Hands-on Advanced Networking Topics: BGP, BGP Hijacking, MPLS, MPLS-based VPNs, Segment Routing, and others

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# Motivation and Introduction to Multiprotocol Label Switching (MPLS)

Introduction to MPLS

- Multiprotocol Label Switching (MPLS) evolved from a number of industry efforts in the mid-to-late 1990s

- The goal was to improve the forwarding speed of IP routers by adopting a key concept from the world of virtual-circuit networks: a fixed-length label

- The label-based forwarding was intended to augment destination-based IP forwarding (selectively labeling datagrams and allowing routers to forward datagrams based on labels)

J. Kurose, K. Ross, Computer Networks, a Top-down Approach, 7th Edition, Pearson

Introduction to MPLS

- The MPLS header is added between the layer-2 (e.g., Ethernet) header and layer-3 (i.e., IP) header

  ➢ The Label Value: First 20 bits are the label value

  ➢ EXP: Three bits are the experimental (EXP) bits. These are solely used for Quality of Service (QoS) purposes

  ➢ S: 1 bit is for Bottom of Stack (BoS)

  ➢ TTL: Last 8 bits are for Time-To-Live
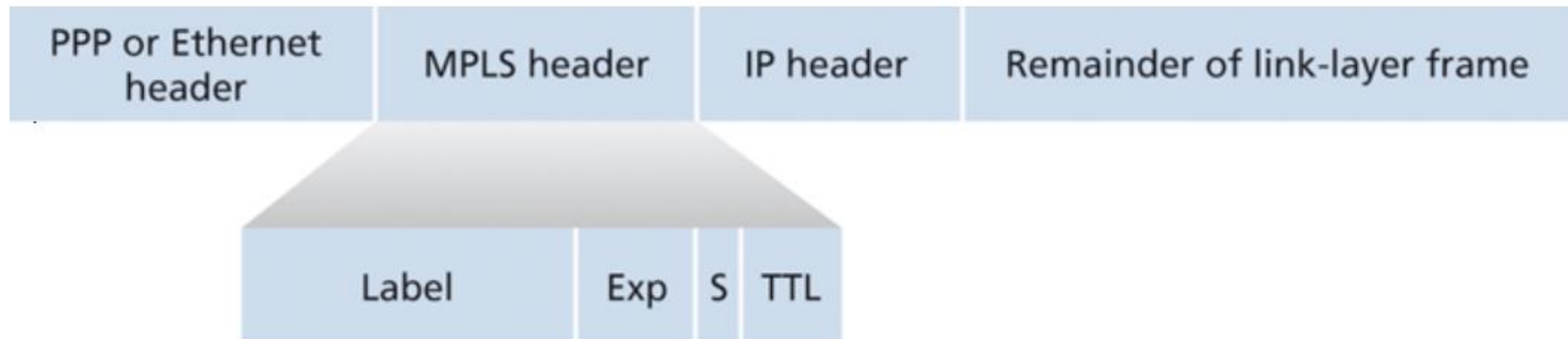
PPP or Ethernet header	MPLS header	IP header	Remainder of link-layer frame

Label	Exp	S	TTL

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MPLS Capable Routers

- From the packet header, an MPLS-enhanced frame can only be sent between routers that are both MPLS capable

- An MPLS-capable router is often referred to as a label-switched router
  It forwards an MPLS frame by looking up the MPLS label in its forwarding table

- The MPLS-capable router need *not* extract the destination IP address and perform a lookup of the longest prefix match in the forwarding table
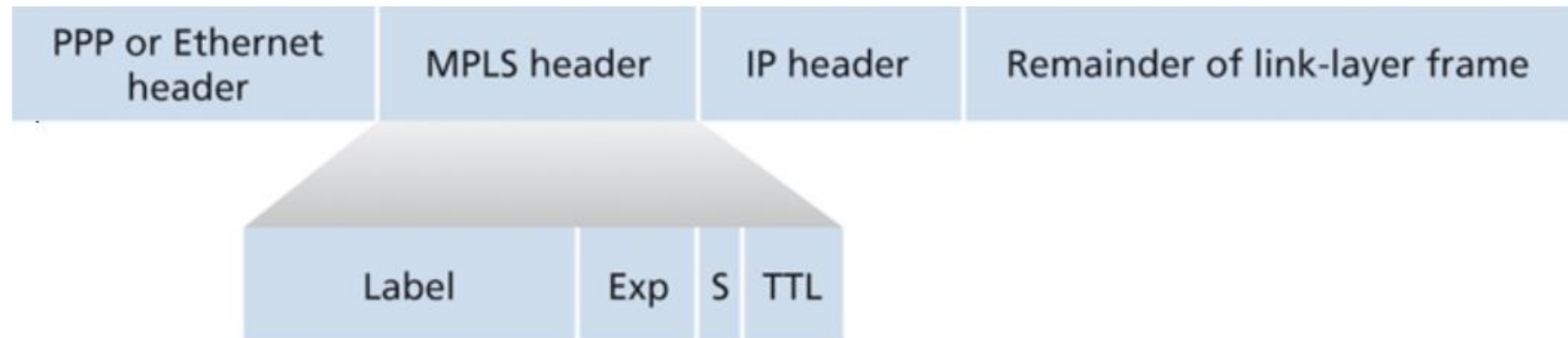
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MPLS Capable Routers

- The true advantages of MPLS and the reason for current interest in MPLS, however, lie not in the potential increases in switching speeds

- Instead, advantages lie in the new traffic management capabilities that MPLS enables
  - Performing traffic engineering
  - Rerouting traffic over a precomputed failover path in response to link failure (fast reroute)
  - Implementing virtual private networks (VPNs)
  - Ethernet VPN (EVPN)
  - Segment routing
 - …

MPLS versus IP paths

- IP routing: path to destination determined by destination address alone
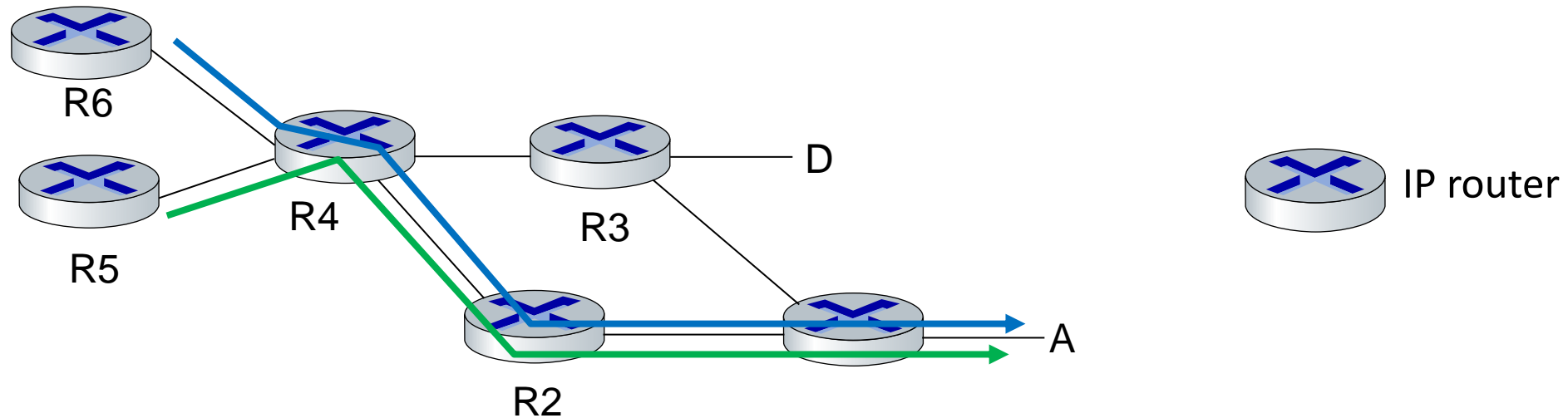
J. Kurose, K. Ross, Computer Networks, a Top-down Approach, 7th Edition, Pearson

MPLS versus IP paths

- MPLS routing: path to destination can be based on source and destination address
  - ➢ Traffic engineering: split traffic load optimally
  - ➢ Fast reroute: precompute backup routes in case of link failure
 - ➢ VPN: isolate / separate traffic from different sources / interfaces

MPLS network

R6

R4

R3

D

R5

R2

R1

A

IP router
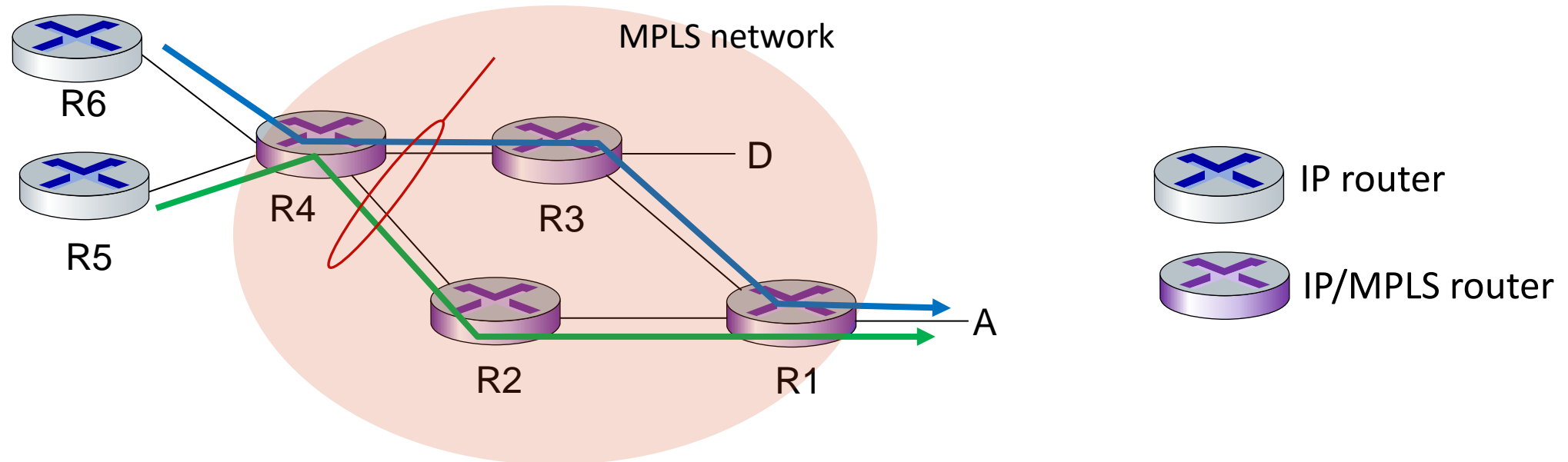
IP/MPLS router

IP/MPLS entry router (R4) can use *different* MPLS routes to destination A, e.g., based on IP source address or other fields (generalized forwarding, ~10 years earlier than SDN)

MPLS Architecture

MPLS Basics

- Routers running within the Internet Service Provider (ISP) use MPLS labels to forward packets

- For each destination network, a predetermined path is created

- The Provider Edge (PE) router performs IP lookup and decides which label to use
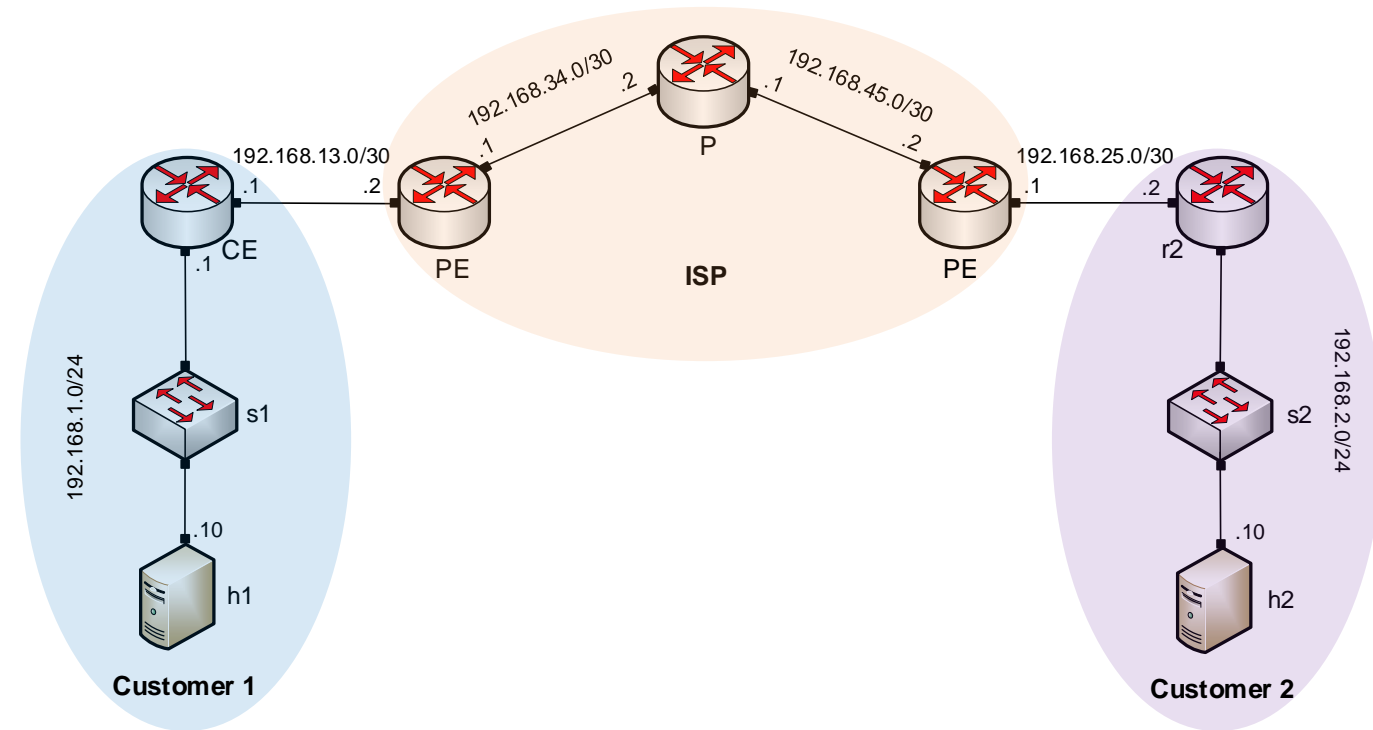
MPLS Basics

- A router that operates at the edge of MPLS network is called Label Edge Router (LER)

- A router that performs routing based on the label is called Label Switch Router (LSR)

- The predetermined path that makes MPLS work is called Label Switched Path (LSP)
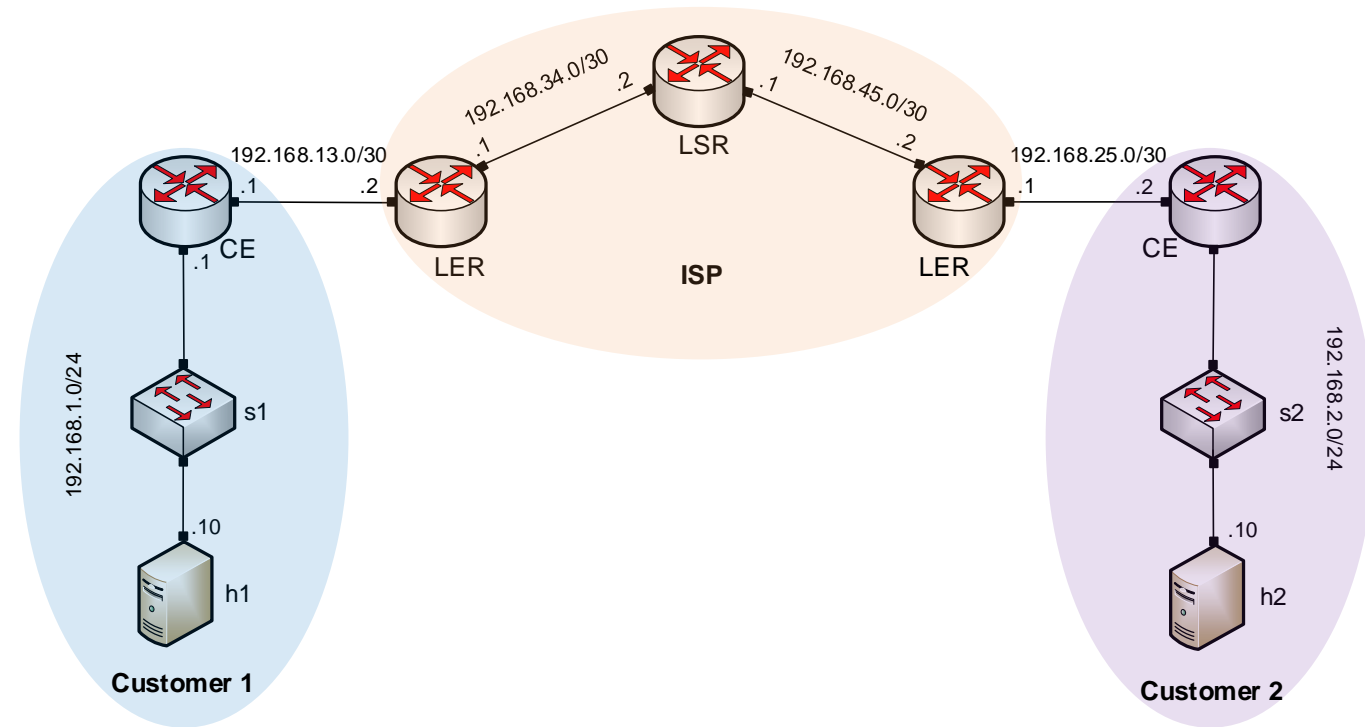
Label Distribution

- Static MPLS
  - ➢ MPLS entries can be configured statically, handling MPLS consists of pushing, swapping, or popping labels

- Label Distribution Protocol (LDP)
  - ➢ LDP is a protocol that automatically generates and exchanges labels between routers

- Resource Reservation Protocol-Traffic Engineering (RSVP-TE)
  - ➢ RSVP-TE is used to establish MPLS transport LSPs when there are traffic engineering requirements
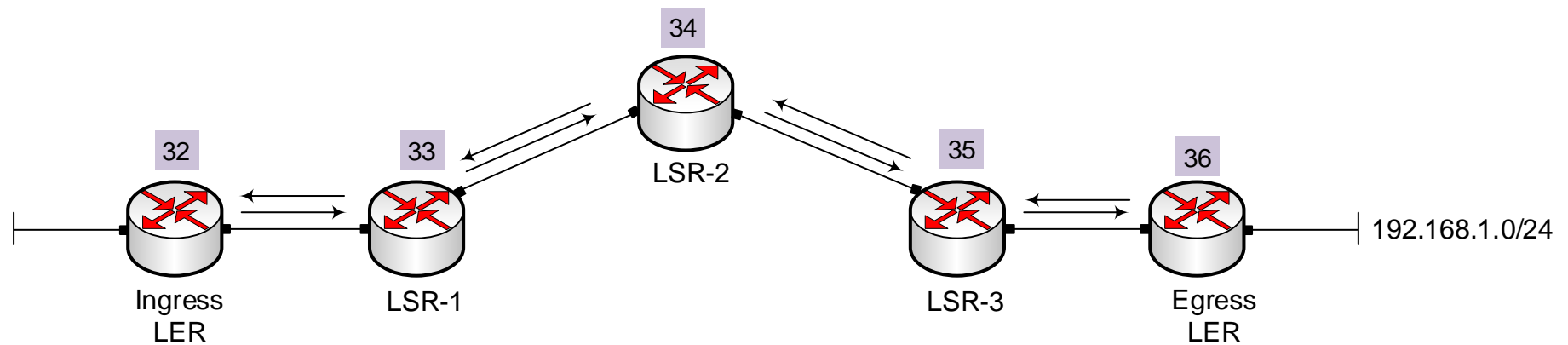
Creating LSP using LDP

1. Assign labels for destination 192.168.1.0/24
   - ➢ Labels generated in a router are called local labels
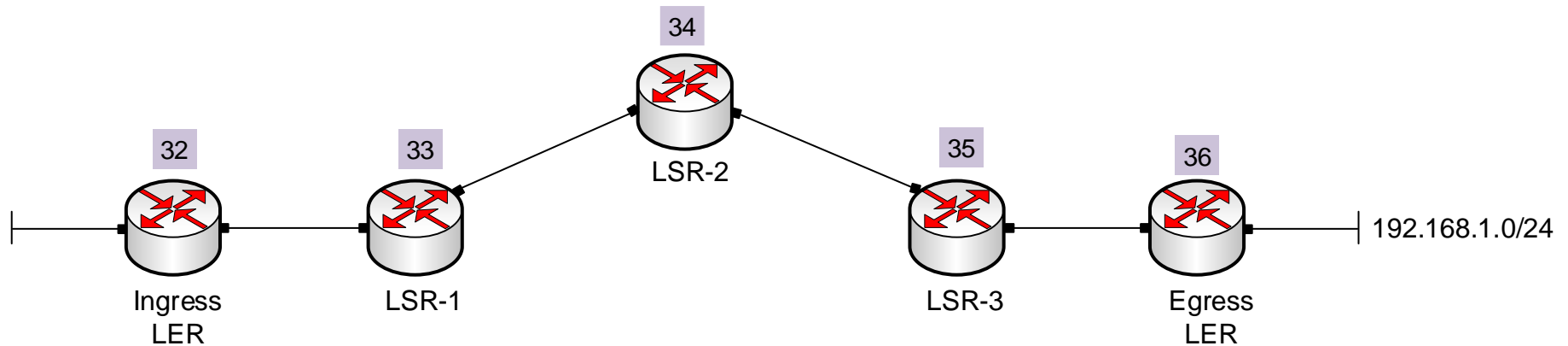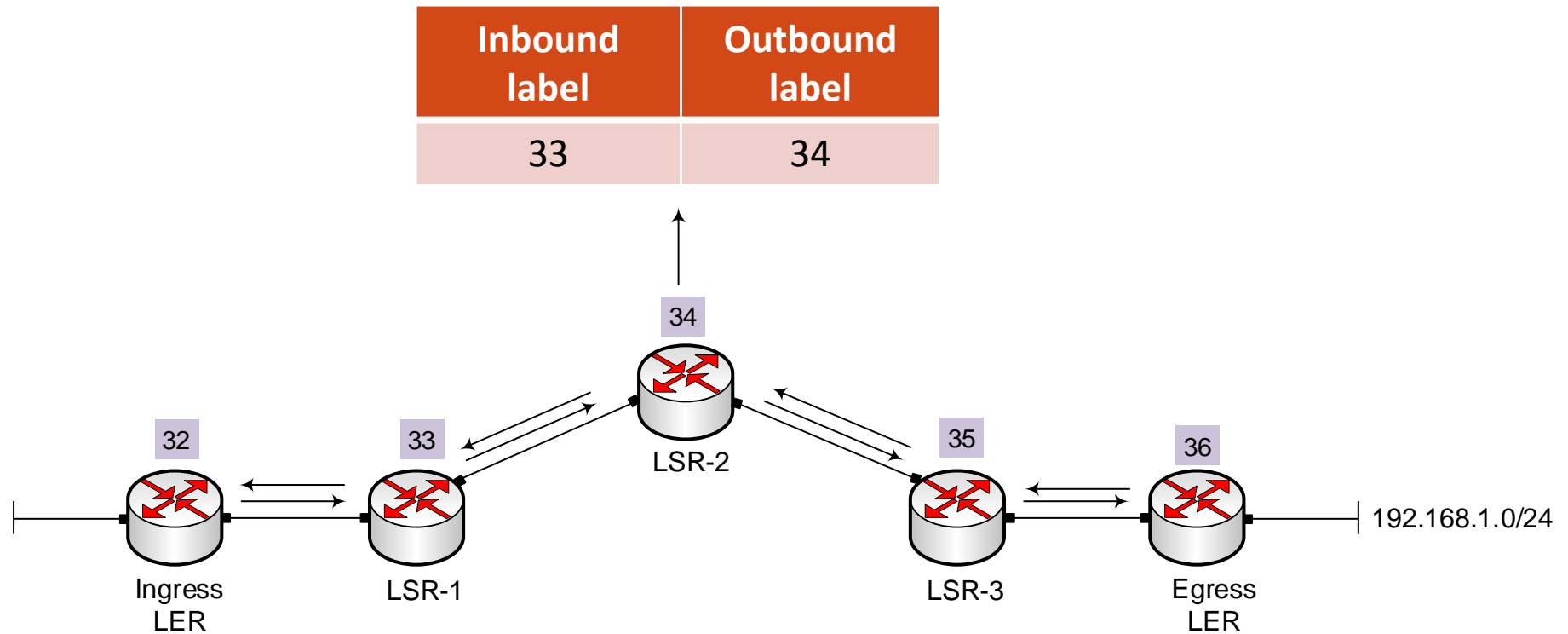
Creating LSP using LDP

2. Share labels with neighbor routers
   ➤ Labels received from neighbors are called remote labels

192.168.1.0/24

Creating LSP using LDP

3. Make routing decision for network 192.168.1.0/24 based on IGP

| Inbound label	Outbound label
33	34

MPLS Operations

- ## Push labels
  - ➢ Ingress LER inserts MPLS header, includes a label in the packet header and delivers to the next router

- ## Swap labels
  - ➢ LSRs swap labels till the packet reaches to egress LER

- ## Pop labels
  - ➢ Egress LER pops the label and delivers the IP packet to the destination
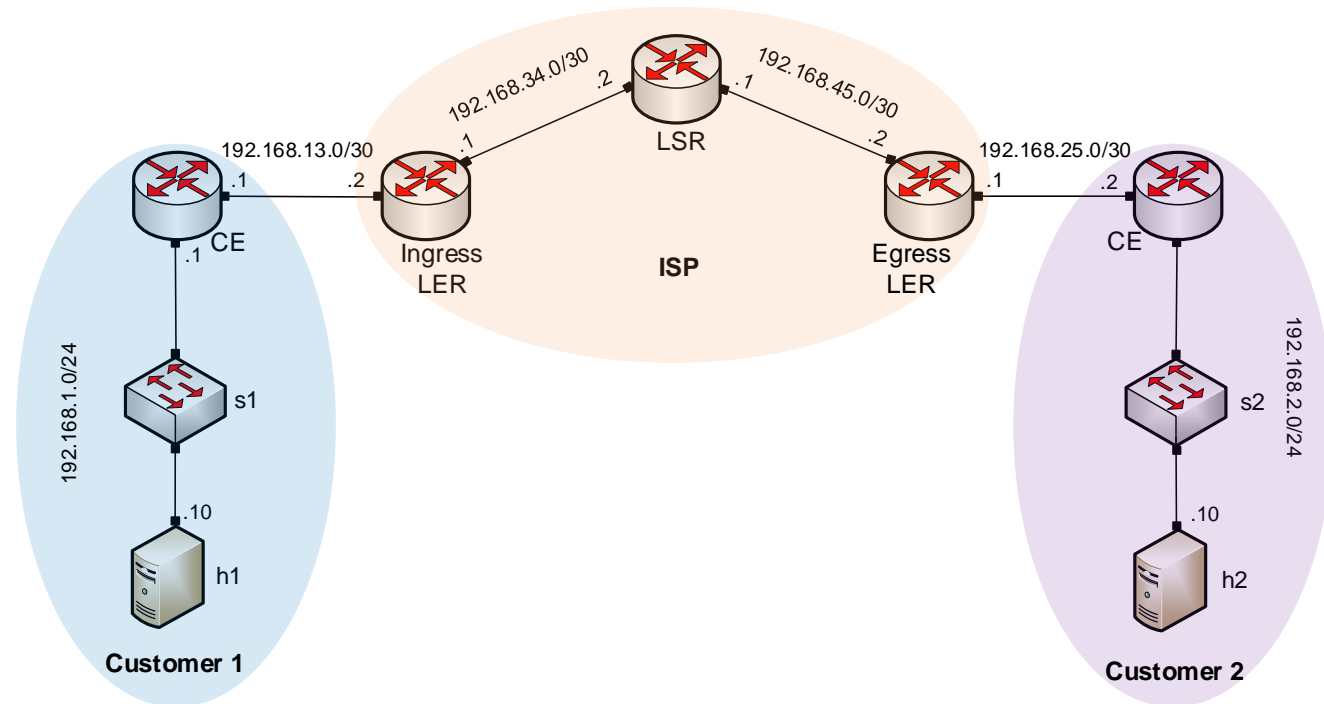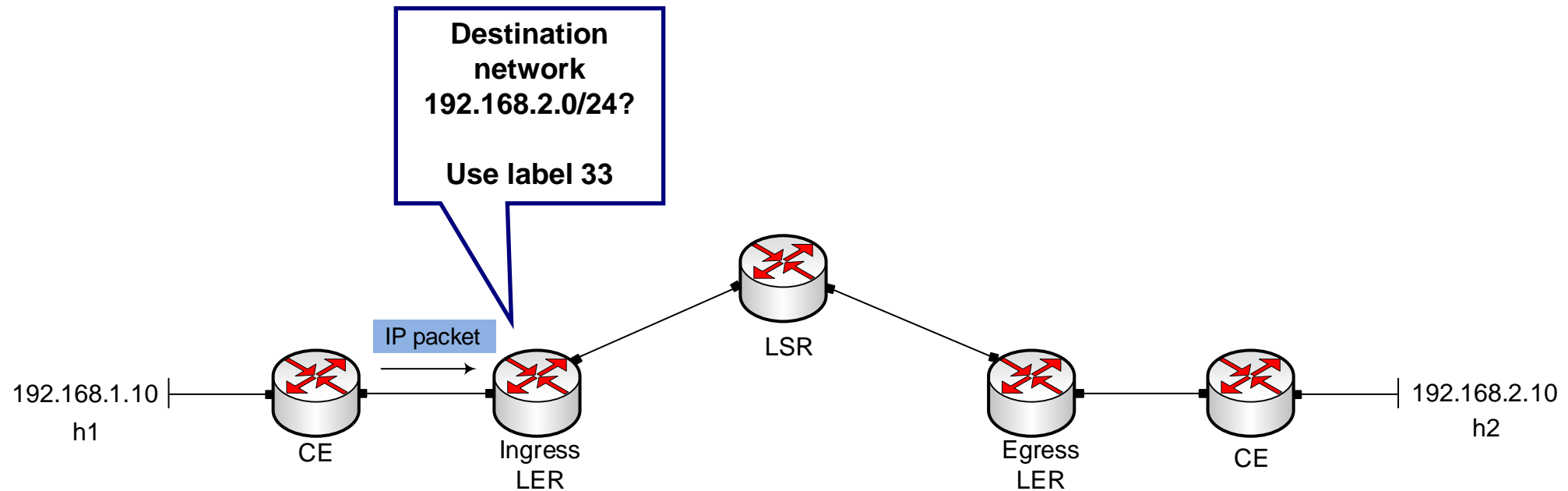
MPLS Forwarding Example

- Customer Edge (CE) routers are connected to LERs

192.168.1.10
h1

CE

Ingress
LER

LSR

Egress
LER

CE

192.168.2.10
h2

ISP
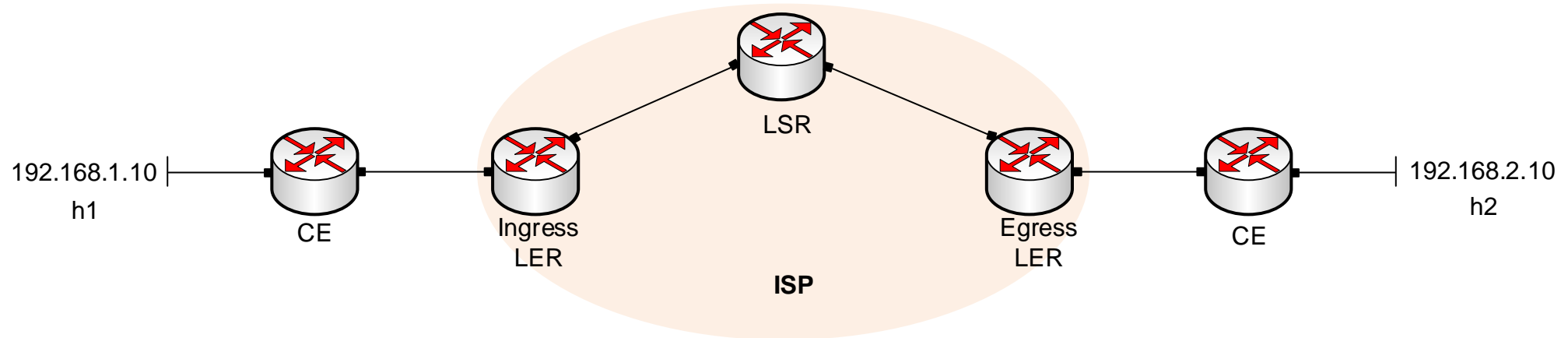
MPLS Forwarding Steps

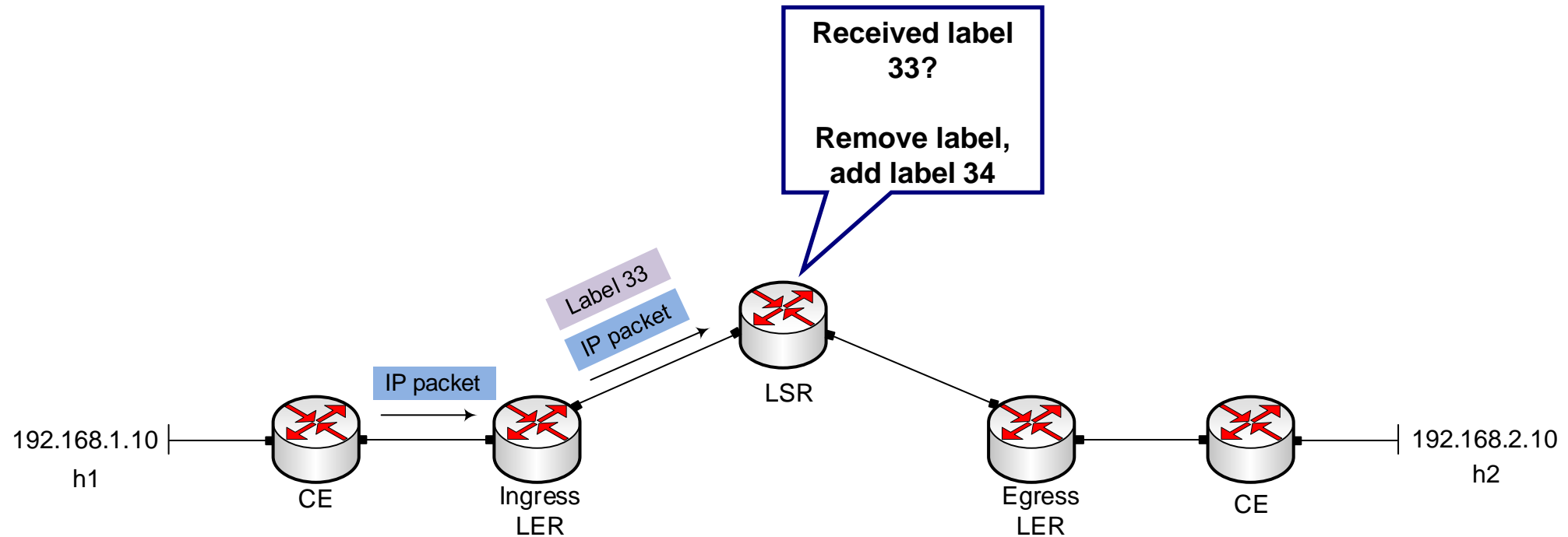Upon the arrival of the IP packet from the CE router, the ingress LER router:

- Performs IP lookup and assigns a label based on the destination address
- Forwards the packet to the LSR router

MPLS Forwarding Steps

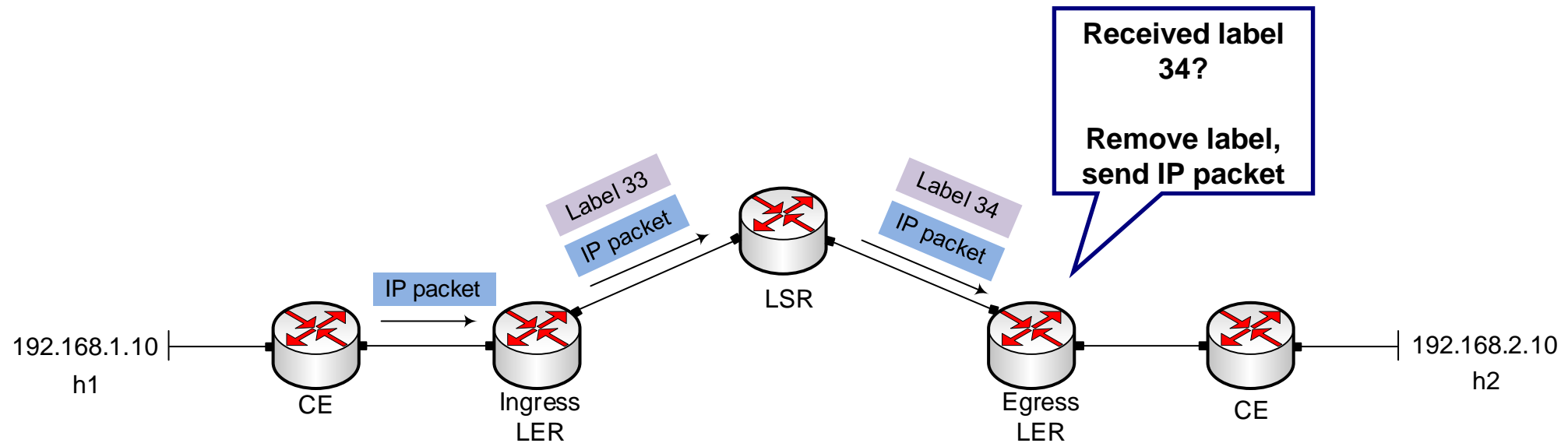Once the LSR router receives the packet with label 33, it:

- Changes (swap) the label to 34
- Forwards the packet to the egress LER
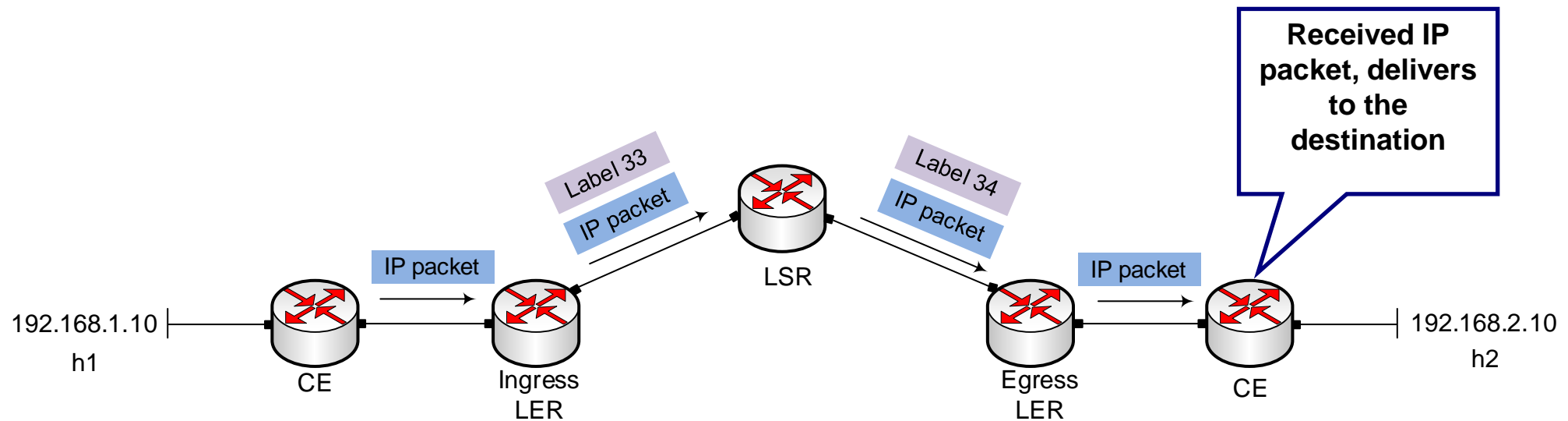
MPLS Forwarding Steps

Once the egress LER receives the packet with label 34, it:

- Removes (pops) the label
- Sends the IP packet to the CE router

MPLS Forwarding Steps

- The CE router receives the IP packet and delivers it to the final destination 192.168.2.10 (host h2)

MPLS Use

- MPLS is often hidden from customers, with the ISP establishing label switch paths for large amounts of traffic, traffic engineering, VPNs, etc.

- Large campus networks also use MPLS for traffic management

- MPLS is a core protocol in modern backbone networks (e.g., FABRIC)
  - https://tinyurl.com/2kr2f2df
  - https://fabric-testbed.net/

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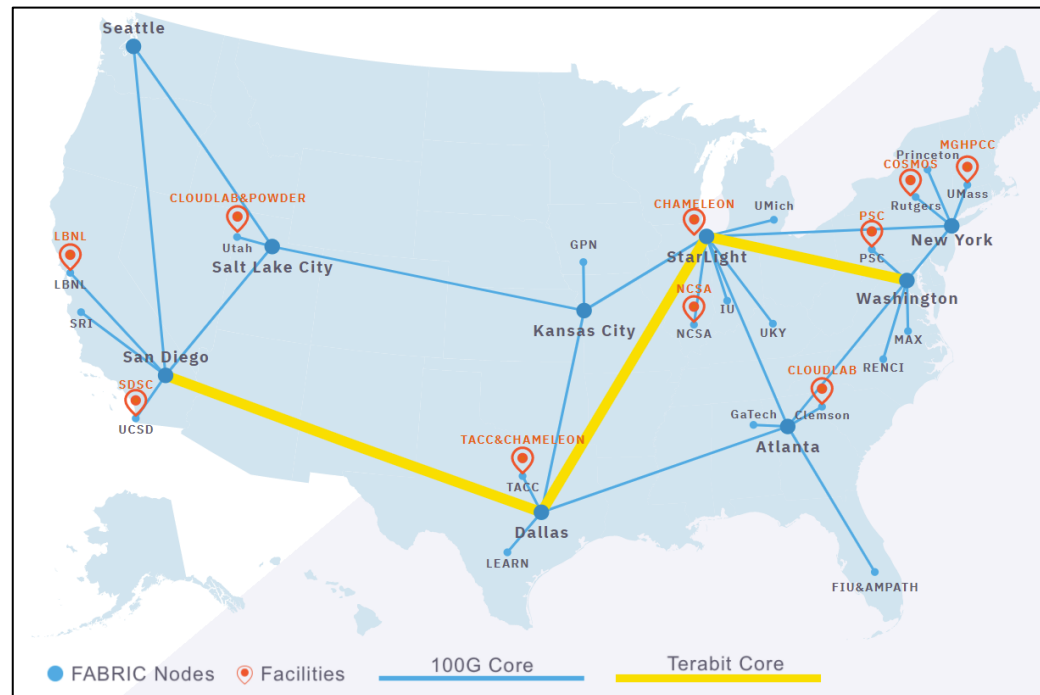
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3.1.3 Network Dataplane Element
The FABRIC Network Dataplane Element is based on device with following key features and capabilities that will be utilized for the FABRIC Network services:

- Switching
  - Traditional VLAN services
  - VLAN Translation
- Routing
  - IPv4
  - IPv6
  - IGP (IS-IS)
  - BGP (Internal and External)
  - Layer 3 VPN Services
- MPLS
  - Segment Routing
  - Traffic Engineering
  - Virtual Private WIre Service (VPWS)
  - Ethernet VPN (EVPN) Service

From "FABRIC Network Services and Peering" (see
https://fabric-testbed.net/resources/design-documents)

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- Will MPLS continue to co-exist?