通過TE隧道實施MPLS VPN

目錄

簡介

本文提供在MPLS網路中透過流量工程(TE)通道實作多重協定標籤交換(MPLS)VPN的組態範例。為了獲得通過TE隧道的MPLS VPN的優點，兩者應在網路中共存。本文檔說明了各種場景，解釋了通過TE隧道的MPLS VPN內的資料包轉發失敗的原因。它還提供了一種可能的解決方案。

必要條件

需求

本文檔的讀者應瞭解以下主題：

- MPLS流量工程和增強功能
- 配置基本MPLS VPN

採用元件

本文件所述內容不限於特定軟體和硬體版本。

慣例

如需文件慣例的詳細資訊，請參閱思科技術提示慣例。

背景理論

如本拓撲所示，在簡單的MPLS VPN配置中，提供商邊緣1(PE1)直接從PE2通過多協定邊界網關協定(MPBGP)獲取VPN字首172.16.13.0/24的VPN標籤（標籤1 [L1]），下一跳作為PE2環回地址。PE1還通過標籤分發協定(LDP)從下一跳P1獲取PE2環回地址的標籤(L2)。

將資料轉發到VPN字首172.16.13.13時，PE1使用標籤堆疊{L2 L1}，並將L2作為外部標籤。L2由傳輸標籤交換路由器(LSR)交換，P1。P2會彈出外部L2，並將資料包轉發到PE2，僅帶有一個L1。要更好地瞭解為什麼P2會彈出第2層，請參閱RFC 3031 中有關倒數第二跳彈出消息(PHP)的3.16節。因此，前往VPN IP第4版(IPv4)首碼172.16.13.0/24的封包會透過MPLS網路進行標籤交換。

如果任何P路由器收到帶有L1（VPN標籤）作為唯一外部標籤而不是{L2 L1}標籤堆疊的資料包，則MPLS VPN轉發操作失敗。發生這種情況的原因是，沒有一台P路由器在其標籤轉發資訊庫(LFIB)中包含L1以交換資料包。

MPLS TE使用資源保留協定(RSVP)來交換標籤。當路由器同時配置了TE和Tag Distribution Protocol(TDP)/LDP時，路由器會收到來自LDP和RSVP的指定字首的不同標籤。來自LDP和RSVP的標籤不必在所有情況下都相同。如果通過LDP介面獲知字首，路由器會在轉發表中安裝LDP標籤；如果通過TE隧道介面獲知字首，路由器會在轉發表中安裝RSVP標籤。

在普通TE通道的情況下（在通道上未啟用LDP/TDP），輸入LSR（在TE通道頭端的LSR）使用與通過TE通道學習的所有路由到達TE通道尾端的相同標籤。

例如，有一個從PE1到P2的TE隧道通過隧道學習字首10.11.11.11/32。P2上的隧道尾端是10.5.5.5,PE1中到達10.5.5.5的標籤是L3。然後，PE1使用L3到達目的地10.11.11.11/32，通過TE隧道獲知。

在上述場景中，當PE1和P2之間存在TE隧道時，考慮PE1將資料轉發到客戶邊緣2(CE2)。 如果L4是VPN標籤，則PE1轉發標籤堆疊為{L3 L4}的資料。P1會彈出L3,P2會收到帶有L4的資料包。PE2是唯一可以正確轉髮帶有外部標籤L4的資料包的LSR。P2沒有與PE2之間的MPBGP會話，因此它不會從PE2接收L4。因此，P2對L2一無所知，它會丟棄該資料包。

後面的配置和**show**輸出演示了這一點，並說明了此問題的一個可能的解決方案。

在CE1和CE2之間進行初始VPN設定，不使用TE隧道

拓撲

組態

此處僅包含組態檔的相關部分：

PE1

```
hostname PE1
ip cef
!
ip vrf aqua
 rd 100:1
 route-target export 1:1
 route-target import 1:1
!
mpls traffic-eng tunnels
!
interface Loopback0
 ip address 10.2.2.2 255.255.255.255
 no ip directed-broadcast
!
interface Ethernet2/0/1
 ip vrf forwarding aqua
 ip address 172.16.1.2 255.255.255.0
!
interface Ethernet2/0/2
 ip address 10.7.7.2 255.255.255.0
 ip router isis
 mpls traffic-eng tunnels
 tag-switching ip
!
router isis
```

```
 passive-interface Loopback0
 net 47.1234.2222.2222.2222.00
 is-type level-1
 metric-style wide
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-1
!
router bgp 1
 bgp log-neighbor-changes
 neighbor 10.11.11.11 remote-as 1
 neighbor 10.11.11.11 update-source Loopback0
 !
 address-family vpnv4
 neighbor 10.11.11.11 activate
 neighbor 10.11.11.11 send-community extended
 exit-address-family
 !
 address-family ipv4
 neighbor 10.11.11.11 activate
 no auto-summary
 no synchronization
 exit-address-family
 !
 address-family ipv4 vrf aqua
 redistribute connected
 no auto-summary
 no synchronization
 exit-address-family
```

PE2

```
hostname PE2
!
ip vrf aqua
 rd 100:1
 route-target export 1:1
 route-target import 1:1
!
mpls traffic-eng tunnels
!
interface Loopback0
 ip address 10.11.11.11 255.255.255.255
!
interface POS0/1
 ip address 10.12.12.10 255.255.255.0
 ip router isis
 mpls traffic-eng tunnels
 tag-switching ip
 crc 16
 clock source internal
!
interface POS5/1
 ip vrf forwarding aqua
 ip address 172.16.13.11 255.255.255.0
 crc 32
 clock source internal
!
router isis
 passive-interface Loopback0
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-1
 net 47.1234.1010.1010.1010.00
 is-type level-1
```

```
 metric-style wide
!
router bgp 1
 bgp log-neighbor-changes
 neighbor 10.2.2.2 remote-as 1
 neighbor 10.2.2.2 update-source Loopback0
 no auto-summary
 !
 address-family vpnv4
 neighbor 10.2.2.2 activate
 neighbor 10.2.2.2 send-community extended
 exit-address-family
 !
 address-family ipv4 vrf aqua
 redistribute connected
 no auto-summary
 no synchronization
 exit-address-family
!
```

驗證

PE2通過PE1和PE2之間的MPBGP對等獲知PE1 VPN IPv4字首172.16.1.0/24。如下所示：

```
PE2# show ip route vrf aqua
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 2 subnets
B       172.16.1.0 [200/0] via 10.2.2.2, 16:09:10
C       172.16.13.0 is directly connected, POS5/1
```

同樣，PE1通過PE1和PE2之間的MPBGP對等獲知PE2 VPN IPv4字首172.16.13.0/24。如下所示：

```
PE1# show ip route vrf aqua
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 2 subnets
B       172.16.13.0 [200/0] via 10.11.11.11, 16:09:49
C       172.16.1.0 is directly connected, Ethernet2/0/1

PE1# show ip route vrf aqua 172.16.13.13
Routing entry for 172.16.13.0/24
  Known via "bgp 1", distance 200, metric 0, type internal
  Last update from 10.11.11.11 16:13:19 ago
  Routing Descriptor Blocks:
  * 10.11.11.11 (Default-IP-Routing-Table), from 10.11.11.11, 16:13:19 ago
```

```
      Route metric is 0, traffic share count is 1
      AS Hops 0, BGP network version 0

PE1# show ip cef vrf aqua 172.16.13.13
172.16.13.0/24, version 11, cached adjacency 10.7.7.7
0 packets, 0 bytes
  tag information set
    local tag: VPN route head
    fast tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
  via 10.11.11.11, 0 dependencies, recursive
    next hop 10.7.7.7, Ethernet2/0/2 via 10.11.11.11/32
    valid cached adjacency
    tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
!--- The label stack used to reach 172.16.13.13 is !--- {17 12308}, where 17 is the outer label
to reach next hop 10.11.11.11 !--- and 12308 is the VPN IPv4 label for 172.16.13.0/24. PE1# show
ip cef 10.11.11.11
10.11.11.11/32, version 31, cached adjacency 10.7.7.7
0 packets, 0 bytes
  tag information set
    local tag: 21
    fast tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17}
  via 10.7.7.7, Ethernet2/0/2, 1 dependency
    next hop 10.7.7.7, Ethernet2/0/2
    valid cached adjacency
    tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17}
!--- Outer label 17 is used to reach next hop 10.11.11.11.
```

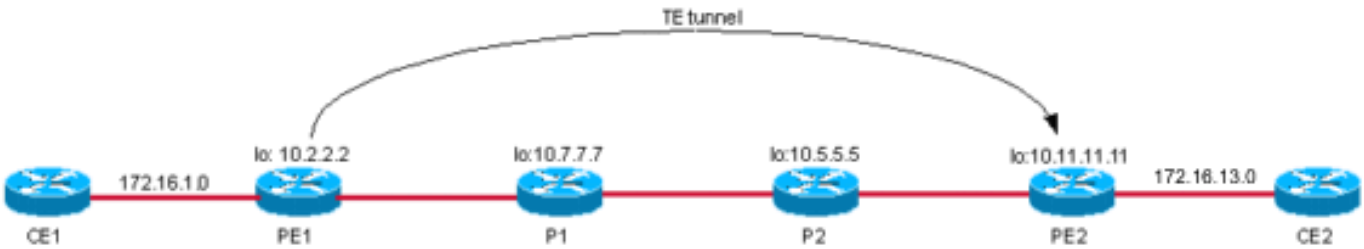
因此，CE1可以通過VPN路由和轉發(VRF)例項「aqua」到達CE2網路上的172.16.13.13，該例項在PE1上使用標籤堆疊{17 12308}進行配置，如上文所示。

此ping輸出可確認連線：

```
CE1# ping 172.16.13.13

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.13, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
```

案例1:TE隧道從PE1到PE2時，通過TE隧道的VPN

拓撲



在使用自動路由通告的PE路由器之間構建TE隧道時，可通過TE隧道介面訪問出口PE BGP下一跳。因此，PE1使用TE標籤到達PE2。

注意：MPLS TE獨立於LDP，這意味著如果您具有從PE到PE的隧道全網狀，則可以在路由器中有效地禁用LDP，並且不需要在TE隧道介面上運行LDP。但是，您必須建立到VPN版本4(VPNv4)路由

的BGP下一躍點的所有隧道。在此配置的示例中，您可以看到此BGP下一跳是PE2上的Loopback0(10.11.11.11)。此相同的環回也是從PE1到PE2的隧道的隧道目標。這說明了為什麼在本示例中，如果返回流量也存在從PE2到PE1的隧道，則可以禁用核心中的LDP。然後，從CE到CE的轉發適用於通過TE隧道傳輸的所有VPNv4流量。如果BGP下一躍點與TE隧道目標不同，LDP必須在核心和TE隧道上運行。

組態

PE1上用於建立PE隧道的額外配置如下所示：

PE1

```
PE1# show run interface tunnel 0
!
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 no ip route-cache distributed
 tunnel destination 10.11.11.11
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng path-option 10 dynamic
end
```

驗證

```
PE1# show ip cef vrf aqua 172.16.13.13
172.16.13.0/24, version 11
0 packets, 0 bytes
  tag information set
    local tag: VPN route head
    fast tag rewrite with Tu0, point2point, tags imposed {19 12308}
  via 10.11.11.11, 0 dependencies, recursive
    next hop 10.11.11.11, Tunnel0 via 10.11.11.11/32
    valid adjacency
    tag rewrite with Tu0, point2point, tags imposed {19 12308}
!--- The label stack to reach 172.16.13.13 is {19 12308}. !--- BGP next hop for the VPNv4 prefix
is 10.11.11.11, which is !--- the same as the TE tunnel destination. PE1# show ip route
10.11.11.11
Routing entry for 10.11.11.11/32
  Known via "isis", distance 115, metric 40, type level-1
  Redistributing via isis
  Last update from 10.11.11.11 on Tunnel0, 00:02:09 ago
  Routing Descriptor Blocks:
  * 10.11.11.11, from 10.11.11.11, via Tunnel0
!--- The route is via Tunnel0. Route metric is 40, traffic share count is 1
```

現在，確認用於通過Tunnel0到達下一跳10.11.11.11的外部標籤。

```
PE1# show mpls traffic-eng tunnels tunnel 0

Name: PE1_t0                              (Tunnel0) Destination: 10.11.11.11
  Status:
    Admin: up         Oper: up     Path: valid       Signalling: connected

    path option 10, type dynamic (Basis for Setup, path weight 30)
```

```
  Config Parameters:
    Bandwidth: 0        kbps (Global)  Priority: 7  7   Affinity: 0x0/0xFFFF
    Metric Type: TE (default)
    AutoRoute:  enabled   LockDown: disabled  Loadshare: 0        bw-based
    auto-bw: disabled

  InLabel  :  -
  OutLabel : Ethernet2/0/2, 19
!--- Label 19 from RSVP is used to reach destination 10.11.11.11/32. RSVP Signalling Info: Src
10.2.2.2, Dst 10.11.11.11, Tun_Id 0, Tun_Instance 31 RSVP Path Info: My Address: 10.7.7.2
Explicit Route: 10.7.7.7 10.8.8.7 10.8.8.5 10.12.12.10 10.11.11.11 Record Route: NONE Tspec: ave
rate=0 kbits, burst=1000 bytes, peak rate=0 kbits RSVP Resv Info: Record Route: NONE Fspec: ave
rate=0 kbits, burst=1000 bytes, peak rate=Inf Shortest Unconstrained Path Info: Path Weight: 30
(TE) Explicit Route: 10.7.7.2 10.7.7.7 10.8.8.7 10.8.8.5 10.12.12.10 10.11.11.11 History:
Tunnel: Time since created: 17 hours, 17 minutes Time since path change: 32 minutes, 54 seconds
Current LSP: Uptime: 32 minutes, 54 seconds Prior LSP: ID: path option 10 [14] Removal Trigger:
tunnel shutdown
```

快速檢視此資訊的另一種方法是使用**show**命令中的輸出修改器，如下所示：

```
PE1# show mpls traffic-eng tunnels tunnel 0 | include Label
  InLabel  :  -
  OutLabel : Ethernet2/0/2, 19
!--- This is the label to reach 10.11.11.11.
```

檢視標籤堆疊。它是19，即TE標籤，用於通過Tunnel0將資料包轉發到下一跳10.11.11.0。

```
PE1# show tag forwarding-table 10.11.11.11 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
21     Pop tag     10.11.11.11/32    0          Tu0         point2point
        MAC/Encaps=14/18, MTU=1500, Tag Stack{19}, via Et2/0/2
        00603E2B02410060835887428847 00013000
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
PE1#
```

因此，PE1將標籤棧{19 12308}發往地址為172.16.13.13的資料包。P1交換標籤19。資料包到達P2,P2將彈出該外部標籤。然後，將資料包轉發到PE2，並且僅帶標籤12308。

在PE2上，接收帶有標籤12308資料包，並根據轉發表中的資訊進行交換。如下所示：

```
PE2# show tag for tags 12308 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
12308  Aggregate   172.16.13.0/24[V]  12256
        MAC/Encaps=0/0, MTU=0, Tag Stack{}
        VPN route: aqua
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
PE2#
```

注意：未顯示，因為傳出標籤是Aggregate。這是因為與標籤關聯的字首是直連路由。

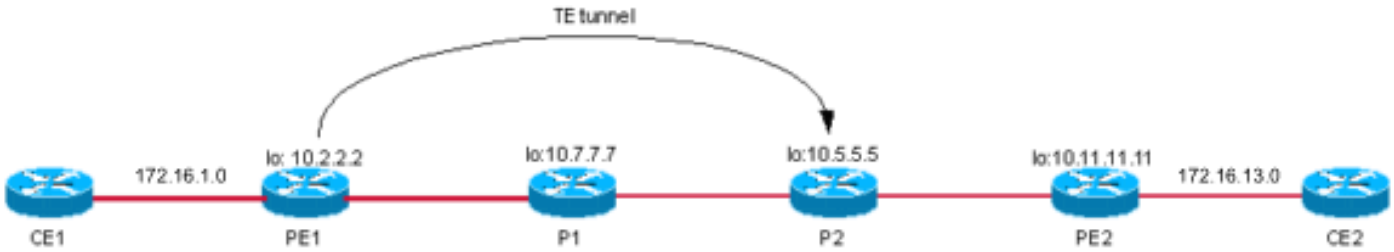
從CE1 ping CE2上的主機，確認通過TE隧道的VPN連線：

```
CE1# ping  172.16.13.13

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.13, timeout is 2 seconds:
```

```
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/13/36 ms
CE1#
```

案例2:TE通道從PE1到P2時，通過TE通道的VPN

拓撲



組態

PE1上基本配置之外的其他TE配置如下所示：

PE1

```
PE1# show run interface tunnel 0
!
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 no ip route-cache distributed
 tunnel destination 10.5.5.5
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng path-option 10 dynamic
end
!
```

驗證

檢查PE1 VRF水線上的字首172.16.13.13的路由。它使用標籤堆疊{19 12308}指向下一個躍點10.11.11.11/32（通過Tunnel0）。

```
PE1# show ip cef vrf aqua 172.16.13.13
172.16.13.0/24, version 11
0 packets, 0 bytes
  tag information set
    local tag: VPN route head
    fast tag rewrite with Tu0, point2point, tags imposed {19 12308}
  via 10.11.11.11, 0 dependencies, recursive
    next hop 10.5.5.5, Tunnel0 via 10.11.11.11/32
    valid adjacency
    tag rewrite with Tu0, point2point, tags imposed {19 12308}
PE1#
```

標籤19（外部標籤）用於到達下一跳10.11.11.11/32，如下所示：

```
PE1# show ip cef 10.11.11.11
10.11.11.11/32, version 37
0 packets, 0 bytes
  tag information set
    local tag: 21
    fast tag rewrite with Tu0, point2point, tags imposed {19}
  via 10.5.5.5, Tunnel0, 1 dependency
    next hop 10.5.5.5, Tunnel0
    valid adjacency
    tag rewrite with Tu0, point2point, tags imposed {19}

PE1# show mpls traffic-eng tunnels tunnel 0

Name: PE1_t0                              (Tunnel0) Destination: 10.5.5.5
  Status:
    Admin: up         Oper: up     Path: valid       Signalling: connected

    path option 10, type dynamic (Basis for Setup, path weight 20)

  Config Parameters:
    Bandwidth: 0        kbps (Global)  Priority: 7  7   Affinity: 0x0/0xFFFF
    Metric Type: TE (default)
    AutoRoute:  enabled   LockDown: disabled  Loadshare: 0        bw-based
    auto-bw: disabled

  InLabel  :  -
  OutLabel : Ethernet2/0/2, 19
  RSVP Signalling Info:
       Src 10.2.2.2, Dst 10.5.5.5, Tun_Id 0, Tun_Instance 33
    RSVP Path Info:
      My Address: 10.7.7.2
      Explicit Route: 10.7.7.7 10.8.8.7 10.8.8.5 10.5.5.5
      Record   Route:  NONE
      Tspec: ave rate=0 kbits, burst=1000 bytes, peak rate=0 kbits
    RSVP Resv Info:
      Record   Route:  NONE
      Fspec: ave rate=0 kbits, burst=1000 bytes, peak rate=Inf
  Shortest Unconstrained Path Info:
    Path Weight: 20 (TE)
    Explicit Route: 10.7.7.2 10.7.7.7 10.8.8.7 10.8.8.5
                    10.5.5.5
  History:
    Tunnel:
      Time since created: 17 hours, 31 minutes
      Time since path change: 8 minutes, 49 seconds
    Current LSP:
      Uptime: 8 minutes, 49 seconds
      Selection: reoptimation
    Prior LSP:
      ID: path option 10 [31]
      Removal Trigger: path verification failed
PE1#

PE1# show mpls traffic-eng tunnels tunnel 0 | i Label
  InLabel  :  -
  OutLabel : Ethernet2/0/2, 19
PE1#
```

來自PE1的封包透過標籤堆疊{19 12308}的TE通道傳送。P1收到封包後，會彈出(PHP)標籤19，並傳送標籤堆疊{12308}的封包。show命令可確認這點：

```
P1> show tag for tag 19
```

```
Local  Outgoing    Prefix           Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id     switched   interface
19     Pop tag     10.2.2.2 0 [33]  2130       Et2/0      10.8.8.5
P1>

P1> show tag for tag 19 detail
Local  Outgoing    Prefix           Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id     switched   interface
19     Pop tag     10.2.2.2 0 [33]  2257       Et2/0      10.8.8.5
       MAC/Encaps=14/14, MTU=1504, Tag Stack{}
       006009E08B0300603E2B02408847
       No output feature configured
P1>
```

P2收到標籤堆疊為{12308}的資料包時，會檢查其LFIB並丟棄該資料包，因為不存在匹配項。以下是P2上的**show**命令輸出：

```
P2# show tag forwarding-table tags 12308 detail
Local  Outgoing    Prefix           Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id     switched   interface
P2#

P2#
7w4d: TAG: Et0/3: recvd: CoS=0, TTL=253, Tag(s)=12308
7w4d: TAG: Et0/3: recvd: CoS=0, TTL=253, Tag(s)=12308
7w4d: TAG: Et0/3: recvd: CoS=0, TTL=253, Tag(s)=12308
7w4d: TAG: Et0/3: recvd: CoS=0, TTL=253, Tag(s)=12308
P2#
P2#
```

說明

此問題的解決方法是在TE隧道上啟用TDP/LDP，並使其成為標籤交換介面。在解決方案所示的示例中，在PE1的Tunnel0上啟用了TDP。P2配置為接受定向hello並形成定向TDP鄰居。因此，PE1通過LDP從P2接收10.11.11.11的標籤。現在Tunnel0成為標籤交換介面，並且TDP已經對通往10.11.11.11的流量啟用，PE1使用這兩個標籤；本發明利用RSVP標籤到達TE尾端，TDP標籤到達10.11.11.11。

在此方案中，如果以下專案為真，PE1使用標籤堆疊{L2 L3 L1}將資料轉發到CE2:

- L1是VPN標籤。
- L2是到達TE尾端的RSVP標籤。
- L3是到達10.11.11.11的TDP標籤（從P2接收）。

解決方案

解決方式為透過TE通道啟用TDP。

組態

此處顯示的是已啟用TDP的PE1上的TE隧道配置。新增加的產品是粗體的。

PE1

```
PE1# show run interface tunnel 0
!
```

```
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 no ip route-cache distributed
 tag-switching ip
!--- This enables TDP. tunnel destination 10.5.5.5
tunnel mode mpls traffic-eng tunnel mpls traffic-eng
autoroute announce tunnel mpls traffic-eng path-option
10 dynamic end !
```

以下是TE通道尾端上接受定向TDP hello的額外配置：

```
P2# show run | i directed-hello
tag-switching tdp discovery directed-hello accept
!--- This configures P2 to accept directed TDP hellos. P2#
```

驗證

```
PE1# show tag tdp neighbor | i Peer
    Peer TDP Ident: 10.7.7.7:0; Local TDP Ident 10.2.2.2:0
    Peer TDP Ident: 10.5.5.5:0; Local TDP Ident 10.2.2.2:0

PE1#
PE1# show ip cef vrf aqua 172.16.13.13
172.16.13.0/24, version 11
0 packets, 0 bytes
  tag information set
    local tag: VPN route head
    fast tag rewrite with Tu0, point2point, tags imposed {19 18 12308}
  via 10.11.11.11, 0 dependencies, recursive
    next hop 10.5.5.5, Tunnel0 via 10.11.11.11/32
    valid adjacency
    tag rewrite with Tu0, point2point, tags imposed {19 18 12308}
PE1#

PE1# show mpls traffic-eng tunnels tunnel 0 | i Label
  InLabel  :  -
  OutLabel : Ethernet2/0/2, 19
!--- This is the TE label learned via RSVP. PE1# PE1# show tag tdp bind 10.11.11.11 32
  tib entry: 10.11.11.11/32, rev 20
        local binding:  tag: 21
        remote binding: tsr: 10.7.7.7:0, tag: 17
        remote binding: tsr: 10.5.5.5:0, tag: 18
!--- This is the TDP label from P2.
```

P1收到標籤堆疊為{19 18 12308}的資料包時，它會彈出標籤19，並將標籤堆疊為{18 12308}的資料包傳送到P2。P2檢查其LFIB中的標籤18，然後彈出該標籤，並通過傳出介面PO2/0/0將其傳送到PE1。PE1收到標籤為12308的資料包，並成功將其切換到CE2。

```
P2# show tag for tag 18
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
18     Pop tag     10.11.11.11/32    117496     POS2/0/0    point2point

P2# show tag tdp discovery
 Local TDP Identifier:
    10.5.5.5:0
    Discovery Sources:
    Interfaces:
```

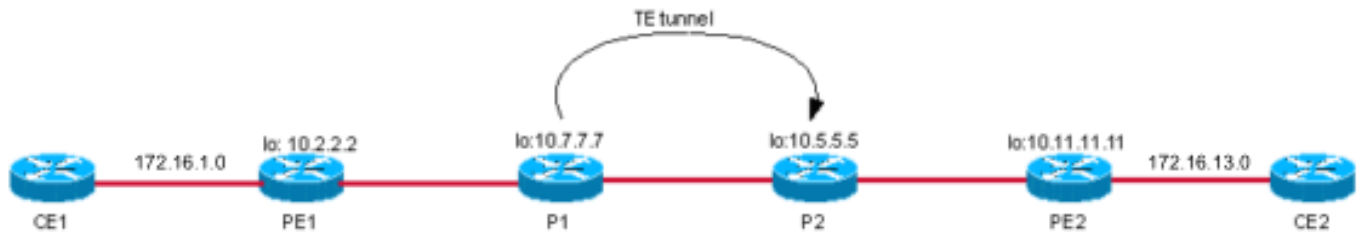
```
        Ethernet0/3 (tdp): xmit/recv
            TDP Id: 10.7.7.7:0
        POS2/0/0 (tdp): xmit/recv
            TDP Id: 10.11.11.11:0
    Directed Hellos:
        10.5.5.5 -> 10.2.2.2 (tdp): passive, xmit/recv
            TDP Id: 10.2.2.2:0

P2# show tag tdp neighbor 10.2.2.2
    Peer TDP Ident: 10.2.2.2:0; Local TDP Ident 10.5.5.5:0
        TCP connection: 10.2.2.2.711 - 10.5.5.5.11690
        State: Oper; PIEs sent/rcvd: 469/465; Downstream
        Up time: 01:41:08
        TDP discovery sources:
          Directed Hello 10.5.5.5 -> 10.2.2.2, passive
        Addresses bound to peer TDP Ident:
          10.7.7.2        172.16.47.166   10.2.2.2

PE1# show tag tdp neighbor 10.5.5.5
    Peer TDP Ident: 10.5.5.5:0; Local TDP Ident 10.2.2.2:0
        TCP connection: 10.5.5.5.11690 - 10.2.2.2.711
        State: Oper; PIEs sent/rcvd: 438/441; Downstream
        Up time: 01:35:08
        TDP discovery sources:
          Directed Hello 10.2.2.2 -> 10.5.5.5, active
!--- This indicates the directed neighbor. Addresses bound to peer TDP Ident: 10.5.5.5
10.12.12.5 10.8.8.5 PE1# show ip route 10.11.11.11
Routing entry for 10.11.11.11/32
  Known via "isis", distance 115, metric 40, type level-1
  Redistributing via isis
B  Last update from 10.5.5.5 on Tunnel0, 01:52:21 ago
  Routing Descriptor Blocks:
  * 10.5.5.5, from 10.11.11.11, via Tunnel0
      Route metric is 40, traffic share count is 1
```

從CE1向CE2上的主機發出ping命令可確認該解決方案。

```
CE1# ping 172.16.13.13

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.13, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
CE1#
```

案例3:未啟用TDP/LDP時，通過P1到P2的TE隧道在CE1和CE2之間建立VPN

拓撲



組態

PE1上的隧道配置如下所示：

PE1

```
P1# show run interface tunnel 0
Building configuration...

Current configuration : 255 bytes
!
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 ip route-cache distributed
 tunnel destination 10.5.5.5
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng path-option 10 dynamic
end
```

驗證

在此處檢驗目的地為CE2 172.16.13.13的資料包如何交換。**show ip cef**命令輸出顯示，前往目的地172.16.13.13的封包使用標籤堆疊{17 12308}交換：

```
PE1# show ip cef vrf aqua 172.16.13.13
172.16.13.0/24, version 18, cached adjacency 10.7.7.7
0 packets, 0 bytes
  tag information set
    local tag: VPN route head
    fast tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
  via 10.11.11.11, 0 dependencies, recursive
    next hop 10.7.7.7, Ethernet2/0/2 via 10.11.11.11/32
    valid cached adjacency
    tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
```

P1收到此資料包時，刪除外部標籤17，並在檢視IP路由表後將資料包切換到Tunnel0。注意此輸出中的`implicit-null OutLabel`;這意味著傳出介面不是標籤交換。

```
P1# show ip cef 10.11.11.11 detail
10.11.11.11/32, version 52
0 packets, 0 bytes
  tag information set
    local tag: 17
    fast tag rewrite with Tu0, point2point, tags imposed {}
  via 10.5.5.5, Tunnel0, 0 dependencies
    next hop 10.5.5.5, Tunnel0
    valid adjacency
    tag rewrite with Tu0, point2point, tags imposed {}

P1# show mpls traffic-eng tunnel tunnel 0 | i Label
  InLabel  :  -
  OutLabel : Ethernet2/0, implicit-null
P1# show tag for 10.11.11.11 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
```

```
tag     tag or VC   or Tunnel Id      switched   interface
17      Untagged    10.11.11.11/32    882        Tu0        point2point
        MAC/Encaps=14/14, MTU=1500, Tag Stack{}, via Et2/0
        006009E08B0300603E2B02408847
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P1# show ip route 10.11.11.11
Routing entry for 10.11.11.11/32
  Known via "isis", distance 115, metric 30, type level-1
  Redistributing via isis
  Last update from 10.5.5.5 on Tunnel0, 00:03:20 ago
  Routing Descriptor Blocks:
  * 10.5.5.5, from 10.11.11.11, via Tunnel0
      Route metric is 30, traffic share count is 1
```

P2收到帶有標籤12308的資料包後，會檢視其轉發表。因為P2無法感知來自CE2的12308標籤，所以它會丟棄資料包。

```
P2# show tag for tag 12308 detail
Local  Outgoing    Prefix           Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id     switched   interface
```

這將中斷發往CE2的VPN資料包的路徑。這由ping CE2 172.16.13.13/32確認。

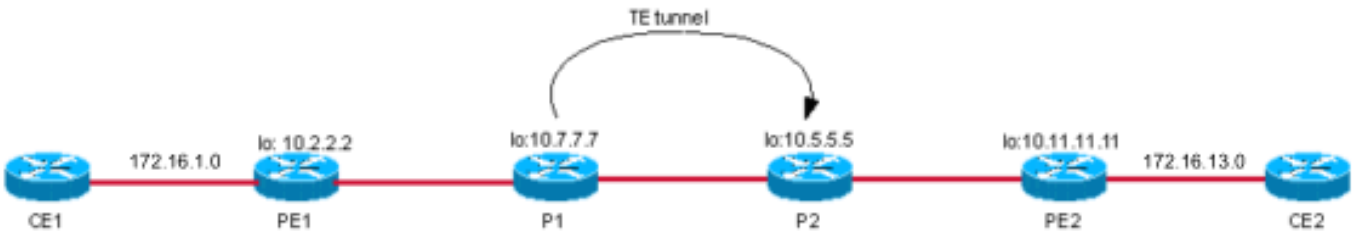
```
PE1#
CE1# ping 172.16.13.13

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.13, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
CE1#
```

解決方案

解決方案是通過隧道啟用LDP/TDP。下一部分將討論此解決方案。

案例4:啟用LDP的P1和P2之間的TE隧道上的VPN

拓撲



組態

在通道上啟用LDP後，P1上的配置如下圖所示。新增加的產品是粗體的。

PE1

```
P1# show run interface tunnel 0
Building configuration...

Current configuration : 273 bytes
!
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 ip route-cache distributed
 mpls label protocol ldp
 tunnel destination 10.5.5.5
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng path-option 10 dynamic
end
!
```

驗證

PE1將資料包傳送到帶有標籤堆疊{17 12308}的字首172.16.13.13/32。

```
PE1#
PE1# show tag for 10.11.11.11 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
21     17          10.11.11.11/32    0          Et2/0/2    10.7.7.7
        MAC/Encaps=14/18, MTU=1500, Tag Stack{17}
        00603E2B02410060835887428847 00011000
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

PE1#
PE1# show ip cef 10.11.11.11 detail
10.11.11.11/32, version 60, cached adjacency 10.7.7.7
0 packets, 0 bytes
  tag information set
    local tag: 21
    fast tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17}
  via 10.7.7.7, Ethernet2/0/2, 1 dependency
    next hop 10.7.7.7, Ethernet2/0/2
    valid cached adjacency
    tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17}

PE1# show ip cef vrf aqua 172.16.13.13
172.16.13.0/24, version 18, cached adjacency 10.7.7.7
0 packets, 0 bytes
  tag information set
    local tag: VPN route head
    fast tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
  via 10.11.11.11, 0 dependencies, recursive
    next hop 10.7.7.7, Ethernet2/0/2 via 10.11.11.11/32
    valid cached adjacency
    tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
```

P1收到標籤堆疊為{17 12308}的資料包，並在其LFIB中查詢標籤17。

```
P1# show tag for tag 17 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
```

```
tag     tag or VC   or Tunnel Id      switched   interface
17      18          10.11.11.11/32    1158       Tu0        point2point
        MAC/Encaps=14/18, MTU=1496, Tag Stack{18}, via Et2/0
        006009E08B0300603E2B02408847 00012000
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P1#

P1# show ip cef 10.11.11.11 detail
10.11.11.11/32, version 52
0 packets, 0 bytes
  tag information set
    local tag: 17
    fast tag rewrite with Tu0, point2point, tags imposed {18}
  via 10.5.5.5, Tunnel0, 0 dependencies
    next hop 10.5.5.5, Tunnel0
    valid adjacency
    tag rewrite with Tu0, point2point, tags imposed {18}
```

它顯示標籤17應交換為標籤18。因此，該封包透過標籤堆疊{18 12308}的通道介面進行交換。

P2透過其標籤堆疊{18 12308}的通道介面接收封包。它會彈出標籤18（因為這是倒數第二跳路由器），然後將資料包交換到PE2，並帶標籤12308。

```
P2# show tag for tag 18 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
18     Pop tag     10.11.11.11/32    127645     PO2/0/0    point2point
        MAC/Encaps=4/4, MTU=4474, Tag Stack{}
        0F008847
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P2#
```

PE2收到帶有12308標籤的資料包，該資料包成功交換到CE2。

```
PE2# show tag forwarding tags 12308 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
12308  Aggregate   172.16.13.0/24[V]  12256
        MAC/Encaps=0/0, MTU=0, Tag Stack{}
        VPN route: aqua
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
PE2#

CE1# ping 172.16.13.13

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.13, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
CE1#
```

案例5:在P1和PE2之間的隧道上的MPLS VPN

拓撲

組態

PE1
P1# **show run interface tunnel 0** Building configuration... Current configuration : 258 bytes ! interface Tunnel0 ip unnumbered Loopback0 no ip directed-broadcast ip route-cache distributed tunnel destination 10.11.11.11 tunnel mode mpls traffic-eng tunnel mpls traffic-eng autoroute announce tunnel mpls traffic-eng path-option 10 dynamic end

驗證

PE1將發往172.16.13.13的資料包傳送到帶有標籤堆疊{17 12308}的下一跳10.11.11。

```
PE1# show ip cef vrf aqua 172.16.13.13
172.16.13.0/24, version 18, cached adjacency 10.7.7.7
0 packets, 0 bytes
  tag information set
    local tag: VPN route head
    fast tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
  via 10.11.11.11, 0 dependencies, recursive
    next hop 10.7.7.7, Ethernet2/0/2 via 10.11.11.11/32
    valid cached adjacency
    tag rewrite with Et2/0/2, 10.7.7.7, tags imposed {17 12308}
```

P1收到標籤堆疊為{17 12308}的資料包。P1檢視其LFIB表並檢查標籤堆疊{17}，並將標籤為{17}的資料包切換到P2。

```
P1# show tag for 10.11.11.11 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
17     Untagged    10.11.11.11/32    411        Tu0         point2point
        MAC/Encaps=14/18, MTU=1500, Tag Stack{17}, via Et2/0
        006009E08B0300603E2B02408847 00011000
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
```

```
P1# show tag for tag 17 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
17     Untagged    10.11.11.11/32    685        Tu0        point2point
        MAC/Encaps=14/18, MTU=1500, Tag Stack{17}, via Et2/0
        006009E08B0300603E2B02408847 00011000
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
P1#

P1# show ip cef 10.11.11.11
10.11.11.11/32, version 67
0 packets, 0 bytes
  tag information set
    local tag: 17
    fast tag rewrite with Tu0, point2point, tags imposed {17}
  via 10.11.11.11, Tunnel0, 0 dependencies
    next hop 10.11.11.11, Tunnel0
    valid adjacency
    tag rewrite with Tu0, point2point, tags imposed {17}
```

P2收到標籤堆疊為{17 12308}的資料包。P2，即倒數第二跳路由器，彈出標籤17。

```
P2# show tag for tag 17 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
17     Pop tag     10.7.7.7 0 [5]    535        PO2/0/0    point2point
        MAC/Encaps=4/4, MTU=4474, Tag Stack{}
        0F008847
        No output feature configured
P2#
```

然後PE2收到帶有標籤的數12308包。P2知道標籤的目標是12308接的。因此，從CE1到CE2的ping為10。

```
PE2# show tag for tag 12308 detail
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
12308  Aggregate   172.16.13.0/24[V]  12776
        MAC/Encaps=0/0, MTU=0, Tag Stack{}
        VPN route: aqua
        No output feature configured
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
PE2#
```

注意：未顯示，因為傳出標籤是Aggregate。這是因為與標籤關聯的字首是直連路由。

```
CE1# ping 172.16.13.13

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.13.13, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
CE1#
```

已知的問題

請參閱現場通知：有關Cisco IOS®軟體的MPLS VPN with TE和MPLS InterAS建議，瞭解詳細資訊

。

結論

當在出口PE上終止TE隧道時，MPLS VPN和TE一起工作，無需任何額外配置。當在任何P路由器上終止TE隧道時（在核心中的PE之前），MPLS VPN流量轉發將失敗，因為到達時資料包的VPN標籤作為外部標籤，而外部標籤不在這些裝置的LFIB中。因此，這些中間路由器無法將資料包轉發到最終目的地VPN客戶網路。在這種情況下，應該在TE通道上啟用LDP/TDP來解決問題。

相關資訊

- 初學者常見問題
- 如何排除MPLS VPN故障
- 使用OSPF的MPLS基本流量工程配置示例
- 配置基本MPLS VPN
- 排除MPLS VPN中的LSP故障
- MPLS支援頁面
- 技術支援 - Cisco Systems