MPLS auf Catalyst Switches der Serie 9000 überprüfen

Inhalt

Einleitung

In diesem Dokument wird beschrieben, wie Multiprotocol Label Switching (MPLS) Layer 3 Virtual Private Network (VPN) auf Catalyst Switches der Serie 9000 konfiguriert und validiert wird.

Voraussetzungen

Anforderungen

Cisco empfiehlt, dass Sie über Kenntnisse in folgenden Bereichen verfügen:

- IP-Weiterleitung
- Border Gateway Protocol (BGP)
- MPLS

Verwendete Komponenten

Die Informationen in diesem Dokument basierend auf folgenden Software- und Hardware-Versionen:

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

Die Informationen in diesem Dokument beziehen sich auf Geräte in einer speziell eingerichteten Testumgebung. Alle Geräte, die in diesem Dokument benutzt wurden, begannen mit einer gelöschten (Nichterfüllungs) Konfiguration. Wenn Ihr Netzwerk in Betrieb ist, stellen Sie sicher, dass Sie die potenziellen Auswirkungen eines Befehls verstehen.

Hintergrundinformationen

MPLS-Layer-3-VPNs (L3VPN) verwenden ein Peer-to-Peer-Modell, das BGP für die Verteilung von VPN-bezogenen Informationen verwendet. Ein MPLS-VPN besteht aus einer Reihe von Standorten, die über ein Core-Netzwerk eines MPLS-Anbieters miteinander verbunden sind. An jedem Kundenstandort sind ein oder mehrere CE-Geräte (Customer Edge) mit einem oder mehreren PE-Geräten verbunden.

Beim konventionellen Layer-3-Routing extrahiert ein Paket im Netzwerk alle für die Weiterleitung relevanten Informationen aus dem Layer-3-Header. Diese Informationen werden dann als Index für eine Suche in der Routing-Tabelle verwendet, um den nächsten Hop für das Paket zu bestimmen.

In der Regel ist das einzige relevante Feld im Header das Zieladressfeld. In einigen Fällen sind jedoch auch andere Headerfelder relevant. Daher muss die Header-Analyse unabhängig an jedem Switch durchgeführt werden, über den das Paket geleitet wird. Darüber hinaus muss an jedem Switch eine komplizierte Tabellensuche durchgeführt werden.

Beim Label-Switching wird die Analyse des Layer-3-Headers nur einmal durchgeführt. Der Layer-3-Header wird dann einem unstrukturierten Wert mit fester Länge, dem so genannten **Alabel,** zugeordnet.

Viele verschiedene Header können demselben Label zugeordnet werden, solange diese Header immer die gleiche Auswahl von Next Hop ergeben. Im Prinzip stellt ein Label eine **Weiterleitungsäquivalenzklasse** (FEC) dar, d. h. eine Gruppe von Paketen, die, wie unterschiedlich sie auch sein mögen, durch die Weiterleitungsfunktion nicht unterscheidbar sind.

Die anfängliche Auswahl eines Labels muss nicht ausschließlich auf dem Inhalt des Layer-3-Paket-Headers basieren. So können beispielsweise Entscheidungen zur Weiterleitung von Paketen bei nachfolgenden Hops auch auf anderen Faktoren basieren.

Sobald eine Bezeichnung zugewiesen ist, wird an der Vorderseite des Layer-3-Pakets ein kurzer

Label-Header hinzugefügt. Dieser Header wird als Teil des Pakets im Netzwerk übertragen. Bei nachfolgenden Hops durch jeden MPLS-Switch im Netzwerk werden Labels ausgetauscht, und Entscheidungen werden mittels MPLS-Forwarding-Tabellensuche nach dem Label im Paket-Header getroffen. Daher muss der Paket-Header während der Paketübertragung durch das Netzwerk nicht neu bewertet werden. Da das Label eine feste Länge und eine unstrukturierte Struktur aufweist, erfolgt die Suche nach der MPLS-Weiterleitungstabelle einfach und schnell.

Jeder Label Switching Router (LSR) im Netzwerk trifft eine unabhängige, lokale Entscheidung darüber, welcher Label-Wert zur Darstellung einer Weiterleitungsäquivalenzklasse verwendet werden soll. Diese Zuordnung wird als Label-Bindung bezeichnet. Jeder LSR informiert seine Nachbarn über die von ihm vorgenommenen Label-Bindungen. Diese Erkennung von Label-Bindings durch benachbarte Switches wird durch folgende Protokolle ermöglicht:

- Label Distribution Protocol (LDP) - Ermöglicht Peer-LSRs in einem MPLS-Netzwerk den Austausch von Label-Informationen zur Unterstützung der Hop-by-Hop-Weiterleitung in einem MPLS-Netzwerk.
- Border Gateway Protocol (BGP) - wird zur Unterstützung von MPLS Virtual Private Networks (VPNs) verwendet.

Wenn ein gekennzeichnetes Paket von LSR A an LSR B gesendet wird, entspricht der vom IP-Paket übertragene Label-Wert dem Label-Wert, den LSR B zugewiesen hat, um die Klasse der Weiterleitungsäquivalenz des Pakets darzustellen. Daher ändert sich der Label-Wert, wenn das IP-Paket das Netzwerk durchläuft.

Verwendung dieses Leitfadens

Der Leitfaden ist in zwei Szenarien unterteilt, und am Ende des Dokuments wird ein Abschnitt zur Validierung der Hardware-Skalierung angezeigt:

- Single-Hop-Adjacency im MPLS-Core
- Equal Cost Multi Path (ECMP)-Adjacencies im MPLS-Core
- Überprüfung der TCAM-Nutzung bei Problemen mit der Skalierung

In jedem Szenario werden Präfixe und Labels für jedes MPLS-Gerät überprüft.

Terminologie

MPLS	Multi-Protocol Label Switching	Eine leistungsstarke Paketweiterleitungstechnologie, die die Leistungs- und Datenverkehrsmanagementfunktionen von Layer-2-Switching (Data Link La 2) mit der Skalierbarkeit, Flexibilität und Leistung von Layer-3-Routing (Net Layer 3) integriert.
PE	Provider-Edge (Switch/Router)	Das Edge-Gerät des Anbieternetzwerks, das IP-Präfixe von einem Kunden empfängt und diese an die MPLS-Cloud weiterleitet.
CE	Kunden-Edge (Switch/Router)	Ein Gerät am Kundenstandort, das mit dem Provider Edge-Router eines IP/MPLS-Netzwerks des Service Providers verbunden ist.
LDP	Label Discovery Protocol	LDP ist ein Protokoll, das automatisch Label zwischen Routern generiert un austauscht. Jeder Router generiert lokal Bezeichnungen für seine Präfixe u gibt die Label-Werte dann an seine Nachbarn weiter.
LSPA	Label Switch Path Array	Der Labelsatz zum Erreichen eines bestimmten MPLS-Ziels. In einem typis L3VPN können Sie ein IGP + VPN-Label verwenden. Wenn ein TE-Tunnel vorhanden ist, verfügen Sie über das TE-Label + IGP + VPN. Der Catalyst

		kann bis zu 6 Labels unterstützen. Dieses Label-Array wird als LSPA bezeichnet.
Label-Stack-ID	Label-Stack-ID	A Ein eindeutiger Index zur Identifizierung eines Label-Stacks (einLSPA-Freigabe möglich).
Label	Label	Das für die Suche verwendete MPLS-Label. Der Label-Stack besteht aus mehreren Labels.
Präfix-ID	Präfixbezeichner	Catalyst 9000 erstellt für jedes Präfix eine globale Ressource (es gibt so vie Präfix-IDs wie Routen bei der Zuweisung pro Präfix-Label).
EM	Genaue Übereinstimmung	Ein Eintrag im Hash-Speicher, der einer 1:1-Übereinstimmung entspricht (Hostroute, Direct Connected Host).
LPM	Längste Präfixzuordnung	Jede Route, die /31 oder kürzer ist (/32 Routen sind EM-Typ).
TCAM	Ternary Content Addressable Memory (Ternärer, inhaltsadressierbarer Speicher)	Ein Speichertyp, der Einträge mit drei verschiedenen Eingaben speichert u abfragt: 0, 1 und X. Dieser Speichertyp muss in Fällen verwendet werden, i denen mehrere Übereinstimmungen mit demselben Eintrag vorhanden sein können und der resultierende Hash für jeden Eintrag nicht eindeutig ist. **Die Tabelle enthält eine Maske oder einen "X"-Wert, mit der festgestellt werden kann, ob er mit diesem Eintrag übereinstimmt oder nicht.**
CAM	Content-Addressable Memory	Allgemeiner Begriff für Hardwarespeicher (Hash/TCAM).
RIB	Basis für Routing-Informationen	die Routing-Tabelle unter "show ip route"
FIB	Basis für Weiterleitungsinformationen	Vereinfachte Tabelle mit Präfixen, die von den RIB- und ARP-Tabellen mit einem Zeiger auf die ADJ-Tabelle hinzugefügt werden
Direkt verbunden	Direkt verbundene Route	Ein lokal verbundenes Host-Präfix (ARP angrenzend)
Indirekt verbunden	Indirekt verbundene Route	Eine Route, die über einen entfernten Next Hop erreicht wird.
ADJ	Adjacency (Tabelle)	Speichert die Next-Hop-Informationen, die für die Paketumschreibung verw werden.
EM	Genaue Übereinstimmung	Verbundene Hosts, indirekte /32-Host-Präfixe
TCAM	Ternary Content Addressable Memory (Ternärer, inhaltsadressierbarer Speicher)	Indirekte Präfixe /31 oder kürzer
FED	Weiterleitungs-Engine-Treiber	Die ASIC-Schicht (Hardware)
FMAN-FP	Weiterleitungs-Manager - Weiterleitungsebene	FMAN-FP verwaltet Softwareobjekte, die FED-Informationen hinzufügen, löschen oder ändern.
SI	Station-Index	Station-Index = Informationen zum Umschreiben von Paketen (RI = Rewrit Index) und Informationen zur ausgehenden Schnittstelle (DI = Destination I

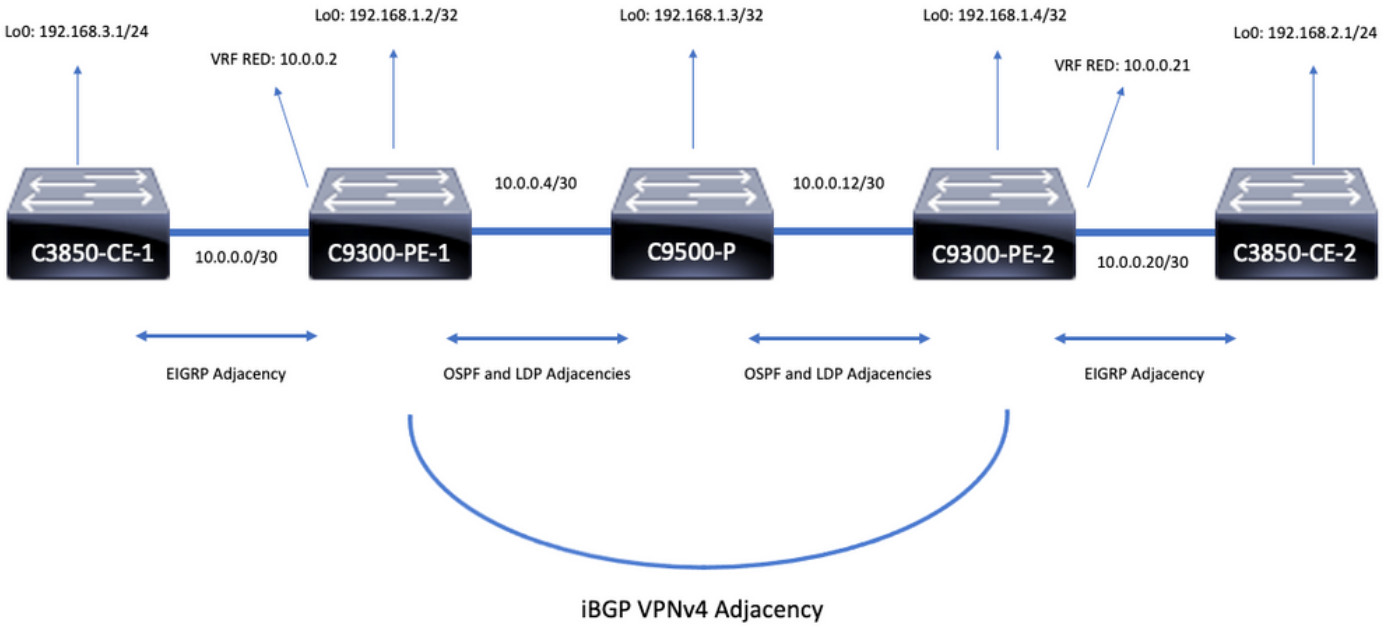
RI	Index umschreiben	Informationen zum Umschreiben der MAC-Adresse für die Layer-3-Weiterle an die nächste Hop-Adjacency
DI	Zielindex	Index, der auf die ausgehende Schnittstelle verweist

Konfigurieren und Überprüfen

Szenario 1. L3VPN mit Single-Hop-Adjazenz im MPLS-Core

Referenztopologie

Für die Zwecke dieses Beispiels fungieren Catalyst Switches der Serie 9300 als PE-Geräte, Catalyst Switches der Serie 9500 in Stackwise Virtual als P-Gerät und Catalyst Switches der Serie 3850 als CE-Geräte.



Konfigurationsdetails

Konfiguration von C3850-CE-1

```
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
```

Konfiguration von C9300-PE-1

```
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
```

Konfiguration von C9500-P

```
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
```

Konfiguration von C9300-CE-2

```
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
```

Konfiguration von C3850-CE-2

```
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
```

Grundlegende Überprüfung

Vor der Validierung der MPLS-Programmierung müssen grundlegende Anforderungen validiert werden:

- Überprüfen der PE-PE-Verbindung
- Validierung des Label Switched Path (LSP) zwischen den PEs
- Validierung der BGPv4-Adjacency zwischen PEs
- Validierung von VPNv4- und LDP-Labels
- Überprüfen der MPLS-Weiterleitungstabelle

Validierung der PE-Verbindung

Sie können den Remote-PE-Loopback und die Quelle vom lokalen Loopback pingen. Dies bestätigt jedoch nicht, dass der MPLS Label Switched Path (LSP) gut ist, da die Loopback-IP-Adressen im Underlay angekündigt werden.

> **Hinweis**: Die PE-zu-PE-MP-BGP-VPNv4-Adjacency wird über ihre jeweiligen Loopback0-Schnittstellen erreicht.

```
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
```

Validieren des Sprachdienstleisters

Sie können einen MPLS-Traceroute vom PE zum PE-Loopback verwenden, um den LSP und alle MPLS-LDP-Labels auf dem Pfad zu validieren.

> **Hinweis**: Dieser MPLS-Traceroute stellt nur ein Label, das LDP-Label, auf. Dies zeigt nicht, dass der Datenverkehr vom CE erfolgreich ist, da dieser Datenverkehr mit zwei Labels, dem VPNv4-Label (inner) und dem LDP-Label (outer), aufgezeichnet wird.

```
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
```

Wenn Sie nicht auf den CE oder ein Gerät hinter dem CE zugreifen können und nachweisen möchten, dass VPNv4- und LDP-Labels erfolgreich bereitgestellt/bereitgestellt werden, können Sie versuchen, einen Ping von der CE-zugewandten Schnittstelle in der VRF-Instanz eines PE an die andere CE-seitige Schnittstelle in der VRF-Instanz des Remote-PE zu senden.

```
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
```

Validierung der BGP VPNv4-Adjacency zwischen PEs

```
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
```

Remote-PE-VPNv4-Adjacency ist aktiv, und es wurde ein Präfix empfangen

```
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
```

Überprüfen, welche Präfixe in der jeweiligen VRF-Instanz ausgetauscht werden

```
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 ?
```

Validierung von VPNv4- und LDP-Labels:

Überprüfen Sie das VPNv4-Label, das zum Erreichen der Präfixe im VRF verwendet wird.

```
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
```

Überprüfen der verwendeten LDP-Labels

```
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
```

Validieren der MPLS-Weiterleitungstabelle

```
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
```

Bestätigen Sie die internen (VPNv4) und äußeren (LDP) Labels, die für die Verbindung zu jedem Präfix in der VRF-Instanz verwendet werden.

```
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
```

Objektmanager-Statistiken **überprüfen**

In idealen Szenarien gibt es keine ausstehenden Objekte

```
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
```

Präfixprogrammierung

Im nächsten Abschnitt wird die Präfixprogrammierung auf den MPLS-Routern C9300-PE-1, C9500-P und C9300-PE-2 behandelt.

C9300-PE-1 Prefix-Programmierung

```
***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]:
150000000000000000000000000000000000000000000000000000000000000000000000460000000000000000000000000000000000000000000000000000000000000000 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-Präfixprogrammierung

```
***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 Prefix-Programmierung

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

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

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

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

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

```
  QOS: Precedence routine (0)
  dflt local label info: other/21 [0x2]
  nexthop 10.0.0.22 GigabitEthernet2/0/1

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

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

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

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

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

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

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

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

Adjacency id: 0x19 (25)
  Interface: GigabitEthernet2/0/1, IF index: 53, Link Type: MCP_LINK_IP
```

```
  Encap: 0:72:78:c8:c9:c2:70:d3:79:be:ae:42:8:0
  Encap Length: 14, Encap Type: MCP_ET_ARPA, MTU: 1500
  Flags: no-l3-inject
  Incomplete behavior type: None
  Fixup: unknown
  Fixup_Flags_2: unknown
  Nexthop addr: 10.0.0.22
  IP FRR MCP_ADJ_IPFRR_NONE 0
  aom id: 659, HW handle: (nil) (created)

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


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

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

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

Entry 0: (handle 0x7f7fb4a10e58)

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


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

C9300-PE-2#show platform software fed switch active ip adj
IPV4 Adj entries
dest            if_name                 dst_mac          si_hdl         ri_hdl         pd_flags
adj_id  Last-modified
----            -------                 -------          ------         ------         --------
```

```
-----   ------------------------
10.0.0.22       GigabitEthernet2/0/1    0072.78c8.c9c2   0x7f7fb4a44048 0x7f7fb4b089d8 0x0
0x19       2021/06/14 16:59:43.447 <-- si_hdl used in next command

C9300-PE-2#show platform hardware fed switch active fwd-asic abstraction print-resource-handle
0x7f7fb4a44048 1 <-- Utilize the si_hdl value from previous command
Handle:0x7f7fb4a44048 Res-Type:ASIC_RSC_SI Res-Switch-Num:255 Asic-Num:255 Feature-
ID:AL_FID_L3_UNICAST_IPV4 Lkp-ftr-id:LKP_FEAT_INVALID ref_count:1
priv_ri/priv_si Handle: 0x7f7fb4b089d8Hardware Indices/Handles: index0:0xb6
mtu_index/l3u_ri_index0:0x0  index1:0xb6  mtu_index/l3u_ri_index1:0x0
Features sharing this resource:66 (1)]
Cookie length: 56
00 00 00 00 00 00 00 00 25 00 00 00 00 00 00 00 00 00 00 08 00 00 72 78 c8 c9 c2 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

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-Label-Programmierung

Der nächste Abschnitt behandelt die VPNv4-Label-Programmierung auf den MPLS-PE-Routern C9300-PE-1 und C9300-PE-2. Der C9500 leitet das VPNv4-Label nicht weiter, daher wird vom C9500 keine Ausgabe ausgegeben.

C9300-PE-1 VPNv4-Label-Programmierung:

Überprüfen Sie das lokale Präfix für den PE, nicht das Remote-Präfix.

```
***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 }
```

Überprüfen Sie das C9300-PE-2 VPNv4-Label:

Überprüfen Sie das lokale Präfix auf den PE, nicht das Remote-Präfix.

```
***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 Label-Programmierung

Im nächsten Abschnitt wird die Programmierung des LDP-Labels auf den MPLS-Routern C9300-PE-1, C9500-P und C9300-PE-2 behandelt.

Das LDP-Label (äußere Bezeichnung) schaltet die Pakete auf das MPLS-Netzwerklabel. Validieren Sie das lokale LDP-Label, das dem Remote-PE angekündigt wird. Validieren Sie nicht das Remote-LDP-Label.

C9300-PE-1 LDP Label-Programmierung:

Validieren Sie das lokale LDP-Label, das dem Remote-PE mitgeteilt wird, und validieren Sie nicht das Remote-LDP-Label. Überprüfen Sie das Etikett aus FED-Sicht und dann rückwärts zu FMAN RP und FMAN FP.

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

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


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

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


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

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


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

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

C9500 LDP Label-Programmierung:

Validieren Sie das lokale LDP-Label, das dem Remote-PE mitgeteilt wird, und validieren Sie nicht das Remote-LDP-Label. Überprüfen Sie das Etikett aus FED-Sicht und dann rückwärts zu FMAN RP und FMAN FP.

```
***Software LDP Label Programming***
C9500-P#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         explicit-n 192.168.1.2/32   23409         Te1/0/1    10.0.0.5  <-- LDP label 16 is
advertised to reach PE 192.168.1.2
17         explicit-n 192.168.1.4/32   23345         Te1/0/2    10.0.0.14 <-- LDP label 17 is
advertised to reach PE 192.168.1.4

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


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

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


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

C9500-P#show platform software object-manager switch active f0 object 654 <-- Use the aom id
from the previous command
Object identifier: 654
  Description: label 0x17
  Status: Done, Epoch: 0, Client data: 0x4b41c08

C9500-P#show platform software object-manager switch active f0 object 654 parents <-- Use the
aom id from the previous command
Object identifier: 515
  Description: adj 0x3f, Flags None
  Status: Done

***FED LDP Label Programming***
C9500-P#show platform software fed switch active mpls forwarding label 16 detail
 LENTRY:label:16 nobj:(LABEL, 23) lentry_hdl:0xec000004
   modify_cnt:6 backwalk_cnt:0
   lspa_handle:0
   AAL: id:3959422980 lbl:16
        eos0:[adj_hdl:0xc3000055, hw_hdl:0x7f28944be3c8]
        eos1:[adj_hdl:0xc3000055, hw_hdl:0x7f28944be1b8]
        deagg_vrf_id = 0 lspa_handle:0
   LABEL:objid:23 link_type:MPLS local_label:16 outlabel:(0, 0) <-- Utilized in previous
commands
       flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xc3000055
```

```
       unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
       bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
       AAL: id:3271557205 lbl:0 smac:d4ad.71b5.dde4 dmac:a0f8.4911.d1d6
            sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
            vlan_id:0 vrf_id:0 ri:0x7f289449bf88, ri_id:0x44 phdl:0xe9000057, ref_cnt:1
            si:0x7f2894489b58, si_id:0x4009, di_id:0x1
   ADJ:objid:63 {link_type:MPLS ifnum:0x41, si:0x57000023, }
```

*****Software LDP Label Programming*****

```
C9500-P#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         explicit-n 192.168.1.2/32   23409         Te1/0/1    10.0.0.5
17         explicit-n 192.168.1.4/32   23345         Te1/0/2    10.0.0.14
```

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

```
C9500-P#show platform software mpls switch active r0 label index 64 <-- Use the obj id from the
FED command


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

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

```
C9500-P#show platform software mpls switch active f0 label index 64 <-- Use the obj id from the
FED command


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

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


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

*****FED LDP Label Programming*****

```
C9500-P#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LABEL, 64) lentry_hdl:0x8d000005
   modify_cnt:6 backwalk_cnt:0
   lspa_handle:0
   AAL: id:2365587461 lbl:17
        eos0:[adj_hdl:0xcc000037, hw_hdl:0x7f2894480438]
        eos1:[adj_hdl:0xcc000037, hw_hdl:0x7f2894480228]
        deagg_vrf_id = 0 lspa_handle:0
   LABEL:objid:64 link_type:MPLS local_label:17 outlabel:(0, 0) <-- Utilized in previous
commands
       flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xcc000037
       unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
       bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
```

```
      AAL: id:3422552119 lbl:0 smac:d4ad.71b5.ddd6 dmac:70d3.79be.ae71
           sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
           vlan_id:0 vrf_id:0 ri:0x7f2894498008, ri_id:0x38 phdl:0x76000058, ref_cnt:1
           si:0x7f2894498478, si_id:0x400b, di_id:0x2
   ADJ:objid:73 {link_type:MPLS ifnum:0x42, si:0x3d000027, }
```

C9300-PE-2 LDP Label-Programmierung:

Validieren Sie das lokale LDP-Label, das dem Remote-PE mitgeteilt wird, und validieren Sie nicht das Remote-LDP-Label. Überprüfen Sie das Etikett aus FED-Sicht und dann rückwärts zu FMAN RP und FMAN FP.

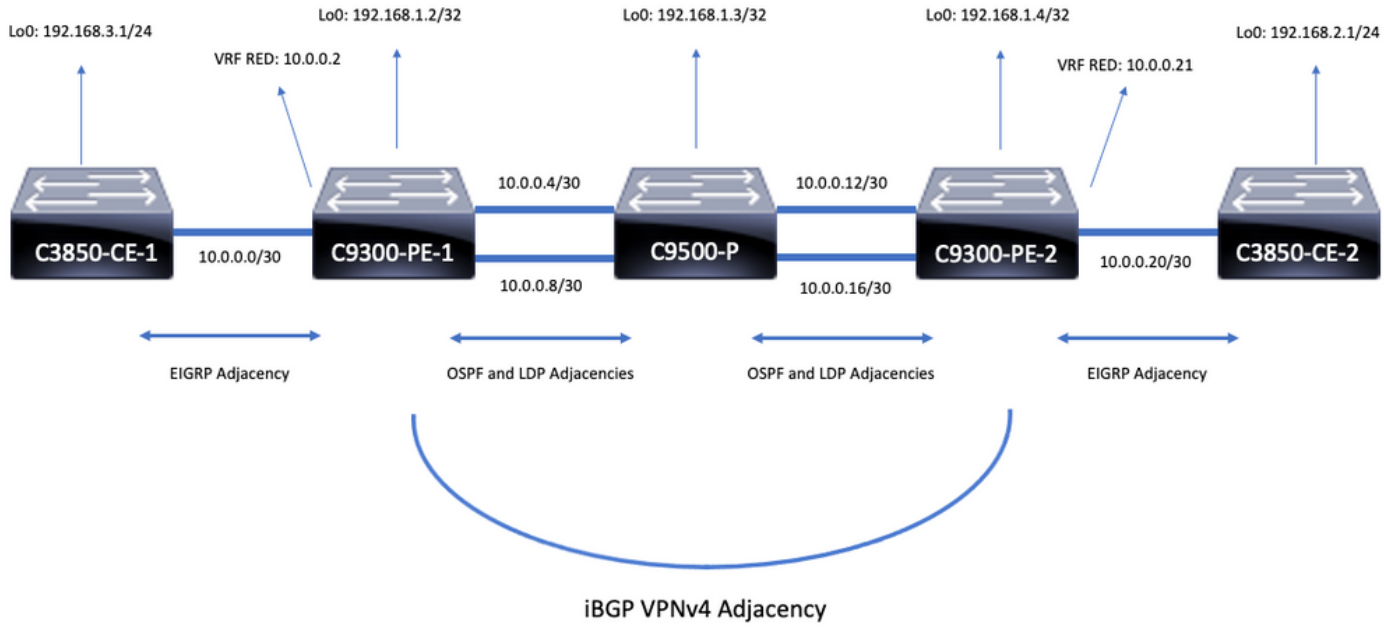
```
***Software LDP Label Programming***
C9300-PE-2#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         Pop Label  192.168.1.3/32   0             Gi2/0/2    10.0.0.13
17         16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

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


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


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


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

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


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

C9300-PE-2#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LABEL, 82) lentry_hdl:0x44000005
```

```
modify_cnt:6 backwalk_cnt:0
lspa_handle:0
AAL: id:1140850693 lbl:17
     eos0:[adj_hdl:0x5f000032, hw_hdl:0x7fe8f8a52798]
     eos1:[adj_hdl:0x5f000032, hw_hdl:0x7fe8f8a52588]
     deagg_vrf_id = 0 lspa_handle:0
LABEL:objid:82 link_type:MPLS local_label:17 outlabel:(16, 0) <-- Used in previous commands
    flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x5f000032
    unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
    bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
    AAL: id:1593835570 lbl:0 smac:70d3.79be.ae71 dmac:d4ad.71b5.ddd6
         sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
         vlan_id:0 vrf_id:0 ri:0x7fe8f8a93c78, ri_id:0x3a phdl:0x9f00004b, ref_cnt:1
         si:0x7fe8f8a91188, si_id:0x4011, di_id:0x535f
ADJ:objid:70 {link_type:MPLS ifnum:0x36, si:0xaa000021, }
```

Szenario 2. L3VPN mit ECMP zwischen PEs und P-Routern

Referenztopologie

Für dieses Beispiel fungieren Catalyst Switches der Serie 3850 als CE-Geräte. Catalyst Switches der Serie 9300 fungieren als PE-Geräte, Catalyst 9500 in Stackwise Virtual als P-Gerät. EIGRP wird zwischen den CE- und PE-Geräten, OSPF- und LDP-Adjacencies im MPLS-Core ausgeführt, mit einer iBGP-VPNv4-Adjacency zwischen den PE-Geräten. Innerhalb des MPLS-Core gibt es ECMP zwischen den PE- und P-Geräten.



Konfigurationsdetails

Konfiguration von C3850-CE-1

```
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
```

Konfiguration von C9300-PE-1

```
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
```

Konfiguration von C9500-P

```
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
```

Konfiguration von C9300-PE-2

```
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
```

Konfiguration von C3850-CE-2

```
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
```

Grundlegende Validierung

Vor der Validierung der MPLS-Programmierung müssen grundlegende Anforderungen validiert werden:

- Überprüfen der PE-PE-Verbindung
- Validierung des Label Switched Path (LSP) zwischen den PEs
- Validierung der BGPv4-Adjacency zwischen PEs
- Validierung von VPNv4- und LDP-Labels
- Überprüfen der MPLS-Weiterleitungstabelle

Validierung der PE-Verbindung

Sie können den Remote-PE-Loopback und die Quelle vom lokalen Loopback pingen. Dies bestätigt jedoch nicht, dass der MPLS Label Switched Path (LSP) gut ist, da die Loopback-IP-Adressen im Underlay angekündigt werden.

> **Hinweis**: Die PE-zu-PE-MP-BGP-VPNv4-Adjacency wird über ihre jeweiligen Loopback0-Schnittstellen erreicht.

```
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
```

Validieren des Sprachdienstleisters

Sie können einen MPLS-Traceroute vom PE zum PE-Loopback verwenden, um den LSP und alle MPLS-LDP-Labels auf dem Pfad zu validieren.

> Hinweis: Dieser MPLS-Traceroute stellt nur ein Label, das LDP-Label, auf. Dies zeigt nicht, dass der Datenverkehr vom CE erfolgreich ist, da dieser Datenverkehr mit zwei Labels, dem VPNv4-Label (inner) und dem LDP-Label (outer), aufgezeichnet wird.

```
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
```

Wenn Sie nicht auf den CE oder ein Gerät hinter dem CE zugreifen können und nachweisen möchten, dass VPNv4- und LDP-Labels erfolgreich bereitgestellt/bereitgestellt werden, können Sie versuchen, einen Ping von der CE-zugewandten Schnittstelle in der VRF-Instanz eines PE an die andere CE-seitige Schnittstelle in der VRF-Instanz des Remote-PE zu senden.

```
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
```

Validierung der BGP VPNv4-Adjacency zwischen PEs

```
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
```

Remote-PE-VPNv4-Adjacency ist aktiv, und es wurde ein Präfix empfangen

```
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
```

Überprüfen, welche Präfixe in der jeweiligen VRF-Instanz ausgetauscht werden

```
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 ?
```

Validierung von VPNv4- und LDP-Labels

```
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
```

Überprüfen der verwendeten LDP-Labels

```
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
```

Validieren der MPLS-Weiterleitungstabelle

```
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
```

Bestätigen Sie die internen (VPNv4) und äußeren (LDP) Labels, die für die Verbindung zu jedem Präfix in der VRF-Instanz verwendet werden.

```
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
```

Objektmanager-Statistiken **überprüfen**:

In idealen Szenarien gibt es keine ausstehenden Objekte

```
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
```

Präfixprogrammierung

Im nächsten Abschnitt wird die Präfixprogrammierung auf den MPLS-Routern C9300-PE-1, C9500-P und C9300-PE-2 behandelt.

C9300-PE-1 Prefix-Programmierung

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

Routing Table: RED
Routing entry for 192.168.2.0/24
  Known via "bgp 69420", distance 200, metric 130816, type internal
  Last update from 192.168.1.4 19:21:45 ago
```

```
  Routing Descriptor Blocks:
  * 192.168.1.4 (default), from 192.168.1.4, 19:21:45 ago <-- Remote PE reachable in the global
routing table
      Route metric is 130816, traffic share count is 1
      AS Hops 0
      MPLS label: 21 <-- VPNv4 label
      MPLS Flags: MPLS Required

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

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

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

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


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


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

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

Index: 0x70, Flags: unknown, Hash Algorithm: , Number of Paths: 2, Number of buckets: 16
```

```
  Anti-polarising Factor: 0xf4a19ba0
  Next Object Type: OBJ_LABEL, OBJ_LABEL
  Next obj handle: 0x6e, 0x6f
  Hash Buckets: 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
  Color Buckets Map: 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
  OM handle: 0x3480641fb8

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


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

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


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

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

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

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

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

***FMAN FP Prefix Programming***
C9300-PE-1#show ip vrf detail
VRF RED (VRF Id = 2); default RD 69:69; default VPNID
```

```
  Old CLI format, supports IPv4 only
  Flags: 0xC
  Interfaces:
    Gi1/0/1
Address family ipv4 unicast (Table ID = 0x2):
  Flags: 0x0
  Export VPN route-target communities
    RT:69:69
  Import VPN route-target communities
    RT:69:69
  No import route-map
  No global export route-map
  No export route-map
  VRF label distribution protocol: not configured
  VRF label allocation mode: per-prefix

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

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

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


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

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

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

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

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


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


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

values from previous command

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

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

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

C9300-PE-1#show platform software adjacency switch active f0 index 0x4e <-- Use the
OBJ_ADJACENCY value from previous command
Number of adjacency objects: 10

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

*****FED Prefix Programming*****

```
C9300-PE-1#show platform software fed switch active ip route vrf-name RED 192.168.2.0/24
vrf   dest                                      htm            flags   SGT   DGID MPLS Last-
modified
---   ----                                      ---            -----   ---   ---- ---- -----
--------------------
2     192.168.2.0/24                            0x7fbae8d86228 0x0     0     0   lspa0x2
2021/06/23 18:50:13.079 <-- HTM value significant for next command
  FIB: prefix_hdl:0x50000026, mpls_ecr_prefix_hdl:0
  ========== OCE chain =====
  LABEL:objid:120 link_type:IP local_label:1048577 outlabel:(21, 0) <-- VPNv4 label
      flags:0x1:(REAL,) pdflags:0x80:(INSTALL_HW_OK,RECIR_ADJ,) adj_handle:0xcb00003c <--
adj_handle and local_adj_hdl values must match
      unsupported recursion:0 olbl_changed 0 local_adj:1 modify_cnt:0
      bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
      AAL: id:3405774908 lbl:19 smac:0000.0000.0000 dmac:0000.0000.0000 <-- Label 19 matches the
local transport label
           sub_type:0 link_type:0 adj_flags:0x10 label_type:0 rewrite_type:PSH2(121)
           vlan_id:0 vrf_id:0 ri:0x7fbae8d73648, ri_id:0x46 phdl:0, ref_cnt:2 <-- ri_id and
ri_idx values must match
           si:0x7fbae8d834d8, si_id:0xb6, di_id:0x5013
  LB:obj_id:112 link_type:IP num_choices:2 Flags:0
      mpls_ecr:1 local_label:19 path_inhw:2 ecrh:0x7d000002 old_ecrh:0
```

```
      modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
      bwalk:[req:0 in_prog:0 nested:0]
    AAL: ecr:id:2097152002 af:0 ecr_type:0 ref:7 ecrh:0x7fbae8a99268(28:2)
    hwhdl:3903427176 ::0x7fbae8a98b98,0x7fbae8a9ad48,0x7fbae8a98b98,0x7fbae8a9ad48
  Sw Enh ECR scale: objid:112 llabel:19 eos:1 #adjs:2 mixed_adj:0
     reprogram_hw:0 ecrhdl:0x7d000002 ecr_hwhdl:0x7fbae8a99268
      mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
      ecr_adj: id:4278190135 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:1744830509
            sih:0x7fbae8a98b98(179) di_id:20499 rih:0x7fbae8a985d8(33)
        adj_lentry [eos0:0x7fbae8d7bf48 eos1:0x7fbae8d76e88]
      ecr_adj: id:1392508984 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:2013265966
            sih:0x7fbae8a9ad48(180) di_id:20499 rih:0x7fbae8a9a788(46)
        adj_lentry [eos0:0x7fbae8d7c1b8 eos1:0x7fbae8d77158]
      ecr_prefix_adj: id:2164260921 (ref:1)
         sih:0x7fbae8d7df08(181) di_id:20499 rih:0x7fbae8d7db98(68)
     LABEL:objid:110 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Label 19 is the local
transport label, Label 17 is the LDP label
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xff000037
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:4278190135 lbl:0 smac:a0f8.4911.d1d6 dmac:d4ad.71b5.dde4 <-- Matches next-hop
information to reach 192.168.2.0/24
              sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
              vlan_id:0 vrf_id:0 ri:0x7fbae8d78c48, ri_id:0x40 phdl:0x9f00004b, ref_cnt:1
              si:0x7fbae8d78fd8, si_id:0x4013, di_id:0x535f <-- di_id utilized in subsequent
commands
     ADJ:objid:75 {link_type:MPLS ifnum:0x36, si:0x22000023, }
     LABEL:objid:111 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Label 19 is the local
transport label, Label 17 is the LDP label
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x53000038
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:1392508984 lbl:0 smac:a0f8.4911.d1d8 dmac:d4ad.71b5.ddc2 <-- Matches next-hop
information to reach 192.168.2.0/24
              sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
              vlan_id:0 vrf_id:0 ri:0x7fbae8d7d0a8, ri_id:0x42 phdl:0x8400004c, ref_cnt:1
              si:0x7fbae8d7a908, si_id:0x4014, di_id:0x5360 <-- di_id utilized in subsequent
commands
     ADJ:objid:78 {link_type:MPLS ifnum:0x37, si:0x74000026, }
  ===============
  MPLS info: mpls_ecr_scale_prefix_adj:0, mpls_lspa_hdl:0xa7000002
    AAL:LSPA: id:2801795074 num_path:1 prefix_id:0x2 delete_hw_hdl_cnt:0
         cookie[64]:
150000000000000000000000000000000000000000000000000000000000000000000000460000000000000000000000000000000000
000000000000000000000000000000000 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-Präfixprogrammierung

```
***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
```

Überprüfen der Präfixe für C9300-PE-2

```
***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-Label-Programmierung

Der nächste Abschnitt behandelt die VPNv4-Label-Programmierung auf den MPLS-PE-Routern C9300-PE-1 und C9300-PE-2. Der C9500=P leitet auf dem VPNv4-Label nicht weiter, sodass keine Ausgabe des C9500-P erfolgt.

C9300-PE-1 VPNv4-Label-Programmierung:

Überprüfen Sie das lokale Präfix für den PE, nicht das Remote-Präfix. Überprüfen Sie das Etikett aus FED-Sicht und dann rückwärts zu FMAN RP und FMAN FP.

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

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


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

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


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

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

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

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

***FED VPNv4 Label Programming***
C9300-PE-1#show platform software fed switch active mpls forwarding label 21 detail
```

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

Überprüfen Sie die C9300-PE-2 VPNv4-Labels.

Überprüfen Sie das lokale Präfix für den PE, nicht das Remote-Präfix. Überprüfen Sie das Etikett aus FED-Sicht und dann rückwärts zu FMAN RP und FMAN FP.

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

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


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


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


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

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

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

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

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

LDP Label-Programmierung

Im nächsten Abschnitt wird die Programmierung des LDP-Labels auf den MPLS-Routern C9300-PE-1, C9500-P und C9300-PE-2 behandelt.

Das LDP-Label (äußere Bezeichnung) schaltet die Pakete auf das MPLS-Netzwerklabel. Validieren Sie das lokale LDP-Label, das dem Remote-PE angekündigt wird. Validieren Sie nicht das Remote-LDP-Label.

C9300-PE-1 LDP Label-Programmierung:

Validieren Sie das lokale LDP-Label, das dem Remote-PE mitgeteilt wird, und validieren Sie nicht das Remote-LDP-Label. Überprüfen Sie das Etikett aus FED-Sicht und dann rückwärts zu FMAN RP und FMAN FP.

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

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

from the FED commands

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

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

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

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

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

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

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

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

C9300-PE-1#**show platform software object-manager switch active f0 object 598 <-- Utilize the aom id from previous commands**

```
Object identifier: 598
  Description: label 0x6e
  Status: Done, Epoch: 0, Client data: 0xe05e6d78
```

C9300-PE-1#**show platform software object-manager switch active f0 object 598 parents <-- Utilize the aom id from previous commands**

```
Object identifier: 531
  Description: adj 0x4b, Flags None
  Status: Done
```

C9300-PE-1#**show platform software object-manager switch active f0 object 599 <-- Utilize the aom id from previous commands**

```
Object identifier: 599
  Description: label 0x6f
  Status: Done, Epoch: 0, Client data: 0xe05e6f78
```

C9300-PE-1#**show platform software object-manager switch active f0 object 599 parents <-- Utilize the aom id from previous commands**

```
Object identifier: 535
  Description: adj 0x4e, Flags None
  Status: Done
```

```
C9300-PE-1#show platform software fed switch active mpls forwarding label 19 detail
 LENTRY:label:19 nobj:(LB, 112) lentry_hdl:0x9000007
   modify_cnt:1 backwalk_cnt:0
   lspa_handle:0
   AAL: id:150994951 lbl:19
        eos0:[adj_hdl:0x7d000002, hw_hdl:0x7fbae8d778b8]
        eos1:[adj_hdl:0x7d000002, hw_hdl:0x7fbae8d776a8]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:112 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:19 path_inhw:2 ecrh:0x7d000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
     AAL: ecr:id:2097152002 af:0 ecr_type:0 ref:7 ecrh:0x7fbae8a99268(28:2)
     hwhdl:3903427176 ::0x7fbae8a98b98,0x7fbae8a9ad48,0x7fbae8a98b98,0x7fbae8a9ad48
   Sw Enh ECR scale: objid:112 llabel:19 eos:1 #adjs:2 mixed_adj:0
      reprogram_hw:0 ecrhdl:0x7d000002 ecr_hwhdl:0x7fbae8a99268
       mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
       ecr_adj: id:4278190135 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:1744830509
             sih:0x7fbae8a98b98(179) di_id:20499 rih:0x7fbae8a985d8(33)
         adj_lentry [eos0:0x7fbae8d7bf48 eos1:0x7fbae8d76e88]
       ecr_adj: id:1392508984 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:2013265966
             sih:0x7fbae8a9ad48(180) di_id:20499 rih:0x7fbae8a9a788(46)
         adj_lentry [eos0:0x7fbae8d7c1b8 eos1:0x7fbae8d77158]
       ecr_prefix_adj: id:2164260921 (ref:1)
          sih:0x7fbae8d7df08(181) di_id:20499 rih:0x7fbae8d7db98(68)
      LABEL:objid:110 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Used in previous
commands
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xff000037
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:4278190135 lbl:0 smac:a0f8.4911.d1d6 dmac:d4ad.71b5.dde4
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7fbae8d78c48, ri_id:0x40 phdl:0x9f00004b, ref_cnt:1
               si:0x7fbae8d78fd8, si_id:0x4013, di_id:0x535f
      ADJ:objid:75 {link_type:MPLS ifnum:0x36, si:0x22000023, }
      LABEL:objid:111 link_type:MPLS local_label:19 outlabel:(17, 0) <-- Used in previous
commands
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x53000038
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1392508984 lbl:0 smac:a0f8.4911.d1d8 dmac:d4ad.71b5.ddc2
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7fbae8d7d0a8, ri_id:0x42 phdl:0x8400004c, ref_cnt:1
               si:0x7fbae8d7a908, si_id:0x4014, di_id:0x5360
      ADJ:objid:78 {link_type:MPLS ifnum:0x37, si:0x74000026, }
```

C9500-P LDP Label-Programmierung:

Validieren Sie das lokale LDP-Label, das dem Remote-PE mitgeteilt wird, und validieren Sie nicht das Remote-LDP-Label. Überprüfen Sie das Etikett aus FED-Sicht und dann rückwärts zu FMAN RP und FMAN FP.

```
***Software LDP Label Programming***
C9500-P#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing   Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         explicit-n 192.168.1.2/32   1240          Te1/0/1    10.0.0.5  <-- LDP Label 16
advertised to reach PE 192.168.1.2
```

```
           explicit-n 192.168.1.2/32   226537        Te2/0/1    10.0.0.9
17         explicit-n 192.168.1.4/32   610           Te1/0/2    10.0.0.14 <-- LDP LAbel 17
advertised to reach PE 192.168.1.4
           explicit-n 192.168.1.4/32   227592        Te2/0/2    10.0.0.18

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


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

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


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

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


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

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


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

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


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

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


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

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

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

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


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


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


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

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


C9500-P#show platform software object-manager switch active f0 object 565 parents
Object identifier: 525
  Description: adj 0x44, Flags None
  Status: Done

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

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

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


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

***FED LDP Label Programming***
C9500-P#show platform software fed switch active mpls forwarding label 16 detail
 LENTRY:label:16 nobj:(LB, 96) lentry_hdl:0xeb000004
   modify_cnt:2 backwalk_cnt:0
   lspa_handle:0
```

```
   AAL: id:3942645764 lbl:16
        eos0:[adj_hdl:0x44000002, hw_hdl:0x7f0b284b4d98]
        eos1:[adj_hdl:0x44000002, hw_hdl:0x7f0b284b4be8]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:96 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:16 path_inhw:2 ecrh:0x44000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
     AAL: ecr:id:1140850690 af:0 ecr_type:0 ref:2 ecrh:0x7f0b284a3998(28:2)
     hwhdl:675953048 ::0x7f0b284b4268,0x7f0b284a1d78,0x7f0b284b4268,0x7f0b284a1d78
   Sw Enh ECR scale: objid:96 llabel:16 eos:1 #adjs:2 mixed_adj:0
      reprogram_hw:0 ecrhdl:0x44000002 ecr_hwhdl:0x7f0b284a3998
       mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
       ecr_adj: id:1610612787 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:1207959601
             sih:0x7f0b284b4268(181) di_id:23709 rih:0x7f0b284b3ca8(31)
         adj_lentry [eos0:0x7f0b284a32d8 eos1:0x7f0b284a3cc8]
       ecr_adj: id:805306420 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:67108914
             sih:0x7f0b284a1d78(182) di_id:23709 rih:0x7f0b284b47d8(44)
         adj_lentry [eos0:0x7f0b284c1608 eos1:0x7f0b284a2138]
       ecr_prefix_adj: id:3976200245 (ref:1)
          sih:0x7f0b284c2bf8(183) di_id:23709 rih:0x7f0b284c2888(50)
      LABEL:objid:94 link_type:MPLS local_label:16 outlabel:(0, 0)
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x60000033
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:1610612787 lbl:0 smac:d4ad.71b5.dde4 dmac:a0f8.4911.d1d6
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284a2cd8, ri_id:0x2e phdl:0xe9000057, ref_cnt:1
               si:0x7f0b284a3048, si_id:0x4009, di_id:0x1
      ADJ:objid:63 {link_type:MPLS ifnum:0x41, si:0x2d000023, }
      LABEL:objid:95 link_type:MPLS local_label:16 outlabel:(0, 0)
          flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x30000034
          unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
          bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
          AAL: id:805306420 lbl:0 smac:d4ad.71b5.ddc2 dmac:a0f8.4911.d1d8
               sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
               vlan_id:0 vrf_id:0 ri:0x7f0b284a57c8, ri_id:0x30 phdl:0x67000059, ref_cnt:1
               si:0x7f0b284a6008, si_id:0x400a, di_id:0x61
      ADJ:objid:68 {link_type:MPLS ifnum:0x43, si:0xef000026, }

C9500-P#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LB, 106) lentry_hdl:0xf6000005
   modify_cnt:1 backwalk_cnt:0
   lspa_handle:0
   AAL: id:4127195141 lbl:17
        eos0:[adj_hdl:0x44000002, hw_hdl:0x7f0b284ce2f8]
        eos1:[adj_hdl:0x44000002, hw_hdl:0x7f0b284ce0e8]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:106 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:17 path_inhw:2 ecrh:0x44000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
     AAL: ecr:id:1140850690 af:0 ecr_type:0 ref:2 ecrh:0x7f0b284a3998(28:2)
     hwhdl:675953048 ::0x7f0b284b4268,0x7f0b284a1d78,0x7f0b284b4268,0x7f0b284a1d78
   Sw Enh ECR scale: objid:106 llabel:17 eos:1 #adjs:2 mixed_adj:0
      reprogram_hw:0 ecrhdl:0x44000002 ecr_hwhdl:0x7f0b284a3998
       mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
       ecr_adj: id:4127195192 is_mpls_adj:1 l3adj_flags:0x100000
         recirc_adj_id:1207959601
             sih:0x7f0b284b4268(181) di_id:23709 rih:0x7f0b284b3ca8(31)
         adj_lentry [eos0:0x7f0b284c38e8 eos1:0x7f0b284cd858]
       ecr_adj: id:1157627961 is_mpls_adj:1 l3adj_flags:0x100000
```

```
        recirc_adj_id:67108914
            sih:0x7f0b284a1d78(182) di_id:23709 rih:0x7f0b284b47d8(44)
        adj_lentry [eos0:0x7f0b284c3af8 eos1:0x7f0b284cdb28]
      ecr_prefix_adj: id:3707764794 (ref:1)
         sih:0x7f0b284c5028(184) di_id:23709 rih:0x7f0b284c4c48(60)
     LABEL:objid:104 link_type:MPLS local_label:17 outlabel:(0, 0)
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xf6000038
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:4127195192 lbl:0 smac:d4ad.71b5.ddd6 dmac:70d3.79be.ae71
              sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
              vlan_id:0 vrf_id:0 ri:0x7f0b284ceaa8, ri_id:0x38 phdl:0x76000058, ref_cnt:1
              si:0x7f0b284ceeb8, si_id:0x400b, di_id:0x2
     ADJ:objid:73 {link_type:MPLS ifnum:0x42, si:0x1f000028, }
     LABEL:objid:105 link_type:MPLS local_label:17 outlabel:(0, 0)
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x45000039
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:1157627961 lbl:0 smac:d4ad.71b5.ddf1 dmac:70d3.79be.ae61
              sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
              vlan_id:0 vrf_id:0 ri:0x7f0b284c4588, ri_id:0x3a phdl:0x5500005a, ref_cnt:1
              si:0x7f0b284d0548, si_id:0x400c, di_id:0x62
     ADJ:objid:78 {link_type:MPLS ifnum:0x44, si:0x4900002a, }
```

C9300-PE-2 LDP Label-Programmierung:

Validieren Sie das lokale LDP-Label, das dem Remote-PE mitgeteilt wird, und validieren Sie nicht das Remote-LDP-Label. Überprüfen Sie zunächst das Label aus FED-Sicht und anschließend den Backtrack zum FMAN RP und FMAN FP.

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

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


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

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

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

***FMAN FP LDP Label Programming***
C9300-PE-2#show platform software mpls switch active f0 label index 106


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

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


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

C9300-PE-2#show platform software object-manager switch active f0 object 548 <-- Use the aom id
value from the previous commands
Object identifier: 548
  Description: label 0x6a
  Status: Done, Epoch: 0, Client data: 0x24843d8


C9300-PE-2#show platform software object-manager switch active f0 object 548 parents <-- Use the
aom id value from the previous commands
Object identifier: 509
  Description: adj 0x4b, Flags None
  Status: Done

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

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

***FED LDP Label Programming***
C9300-PE-2#show platform software fed switch active mpls forwarding label 17 detail
 LENTRY:label:17 nobj:(LB, 108) lentry_hdl:0x64000005
   modify_cnt:1 backwalk_cnt:0
   lspa_handle:0
   AAL: id:1677721605 lbl:17
        eos0:[adj_hdl:0xa0000002, hw_hdl:0x7f0650a5c8e8]
        eos1:[adj_hdl:0xa0000002, hw_hdl:0x7f0650a5b908]
        deagg_vrf_id = 0 lspa_handle:0
   LB:obj_id:108 link_type:IP num_choices:2 Flags:0
       mpls_ecr:1 local_label:17 path_inhw:2 ecrh:0xa0000002 old_ecrh:0
       modify_cnt:0 bwalk_cnt:0 subwalk_cnt:0 finish_cnt:0
       bwalk:[req:0 in_prog:0 nested:0]
```

```
    AAL: ecr:id:2684354562 af:0 ecr_type:0 ref:7 ecrh:0x7f0650a62888(28:2)
    hwhdl:1353066632 ::0x7f0650a60998,0x7f0650a630d8,0x7f0650a60998,0x7f0650a630d8
  Sw Enh ECR scale: objid:108 llabel:17 eos:1 #adjs:2 mixed_adj:0
     reprogram_hw:0 ecrhdl:0xa0000002 ecr_hwhdl:0x7f0650a62888
      mod_cnt:0 prev_npath:0 pmismatch:0 pordermatch:0
      ecr_adj: id:436207667 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:2113929262
            sih:0x7f0650a60998(178) di_id:20507 rih:0x7f0650a60378(50)
        adj_lentry [eos0:0x7f0650a877d8 eos1:0x7f0650a1cf78]
      ecr_adj: id:3976200246 is_mpls_adj:1 l3adj_flags:0x100000
        recirc_adj_id:1509949487
            sih:0x7f0650a630d8(179) di_id:20507 rih:0x7f0650a62b18(51)
        adj_lentry [eos0:0x7f0650a87a48 eos1:0x7f0650a1d188]
      ecr_prefix_adj: id:2919235640 (ref:1)
         sih:0x7f0650a87558(180) di_id:20507 rih:0x7f0650a871d8(68)
     LABEL:objid:106 link_type:MPLS local_label:17 outlabel:(16, 0) <-- Used in previous
commands
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0x1a000033
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:436207667 lbl:0 smac:70d3.79be.ae71 dmac:d4ad.71b5.ddd6
              sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
              vlan_id:0 vrf_id:0 ri:0x7f0650a67d48, ri_id:0x3a phdl:0x9f00004b, ref_cnt:1
              si:0x7f0650a65408, si_id:0x4010, di_id:0x535f
     ADJ:objid:75 {link_type:MPLS ifnum:0x36, si:0x35000023, }
     LABEL:objid:107 link_type:MPLS local_label:17 outlabel:(16, 0) <-- Used in previous
commands
         flags:0x1:(REAL,) pdflags:0:(INSTALL_HW_OK,) adj_handle:0xed000036
         unsupported recursion:0 olbl_changed 0 local_adj:0 modify_cnt:0
         bwalk_cnt:0 subwalk_cnt:0 collapsed_oce:0
         AAL: id:3976200246 lbl:0 smac:70d3.79be.ae61 dmac:d4ad.71b5.ddf1
              sub_type:0 link_type:2 adj_flags:0 label_type:2 rewrite_type:PSH1(119)
              vlan_id:0 vrf_id:0 ri:0x7f0650a6f4f8, ri_id:0x40 phdl:0x8400004c, ref_cnt:1
              si:0x7f0650a73088, si_id:0x4013, di_id:0x5360
     ADJ:objid:78 {link_type:MPLS ifnum:0x37, si:0xa2000025, }
```

Fehlerbehebung bei Hardwareskalierung

Dieser Abschnitt enthält Informationen, die Sie zur Fehlerbehebung bei Ihrer Konfiguration verwenden können.

MPLS-Hardware-Syslogs

Wenn Ihnen eine bestimmte Ressource (z. B. MPLS-Labels) fehlt, werden SYSLOG-Meldungen vom System generiert.

Wichtige Punkte

- MPLS-LABEL wird zur **Label-Einstufung** verwendet. (Diese Ressource wird verwendet, wenn Präfixe von einem lokalen CE empfangen werden.)
- LSPA wird zur **Label-Erstellung** verwendet. (Diese Ressource wird verwendet, wenn Präfixe von einem Remote-PE abgerufen werden.)

MPLS-Protokollmeldung	Definition	Wiederherstellungsaktion
%FED_L3_ERRMSG-3-RSRC_ERR: Switch 1 R0/0: gefüttert: Zuweisung von Hardwareressourcen für **die fib-Eingabe**	Der für IP-Präfixe reservierten Hardware fehlt der Speicherplatz (EM oder	Führen Sie eine der folgenden Aktionen durch, um die Anzahl Präfixe zu reduzieren, die der

aufgrund von Hardwareressourcenerschöpfung fehlgeschlagen	TCAM).	**oder Remote-PE** erfasst: 1. Präfixe im CE zusammenfas 2. Ändern des Label-Zuweisungsmodus von pro Prä pro VRF
%FED_L3_ERRMSG-3-**mpls_out_of_resource**: Switch 1 R0/0: gefüttert: **Out-of-Resource für MPLS LABEL ENTRY**. Lokale Bezeichnung konnte nicht programmiert werden:8205 (8192/8192) in Hardware	**Lokale Labelzuweisung:** Der für lokale MPLS-Labels reservierten Hardware-Platz ist erschöpft (EM oder TCAM)	Führen Sie eine der folgenden Aktionen durch, um die Anzahl auf dem **lokalen PE** verwendet Tabellen zu reduzieren: 1. Präfixe auf lokalem CE oder lokalem PE zusammenfassen 2. Ändern des Label-Zuweisungsmodus von pro Prä pro VRF im lokalen PE
%FED_L3_ERRMSG-3-MPLS_LENTRY_PAUSE: Switch 1 R0/0: gefüttert: **kritischer Grenzwert für MPLS LABEL ENTRY-**Ressource **erreicht**. **Einträge erstellen PAUSED**.	**Lokale Label-Zuweisung:** Der für lokale MPLS-Labels reservierten Hardware ist kein Platz mehr vorhanden (EM oder TCAM)	Führen Sie eine der folgenden Aktionen durch, um die Anzahl auf dem **lokalen PE** verwendet Tabellen zu reduzieren: 1. Präfixe auf lokalem CE oder lokalem PE zusammenfassen 2. Ändern des Label-Zuweisungsmodus von pro Prä pro VRF im lokalen PE
%FED_L3_ERRMSG-3-mpls_out_of_resource: Switch 1 R0/0: gefüttert: **Out of Resource für MPLS LSPA**. **Die Hardware konnte nicht programmiert werden.**	**Remote-Label-Zuweisung:** Der für LSPA-Remote-Labels reservierten Hardware fehlt der Platz.	Führen Sie eine der folgenden Aktionen durch, um die Anzahl in **Remote-PE** verwendeten Ka zu reduzieren: 1. Präfixe an Remote-CE oder Remote-PE zusammenfassen 2. Ändern des Label-Zuweisungsmodus von "per pr in "per vrf" auf dem Remote-PE

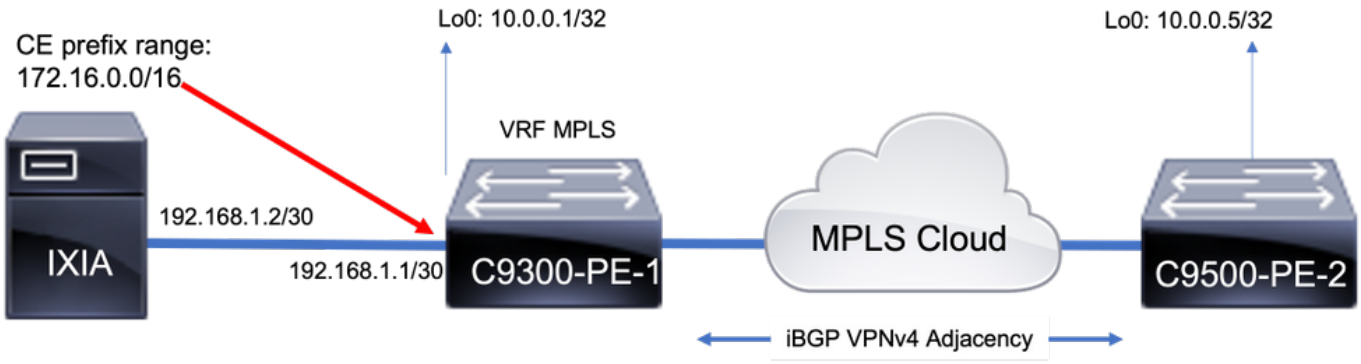
Befehle zur Hardwarevalidierung

show platform hardware-basiertes active fwd-asic resource tcam utilizationbefehl ist der erste Ort, an dem Sie prüfen möchten, ob ein Problem mit der Hardware-Skalierung vorliegt. Die Informationen werden auf ASIC-Basis angezeigt.

In diesem Abschnitt werden PE-Learning-Präfixe vom BGP in VRF-MPLS mit den hier beschriebenen Parametern angezeigt:

- Die standardmäßige Zuweisung pro Präfix wird verwendet.
- PE ist C9300-48U mit Cisco IOS-XE 17.3.4
- CE ist Ixia als BGP-Nachbar, der Präfixe an eine Schnittstelle in VRF-MPLS weitergibt.
- Die verwendete Präfixlänge ist /28. Daher verwendet die Plattform TCAM für Präfixlängen /31 oder kürzer
- Diese Plattform verwendet zunächst EM-Speicher für MPLS/BGP-Labels und überfließt dann zum TCAM, wenn das EM voll ist.

Topologie



Baseline-Ressourcennutzung

Vor dem Hinzufügen von Präfixen ist eine gewisse Basisnutzung vorhanden:

- Diese Baseline wurde nach der Bildung von MPLS-LDP-Nachbarn in einer globalen Tabelle verwendet.
- Von dieser Baseline aus werden VPNv4-Präfixe in VRF-MPLS hinzugefügt
- Ihre Basiszahlen können variieren. Es hängt davon ab, was bereits auf dem Switch programmiert ist.

> **Anmerkung:** In diesem Beispiel werden Präfixe von einer CE-PE-Seite hinzugefügt, was dazu führt, dass Ressourcen wie LSPA nur dem Remote-PE zugewiesen werden, der zur Erreichbarkeit einen Label-Stack verwenden muss. In realen Szenarien würde die Ressource auf beiden PE-Geräten zugewiesen.

```
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
```

> **Hinweis**: SI/RI/DI sind Ressourcen, die für das Umschreiben von Paketen, den Zielport usw. erforderlich sind. Zur Fehlerbehebung bei Problemen mit SI/DI/RI siehe Artikel Hardwareressourcen für Catalyst 9000-Switches verstehen

1000 BGP VPNv4-Präfixe hinzufügen

Neighbor (Ixia) wurde mit 1.000 Präfixen erweitert, die VRF MPLS vom CE hinzugefügt wurden

9300 Lokaler PE (mit CE verbunden)

```
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
```

Remote-PE-Router 9500H (über MPLS gelernt)

```
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)
```

Anmerkung: Allgemeine Informationen zum Catalyst 9000-TCAM oder Einzelheiten zur Überprüfung von TCAM auf andere Funktionen finden Sie im Artikel Hardwareressourcen für Catalyst 9000-Switches verstehen.

Anmerkung: ADJ (Adjacencies) sind eine gemeinsam genutzte Ressource. Zur Fehlerbehebung bei ADJ-Problemen lesen Sie den Artikel Hardwareressourcen für Catalyst 9000-Switches.

MPLS-Label und IPv4-Skalierungsbegrenzung und -Bereinigung

Wenn die MPLS-Funktion verwendet wird und zu viele Hardware-Ressourcen benötigt werden, kann in den meisten Fällen eine Änderung der Label-Zuweisung von (Standard) pro Präfix zu pro VRF hilfreich sein. In diesem Beispiel wird die Ressourcenzuweisung vor und nach (**in diesem Fall ist der 9500 das CE-PE-Gerät**) berücksichtigt.

```
### 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
```

Anmerkung: Die Ressourcenauslastung in der **Übersicht zu aktiven Multipls in der show plattformsoftware-basierten Switch-Übersicht** zeigt auch diese Reduzierung bei LABEL oder LSPA (je nachdem, was zutreffend ist).

Zu sammelnde Befehle für das TAC

Die häufigsten Hardwareressourcenprobleme im Zusammenhang mit MPLS werden in diesem Leitfaden mit geeigneten Abhilfemaßnahmen behandelt. Falls dieses Handbuch Ihr Problem jedoch nicht beheben konnte, sammeln Sie die angezeigte Befehlsliste und fügen Sie sie der Serviceanfrage hinzu.

```
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
```

Zugehörige Informationen

[Technischer Support und Dokumentation für Cisco Systeme]

[Multiprotocol Label Switching (MPLS) - Konfigurationsleitfaden, Cisco IOS XE Cupertino 17.7.x (Catalyst Switches der Serie 9300)]

Multiprotocol Label Switching (MPLS) - Konfigurationsleitfaden, Cisco IOS XE Cupertino 17.7.x (Catalyst Switches der Serie 9500)

Hardwareressourcen für Catalyst Switches der Serie 9000