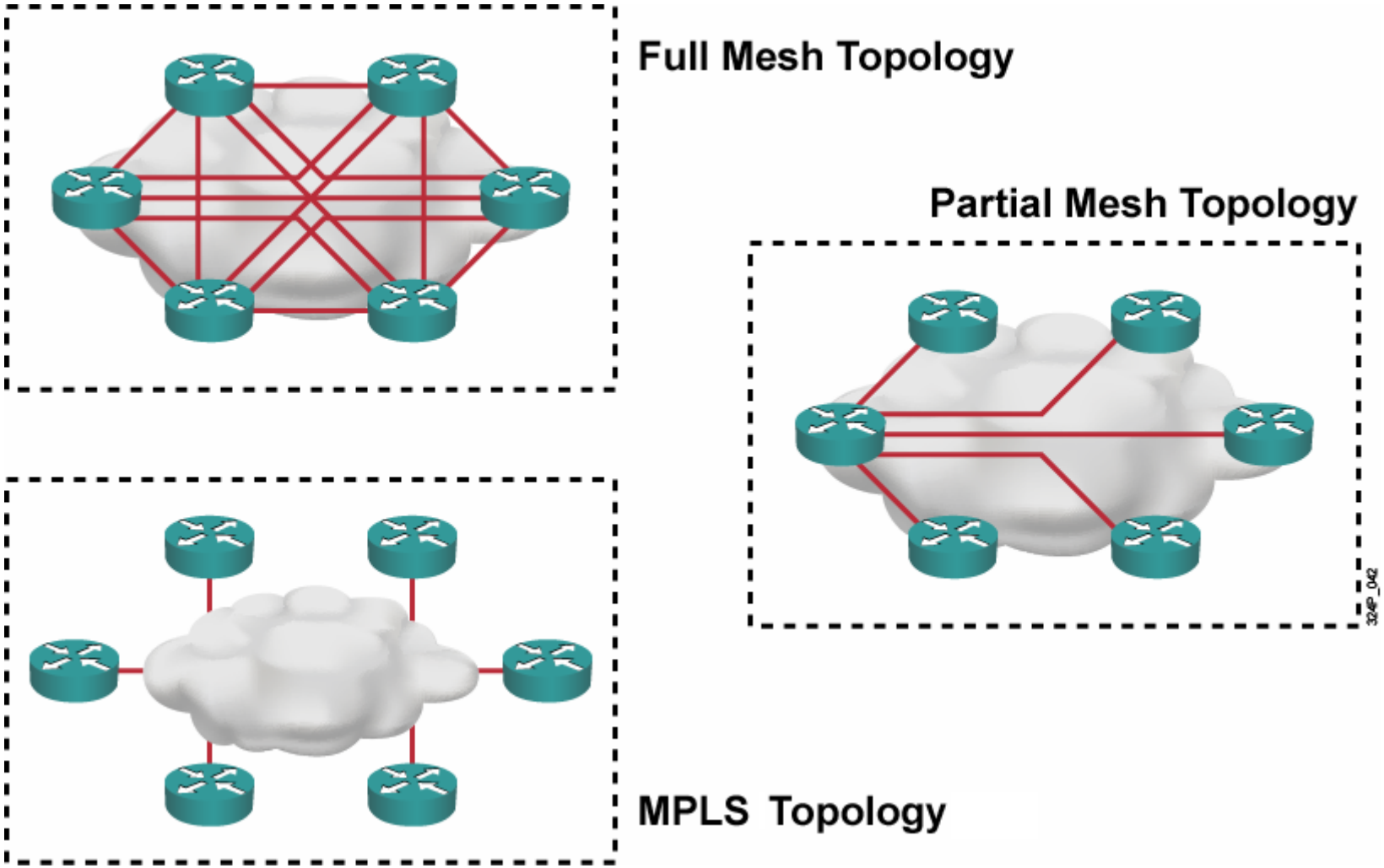
MPLS

WAN Topologies



Multiprotocol Label Switching (MPLS)

- IETF standard , RFC3031
- Basic idea was to combine IP routing protocols with a forwarding algoritm based on a header with fixed length label instead of the longest prefix match on the destination IP address in the IP header
- Label switching makes it possible to make forwarding decisions based on more complex criterias than IP dst address, but still keeping a simple lookup

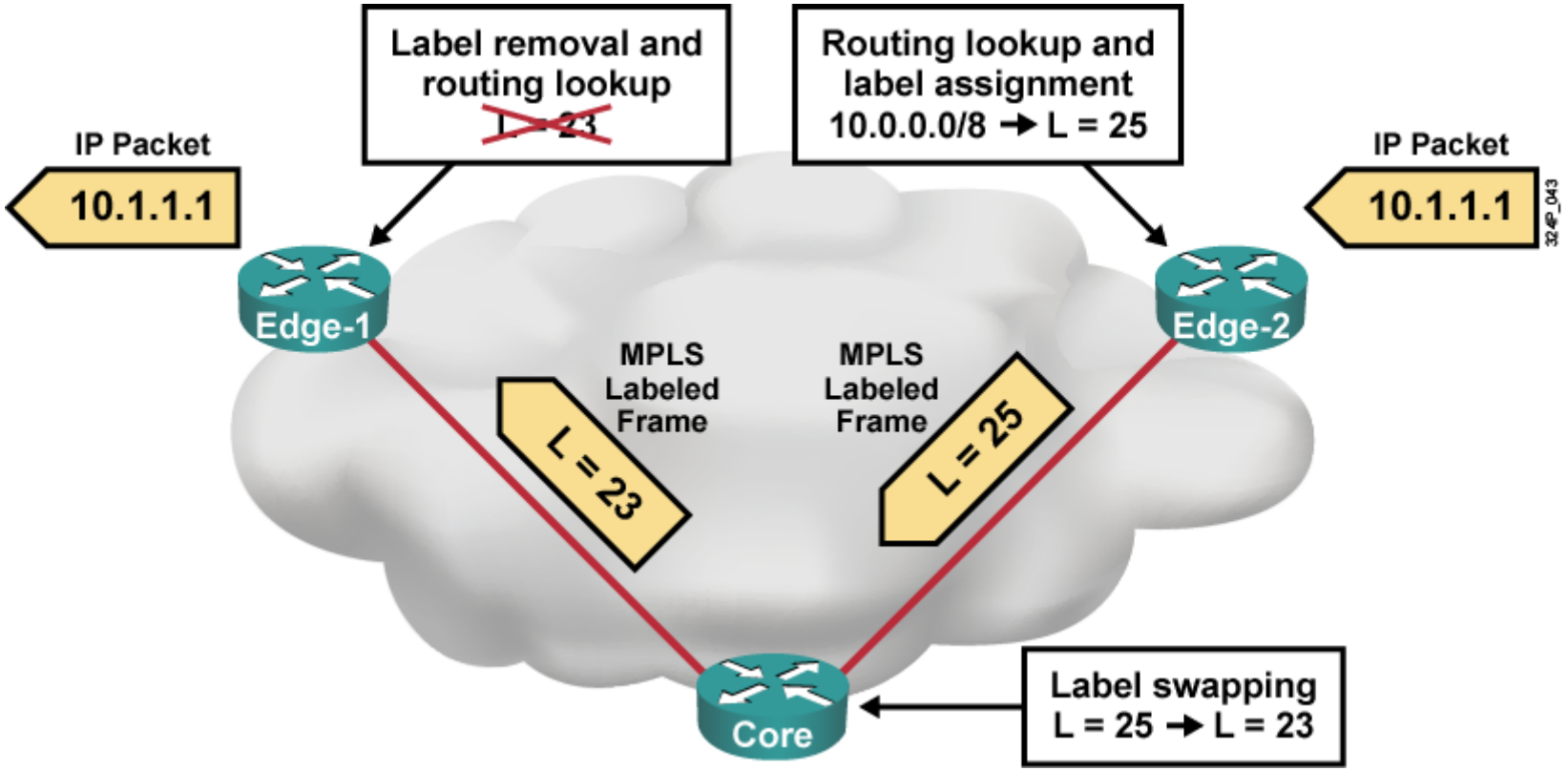
Basic Multiprotocol Label Switching (MPLS) Features

- MPLS reduces routing lookups.
- MPLS forwards packets based on labels.
- Labels usually correspond to IP destination networks (equal to traditional IP forwarding).
- Labels can also correspond to other parameters:
  - Layer 3 VPN destination
  - Layer 2 circuit
  - Outgoing interface on the egress router
  - QoS
  - Source address
- MPLS supports forwarding of all Layer 3 protocols, not just IP.

Application of MPLS

- Traffic engineering & Route control
- QoS – Diff-serv
- VPNs MPLS

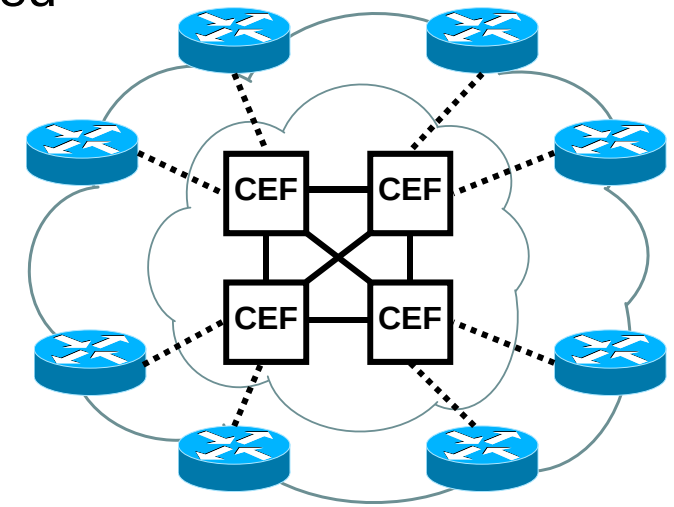
MPLS Operation



- Only edge routers must perform a routing lookup.
- Core routers switch packets based on simple label lookups and swap labels.

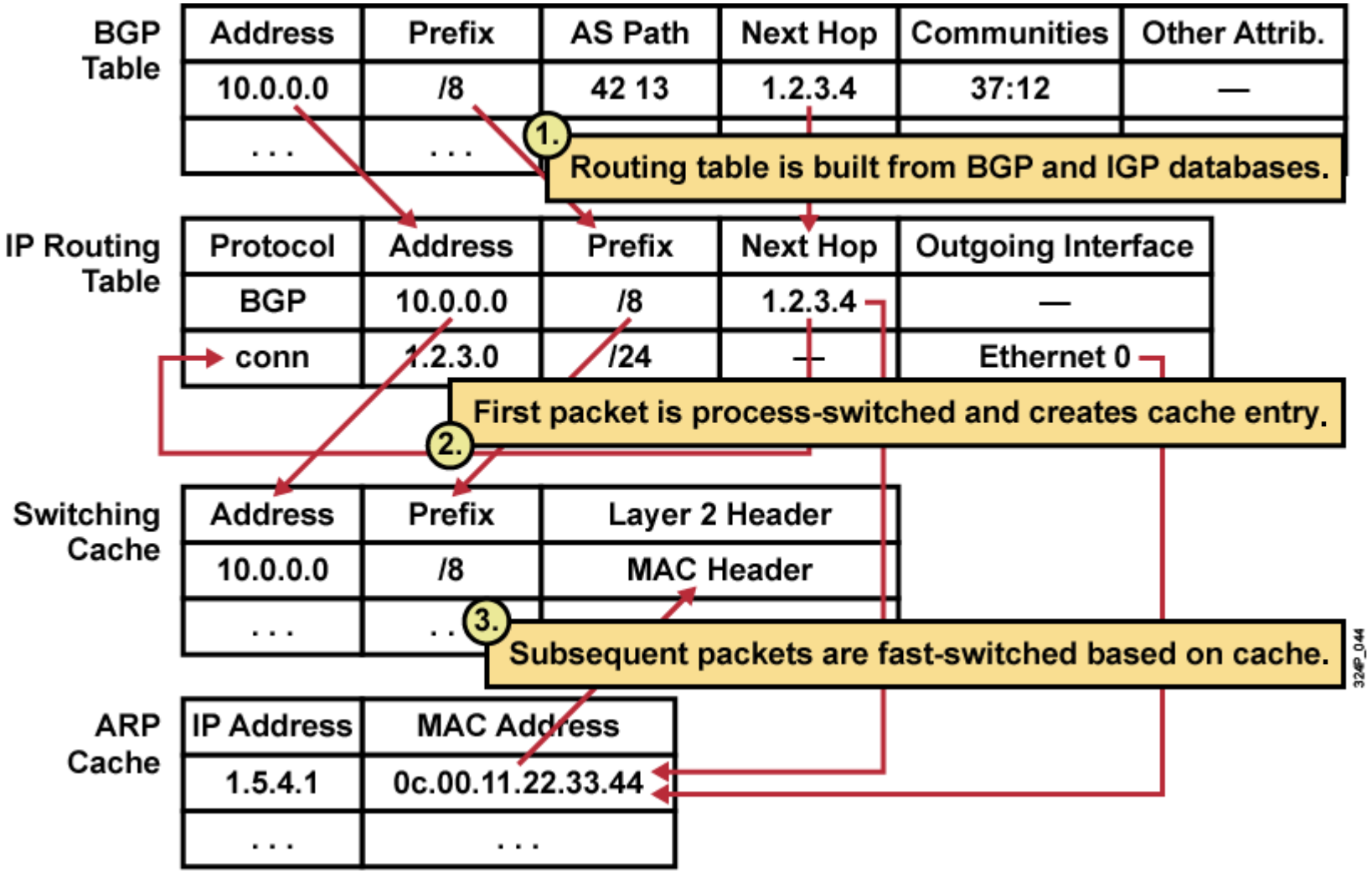
Cisco IOS Platform Switching Mechanisms

- Process switching, or routing table-driven switching:
  - Full lookup is performed at every packet
- Fast switching, or cache-driven switching:
  - Most recent destinations are entered in the cache
  - First packet is always process-switched
- Topology-driven switching:
  - CEF (prebuilt FIB table)

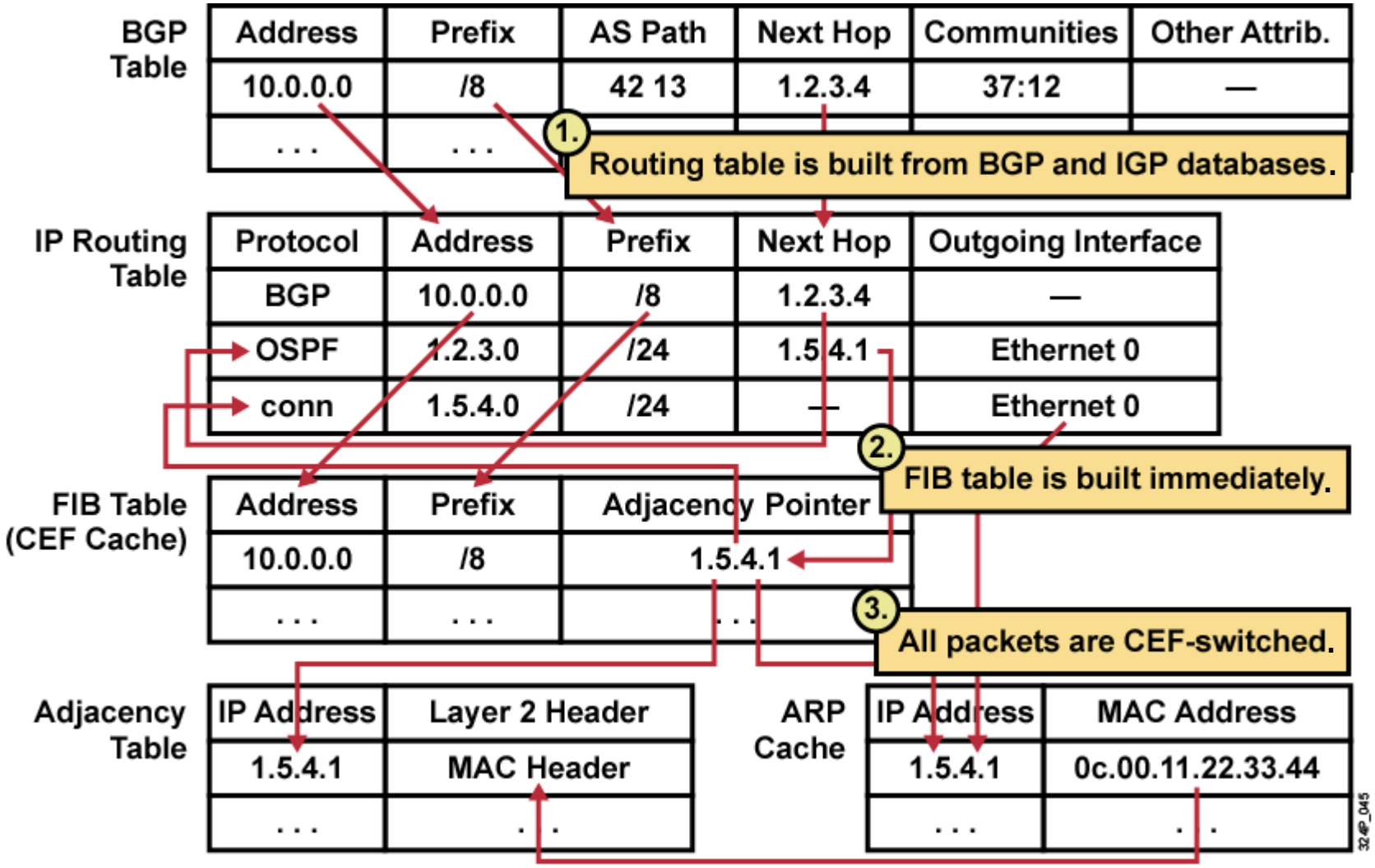


Cisco Express Forwarding

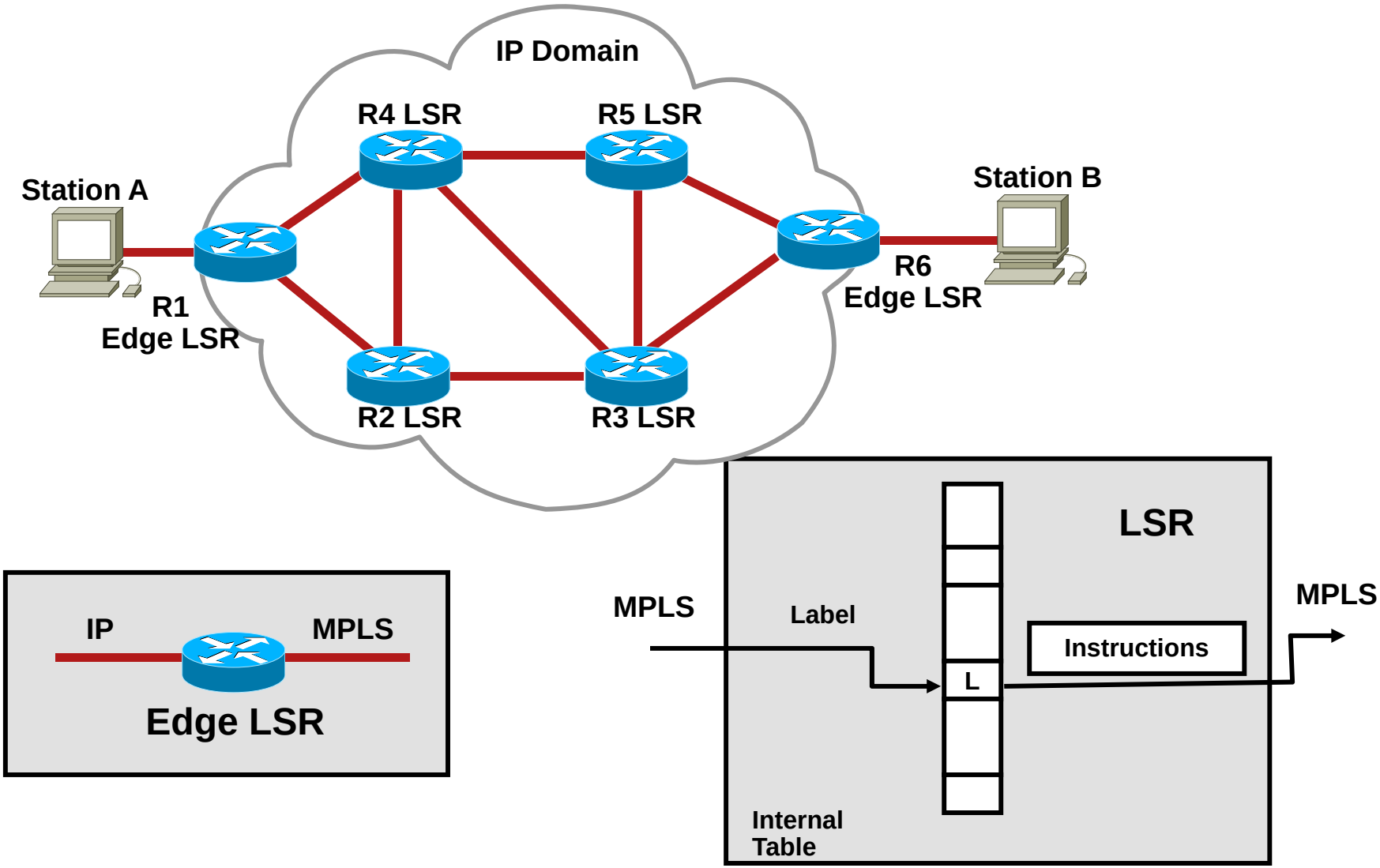
Standard IP Switching Overview



CEF Switching Overview



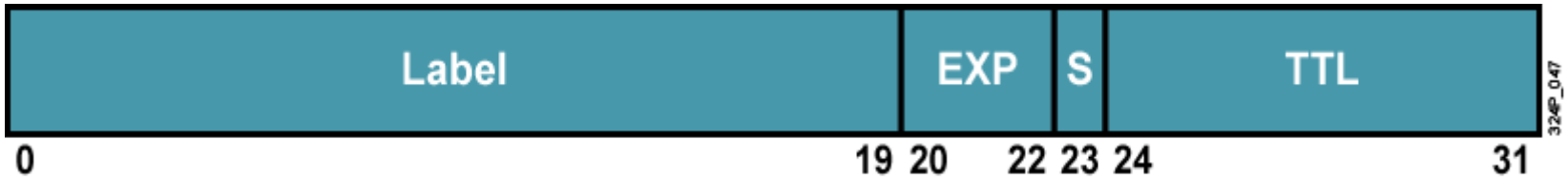
MPLS Switching Overview



MPLS Characteristics

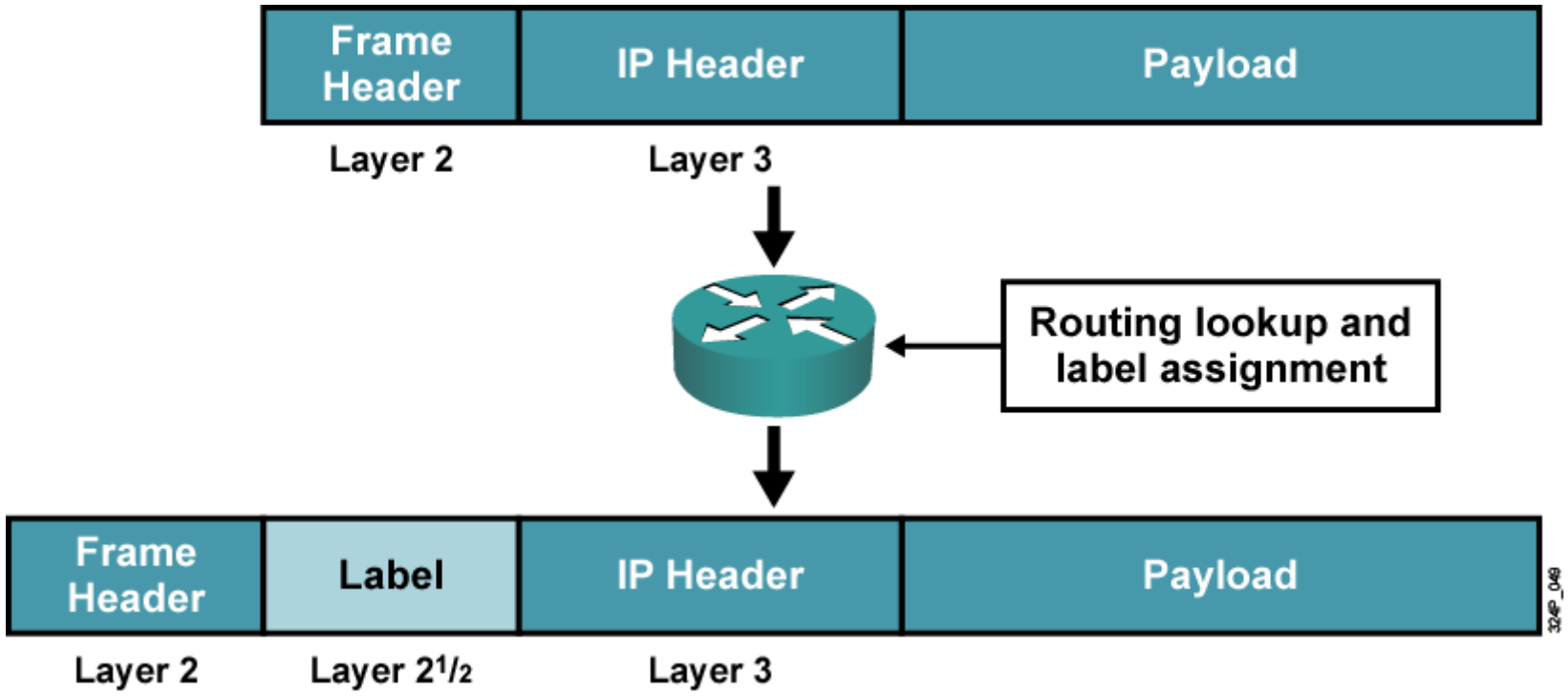
- MPLS technology is intended to be used anywhere, regardless of Layer 1 media and Layer 2 protocol.
- MPLS uses a 32-bit label field that is inserted between Layer 2 and Layer 3 headers (frame mode MPLS).
- MPLS over ATM uses the ATM header as the label (cell mode MPLS).

Label Format



Field	Description
20-bit label	The actual label. Values 0 to 15 are reserved.
3-bit experimental (EXP) field	Undefined in the RFC. Used by Cisco to define a class of service (CoS) (IP precedence).
1-bit bottom-of-stack indicator	MPLS allows multiple labels to be inserted. The bottom-of-stack bit determines if this label is the last label in the packet. If this bit is set (1), the setting indicates that this label is the last label.
8-bit Time to Live (TTL) field	Has the same purpose as the TTL field in the IP header.

Frame Mode MPLS Operation

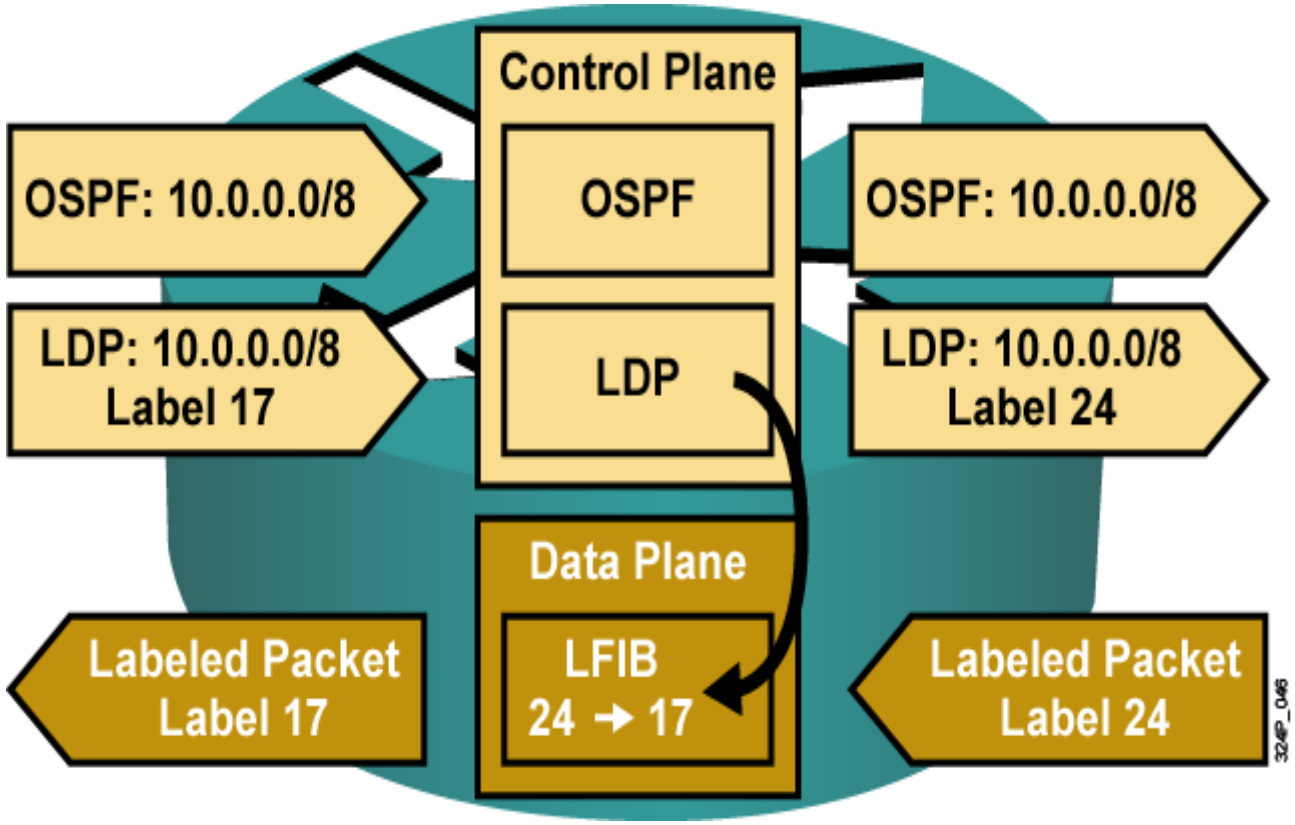


Note: The type or protocol ID field indicates as MPLS enabled layer-3 protocol.

Major Components of MPLS Architecture

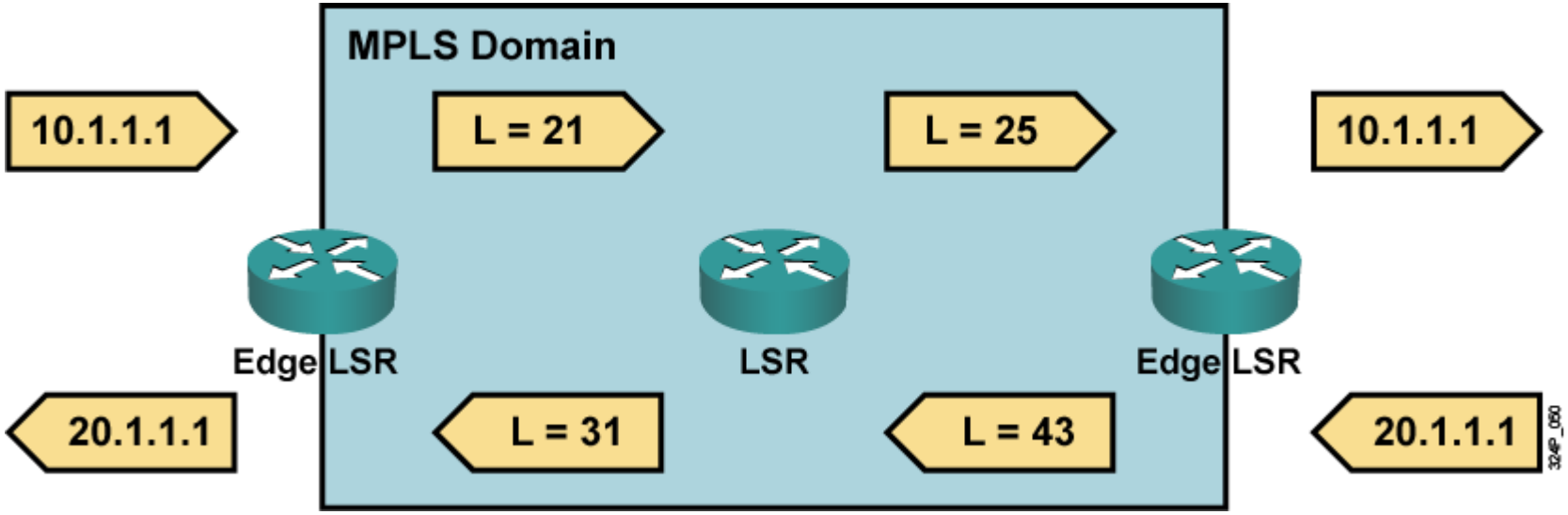
- Control plane:
  - Exchanges routing information and labels
  - Contains complex mechanisms, such as OSPF, EIGRP, IS-IS, and BGP, to exchange routing information
  - Exchanges labels, such as LDP, BGP, and RSVP
- Data plane:
  - Forwards packets based on labels
  - Has a simple forwarding engine

Control Plane Components Example



- Information from control plane is sent to the data plane.

Label Switch Routers (LSRs)



- LSR primarily forwards labeled packets (swap label).
- Edge LSR:

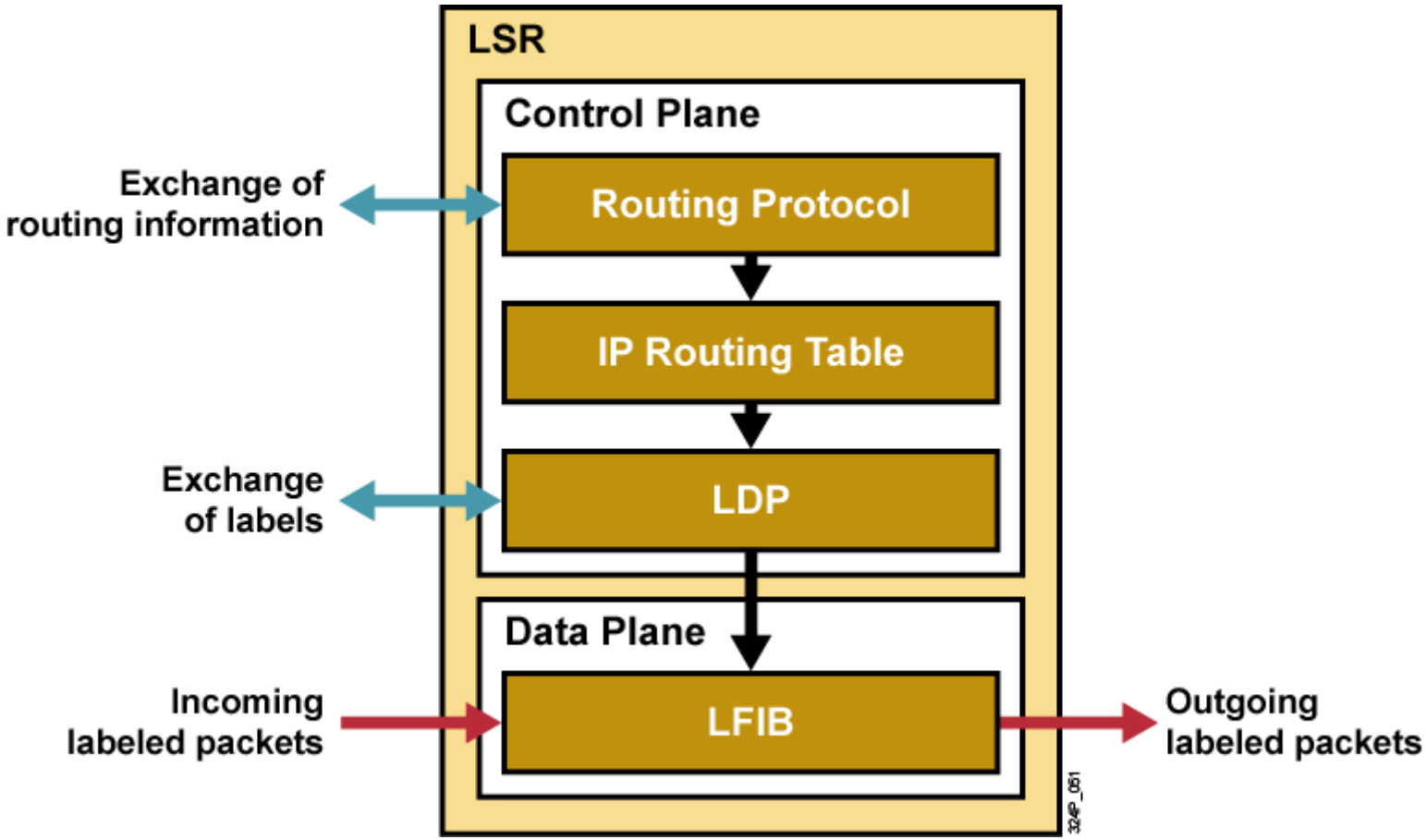
  Labels IP packets (impose label) and forwards them into the MPLS domain.

  Removes labels (pop label) and forwards IP packets out of the MPLS domain.

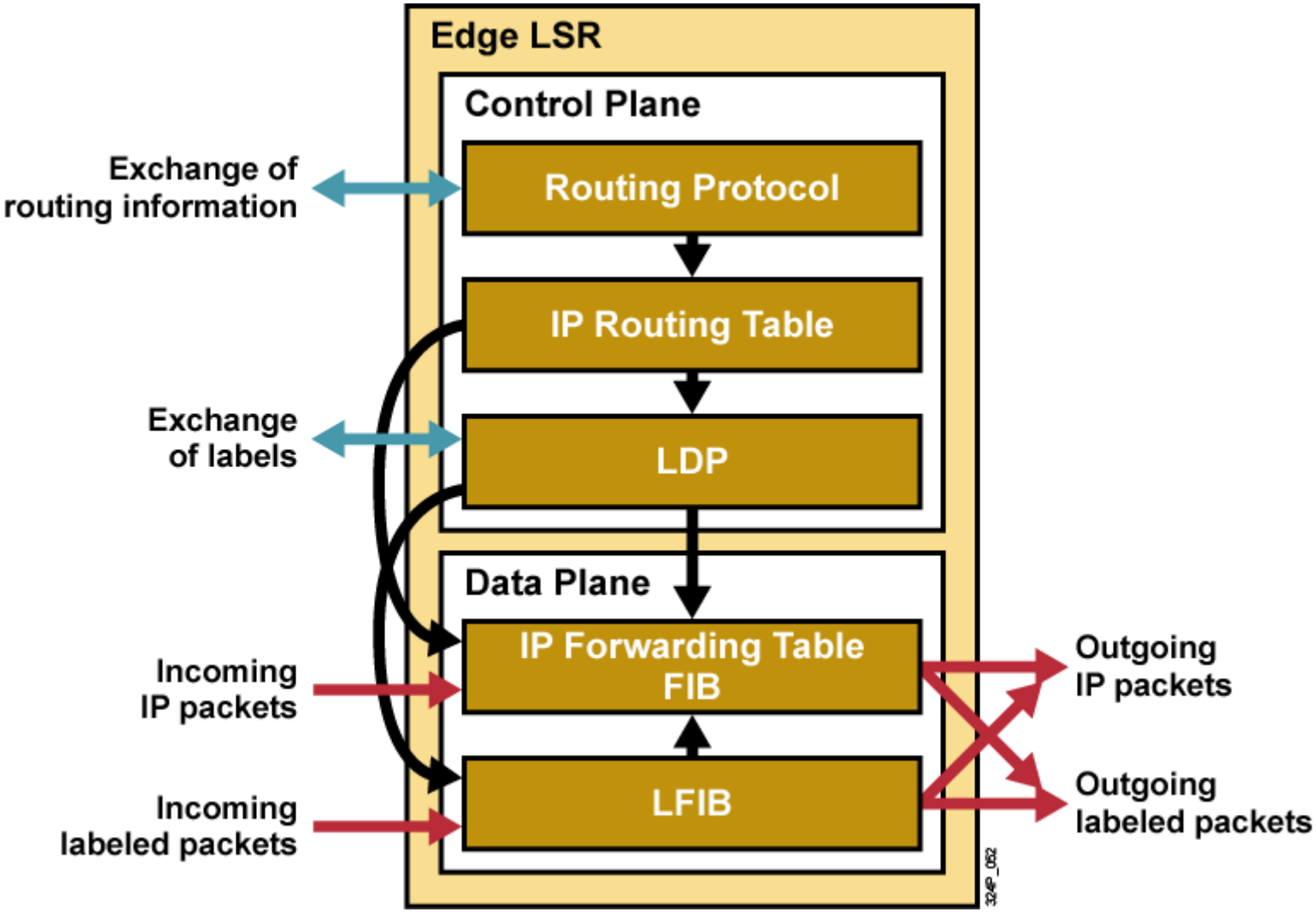
Functions of LSRs

Component	Function
Control plane	– Exchanges routing information – Exchanges labels
Data plane	– Forwards packets (LSRs and Edge LSRs)

Component Architecture of LSR



Component Architecture of Edge LSR

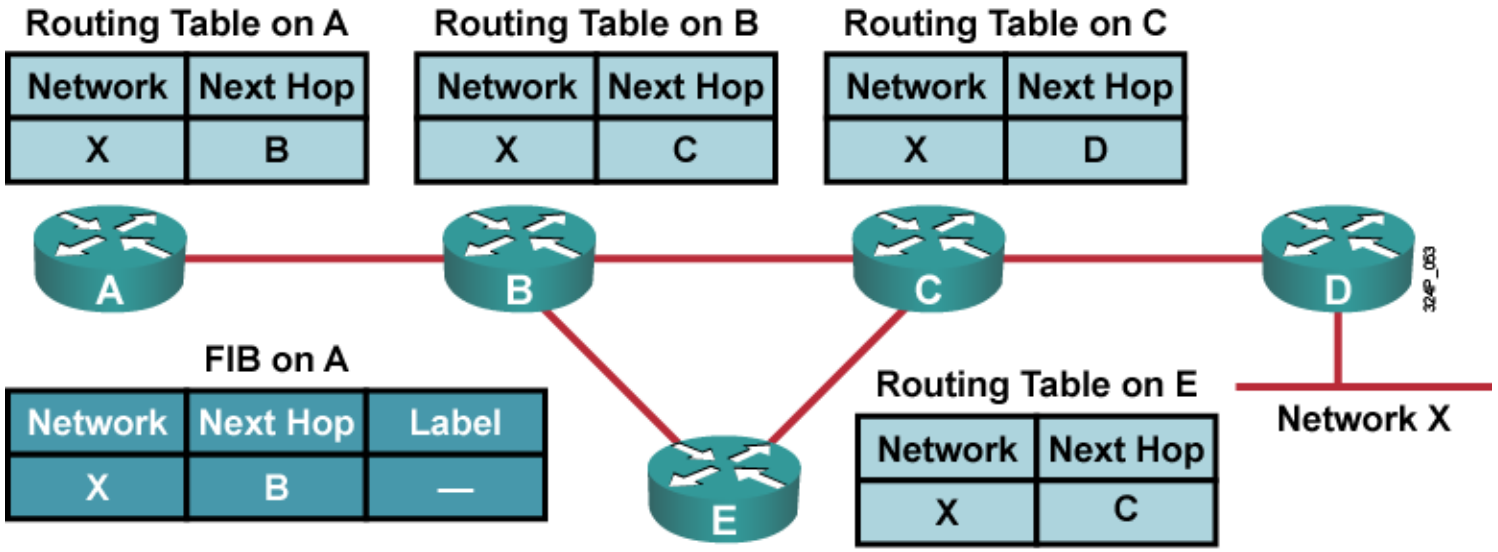


Label Allocation in a Frame Mode MPLS Environment

- Label allocation and distribution in a frame mode MPLS network follows these steps:
  1. IP routing protocols build the IP routing table.
  2. Each LSR independently assigns a label to every destination in the IP routing table.
  3. LSRs announce their assigned labels to all other LSRs.
  4. Every LSR builds LIB, LFIB, and FIB data structures based on the received labels.

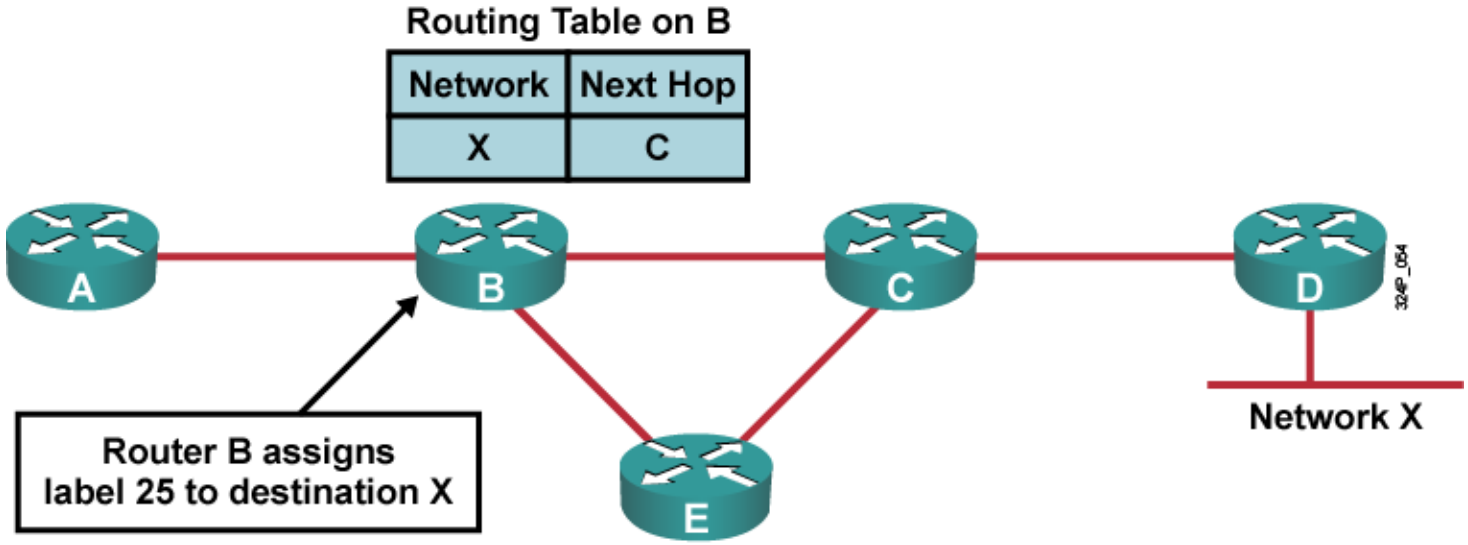
Note: Label allocation, label imposing, label swapping, and label popping usually happen in the service provider network, not the customer (enterprise) network. Customer routers never see a label.

Building the IP Routing Table



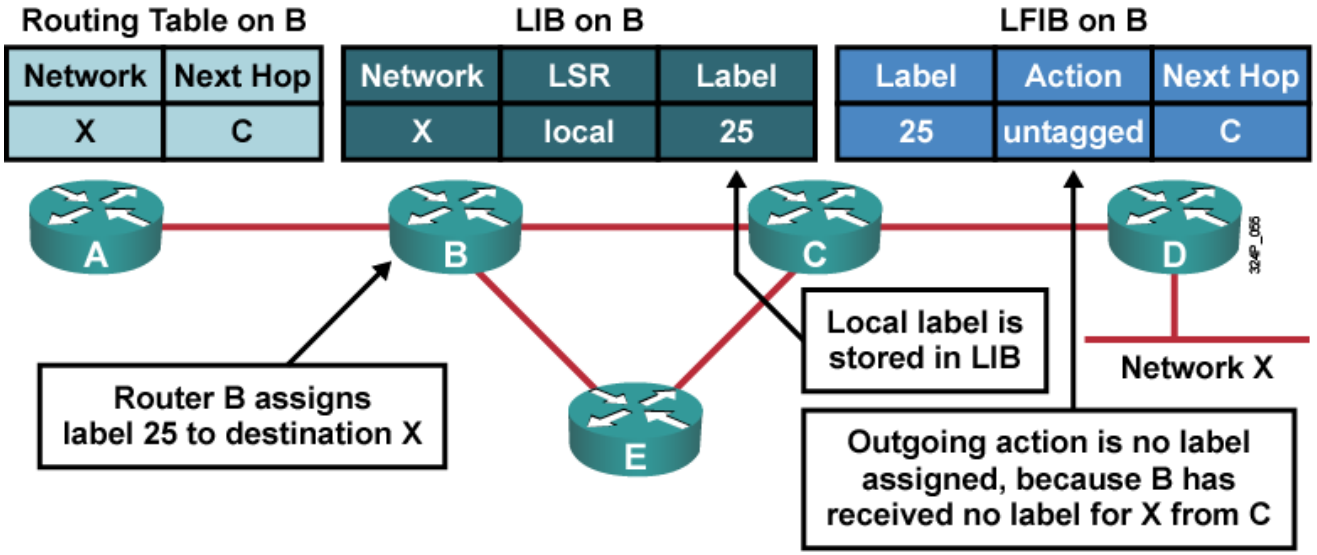
- IP routing protocols are used to build IP routing tables on all LSRs.
- FIBs are built based on IP routing tables, initially with no labeling information.

Allocating Labels



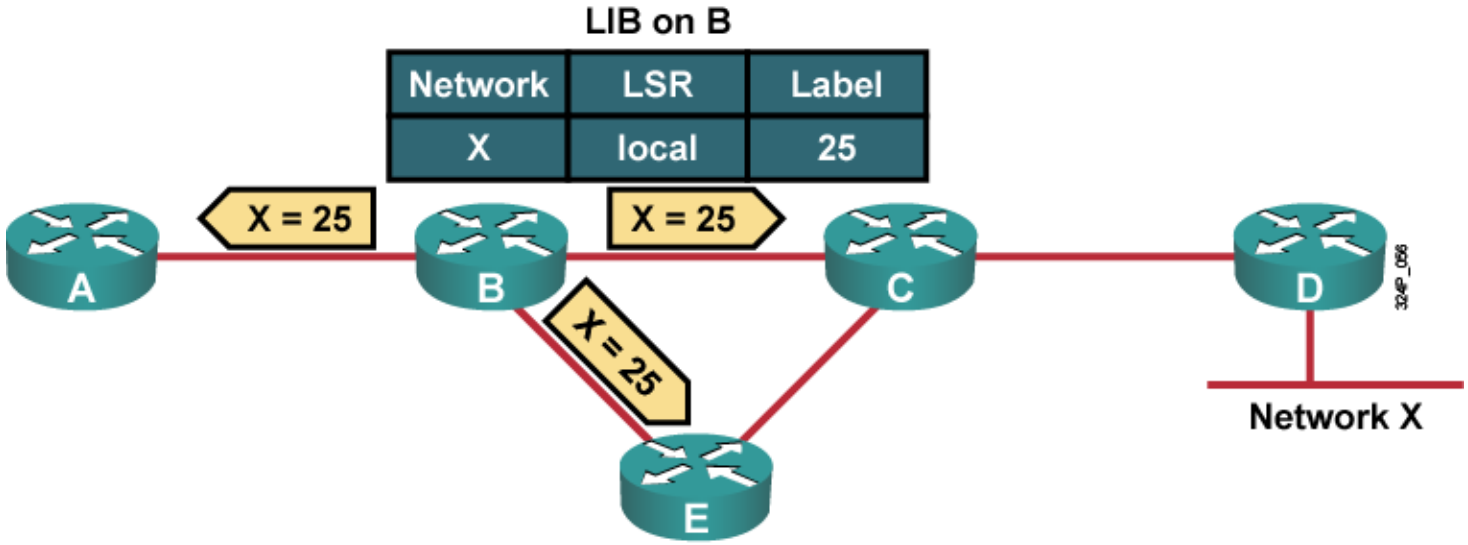
- Every LSR allocates a label for every destination in the IP routing table.
- Labels have local significance.
- Label allocations are asynchronous.

LIB and LFIB Setup



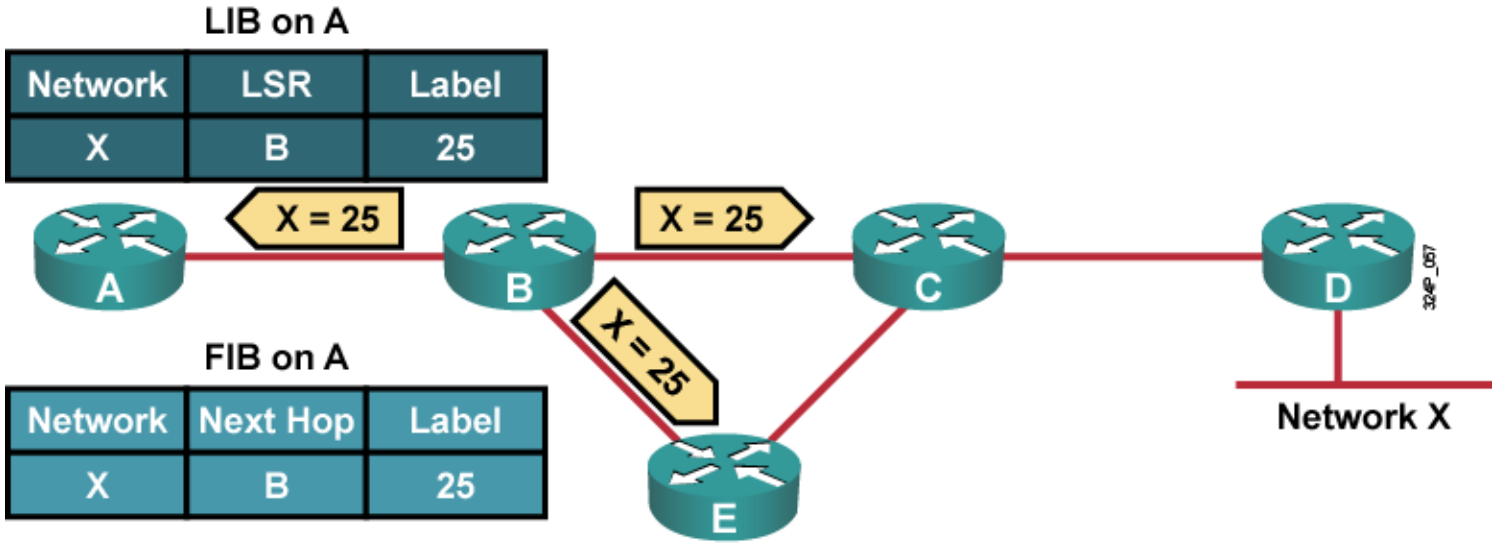
- LIB and LFIB structures have to be initialized on the LSR that is allocating the label.
- Untagged action removes the label from the frame and causes the router to send a pure IP packet.

Label Distribution and Advertisement



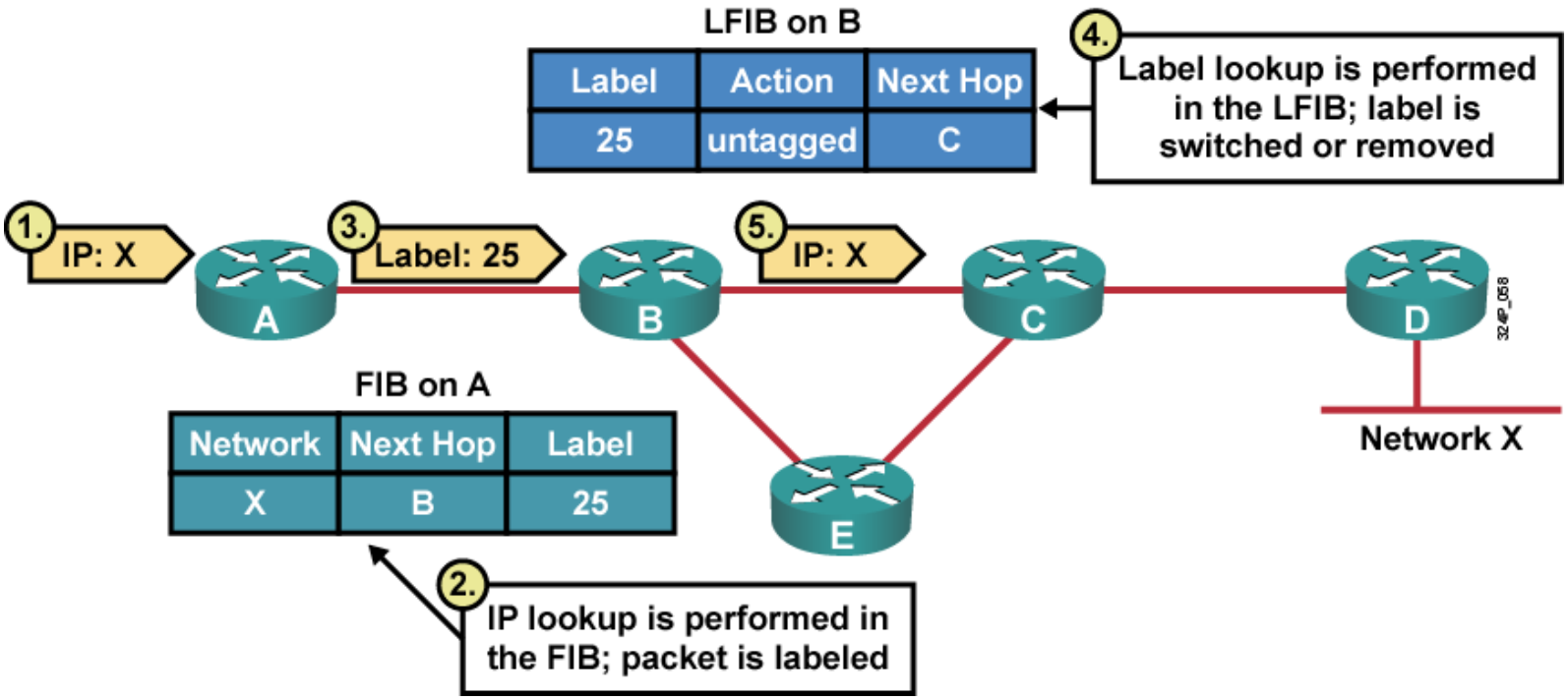
- The allocated label is advertised to all neighbor LSRs, regardless of whether the neighbors are upstream or downstream LSRs for the destination.

Receiving Label Advertisement



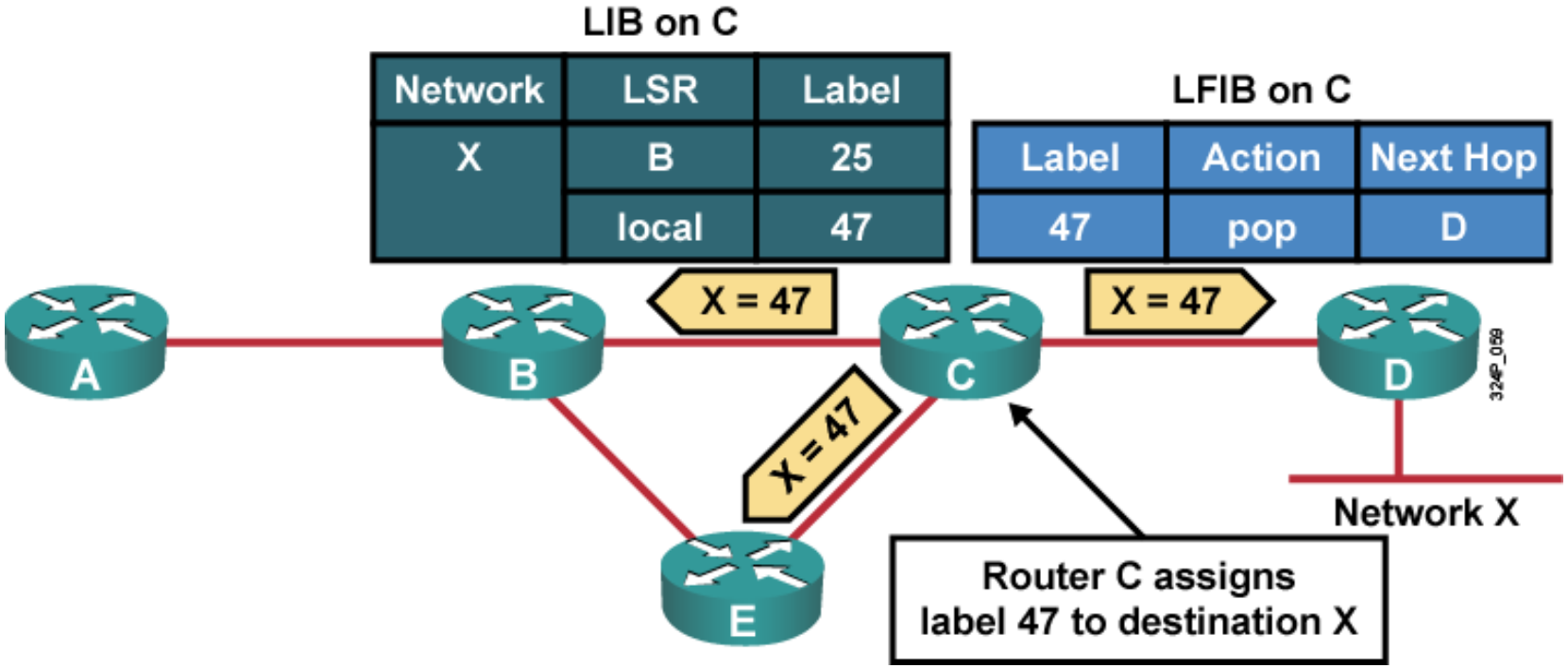
- Every LSR stores the received label in the LSR's LIB.
- Edge LSRs that receive the label from their next hop also store the label information in the FIB.

Interim Packet Propagation



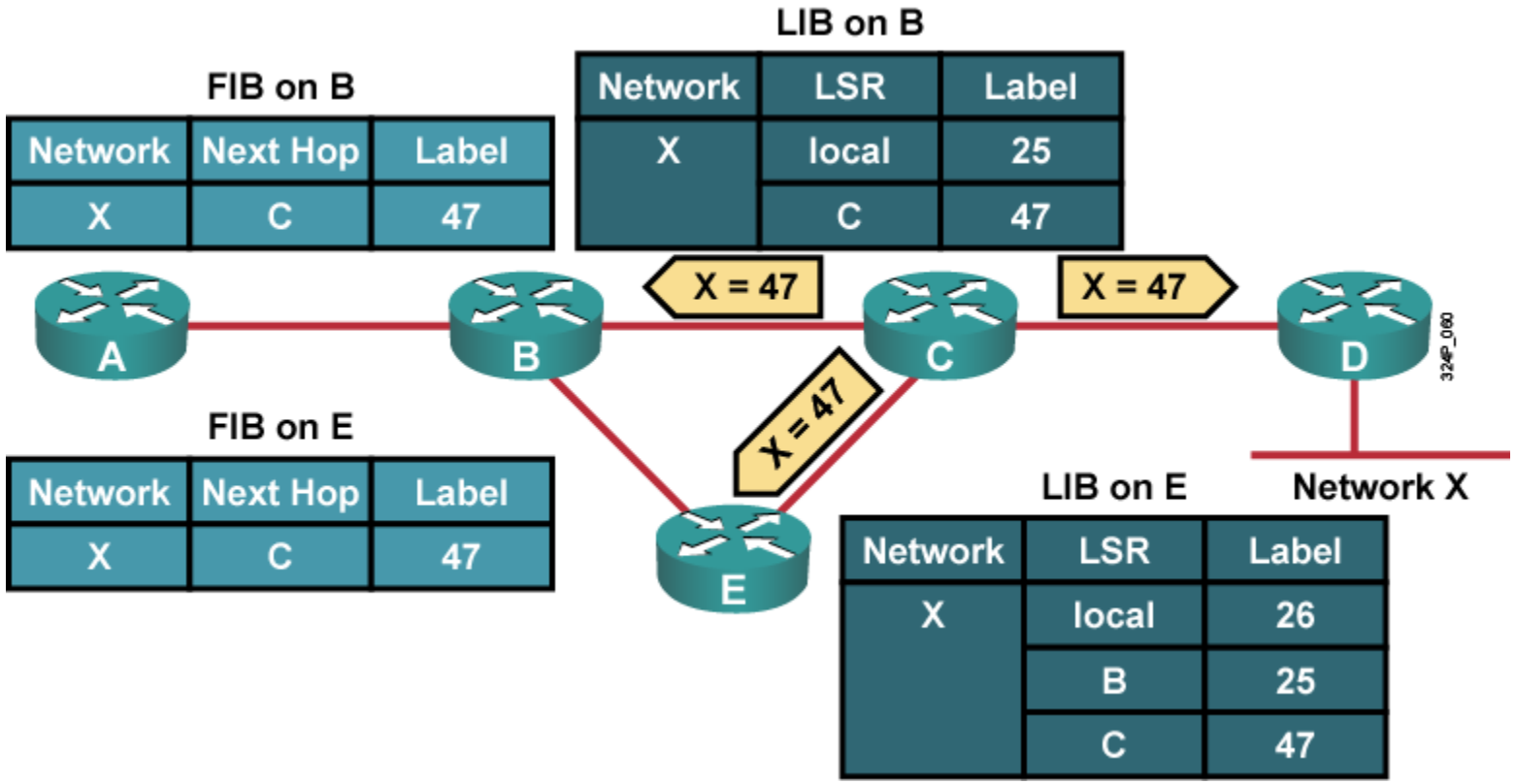
- Forwarded IP packets are labeled only on the path segments where the labels have already been assigned.

Further Label Allocation



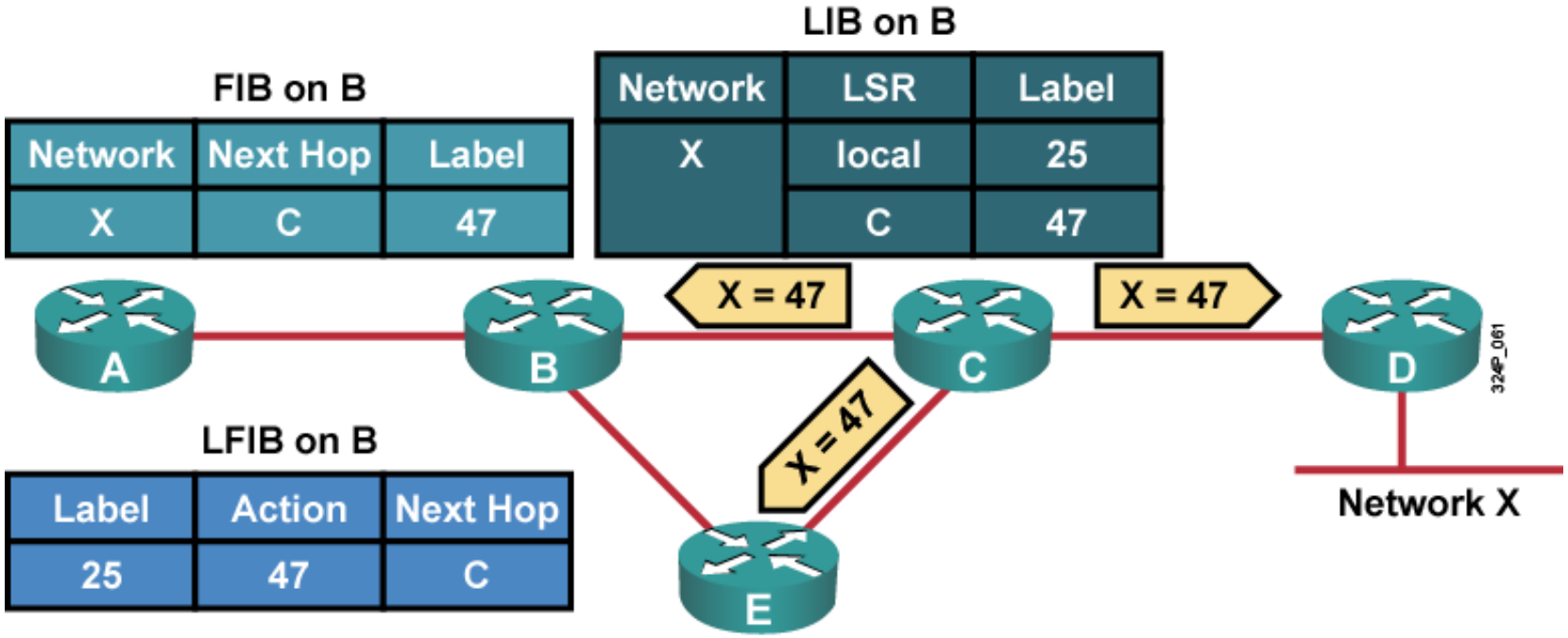
- Every LSR will eventually assign a label for every destination.

Receiving Label Advertisement



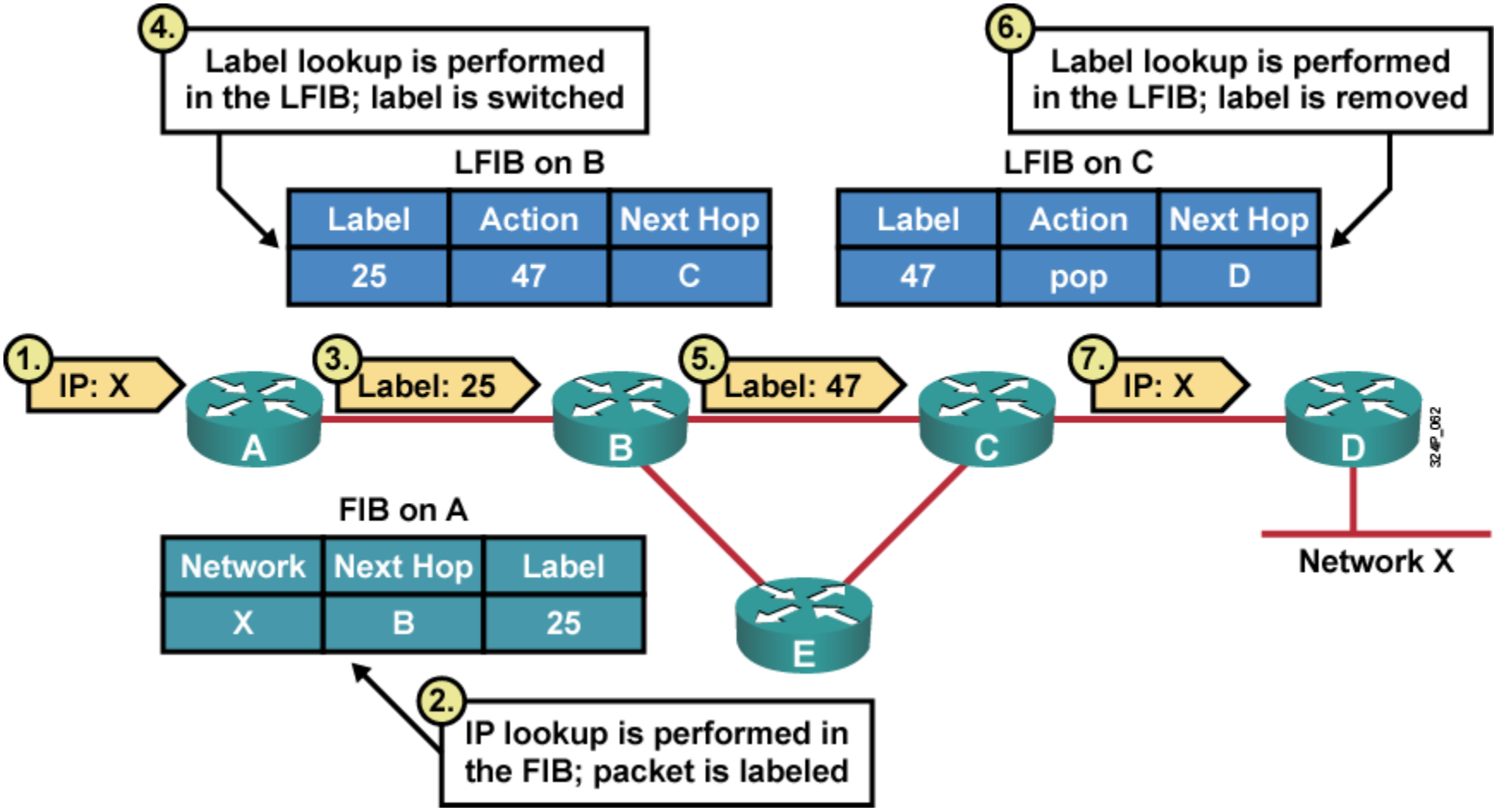
- Every LSR stores received information in its LIB.
- LSRs that receive their label from their next-hop LSR also populate the IP forwarding table.

Populating the LFIB Table



- Router B has already assigned a label to Network X and created an entry in the LFIB.
- The outgoing label is inserted in the LFIB after the label is received from the next-hop LSR.

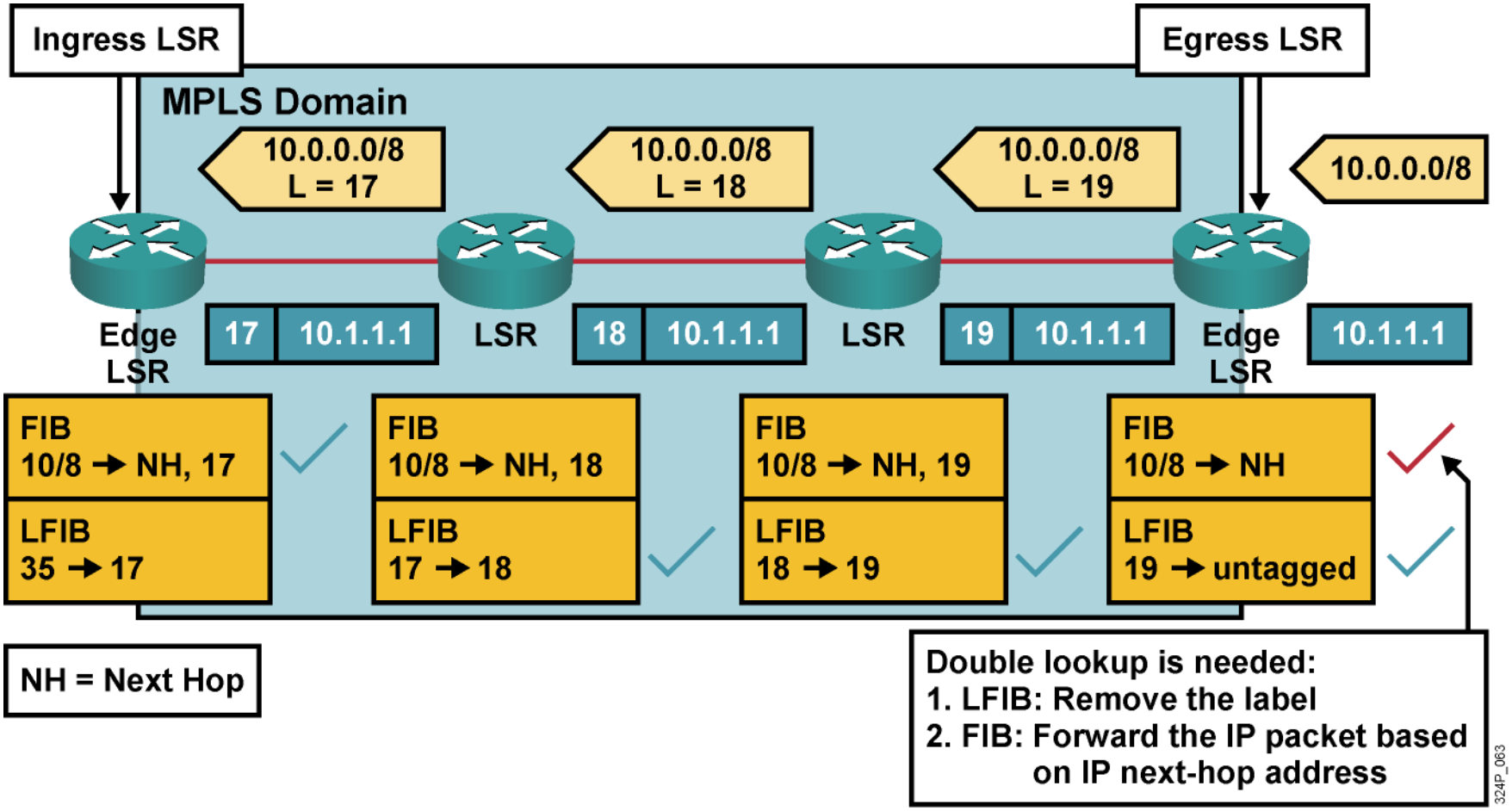
Packet Propagation Across an MPLS Network



Penultimate Hop Popping (PHP)

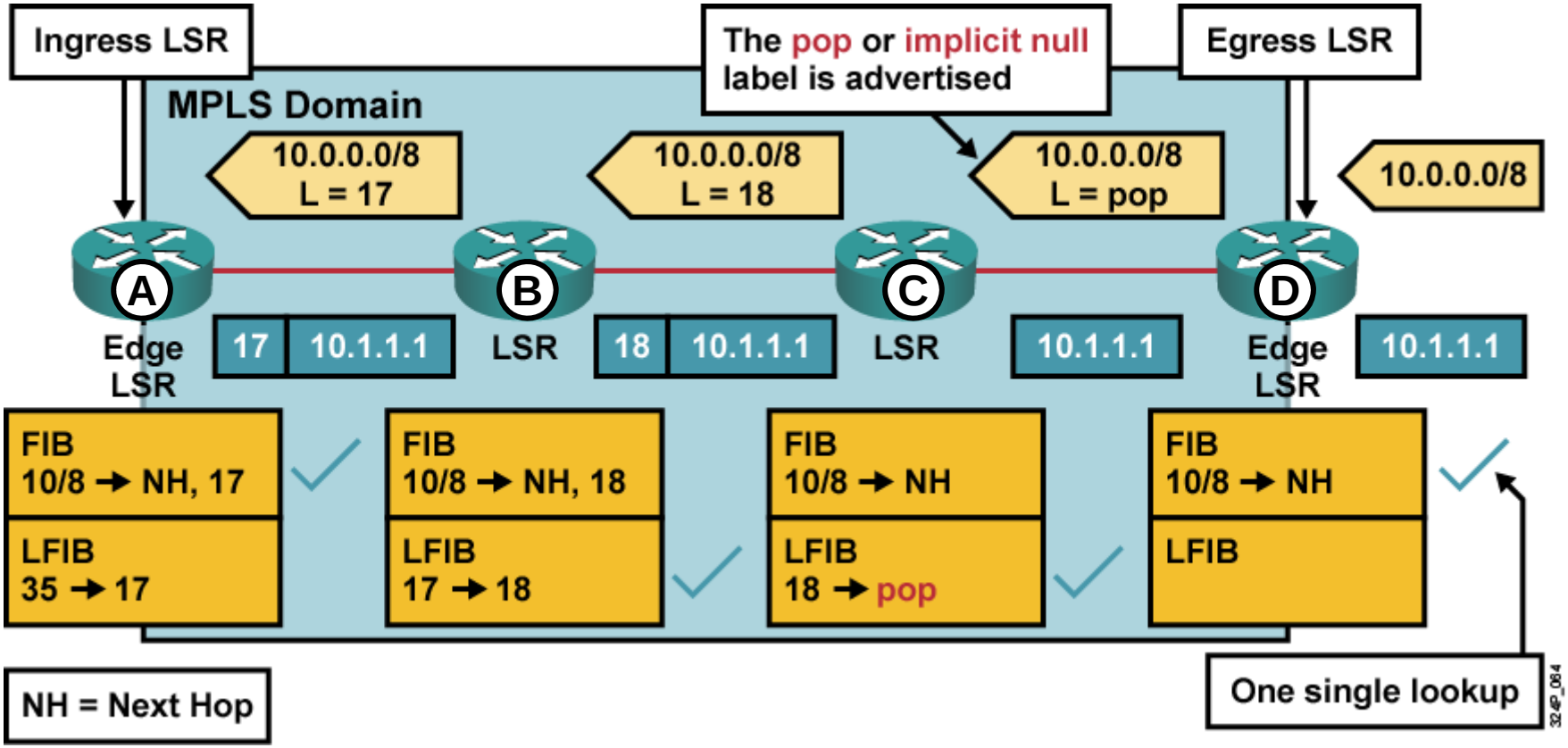
- PHP optimizes MPLS performance by reducing CPU effort on Edge LSRs.
- The Edge LSR advertises a pop or implicit null label (value of 3) to a neighbor.
- The pop tells the neighbor to use PHP.

MPLS Without PHP



- A double lookup is required.

MPLS with PHP



- A label is removed on the router that is located before the last hop within an MPLS domain (the penultimate router).

Label Switched Path LSP

Two mechanisms to do path selection

Independet

- Hop-by- hop
- Regular routing protocol to select the path

Ordered

- Explicit routing
- Path completely specified by edge LSR

Label Distribution

Need to have signaling between LSRs and set up LSP

- Label distributions

LDP (Label Distribution Protocol)

RSVP(Resourse Reservation Protocol)

BGP