SR Basic Principle

Foreword

- As a key technology of SDN, SR (Segment Routing) is also a key technology for simplified protocols advocated by IP networks. It is widely used in IP networks. The course will analyze the SR technology.

Objectives

- Upon completion of this course, you will be able to:
  - Describe the advantages of SR.
  - Describe the basic concepts and working principles of SR.

Contents

Introduzione – Source Routing

Per descrivere «Segment Routing» (SR) è necessario conoscere il «source routing»;

Source Routing

The ability for a node to **specify a unicast forwarding path**, other than the normal shortest path, that a particular packet will traverse.

Source

the point at which the explicit route is imposed.

Source routing is basically an option in IP (layer 3) where a packet can instruct a network which hops to send the packet to.

Introduzione – Source Routing

Source Routing è specificato in **RFC 791** (Internet Protocol);

Nel campo option è possibile specificare con due opzioni (3,9) se è realizzato in modo «Loose» o in modo «Strict»:

Loose

Loose Source Routing allows an originating system to list landmark routers that a datagram must visit on the way to its destination. In between these landmark routers, the datagram may be sent wherever the network tells it to go.

Strict

Strict Source Routing allows an originating system to list the specific routers that a datagram must visit on the way to its destination. No deviation from this list is allowed.

Introduzione – Source Routing

```
Frame 22398: 106 bytes on wire (848 bits), 106 bytes captured (848 bits)
Ethernet II, Src: 74:46:a0:ae:a3:c2 (74:46:a0:ae:a3:c2), Dst: 80:c1:6e:f1:a6:c0 (80:c1:6e:f1:a6:c0)
Internet Protocol, Src: 192.168.188.11 (192.168.188.11), Dst: 192.168.188.12 (192.168.188.12)
    Version: 4
    Header length: 28 bytes
    Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    Total Length: 92
    Identification: 0x21c4 (8644)
    Flags: 0x02 (Don't Fragment)
    Fragment offset: 0
    Time to live: 64
    Protocol: ICMP (1)
    Header checksum: 0x9749 [correct]
    Source: 192.168.188.11 (192.168.188.11)
    Destination: 192.168.188.12 (192.168.188.12)
    Options: (8 bytes)
        NOP
        Loose source route (7 bytes)
            Pointer: 4
            192.168.188.250 <- (current)
Internet Control Message Protocol
```

Introduzione – RSVP

RSVP – RFC 2205

- utilizzato da un host per richiedere alcune specifiche qualità di servizio dalla rete, per un data-stream;
- i router lo possono utilizzare per gestire le richieste QoS in tutti i nodi di un path interessato da un dato data-stream;
- le richieste RSVP fanno in modo che ogni nodo del path riservi delle risorse per un servizio;
- non trasporta dati a livello applicazione è un Internet Control Protocol in grado di cooperare con i protocolli di routing;

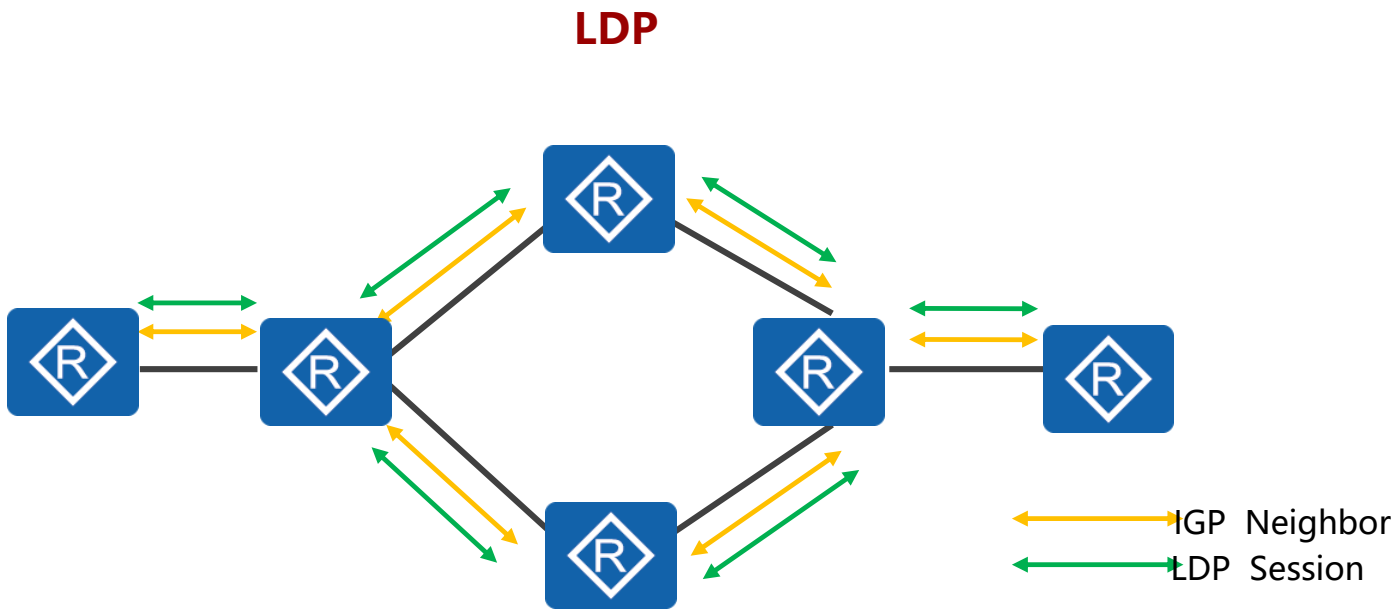
Introduzione – CSPF

CSPF

- Estensione di SPF che determina lo shortest-path sulla base di un insieme di vincoli;
  - Viene eseguito l’ algorirmo SPF dopo avere effettuato il pruning di tutti i percorsi che vìolano l’ insieme dei vincoli.
- Metriche utilizzate:
  - Richiesta di banda;
  - Limiti sul numero di nodi da attraversare;
  - Priorità dei Label Switching Paths;
  - Banda disponibile per link;
- Sorgenti di informazione:
  - Traffic Engineering Database (TED);

Contents

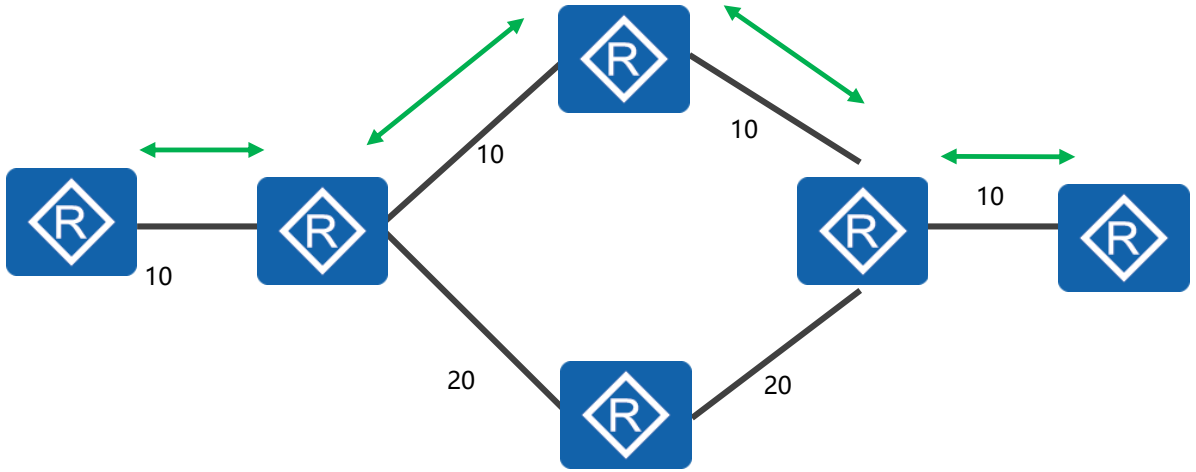
SR Background - Problems Faced by LDP



ECMP: Equal Cost Multi Path

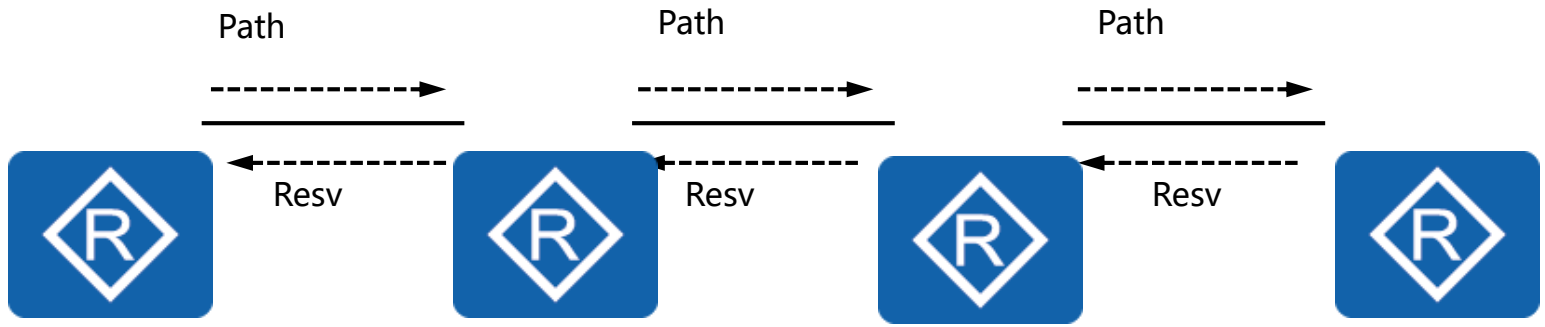
- LDP depends on IGP and uses local label switching to support ECMP.
- Disadvantages: LDP has 11 types of protocol packets, which greatly increase link bandwidth consumption and device CPU usage.

SR Background - Problems Faced by LDP



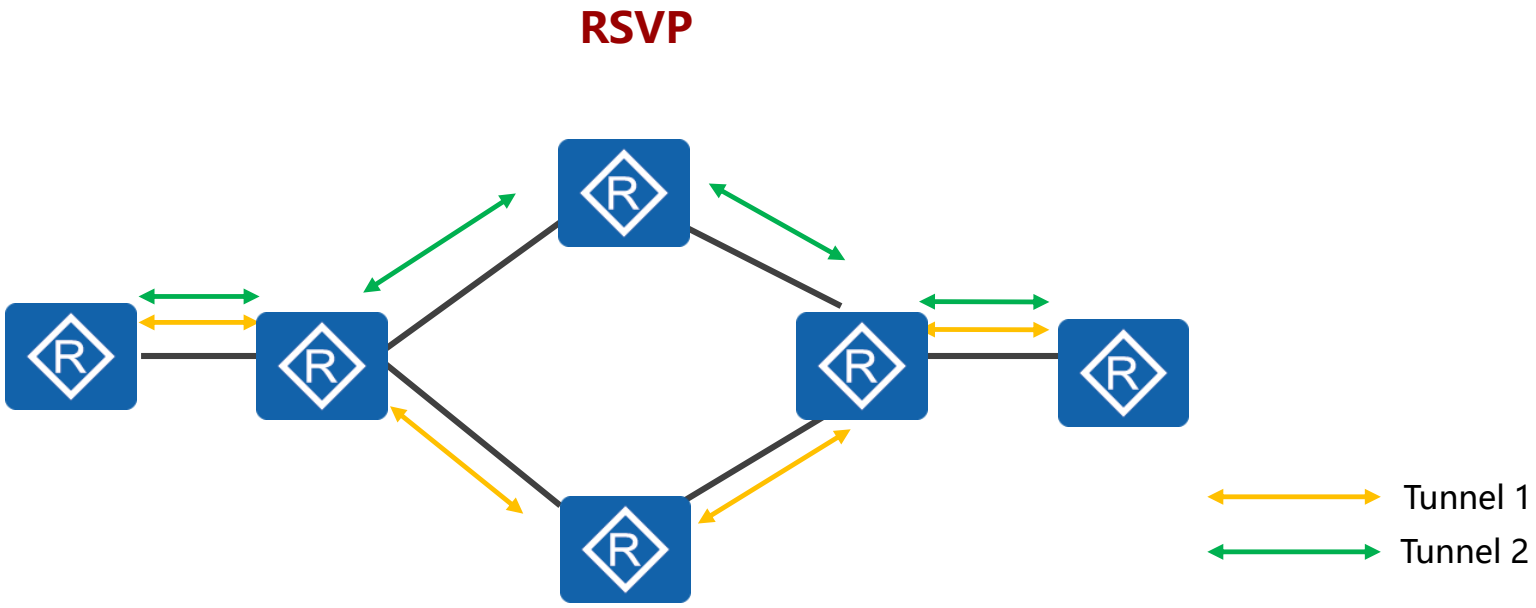
- LDP supports only the shortest IGP path (minimum cost) for path calculation. TE(Traffic Engineering) is not supported.

SR Background - Problems Faced by RSVP



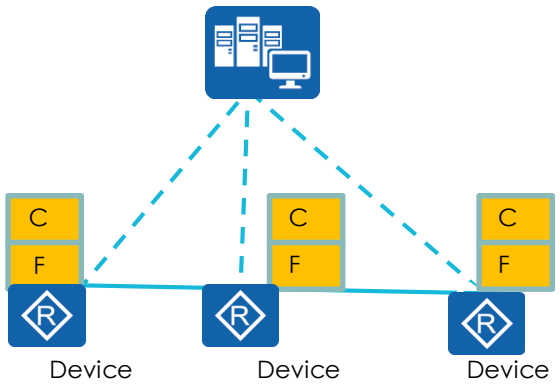
- RSVP creates an end-to-end LSP hop by hop based on the CSPF path calculation result. The label is a local label.
- Hop-by-hop, traversing nodes maintain the status of the tunnel. Even if SDN is used, the tunnel status needs to be maintained.
- RSVP TE configuration is complex.
- Complex ECMP implementation.
- Eight types of RSVP protocol packets occupy network bandwidth and CPU processing.

SR Background - Problems Faced by RSVP



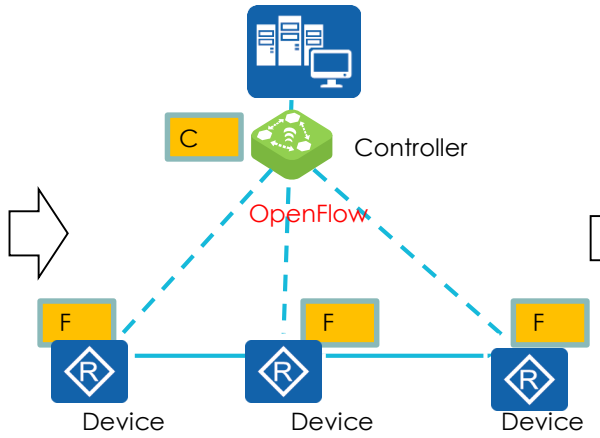
- RSVP is complex in load balancing and needs to be configured with multiple tunnels, which brings huge workload to configuration and maintenance.

SR Generation Background -SR Technology



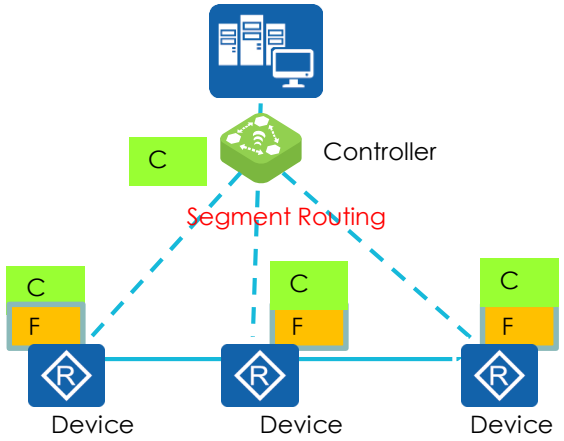
Traditional network

- The protocol evolution is slow. It takes several years from requirement submission to version release.
- The OPEX increases linearly with the scale.
- Lack of flexible deployment and use modes cannot meet service providers' requirements for fast network service deployment.



Revolutionary SDN network

- ~~Network faults can be rectified only when the controller is faulty. The reliability is poor.~~
- The number of flow tables on a large-scale network is large, and the flow table delivery rate has a performance bottleneck.
- It is a subversion of traditional networks and is not supported by equipment vendors and carriers.

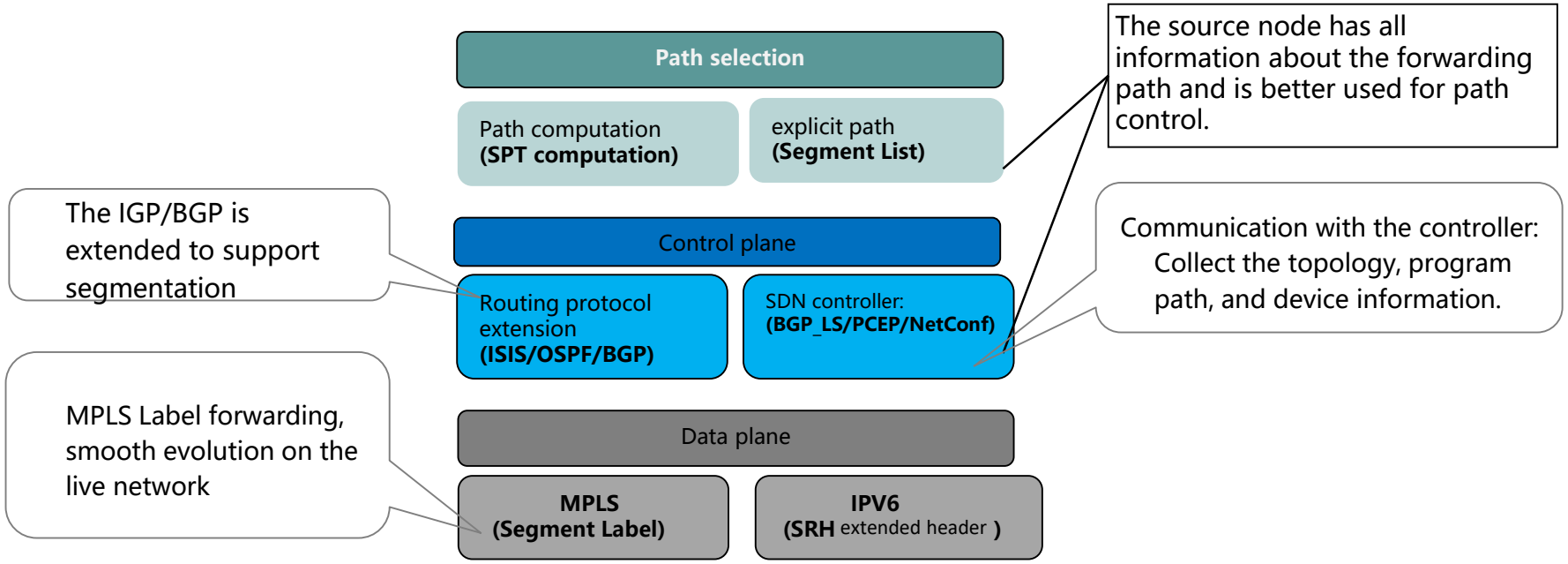


Incremental SDN network

- The existing protocols can be expanded to achieve better smooth evolution.
- Provides the balance between centralized control and distributed deployment.
- Uses the source routing technology to provide fast interaction between the network and upper-layer applications.

SR Background -SR Technical Framework

- SR is a technical solution of packet forwarding provided by adding a series of segment identifiers to a packet only on the source (an explicit path loading node) node



SR Background

Control Planes

Distributed Scenario

The segments are allocated and signaled by IS-IS or OSPF or BGP. A node individually decides to steer packets on an SR Policy. A node individually computes the SR Policy.

Centralized Scenario

The segments are allocated and instantiated by an SR controller. The SR controller decides which nodes need to steer which packets on which source-routed policies. The SR controller computes the source-routed policies. The SR architecture does not restrict how the controller programs the network.

SR Background

SR can be **directly applied to the MPLS architecture** with no change to the forwarding plane [SR-MPLS]. A segment is encoded as an MPLS label.

SR can be **applied to the IPv6 architecture** with a new type of routing header called the SR Header (SRH) [IPv6-SRH]. An instruction is associated with a segment and encoded as an IPv6 address. An SRv6 segment is also called an SRv6 SID. An SR Policy is instantiated as an ordered list of SRv6 SIDs in the routing header.

Contents

HUAWEI

SR Background

- Segment Routing (SR) is a flexible, scalable way of doing **source routing**.

Segment

an instruction a node executes on the incoming packet (e.g., forward packet according to shortest path to destination, or, forward packet through a specific interface, or, deliver the packet to a given application/service instance);

Un segmento può essere associato:

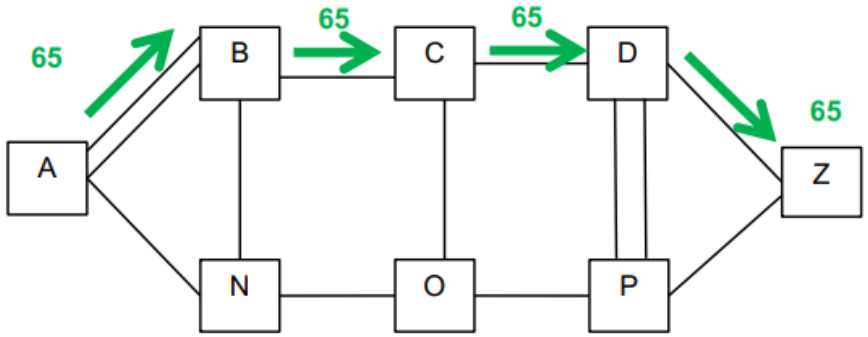
- ad una istruzione topologica locale o globale;
- ad una istruzione di servizio o QoS;

Basic Concepts of SR

- **SR Domain**:Segment Routing Domain.It indicates the set of SR nodes.
- **SID**: Segment ID. Segment Routing defines the destination address prefix / node and adjacency on the network as a segment and assigns segment IDs to these destination address prefixes / nodes and adjacencies. The segment ID is equivalent to the MPLS label in the traditional MPLS technology, and is mapped to the MPLS label at the forwarding plane.
- **SRGB**: Segment routing global block,Local tag set reserved for a global segment. In MPLS, SRGB is a set of local labels reserved for global labels. In IPv6, SRGB is a set of IPv6 addresses that have not been used globally.
- **Segment List**: It is a sort set of destination address prefix SID / node SID and adjacent SID ordered list, and is used to identify a complete label switching path LSP(Label Switched Path). In the MPLS architecture, the segment list is encapsulated in the packet header to guide forwarding.

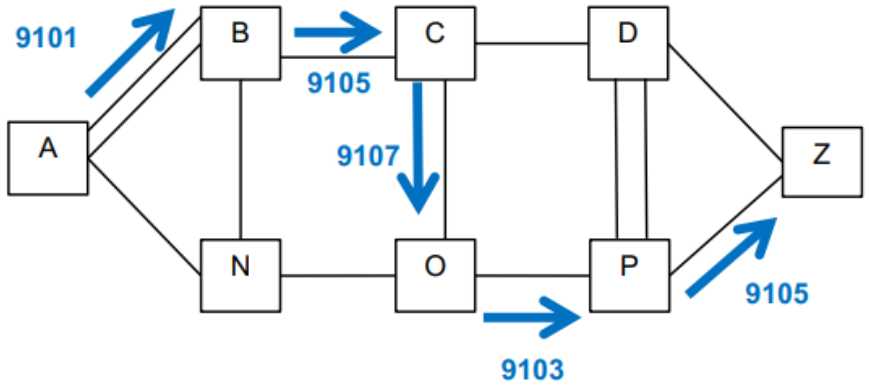
Segment

Prefix/Node SID



- Globally significant within SR domain
- Any node in SR domain can execute the associated instruction
- All nodes switch packet towards prefix/node via shortest path
- Advertised as a relative (index) value
- Make use of a per-node reserved block (SR Global Block or SRGB)

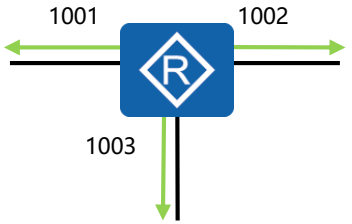
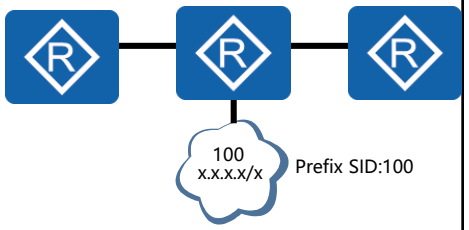
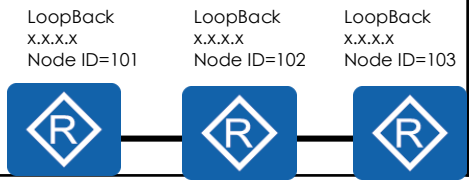
Adjacency SID



- Locally significant to node allocating it
- Node processes SID and switches packet towards adjacency
- Only originating node can execute the associated instruction
- Advertised as an absolute value

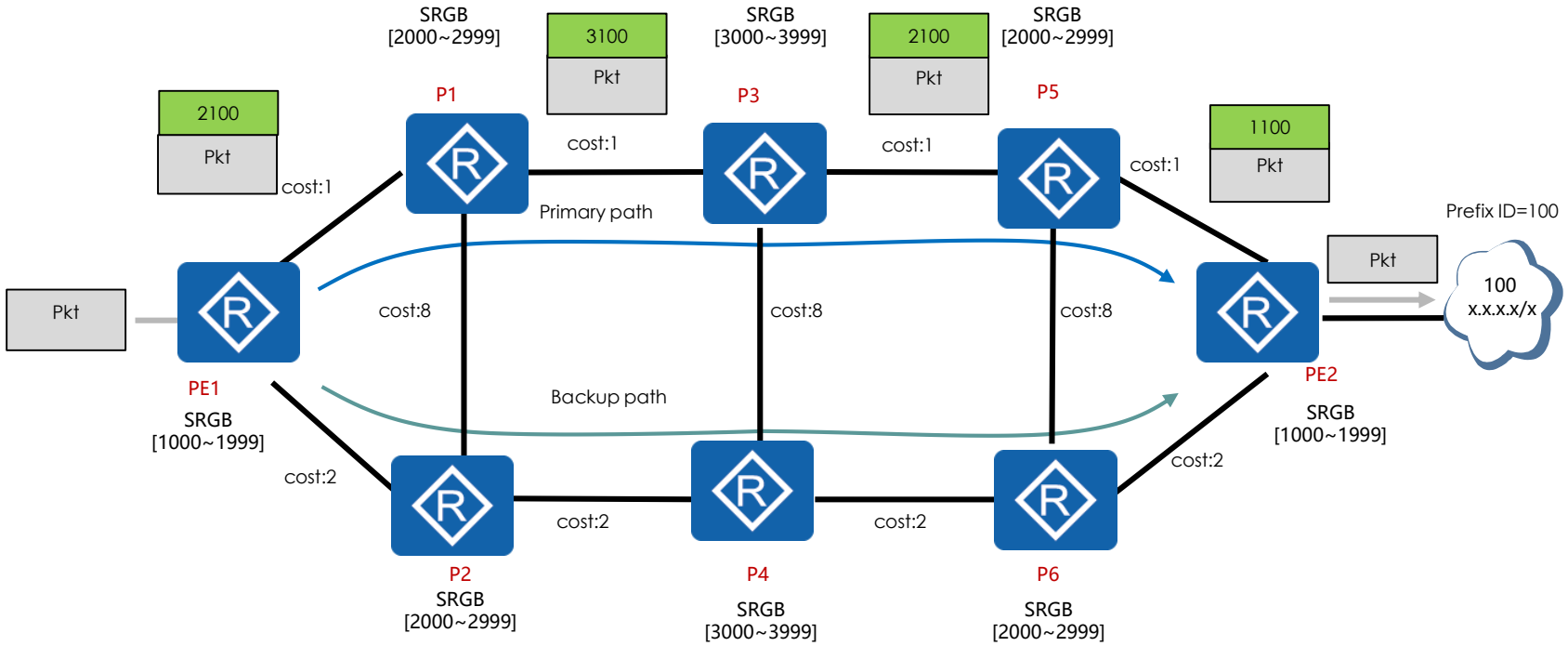
Segment

- The basic concept of SR is to divide the network into different Segments and then combine them to guide packet forwarding based on the specified path.
- SID: Segment ID, which identifies a unique segment. On the forwarding plane, MPLS labels are mapped.
- Three basic segments of SR: Adjacent segment, prefix segment, and node segment.

Segment	Generation Mode	Function	Example
Adjacency Segment	Dynamically allocated by source nodes through protocols	It identifies an adjacency of a node on the network. It is allocated by the IGP protocol of the source node. It is valid only on the local node and has certain directivity. It is flooded to other NEs through IGP. It is globally visible and valid locally. It is identified by Adjacency Segment ID. Adjacency SID is a local SID outside the SRGB range.	
Prefix Segment	Manually configured	It identifies the prefix of a destination address on the network. It is globally visible and globally valid, and is flooded to other NEs through IGP. Prefix SID is the offset value in the SRGB range advertised by the source end. The receive end calculates the actual label value based on the SRGB value to generate MPLS forwarding entries.。	
Node Segment	Manually configured	It is a special Prefix Segment used to identify a specific node. Configure an IP address as the prefix of the loopback interface on the node. The Prefix SID of the node is Node SID.	

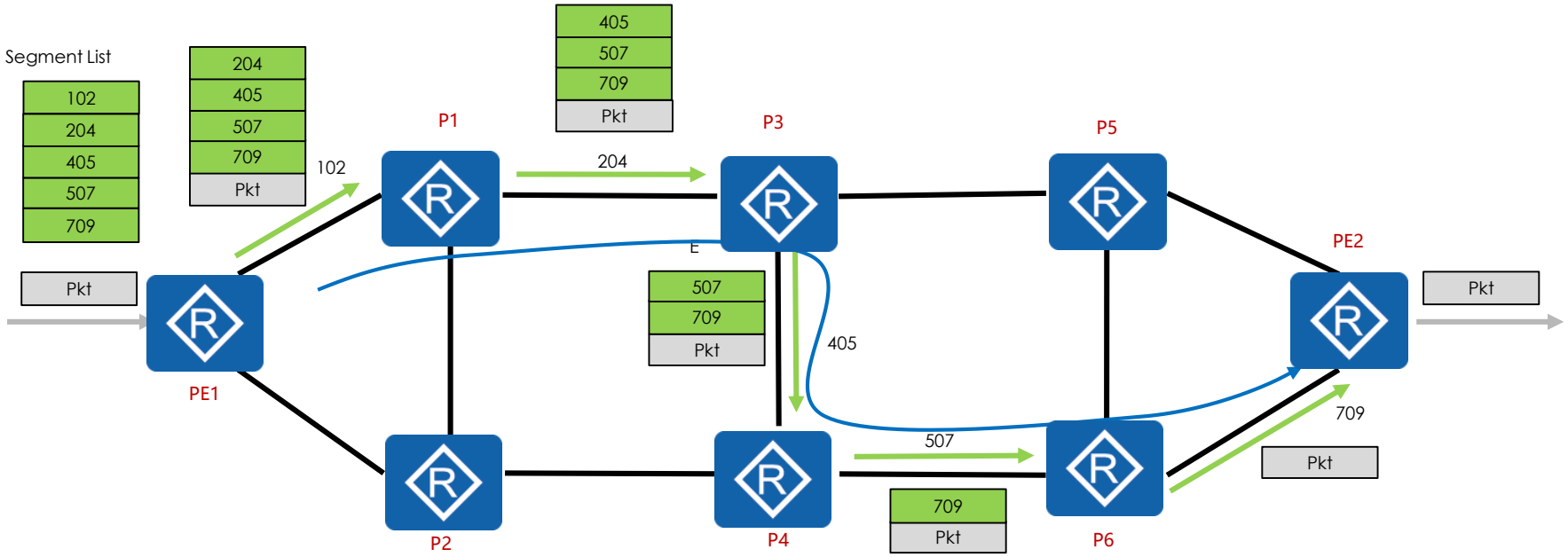
Segment —Prefix Segment

- Based on Prefix Segment: IGP uses the SPF algorithm to calculate the shortest path, which is also called SR-BE. As shown in the following figure, node Z is the destination node and its Prefix SID is 100. After IGP flooding is enabled, all devices in the IGP area learn the Prefix SID of PE2, and then use the SPF algorithm to obtain the shortest path to PE2.



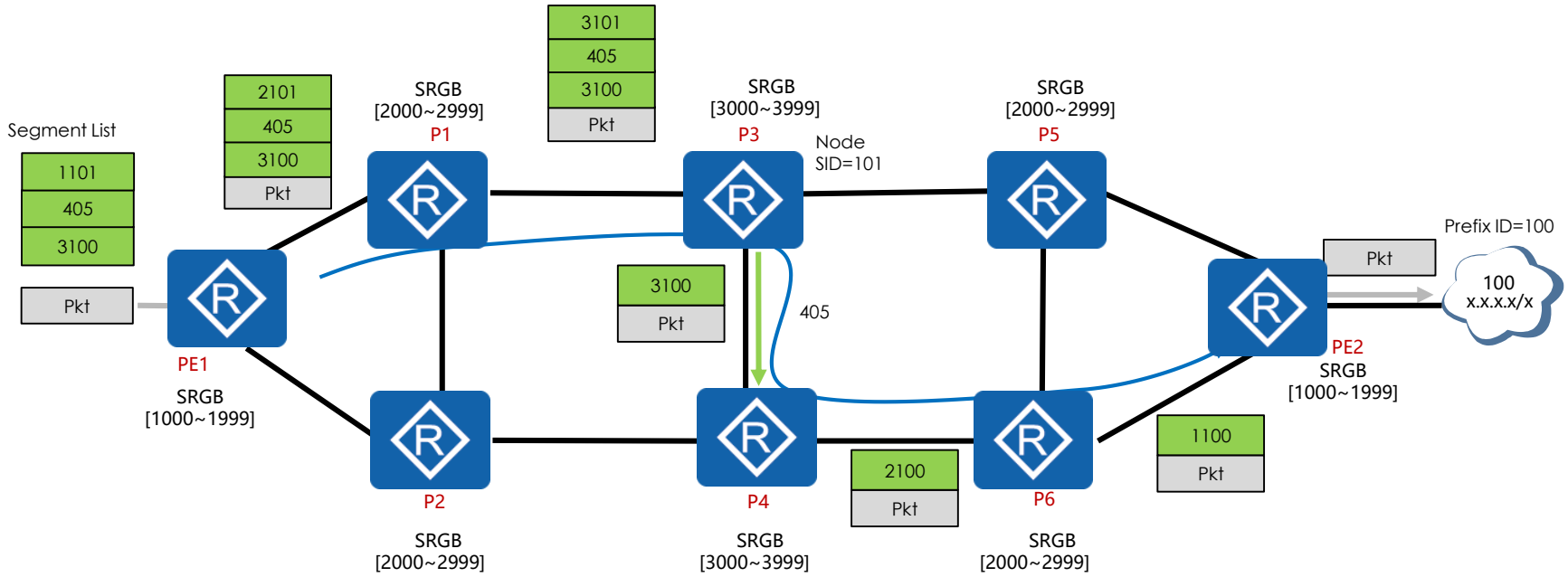
Segment —Adjacency Segment

- Based on Adjacency Segment: The head node specifies a strict explicit path (Strict Explicit). In this manner, path adjustment and traffic adjustment can be performed in a centralized manner, so that Software-Defined Networking (SDN) can be better implemented. The Adjacency Segment is mainly used for the Traffic Engineering (SR-TE).

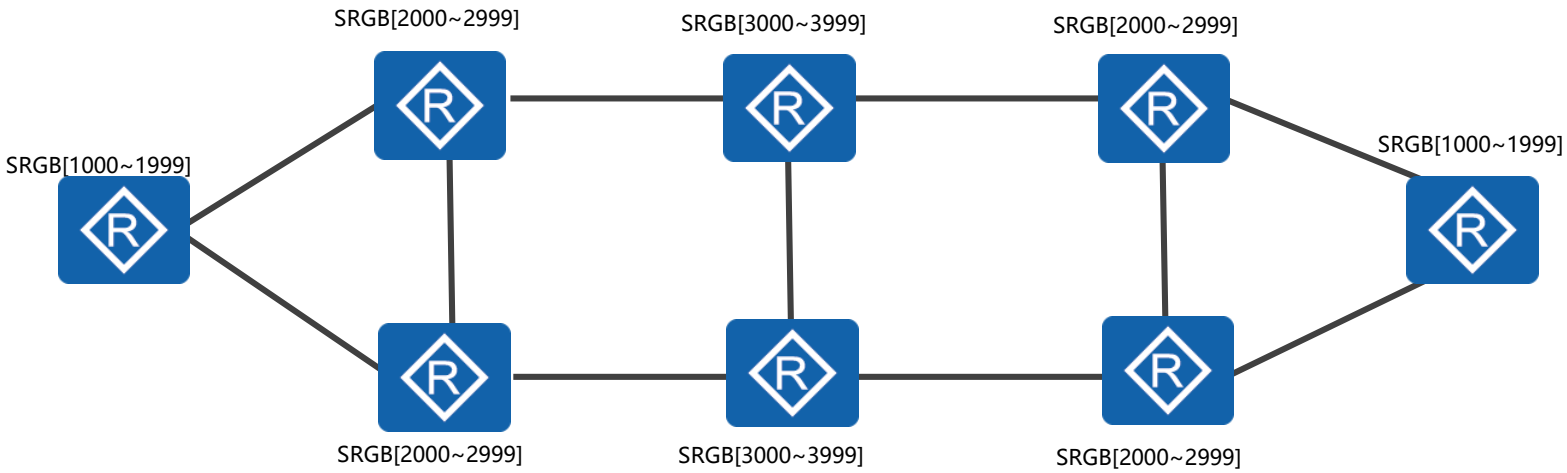


Segment —Adjacency Segment + Node Segment

- Adjacency Segment +Node Segment: A combination of an explicit path and a shortest path is called a Loose Explicit (Loose Explicit). It is mainly used for SR-TE.



SRGB

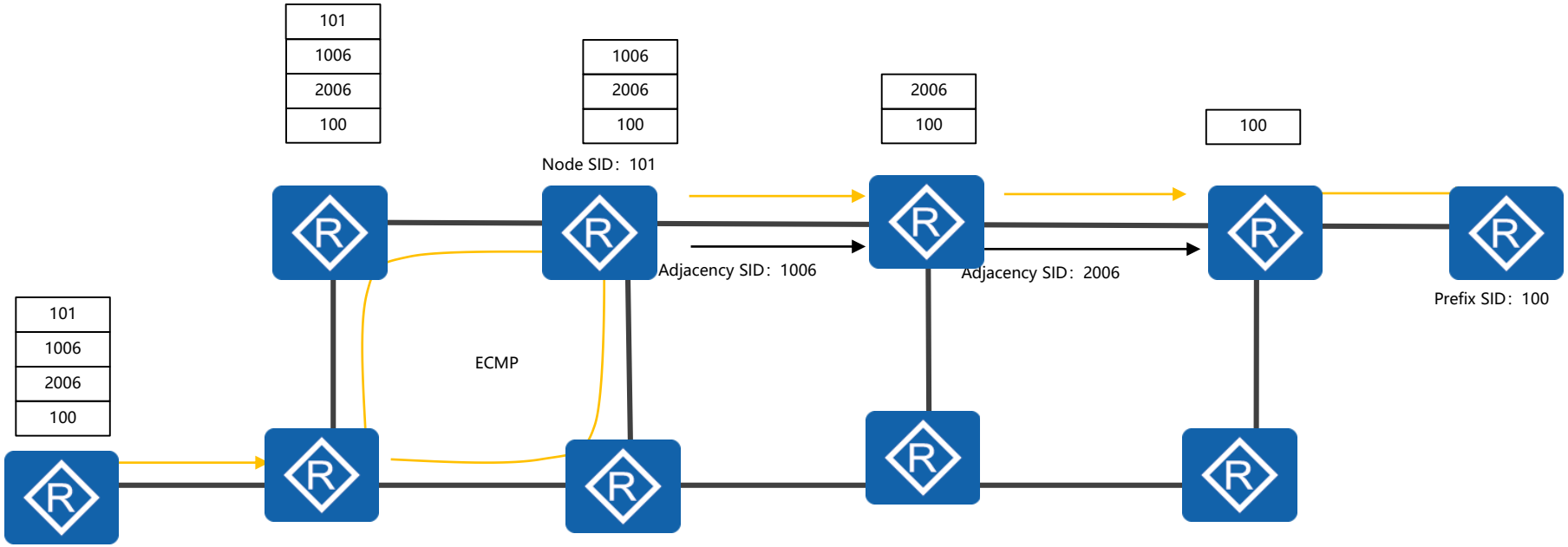


- The SRGB is a segment isolated from local label resources, and is specially used for Segment Routing, so that the Segment Routing global label and the traditional MPLS coexist locally.
- The node ID is the basis of the node SID. The globally unique node label must not conflict with the local label.
- The SRGB range and start value need to be configured. Based on the start value, the index value of the node SID is offset to obtain the local label.
- Why is the SRGB range of each device not the same?
  - The scope of SRGB is not specified in the standard, and the implementation of different vendors is different.
  - In the case of coexistence with traditional MPLS, the idle label space on each device cannot be the same.

Contents

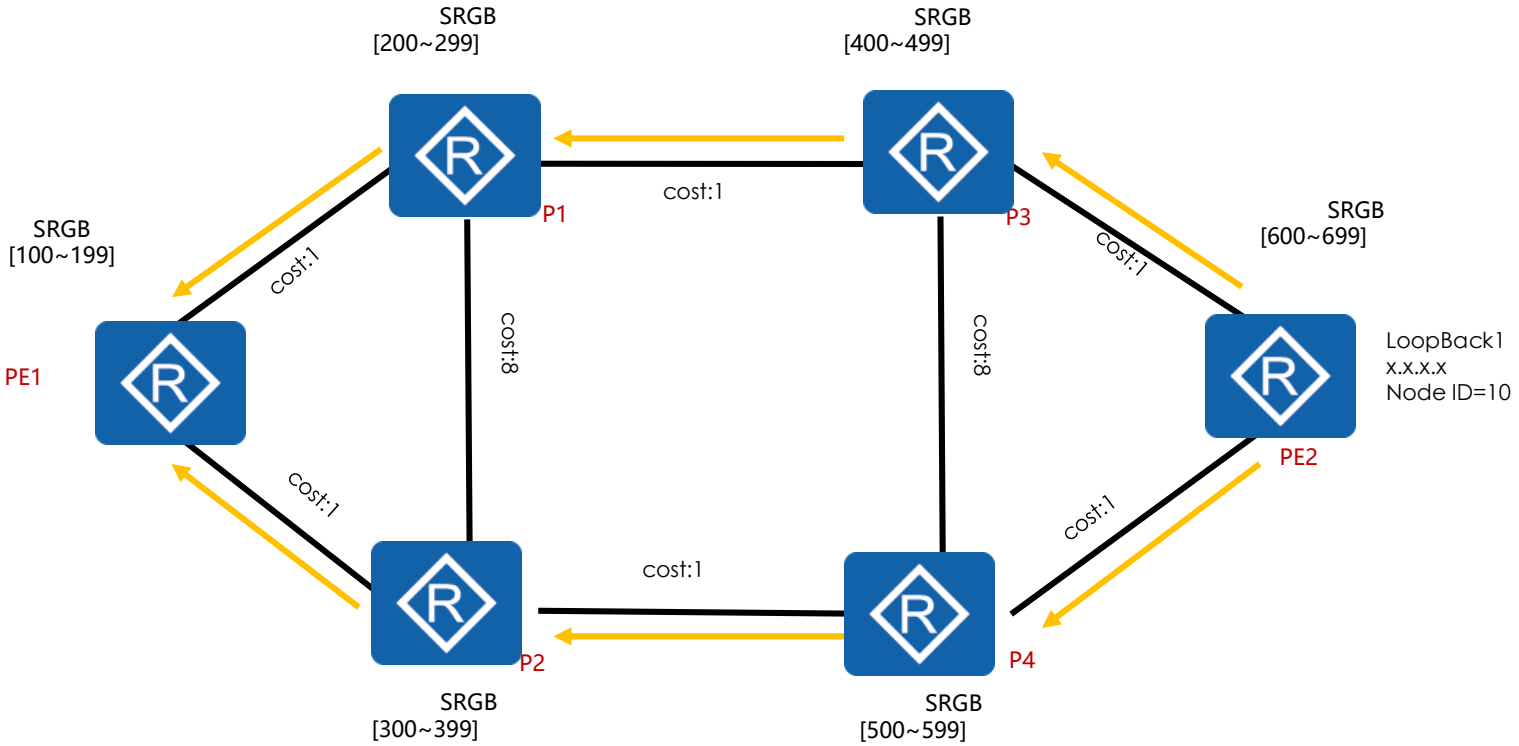
HUAWEI

Principle of SR



- SR is a protocol designed for forwarding data packets on the network based on the MPLS protocol and based on the source routing technology.
- SR divides the destination address prefix / node and adjacency in the network into segments and allocates SID (Segment ID) to these segments. The Adjacency SID (adjacent segment) and Prefix/Node SID (destination address prefix / node segment) are arranged in order to obtain a forwarding path.

Working Principle of SR- (IS-IS SR-BE) (Control Plane)



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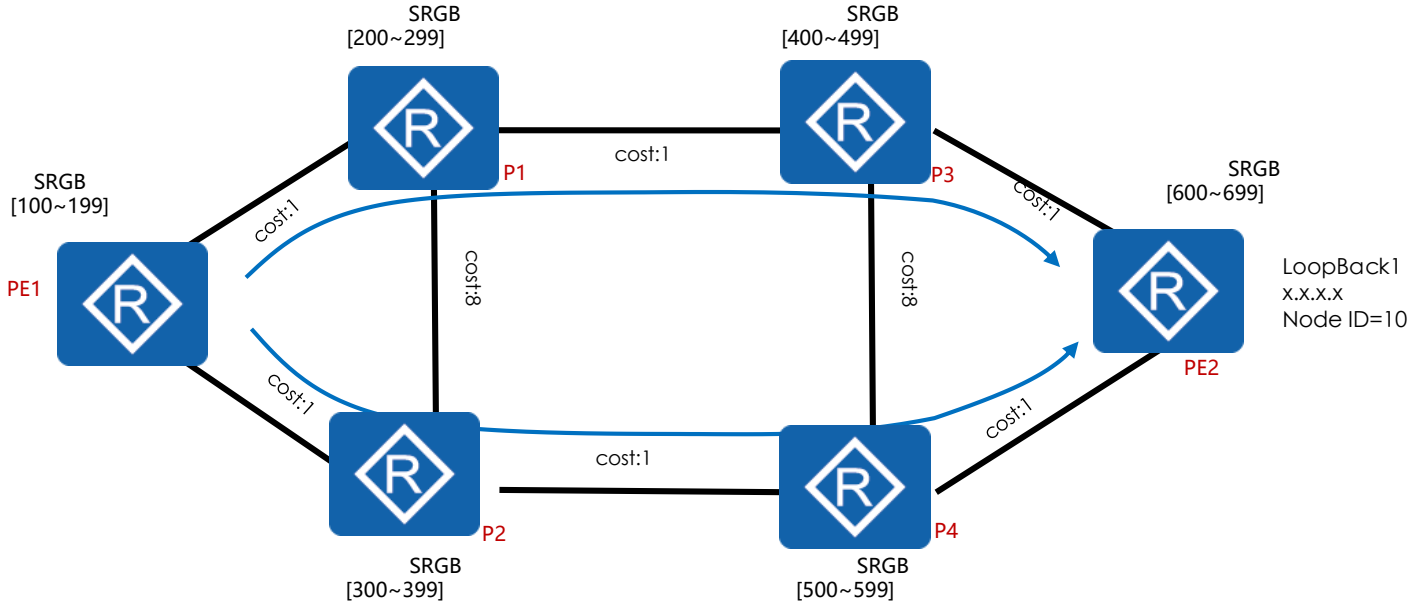


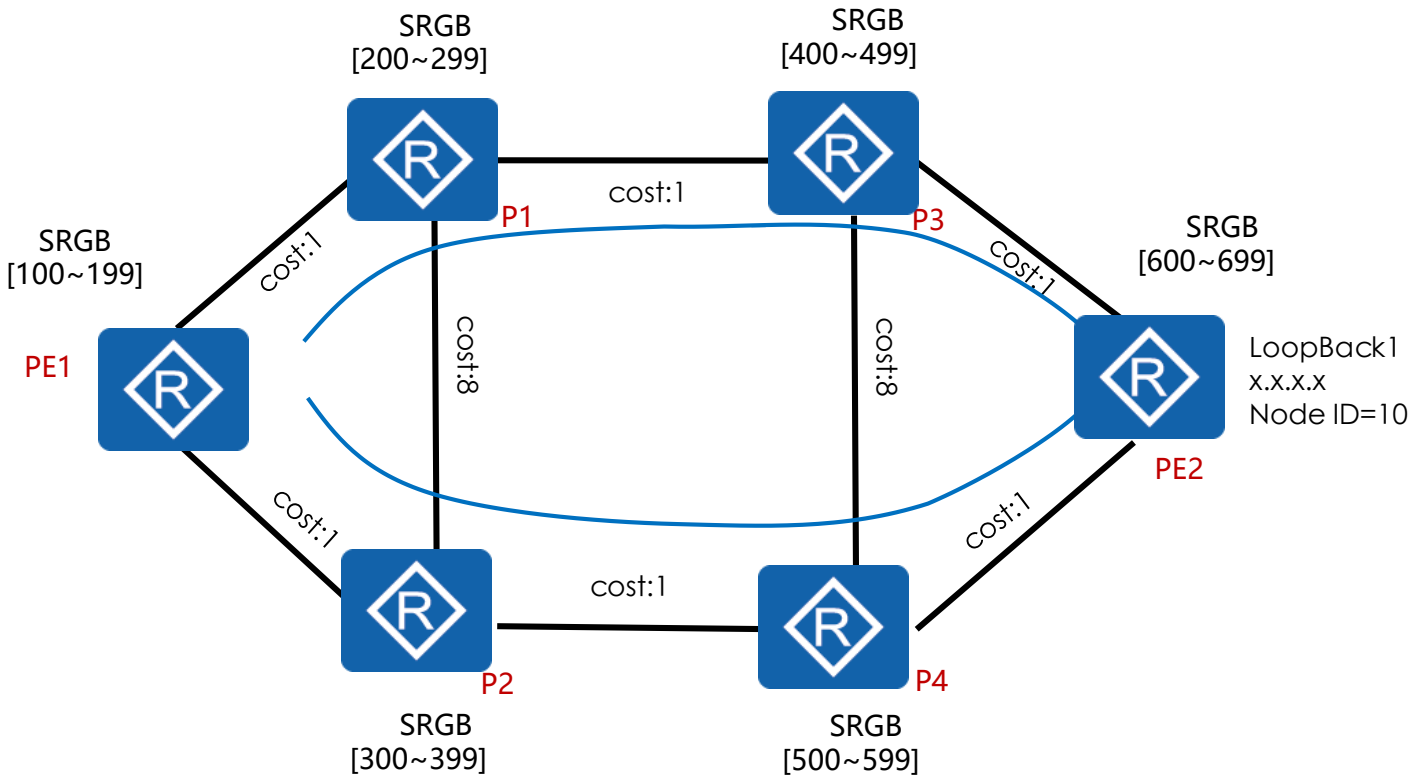
PE1→P1→P3→PE2: Label forwarding entry generated by each node for the Node SID 10

Node	InLabel	Outlabel	Interface
PE1	110	210	PE1->P1
P1	210	410	P1->P3
P3	410	610	P3->PE2
PE2	610	NA	NA

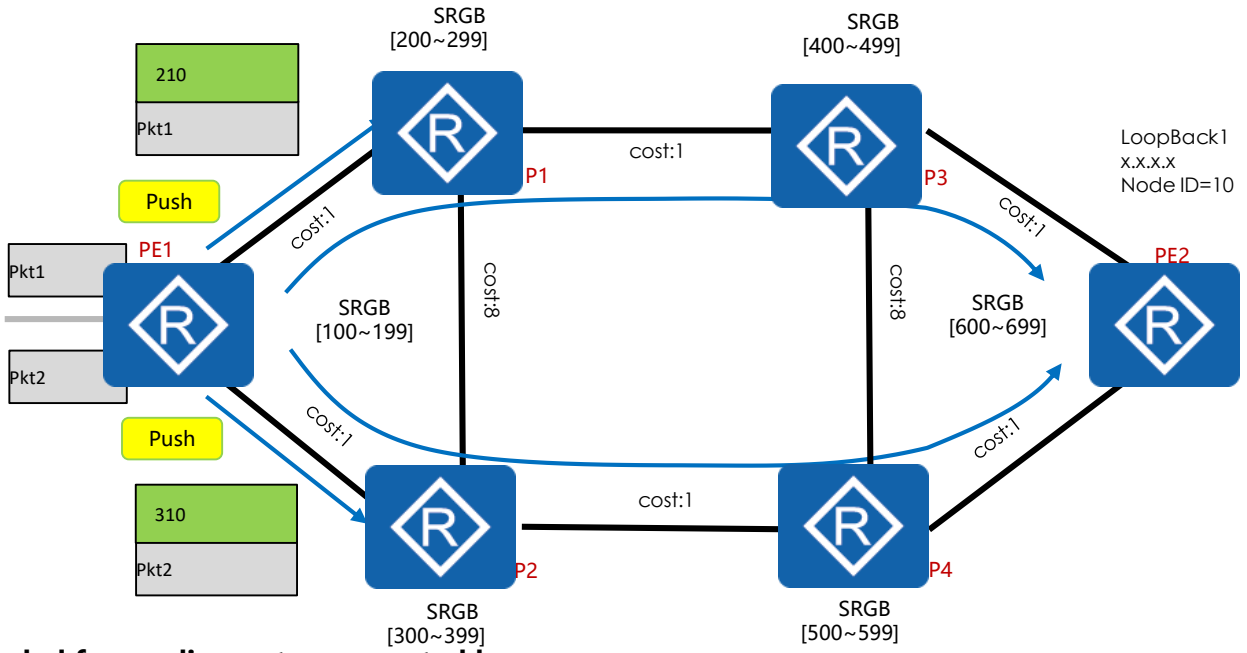
PE1→P2→P4→PE2: : Label forwarding entry generated by each node for the Node SID 10

Node	InLabel	Outlabel	Interface
PE1	110	310	PE1->P2
P2	310	510	P2->P4
P4	510	610	P4>PE2
PE2	610	NA	NA

Working Principle of SR- (IS-IS SR-BE) (Control Plane)



Working Principle of SR- (IS-IS SR-BE) (Data Plane)



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PE2	610	NA	NA

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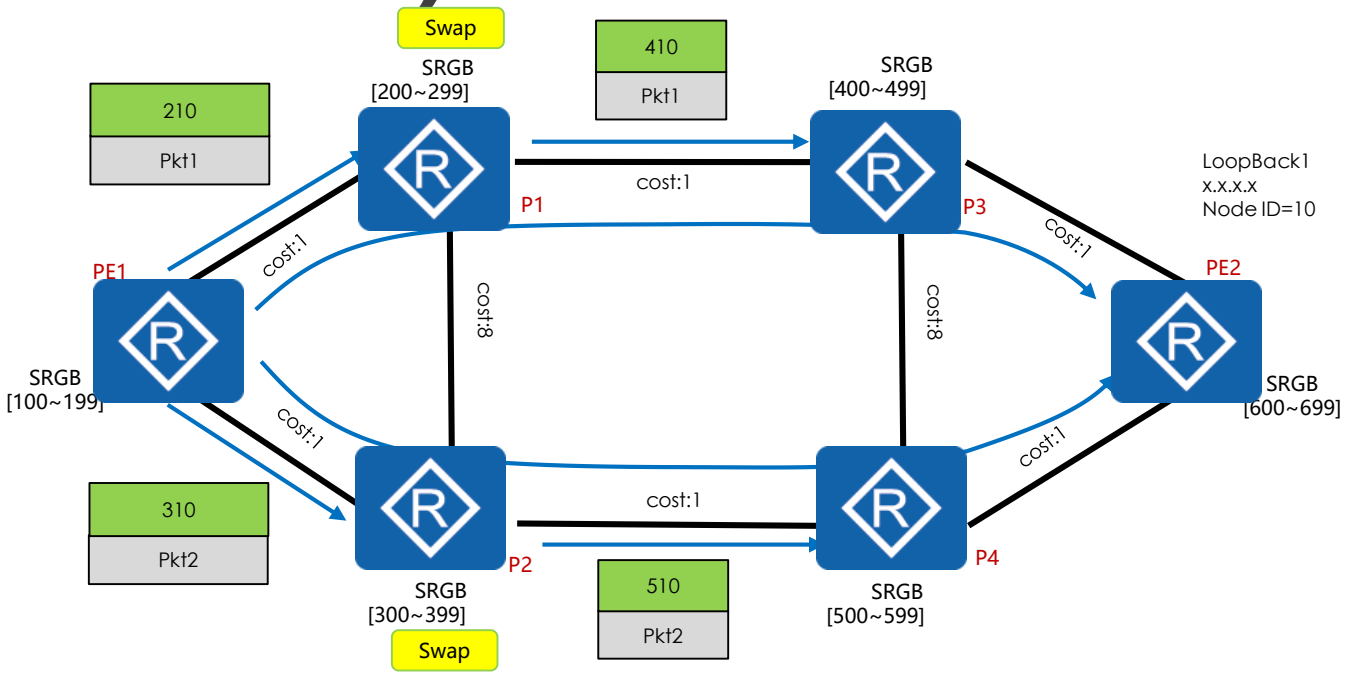

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PE1→P2→P4→PE2: : Label forwarding entry generated by each node for the Node SID 10

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PE1	110	310	PE1->P2
P2	310	510	P2->P4
P4	510	610	P4>PE2
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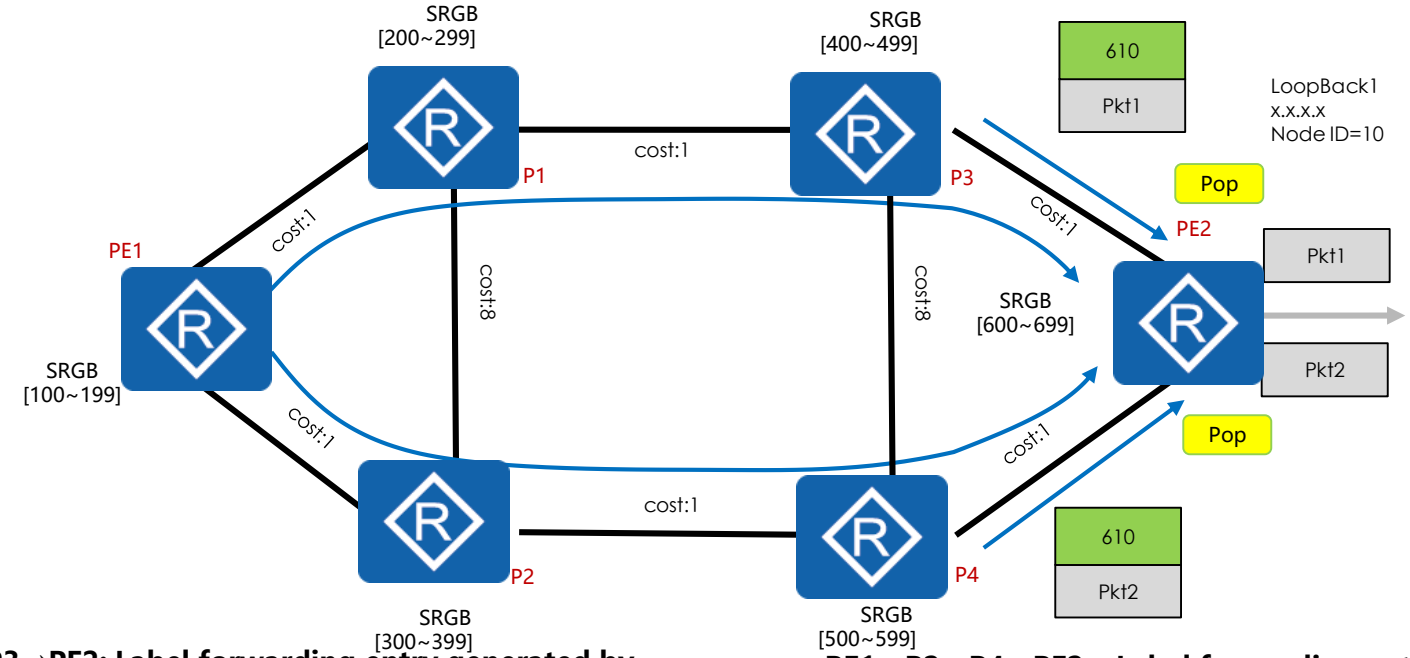
Working Principle of SR- (IS-IS SR-BE) (Data Plane)



PE1→P1→P3→PE2: Label forwarding entry generated by each node for the Node SID 10

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PE1→P2→P4→PE2: : Label forwarding entry generated by each node for the Node SID 10

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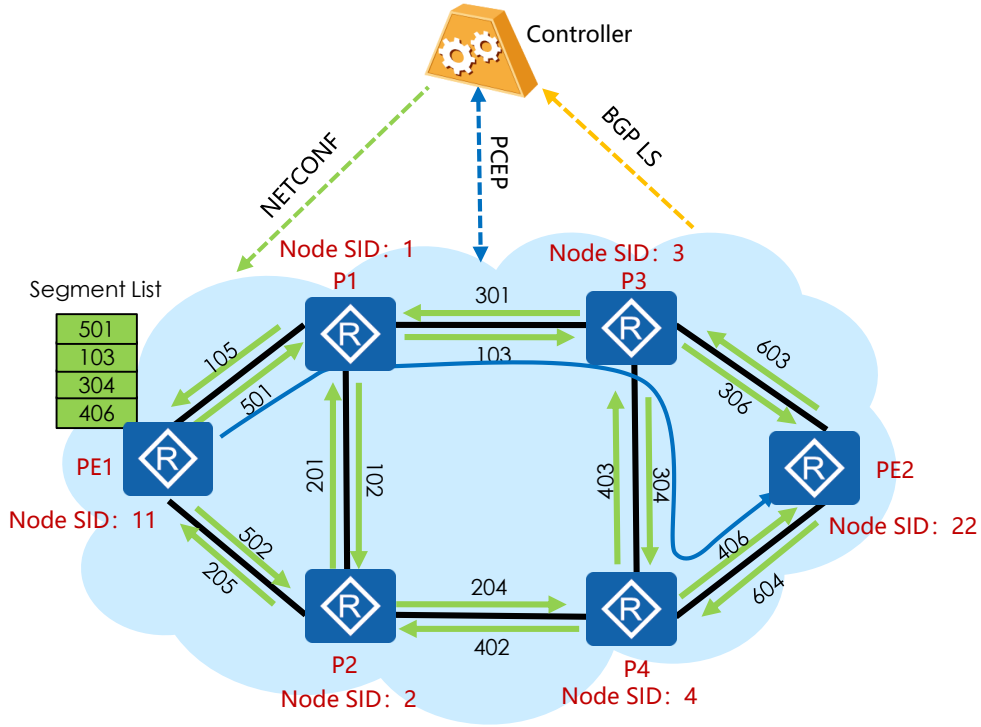
PE2	610	NA	NA

Working Principle of SR- (IS-IS SR-TE) (Control Plane)



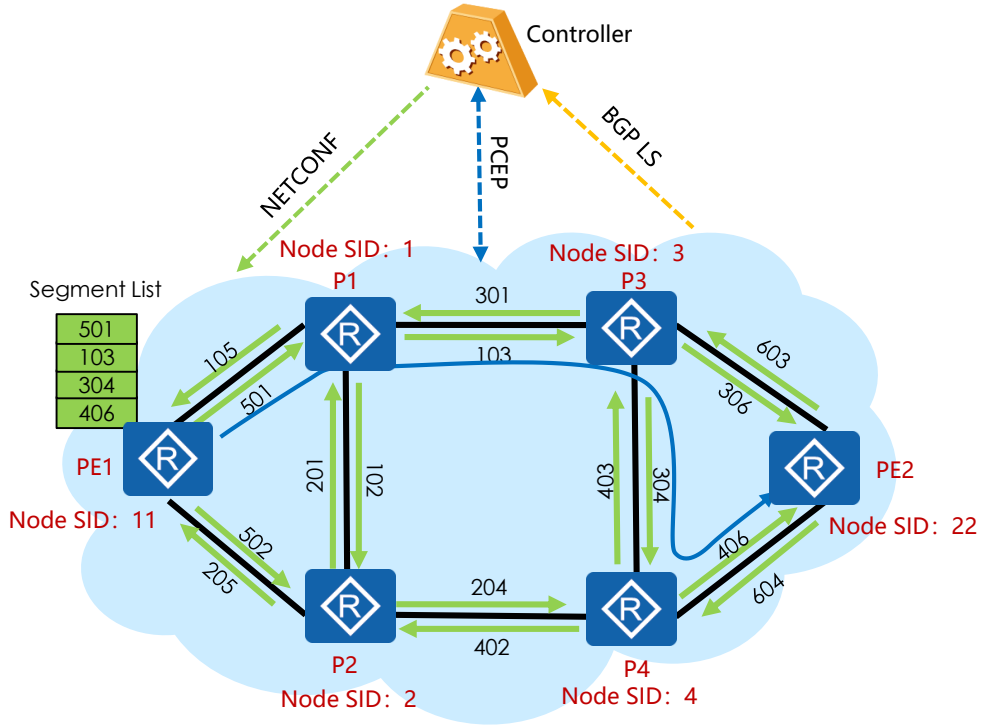
Note:

1. All nodes use the same SRGB[1000, 1999].
2. The cost values of all links are 1.

Label table on the controller

Node	Adjacency	label
PE1	NA	1011
PE1	Link PE1 to P1	501
PE1	Link PE1 to P2	502
P1	NA	1001
P1	Link P1 to PE1	105
P1	Link P1 to P2	102
P1	Link P1 to P3	103
.....	.....	.....

Working Principle of SR- (IS-IS SR-TE) (Control Plane)



Note:

1. All nodes use the same SRGB[1000, 1999].
2. The cost values of all links are 1.

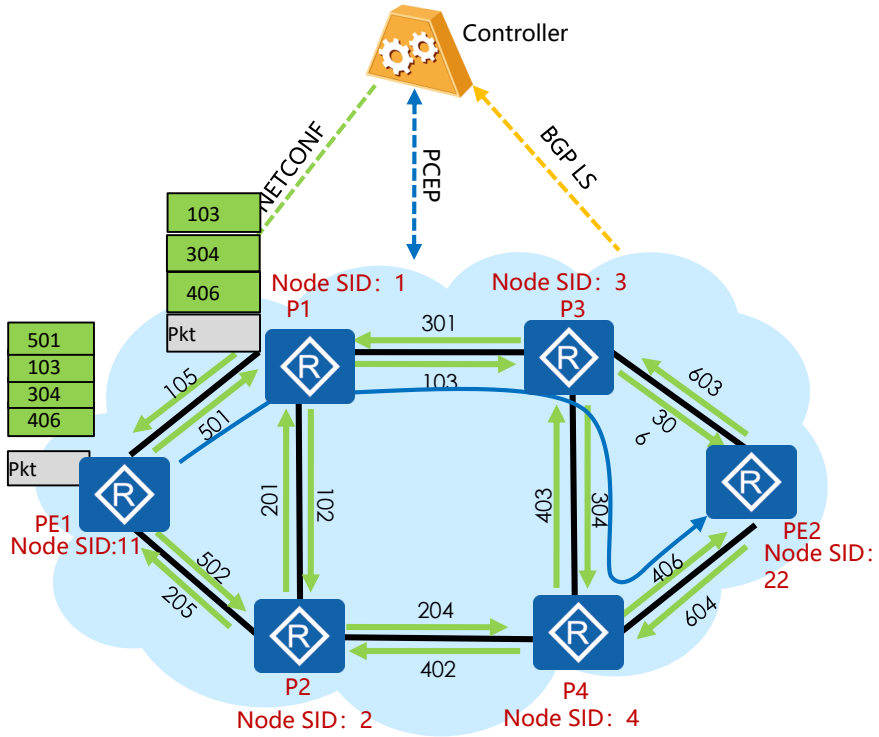
Label forwarding entries on PE1

SID/Inlabel	Outlabel	Interface
1011	NA	NA
501	NA	PE1->P1
502	NA	PE1>P2
1001	1001	PE1->P1
1002	1002	PE1->P2
1003	1003	PE1->P1
1004	1004	PE1->P2
1022	1022	PE1->P1
1022	1022	PE1->P2

SR-TE Tunnel label stack encapsulation table on PE1

SR-TE Tunnel	Segment List
Tunnel 1	501/103/304/406
.....	.....

Working Principle of SR- (SR-TE Strict Explicit Path) (Data Plane)



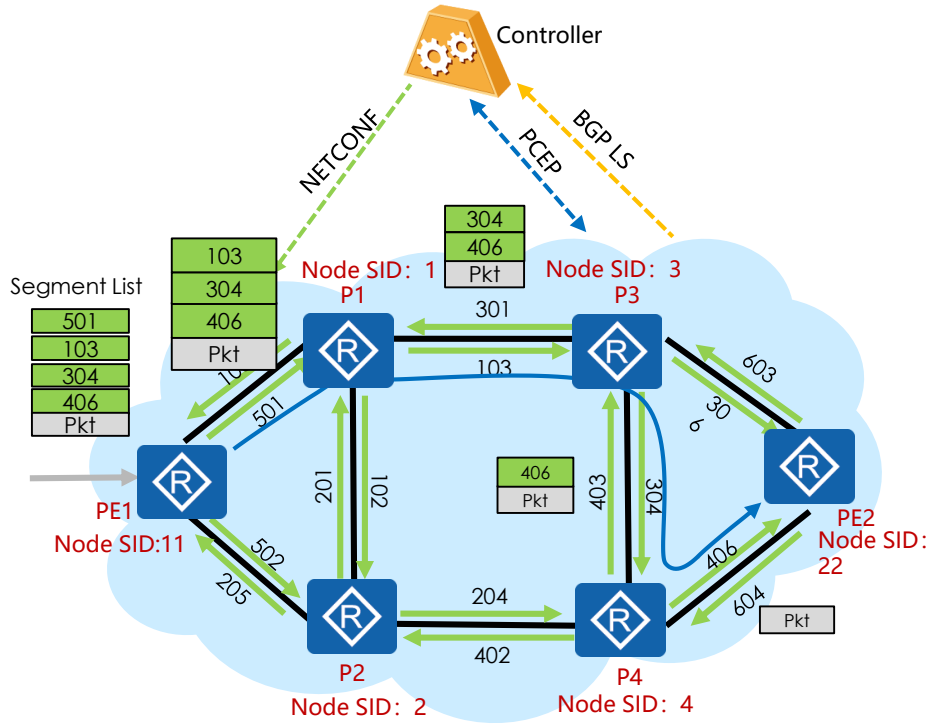
Note:

1. All nodes use the same SRGB[1000, 1999].
2. The cost values of all links are 1.

The following table shows the label forwarding entries on each node on the SR-TE Tunnel path from PE1 to PE2.

Node	SID/Inlabel	Outlabel	Interface
PE1	501	NA	PE1->P1
P1	103	NA	P1->P3
P3	304	NA	P3->P4
P4	406	NA	P4->PE2

Working Principle of SR- (SR-TE Strict Explicit Path) (Data Plane)



The following table shows the label forwarding entries on each node on the SR-TE Tunnel path from PE1 to PE2.

Node	SID/Inlabel	Outlabel	Interface
PE1	501	NA	PE1->P1
P1	103	NA	P1->P3
P3	304	NA	P3->P4
P4	406	NA	P4->PE2

Note:

1. All nodes use the same SRGB[1000, 1999].
2. The cost values of all links are 1.

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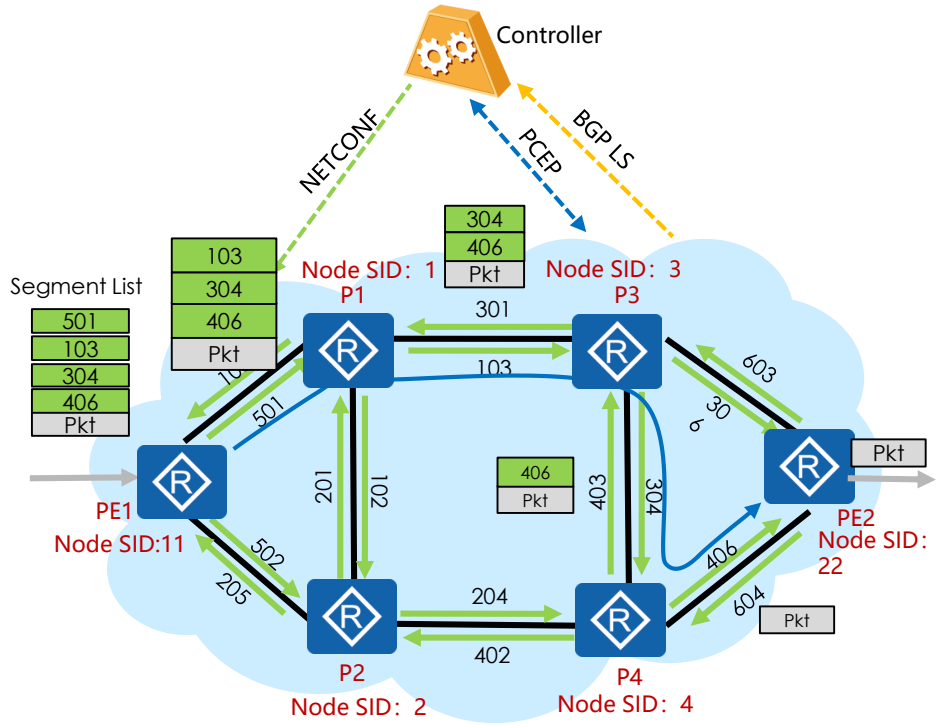

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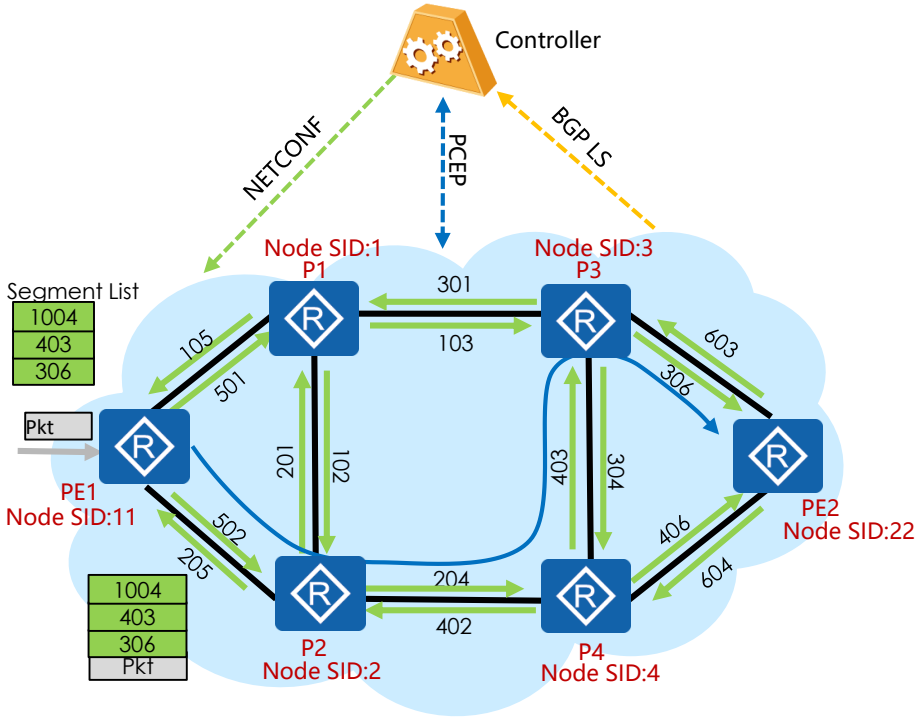

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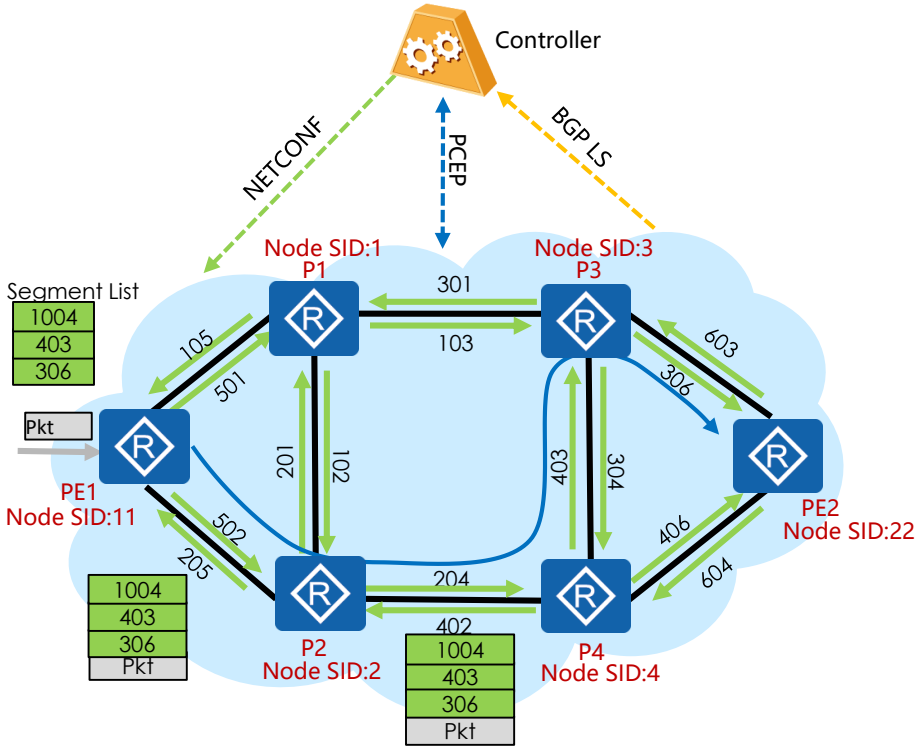
PE1	1004	1004	PE1->P2
P2	1004	1004	P2->P4
P4	1004	NA	NA
P4	403	NA	P4->P3
P3	306	NA	P3->PE2

Working Principle of SR- (SR-TE Loose Explicit Path) (Data Plane)



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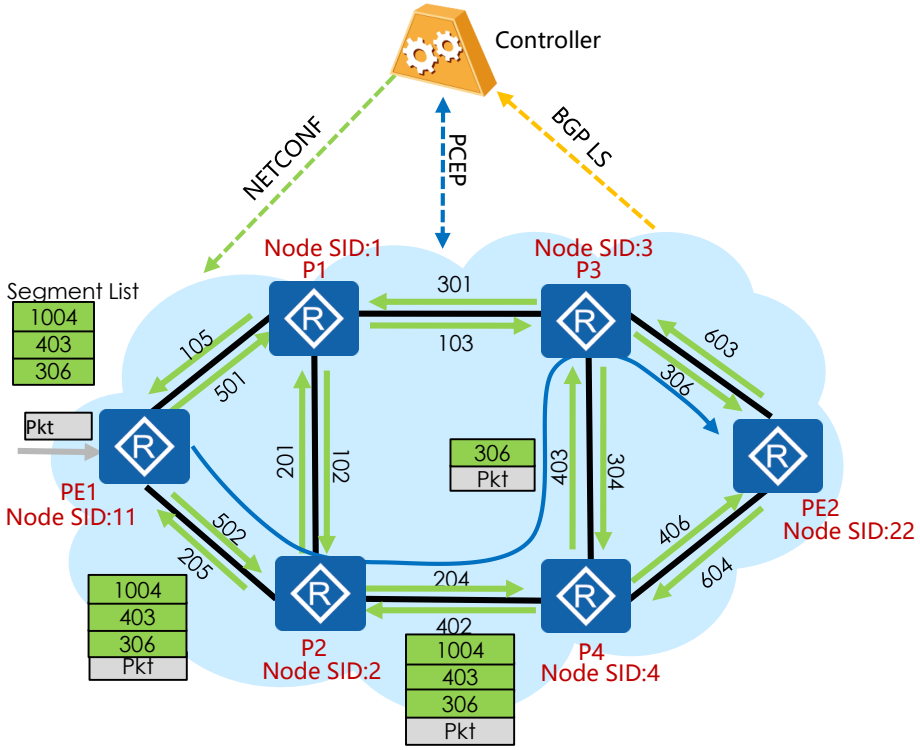

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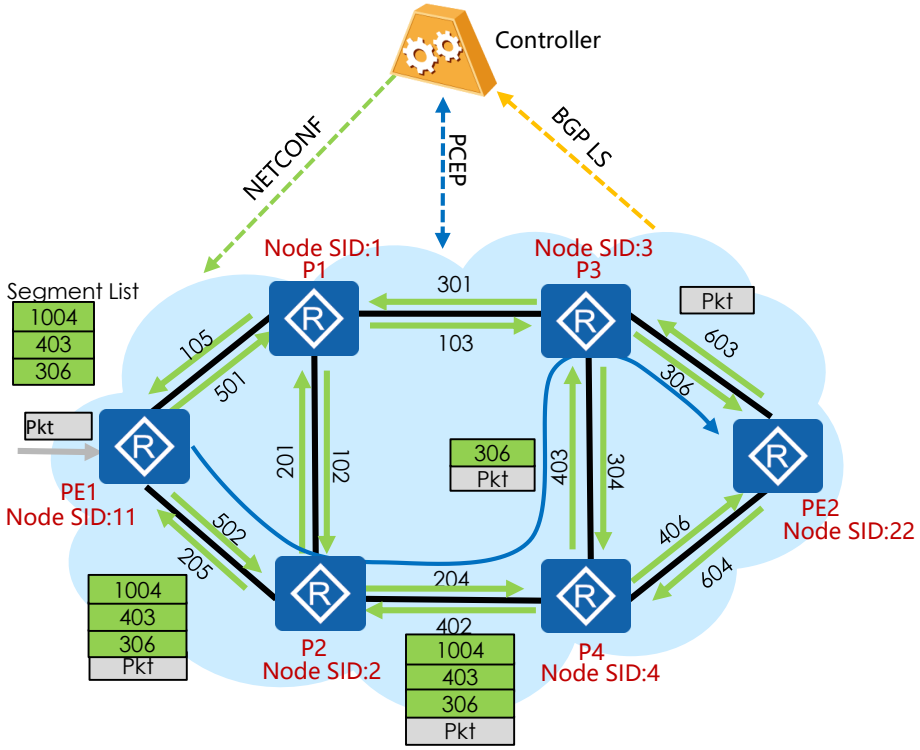

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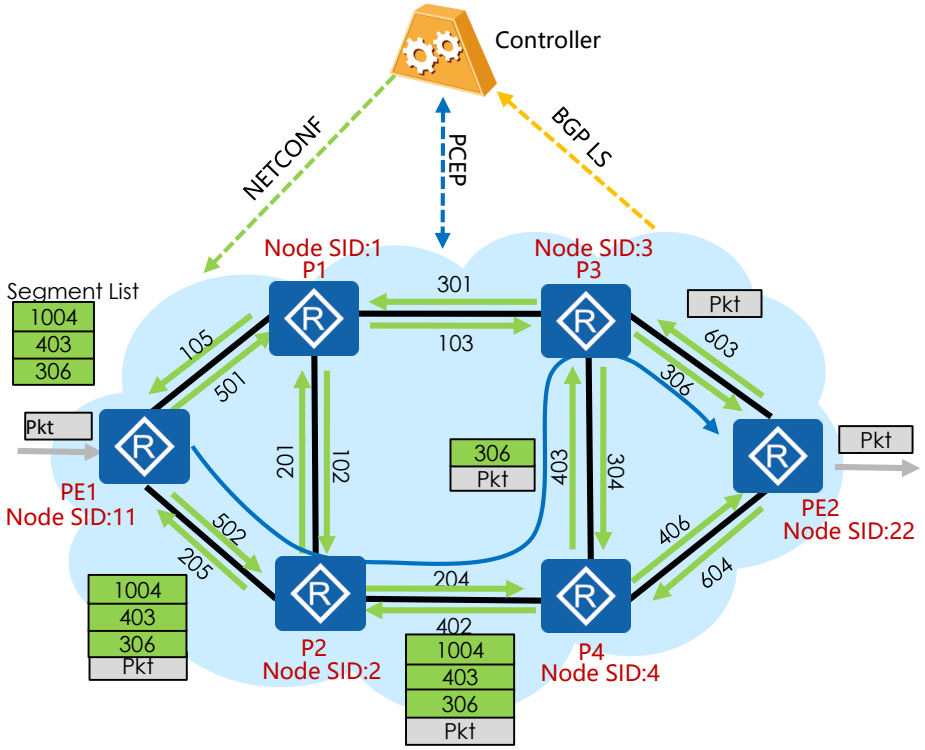

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Quiz

1. Which of the followings are the SR tunnel type ?( )
   A. SR-BE tunnel
   B. SR-TE Loose Explicit Path tunnel
   C. SR-BE Loose Explicit Path tunnel
   D. SR-TE SR-TE Strict Explicit Path
2. Which of the following actions may be performed when packets are forwarded based on the SR label? ( )
   A. Push
   B. Pop
   C. Swap
   D. Switch

Summary

- SR Background
- Basic Concepts of SR
- SR technical architecture
- Working Principles of the SR


Thank You
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