設定基於非路徑計算元件(PCE)的區域間分段路由流量工程(SR-TE)

目錄

簡介

本檔案將說明了解、設定和驗證沒有路徑計算元素控制器的區域間SR-TE的各個方面。

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必要條件

本檔案沒有先決條件。

需求

本文件沒有特定需求。

採用元件

本檔案中的資訊是根據Cisco IOS-XR®和IOS-XE®。

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

多域SR-TE簡介

分段路由流量工程(SR-TE)提供引導流量通過核心的功能，而不會在核心中形成任何狀態會話。SR-

TE策略表示為指定路徑的段清單，稱為段ID(SID)清單。不需要任何訊號，因為狀態在封包中，且支援SR的傳輸路由器會將SID清單作為一組指令處理。

傳統上，多域通過資源預留協定流量工程(RSVP-TE)來實現，通過在顯式路徑選項中使用鬆散的下一跳擴展。當執行計算時，管理員會建立一個路徑，在該路徑中，區域間網際網路協定(IP)地址定義鬆散，以允許通過約束最短路徑優先(CSPF)進行端到端計算。

SR-TE沒有鬆散下一跳的概念，因此對於多域計算，問題是如何執行此過程？計算是可能的，實際設計是放置一個集中控制器(XTC、WAE、NOS)以便執行相應的多域計算。將計算從頭端分流到頭端，將使裝置能夠計算路徑，而無需檢視整個拓撲。因為使用了路徑計算元素(PCE)實體，其理念是該實體具有域的完整可見性，執行計算並跟蹤所計算的LSP。

如果暫時無法設定控制器，並且需要在分段路由核心中進行多域計算，則我們可以執行不同的配置，以允許在區域間方案中建立隧道。

路徑型別

SR-TE允許我們定義多個路徑型別，通常稱為顯式路徑和動態路徑。對於動態路徑和顯式路徑，這是簡單的，我們讓SR-TE演算法根據動態條件來計算路徑，通常是TE或IGP度量到尾端。對於顯式路徑，我們可以定義多種型別，可以做的有很多：

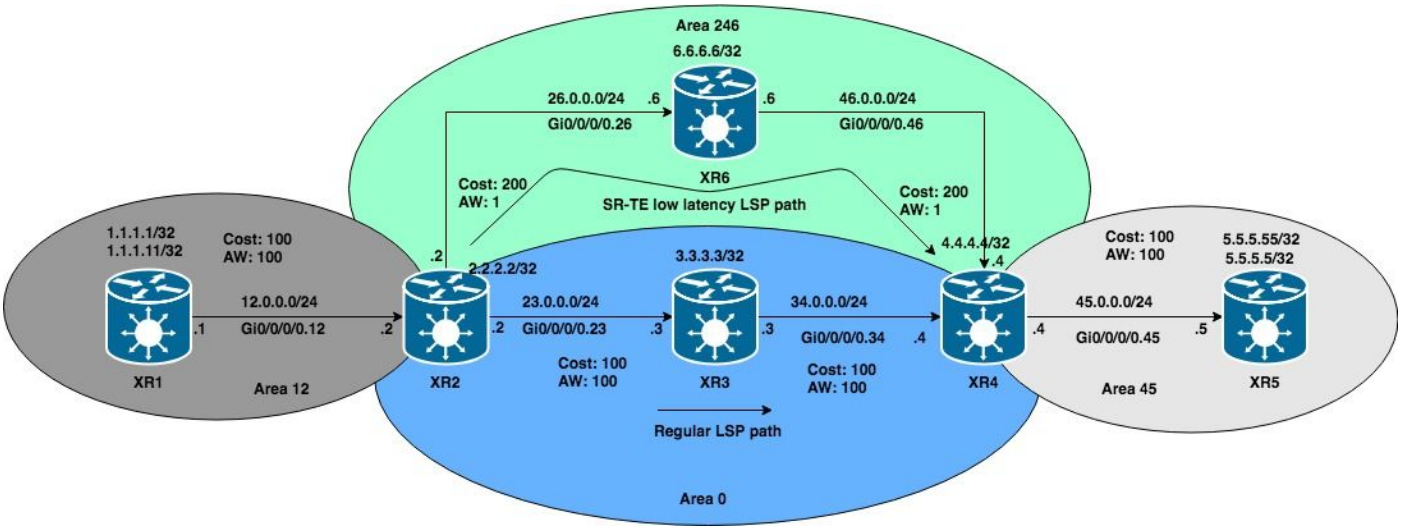
- 僅作為標籤的SID（僅限MPLS）
- 僅作為IPv6地址的SID（僅限SRv6）
- 具有可選SID的IPv4節點地址
- 具有可選SID的IPv6節點地址
- IPv4地址+具有可選SID的介面索引
- 具有可選SID的IPv4本地和遠端地址
- IPv6 +具有可選SID的介面索引
- 具有可選SID的IPv6本地和遠端地址

定義區域間SR-TE策略時，我們必須定義通往末端的顯式路徑，這是因為我們沒有拓撲的完整可視性。對於區域間SR-TE，我們需要按如下方式配置策略：

- 帶尾端SID標籤的顯式路徑
- 具有傳輸+ SID標籤的顯式路徑
- 具有本地IPv4地址+ SID標籤的顯式路徑

附註：如果需要動態區域間路徑選項，則 必須將路徑計算委託給PCE實體。

拓撲圖



在接下來的情況下，我們將使用此OSPF區域間拓撲，示例將基於嘗試計算跨越區域邊界的XR1到XR5的SR-TE隧道。

[擾流器](#)

附註：SR-TE的示例基於OSPF，但它也適用於IS-IS。

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初始配置

XR1

```
hostname XR1
icmp ipv4 rate-limit unreachable disable
interface Loopback0
 ipv4 address 1.1.1.1 255.255.255.255
!
interface Loopback1
 ipv4 address 1.1.1.11 255.255.255.255
!
interface GigabitEthernet0/0/0/0.12
 ipv4 address 12.0.0.1 255.255.255.0
 encapsulation dot1q 12
!
router ospf 1
 router-id 1.1.1.1
 segment-routing mpls
 segment-routing forwarding mpls
 segment-routing sr-prefer
 address-family ipv4
 area 12
  mpls traffic-eng
  interface Loopback0
   prefix-sid index 1
  !
  interface Loopback1
   prefix-sid index 11
  !
  interface GigabitEthernet0/0/0/0.12
   cost 100
   network point-to-point
  !
 !
 mpls traffic-eng router-id Loopback0
```

```
!
mpls traffic-eng
 interface GigabitEthernet0/0/0/0.12
  admin-weight 100
 !
!
end
```

XR2

```
hostname XR2
logging console debugging
explicit-path identifier 4
 index 10 next-label 16004
!
interface Loopback0
 ipv4 address 2.2.2.2 255.255.255.255
!
interface GigabitEthernet0/0/0/0.12
 ipv4 address 12.0.0.2 255.255.255.0
 encapsulation dot1q 12
!
interface GigabitEthernet0/0/0/0.23
 ipv4 address 23.0.0.2 255.255.255.0
 encapsulation dot1q 23
!
interface GigabitEthernet0/0/0/0.26
 ipv4 address 26.0.0.2 255.255.255.0
 encapsulation dot1q 26
!
router ospf 1
 router-id 2.2.2.2
 segment-routing mpls
 segment-routing forwarding mpls
 segment-routing sr-prefer
 address-family ipv4
 area 0
  mpls traffic-eng
  interface Loopback0
   prefix-sid index 2
  !
  interface GigabitEthernet0/0/0/0.23
   cost 100
   network point-to-point
  !
 !
 area 12
  mpls traffic-eng
  interface GigabitEthernet0/0/0/0.12
   cost 100
   network point-to-point
  !
 !
 area 246
  mpls traffic-eng
  interface GigabitEthernet0/0/0/0.26
   cost 200
   network point-to-point
  !
 !
 mpls traffic-eng router-id Loopback0
!
mpls oam
!
```

```
mpls traffic-eng
 interface GigabitEthernet0/0/0/0.12
  admin-weight 100
 !
 interface GigabitEthernet0/0/0/0.23
  admin-weight 100
 !
 interface GigabitEthernet0/0/0/0.26
  admin-weight 1
 !
!
end
```

XR3

```
hostname XRv3
interface Loopback0
 ipv4 address 3.3.3.3 255.255.255.255
!
interface MgmtEth0/0/CPU0/0
 shutdown
!
interface GigabitEthernet0/0/0/0.23
 ipv4 address 23.0.0.3 255.255.255.0
 encapsulation dot1q 23
!
interface GigabitEthernet0/0/0/0.34
 ipv4 address 34.0.0.3 255.255.255.0
 encapsulation dot1q 34
!
router ospf 1
 router-id 3.3.3.3
 segment-routing mpls
 segment-routing forwarding mpls
 segment-routing sr-prefer
 address-family ipv4
 area 0
  mpls traffic-eng
  interface Loopback0
   prefix-sid index 3
  !
  interface GigabitEthernet0/0/0/0.23
   cost 100
   network point-to-point
  !
  interface GigabitEthernet0/0/0/0.34
   cost 100
   network point-to-point
  !
 !
 mpls traffic-eng router-id Loopback0
!
mpls oam
!
mpls traffic-eng
 interface GigabitEthernet0/0/0/0.23
  admin-weight 100
 !
 interface GigabitEthernet0/0/0/0.34
  admin-weight 100
 !
!
end
```

XR4

```
hostname XR4
interface Loopback0
 ipv4 address 4.4.4.4 255.255.255.255
!
interface GigabitEthernet0/0/0/0.34
 ipv4 address 34.0.0.4 255.255.255.0
 encapsulation dot1q 34
!
interface GigabitEthernet0/0/0/0.45
 ipv4 address 45.0.0.4 255.255.255.0
 encapsulation dot1q 45
!
interface GigabitEthernet0/0/0/0.46
 ipv4 address 46.0.0.4 255.255.255.0
 encapsulation dot1q 46
!
router ospf 1
 distribute bgp-ls
 router-id 4.4.4.4
 segment-routing mpls
 segment-routing forwarding mpls
 segment-routing sr-prefer
 address-family ipv4
 area 0
  mpls traffic-eng
  interface Loopback0
   prefix-sid index 4
  !
  interface GigabitEthernet0/0/0/0.34
   cost 100
   network point-to-point
  !
 !
 area 45
  mpls traffic-eng
  interface GigabitEthernet0/0/0/0.45
   cost 100
   network point-to-point
  !
 !
 area 246
  mpls traffic-eng
  interface GigabitEthernet0/0/0/0.46
   cost 200
   network point-to-point
  !
 !
 mpls traffic-eng router-id Loopback0
!
mpls oam
!
mpls traffic-eng
 interface GigabitEthernet0/0/0/0.34
  admin-weight 100
 !
 interface GigabitEthernet0/0/0/0.45
  admin-weight 100
 !
 interface GigabitEthernet0/0/0/0.46
  admin-weight 1
 !
```

```
!
end
```

XR5

```
hostname XRv5
interface Loopback0
 ipv4 address 5.5.5.5 255.255.255.255
!
interface Loopback1
 ipv4 address 5.5.5.55 255.255.255.255
!
interface GigabitEthernet0/0/0/0.45
 ipv4 address 45.0.0.5 255.255.255.0
 encapsulation dot1q 45
!
router ospf 1
 router-id 5.5.5.5
 segment-routing mpls
 segment-routing forwarding mpls
 segment-routing sr-prefer
 address-family ipv4
 area 45
  mpls traffic-eng
  interface Loopback0
   prefix-sid index 5
  !
  interface Loopback1
   prefix-sid index 55
  !
  interface GigabitEthernet0/0/0/0.45
   cost 100
   network point-to-point
  !
 !
 mpls traffic-eng router-id Loopback0
!
mpls oam
!
mpls traffic-eng
 interface GigabitEthernet0/0/0/0.45
  admin-weight 100
 !
!
end
```

XR6

```
hostname XR6
icmp ipv4 rate-limit unreachable disable
interface Loopback0
 ipv4 address 6.6.6.6 255.255.255.255
!
interface GigabitEthernet0/0/0/0.26
 ipv4 address 26.0.0.6 255.255.255.0
 encapsulation dot1q 26
!
interface GigabitEthernet0/0/0/0.46
 ipv4 address 46.0.0.6 255.255.255.0
 encapsulation dot1q 46
!
router ospf 1
 router-id 6.6.6.6
 segment-routing mpls
```

```
 segment-routing forwarding mpls
 segment-routing sr-prefer
 address-family ipv4
 area 246
  mpls traffic-eng
  interface Loopback0
   prefix-sid index 6
  !
  interface GigabitEthernet0/0/0/0.26
   cost 200
   network point-to-point
  !
  interface GigabitEthernet0/0/0/0.46
   cost 200
   network point-to-point
  !
 !
 mpls traffic-eng router-id Loopback0
!
mpls oam
!
mpls traffic-eng
 interface GigabitEthernet0/0/0/0.26
  admin-weight 1
 !
 interface GigabitEthernet0/0/0/0.46
  admin-weight 1
 !
!
end
```

OSPF域中的裝置已在它們之間構建LSP，我們可以檢查XR1到XR5之間的LSP來驗證這一點。

```
RP/0/0/CPU0:XR1#ping mpls ipv4 5.5.5.5/32 fec-type generic verbose
Sending 5, 100-byte MPLS Echos to 5.5.5.5/32, timeout is 2 seconds, send interval is 0 msec:
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 rx label, 'P' - no rx intf label prot,
'p' - premature termination of LSP, 'R' - transit router, 'I' - unknown upstream index, 'X' -
unknown return code, 'x' - return code 0 Type escape sequence to abort.
!      size 100, reply addr 45.0.0.5, return code 3
!      size 100, reply addr 45.0.0.5, return code 3
!      size 100, reply addr 45.0.0.5, return code 3
!      size 100, reply addr 45.0.0.5, return code 3
!      size 100, reply addr 45.0.0.5, return code 3

Success rate is 100 percent (5/5), round-trip min/avg/max = 1/6/10 ms
```

SR-TE策略配置

案例#1:具有尾端具有字首 — SID的顯式路徑的區域間服務請求SR-TE隧道

我們將從XR1建立SR-TE策略，以計算指向XR5 prefix-SID(對應於5.5.5.5/32)的路徑。字首5.5.5.5/32的索引已配置為5，這是我們將提供給PCALC以計算該路徑的唯一標籤。

附註：拓撲中的所有路由器都具有相同的SRGB塊。

```
explicit-path name CASE1
 index 10 next-label 16005
```

```
!
interface tunnel-te15
 ipv4 unnumbered Loopback0
 autoroute destination 5.5.5.5
 destination 5.5.5.5
 path-selection
  metric te
  segment-routing adjacency unprotected
 !
 path-option 1 explicit name CASE1 segment-routing
!
```

[擾流器]

附註：自動通告在區域間案例中不起作用。

附註：自動通告在區域間案例中不起作用。

驗證

當提供SID清單作為計算的輸入時，只驗證第一個標籤，如果滿足此條件，隧道將啟動。如果驗證通道，我們可以看到通道已啟動，且路由正在執行。

```
RP/0/0/CPU0:XR1#show mpls traffic-eng tunnels segment-routing p2p 15

Name: tunnel-te15  Destination: 5.5.5.5  Ifhandle:0x130
  Signalled-Name: XR1_t15
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 1, (Segment-Routing) type explicit CASE1 (Basis for Setup)
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 0 kbps  CT0
    Creation Time: Mon Nov 26 02:14:33 2018 (00:14:34 ago)
  Config Parameters:
    Bandwidth:        0 kbps (CT0) Priority:  7  7 Affinity: 0x0/0xffff
    Metric Type: TE (interface)
    Path Selection:
      Tiebreaker: Min-fill (default)
      Protection: Unprotected Adjacency
    Hop-limit: disabled
    Cost-limit: disabled
    Path-invalidation timeout: 10000 msec (default), Action: Tear (default)
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forward class: 0 (default)
    Forwarding-Adjacency: disabled
    Autoroute Destinations: 1
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Path Protection: Not Enabled
    BFD Fast Detection: Disabled
    Reoptimization after affinity failure: Enabled
    SRLG discovery: Disabled
  History:
    Tunnel has been up for: 00:04:43 (since Mon Nov 26 02:24:24 UTC 2018)
    Current LSP:
      Uptime: 00:04:43 (since Mon Nov 26 02:24:24 UTC 2018)
    Prior LSP:
      ID: 5 Path Option: 1
      Removal Trigger: tunnel shutdown

  Segment-Routing Path Info (OSPF 1 area 12)
```

```
    Segment0[Node]: 5.5.5.5, Label: 16005
Displayed 1 (of 1) heads, 0 (of 0) midpoints, 0 (of 0) tails
Displayed 1 up, 0 down, 0 recovering, 0 recovered heads
```

[擾流器]

注意：可以使用debug mpls traffic-eng path lookup 命令驗證PCALC事件。

注意：可以使用debug mpls traffic-eng path lookup命令驗證PCALC事件。
如果檢查全域RIB，可以看到經由通道介面15設定到5.5.5.5/32的路由。

```
RP/0/0/CPU0:XR1#show route 5.5.5.5
Routing entry for 5.5.5.5/32
  Known via "te-client", distance 2, metric 401 (connected)
  Installed Nov 26 02:24:24.336 for 00:07:03
  Routing Descriptor Blocks
    directly connected, via tunnel-te15
      Route metric is 401
  No advertising protos.
```

如果檢查LFIB，我們可以看到tunnel-te15已經安裝並準備進行轉發。

```
RP/0/0/CPU0:XR1#ping 5.5.5.5 source 1.1.1.1 repeat 100 size 1500

Type escape sequence to abort.
Sending 100, 1500-byte ICMP Echos to 5.5.5.5, timeout is 2 seconds:
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!
Success rate is 100 percent (100/100), round-trip min/avg/max = 9/12/19 ms

RP/0/0/CPU0:XR1#show mpls forwarding tunnels detail
Tunnel        Outgoing    Outgoing     Next Hop        Bytes
Name          Label       Interface                    Switched
------------- ----------- ------------ --------------- ------------
tt15          (SR) 16005       Gi0/0/0/0.12 12.0.0.2        150400
     Updated: Nov 26 02:24:24.357
     Version: 200, Priority: 2
     Label Stack (Top -> Bottom): { 16005 }
     NHID: 0x0, Encap-ID: N/A, Path idx: 0, Backup path idx: 0, Weight: 0
     MAC/Encaps: 18/22, MTU: 1500
     Packets Switched: 100

  Interface Name: tunnel-te15, Interface Handle: 0x00000130, Local Label: 24003
  Forwarding Class: 0, Weight: 0
  Packets/Bytes Switched: 100/150000
```

案例#2:區域間SR-TE隧道，具有本地具有IPv4地址的顯式路徑+字首SID

為區域間定義SR-TE策略時，我們可以選擇混合標籤和IPv4地址。為了使PCALC成功計算到末端的路徑，為計算提供的IPv4地址必須是區域的本地地址，而對於區域以外的元素，必須提供字首鄰接SID。

```
explicit-path name CASE2
 index 10 next-address strict ipv4 unicast 12.0.0.2
 index 20 next-label 16006
```

```
 index 50 next-label 16005
!
interface tunnel-te15
 ipv4 unnumbered Loopback0
 autoroute destination 5.5.5.5
 destination 5.5.5.5
 path-selection
  metric te
  segment-routing adjacency unprotected
 !
 path-option 1 explicit name CASE2 segment-routing
!
```

驗證

如前所述，我們已向PCALC指出路徑必須通過XR6(16006)，然後到達最終字首SID(16005)。 驗證隧道計算結果可以看出它是如何計算的。

```
RP/0/0/CPU0:XR1#show mpls traffic-eng tunnels segment-routing p2p 15

Name: tunnel-te15  Destination: 5.5.5.5  Ifhandle:0x130
  Signalled-Name: XR1_t15
  Status:
    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 1, (Segment-Routing) type explicit CASE2 (Basis for Setup)
    G-PID: 0x0800 (derived from egress interface properties)
    Bandwidth Requested: 0 kbps  CT0
    Creation Time: Mon Nov 26 02:14:33 2018 (00:40:44 ago)
  Config Parameters:
    Bandwidth:        0 kbps (CT0) Priority:  7  7 Affinity: 0x0/0xffff
    Metric Type: TE (interface)
    Path Selection:
      Tiebreaker: Min-fill (default)
      Protection: Unprotected Adjacency
    Hop-limit: disabled
    Cost-limit: disabled
    Path-invalidation timeout: 10000 msec (default), Action: Tear (default)
    AutoRoute: disabled  LockDown: disabled   Policy class: not set
    Forward class: 0 (default)
    Forwarding-Adjacency: disabled
    Autoroute Destinations: 1
    Loadshare:          0 equal loadshares
    Auto-bw: disabled
    Path Protection: Not Enabled
    BFD Fast Detection: Disabled
    Reoptimization after affinity failure: Enabled
    SRLG discovery: Disabled
  History:
    Tunnel has been up for: 00:08:47 (since Mon Nov 26 02:46:30 UTC 2018)
    Current LSP:
      Uptime: 00:00:10 (since Mon Nov 26 02:55:07 UTC 2018)
    Reopt. LSP:
      Last Failure:
        LSP not signalled, identical to the [CURRENT] LSP
        Date/Time: Mon Nov 26 02:52:43 UTC 2018 [00:02:34 ago]
    Prior LSP:
      ID: 9 Path Option: 1
      Removal Trigger: reoptimization completed

  Segment-Routing Path Info (OSPF 1 area 12)
```

```
    Segment0[Link]: 12.0.0.1 - 12.0.0.2, Label: 24001
    Segment1[Node]: 6.6.6.6, Label: 16006
    Segment2[Node]: 5.5.5.5, Label: 16005
Displayed 1 (of 1) heads, 0 (of 0) midpoints, 0 (of 0) tails
Displayed 1 up, 0 down, 0 recovering, 0 recovered heads
```

如果使用traceroute ，我們可以看到下一跳，我們實際上通過XR6。

```
RP/0/0/CPU0:XR1#traceroute 5.5.5.5 source 1.1.1.1

Type escape sequence to abort.
Tracing the route to 5.5.5.5

 1  12.0.0.2 [MPLS: Labels 16006/16005 Exp 0] 9 msec  0 msec  0 msec
 2  26.0.0.6 [MPLS: Label 16005 Exp 0] 0 msec  0 msec  0 msec
 3  46.0.0.4 [MPLS: Label 16005 Exp 0] 0 msec  9 msec  0 msec
 4  45.0.0.5 9 msec  *  9 msec
```

案例#3:區域間SR-TE隧道，具有本地具有IPv4地址的顯式路徑+字首 — SID次優路由

我們可能會遇到這樣的情況：定義字首SID，但形成次優或循環流量模式。在這種情況下，我們將建立此情境。

```
explicit-path name CASE3
 index 10 next-address strict ipv4 unicast 12.0.0.2
 index 20 next-label 16006
 index 30 next-label 16002
 index 40 next-label 16003
 index 50 next-label 16005
!
interface tunnel-te15
ipv4 unnumbered Loopback0
autoroute destination 5.5.5.5
destination 5.5.5.5
path-selection
metric te
segment-routing adjacency unprotected
!
path-option 1 explicit name CASE3 segment-routing
```

根據字首SID，我們可以看到流量應該通過XR6 -> XR2 -> XR3 -> XR5的字首SID。

```
RP/0/0/CPU0:XR1#show mpls traffic-eng tunnels segment-routing p2p 15

    Admin:    up Oper:   up   Path:  valid   Signalling: connected

    path option 1, (Segment-Routing) type explicit CASE3 (Basis for Setup)

<<Output omitted>>
  Segment-Routing Path Info (OSPF 1 area 12)
    Segment0[Link]: 12.0.0.1 - 12.0.0.2, Label: 24001
    Segment1[Node]: 6.6.6.6, Label: 16006
    Segment2[Node]: 2.2.2.2, Label: 16002
    Segment3[Node]: 3.3.3.3, Label: 16003
    Segment4[Node]: 5.5.5.5, Label: 16005
Displayed 1 (of 1) heads, 0 (of 0) midpoints, 0 (of 0) tails
```

如果我們追蹤到5.5.5.5/32的路徑，我們可以看到我們在XR2和XR6之間形成了一個環路，即使這是次優路徑，我們仍然可以路由到XR5.5.5.5/32，而不會出現問題，因為LSP設定正確。

```
RP/0/0/CPU0:XR1#traceroute 5.5.5.5 source 1.1.1.1


Type escape sequence to abort.
Tracing the route to 5.5.5.5

 1  12.0.0.2 [MPLS: Labels 16006/16002/16003/16005 Exp 0] 19 msec  19 msec  9 msec
 2  26.0.0.6 [MPLS: Labels 16002/16003/16005 Exp 0] 9 msec  9 msec  9 msec
 3  26.0.0.2 [MPLS: Labels 16003/16005 Exp 0] 9 msec  9 msec  9 msec
 4  23.0.0.3 [MPLS: Label 16005 Exp 0] 9 msec  9 msec  9 msec
 5  34.0.0.4 [MPLS: Label 16005 Exp 0] 9 msec  9 msec  9 msec
 6  45.0.0.5 9 msec  *  9 msec
```

摘要

在分段路由流量工程中建立不帶PCE的多域策略時，我們沒有完整的鏈路狀態資料庫檢視，因此，由於缺乏可視性，我們必須設定滿足特定路由要求的顯式路徑。區域間隧道是可能的，它將通過定義顯式路徑來實現，這些路徑具有IPv4地址、鄰接SID和/或本地區域的字首SID（具有傳輸裝置的字首SID和/或SR-TE策略的尾端）。其他顯式路徑定義將失敗。