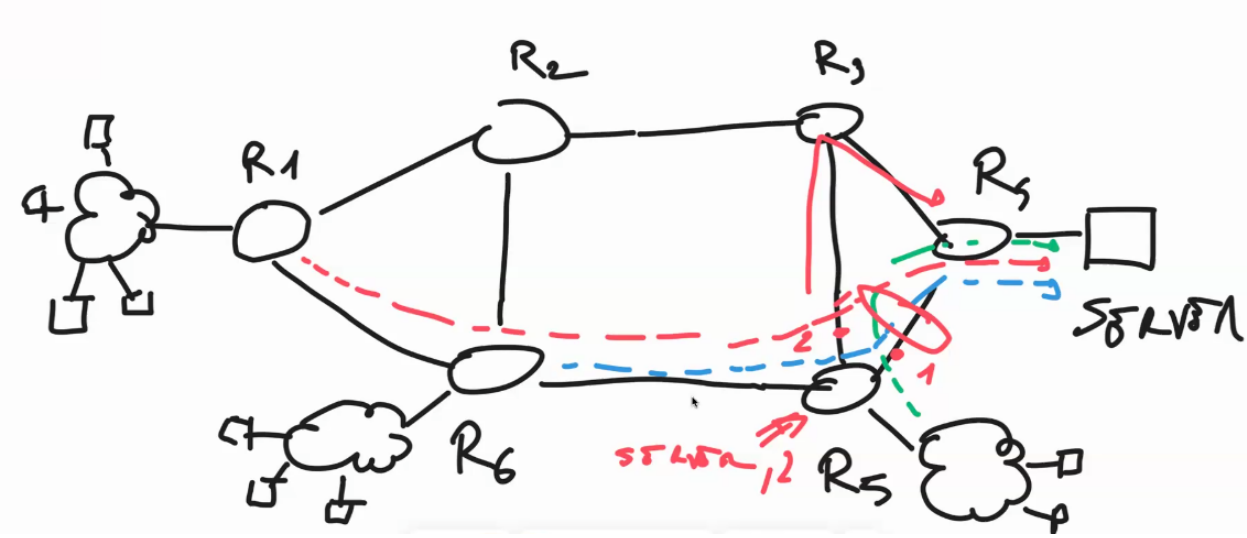
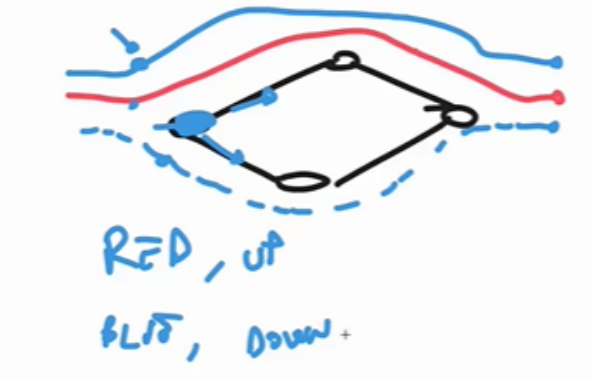
09 - Multi Protocol Label Switching (MPLS)

Client layer

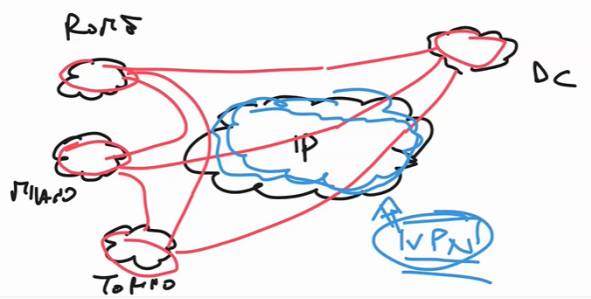
The three main services that a client typically seeks are **Traffic Engineering**, **Virtual Private Network (VPN)**, and **Fast Restoration Service**.



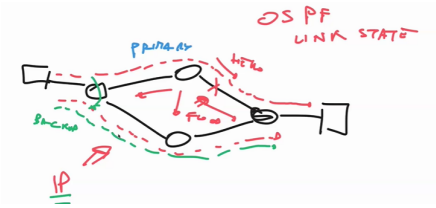
Traffic Engineering: The goal is to distribute traffic evenly across all available links, balancing it efficiently with the network's resources to optimize performance and avoid congestion.



Virtual Private Network (VPN): A VPN provides a logical connection over the optical network, enabling secure and private communication between client devices. This service is typically provided by a service provider.



Fast Restoration Service: This service ensures quick reaction to failures. In IP networks, **OSPF** (link-state protocol) notifies all nodes of a failure, prompting them to recompute paths. Alternatively, **backup paths** can be preconfigured, allowing immediate restoration. However, this preconfiguration is not typically feasible in IP networks, making it more suitable for optical networks.



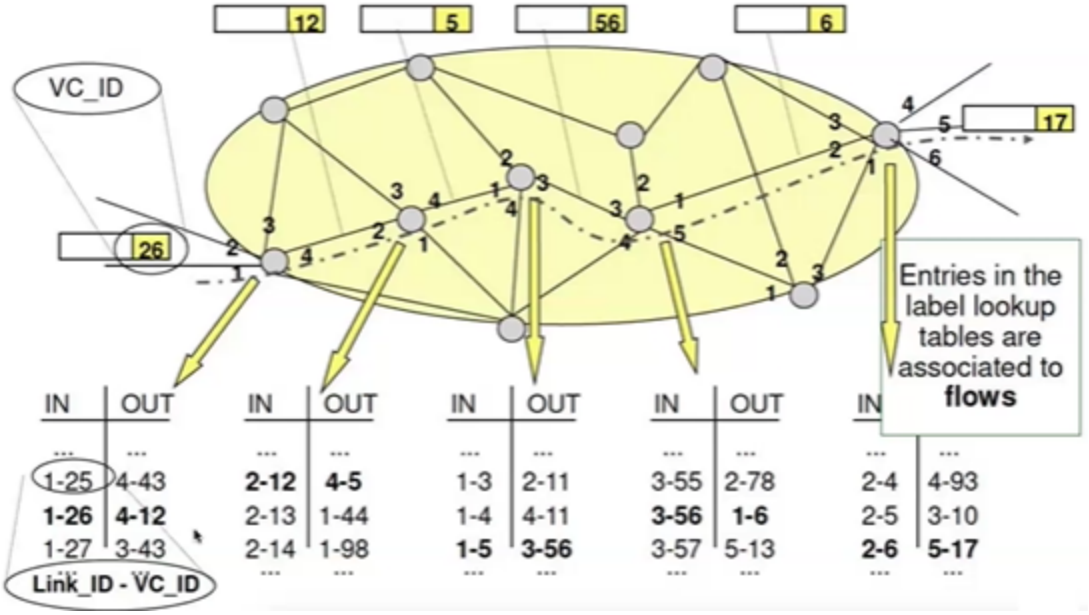
Multi Prococol Label Switching (MPLS)

MPLS: what it is

MPLS (Multiprotocol Label Switching) improves the services that the IP layer can offer, such as **QoS** and **SLAs**. MPLS operates in a connection-oriented environment, where routing is not based on source and destination addresses, but rather on labels—unique identifiers for specific connections.

MPLS is optimal to provide **Traffic Engineering**, **Virtual Private Network (VPN)**, and **Fast Restoration Service**.

MPLS: how it work



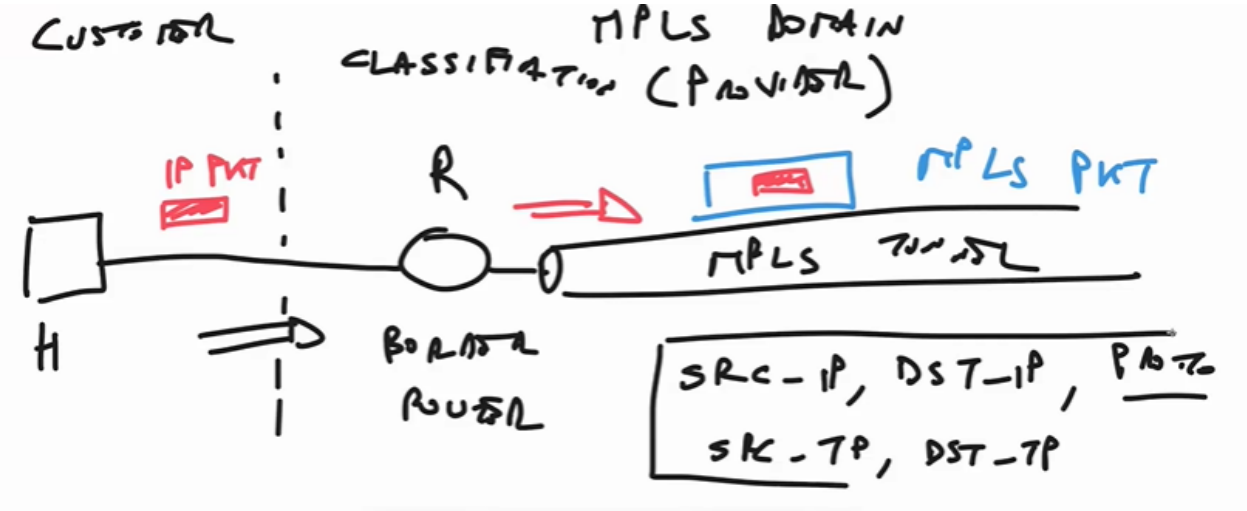
Creating a connection in MPLS means configuring each switching element (router) to handle the communication. For example, the notation $1 - 26 \mid 4 - 12$ indicates the connection setup:

- **1** represents the input interface
- **26** is the label for the input
- **4** is the output interface
- **12** is the new label for the output.

This configuration ensures that the router can correctly forward the data along the specified path using the assigned labels.

In this way the router don’t need to look at destination address but it look at input port and label, able him to address different packets which are goign to the same destiantion witouth caring about their path (so don’t care about the amount of traffic on a link)

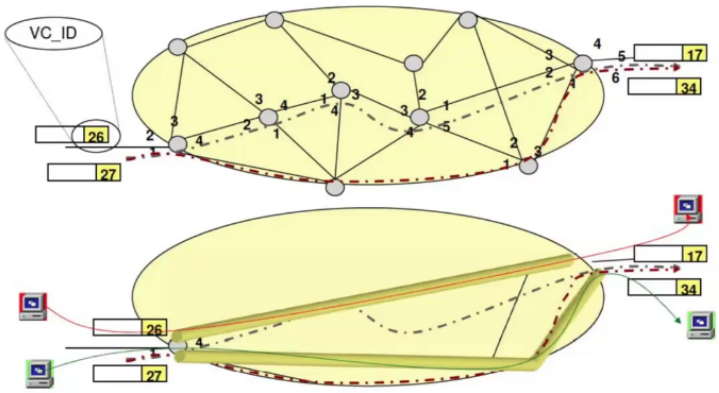
MPLS: packeting



The
border router, which is connected to the host, receives IP packets and injects them into the MPLS network by encapsulating them as MPLS packets (Label Switching Packet LSP) and adding the label we discussed. This router performs a function called **classification**, which involves analyzing the incoming packet's information to determine the appropriate MPLS tunnel.

The classification process typically examines details from the IP header, such as the source IP, destination IP, protocol type (indicating the type of message inside the encapsulated packet), and the source and destination transport ports. This ensures that the packet is routed correctly within the MPLS network based on its destination and service requirements

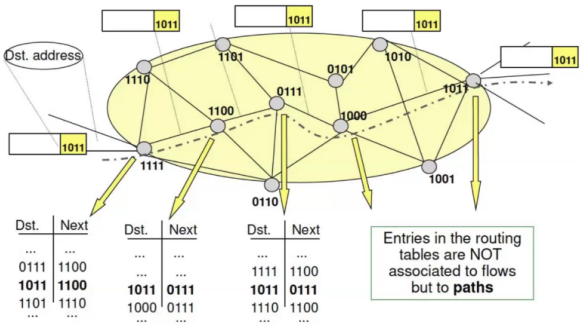
Connection-oriented packet network

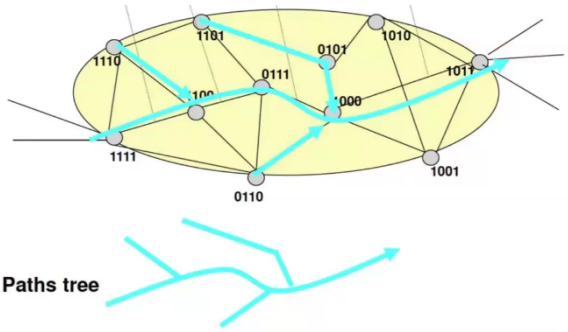


When discussing **MPLS**, it allows us to define an **end-to-end tunnel** that spans the MPLS domain. Multiple tunnels can also exist with the same source (such as a border router) and destination, enabling flexible traffic management and separation of flows.

We can speak about the **overlay model**, an end-to-end tunnel is built on top of an underlying network. This approach abstracts the complexity of the physical network while providing logical connectivity between endpoints.

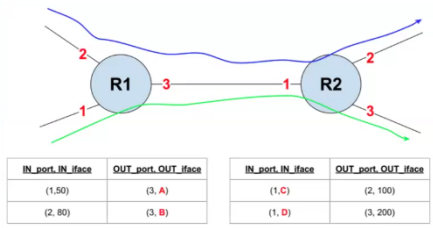
Connection-less packet network





Each subpath is selected as the one with the smallest cost (shortest path). This approach not only optimizes the routing but also solves the routing loop problem and prevents excessive traffic from accumulating on a single link.

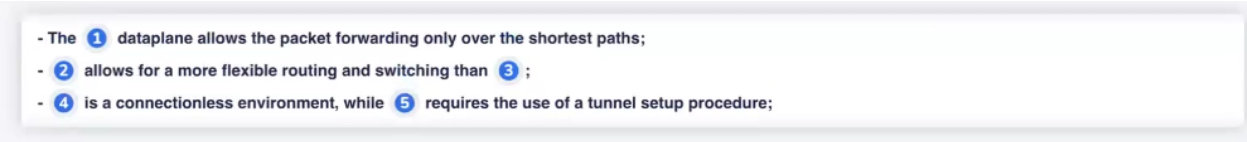
Quiz



Correct answer: none of the above because $D = A, C = B$ and $A \neq B$ (need one more constraint!)

Quiz

Fill spaces with **MPLS** or **IP**



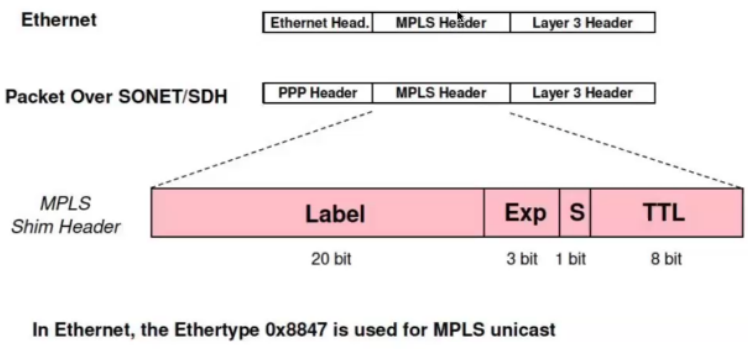
IP, MPLS, IP, IP, MPLS

MPLS network

MPSL router

Every node that supports IP also supports MPLS. A Layer 3 node is divided into two main components:

- **Switching Component**: Responsible for moving packets from the input to the output interface. This can be based on the IP address (in traditional routing) or the MPLS label (in MPLS networks).
- **Control Plane**: Handles routing protocols and supports the **Label Distribution Protocol (LDP)** to distribute labels among MPLS devices, ensuring proper label-based packet forwarding.

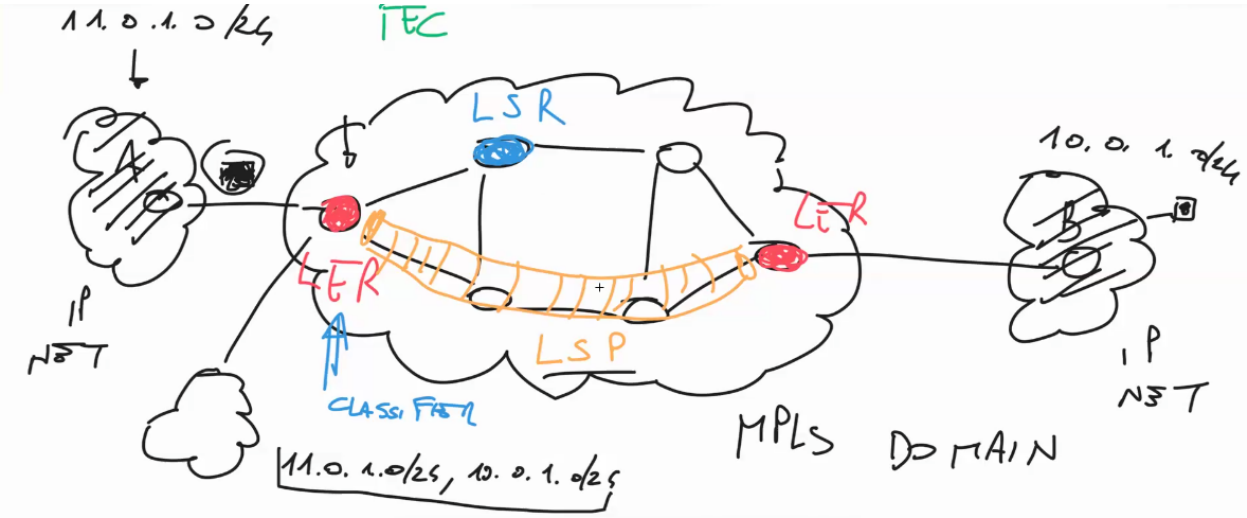


In Ethernet, the Ethertype 0x8847 is used for MPLS unicast

MPLS domain

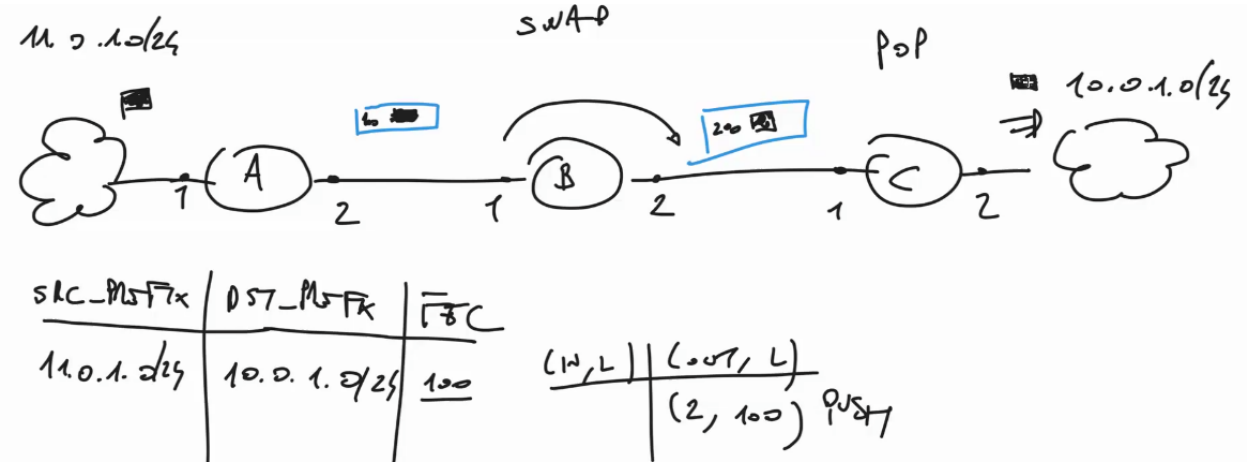
The **MPLS Domain** refers to a set of routers that support MPLS functionality.

- **LER (Label Edge Router)**: These are special routers located at the borders of the MPLS domain. They are responsible for inserting and removing MPLS labels as packets enter and leave the MPLS network.
- **LSR (Label Switching Router)**: These are internal routers within the MPLS domain that perform the core task of label switching, forwarding packets based on their MPLS labels.
- **LSP (Label Switched Path)**: This is an end-to-end tunnel within the MPLS domain, established to forward packets along a predefined path using labels (its a virtual path).
- **Label Distribution Protocol (LDP)**: Together with traditional IP routing protocols, LDP is used to distribute labels among MPLS devices.
- **Forwarding Equivalence Class (FEC)**: A set of IP packets that are forwarded in the same way and receive the same treatment.



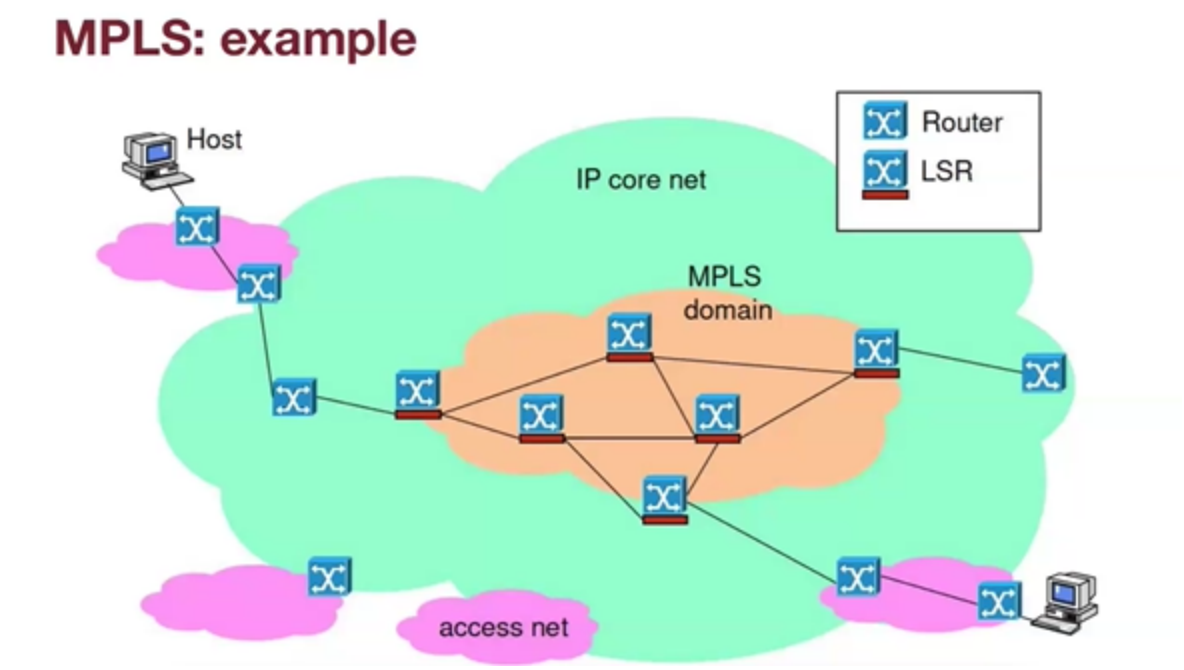
When a customer generates a packet (specifically an IP packet), the **Label Edge Router (LER)** must perform MPLS encapsulation by adding a 32-bit MPLS header. The LER also determines the appropriate MPLS label for the incoming packet. This process involves **classification** based on **FEC (Forward Equivalence Class)**.

FEC refers to a set of packets that must be processed in the same way within the MPLS domain. Packets in the same FEC share the same path, the same priority, and other handling characteristics. The classification process uses information such as the source IP, destination IP, protocol type (indicating the type of message inside the encapsulated packet), and the source and destination transport ports to group packets into the appropriate FEC.
The
LSP (Label Switched Path) is the result (output) of a control plane function called **LDP (Label Distribution Protocol)**. LDP consists of a set of messages exchanged between MPLS nodes to establish and manage the LSPs, enabling label-based forwarding across the MPLS network.



FEC (Forward Equivalence Class) represents the label to use and is maintained in the table of a **Label Edge Router (LER)**, such as at Node A for interface 1.

- **Push**: The action of adding an MPLS header, performed at interface 2 of Node A. This encapsulates the IP packet by wrapping it with an MPLS label.
- **Swap**: The action of replacing an existing label with a new one as the packet moves through the network.
- **Pop**: The action of removing the MPLS header, performed at the egress node (e.g., Node C), to restore the original IP packet for delivery.

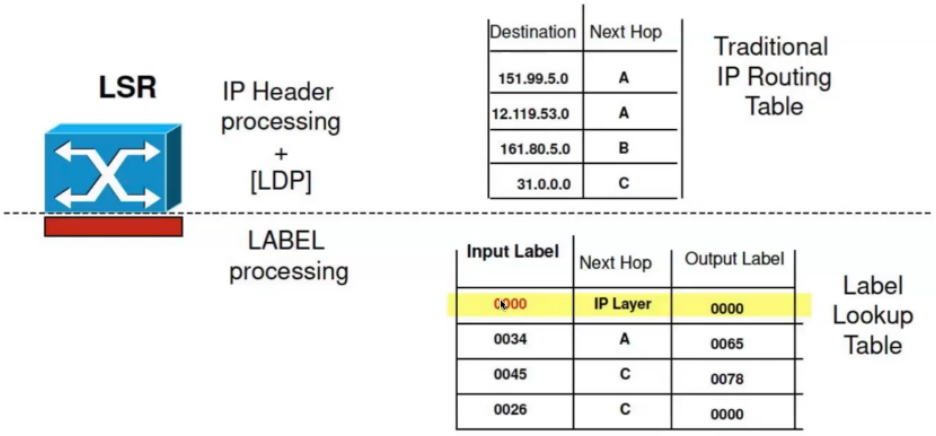


Quiz

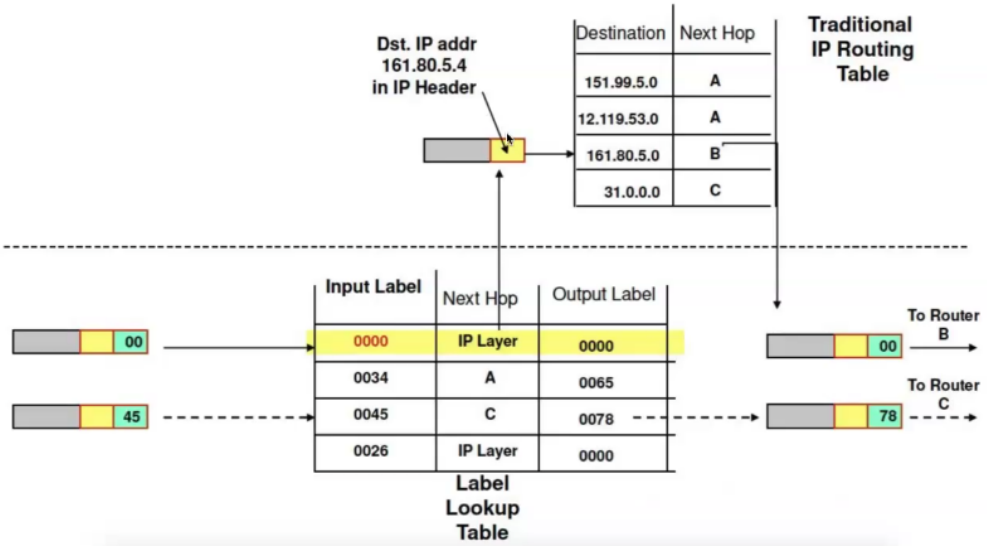
- pkt: encapsualted packets
- color: a MPLS header, can be added multiple MPLS header

Correct answer: A-pop, B-swap, C-push

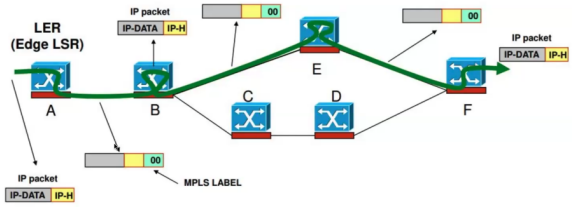
Structure of a Label Switched Router



A special MPLS label **00** indicates that the packet should bypass MPLS label switching and instead use the traditional IP routing table for delivery. This is done in different cases e.g. also for when I want to provide differen QoS, real-time communication with a certain requirements of latency, preserve bandwidth, ...



Connectionless forwarding along the IP path



Connection oriented forwarding along a LSP