CHAPTER 5:

MPLS

Structure

In this chapter, we will cover the following topics:

- MPLS Fundamentals
- MPLS LDP
- MPLS TE
- MPLS VPN
- MPLS Troubleshooting

MPLS Fundamentals

1. What is MPLS?

MPLS (Multiprotocol label switching) is a process of data forwarding packets due to the labels. It uses a label table as a forwarding table (**LFIB**) instead of routing tables to forward data packets at high speeds with less complexity. Paths are predetermined in the MPLS network, which controls the path at a high level.

2. When do we use MPLS in the network?

ISPs (Internet Service Provider) often use MPLS to provide high-performance and scalable networks, reducing latency and downtime. Enterprise networks also use MPLS to reduce complexity and improve performance. We can use it to connect multiple branches in various locations.

3. What are the benefits of MPLS?

- **Fast convergence** due to label-based switching instead of looking routing table
- **Scalability** to IP VPNs
- **Low network congestion** with MPLS-TE
- **Reliable** and **secure**
- **QoS** integration with managing latency, jitter, and packet loss for various traffics (voice, video, email, etc.)
- **Reduce CPU usage**
- **Decrease network complexity**

4. How to implement MPLS?

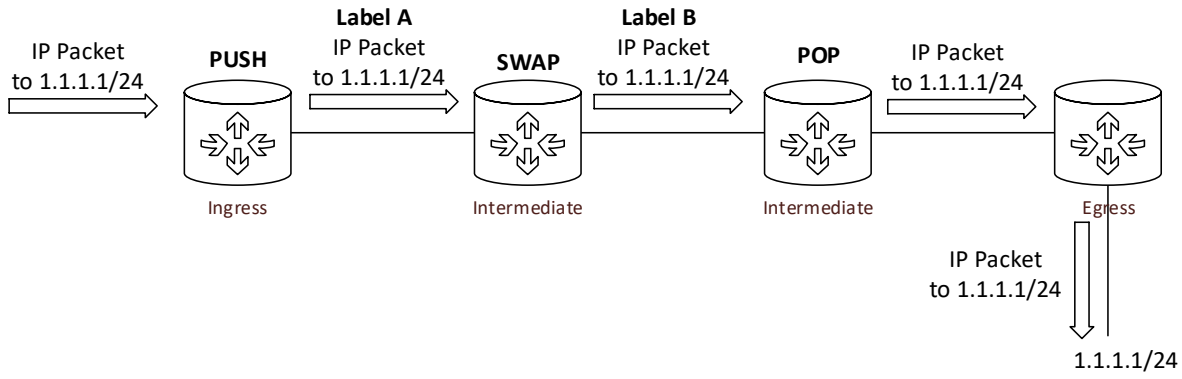
1. Enable **CEF** (Cisco Express Forwarding) in Cisco devices.
2. Configure **IGP** (OSPF, IS-IS) in all routers in the MPLS network.
3. Enable **MPLS** in the global mode.
4. Configure Label protocol to establish LSPs (**LDP**, RSVP, etc).
5. Configue MPLS LSR **router-id**. It must be reachable in the network to connet neighbors.

5. How MPLS works?

In the MPLS network, packets are forwarded by adding, switching, or removing labels. In each router on the path, the label is swapped until the end of the MPLS network. It allows for fast and efficient routing because the router doesn't check the destination node or address of receiving the packet. It only checks the label information to forward the packet to the next hop.

1. The **edge LSR** router (**LER** - Label Edge Router) receives the data packet at the MPLS network's beginning.
2. LER checks the routing table to determine the next hop. If the destination is in the MPLS network, it adds a label to the packet header between Layer-2 and Layer-3.
3. LER forwards the packet into the MPLS network.
4. The packet is forwarded in the MPLS network with the LSRs until it reaches the destination LSR as Egress LSR. Each LSR swapped the label with the new one.
5. Egress LSR removes MPLS labels and checks the destination IP address in the routing table to send the packet out of the MPLS network.

The following figure shows an IP packet destination to 1.1.1.1 that reaches the Ingress LSR, and LSR adds a label and forwards to the next hop. With this step, all LSRs check the label information to forward the packet, and LSR replaces or swaps the old label with the new one. It continues in all intermediate LSRs. In the last hop before the Egress LSR, intermediate LSR removes all labels and forwards to packet to the EgressEgress LSR as an IP packet, not an MPLS packet.



6. Is the IGP or BGP mandatory to implement MPLS?

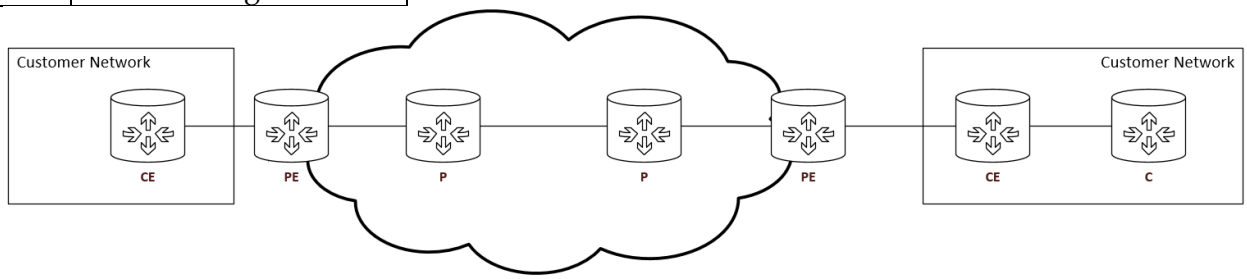
IGP is mandatory to implement MPLS. But BGP is not mandatory to implement basic MPLS.

7. What is the relationship between MPLS and the IGP?

IGP defines reachability and the binding/mapping between FEC (Forwarding Equivalence Class) and the next-hop address. MPLS learns routing information from IGP.

8. What are the MPLS router types?

C	Customer Router
CE	Customer Edge Router
P	Provider Router
PE	Provider Edge Router

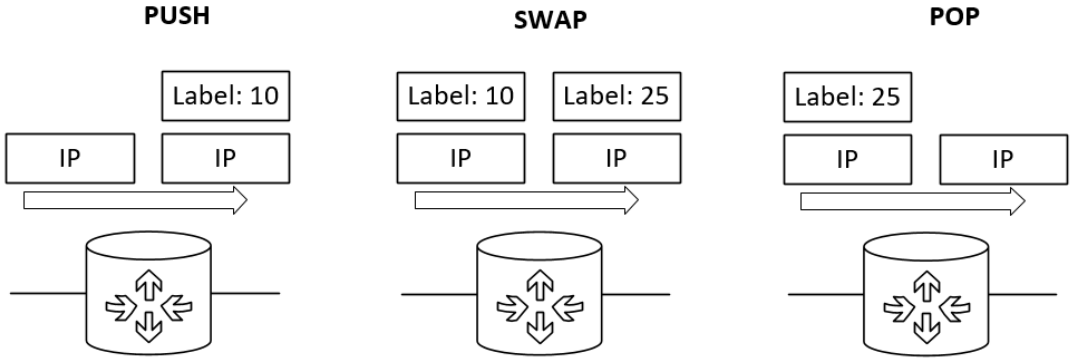


9. What is the difference between a P and a PE router?

P routers have no routes to the customer network, and PE routers have these routes. P routers don't need an MP-iBGP implementation, but PE routers must have.

10. What are the fuctions done by MPLS?

- **Push**: Ingress LSRs add a label as "**Push**" to put the packet in the MPLS network with a label.
- **Swap**: Intermediate LSRs replace or swap the label when it gets the packet as "**Swap**". It removes the old label by adding the new one a.
- **Pop**: Egress LSRs remove the label before the packet exits the MPLS network as "**Pop**".



11. How many bits in the MPLS header?

Layer 2 Header	MPLS Header				IP Packet
	Label Value	Exp	S	TTL	
	20 bits	*3 bits*	*1 bit*	*8 bits*	

Label Value (20 bits): Label information is stored in this field.

Experimental (3 bits): It's an undefined part of the MPLS header. It's used for QoS, and Cisco uses it as an IP precedence value.

Bottom-of-Stack (1 bit): Network packet can have MPLS labels more than one. This field shows the last or bottom label in the header. If the value is 1, it identifies the last label in the stack. Otherwise, the value is 0.

TTL (8 bits): It shows the time to live that the label can transfer the max of router count. It decreases by 1 in each hop. Label discards if the TTL value is 0.

12. What is PHP (Penultimate Hop Popping)?

Egress LSR, the last router in the MPLS network, is the **ultimate router**. The 2nd last router is the **penultimate router**. In the penultimate router, the last label is removed with the PHP feature to send to the last or ultimate router. It removes the MPLS label by the "Pop" function before it reaches the egress router.

The Pop function is done before the egress router. Because many LSPs may share the same egress router, PHP reduces the amount of work to do in the egress router and reduces network congestion.

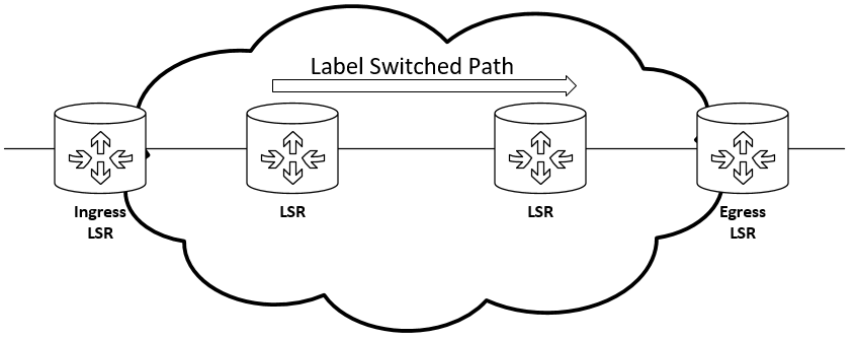
13. What are the MPLS components?

- **LSR** (Label switch router) is a router that supports MPLS.
- **LSP** (Label Switched Path) is the path that the IP packets travel through the MPLS network.
- **FEC** (Forwarding Equivalence Class) is a group of packets forwarded on the same path and treatment.
- **LIB** (Label Information Base) keeps LSR and Label information by LDP, and all possible remote bindings are stored in the LIB.
- **LFIB** (Label Forwarding Information Base) is used to forward the MPLS packets by selecting the best possbile remote binding in LIB.

14. What is LSR?

LSR (Label switch router) is a router that supports MPLS.

- **Ingress LSRs** (Label Edge Router - **LER**): It receives a packet without any label and sends it to the data link layer after **adding** a label to the packet. It's an **Edge LSR**.
- **Intermediate LSRs**: It receives the packet with the label and sends it to the data link layer after **swapping** the old label with the new one.
- **Egress LSRs**: It receives a labeled packet and sends it to the data link layer after **removing** the label on the packet. It's an **Edge LSR**.



15. What is LSP?

LSP (Label Switched Path) is the path that the IP packets travel through the MPLS network. It transmits traffic from the ingress to the egress LSRs as a one-direction path.

16. What is the LSP Creation Process?

MPLS labels are distributed from downstream LSRs to upstream LSRs.

1. The downstream LSR identifies FECs based on the IP routing table
2. It assigns a label to each FEC, and saves the mapping between labels and FECs.
3. Then, it encapsulates the mapping into a message and sends it to the upstream LSR.
4. After all LSRs make same process, LFIB is created and LSP is established.

17. What is the difference between Static and Dynamic LSP?

Dynamic LSPs consume more resources than static LSPs because of exchanging and processing packets.

Dynamic LSPs prevent network black holes by detecting network topology changes, and service interrupts. Then, they dynamically establish new LSPs to recover from the failure. There is no mechanism in the Static LSP.

18. What are the LSP types?

There are two types of LSPs such as **static** and **dynamic LSP**. Dynamic LSP is categorized in LPD, RSVP, and MP-BGP.

Static LSP: It's similar to static routes, such as manually configuring labels on all MPLS-involved routers. There is no signaling protocol and no error handling or alarm.

LDP LSP: LDP is a signaling protocol in MPLS routers, and label exchange is dynamically done by LDP when the LDP is configured on the routers. It's a simple and fast signaling protocol to create an MPLS network with auto-configured LSP adjacencies according to the static LSP.

RSVP LSP: RSVP is used to configure LSP paths dynamically, like LDP. It uses MPLS TE (Traffic Engineering) and configures only the ingress LSR. Intermediate and egress LSRs collect the signaling information from LER and configure LSP. There are two types of RSVP LSP.

> **Explicit-path LSP**: It's similar to static LSP with a more straightforward configuration. LSP of the intermediate devices must be configured manually. There are options as strict, loose, or strict&loose to configure.
>
> **Constrained-path LSP**: Intermediate LSR's LSP is calculated by the device dynamically. The calculation parameters depend on IGP protocols and network resource usage. MPLS TE must be enabled to use this feature.

Constrained-path LSP is bound to a single IGP domain, so they cannot travel through another AS. **Explicit-path LSP** is configured manually. So, it's independent of the IGP domain and can reach various AS.

MP-BGP: It's a BGP extension that assigns labels to MPLS VPN and inter-AS VPN routes.

19. What is FEC?

FEC (Forwarding Equivalence Class) is a group of packets forwarded on the same path and treatment. All packets that belong to the same FEC have the same label. So it's a way to describe shared paths in the network for some group of packets. Ingress LSR classifies and adds labels to the packets. So it decides which packets belong to which FEC.

FEC Examples:

- Packets with destination IP addresses match the same prefix.
- Multicast packets belong to a specific multicast group.
- Packets are processed in the same mode based on the process or the IP DSCP field.