1.4 (default), from 192.168.1.4, 19:21:45 ago <-- Remote PE reachable in the global
routing table
      Route metric is 130816, traffic share count is 1
      AS Hops 0
      MPLS label: 21 <-- VPNv4 label
      MPLS Flags: MPLS Required

C9300-PE-1#show ip route 192.168.1.4
Routing entry for 192.168.1.4/32
  Known via "ospf 420", distance 110, metric 3, type intra area
  Last update from 10.0.0.10 on GigabitEthernet1/0/3, 19:23:17 ago
  Routing Descriptor Blocks:
    10.0.0.10, from 192.168.1.4, 19:23:17 ago, via GigabitEthernet1/0/3 <-- Next-hop to reach
192.168.1.4
      Route metric is 3, traffic share count is 1
  * 10.0.0.6, from 192.168.1.4, 19:23:17 ago, via GigabitEthernet1/0/2  <-- Next-hop to reach
192.168.1.4
      Route metric is 3, traffic share count is 1

***FMAN RP Prefix Programming***
C9300-PE-1#show ip vrf detail
VRF RED (VRF Id = 2); default RD 69:69; default VPNID <-- VRF ID is important in subsequent
command
  Old CLI format, supports IPv4 only
  Flags: 0xC
```

```
  Interfaces:
    Gi1/0/1
Address family ipv4 unicast (Table ID = 0x2):
  Flags: 0x0
  Export VPN route-target communities
    RT:69:69
  Import VPN route-target communities
    RT:69:69
  No import route-map
  No global export route-map
  No export route-map
  VRF label distribution protocol: not configured
  VRF label allocation mode: per-prefix

C9300-PE-1#show platform software ip switch active r0 cef table index 2 prefix 192.168.2.0/24 <-
- Index value is the VRF ID from previous command
Forwarding Table

Prefix/Len                      Next Object      Index
-----------------------------------------------------------------
192.168.2.0/24                  OBJ_LABEL        0x78


C9300-PE-1#show platform software mpls switch active r0 label index 0x78 <-- Utilize the Index
value from previous command


Label OCE 0x78 -> OBJ_LOADBALANCE (0x70) <-- Utilized in next command
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x15
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480644d88

C9300-PE-1#show platform software loadinfo switch active r0 index 0x70 <-- Utilize the
OBJ_LOADBALANCE value from previous command
Number of loadinfo objects: 8

Index: 0x70, Flags: unknown, Hash Algorithm: , Number of Paths: 2, Number of buckets: 16
  Anti-polarising Factor: 0xf4a19ba0
  Next Object Type: OBJ_LABEL, OBJ_LABEL
  Next obj handle: 0x6e, 0x6f
  Hash Buckets: 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
  Color Buckets Map: 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
  OM handle: 0x3480641fb8

C9300-PE-1#show platform software mpls switch active r0 label index 0x6e <-- Utilize the obj
handle value from previous command


Label OCE 0x6e -> OBJ_ADJACENCY (0x4b)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x34806420d0

C9300-PE-1#show platform software mpls switch active r0 label index 0x6f <-- Utilize the obj
handle value from previous command


Label OCE 0x6f -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480642268
```

```
C9300-PE-1#show platform software adjacency switch active r0 index 0x4b <-- Utilize the
OBJ_ADJACENCY value from previous command
Number of adjacency objects: 10

Adjacency id: 0x4b (75)
  Interface: GigabitEthernet1/0/2, IF index: 54, Link Type: MCP_LINK_TAG
  Encap: d4:ad:71:b5:dd:e4:a0:f8:49:11:d1:d6:88:47 <-- MAC ending in DDE4 is the DMAC, MAC
ending in D1D6 is SMAC, 8847 is MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.6 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x34806375f8

C9300-PE-1#show platform software adjacency switch active r0 index 0x4e <-- Utilize the
OBJ_ADJACENCY value from previous command
Number of adjacency objects: 10

Adjacency id: 0x4e (78)
  Interface: GigabitEthernet1/0/3, IF index: 55, Link Type: MCP_LINK_TAG
  Encap: d4:ad:71:b5:dd:c2:a0:f8:49:11:d1:d8:88:47 <-- MAC ending DDC2 is the DMAC, MAC ending
in D1D8 is the SMAC, 8847 is the MPLS ETPYE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.10 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x3480638200

***FMAN FP Prefix Programming***
C9300-PE-1#show ip vrf detail
VRF RED (VRF Id = 2); default RD 69:69; default VPNID
  Old CLI format, supports IPv4 only
  Flags: 0xC
  Interfaces:
    Gi1/0/1
Address family ipv4 unicast (Table ID = 0x2):
  Flags: 0x0
  Export VPN route-target communities
    RT:69:69
  Import VPN route-target communities
    RT:69:69
  No import route-map
  No global export route-map
  No export route-map
  VRF label distribution protocol: not configured
  VRF label allocation mode: per-prefix

C9300-PE-1#show platform software ip switch active f0 cef table index 2 prefix 192.168.2.0/24
detail <-- Index value is the VRF ID from previous command
Forwarding Table

192.168.2.0/24 -> OBJ_LABEL (0x78), urpf: 118
Prefix Flags: unknown
aom id: 618, HW handle: (nil) (created)

C9300-PE-1#show platform software mpls switch active f0 label index 0x78 <-- Use the OBJ_LABEL
value from previous command
```

```
Label OCE 0x78 -> OBJ_LOADBALANCE (0x70)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x15
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 617, CPP handle: 0xdeadbeef (created)

C9300-PE-1#show platform software object-manager switch active f0 object 617 parents <-- Use the
aom id from previous command
Object identifier: 600
  Description: LB 0x70
  Status: Done

C9300-PE-1#show platform software loadinfo switch active f0 index 0x70 <-- Use the LB value from
previous command
Number of loadinfo objects: 8

Index: 0x70, Flags: unknown, Hash Algorithm: , Number of Paths: 2, Number of buckets: 16
  Anti-polarising Factor: 0xf4a19ba0
  Next Object Type: OBJ_LABEL, OBJ_LABEL
  Next obj handle: 0x6e, 0x6f
  Hash Buckets: 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
  Color Buckets Map: 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
  aom id: 600, HW handle: (nil)

C9300-PE-1#show platform software mpls switch active f0 label index 0x6e <-- Use the obj handle
values from previous commands


Label OCE 0x6e -> OBJ_ADJACENCY (0x4b)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 598, CPP handle: 0xdeadbeef (created)


C9300-PE-1#show platform software mpls switch active f0 label index 0x6f <-- Use the obj handle
values from previous command


Label OCE 0x6f -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 599, CPP handle: 0xdeadbeef (created)

C9300-PE-1#show platform software adjacency switch active f0 index 0x4b <-- Use the
OBJ_ADJACENCY value from previous command
Number of adjacency objects: 10

Adjacency id: 0x4b (75)
  Interface: GigabitEthernet1/0/2, IF index: 54, Link Type: MCP_LINK_TAG
  Encap: d4:ad:71:b5:dd:e4:a0:f8:49:11:d1:d6:88:47
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.6
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 531, HW handle: (nil) (created)

C9300-PE-1#show platform software adjacency switch active f0 index 0x4e <-- Use the
```

OBJ_ADJACENCY value from previous command
Number of adjacency objects: 10

Adjacency id: 0x4e (78)
  Interface: GigabitEthernet1/0/3, IF index: 55, Link Type: MCP_LINK_TAG
  Encap: d4:ad:71:b5:dd:c2:a0:f8:49:11:d1:d8:88:47
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.10
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 535, HW handle: (nil) (created)

*****FED Prefix Programming*****
C9300-PE-1#**show platform software fed switch active ip route vrf-name RED 192.168.2.0/24**
vrf   dest   htm   flags   SGT   DGID MPLS Last-modified
---   ----   ---   -----   ---   ---- ---- ----------
2   192.168.2.0/24   **0x7fbae8d86228** 0x0   0   0   lspa0x2
2021/06/23 18:50:13.079 **<-- HTM value significant for next command**
  FIB: prefix_hdl:0x50000026, mpls_ecr_prefix_hdl:0
  ========== OCE chain =====
  LABEL:objid:120 link_type:IP local_label:1048577 outlabel:(**21**, 0) **<-- VPNv4 label**
      flags:0x1:(REAL,) pdflags:0x80:(INSTALL_HW_OK,RECIR_ADJ,) **adj_handle:0xcb00003c <-- adj_handle and local_adj_hdl values must match**
      unsupported recursion:0 olbl_changed 0 local_adj:1 modify_cnt:0
      bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
      AAL: id:3405774908 lbl:**19** smac:0000.0000.0000 dmac:0000.0000.0000 **<-- Label 19 matches the local transport label**
           sub_type:0 link_type:0 adj_flags:0x10 label_type:0 rewrite_type:PSH2(121)
           vlan_id:0 vrf_id:0 ri:0x7fbae8d73648, **ri_id:0x46** phdl:0, ref_cnt:2 **<-- ri_id and ri_idx values must match**
           si:0x7fbae8d834d8, si_id:0xb6, di_id:0x5013
  LB:obj_id:112 link_type:IP num_choices:2 Flags:0
      mpls_ecr:1 local_label:19 path_inhw:2 ecrh:0x7d000002 old_ecrh:0
      modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
      bwalk:[req:0 in_prog:0 nested:0]
    AAL: ecr:id:2097152002 af:0 ecr_type:0 ref:7 ecrh:0x7fbae8a99268(28:2)
    hwhdl:3903427176 ::0x7fbae8a98b98,0x7fbae8a9ad48,0x7fbae8a98b98,0x7fbae8a9ad48
  Sw Enh ECR scale: objid:112 llabel:19 eos:1 #adjs:2 mixed_adj:0
     reprogram_hw:0 ecrhdl:0x7d000002 ecr_hwhdl:0x7fbae8a99268
      mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
      ecr_adj: id:4278190135 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:1744830509
            sih:0x7fbae8a98b98(179) di_id:20499 rih:0x7fbae8a985d8(33)
        adj_lentry [eos0:0x7fbae8d7bf48 eos1:0x7fbae8d76e88]
      ecr_adj: id:1392508984 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:2013265966
            sih:0x7fbae8a9ad48(180) di_id:20499 rih:0x7fbae8a9a788(46)
        adj_lentry [eos0:0x7fbae8d7c1b8 eos1:0x7fbae8d77158]
      ecr_prefix_adj: id:2164260921 (ref:1)
         sih:0x7fbae8d7df08(181) di_id:20499 rih:0x7fbae8d7db98(68)
     LABEL:objid:110 link_type:MPLS local_label:**19** outlabel:(**17**, 0) **<-- Label 19 is the local transport label, Label 17 is the LDP label**
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xff000037
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:4278190135 lbl:0 smac:**a0f8.4911.d1d6 dmac:d4ad.71b5.dde4 <-- Matches next-hop information to reach 192.168.2.0/24**
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7fbae8d78c48, ri_id:0x40 phdl:0x9f00004b, ref_cnt:1

```
              si:0x7fbae8d78fd8, si_id:0x4013, di_id:0x535f <-- di_id utilized in subsequent
commands
     ADJ:objid:75 {link_type:MPLS ifnum:0x36, si:0x22000023, }
     LABEL:objid:111 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Label 19 is the local
transport label, Label 17 is the LDP label
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x53000038
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1392508984 lbl:0 smac:a0f8.4911.d1d8 dmac:d4ad.71b5.ddc2 <-- Matches next-hop
information to reach 192.168.2.0/24
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7fbae8d7d0a8, ri_id:0x42 phdl:0x8400004c, ref_cnt:1
               si:0x7fbae8d7a908, si_id:0x4014, di_id:0x5360 <-- di_id utilized in subsequent
commands
     ADJ:objid:78 {link_type:MPLS ifnum:0x37, si:0x74000026, }
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0, mpls_lspa_hdl:0xa7000002
    AAL:LSPA: id:2801795074 num_path:1 prefix_id:0x2 delete_hw_hdl_cnt:0
         cookie[64]:
150000000000000000000000000000000000000000000000000000000000000000000000460000000000000000000000000000000000
00000000000000000000000000000000 status:ok
          vpn_lbl:21 local_adj_hdl:0xcb00003c hw_hdl:0x7fbae8d86018 ri_idx:0x46 <-- vpn_lbl
matches the VPNv4 label, adj_handle and local_adj_hdl values must match, ri_id and ri_idx must
match
  ===============

C9300-PE-1#show platform hardware fed switch active fwd-asic abstraction print-resource-handle
0x7fbae8d86228 1 <-- Utilize the HTM value from previous command
Handle:0x7fbae8d86228 Res-Type:ASIC_RSC_HASH_TCAM Res-Switch-Num:0 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_IPV4_L3_UNICAST ref_count:1
priv_ri/priv_si Handle: (nil)Hardware Indices/Handles: handle [ASIC: 0]: 0x7fbae8d71f58

Detailed Resource Information (ASIC# 0)
---------------------------------------
Number of HTM Entries: 1

Entry 0: (handle 0x7fbae8d71f58)

Absolute Index: 92181
Time Stamp: 1
KEY - vrf:2 mtr:0 prefix:192.168.2.0 rcp_redirect_index:0x0
MASK - vrf:255 mtr:0 prefix:255.255.255.0 rcp_redirect_index:0x0
FWD-AD = afd_label_flag:0 icmp_redir_enable:1 lvx_smr_enabled:0, dstNatType:0 priority:5
afdLabelOrDestClientId:0 SI:182 destined_to_us:0 hw_stats_idx:0 stats_id:0
redirectSetRouterMac:0 dgtIdx:0 destModIndex:0 dstNatTypeOrVpnPrefixPtrMsb:0 vpnPrefixPtr:0x2
SRC-AD = learning_violation:1 need_to_learn:1  locally_connected:0 staticentryViolation:0
rpfValid:1 rpfLe:0 rpfLePointer:0 rpfForcePass:0 rpfForceFail:0 reachableviaSome:0
rpfCheckIncomplete:0 defaultRoute:0 ChainPtrValid:0 ChainPtrOrPortLeIndex:72 UseRpfmatchTable:0
rpfIncomplete:0 is_src_ce:0 sgtValid:0 sgt:0 src_rloc_trusted:0,sgtCacheControl1 = 0,
sgtCacheControl0 = 0
port_label:0x0 port_mask:0x0 vlan_label:0x0 vlan_mask:0x0 l3if_label:0x0 l3if_mask:0x0
group_label:0x0 group_mask:0x0


============================================================

C9300-PE-1#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x535f 0x535f <-- Utilize the di_id from the previous command
ASIC#0:

index = 0x535f
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
```

```
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x535f
pmap = 0x00000000 0x00000002 <-- Looking at 0x00000002, in binary that is 0000 0000 0000 0000
000 0000 0000 0010 = Port 1 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9300-PE-1#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x5360 0x5360 <-- Utilize the di_id from the previous command ASIC#0:
ASIC#0:

index = 0x5360
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x5360
pmap = 0x00000000 0x00000004 <-- Looking at 0x00000004, in binary that is 0000 0000 0000 0000
0000 0000 0000 0100 = Port 2 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
```

```
npuIndex = 0
stripSeg = 0
copySeg = 0

C9300-PE-1#show platform software fed switch active ifm map
Interface                IF_ID    Inst Asic Core Port SubPort Mac  Cntx LPN  GPN  Type Active
GigabitEthernet1/0/2     0x36       1   0   1    1      0      6    7    2    2    NIF  Y <--
Port 1 is an egress port, Gi1/0/2
GigabitEthernet1/0/3     0x37       1   0   1    2      0      28   8    3    3    NIF  Y <--
Port 2 is an egress port, Gi1/0/3
```

C9500首碼程式

```
***Software Prefix Programming***
C9500-P#show ip route 192.168.1.4
Routing entry for 192.168.1.4/32
  Known via "ospf 420", distance 110, metric 2, type intra area
  Last update from 10.0.0.18 on TenGigabitEthernet2/0/2, 20:15:25 ago
  Routing Descriptor Blocks:
    10.0.0.18, from 192.168.1.4, 20:15:25 ago, via TenGigabitEthernet2/0/2 <-- Next-hop towards
192.168.1.4
      Route metric is 2, traffic share count is 1
  * 10.0.0.14, from 192.168.1.4, 20:15:25 ago, via TenGigabitEthernet1/0/2 <-- Next-hop towards
192.168.1.4
      Route metric is 2, traffic share count is 1

C9500-P#show ip cef 192.168.1.4 detail
192.168.1.4/32, epoch 4, per-destination sharing
  dflt local label info: global/17 [0x3]
  nexthop 10.0.0.14 TenGigabitEthernet1/0/2 label explicit-null-(local:17) <-- Explicit null to
reach 192.168.1.4
  nexthop 10.0.0.18 TenGigabitEthernet2/0/2 label explicit-null-(local:17) <-- Explicit null to
reach 192.168.1.4

***FMAN RP Prefix Programming***
C9500-P#show platform software ip switch active r0 cef prefix 192.168.1.4/32
Forwarding Table

Prefix/Len                     Next Object      Index
----------------------------------------------------------------
192.168.1.4/32                 OBJ_LOADBALANCE  0x6a

C9500-P#show platform software loadinfo switch active r0 index 0x6a <-- Use the OBJ_LOADBALANCE
value from previous command
Number of loadinfo objects: 4

Index: 0x6a, Flags: unknown, Hash Algorithm: , Number of Paths: 2, Number of buckets: 16
  Anti-polarising Factor: 0x57a70068
  Next Object Type: OBJ_LABEL, OBJ_LABEL
  Next obj handle: 0x68, 0x69
  Hash Buckets: 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
  Color Buckets Map: 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
  OM handle: 0x348064de58

C9500-P#show platform software mpls switch active r0 label index 0x68 <-- Use the obj handle
values from the previous command


Label OCE 0x68 -> OBJ_ADJACENCY (0x49)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
```

```
  OM handle: 0x348064df70

C9500-P#show platform software mpls switch active r0 label index 0x69


Label OCE 0x69 -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x348064e108

C9500-P#show platform software adjacency switch active r0 index 0x49 <-- Use the OBJ_ADJACENCY
values from previous commands
Number of adjacency objects: 16

Adjacency id: 0x49 (73)
  Interface: TenGigabitEthernet1/0/2, IF index: 66, Link Type: MCP_LINK_TAG
  Encap: 70:d3:79:be:ae:71:d4:ad:71:b5:dd:d6:88:47 <-- MAC ending in AE71 is the DMAC, MAC
ending is B5DD is SMAC, 8847 is MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.14 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x3480647700


C9500-P#show platform software adjacency switch active r0 index 0x4e <-- Use the OBJ_ADJACENCY
values from previous commands
Number of adjacency objects: 16

Adjacency id: 0x4e (78)
  Interface: TenGigabitEthernet2/0/2, IF index: 68, Link Type: MCP_LINK_TAG
  Encap: 70:d3:79:be:ae:61:d4:ad:71:b5:dd:f1:88:47 <-- MAC ending in AE61 is DMAC, MAC ending in
B5DD is SMAC, 8847 is MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.18 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x3480648f68

***FMAN FP Prefix Programming***
C9500-P#show platform software ip switch active f0 cef prefix 192.168.1.4/32
Forwarding Table

Prefix/Len                     Next Object      Index
----------------------------------------------------------------
192.168.1.4/32                 OBJ_LOADBALANCE  0x6a

C9500-P#show platform software loadinfo switch active f0 index 0x6a <-- Use the OBJ_LOADBALANCE
value from previous command
Number of loadinfo objects: 4

Index: 0x6a, Flags: unknown, Hash Algorithm: , Number of Paths: 2, Number of buckets: 16
  Anti-polarising Factor: 0x57a70068
  Next Object Type: OBJ_LABEL, OBJ_LABEL
  Next obj handle: 0x68, 0x69
  Hash Buckets: 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
  Color Buckets Map: 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
```

```
  aom id: 578, HW handle: (nil)

C9500-P#show platform software mpls switch active f0 label index 0x68 <-- Use the obj handle
values from previous command


Label OCE 0x68 -> OBJ_ADJACENCY (0x49)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 576, CPP handle: 0xdeadbeef (created)

C9500-P#show platform software mpls switch active f0 label index 0x69 <-- Use the obj handle
values from previous command


Label OCE 0x69 -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 577, CPP handle: 0xdeadbeef (created)

C9500-P#show platform software adjacency switch active f0 index 0x49 <-- Use the OBJ_ADJACENCY
values from previous commands
Number of adjacency objects: 16

Adjacency id: 0x49 (73)
  Interface: TenGigabitEthernet1/0/2, IF index: 66, Link Type: MCP_LINK_TAG
  Encap: 70:d3:79:be:ae:71:d4:ad:71:b5:dd:d6:88:47 <-- MAC ending in AE71 is the DMAC, MAC
ending in DDD6 is the SMAC, 8847 is the MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.14 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 536, HW handle: (nil) (created)

C9500-P#show platform software adjacency switch active f0 index 0x4e <-- Use the OBJ_ADJACENCY
values from previous commands
Number of adjacency objects: 16

Adjacency id: 0x4e (78)
  Interface: TenGigabitEthernet2/0/2, IF index: 68, Link Type: MCP_LINK_TAG
  Encap: 70:d3:79:be:ae:61:d4:ad:71:b5:dd:f1:88:47 <-- MAC ending in AE61 is the DMAC, MAC
ending in DDF1 is the SMAC, 8847 is the MPLS ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: unknown
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.18 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 545, HW handle: (nil) (created)

***FED Prefix Programming***
C9500-P#show platform software fed switch active ip route 192.168.1.4/32
vrf   dest                                    htm            flags   SGT   DGID MPLS Last-
modified
---   ----                                    ---            -----   ---   ---- ---- -----
-------------------
0     192.168.1.4/32                          0x7f0b284c1118 0x0     0     0
2021/06/23 18:47:01.761 <-- HTM value important for subsequent command
```

```
  FIB: prefix_hdl:0x9b000020, mpls_ecr_prefix_hdl:0xdd00003a
  ========== OCE chain =====
  LB:obj_id:106 link_type:IP num_choices:2 Flags:0
      mpls_ecr:1 local_label:17 path_inhw:2 ecrh:0x44000002 old_ecrh:0
      modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
      bwalk:[req:0 in_prog:0 nested:0]
    AAL: ecr:id:1140850690 af:0 ecr_type:0 ref:2 ecrh:0x7f0b284a3998(28:2)
    hwhdl:675953048 ::0x7f0b284b4268,0x7f0b284a1d78,0x7f0b284b4268,0x7f0b284a1d78
  Sw Enh ECR scale: objid:106 llabel:17 eos:1 #adjs:2 mixed_adj:0
     reprogram_hw:0 ecrhdl:0x44000002 ecr_hwhdl:0x7f0b284a3998
      mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
      ecr_adj: id:4127195192 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:1207959601
            sih:0x7f0b284b4268(181) di_id:23709 rih:0x7f0b284b3ca8(31)
        adj_lentry [eos0:0x7f0b284c38e8 eos1:0x7f0b284cd858]
      ecr_adj: id:1157627961 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:67108914
            sih:0x7f0b284a1d78(182) di_id:23709 rih:0x7f0b284b47d8(44)
        adj_lentry [eos0:0x7f0b284c3af8 eos1:0x7f0b284cdb28]
      ecr_prefix_adj: id:3707764794 (ref:1)
         sih:0x7f0b284c5028(184) di_id:23709 rih:0x7f0b284c4c48(60)
     LABEL:objid:104 link_type:MPLS local_label:17 outlabel:(0, 0) <-- Label 17 is the local
transport label, 0 is the LDP label
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xf6000038
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:4127195192 lbl:0 smac:d4ad.71b5.ddd6 dmac:70d3.79be.ae71 <-- Matches the next-
hop information to reach 192.168.1.4/32
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284ceaa8, ri_id:0x38 phdl:0x76000058, ref_cnt:1
               si:0x7f0b284ceeb8, si_id:0x400b, di_id:0x2 <-- Used in subsequent commands
     ADJ:objid:73 {link_type:MPLS ifnum:0x42, si:0x1f000028, }
     LABEL:objid:105 link_type:MPLS local_label:17 outlabel:(0, 0) <-- Label 17 is the local
transport label, 0 is the LDP label
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x45000039
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1157627961 lbl:0 smac:d4ad.71b5.ddf1 dmac:70d3.79be.ae61 <-- Matches the next-
hop information to reach 192.168.1.4/32
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284c4588, ri_id:0x3a phdl:0x5500005a, ref_cnt:1
               si:0x7f0b284d0548, si_id:0x400c, di_id:0x62 <-- Used in subsequent commands
     ADJ:objid:78 {link_type:MPLS ifnum:0x44, si:0x4900002a, }
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0xdd00003a, mpls_lspa_hdl:0
  ===============

C9500-P#show platform hardware fed switch active fwd-asic abstraction print-resource-handle
0x7f0b284c1118 1 <-- Use the HTM value from previous command
Handle:0x7f0b284c1118 Res-Type:ASIC_RSC_HASH_TCAM Res-Switch-Num:0 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_IPV4_L3_UNICAST ref_count:1
priv_ri/priv_si Handle: (nil)Hardware Indices/Handles: handle [ASIC: 0]: 0x7f0b284c1328
Features sharing this resource:Cookie length: 12
04 01 a8 c0 00 00 00 d0 07 00 00 00

Detailed Resource Information (ASIC# 0)
---------------------------------------
Number of HTM Entries: 1

Entry 0: (handle 0x7f0b284c1328)

Absolute Index: 126650
Time Stamp: 1
KEY - vrf:0 mtr:0 prefix:192.168.1.4 rcp_redirect_index:0x0
```

```
MASK - vrf:0 mtr:0 prefix:0.0.0.0 rcp_redirect_index:0x0
FWD-AD = afd_label_flag:0 icmp_redir_enable:1 lvx_smr_enabled:0, dstNatType:0 priority:5
afdLabelOrDestClientId:0 SI:184 destined_to_us:0 hw_stats_idx:1 stats_id:0
redirectSetRouterMac:0 dgtIdx:0 destModIndex:0 dstNatTypeOrVpnPrefixPtrMsb:0 vpnPrefixPtr:0
SRC-AD = learning_violation:0 need_to_learn:0  locally_connected:0 staticentryViolation:0
rpfValid:1 rpfLe:2 rpfLePointer:0 rpfForcePass:0 rpfForceFail:0 reachableviaSome:1
rpfCheckIncomplete:0 defaultRoute:0 ChainPtrValid:0 ChainPtrOrPortLeIndex:72 UseRpfmatchTable:1
rpfIncomplete:0 is_src_ce:0 sgtValid:0 sgt:0 src_rloc_trusted:0,sgtCacheControl1 = 0,
sgtCacheControl0 = 0
port_label:0x0 port_mask:0x0 vlan_label:0x0 vlan_mask:0x0 l3if_label:0x0 l3if_mask:0x0
group_label:0x0 group_mask:0x0


==============================================================

C9500-P#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x2 0x2 <-- Use the di_id values from previous command
ASIC#0:

index = 0x2
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x2
pmap = 0x00000000 0x00000002 <-- Looking at 0x00000002, in binary that is 0000 0000 0000 0000
0000 0000 0000 0010 = Port 1 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9500-P#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x62 0x62
ASIC#0:

index = 0x62
pmap = 0x00000000 0x00008000 <-- Looking at 0x00008000, in binary that is 0000 0000 0000 0000
1000 0000 0000 0000 = Port 15 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
```

```
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x62
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9500-P#show platform software fed switch standby ip route 192.168.1.4/32
vrf   dest                                      htm            flags   SGT   DGID MPLS Last-
modified
---   ----                                      ---            -----   ---   ---- ---- -----
-------------------
0     192.168.1.4/32                            0x7f57c0545938 0x0     0     0
2021/06/23 18:46:51.399 <-- HTM value used in subsequent command
  FIB: prefix_hdl:0x29000020, mpls_ecr_prefix_hdl:0x8f000039
  ========== OCE chain =====
  LB:obj_id:106 link_type:IP num_choices:2 Flags:0
      mpls_ecr:1 local_label:17 path_inhw:2 ecrh:0xf1000002 old_ecrh:0
      modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
      bwalk:[req:0 in_prog:0 nested:0]
    AAL: ecr:id:4043309058 af:0 ecr_type:0 ref:2 ecrh:0x7f57c04d2148(28:2)
    hwhdl:3226280264 ::0x7f57c0547538,0x7f57c05497d8,0x7f57c0547538,0x7f57c05497d8
  Sw Enh ECR scale: objid:106 llabel:17 eos:1 #adjs:2 mixed_adj:0
     reprogram_hw:0 ecrhdl:0xf1000002 ecr_hwhdl:0x7f57c04d2148
      mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
      ecr_adj: id:201326647 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:3925868592
            sih:0x7f57c0547538(181) di_id:23717 rih:0x7f57c0546f18(31)
        adj_lentry [eos0:0x7f57c04c8a08 eos1:0x7f57c04d07f8]
      ecr_adj: id:738197560 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:3070230577
            sih:0x7f57c05497d8(182) di_id:23717 rih:0x7f57c0547838(44)
        adj_lentry [eos0:0x7f57c04c8c18 eos1:0x7f57c04d0ac8]
      ecr_prefix_adj: id:2399141945 (ref:1)
         sih:0x7f57c04c8788(184) di_id:23717 rih:0x7f57c04c8508(60)
     LABEL:objid:104 link_type:MPLS local_label:17 outlabel:(0, 0) <-- Label 17 is the local
transport label, 0 is the LDP label
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xc000037
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:201326647 lbl:0 smac:d4ad.71b5.ddd6 dmac:70d3.79be.ae71 <-- Matches next-hop
information to reach 192.168.1.4/32
              sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
              vlan_id:0 vrf_id:0 ri:0x7f57c04d18e8, ri_id:0x38 phdl:0x76000058, ref_cnt:1
```

```
             si:0x7f57c04d1b18, si_id:0x400b, di_id:0x2 <-- di_id utilized in subsequent
commands
     ADJ:objid:73 {link_type:MPLS ifnum:0x42, si:0xdf000027, }
     LABEL:objid:105 link_type:MPLS local_label:17 outlabel:(0, 0) <-- Label 17 is the local
transport label, 0 is the LDP label
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x2c000038
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:738197560 lbl:0 smac:d4ad.71b5.ddf1 dmac:70d3.79be.ae61 <-- Matches next-hop
information to reach 192.168.1.4/32
             sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
             vlan_id:0 vrf_id:0 ri:0x7f57c04da418, ri_id:0x3a phdl:0x5500005a, ref_cnt:1
             si:0x7f57c04da838, si_id:0x400c, di_id:0x62 <-- di_id utilized in subsequent
commands
     ADJ:objid:78 {link_type:MPLS ifnum:0x44, si:0xfa000029, }
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0x8f000039, mpls_lspa_hdl:0
  ===============

C9500-P#show platform hardware fed switch standby fwd-asic resource asic all destination-index
range 0x62 0x62
ASIC#0:

index = 0x62
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x62
pmap = 0x00000000 0x00000002 <-- Looking at 0x000000002, in binary that is 0000 0000 0000 0000
0000 0000 0000 0010 = Port 1 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9500-P#show platform hardware fed switch standby fwd-asic resource asic all destination-index
range 0x2 0x2
ASIC#0:

index = 0x2
pmap = 0x00000000 0x00008000 <-- Looking at 0x00008000, in binary that is 0000 0000 0000 0000
1000 0000 0000 0000 = Port 15 (Zero based, count right to left)
```

```
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x2
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9500-P#show platform software fed switch active ifm mappings
Interface                IF_ID    Inst Asic Core Port SubPort Mac  Cntx LPN  GPN  Type Active
TenGigabitEthernet1/0/2  0x42       1   0   1    1      0      10   1    2    2    NIF  Y <--
Port 1 is an egres port, TenGi1/0/2
TenGigabitEthernet1/0/16 0x18       0   0   0    15     0      8    11   16   2360 NIF  Y <--
Port 15 is the SVL

C9500-P#show platform software fed switch standby ifm mappings
Interface                IF_ID    Inst Asic Core Port SubPort Mac  Cntx LPN  GPN  Type Active
TenGigabitEthernet2/0/2  0x44       1   0   1    1      0      10   1    2    98   NIF  Y <--
Port 1 is an egres port, TenGi2/0/2
TenGigabitEthernet2/0/16 0x33       0   0   0    15     0      8    11   16   2360 NIF  Y <--
Port 15 is the SVL
```

驗證C9300-PE-2字首

```
***Software Prefix Programming***
C9300-PE-2#show ip route vrf RED 192.168.2.0

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "eigrp 400", distance 90, metric 130816, precedence routine (0), type internal
  Redistributing via eigrp 400, bgp 69420
  Advertised by bgp 69420
  Last update from 10.0.0.22 on GigabitEthernet2/0/1, 21:35:22 ago
  Routing Descriptor Blocks:
  * 10.0.0.22, from 10.0.0.22, 21:35:22 ago, via GigabitEthernet2/0/1 <-- Next-hop to reach
192.168.2.0/24
      Route metric is 130816, traffic share count is 1
      Total delay is 5010 microseconds, minimum bandwidth is 1000000 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
```

```
      Loading 1/255, Hops 1

C9300-PE-2#show ip route vrf RED 10.0.0.22

Routing Table: RED
Routing entry for 10.0.0.20/30
  Known via "connected", distance 0, metric 0 (connected, via interface)
  Redistributing via eigrp 400, bgp 69420
  Advertised by bgp 69420
  Routing Descriptor Blocks:
  * directly connected, via GigabitEthernet2/0/1
      Route metric is 0, traffic share count is 1

C9300-PE-2#show ip cef vrf RED 192.168.2.0/24 detail
192.168.2.0/24, epoch 0
  QOS: Precedence routine (0)
  dflt local label info: other/21 [0x2] <-- VPNv4 Label
  nexthop 10.0.0.22 GigabitEthernet2/0/1

***FMAN RP Prefix Programming***
C9300-PE-2#show ip vrf detail
VRF RED (VRF Id = 2); default RD 69:69; default VPNID <-- VRF ID used in next command
  Old CLI format, supports IPv4 only
  Flags: 0xC
  Interfaces:
    Gi2/0/1
Address family ipv4 unicast (Table ID = 0x2):
  Flags: 0x0
  Export VPN route-target communities
    RT:69:69
  Import VPN route-target communities
    RT:69:69
  No import route-map
  No global export route-map
  No export route-map
  VRF label distribution protocol: not configured
  VRF label allocation mode: per-prefix

C9300-PE-2#show platform software ip switch active r0 cef table index 2 prefix 192.168.2.0/24 <-
- Use the VRF ID from previous command
Forwarding Table

Prefix/Len                     Next Object      Index
-----------------------------------------------------------------
192.168.2.0/24                 OBJ_ADJACENCY    0x3a

C9300-PE-2#show platform software adjacency switch active r0 index 0x3a <-- Use the
OBJ_ADJACENCY value from previous command
Number of adjacency objects: 10

Adjacency id: 0x3a (58)
  Interface: GigabitEthernet2/0/1, IF index: 53, Link Type: MCP_LINK_IP
  Encap: 0:72:78:c8:c9:c2:70:d3:79:be:ae:42:8:0 <-- MAC ending in C9C2 is the DMAC, MAC ending
in AE42 is SMAC, 0800 is IP ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: no-l3-inject
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.22 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  OM handle: 0x348062b578

***FMAN FP Prefix Programming***
```

```
C9300-PE-2#show platform software ip switch active f0 cef table index 2 prefix 192.168.2.0/24
Forwarding Table

Prefix/Len                      Next Object      Index
-----------------------------------------------------------------
192.168.2.0/24                  OBJ_ADJACENCY    0x3a

C9300-PE-2#show platform software adjacency switch active f0 index 0x3a <-- Use the
OBJ_ADJACENCY value from previous command
Number of adjacency objects: 10

Adjacency id: 0x3a (58)
  Interface: GigabitEthernet2/0/1, IF index: 53, Link Type: MCP_LINK_IP
  Encap: 0:72:78:c8:c9:c2:70:d3:79:be:ae:42:8:0 <-- MAC ending in C9C2 is the DMAC, MAC ending
in AE42 is SMAC, 0800 is IP ETYPE
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: no-l3-inject
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.22 <-- Next-hop IP address
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 477, HW handle: (nil) (created)

***FED Prefix Programming***
C9300-PE-2#show platform hardware fed switch active ip route vrf-name RED 192.168.2.0/24
vrf   dest                                    htm            flags   SGT   DGID MPLS Last-
modified
---   ----                                    ---            -----   ---   ---- ---- -----
-------------------
2     192.168.2.0/24                          0x7f0650a7e3e8 0x0     0     0
2021/06/23 18:46:56.801 <-- HTM value used in subsequent command
  FIB: prefix_hdl:0x38000016, mpls_ecr_prefix_hdl:0
  ========== OCE chain =====
  ADJ:objid:58 {link_type:IP ifnum:0x35, si:0x9700001b, IPv4:       10.0.0.22 } <-- objid
relevant in subsequent command, 10.0.0.22 is the next-hop IP
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0, mpls_lspa_hdl:0
  ===============

C9300-PE-2#show platform hardware fed switch active fwd-asic abstraction print-resource-handle
0x7f0650a7e3e8 1 <-- Use the HTM value from previous command
Handle:0x7f0650a7e3e8 Res-Type:ASIC_RSC_HASH_TCAM Res-Switch-Num:0 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_IPV4_L3_UNICAST ref_count:1
priv_ri/priv_si Handle: (nil)Hardware Indices/Handles: handle [ASIC: 0]: 0x7f0650ba4028

Detailed Resource Information (ASIC# 0)
---------------------------------------
Number of HTM Entries: 1

Entry 0: (handle 0x7f0650ba4028)

Absolute Index: 92180
Time Stamp: 1
KEY - vrf:2 mtr:0 prefix:192.168.2.0 rcp_redirect_index:0x0
MASK - vrf:255 mtr:0 prefix:255.255.255.0 rcp_redirect_index:0x0
(SI value used later)
FWD-AD = afd_label_flag:0 icmp_redir_enable:1 lvx_smr_enabled:0, dstNatType:0 priority:5
afdLabelOrDestClientId:0 SI:173 destined_to_us:0 hw_stats_idx:1 stats_id:0
redirectSetRouterMac:0 dgtIdx:0 destModIndex:0 dstNatTypeOrVpnPrefixPtrMsb:0 vpnPrefixPtr:0
SRC-AD = learning_violation:1 need_to_learn:1  locally_connected:0 staticentryViolation:0
rpfValid:1 rpfLe:37 rpfLePointer:0 rpfForcePass:0 rpfForceFail:0 reachableviaSome:1
rpfCheckIncomplete:0 defaultRoute:0 ChainPtrValid:0 ChainPtrOrPortLeIndex:72 UseRpfmatchTable:0
rpfIncomplete:0 is_src_ce:0 sgtValid:0 sgt:0 src_rloc_trusted:0,sgtCacheControl1 = 0,
```

```
sgtCacheControl0 = 0
port_label:0x0 port_mask:0x0 vlan_label:0x0 vlan_mask:0x0 l3if_label:0x0 l3if_mask:0x0
group_label:0x0 group_mask:0x0


============================================================

C9300-PE-2#show platform software fed switch active ip adj
IPV4 Adj entries
dest            if_name                 dst_mac          si_hdl         ri_hdl         pd_flags
adj_id  Last-modified
----            -------                 -------          ------         ------         --------
-----   ------------------------
10.0.0.22       GigabitEthernet2/0/1    0072.78c8.c9c2   0x7f0650a32858 0x7f0650a1af48 0x0
0x3a       2021/06/23 18:46:52.956

C9300-PE-2#show ip arp vrf RED 10.0.0.22
Protocol    Address        Age (min)  Hardware Addr  Type Interface
Internet    10.0.0.22           131   0072.78c8.c9c2 ARPA GigabitEthernet2/0/1  <-- dst_mac
matches the ARP entry

C9300-PE-2#show platform hardware fed fwd-asic abstraction print-resource-handle 0x7f0650a32858
1 <-- Use the HTM value from previous command
Handle:0x7f0650a32858 Res-Type:ASIC_RSC_SI Res-Switch-Num:255 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_INVALID ref_count:1
priv_ri/priv_si Handle: 0x7f0650a1af48Hardware Indices/Handles: index0:0xad
mtu_index/l3u_ri_index0:0x0  index1:0xad  mtu_index/l3u_ri_index1:0x0
Features sharing this resource:66 (1)]
Cookie length: 56
00 00 00 00 00 00 00 00 25 00 00 00 00 00 00 00 00 00 00 00 08 00 00 72 78 c8 c9 c2 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Detailed Resource Information (ASIC# 0)
----------------------------------------


Station Index (SI) [0xad]
RI = 0x18
DI = 0x5338
stationTableGenericLabel = 0
stationFdConstructionLabel = 0x7
lookupSkipIdIndex = 0
rcpServiceId = 0
dejaVuPreCheckEn = 0
Replication Bitmap: CD

Detailed Resource Information (ASIC# 1)
----------------------------------------


Station Index (SI) [0xad]
RI = 0x18
DI = 0x5338
stationTableGenericLabel = 0
stationFdConstructionLabel = 0x7
lookupSkipIdIndex = 0
rcpServiceId = 0
dejaVuPreCheckEn = 0
Replication Bitmap: LD

============================================================

C9300-PE-2#show platform hardware fed switch active fwd-asic resource asic all destination-index
range 0x5338 0x5338 <-- Use the DI value from previous command
```

```
ASIC#0:

index = 0x5338
pmap = 0x00000000 0x00000000
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0
ASIC#1:

index = 0x5338
pmap = 0x00000000 0x00000001 <-- Looking at 0x00000001, in binary that is 0000 0000 0000 0000
0000 0000 0000 0001 = Port 0 (Zero based, count right to left)
cmi = 0x0
rcp_pmap = 0x0
al_rsc_cmi
CPU Map Index (CMI) [0]
ctiLo0 = 0
ctiLo1 = 0
ctiLo2 = 0
cpuQNum0 = 0
cpuQNum1 = 0
cpuQNum2 = 0
npuIndex = 0
stripSeg = 0
copySeg = 0

C9300-PE-2#show platform software fed switch active ifm mappings
Interface                IF_ID    Inst Asic Core Port SubPort Mac  Cntx LPN  GPN  Type Active
GigabitEthernet2/0/1     0x35       1   0   1    0      0      26   6    1    97   NIF  Y    <-
- Port 0 is the egress port, Gi2/0/1
```

VPNv4標籤程式設計

下一部分介紹MPLS PE路由器（C9300-PE-1和C9300-PE-2）上的VPNv4標籤程式設計。C9500=P不會在VPNv4標籤上轉發，因此沒有來自C9500-P的輸出。

C9300-PE-1 VPNv4標籤程式設計：

檢查PE的本地字首，而不是遠端字首。從FED角度檢查標籤，然後回溯至FMAN RP和FMAN FP。

```
***Software VPNv4 Label Programming***
C9300-PE-1#show ip cef vrf RED 192.168.3.0/24 detail
192.168.3.0/24, epoch 0
  QOS: Precedence routine (0)
  dflt local label info: other/21 [0x2] <-- VPNv4 label assocaited with the local prefix
  nexthop 10.0.0.1 GigabitEthernet1/0/1

***FMAN RP VPNv4 Label Programming***
C9300-PE-1#show platform software mpls switch active r0 eos index 117 <-- Utilize the objid from
the FED command
```

```
EOS Choice 0x75, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x74
  OM handle: 0x3480644470

***FMAN FP VPNv4 Label Programming***
C9300-PE-1#show platform software mpls switch active f0 eos index 117 <-- Utilize the objid from
the FED command


EOS Choice 0x75, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x74
  aom id: 612, CPP handle: 0xdeadbeef (created), flags: 0

C9300-PE-1#show platform software object-manager switch active f0 object 612 <-- Use the aom id
from previous command
Object identifier: 612
  Description: EOS Choice 0x75
  Status: Done, Epoch: 0, Client data: 0xe05e9318

C9300-PE-1#show platform software object-manager switch active f0 object 612 parents <-- Use the
aom id from previous command
Object identifier: 7
  Description: Special Object adj_drop
  Status: Done

Object identifier: 611
  Description: label 0x74
  Status: Done

***FED VPNv4 Label Programming***
C9300-PE-1#show platform software fed switch active mpls forwarding label 21 detail
 LENTRY:label:21 nobj:(EOS, 117) lentry_hdl:0x8b000009
   modify_cnt:0 backwalk_cnt:0
   lspa_handle:0
   AAL: id:2332033033 lbl:21
        eos0:[adj_hdl:0, hw_hdl:0x7fbae8d87428]
        eos1:[adj_hdl:0x4300003b, hw_hdl:0x7fbae8d87278]
        deagg_vrf_id = 0 lspa_handle:0
   EOS:objid:117 local_label:0 flags:0:() pdflags:0 <-- Utilized in previous commands
      nobj0:(ADJ SPECIAL,DROP 0), nobj1:(LABEL, 116) modify:0 bwalk:0
      LABEL:objid:116 link_type:IP local_label:21 outlabel:(1048577, 0)
          flags:0xc:(UHP,POP,) pdflags:0x2:(INSTALL_HW_OK,) adj_handle:0x4300003b
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1124073531 lbl:0 smac:a0f8.4911.d1e4 dmac:0072.78c8.06e4
               sub_type:0 link_type:0 adj_flags:0x2 label_type:1 rewrite_type:POP2IP(135)
               vlan_id:0 vrf_id:0 ri:0x7fbae8d811b8, ri_id:0x3e phdl:0xf1000024, ref_cnt:1
               si:0x7fbae8d72078, si_id:0x4012, di_id:0x5338
      ADJ:objid:58 {link_type:IP ifnum:0x35, si:0x1900001b, IPv4:        10.0.0.1 }
```

驗證C9300-PE-2 VPNv4標籤

請檢查PE的本地字首，而不是遠端字首。從FED角度檢查標籤，然後回溯至FMAN RP和FMAN FP。

```
C9300-PE-2#show ip cef vrf RED 192.168.2.0/24 detail
192.168.2.0/24, epoch 0
```

```
  QOS: Precedence routine (0)
  dflt local label info: other/21 [0x2] <-- VPNv4 label associated with the local prefix
  nexthop 10.0.0.22 GigabitEthernet2/0/1

C9300-PE-2#show platform software mpls switch active r0 eos index 118 <-- Utilize the objid
value from the FED command


EOS Choice 0x76, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x75
  OM handle: 0x34806402d0


C9300-PE-2#show platform software mpls switch active f0 eos index 118 <-- Utilize the objid
value from the FED command


EOS Choice 0x76, Number of paths: 2
  Next Object Type: OBJ_ADJ_DROP,OBJ_LABEL
  Next Object Index: 0,0x75
  aom id: 589, CPP handle: 0xdeadbeef (created), flags: 0

C9300-PE-2#show platform software object-manager switch active f0 object 589 <-- Utilize the aom
id from the previous command
Object identifier: 589
  Description: EOS Choice 0x76
  Status: Done, Epoch: 0, Client data: 0x248cac8

C9300-PE-2#show platform software object-manager switch active f0 object 589 parents <-- Utilize
the aom id from the previous command
Object identifier: 7
  Description: Special Object adj_drop
  Status: Done

Object identifier: 588
  Description: label 0x75
  Status: Done

C9300-PE-2#show platform software fed switch active mpls forwarding label 21 detail
 LENTRY:label:21 nobj:(EOS, 118) lentry_hdl:0x63000009
   modify_cnt:0 backwalk_cnt:0
   lspa_handle:0
   AAL: id:1660944393 lbl:21
        eos0:[adj_hdl:0, hw_hdl:0x7f0650a40408]
        eos1:[adj_hdl:0xcb00003a, hw_hdl:0x7f0650a401f8]
        deagg_vrf_id = 0 lspa_handle:0
   EOS:objid:118 local_label:0 flags:0:() pdflags:0
      nobj0:(ADJ SPECIAL,DROP 0), nobj1:(LABEL, 117) modify:0 bwalk:0
      LABEL:objid:117 link_type:IP local_label:21 outlabel:(1048577, 0)
          flags:0xc:(UHP,POP,) pdflags:0x2:(INSTALL_HW_OK,) adj_handle:0xcb00003a
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:3405774906 lbl:0 smac:70d3.79be.ae42 dmac:0072.78c8.c9c2
               sub_type:0 link_type:0 adj_flags:0x2 label_type:1 rewrite_type:POP2IP(135)
               vlan_id:0 vrf_id:0 ri:0x7f0650a3f2a8, ri_id:0x48 phdl:0xf1000024, ref_cnt:1
               si:0x7f0650a3d5e8, si_id:0x400a, di_id:0x5338
      ADJ:objid:58 {link_type:IP ifnum:0x35, si:0x9700001b, IPv4:       10.0.0.22 }
```

LDP標籤程式設計

下一節將介紹MPLS路由器C9300-PE-1、C9500-P和C9300-PE-2上的LDP標籤程式設計。

LDP（外部）標籤是MPLS網路標籤交換資料包的方式。驗證通告到遠端PE的本地LDP標籤，不要驗證遠端LDP標籤。

C9300-PE-1 LDP標籤程式設計：

驗證向遠端PE通告的本地LDP標籤，不要驗證遠端LDP標籤。從FED的角度檢查標籤，然後回溯至FMAN RP和FMAN FP。

```
***Software LDP Label Programming***
C9300-PE-1#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi1/0/2    10.0.0.6
           Pop Label  192.168.1.3/32   0             Gi1/0/3    10.0.0.10
17         Pop Label  10.0.0.16/30     0             Gi1/0/2    10.0.0.6
           Pop Label  10.0.0.16/30     0             Gi1/0/3    10.0.0.10
18         Pop Label  10.0.0.12/30     0             Gi1/0/2    10.0.0.6
           Pop Label  10.0.0.12/30     0             Gi1/0/3    10.0.0.10
19         17         192.168.1.4/32   0             Gi1/0/2    10.0.0.6 <-- LDP label 19 is
advertised to reach PE 192.168.1.4
           17         192.168.1.4/32   0             Gi1/0/3    10.0.0.10
20         No Label   10.0.0.0/30[V]   630           aggregate/RED
21         No Label   192.168.3.0/24[V]   \
                                       0             Gi1/0/1    10.0.0.1

***FMAN RP LDP Label Programming***
C9300-PE-1#show platform software mpls switch active r0 label index 110 <-- Use the objid value
from the FED commands


Label OCE 0x6e -> OBJ_ADJACENCY (0x4b)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x34806420d0

C9300-PE-1#show platform software mpls switch active r0 label index 111 <-- Use the objid value
from the FED commands


Label OCE 0x6f -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480642268

***FMAN FP LDP Label Programming***
C9300-PE-1#show platform software mpls switch active f0 label index 110 <-- Use the objid value
from the FED commands


Label OCE 0x6e -> OBJ_ADJACENCY (0x4b)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 598, CPP handle: 0xdeadbeef (created)

C9300-PE-1#show platform software mpls switch active f0 label index 111 <-- Use the objid value
from the FED commands
```

```
Label OCE 0x6f -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x11
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 599, CPP handle: 0xdeadbeef (created)

C9300-PE-1#show platform software object-manager switch active f0 object 598 <-- Utilize the aom
id from previous commands
Object identifier: 598
  Description: label 0x6e
  Status: Done, Epoch: 0, Client data: 0xe05e6d78

C9300-PE-1#show platform software object-manager switch active f0 object 598 parents <-- Utilize
the aom id from previous commands
Object identifier: 531
  Description: adj 0x4b, Flags None
  Status: Done

C9300-PE-1#show platform software object-manager switch active f0 object 599 <-- Utilize the aom
id from previous commands
Object identifier: 599
  Description: label 0x6f
  Status: Done, Epoch: 0, Client data: 0xe05e6f78


C9300-PE-1#show platform software object-manager switch active f0 object 599 parents <-- Utilize
the aom id from previous commands
Object identifier: 535
  Description: adj 0x4e, Flags None
  Status: Done

C9300-PE-1#show platform software fed switch active mpls forwarding label 19 detail
 LENTRY:label:19 nobj:(LB, 112) lentry_hdl:0x9000007
   modify_cnt:1 backwalk_cnt:0
   lspa_handle:0
   AAL: id:150994951 lbl:19
        eos0:[adj_hdl:0x7d000002, hw_hdl:0x7fbae8d778b8]
        eos1:[adj_hdl:0x7d000002, hw_hdl:0x7fbae8d776a8]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:112 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:19 path_inhw:2 ecrh:0x7d000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
     AAL: ecr:id:2097152002 af:0 ecr_type:0 ref:7 ecrh:0x7fbae8a99268(28:2)
     hwhdl:3903427176 ::0x7fbae8a98b98,0x7fbae8a9ad48,0x7fbae8a98b98,0x7fbae8a9ad48
   Sw Enh ECR scale: objid:112 llabel:19 eos:1 #adjs:2 mixed_adj:0
      reprogram_hw:0 ecrhdl:0x7d000002 ecr_hwhdl:0x7fbae8a99268
       mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
       ecr_adj: id:4278190135 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:1744830509
             sih:0x7fbae8a98b98(179) di_id:20499 rih:0x7fbae8a985d8(33)
         adj_lentry [eos0:0x7fbae8d7bf48 eos1:0x7fbae8d76e88]
       ecr_adj: id:1392508984 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:2013265966
             sih:0x7fbae8a9ad48(180) di_id:20499 rih:0x7fbae8a9a788(46)
         adj_lentry [eos0:0x7fbae8d7c1b8 eos1:0x7fbae8d77158]
       ecr_prefix_adj: id:2164260921 (ref:1)
          sih:0x7fbae8d7df08(181) di_id:20499 rih:0x7fbae8d7db98(68)
      LABEL:objid:110 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Used in previous
commands
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xff000037
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:4278190135 lbl:0 smac:a0f8.4911.d1d6 dmac:d4ad.71b5.dde4
```

```
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7fbae8d78c48, ri_id:0x40 phdl:0x9f00004b, ref_cnt:1
               si:0x7fbae8d78fd8, si_id:0x4013, di_id:0x535f
      ADJ:objid:75 {link_type:MPLS ifnum:0x36, si:0x22000023, }
      LABEL:objid:111 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Used in previous
commands
           flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x53000038
           unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
           bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
           AAL: id:1392508984 lbl:0 smac:a0f8.4911.d1d8 dmac:d4ad.71b5.ddc2
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7fbae8d7d0a8, ri_id:0x42 phdl:0x8400004c, ref_cnt:1
               si:0x7fbae8d7a908, si_id:0x4014, di_id:0x5360
      ADJ:objid:78 {link_type:MPLS ifnum:0x37, si:0x74000026, }
```

C9500-P LDP標籤程式設計：

驗證向遠端PE通告的本地LDP標籤，不要驗證遠端LDP標籤。從FED的角度檢查標籤，然後回溯至FMAN RP和FMAN FP。

```
***Software LDP Label Programming***
C9500-P#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         explicit-n 192.168.1.2/32   1240          Te1/0/1    10.0.0.5  <-- LDP Label 16
advertised to reach PE 192.168.1.2
           explicit-n 192.168.1.2/32   226537        Te2/0/1    10.0.0.9
17         explicit-n 192.168.1.4/32   610           Te1/0/2    10.0.0.14 <-- LDP LAbel 17
advertised to reach PE 192.168.1.4
           explicit-n 192.168.1.4/32   227592        Te2/0/2    10.0.0.18

***FMAN RP LDP Label Programming***
C9500-P#show platform software mpls switch active r0 label index 94


Label OCE 0x5e -> OBJ_ADJACENCY (0x3f)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x348064c530

C9500-P#show platform software mpls switch active r0 label index 95


Label OCE 0x5f -> OBJ_ADJACENCY (0x44)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x348064c6c8

C9500-P#show platform software mpls switch active r0 label index 104


Label OCE 0x68 -> OBJ_ADJACENCY (0x49)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x348064df70

C9500-P#show platform software mpls switch active r0 label index 105
```

```
Label OCE 0x69 -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x348064e108

***FMAN FP LDP Label Programming***
C9500-P#show platform software mpls switch active f0 label index 94


Label OCE 0x5e -> OBJ_ADJACENCY (0x3f)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 564, CPP handle: 0xdeadbeef (created)

C9500-P#show platform software mpls switch active f0 label index 95


Label OCE 0x5f -> OBJ_ADJACENCY (0x44)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 565, CPP handle: 0xdeadbeef (created)

C9500-P#show platform software mpls switch active f0 label index 104


Label OCE 0x68 -> OBJ_ADJACENCY (0x49)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 576, CPP handle: 0xdeadbeef (created)

C9500-P#show platform software mpls switch active f0 label index 105


Label OCE 0x69 -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 577, CPP handle: 0xdeadbeef (created)


C9500-P#show platform software object-manager switch active f0 object 564
Object identifier: 564
  Description: label 0x5e
  Status: Done, Epoch: 0, Client data: 0x4f737108


C9500-P#show platform software object-manager switch active f0 object 564 parents
Object identifier: 515
  Description: adj 0x3f, Flags None
  Status: Done

C9500-P#show platform software object-manager switch active f0 object 565
Object identifier: 565
  Description: label 0x5f
  Status: Done, Epoch: 0, Client data: 0x4f737448


C9500-P#show platform software object-manager switch active f0 object 565 parents
Object identifier: 525
```

```
  Description: adj 0x44, Flags None
  Status: Done

C9500-P#show platform software object-manager switch active f0 object 576
Object identifier: 576
  Description: label 0x68
  Status: Done, Epoch: 0, Client data: 0x4f6d4bf8

C9500-P#show platform software object-manager switch active f0 object 576 parents
Object identifier: 536
  Description: adj 0x49, Flags None
  Status: Done

C9500-P#show platform software object-manager switch active f0 object 577
Object identifier: 577
  Description: label 0x69
  Status: Done, Epoch: 0, Client data: 0x4f737f78


C9500-P#show platform software object-manager switch active f0 object 577 parents
Object identifier: 545
  Description: adj 0x4e, Flags None
  Status: Done

***FED LDP Label Programming***
C9500-P#show platform software fed switch active mpls forwarding label 16 detail
 LENTRY:label:16 nobj:(LB, 96) lentry_hdl:0xeb000004
   modify_cnt:2 backwalk_cnt:0
   lspa_handle:0
   AAL: id:3942645764 lbl:16
        eos0:[adj_hdl:0x44000002, hw_hdl:0x7f0b284b4d98]
        eos1:[adj_hdl:0x44000002, hw_hdl:0x7f0b284b4be8]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:96 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:16 path_inhw:2 ecrh:0x44000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
     AAL: ecr:id:1140850690 af:0 ecr_type:0 ref:2 ecrh:0x7f0b284a3998(28:2)
     hwhdl:675953048 ::0x7f0b284b4268,0x7f0b284a1d78,0x7f0b284b4268,0x7f0b284a1d78
   Sw Enh ECR scale: objid:96 llabel:16 eos:1 #adjs:2 mixed_adj:0
      reprogram_hw:0 ecrhdl:0x44000002 ecr_hwhdl:0x7f0b284a3998
       mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
       ecr_adj: id:1610612787 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:1207959601
             sih:0x7f0b284b4268(181) di_id:23709 rih:0x7f0b284b3ca8(31)
         adj_lentry [eos0:0x7f0b284a32d8 eos1:0x7f0b284a3cc8]
       ecr_adj: id:805306420 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:67108914
             sih:0x7f0b284a1d78(182) di_id:23709 rih:0x7f0b284b47d8(44)
         adj_lentry [eos0:0x7f0b284c1608 eos1:0x7f0b284a2138]
       ecr_prefix_adj: id:3976200245 (ref:1)
          sih:0x7f0b284c2bf8(183) di_id:23709 rih:0x7f0b284c2888(50)
      LABEL:objid:94 link_type:MPLS local_label:16 outlabel:(0, 0)
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x60000033
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1610612787 lbl:0 smac:d4ad.71b5.dde4 dmac:a0f8.4911.d1d6
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284a2cd8, ri_id:0x2e phdl:0xe9000057, ref_cnt:1
               si:0x7f0b284a3048, si_id:0x4009, di_id:0x1
      ADJ:objid:63 {link_type:MPLS ifnum:0x41, si:0x2d000023, }
      LABEL:objid:95 link_type:MPLS local_label:16 outlabel:(0, 0)
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x30000034
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
```

```
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:805306420 lbl:0 smac:d4ad.71b5.ddc2 dmac:a0f8.4911.d1d8
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284a57c8, ri_id:0x30 phdl:0x67000059, ref_cnt:1
               si:0x7f0b284a6008, si_id:0x400a, di_id:0x61
      ADJ:objid:68 {link_type:MPLS ifnum:0x43, si:0xef000026, }

C9500-P#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LB, 106) lentry_hdl:0xf6000005
   modify_cnt:1 backwalk_cnt:0
   lspa_handle:0
   AAL: id:4127195141 lbl:17
        eos0:[adj_hdl:0x44000002, hw_hdl:0x7f0b284ce2f8]
        eos1:[adj_hdl:0x44000002, hw_hdl:0x7f0b284ce0e8]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:106 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:17 path_inhw:2 ecrh:0x44000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
     AAL: ecr:id:1140850690 af:0 ecr_type:0 ref:2 ecrh:0x7f0b284a3998(28:2)
     hwhdl:675953048 ::0x7f0b284b4268,0x7f0b284a1d78,0x7f0b284b4268,0x7f0b284a1d78
   Sw Enh ECR scale: objid:106 llabel:17 eos:1 #adjs:2 mixed_adj:0
      reprogram_hw:0 ecrhdl:0x44000002 ecr_hwhdl:0x7f0b284a3998
       mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
       ecr_adj: id:4127195192 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:1207959601
             sih:0x7f0b284b4268(181) di_id:23709 rih:0x7f0b284b3ca8(31)
         adj_lentry [eos0:0x7f0b284c38e8 eos1:0x7f0b284cd858]
       ecr_adj: id:1157627961 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:67108914
             sih:0x7f0b284a1d78(182) di_id:23709 rih:0x7f0b284b47d8(44)
         adj_lentry [eos0:0x7f0b284c3af8 eos1:0x7f0b284cdb28]
       ecr_prefix_adj: id:3707764794 (ref:1)
          sih:0x7f0b284c5028(184) di_id:23709 rih:0x7f0b284c4c48(60)
      LABEL:objid:104 link_type:MPLS local_label:17 outlabel:(0, 0)
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xf6000038
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:4127195192 lbl:0 smac:d4ad.71b5.ddd6 dmac:70d3.79be.ae71
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284ceaa8, ri_id:0x38 phdl:0x76000058, ref_cnt:1
               si:0x7f0b284ceeb8, si_id:0x400b, di_id:0x2
      ADJ:objid:73 {link_type:MPLS ifnum:0x42, si:0x1f000028, }
      LABEL:objid:105 link_type:MPLS local_label:17 outlabel:(0, 0)
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x45000039
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1157627961 lbl:0 smac:d4ad.71b5.ddf1 dmac:70d3.79be.ae61
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284c4588, ri_id:0x3a phdl:0x5500005a, ref_cnt:1
               si:0x7f0b284d0548, si_id:0x400c, di_id:0x62
      ADJ:objid:78 {link_type:MPLS ifnum:0x44, si:0x4900002a, }
```

C9300-PE-2 LDP標籤程式設計：

驗證向遠端PE通告的本地LDP標籤，不要驗證遠端LDP標籤。首先從FED的視角檢查標籤，然後回溯至FMAN RP和FMAN FP。

```
***Software LDP Label Programming***
C9300-PE-2#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
```

```
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi2/0/2    10.0.0.13
           Pop Label  192.168.1.3/32   0             Gi2/0/3    10.0.0.17
17         16         192.168.1.2/32   0             Gi2/0/2    10.0.0.13 <-- LDP Label 17 is
advertised to Remote PE 192.168.1.2
           16         192.168.1.2/32   0             Gi2/0/3    10.0.0.17
18         Pop Label  10.0.0.4/30      0             Gi2/0/2    10.0.0.13
           Pop Label  10.0.0.4/30      0             Gi2/0/3    10.0.0.17
19         Pop Label  10.0.0.8/30      0             Gi2/0/2    10.0.0.13
           Pop Label  10.0.0.8/30      0             Gi2/0/3    10.0.0.17
20         No Label   10.0.0.20/30[V]  630           aggregate/RED
21         No Label   192.168.2.0/24[V]   \
                                       0             Gi2/0/1    10.0.0.22
```

*****FMAN RP Label Programming*****

C9300-PE-2#**show platform software mpls switch active r0 label index 106 <-- Use the objid values from the FED commands**

```
Label OCE 0x6a -> OBJ_ADJACENCY (0x4b)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x10
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480637358
```

C9300-PE-2#**show platform software mpls switch active r0 label index 107 <-- Use the objid values from the FED commands**

```
Label OCE 0x6b -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x10
  Backup flags: Pop, UHP, backup label 0x100001
  OM handle: 0x3480638c10
```

*****FMAN FP LDP Label Programming*****

C9300-PE-2#**show platform software mpls switch active f0 label index 106**

```
Label OCE 0x6a -> OBJ_ADJACENCY (0x4b)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x10
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 548, CPP handle: 0xdeadbeef (created)
```

C9300-PE-2#**show platform software mpls switch active f0 label index 107**

```
Label OCE 0x6b -> OBJ_ADJACENCY (0x4e)
  Flags: Real, Number of labels in the OCE: 1
  Label values: 0x10
  Backup flags: Pop, UHP, backup label 0x100001
  aom id: 549, CPP handle: 0xdeadbeef (created)
```

C9300-PE-2#**show platform software object-manager switch active f0 object 548 <-- Use the aom id value from the previous commands**

```
Object identifier: 548
  Description: label 0x6a
  Status: Done, Epoch: 0, Client data: 0x24843d8
```

C9300-PE-2#**show platform software object-manager switch active f0 object 548 parents <-- Use the aom id value from the previous commands**

```
Object identifier: 509
```

```
  Description: adj 0x4b, Flags None
  Status: Done

C9300-PE-2#show platform software object-manager switch active f0 object 549 <-- Use the aom id
value from the previous commands
Object identifier: 549
  Description: label 0x6b
  Status: Done, Epoch: 0, Client data: 0x2484518

C9300-PE-2#show platform software object-manager switch active f0 object 549 parents <-- Use the
aom id value from the previous commands
Object identifier: 513
  Description: adj 0x4e, Flags None
  Status: Done

***FED LDP Label Programming***
C9300-PE-2#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LB, 108) lentry_hdl:0x64000005
   modify_cnt:1 backwalk_cnt:0
   lspa_handle:0
   AAL: id:1677721605 lbl:17
        eos0:[adj_hdl:0xa0000002, hw_hdl:0x7f0650a5c8e8]
        eos1:[adj_hdl:0xa0000002, hw_hdl:0x7f0650a5b908]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:108 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:17 path_inhw:2 ecrh:0xa0000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
     AAL: ecr:id:2684354562 af:0 ecr_type:0 ref:7 ecrh:0x7f0650a62888(28:2)
     hwhdl:1353066632 ::0x7f0650a60998,0x7f0650a630d8,0x7f0650a60998,0x7f0650a630d8
   Sw Enh ECR scale: objid:108 llabel:17 eos:1 #adjs:2 mixed_adj:0
      reprogram_hw:0 ecrhdl:0xa0000002 ecr_hwhdl:0x7f0650a62888
       mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
       ecr_adj: id:436207667 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:2113929262
             sih:0x7f0650a60998(178) di_id:20507 rih:0x7f0650a60378(50)
         adj_lentry [eos0:0x7f0650a877d8 eos1:0x7f0650a1cf78]
       ecr_adj: id:3976200246 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:1509949487
             sih:0x7f0650a630d8(179) di_id:20507 rih:0x7f0650a62b18(51)
         adj_lentry [eos0:0x7f0650a87a48 eos1:0x7f0650a1d188]
       ecr_prefix_adj: id:2919235640 (ref:1)
          sih:0x7f0650a87558(180) di_id:20507 rih:0x7f0650a871d8(68)
     LABEL:objid:106 link_type:MPLS local_label:17 outlabel:(16, 0) <-- Used in previous
commands
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x1a000033
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:436207667 lbl:0 smac:70d3.79be.ae71 dmac:d4ad.71b5.ddd6
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0650a67d48, ri_id:0x3a phdl:0x9f00004b, ref_cnt:1
               si:0x7f0650a65408, si_id:0x4010, di_id:0x535f
     ADJ:objid:75 {link_type:MPLS ifnum:0x36, si:0x35000023, }
     LABEL:objid:107 link_type:MPLS local_label:17 outlabel:(16, 0) <-- Used in previous
commands
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xed000036
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:3976200246 lbl:0 smac:70d3.79be.ae61 dmac:d4ad.71b5.ddf1
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0650a6f4f8, ri_id:0x40 phdl:0x8400004c, ref_cnt:1
               si:0x7f0650a73088, si_id:0x4013, di_id:0x5360
     ADJ:objid:78 {link_type:MPLS ifnum:0x37, si:0xa2000025, }
```

硬體擴展故障排除

本節提供的資訊可用於對組態進行疑難排解。

MPLS硬體系統日誌

如果某個特定資源（如MPLS標籤）用盡，則系統生成SYSLOG消息。

需要記住的要點

- MPLS標籤用於標**簽處置。**（從本地CE獲取字首時會佔用此資源）
- LSPA用於**標籤強制。**（從遠端PE獲取字首時會佔用此資源）

MPLS日誌消息	定義	恢復操作
%FED_L3_ERRMSG-3-RSRC_ERR:交換機1 R0/0:fed：由於硬體資源耗盡，無法**為fib條目分配硬體資源**	為IP字首保留的硬體空間已用盡（EM或TCAM）	執行以下操作之一以減少本地或PE獲**知的字首數量**: 1.在CE上彙總字首 2.將標籤分配模式從每個字首更每個vrf
%FED_L3_ERRMSG-3-**mpls_out_of_resource**:交換機1 R0/0:美聯儲：**MPLS標籤條目的資源不足。**無法對硬體中的本地標籤：8205(8192/8192)進行程式設計	**本地標籤分配**：為MPLS本地標籤保留的硬體空間已用盡（EM或TCAM）	執行以下操作之一以減少本地P使用的**標籤數：** 1.彙總本地CE或本地PE上的字 2.在本地PE上將標籤分配模式從字首更改為每個VRF
%FED_L3_ERRMSG-3-MPLS_LENTRY_PAUSE:交換機1 R0/0:美聯儲：**已達到MPLS標籤條目資源的嚴重**限制。**條目建立已暫停。**	**本地標籤分配：**為MPLS本地標籤保留的硬體空間已用盡（EM或TCAM）	執行以下操作之一以減少本地P使用的**標籤數**: 1.彙總本地CE或本地PE上的字 2.在本地PE上將標籤分配模式從字首更改為每個VRF
%FED_L3_ERRMSG-3-mpls_out_of_resource:交換機1 R0/0:美聯儲：**MPLS LSPA資源不足。無法在硬體中程式設計**	**遠端標籤分配：** 為LSPA遠端標籤保留的硬體空間已用盡	執行以下操作之一以減少遠端P使用的**標籤數**: 1.總結遠端CE或遠端PE上的字 2.將遠端PE上的標籤分配模式從字首更改為每個VRF

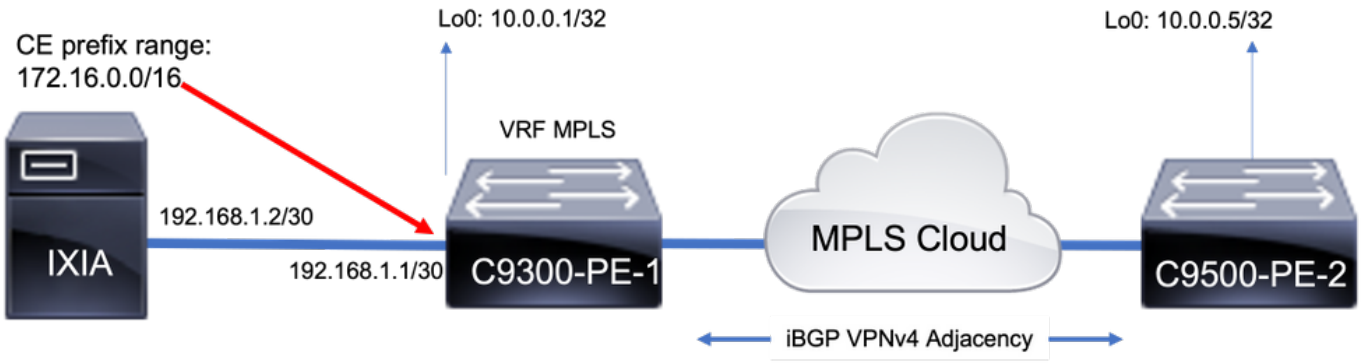
硬體驗證命令

show platform hardware fed active fwd-asic resource tcam utilizationcommand是如果您遇到硬體擴展問題，首先要評估的地方。它以每個ASIC為基礎顯示資訊。

此部分顯示從vrf MPLS中的BGP獲取的PE學習字首，其引數如下所述：

- 使用預設每字首標籤分配
- PE是採用Cisco IOS-XE 17.3.4的C9300-48U
- CE是Ixia作為BGP鄰居，它向vrf MPLS中的介面通告字首
- 使用的字首長度為/28。因此，平台使用TCAM作為字首長度/31或更短
- 此平台首先將EM記憶體用於MPLS/BGP標籤，然後在EM變滿時溢位到TCAM

拓撲



基線資源使用情況

在新增任何字首之前，有一些基本用法：

- 此基線是在全域性表中形成MPLS LDP鄰居之後提取的
- 從此基線起，VPNv4字首將新增到VRF MPLS中
- 您的基線數字可能有所不同。視交換器上已程式設計的內容而定

附註：在本示例中，從一個CE-PE端新增字首，這導致僅在遠端PE上分配了LSPA等資源，這些資源需要使用標籤堆疊來實現可達性。在現實場景中，資源將在兩個PE裝置上分配。

```
C9300-48U#show version | inc IOS
Cisco IOS XE Software, Version 17.03.04
Cisco IOS Software [Amsterdam], Catalyst L3 Switch Software (CAT9K_IOSXE), Version 17.3.4,
RELEASE SOFTWARE (fc3)

C9300-48U#show platform hardware fed switch active fwd-asic resource tcam utilization
Codes: EM - Exact_Match, I - Input, O - Output, IO - Input & Output, NA - Not Applicable

CAM Utilization for ASIC  [0]
 Table                  Subtype      Dir      Max      Used     %Used       V4       V6      MPLS
Other
 ----------------------------------------------------------------------------------------------
-------
 Mac Address Table      EM           I       32768       20    0.06%        0        0         0
20
 Mac Address Table      TCAM         I        1024       21    2.05%        0        0         0
21
 L3 Multicast           EM           I        8192        0    0.00%        0        0         0
0
 L3 Multicast           TCAM         I         512        9    1.76%        3        6         0
0
 L2 Multicast           EM           I        8192        0    0.00%        0        0         0
0
 L2 Multicast           TCAM         I         512       11    2.15%        3        8         0
0
 IP Route Table         EM           I       24576       23    0.09%       14        0         9
0  <-- 23 EM (hash) base usage
 IP Route Table         TCAM         I        8192       25    0.31%       12       10         2
1  <-- 25 TCAM base usage


C9300-48U#show platform software fed switch active mpls summary | b Resource shar
Resource sharing info:
SI: 4/65536
RI: 10/65536
Well Known Index: 49/2048
```

```
Tcam: 21/57344
lv1_ecr: 0/64
lv2_ecr: 0/256
lspa: 0/16385
label_stack_id: 2/65537
vpn_spoke_id: 0/255
indirect_si: 0/255
RSM resource database stats:
Num of (L3+mpls) ADJ entries allocated: 36/131072
  Num of LABEL entries allocated: 4/8192            <-- Baseline label usage = 4 (label entries
allocated on local PE-CE side)
Num of LSPA entries allocated: 0/8192             <-- LSPA resource used when prefix learnt
from another PE, not from a local CE (The SDM template determines max value)
Num of local adjs in mpls adjs: 3
Num of SI stats allocated: 6/49152
Adjs stats allocated by MPLS:
Num of mpls adjs: 11
Num of L3 adjs: 0
Num of VPN prefix_id: 0
<...snip...>
Other MPLS resource alloc error stats:             <-- reported resource allocation issues
shown here
LENTRY out-of-resource errors: 0
LENTRY general errors: 0
LSPA out-of-resource errors: 0
LSPA general errors: 0
ADJ out-of-resource errors: 0
SI stats alloc error: 0
MPLS ADJ stats error: 0
MPLS ADJ stats last error rc: 0
```

註:SI/RI/DI是資料包重寫、目標埠等所需的資源。要排除SI/DI/RI問題，請參閱文章瞭解Catalyst 9000交換機上的硬體資源

新增1000 BGP VPNv4字首

鄰居(Ixia)從CE向VRF MPLS新增了1000字首

9300本地PE（連線到CE）

```
C9300-48U#show bgp vpnv4 unicast all summary
BGP router identifier 10.0.0.1, local AS number 65000
<...snip...> Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd 10.0.0.5 4 65000
102 304 3001 0 0 01:28:23 0 192.168.1.2     4        65005     102       5     3001    0    0
00:00:58     1000 <-- PE learns 1000 prefixes from CE device
C9300-48U#show bgp vpnv4 unicast all | count /28
Number of lines which match regexp = 1000         <-- All 1000 prefixes are /28
C9300-48U#show platform hardware fed switch active fwd-asic resource tcam utilization
Codes: EM - Exact_Match, I - Input, O - Output, IO - Input & Output, NA - Not Applicable

CAM Utilization for ASIC  [0]
 Table                  Subtype      Dir      Max      Used    %Used       V4       V6     MPLS
Other
 ----------------------------------------------------------------------------------------------
-------
 Mac Address Table      EM           I       32768       20    0.06%        0        0        0
20
 Mac Address Table      TCAM         I        1024       21    2.05%        0        0        0
21
 L3 Multicast           EM           I        8192        0    0.00%        0        0        0
```

```
0
 L3 Multicast           TCAM         I         512        9    1.76%        3        6        0
0
 L2 Multicast           EM           I        8192        0    0.00%        0        0        0
0
 L2 Multicast           TCAM         I         512       11    2.15%        3        8        0
0
 IP Route Table         EM           I       24576     2023    8.23%       14        0     2009
0
 IP Route Table         TCAM         I        8192     1025   12.51%     1012       10        2
1

<-- 25 base + 1000 /28 prefixes = 1025 TCAM entries
<-- MPLS labels are added to EM, and each MPLS label uses 2 entries (one IPv4 prefix, and one
MPLS label results in 3 entries used in hardware)

C9300-48U#show platform software fed switch active mpls summary | b Resource shar
  Resource sharing info:
    SI: 4/65536
    RI: 1010/65536
    Well Known Index: 49/2048
    Tcam: 1021/57344
    lv1_ecr: 0/64
    lv2_ecr: 0/256
    lspa: 0/16385
    label_stack_id: 1002/65537
    vpn_spoke_id: 0/255
    indirect_si: 0/255
  RSM resource database stats:
    Num of (L3+mpls) ADJ entries allocated: 1036/131072
    Num of LABEL entries allocated: 1004/8192              <-- Increased by 1000 on local PE
    Num of LSPA entries allocated: 0/8192                  <-- No prefixes learnt from remote
PE, no LSPA allocated
    Num of local adjs in mpls adjs: 3
    Num of SI stats allocated: 1006/49152
    Adjs stats allocated by MPLS:
    Num of mpls adjs: 1011
      Num of L3 adjs: 0
    Num of VPN prefix_id: 0
<...snip...>
  Other MPLS resource alloc error stats:  <-- no resource allocation issues
    LENTRY out-of-resource errors: 0
    LENTRY general errors: 0
    LSPA out-of-resource errors: 0
    LSPA general errors: 0
    ADJ out-of-resource errors: 0
    SI stats alloc error: 0
    MPLS ADJ stats error: 0
    MPLS ADJ stats last error rc: 0

<-- Resources shown in baseline outputs are now increased by 1000
```

9500H遠端PE（透過MPLS學習）

```
C9500-24Y4C#show platform hardware fed active fwd-asic resource tcam utilization
Codes: EM - Exact_Match, I - Input, O - Output, IO - Input & Output, NA - Not Applicable

CAM Utilization for ASIC  [0]
 Table                  Subtype      Dir      Max      Used    %Used       V4       V6     MPLS
Other
 ----------------------------------------------------------------------------------------------
-------
 Mac Address Table      EM           I       32768       19    0.06%        0        0        0
```

```
19
 Mac Address Table      TCAM         I         768       21    2.73%        0        0        0
21
 L3 Multicast           EM           I       32768        0    0.00%        0        0        0
0
 L3 Multicast           TCAM         I         768        6    0.78%        3        3        0
0
 L2 Multicast           TCAM         I        2304        7    0.30%        3        4        0
0
 IP Route Table         EM/LPM       I      212992     1012    0.48%     1003        0        9
0
 IP Route Table         TCAM         I        1536       28    1.82%       23        3        2
0
CTS Cell Matrix/VPN
Label                   EM           O       32768      992    3.03%        0        0      992
0   <-- MPLS VPN used 992 entries
CTS Cell Matrix/VPN
Label TCAM O 768 9 1.17% 0 0 8 1

<-- 1000 /28 IPv4 prefixes learned from remote PE (On the 9500HP these /28 prefixes are be
stored in EM/LPM memory, not TCAM)
<-- Hardware shared between CTS and VPN (resource is used when prefixes learned PE-PE, label
imposition)
C9500-24Y4C#show platform software fed active mpls summary | b Resource shar
  Resource sharing info:
    SI: 4/131072
    RI: 11/98304
    Well Known Index: 48/2048
    Tcam: 20/245760
    lv1_ecr: 0/64
    lv2_ecr: 0/256
    lspa: 1000/65536
    label_stack_id: 2/65537
    vpn_spoke_id: 0/255
    indirect_si: 0/255
  RSM resource database stats:
    Num of (L3+mpls) ADJ entries allocated: 37/196608
    Num of LABEL entries allocated: 4/45056                <-- LABEL does not increase (no
prefixes learnt from a local CE)
    Num of LSPA entries allocated: 1000/32768              <-- LSPA usage increased by 1000
(these prefixes require label stack to reach)
    Num of local adjs in mpls adjs: 4
    Num of SI stats allocated: 6/49152
    Adjs stats allocated by MPLS:
      Num of mpls adjs: 12
      Num of L3 adjs: 0
    Num of VPN prefix_id: 1000
  AL MPLS SI/RI resource alloc stats:
    SI allocated: 1
    RI allocated: 6
    SI_STATS allocated: 6
    Unknowns allocs: 0
    Alloc no resource: 0
    Alloc errors: 0
    Free errors: 0
    Invalid free: 0
    Free unknown: 0
  Other MPLS resource alloc error stats:                   <-- no resource allocation issues
    LENTRY out-of-resource errors: 0
    LENTRY general errors: 0
    LSPA out-of-resource errors: 0
    LSPA general errors: 0
    ADJ out-of-resource errors: 0
    SI stats alloc error: 0
```

```
    MPLS ADJ stats error: 0
    MPLS ADJ stats last error rc: 0

<-- Different resources are allocated to reach a local prefix (LABEL) versus a remote prefix
(LSPA)
```

附註：有關Catalyst 9000 TCAM的一般資訊或如何檢查TCAM的其他功能的詳細資訊，請參閱瞭解Catalyst 9000交換機上的硬體資源文章。

附註：ADJ（鄰接關係）是一種共用資源。若要疑難排解ADJ問題，請參閱瞭解Catalyst 9000交換器上的硬體資源文章。

MPLS標籤和IPv4規模限制和補救

在大多數使用MPLS功能且佔用太多硬體資源的情況下，將標籤分配從（預設）每個字首更改為per-vrf會有所幫助。在此示例中，請考慮前後資源分配(在這種情況下，9500是CE-PE裝置)。

```
### Usage with per-prefix label allocation ###

C9500-24Y4C#show platform hardware fed active fwd-asic resource tcam utilization
Codes: EM - Exact_Match, I - Input, O - Output, IO - Input & Output, NA - Not Applicable

CAM Utilization for ASIC  [0]
 Table                  Subtype      Dir      Max      Used    %Used       V4       V6     MPLS
Other
 ----------------------------------------------------------------------------------------------
-------
 Mac Address Table      EM           I       32768       19    0.06%        0        0        0
19
 Mac Address Table      TCAM         I         768       21    2.73%        0        0        0
21
 L3 Multicast           EM           I       32768        0    0.00%        0        0        0
0
 L3 Multicast           TCAM         I         768        6    0.78%        3        3        0
0
 L2 Multicast           TCAM         I        2304        7    0.30%        3        4        0
0
 IP Route Table         EM/LPM       I      212992     3023    1.42%     1014        0     2009
0  <-- 1 IPv4 prefix entry + 2 entries for labels (2 labels created per every 1 IPv4 prefix)
 IP Route Table         TCAM         I        1536       17    1.11%       12        3        2
0


### New usage after change to per-vrf lable allocation ###
C9500-24Y4C(config)#mpls label mode vrf MPLS protocol all-afs per-vrf
C9500-24Y4C#show bgp vpnv4 unicast all BGP table version is 164901, local router ID is 10.0.0.5
     Network          Next Hop            Metric LocPrf Weight Path
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
              t secondary path, L long-lived-stale,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found
Network Next Hop Metric LocPrf Weight Path
Route Distinguisher: 1:1 (default for vrf MPLS) *>   172.30.0.0/24    192.168.3.2           2219
0 65100 65101 65102 65103 {65104} e
<...snip...>
```

```
C9500-24Y4C#show bgp vpnv4 unicast all 172.30.0.0
BGP routing table entry for 1:1:172.30.0.0/24, version 163902
Paths: (1 available, best #1, table MPLS)
  Advertised to update-groups:
     8
  Refresh Epoch 1
  65100 65101 65102 65103 {65104}
    192.168.3.2 (via vrf MPLS) from 192.168.3.2 (192.168.3.2)
      Origin EGP, metric 2219, localpref 100, valid, external, best
      Extended Community: RT:1:1
      mpls labels in/out IPv4 VRF Aggr:18116/nolabel    <-- Verify you see a 'VRF Aggr' label
type
      rx pathid: 0, tx pathid: 0x0
      Updated on Dec 9 2021 19:50:22 UTC


### Usage with per-vrf label allocation ###
Allocation on both local and remote PE is dramatically reduced via change to label allocation
mode

local switch (PE-CE)
C9500-24Y4C#show platform hardware fed active fwd-asic resource tcam utilization
Codes: EM - Exact_Match, I - Input, O - Output, IO - Input & Output, NA - Not Applicable

CAM Utilization for ASIC  [0]
 Table                  Subtype      Dir      Max     Used    %Used       V4       V6     MPLS
Other
 ----------------------------------------------------------------------------------------------
-------
 Mac Address Table      EM           I       32768       19    0.06%        0        0        0
19
 Mac Address Table      TCAM         I         768       21    2.73%        0        0        0
21
 L3 Multicast           EM           I       32768        0    0.00%        0        0        0
0
 L3 Multicast           TCAM         I         768        6    0.78%        3        3        0
0
 L2 Multicast           TCAM         I        2304        7    0.30%        3        4        0
0
 IP Route Table         EM/LPM       I      212992     1025    0.48%     1014        0       11
0  <-- one local LABEL used to reach the CE learnt prefixes
 IP Route Table         TCAM         I        1536       17    1.11%       12        3        2
0
 QOS ACL                TCAM         I        1024       45    4.39%       15       20        0
10


remote switch (PE-PE)
C9300-48U#show platform hardware fed switch active fwd-asic resource tcam utilization
Codes: EM - Exact_Match, I - Input, O - Output, IO - Input & Output, NA - Not Applicable

CAM Utilization for ASIC  [0]
 Table                  Subtype      Dir      Max     Used    %Used       V4       V6     MPLS
Other
 ----------------------------------------------------------------------------------------------
-------
<...snip...>
 IP Route Table         EM           I       24576       23    0.09%       14        0        9
0
 IP Route Table         TCAM         I        8192     1025   12.51%     1012       10        2
1  <-- Still 1:1 usage for IPv4 prefixes
<...snip...>
 CTS Cell Matrix/VPN
```

```
 Label                  EM          O        8192        1    0.01%        0        0        1
0  <-- one remote LSPA used to reach the PE learnt prefixes
```

附註：**show platform software fed switch active mpls summary**中的資源使用率也顯示LABEL或LSPA（視適用情況而定）的減少情況。

為TAC收集的命令

本指南介紹了與MPLS相關的最常見硬體資源問題，並提供了相應的補救步驟。但是，如果此指南未解決您的問題，請收集所示的命令清單，並將它們附加到服務請求。

```
show ip route summary
show ip bgp vpnv4 all | redirect flash:bgp_vpnv4_all
show ip bgp vpnv4 all summary
show ip route vrf  <vrf-name>  summary
show mpls forwarding-table summary
show ip cef vrf <name>  | redirect flash:sh_ip_cef_vrf_<name>
show ip cef vrf <name> summary
show platform software fed switch active ip route summary
show platform software mpls switch <all switches> f0 forwarding-table
show platform software mpls switch <all switches>  f0 label
show platform software mpls switch <all switches>  f0 eos
show platform software object-manager switch <all switches>  f0 error-object
show platform software object-manager switch <all switches>  f0 pending-issue-update
show platform software fed switch <all switches>  mpls label_oce all detail
show platform software fed switch  <all switches> mpls eos all det
show platform software fed switch <all switches> mpls summary
show platform software fed switch active mpls forwarding all detail
show platform software object-manager switch 1 f0 statistics
show tech-support mpls | redirect flash:sh_tech_mpls
show logging | redirect flash:sh_logging_console
show platform hard fed switch active fwd resource tcam table sghash asic 0 format 0 | redirect
flash:vpn_lspa

request platform software trace archive last 30 days target flash
```

相關資訊

[技術支援與文件 - Cisco Systems]

[多重協定標籤交換(MPLS)組態設定指南，Cisco IOS XE Cupertino 17.7.x（Catalyst 9300交換器）]

[多重協定標籤交換(MPLS)組態設定指南，Cisco IOS XE Cupertino 17.7.x（Catalyst 9500交換器）]

[瞭解Catalyst 9000交換器上的硬體資源]