1. **Cấu hình định tuyến đoạn cơ sở**

Ví dụ R1:

* **show mpls label table detail ( Hiển thị chi tiết bảng Nhãn MPLS)**

Table Label Owner State Rewrite

----- ------- ------------------------------- ------ -------

0 0 LSD(A) InUse Yes

0 1 LSD(A) InUse Yes

0 2 LSD(A) InUse Yes

0 13 LSD(A) InUse Yes

0 16000 OSPF(A):ospf-1 InUse No

(Lbl-blk SRGB, vers:0, (start\_label=16000, size=8000)

0 24000 OSPF(A):ospf-1 InUse Yes

(SR Adj Segment IPv4, vers:0, index=0, type=2, intf=Gi0/0/0/1, nh=10.1.3.3)

0 24001 OSPF(A):ospf-1 InUse Yes

(SR Adj Segment IPv4, vers:0, index=0, type=2, intf=Gi0/0/0/0, nh=10.1.2.2)

* **show mpls label range (Hiển thị phạm vi của không gian nhãn cục bộ MPLS)**

Range for dynamic labels: Min/Max: 24000/1048575

* **show mpls forwarding (Hiển thị chuyển tiếp MPLS)**

Local Outgoing Prefix Outgoing Next Hop Bytes

Label Label or ID Interface Switched

------ ----------- ------------------ ------------ --------------- ------------

16002 Pop SR Pfx (idx 2) Gi0/0/0/0 10.1.2.2 0

16003 Pop SR Pfx (idx 3) Gi0/0/0/1 10.1.3.3 0

16004 16004 SR Pfx (idx 4) Gi0/0/0/0 10.1.2.2 0

16004 SR Pfx (idx 4) Gi0/0/0/1 10.1.3.3 0

16005 16005 SR Pfx (idx 5) Gi0/0/0/0 10.1.2.2 0

16005 SR Pfx (idx 5) Gi0/0/0/1 10.1.3.3 0

16006 16006 SR Pfx (idx 6) Gi0/0/0/0 10.1.2.2 0

16006 SR Pfx (idx 6) Gi0/0/0/1 10.1.3.3 0

24000 Pop SR Adj (idx 0) Gi0/0/0/1 10.1.3.3 0

24001 Pop SR Adj (idx 0) Gi0/0/0/0 10.1.2.2 0

* **show mpls forwarding labels 16006 detail (Hiển thị chi tiết nhãn chuyển tiếp mpls 16006)**

Local Outgoing Prefix Outgoing Next Hop Bytes

Label Label or ID Interface Switched

------ ----------- ------------------ ------------ --------------- ------------

16006 16006 SR Pfx (idx 6) Gi0/0/0/0 10.1.2.2 0

Updated: Dec 3 15:52:47.065

Version: 34, Priority: 1

Label Stack (Top -> Bottom): { 16006 }

NHID: 0x0, Encap-ID: N/A, Path idx: 0, Backup path idx: 0, Weight: 0

MAC/Encaps: 4/8, MTU: 1500

Outgoing Interface: GigabitEthernet0/0/0/0 (ifhandle 0x01000018)

Packets Switched: 0

16006 SR Pfx (idx 6) Gi0/0/0/1 10.1.3.3 0

Updated: Dec 3 15:52:47.065

Version: 34, Priority: 1

Label Stack (Top -> Bottom): { 16006 }

NHID: 0x0, Encap-ID: N/A, Path idx: 1, Backup path idx: 0, Weight: 0

MAC/Encaps: 4/8, MTU: 1500

Outgoing Interface: GigabitEthernet0/0/0/1 (ifhandle 0x01000030)

Packets Switched: 0

Traffic-Matrix Packets/Bytes Switched: 0/0

* **Show cef 172.16.1.6/32 (Xác minh nội dung FIB của bộ định tuyến)**

172.16.1.6/32, version 50, labeled SR, internal 0x1000001 0x81 (ptr 0xde0bb30) [1], 0x0 (0xdfcd7a8), 0xa28 (0xe4dc268)

Updated Dec 3 15:54:39.415

remote adjacency to GigabitEthernet0/0/0/1

Prefix Len 32, traffic index 0, precedence n/a, priority 1

via 10.1.3.3/32, GigabitEthernet0/0/0/1, 6 dependencies, weight 0, class 0 [flags0x0]

path-idx 0 NHID 0x0 [0xebbe1d0 0x0]

next hop 10.1.3.3/32

remote adjacency

local label 16006 labels imposed {16006}

* **ping mpls nil-fec labels 16006 output interface gigabitEthernet 0/0/0/0 nexthop 10.1.2.2 (Ping tiền tố loopback SID cho một bộ định tuyến. Thay đổi giao diện đầu ra và next-hop cho phù hợp)**

Sending 5, 100-byte MPLS Echos with Nil FEC with labels [16006],

timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - time out,

'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 terminati on of LSP,

'R' - transit router, 'I' - unknown upstream index,

'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

!!!!!

Success rate is 100 **percent (5/5),** round-trip min/avg/ma x = 35/91/301 ms

* **trace mpls nil-fec labels 16006 output interface gigabitEthernet 0/0/0/0 nexthop 10.1.2.2 ( theo dõi mpls nhãn nil-fec giao diện đầu ra 16006 gigabitEthernet 0/0/0/0 nexthop 10.1.2.2)**

Tracing MPLS Label Switched Path with Nil FEC with labels [16006], 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 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.

0 10.1.2.1 MRU 1500 [Labels: 16006/explicit-null Exp: 0/0]

**L** 1 10.1.2.2 MRU 1500 [Labels: 16006/explicit-null Exp: 0/0] 30 ms

**D** 2 10.2.4.4 MRU 1500 [Labels: implicit-null/explicit-null Exp: 0/0] 30 ms

1. **Sử dụng các giá trị chỉ mục SID với các SRGB khác nhau trên tất cả các bộ định tuyến**

Ví dụ trên R1:

* **show mpls label table detail**

Table Label Owner State Rewrite

----- ------- ------------------------------- ------ -------

0 0 LSD(A) InUse Yes

0 1 LSD(A) InUse Yes

0 2 LSD(A) InUse Yes

0 13 LSD(A) InUse Yes

0 16000 OSPF(A):ospf-1 InUse No

(Lbl-blk SRGB, vers:0, (start\_label=16000, size=1000)

0 24000 OSPF(A):ospf-1 InUse Yes

(SR Adj Segment IPv4, vers:0, index=0, type=2, intf=Gi0/0/0/0, nh=10.1.2.2)

0 24001 OSPF(A):ospf-1 InUse Yes

(SR Adj Segment IPv4, vers:0, index=0, type=2, intf=Gi0/0/0/1, nh=10.1.3.3)

* show mpls label range

Range for dynamic labels: Min/Max: 24000/1048575

* **show mpls forwarding**

Local Outgoing Prefix Outgoing Next Hop Bytes

Label Label or ID Interface Switched

------ ----------- ------------------ ------------ --------------- ------------

16200 Pop SR Pfx (idx 200) Gi0/0/0/0 10.1.2.2 0

16300 Pop SR Pfx (idx 300) Gi0/0/0/1 10.1.3.3 0

16400 17400 SR Pfx (idx 400) Gi0/0/0/0 10.1.2.2 0

18400 SR Pfx (idx 400) Gi0/0/0/1 10.1.3.3 0

16500 17500 SR Pfx (idx 500) Gi0/0/0/0 10.1.2.2 0

18500 SR Pfx (idx 500) Gi0/0/0/1 10.1.3.3 0

16600 17600 SR Pfx (idx 600) Gi0/0/0/0 10.1.2.2 0

18600 SR Pfx (idx 600) Gi0/0/0/1 10.1.3.3 0

24000 Pop SR Adj (idx 0) Gi0/0/0/0 10.1.2.2 0

24001 Pop SR Adj (idx 0) Gi0/0/0/1 10.1.3.3 0

* **show mpls forwarding labels 16600 detail**

Local Outgoing Prefix Outgoing Next Hop Bytes

Label Label or ID Interface Switched

------ ----------- ------------------ ------------ --------------- ------------

16600 17600 SR Pfx (idx 600) Gi0/0/0/0 10.1.2.2 0

Updated: Dec 3 17:12:03.053

Version: 114, Priority: 1

Label Stack (Top -> Bottom): { 17600 }

NHID: 0x0, Encap-ID: N/A, Path idx: 0, Backup path idx: 0, Weight: 0

MAC/Encaps: 4/8, MTU: 1500

Outgoing Interface: GigabitEthernet0/0/0/0 (ifhandle 0x01000018)

Packets Switched: 0

18600 SR Pfx (idx 600) Gi0/0/0/1 10.1.3.3 0

Updated: Dec 3 17:12:03.053

Version: 114, Priority: 1

Label Stack (Top -> Bottom): { 18600 }

NHID: 0x0, Encap-ID: N/A, Path idx: 1, Backup path idx: 0, Weight: 0

MAC/Encaps: 4/8, MTU: 1500

Outgoing Interface: GigabitEthernet0/0/0/1 (ifhandle 0x01000030)

Packets Switched: 0

Traffic-Matrix Packets/Bytes Switched: 0/0

* **show ospf database opaque-area self-originate**

OSPF Router with ID (1.1.1.1) (Process ID 1)

Type-10 Opaque Link Area Link States (Area 0)

LS age: 603

Options: (No TOS-capability, DC)

LS Type: Opaque Area Link

Link State ID: 1.0.0.0

Opaque Type: 1

Opaque ID: 0

Advertising Router: 1.1.1.1

LS Seq Number: 80000001

Checksum: 0x58d1

Length: 28

MPLS TE router ID : 1.1.1.1

Number of Links : 0

LS age: 603

Options: (No TOS-capability, DC)

LS Type: Opaque Area Link

Link State ID: 1.0.0.6

Opaque Type: 1

Opaque ID: 6

Advertising Router: 1.1.1.1

LS Seq Number: 80000001

Checksum: 0xfd61

Length: 80

Link connected to Point-to-Point network

Link ID : 172.16.1.2

(all bandwidths in bytes/sec)

Interface Address : 10.1.2.1

Neighbor Address : 10.1.2.2

Admin Metric : 1

Maximum bandwidth : 125000000

IGP Metric : 1

Number of Links : 1

LS age: 603

Options: (No TOS-capability, DC)

LS Type: Opaque Area Link

Link State ID: 1.0.0.7

Opaque Type: 1

Opaque ID: 7

Advertising Router: 1.1.1.1

LS Seq Number: 80000001

Checksum: 0x72e7

Length: 80

Link connected to Point-to-Point network

Link ID : 172.16.1.3

(all bandwidths in bytes/sec)

Interface Address : 10.1.3.1

Neighbor Address : 10.1.3.3

Admin Metric : 1

Maximum bandwidth : 125000000

IGP Metric : 1

Number of Links : 1

LS age: 423

Options: (No TOS-capability, DC)

LS Type: Opaque Area Link

Link State ID: 4.0.0.0

Opaque Type: 4

Opaque ID: 0

Advertising Router: 1.1.1.1

LS Seq Number: 80000009

Checksum: 0x2981

Length: 60

Router Information TLV: Length: 4

Capabilities:

Graceful Restart Helper Capable

Stub Router Capable

Traffic Engineering enabled area

All capability bits: 0x70000000

Segment Routing Algorithm TLV: Length: 2

Algorithm: 0

Algorithm: 1

Segment Routing Range TLV: Length: 12

Range Size: 1000

SID sub-TLV: Length 3

Label: 16000

Node MSD TLV: Length: 2

Type: 1, Value 10

LS age: 598

Options: (No TOS-capability, DC)

LS Type: Opaque Area Link

Link State ID: 8.0.0.6

Opaque Type: 8

Opaque ID: 6

Advertising Router: 1.1.1.1

LS Seq Number: 80000003

Checksum: 0x585e

Length: 100

Extended Link TLV: Length: 76

Link-type : 1

Link ID : 172.16.1.2

Link Data : 10.1.2.1

Adj sub-TLV: Length: 7

Flags : 0x60

MTID : 0

Weight : 0

Label : 24000

Local-ID Remote-ID sub-TLV: Length: 8

Local Interface ID: 6

Remote Interface ID: 6

Remote If Address sub-TLV: Length: 4

Neighbor Address: 10.1.2.2

Link MSD sub-TLV: Length: 2

Type: 1, Value 10

LS age: 598

Options: (No TOS-capability, DC)

LS Type: Opaque Area Link

Link State ID: 8.0.0.7

Opaque Type: 8

Opaque ID: 7

Advertising Router: 1.1.1.1

LS Seq Number: 80000003

Checksum: 0xfdae

Length: 100

Extended Link TLV: Length: 76

Link-type : 1

Link ID : 172.16.1.3

Link Data : 10.1.3.1

Adj sub-TLV: Length: 7

Flags : 0x60

MTID : 0

Weight : 0

Label : 24001

Local-ID Remote-ID sub-TLV: Length: 8

Local Interface ID: 7

Remote Interface ID: 6

Remote If Address sub-TLV: Length: 4

Neighbor Address: 10.1.3.3

Link MSD sub-TLV: Length: 2

Type: 1, Value 10

* **show cef 172.16.1.6/32**

172.16.1.6/32, version 114, labeled SR, internal 0x1000001 0x81 (ptr 0xe16bc68))

Updated Dec 3 17:12:03.053

remote adjacency to GigabitEthernet0/0/0/0

Prefix Len 32, traffic index 0, precedence n/a, priority 1

via 10.1.2.2/32, GigabitEthernet0/0/0/0, 6 dependencies, weight 0, class 0 []

path-idx 0 NHID 0x0 [0xebbe2f0 0x0]

next hop 10.1.2.2/32

remote adjacency

local label 16600 labels imposed {17600}

via 10.1.3.3/32, GigabitEthernet0/0/0/1, 6 dependencies, weight 0, class 0 []

path-idx 1 NHID 0x0 [0xebbe380 0x0]

next hop 10.1.3.3/32

remote adjacency

local label 16600 labels imposed {18600}

* **ping mpls nil-fec labels 17600 output interface gigabitEthernet 0/0/0/0 nexthop 10.1.2.2**

Sending 5, 100-byte MPLS Echos with Nil FEC with labels [17600],

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.

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 145/159/195 ms

* **trace mpls nil-fec labels 17600 output interface gigabitEthernet 0/0/0/0 nexthop 10.1.2.2**

Tracing MPLS Label Switched Path with Nil FEC with labels [17600], timeout is 2s

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.

0 10.1.2.1 MRU 1500 [Labels: 17600/explicit-null Exp: 0/0]

**L** 1 10.1.2.2 MRU 1500 [Labels: 20600/explicit-null Exp: 0/0] 99 ms

**D** 2 10.2.4.4 MRU 1500 [Labels: implicit-null Exp: 0] 113 ms

1. **Kỹ thuật lưu lượng định tuyến phân đoạn theo Tunnels**

Ví dụ trên R1:

* **show mpls traffic-eng tunnels 0 detail**

Name: tunnel-te0 Destination: 172.16.1.6 Ifhandle:0x24

Signalled-Name: ios\_t0

Status:

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

path option 1, (Segment-Routing) type explicit SR-TE-PATH-1 (Basis for Setu)

G-PID: 0x0800 (derived from egress interface properties)

Bandwidth Requested: 0 kbps CT0

Creation Time: Sat Dec 3 18:07:56 2022 (00:01:27 ago)

Config Parameters:

Bandwidth: 0 kbps (CT0) Priority: 7 7 Affinity: 0x0/0xffff

Metric Type: TE (global)

Path Selection:

Tiebreaker: Min-fill (default)

Protection: any (default)

Hop-limit: disabled

Cost-limit: disabled

Delay-limit: disabled

Path-invalidation timeout: 10000 msec (default), Action: Tear (default)

AutoRoute: disabled LockDown: disabled Policy class: not set

Forward class: 0 (not enabled)

Forwarding-Adjacency: disabled

Autoroute Destinations: 0

Loadshare: 0 equal loadshares

Auto-bw: disabled

Auto-Capacity: Disabled:

Path Protection: Not Enabled

BFD Fast Detection: Disabled

Reoptimization after affinity failure: Enabled

SRLG discovery: Disabled

SNMP Index: 12

Binding SID: 24002

History:

Tunnel has been up for: 00:01:27 (since Sat Dec 03 18:07:56 UTC 2022)

Current LSP:

Uptime: 00:01:27 (since Sat Dec 03 18:07:56 UTC 2022)

Current LSP Info:

Instance: 2, Signaling Area: OSPF 1 area 0

Uptime: 00:01:27 (since Sat Dec 03 18:07:56 UTC 2022)

Soft Preemption: None

SRLGs: not collected

Path Info:

Segment-Routing Path Info (OSPF 1 area 0)

Segment0[Node]: 172.16.1.2, Label: 16200

Segment1[Node]: 172.16.1.3, Label: 17300

Segment2[Node]: 172.16.1.4, Label: 18400

Segment3[Node]: 172.16.1.5, Label: 19500

Segment4[Node]: 172.16.1.6, Label: 20600

Persistent Forwarding Statistics:

Out Bytes: 0

Out Packets: 0

Displayed 1 (of 1) heads, 0 (of 0) midpoints, 0 (of 0) tails

**Displayed 1 up, 0 down, 0 recovering, 0 recovered heads**

* **show mpls traffic-eng tunnels brief**

TUNNEL NAME DESTINATION STATUS STATE

tunnel-te0 172.16.1.6 up up

Displayed 1 (of 1) heads, 0 (of 0) midpoints, 0 (of 0) tails

**Displayed 1 up, 0 down, 0 recovering, 0 recovered heads**

* **show mpls traffic-eng tunnels summary \*\*\***

Path Selection Tiebreaker: Min-fill (default)

LSP Tunnels Process**: running**, **not registered with RSVP**

RSVP Process:  **running**

Forwarding:  **enabled**

Periodic reoptimization: every 3600 seconds, next in 3279 seconds

Periodic FRR Promotion: every 300 seconds, next in 290 seconds

Periodic auto-bw collection: 5 minute(s) (disabled)

Signalling Summary:

Head: 1 interfaces, 1 active signalling attempts, 1 established

1 explicit, 0 dynamic

1 activations, 0 deactivations

0 recovering, 0 recovered

Mids: 0

Tails: 0

Fast ReRoute Summary:

Head: 0 FRR tunnels, 0 protected, 0 rerouted

Mid: 0 FRR tunnels, 0 protected, 0 rerouted

Summary: 0 protected, 0 link protected, 0 node protected, 0 bw protected

Backup: 0 tunnels, 0 assigned

Interface: 0 protected, 0 rerouted

Bidirectional Tunnel Summary:

Tunnel Head: 0 total, 0 connected, 0 associated, 0 co-routed

Tunnel Tail: 0 total, 0 connected, 0 associated, 0 co-routed

LSPs Head: 0 established, 0 proceeding, 0 associated, 0 standby

LSPs Mid: 0 established, 0 proceeding, 0 associated, 0 standby

LSPs Tail: 0 established, 0 proceeding, 0 associated, 0 standby

GMPLS UNI Summary:

Heads: 0 up, 0 down

Tails: 0 up, 0 down

GMPLS NNI Summary:

Heads: 0 up, 0 down

Mids : 0 up, 0 down

Tails: 0 up, 0 down

* **ping 6.6.6.6 (Lo1 của R6)**

RP/0/RP0/CPU0:ios#ping 6.6.6.6

Sat Dec 3 18:14:16.229 UTC

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 6.6.6.6, timeout is 2 seconds:

!!!!!

Success rate is 100 percent (5/5), round-trip min/avg/max = 24/27/39 ms