Catalyst 9000 스위치에서 MPLS 확인

목차

소개

이 문서에서는 Catalyst 9000 Series 스위치에서 MPLS(Multiprotocol Label Switching) 레이어 3 VPN(Virtual Private Network)을 구성하고 검증하는 방법에 대해 설명합니다.

사전 요구 사항

요구 사항

다음 주제에 대한 지식을 보유하고 있으면 유용합니다.

- IP 전달
- BGP(Border Gateway Protocol)

- MPLS

사용되는 구성 요소

이 문서의 정보는 다음 소프트웨어 및 하드웨어 버전을 기반으로 합니다.

- Cisco IOS® XE 16.12.4의 C9500
- C9300 on Cisco IOS® XE 16.12.4
- C3850 on Cisco IOS® XE 16.9.6

이 문서의 정보는 특정 랩 환경의 디바이스를 토대로 작성되었습니다. 이 문서에 사용된 모든 디바이스는 초기화된(기본) 컨피그레이션으로 시작되었습니다. 네트워크가 작동 중인 경우 모든 명령의 잠재적인 영향을 이해해야 합니다.

배경 정보

MPLS L3VPN(Layer 3 VPN)은 BGP를 사용하여 VPN 관련 정보를 배포하는 피어 투 피어 모델을 사용합니다. MPLS VPN은 MPLS 제공자 코어 네트워크를 통해 상호 연결된 사이트 집합으로 구성됩니다. 각 고객 사이트에서 하나 이상의 CE(customer edge) 디바이스가 하나 이상의 PE(edge) 장치에 연결됩니다.

기존 레이어 3 라우팅에서 패킷이 네트워크를 통과하면서 각 스위치는 레이어 3 헤더에서 패킷을 전달하는 데 관련된 모든 정보를 추출합니다. 그런 다음 이 정보를 라우팅 테이블 조회의 인덱스로 사용하여 패킷의 다음 홉을 결정합니다.

가장 일반적인 경우 헤더의 관련 필드만 대상 주소 필드이지만 경우에 따라 다른 헤더 필드도 관련될 수 있습니다. 따라서 패킷이 통과하는 각 스위치에서 헤더 분석을 독립적으로 수행해야 합니다. 또한 각 스위치에서 복잡한 테이블 조회를 수행해야 합니다.

레이블 전환에서 레이어 3 헤더의 분석은 한 번만 수행됩니다. 그런 다음 레이어 3 헤더는 고정된 길이인 비정형 값(alabable)으로 **매핑됩니다.**

여러 헤더가 동일한 레이블에 매핑될 수 있습니다. 단, 이러한 헤더가 항상 다음 홉을 동일하게 선택하기만 하면 됩니다. 실제로 레이블은 포워딩 **등가 클래스**(FEC)를 나타냅니다. 즉, 포워딩 함수와 구분할 수 있는 패킷 집합입니다.

레이블의 초기 선택은 레이어 3 패킷 헤더의 내용만을 기반으로 할 필요는 없습니다. 예를 들어, 후속 홉에서 패킷을 전달하는 결정은 다른 요소를 기반으로 할 수도 있습니다.

레이블을 할당하면 짧은 레이블 헤더가 레이어 3 패킷의 전면에 추가됩니다. 이 헤더는 패킷의 일부로 네트워크를 통해 전달됩니다. 네트워크의 각 MPLS 스위치를 통해 후속 홉에서 레이블을 교체하고 패킷 헤더에 전달되는 레이블에 대한 MPLS 포워딩 테이블 조회를 통해 결정을 수행합니다. 따라서 네트워크를 통해 패킷을 전송하는 동안 패킷 헤더를 재평가할 필요가 없습니다. 레이블은 고정된 길이와 구조화되지 않았으므로 MPLS 포워딩 테이블 조회 프로세스는 간단하며 빠릅니다.

네트워크의 각 LSR(Label Switching Router)은 포워딩 동등 클래스를 나타내는 데 사용할 레이블 값에 대해 독립적인 로컬 결정을 합니다. 이 연결을 레이블 바인딩이라고 합니다. 각 LSR은 네이버에 자신이 만든 레이블 바인딩을 알립니다. 인접한 스위치의 레이블 바인딩에 대한 이러한 인식은 다음 프로토콜에서 지원합니다.

- LDP(Label Distribution Protocol) - MPLS 네트워크의 피어 LSR이 레이블 정보를 교환하여 MPLS 네트워크에서 hop-by-hop 전달을 지원할 수 있도록 합니다.
- BGP(Border Gateway Protocol) - MPLS VPN(Virtual Private Network)을 지원하는 데 사용됩니다.

레이블이 지정된 패킷이 LSR A에서 LSR B로 전송될 때 IP 패킷에 의해 전달되는 레이블 값은 LSR B가 패킷의 포워딩 동등 클래스를 나타내기 위해 할당한 레이블 값입니다. 따라서 IP 패킷이 네트워크를 통과할 때 레이블 값이 변경됩니다.

이 가이드 사용 방법

이 가이드는 두 가지 시나리오로 구분되며, 문서 끝에 하드웨어 크기 검증 섹션이 표시됩니다.

- MPLS 코어 내에서 단일 홉의 인접성
- MPLS 코어 내의 ECMP(Equal Cost Multi-Path) 인접성
- TCAM에서 확장성 문제를 확인하는 방법

각 시나리오에서는 각 MPLS 디바이스에 대한 접두사 및 레이블 확인을 다룹니다.

용어

|		
MPLS	다중 프로토콜 레이블 스위칭	데이터 링크 레이어(레이어 2) 스위칭의 성능 및 트래픽 관리 기능을 네트워... 이어(레이어 3) 라우팅의 확장성, 유연성 및 성능과 통합하는 고성능 패킷 포... 기술입니다.
PE	공급자 에지(스위치/라우터)	고객 CE에서 IP 접두사를 수신하여 MPLS 클라우드에 전달하는 공급자 네트... 의 에지 디바이스입니다.
CE	고객 에지(스위치/라우터)	서비스 공급자 IP/MPLS 네트워크의 공급자 에지 라우터에 연결된 고객 프라... 의 디바이스.
LDP	레이블 검색 프로토콜	LDP는 라우터 간에 레이블을 자동으로 생성하고 교환하는 프로토콜입니다. 우터는 접두사에 대한 레이블을 로컬에서 생성한 다음 레이블 값을 인접 디바... 스에 알립니다.
LSPA	레이블 스위치 경로 배열	특정 MPLS 대상에 도달할 레이블 집합입니다. 일반적인 L3VPN에서는 IGP... VPN 레이블을 사용할 수 있습니다. TE 터널이 있는 경우 TE 레이블 + IGP +... VPN이 있습니다. Catalyst 9000은 최대 6개의 레이블을 지원할 수 있으며, 한 레이블 배열을 LSPA라고 합니다.
레이블 스택 ID	레이블 스택 ID	A 레이블 스택을 식별하는 고유 인덱스(A)LSPA 공유를 클릭합니다.)
레이블	레이블	조회에 사용되는 MPLS 레이블입니다. 여러 레이블이 레이블 스택을 구성합... .
접두사 ID	접두사 식별자	Catalyst 9000은 모든 접두사에 대한 글로벌 리소스를 생성합니다(접두사 레... 당 할당 시 경로가 있는 것과 동일한 접두사 ID가 있음).
EM	정확히 일치	1:1 일치(호스트 경로, 직접 연결 호스트)인 해시 메모리의 항목입니다.
LPM	가장 긴 접두사 일치	/31 이하 경로(/32 경로는 EM 유형)입니다.
TCAM	Ternary Content-Addressable 메모리	세 가지 다른 입력으로 항목을 저장하고 쿼리하는 메모리 유형입니다. 0, 1 및... 이 유형의 메모리는 동일한 항목에 대해 여러 일치 항목이 있을 수 있고 각 항... 대한 결과 해시가 고유하지 않을 경우 사용해야 합니다. **이 테이블에는 이 항... 일치하는지 또는 일치하지 않는지 확인할 수 있는 마스크 또는 "X" 값이 포함... 다.**
CAM	콘텐츠 주소 지정 가능 메모리	하드웨어 메모리(해시/TCAM)의 일반 용어입니다.

리브	라우팅 정보 기반	'show ip route'에 표시되는 라우팅 테이블
FIB	포워딩 정보 기반	RIB 및 ARP 테이블에 추가된 접두사와 ADJ 테이블에 대한 포인터가 있는 ~~된 테이블
직접 연결됨	직접 연결된 경로	로컬로 연결된 호스트 접두사(ARP 인접)
간접적으로 연결됨	간접적으로 연결된 경로	원격 next hop을 통해 도달하는 경로
ADJ	인접성(표)	패킷 재작성에 사용되는 다음 hop 정보를 저장합니다.
EM	정확히 일치	연결된 호스트, 간접/32 호스트 접두사
TCAM	Ternary Content-Addressable 메모리	간접 접두사/31 이하
연방	포워드 엔진 드라이버	ASIC(하드웨어) 레이어
FMAN-FP	전달 관리자 - 전달 평면	FMAN-FP는 FED 정보를 추가, 삭제 또는 수정하는 소프트웨어 객체를 관리~다.
SI	스테이션 인덱스	스테이션 인덱스 = 패킷 재작성 정보(RI = 재작성 인덱스) 및 아웃바운드 인~이스 정보(DI = 대상 인덱스)
리	인덱스 다시 작성	다음 hop 인접성으로 포워딩하는 레이어 3에 대한 MAC 주소 재작성 정보
DI	대상 인덱스	아웃바운드 인터페이스를 가리키는 색인

구성 및 확인

시나리오 1. MPLS 코어에서 단일 홉의 인접성이 있는 L3VPN

참조 토폴로지

이 예에서 Catalyst 9300 스위치는 PE 장치, Stackwise Virtual의 Catalyst 9500은 P 장치로, Catalyst 3850 스위치는 CE 장치로 작동합니다.
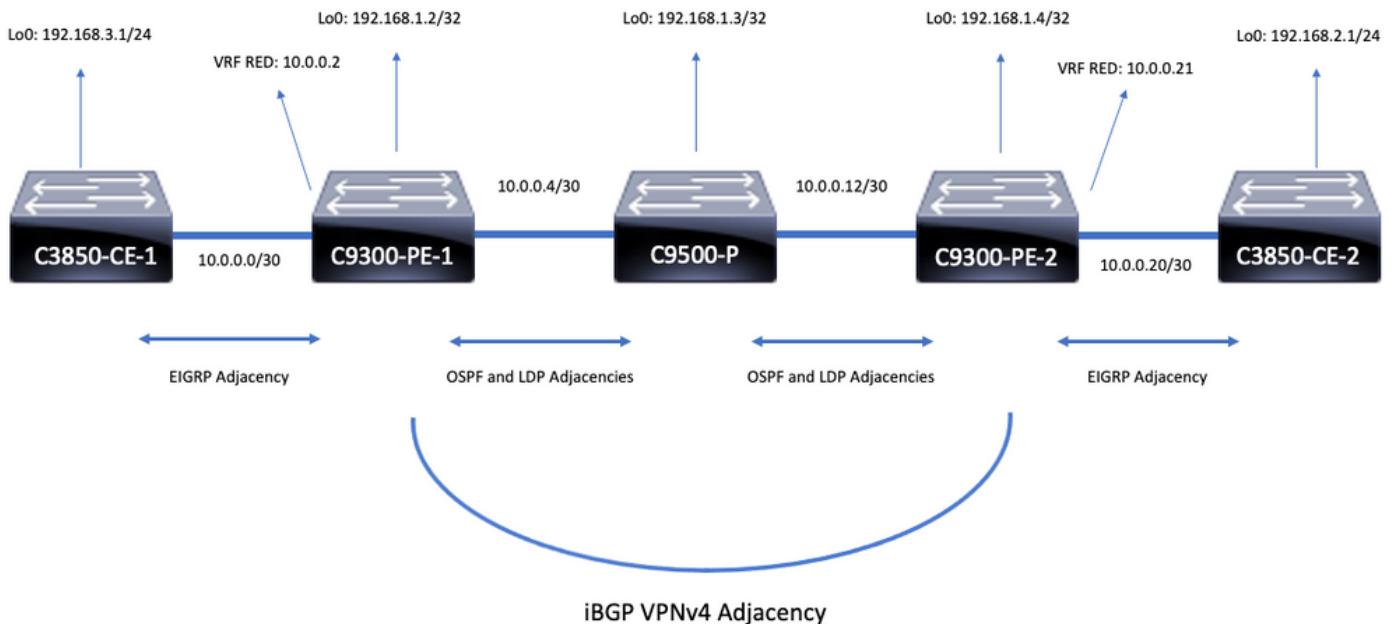
구성 세부 정보

C3850-CE-1 구성

```
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 구성

```
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 구성

```
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 구성

```
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 구성

```
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
```

기본 확인

MPLS 프로그래밍을 검증하기 전에 검증해야 하는 기본 요구 사항이 있습니다.

- PE에서 PE로의 연결이 있는지 확인합니다.
- PE 간의 LSP(Label Switched Path) 검증
- PE 간 BGPv4 인접성 확인
- VPNv4 및 LDP 레이블 검증
- MPLS 포워딩 테이블 검증

PE 대 PE 연결 확인

로컬 루프백에서 원격 PE 루프백 및 소스를 ping할 수 있지만, 루프백 IP 주소가 언더레이에서 알려지므로 MPLS LSP(Label Switched Path)가 정상인지 확인하지는 않습니다.

> **참고**: PE-MP-BGP VPNv4 인접성은 해당 Loopback0 인터페이스를 통해 달성됩니다.

```
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
```

LSP 검증

PE에서 PE 루프백으로 MPLS traceroute를 사용하여 경로를 따라 LSP 및 모든 MPLS LDP 레이블을 검증할 수 있습니다.

> **참고**: 이 MPLS traceroute는 LDP 레이블인 하나의 레이블만 부과하며, 트래픽이 2개의 레이블, VPNv4(내부) 레이블 및 LDP(외부) 레이블로 지정되므로 CE의 트래픽이 성공했음을 입증하지 않습니다.

```
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
```

CE 또는 CE 뒤의 디바이스에 대한 액세스 권한이 없고 VPNv4 및 LDP 레이블 부과/폐기가 성공했음을 시연하려는 경우 PE의 VRF에 있는 CE 연결 인터페이스에서 원격 PE의 VRF에 있는 다른 CE 연결 인터페이스로 ping을 시도할 수 있습니다.

```
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
```

PE 간 BGP VPNv4 인접성 확인

```
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

원격 PE VPNv4 인접성이 작동되고 접두사가 수신되었습니다.

```
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
```

특정 VRF에서 교환되는 접두사 확인

```
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 ?
```

VPNv4 및 LDP 레이블 검증:

VRF의 접두사에 도달하는 데 사용되는 VPNv4 레이블을 확인합니다.

```
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
```

사용 중인 LDP 레이블 확인

```
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
```

MPLS 포워딩 테이블 검증

```
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
```

VRF의 각 지정된 접두사에 도달하는 데 사용되는 내부(VPNv4) 및 외부(LDP) 레이블을 확인합니다.

```
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
```

객체 관리자 통계 확인

이상적인 시나리오에서는 보류 중인 개체가 없습니다.

```
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
```

접두사 프로그래밍

다음 섹션에서는 MPLS 라우터, C9300-PE-1, C9500-P 및 C9300-PE-2의 접두사 프로그래밍을 다룹니다.

C9300-PE-1 접두사 프로그래밍


```
***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]:
150000000000000000000000000000000000000000000000000000000000460000000000000000000000000000000
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 접두사 프로그래밍

```
***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 접두사 프로그래밍

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 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


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 레이블 프로그래밍

다음 섹션에서는 MPLS PE 라우터, C9300-PE-1 및 C9300-PE-2에서 VPNv4 레이블 프로그래밍에 대해 설명합니다. C9500은 VPNv4 레이블에서 전달되지 않으므로 C9500에서 출력되지 않습니다.

C9300-PE-1 VPNv4 레이블 프로그래밍:

원격 접두사가 아닌 PE에 대한 로컬 접두사를 확인합니다.

```
***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 }
```

C9300-PE-2 VPNv4 레이블 확인:

원격 접두사가 아닌 PE에 대한 로컬 접두사를 확인합니다.

```
***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 레이블 프로그래밍

다음 섹션에서는 MPLS 라우터, C9300-PE-1, C9500-P 및 C9300-PE-2의 LDP 레이블 프로그래밍을 다룹니다.

LDP(외부) 레이블은 MPLS 네트워크 레이블에서 패킷을 전환하는 것입니다. 원격 PE에 광고되는 로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다.

C9300-PE-1 LDP 레이블 프로그래밍:

원격 PE에 광고되는 로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다. FED 관점에서 레이블을 확인한 다음 FMAN RP 및 FMAN FP로 백트랙합니다.

```
***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 레이블 프로그래밍:

원격 PE에 광고되는 로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다. FED 관점에서 레이블을 확인한 다음 FMAN RP 및 FMAN FP로 백트랙합니다.


```
***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 레이블 프로그래밍:

원격 PE에 광고되는 로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다. FED 관
점에서 레이블을 확인한 다음 FMAN RP 및 FMAN FP로 백트랙합니다.


```
***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, }
```

시나리오 2. PE와 P 라우터 간 ECMP가 있는 L3VPN

참조 토폴로지

이 예에서 Catalyst 3850 스위치는 CE 장치로 작동하며, Catalyst 9300 스위치는 PE 장치, Catalyst 9500은 Stackwise Virtual에서 P 장치로 작동합니다. EIGRP는 MPLS 코어의 CE 및 PE 디바이스, OSPF 및 LDP 인접성 사이에서 실행되며 PE 디바이스 간에 iBGP VPNv4 인접성이 있습니다. MPLS 코어 내에서는 PE와 P 디바이스 간에 ECMP가 있습니다.
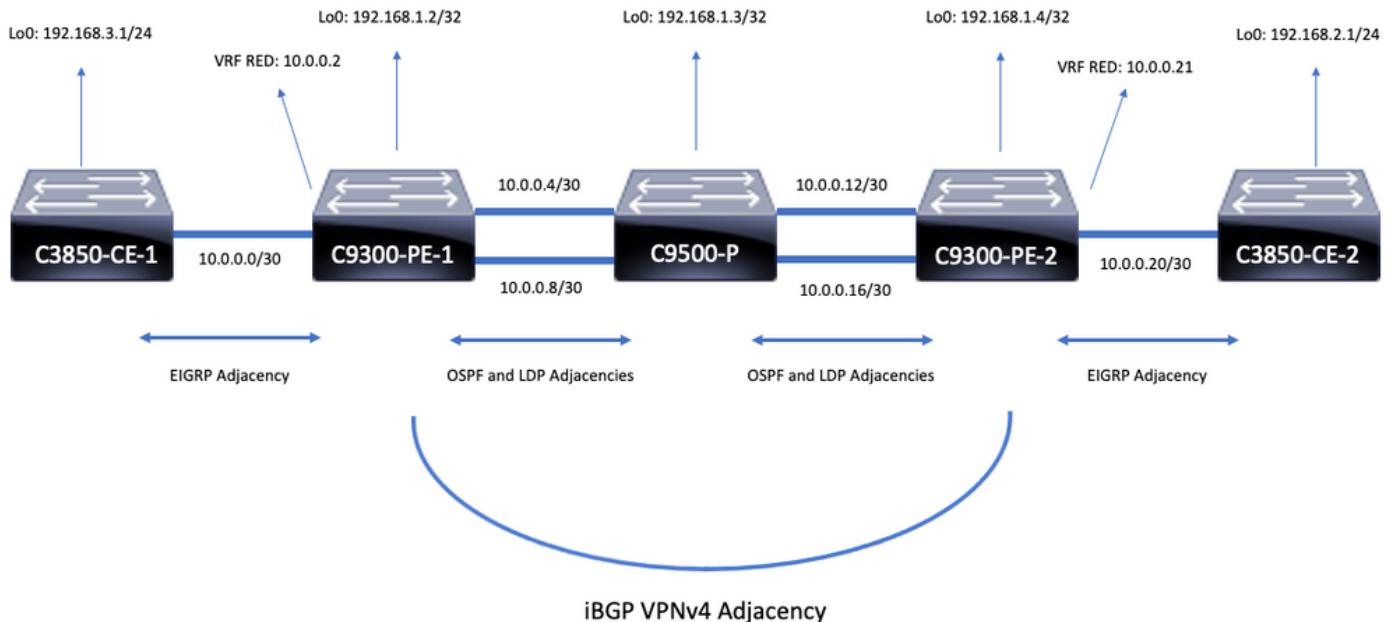
구성 세부 정보

C3850-CE-1 구성

```
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 구성

```
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 구성

```
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 구성

```
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 구성

```
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
```

기본 검증

MPLS 프로그래밍을 검증하기 전에 검증해야 하는 기본 요구 사항이 있습니다.

- PE에서 PE로의 연결이 있는지 확인합니다.
- PE 간의 LSP(Label Switched Path) 검증
- PE 간 BGPv4 인접성 확인
- VPNv4 및 LDP 레이블 검증
- MPLS 포워딩 테이블 검증

PE-PE 연결 확인

로컬 루프백에서 원격 PE 루프백 및 소스를 ping할 수 있지만, 루프백 IP 주소가 언더레이에서 알려지므로 MPLS LSP(Label Switched Path)가 정상인지 확인하지는 않습니다.

참고: PE-MP-BGP VPNv4 인접성은 해당 Loopback0 인터페이스를 통해 달성됩니다.

```
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
```

LSP 검증

PE에서 PE 루프백으로 MPLS traceroute를 사용하여 경로를 따라 LSP 및 모든 MPLS LDP 레이블을 검증할 수 있습니다.

참고: 이 MPLS traceroute는 LDP 레이블인 하나의 레이블만 부과하며, 트래픽이 2개의 레이블, VPNv4(내부) 레이블 및 LDP(외부) 레이블로 지정되므로 CE의 트래픽이 성공했음을 입증하지 않습니다.

```
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
```

CE 또는 CE 뒤의 디바이스에 대한 액세스 권한이 없고 VPNv4 및 LDP 레이블 부과/폐기가 성공했음을 시연하려는 경우 PE의 VRF에 있는 CE 연결 인터페이스에서 원격 PE의 VRF에 있는 다른 CE 연결 인터페이스로 ping을 시도할 수 있습니다.

```
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
```

PE 간 BGP VPNv4 인접성 확인

```
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
```

원격 PE VPNv4 인접성이 작동되고 접두사가 수신되었습니다.

```
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
```

특정 VRF에서 교환되는 접두사 확인

```
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 ?
```

VPNv4 및 LDP 레이블 검증

```
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

사용 중인 LDP 레이블 확인

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

MPLS 포워딩 테이블 검증

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
```

VRF의 각 지정된 접두사에 도달하는 데 사용되는 내부(VPNv4) 및 외부(LDP) 레이블을 확인합니다.

```
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
```

객체 관리자 통계 확인:

이상적인 시나리오에서는 보류 중인 개체가 없습니다.

```
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
```

접두사 프로그래밍

다음 섹션에서는 MPLS 라우터, C9300-PE-1, C9500-P 및 C9300-PE-2의 접두사 프로그래밍을 다룹니다.

C9300-PE-1 접두사 프로그래밍

```
***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]:
150000000000000000000000000000000000000000000000000000000000000046000000000000000000000000000000
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 접두사 프로그래밍

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

C9300-PE-2 접두사 확인

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


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 레이블 프로그래밍

다음 섹션에서는 MPLS PE 라우터, C9300-PE-1 및 C9300-PE-2의 VPNv4 레이블 프로그래밍에 대해 설명합니다. C9500=P는 VPNv4 레이블에서 전달되지 않으므로 C9500-P에서 출력되지 않습니다.

C9300-PE-1 VPNv4 레이블 프로그래밍:

원격 접두사가 아닌 PE에 대한 로컬 접두사를 확인합니다. FED 관점에서 레이블을 확인한 다음 FMAN RP 및 FMAN FP로 백트랙합니다.

```
***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 }
```

C9300-PE-2 VPNv4 레이블 확인

원격 접두사가 아닌 PE에 대한 로컬 접두사를 확인합니다. FED 관점에서 레이블을 확인한 다음
FMAN RP 및 FMAN FP로 백트랙합니다.


```
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 레이블 프로그래밍

다음 섹션에서는 MPLS 라우터, C9300-PE-1, C9500-P 및 C9300-PE-2의 LDP 레이블 프로그래밍
을 다룹니다.

LDP(외부) 레이블은 MPLS 네트워크 레이블에서 패킷을 전환하는 것입니다. 원격 PE에 광고되는

로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다.

C9300-PE-1 LDP 레이블 프로그래밍:

원격 PE에 광고되는 로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다. FED 관점에서 레이블을 확인한 다음 FMAN RP 및 FMAN FP로 백트랙합니다.

```
***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 레이블 프로그래밍:

원격 PE에 광고되는 로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다. FED 관점에서 레이블을 확인한 다음 FMAN RP 및 FMAN FP로 백트랙합니다.

```
***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 레이블 프로그래밍:

원격 PE에 광고되는 로컬 LDP 레이블을 검증하고 원격 LDP 레이블을 검증하지 않습니다. 먼저 FED 관점에서 레이블을 확인한 다음 FMAN RP 및 FMAN FP로 백트랙합니다.

```
***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, }
```

하드웨어 확장 문제 해결

이 섹션에서는 컨피그레이션 문제를 해결하는 데 사용할 수 있는 정보를 제공합니다.

MPLS 하드웨어 Syslog

MPLS 레이블과 같은 특정 리소스가 부족하면 시스템에서 SYSLOG 메시지가 생성됩니다.

기억해야 할 핵심 사항

- MPLS LABEL은 **레이블 처리**에 사용됩니다. (이 리소스는 접두사가 로컬 CE에서 학습될 때 사용됩니다.)
- LSPA는 **레이블 부과에** 사용됩니다. 이 리소스는 접두사가 원격 PE에서 학습될 때 사용됩니다.

MPLS 로그 메시지	정의	복구 작업
%FED_L3_ERRMSG-3-RSRC_ERR: 스위치 1 R0/0: fed: **하드웨어 리소스 소모로 인해 fib 항목에** 하드웨어 리소스**를 할당하지 못했습니다.**	IP 접두사에 예약된 하드웨어의 공간이 부족합니다(EM 또는 TCAM).	**로컬 또는 원격 PE**에서 학습한 사 수를 줄이려면 다음 작업 중 를 수행합니다. 1. CE에서 접두사를 요약합니다 2. 레이블 할당 모드를 접두사당 vrf당 모드로 변경합니다.
%FED_L3_ERRMSG-3-mpls_out_of_resource: 스위치 1 R0/0: 피드: **MPLS 레이블 항목에 대한 리소스가 부족합니다.** 하드웨어에서 로컬 레이블 8205(8192/8192)를 프로그래밍하지 못했습니다.	**로컬 레이블 할당:** MPLS 로컬 레이블에 예약된 하드웨어의 공간이 부족합니다(EM 또는 TCAM).	**로컬 PE**에서 사용되는 레이블 줄이려면 다음 작업 중 하나를 합니다. 1. 로컬 CE 또는 로컬 PE에서 접사를 요약합니다. 2. 로컬 PE에서 레이블 할당 모 접두사별로 VRF로 변경합니다
%FED_L3_ERRMSG-3-MPLS_LENTRY_PAUSE: 스위치 1 R0/0: 피드: **MPLS LABEL ENTRY 리소스에 대한 한계 제한에** 도달했습니다. **항목 만들기 일시 중지됨.**	**로컬 레이블 할당:** MPLS 로컬 레이블용으로 예약된 하드웨어의 공간이 부족합니다(EM 또는 TCAM).	**로컬 PE**에서 사용되는 레이블 줄이려면 다음 작업 중 하나를 합니다. 1. 로컬 CE 또는 로컬 PE에서 접사를 요약합니다. 2. 로컬 PE에서 레이블 할당 모 접두사별로 VRF로 변경합니다 **원격 PE**에서 사용되는 레이블 줄이려면 다음 작업 중 하나를 합니다.
%FED_L3_ERRMSG-3-mpls_out_of_resource: 스위치 1 R0/0: 피드: **MPLS LSPA에 대한 리소스가 부족합니다. 하드웨어에서 프로그래밍하지 못했습니다.**	**원격 레이블 할당:** LSPA 원격 레이블용으로 예약된 하드웨어 공간이 부족합니다.	1. 원격 CE 또는 원격 PE에서 접사를 요약합니다. 2. 원격 PE에서 레이블 할당 모 접두사 단위로 변경합니다.

하드웨어 검증 명령

show platform hardware fed active fwd-asic resource tcam utilizationcommand는 하드웨어 스케일 문제가 있는지 평가하려는 첫 번째 위치입니다. ASIC별로 정보를 표시합니다.

이 섹션에서는 vrf MPLS에서 BGP의 PE 학습 접두사와 여기에 설명된 매개변수를 보여줍니다.

- 기본 접두사 레이블 할당이 사용됩니다.

- PE는 C9300-48U(Cisco IOS-XE 17.3.4 포함)
- CE는 vrf MPLS의 인터페이스에 접두사를 광고하는 BGP 네이버로서 Ixia입니다.
- 사용된 접두사 길이는 /28입니다. 따라서 플랫폼에서는 접두사 길이 /31보다 짧은 TCAM을 사용합니다.
- 이 플랫폼은 먼저 MPLS/BGP 레이블에 EM 메모리를 사용한 다음 EM이 가득 차면 TCAM으로 오버플로됩니다.

토폴로지

CE prefix range:
172.16.0.0/16

Lo0: 10.0.0.1/32

VRF MPLS

192.168.1.2/30

IXIA

192.168.1.1/30   C9300-PE-1

MPLS Cloud

iBGP VPNv4 Adjacency

Lo0: 10.0.0.5/32

C9500-PE-2
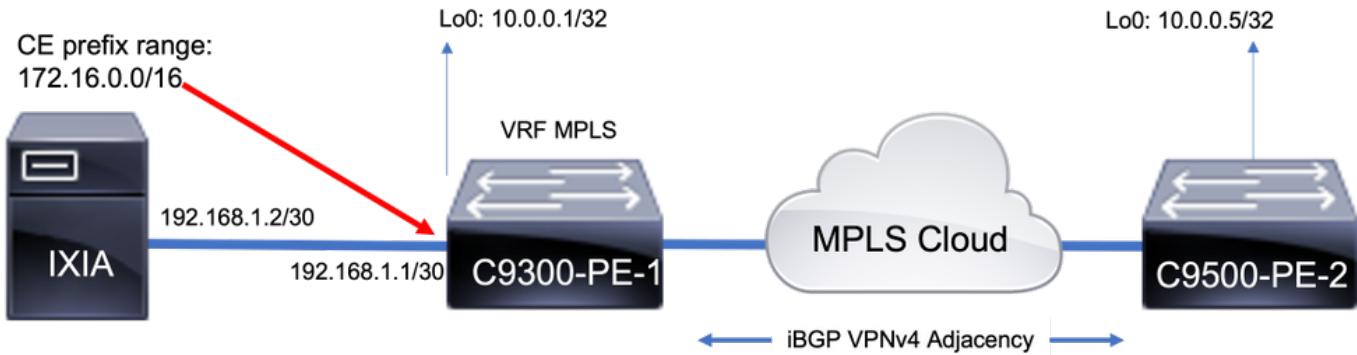
기준 자원 사용량

접두사를 추가하기 전에 몇 가지 기본 사용이 있습니다.

- 이 베이스라인은 MPLS LDP 인접 디바이스가 글로벌 테이블에 구성된 후에 작성되었습니다.
- 이 기준에서 VPNv4 접두사는 VRF MPLS에 추가됩니다
- 기준 번호는 다를 수 있습니다. 스위치에 이미 프로그래밍된 항목에 따라 달라집니다.

  참고: 이 예에서 접두사는 하나의 CE-PE에서 추가되어 연결성을 위해 레이블 스택을 사용해야 하는 원격 PE에만 할당된 LSPA와 같은 리소스가 됩니다. 실제 시나리오에서 리소스는 두 PE 디바이스 모두에 할당됩니다.

```
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
```

참고: SI/RI/DI는 패킷 재작성, 대상 포트 등에 필요한 리소스입니다. SI/DI/RI 문제를 해결하려면 [Catalyst 9000 스위치의 하드웨어 리소스 이해](#) 문서를 참조하십시오.

1000개의 BGP VPNv4 접두사 추가

CE에서 VRF MPLS에 1000개의 접두사를 추가한 인접 디바이스(Ixia)

9300 로컬 PE(CE에 연결됨)

```
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 원격 PE(MPLS를 통해 학습)

```
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)
```

> **참고:** 일반적인 Catalyst 9000 TCAM 정보 또는 TCAM에서 다른 기능을 확인하는 방법에 대한 자세한 내용은 <u>Understand Hardware Resources on Catalyst 900 Switch</u>를 참조하십시오.

> **참고:** ADJ(인접성)는 공유 리소스입니다. ADJ의 문제를 해결하려면 <u>Catalyst 9000 스위치의 하드웨어 리소스 이해</u> 문서를 참조하십시<u>오.</u>

MPLS 레이블 및 IPv4 확장 제한 및 교정

대부분의 경우 MPLS 기능이 사용되고 너무 많은 하드웨어 리소스가 소비되는 경우 접두사당(기본값)에서 VRF당 레이블 할당을 변경하면 도움이 됩니다. 이 예에서는 전후 리소스 할당을 고려합니다(**이 경우 9500은 CE-PE 장치임**).

```
### 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
```

참고: show platform software fed switch active mpls summary의 리소스 사용량은 LABEL 또는 LSPA의 이러한 감소(적용 가능한 경우)를 보여줍니다.

TAC에 대한 수집 명령

MPLS와 관련된 가장 일반적인 하드웨어 리소스 문제는 이 가이드에서 적절한 교정 단계를 다룹니다. 그러나 이 가이드에서 문제를 해결하지 못한 경우 표시된 명령 목록을 수집하고 서비스 요청에 첨부하십시오.

```
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
```

관련 정보

기술 지원 및 문서 – Cisco Systems

MPLS(Multiprotocol Label Switching) 컨피그레이션 가이드, Cisco IOS XE Cupertion 17.7.x(Catalyst 9300 스위치)

MPLS(Multiprotocol Label Switching) 컨피그레이션 가이드, Cisco IOS XE Cupertion 17.7.x(Catalyst 9500 스위치)

Catalyst 9000 스위치의 하드웨어 리소스 이해