

Module 1 - 1

Introducing Basic MPLS Concepts

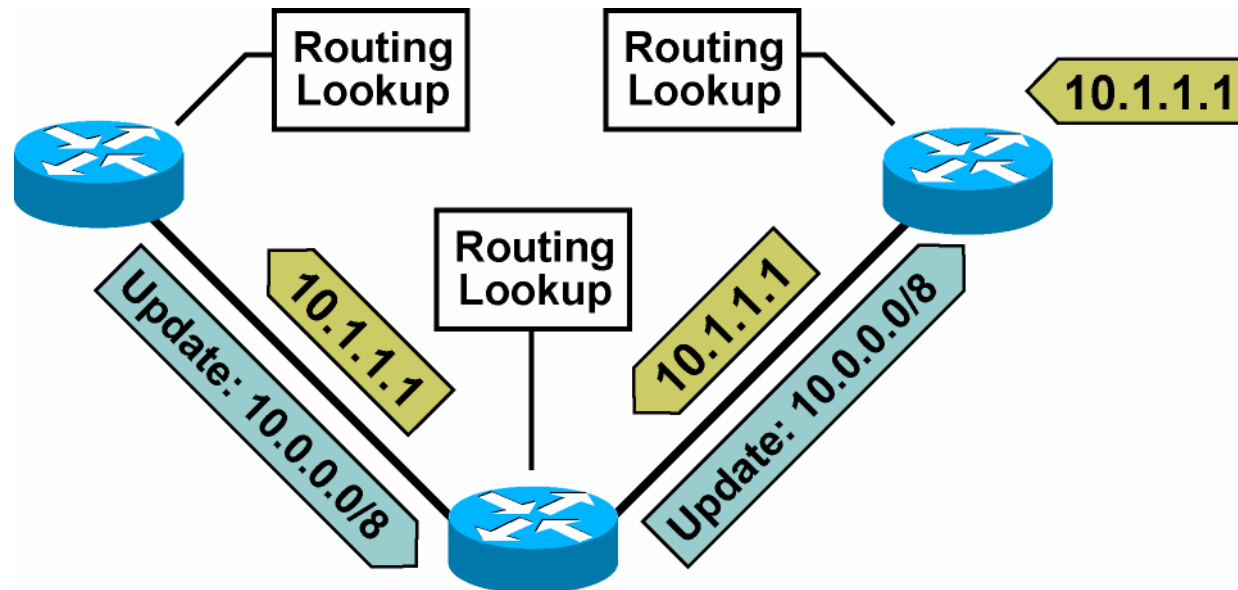


Drawbacks of Traditional IP Routing

- **Routing protocols are used to distribute Layer 3 routing information.**
- **Forwarding is based on the destination address only.**
- **Routing lookups are performed on every hop.**

Drawbacks of Traditional IP Routing: Traditional IP Forwarding

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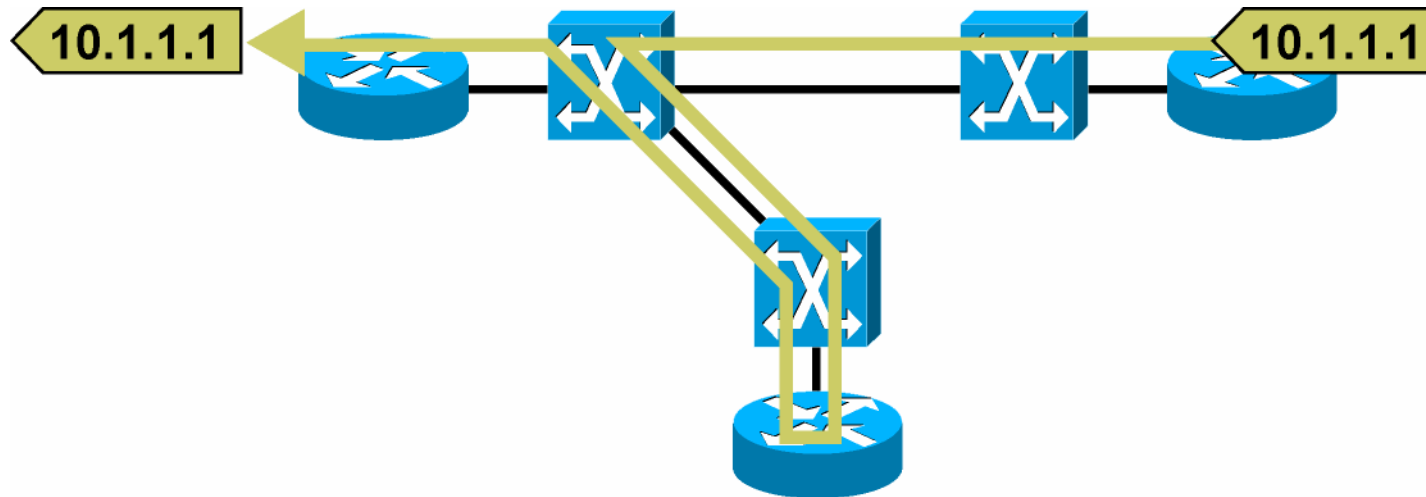


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- Every router may need full Internet routing information (more than 100,000 routes).
- Destination-based routing lookup is needed on every hop.

Drawbacks of Traditional IP Routing: IP over ATM

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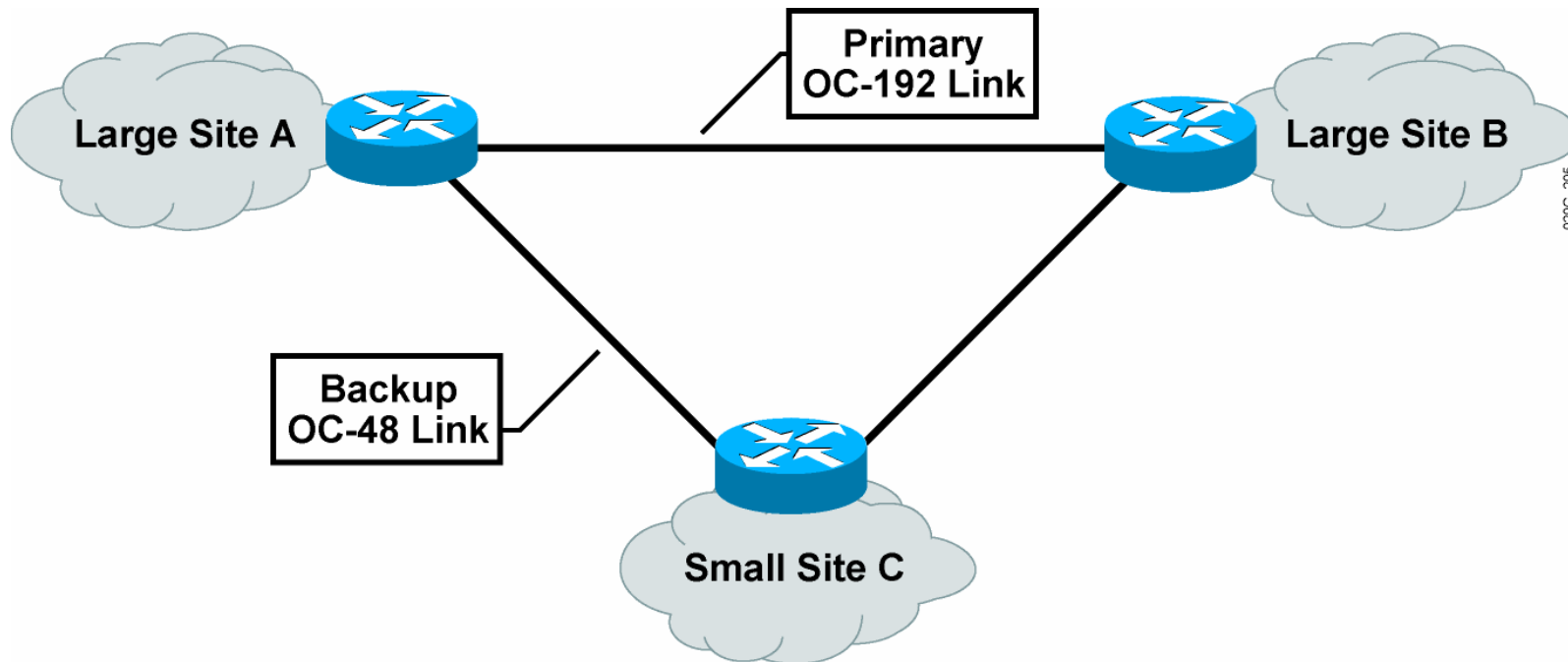


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- Layer 2 devices have no knowledge of Layer 3 routing information—virtual circuits must be manually established.
- Layer 2 topology may be different from Layer 3 topology, resulting in suboptimal paths and link use.
- Even if the two topologies overlap, the hub-and-spoke topology is usually used because of easier management.

Drawbacks of Traditional IP Routing: Traffic Engineering

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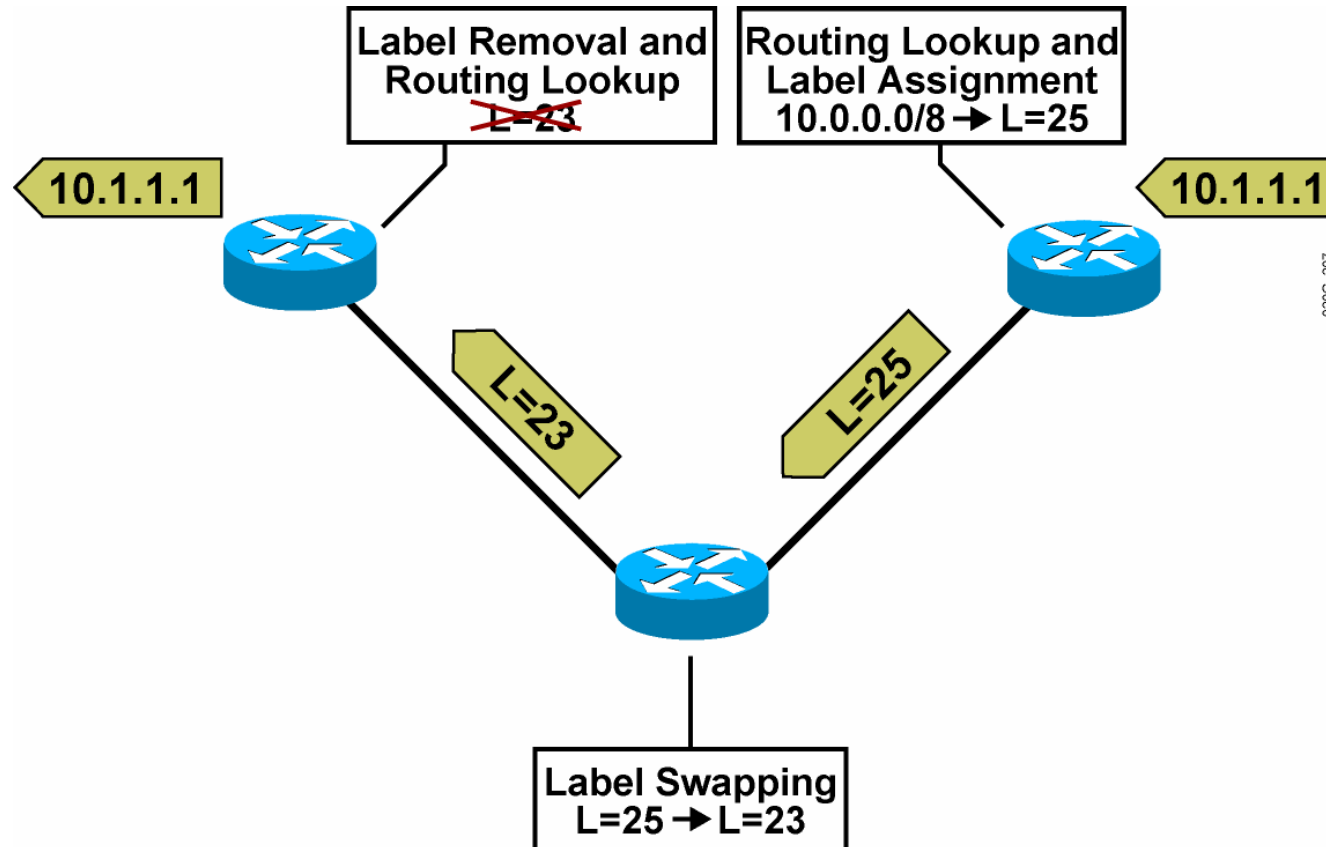


- Most traffic goes between large sites A and B, and uses only the primary link.
- Destination-based routing does not provide any mechanism for load balancing across unequal paths.
- Policy-based routing can be used to forward packets based on other parameters, but this is not a scalable solution.

Basic MPLS Concepts

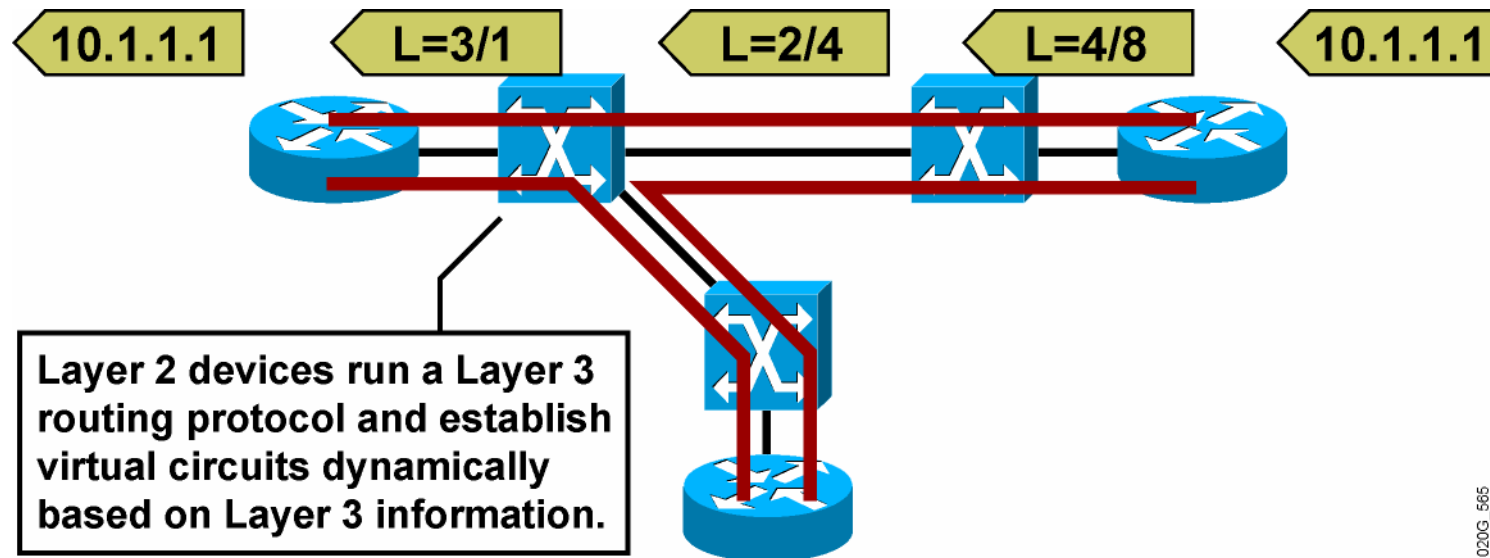
- **MPLS is a new forwarding mechanism in which packets are forwarded based on labels.**
- **Labels usually correspond to IP destination networks (equal to traditional IP forwarding).**
- **Labels can also correspond to other parameters, such as QoS or source address.**
- **MPLS was designed to support forwarding of other protocols as well.**

Basic MPLS Concepts Example



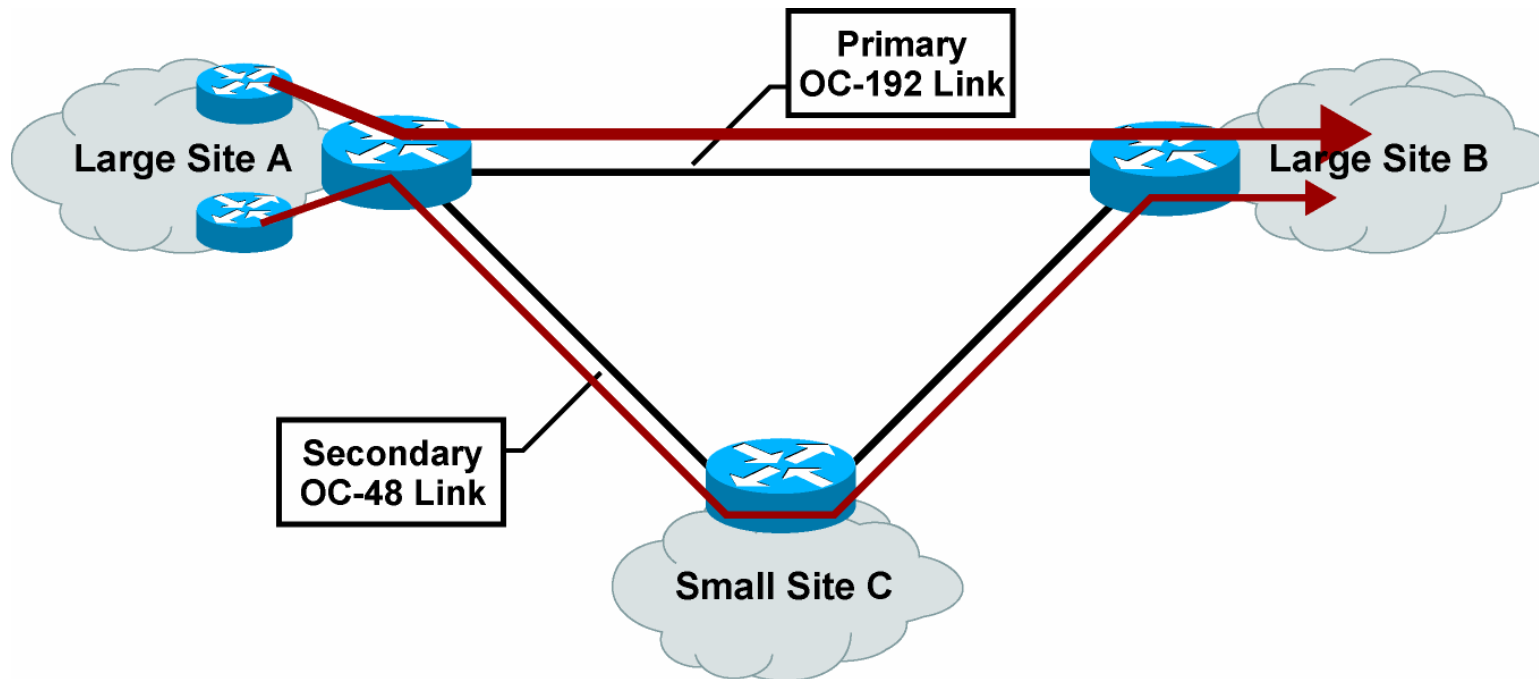
- Only edge routers must perform a routing lookup.
- Core routers switch packets based on simple label lookups and swap labels.

MPLS vs. IP over ATM



- Layer 2 devices are IP-aware and run a routing protocol.
- There is no need to manually establish virtual circuits.
- MPLS provides a virtual full mesh topology.

Traffic Engineering with MPLS

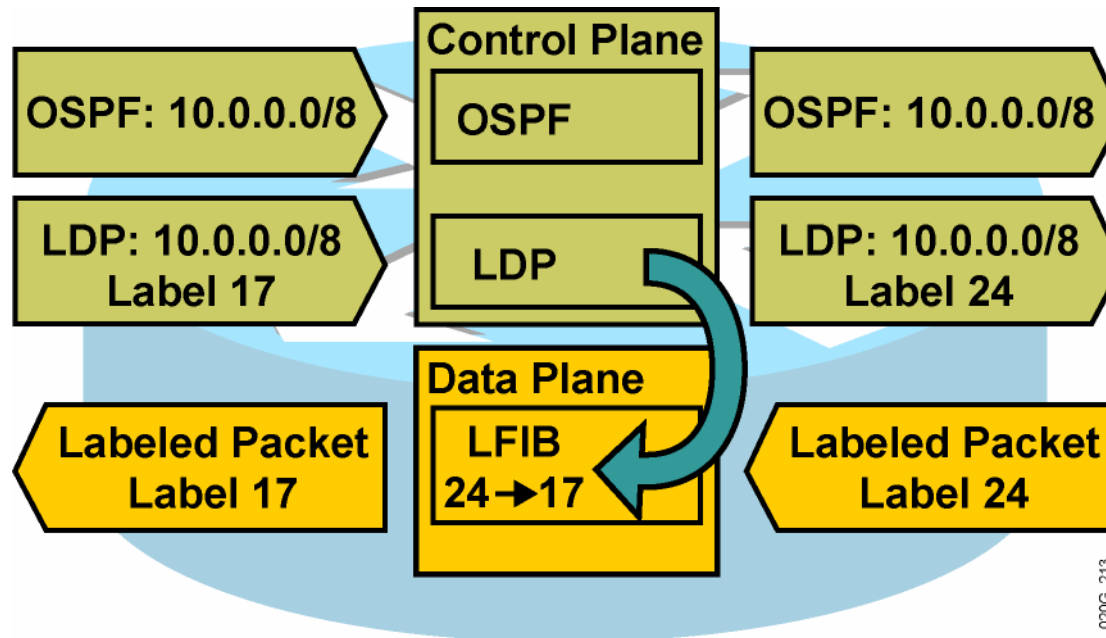


- Traffic can be forwarded based on other parameters (QoS, source, and so on).
- Load sharing across unequal paths can be achieved.

MPLS has two major components:

- **Control plane:** Exchanges Layer 3 routing information and labels; contains complex mechanisms to exchange routing information, such as OSPF, EIGRP, IS-IS, and BGP, and to exchange labels; such as LDP, and RSVP
- **Data plane:** Forwards packets based on labels; has a simple forwarding engine

MPLS Architecture (Cont.)



Router functionality is divided into two major parts: the control plane and the data plane

MPLS Labels

- **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**).**

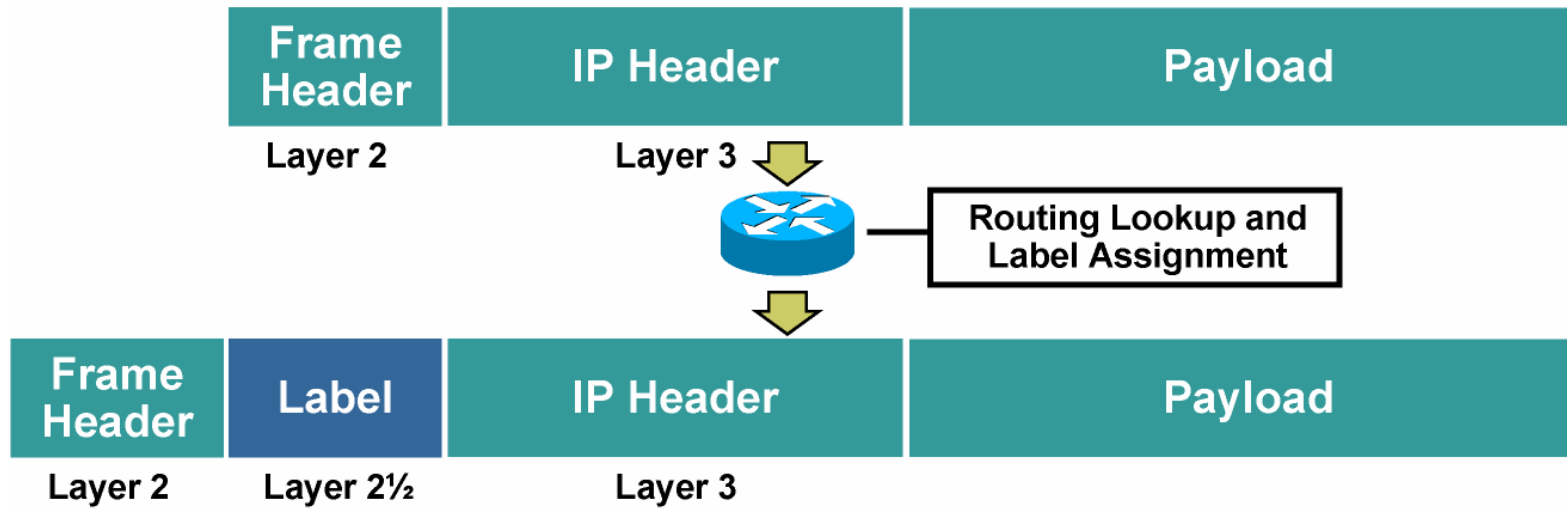
MPLS Labels: Label Format



MPLS uses a 32-bit label field that contains the following information:

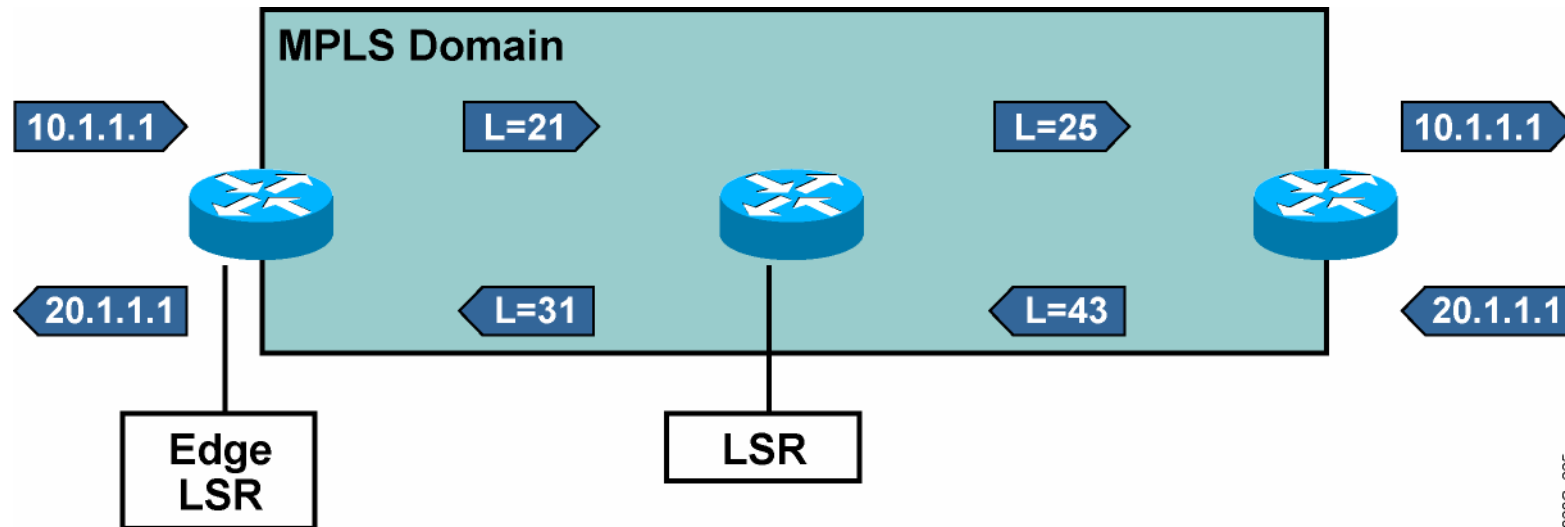
- **20-bit label**
- **3-bit experimental field**
- **1-bit bottom-of-stack indicator**
- **8-bit TTL field**

MPLS Labels: Frame-Mode MPLS



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Label Switch Routers



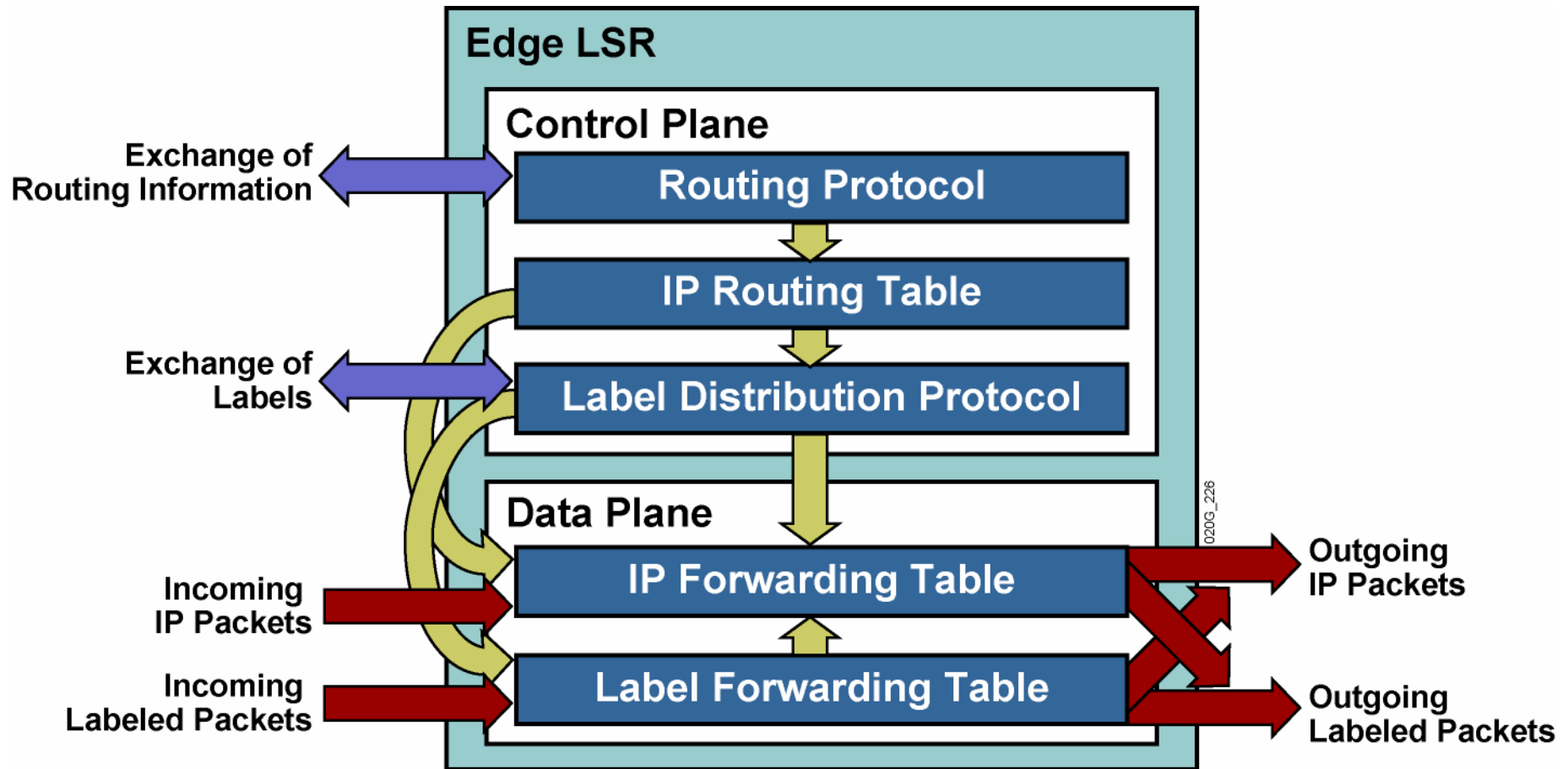
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- **LSR** primarily forwards labeled packets (label swapping).
- **Edge LSR** primarily labels IP packets and forwards them into the MPLS domain, or removes labels and forwards IP packets out of the MPLS domain.

Label Switch Routers: Architecture of LSRs

- **LSRs, regardless of the type, perform these functions:**
 - **Exchange routing information**
 - **Exchange labels**
 - **Forward packets (LSRs and edge LSRs) or cells (ATM LSRs and ATM edge LSRs)**
- **The first two functions are part of the control plane.**
- **The last function is part of the data plane.**

Label Switch Routers: Architecture of Edge LSRs



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Identifying MPLS Applications



MPLS Applications

- **MPLS is already used in many different applications:**
 - **Unicast IP routing**
 - **Multicast IP routing**
 - **MPLS TE**
 - **QoS**
 - **MPLS L2/L3 VPNs (course focus)**
 - **EoMPLS**
 - **VPLS**
- **Regardless of the application, the functionality is always split into the control plane and the data (forwarding) plane:**
 - **The applications differ only in the control plane.**
 - **The applications all use a common label-switching data (forwarding) plane.**
 - **Edge LSR Layer 3 data planes may differ.**

Unicast IP Routing

- **Two mechanisms are needed on the control plane:**
 - **IP routing protocol (OSPF, IS-IS, EIGRP, and so on)**
 - **Label distribution protocol (LDP)**
- **A routing protocol carries the information about the reachability of networks.**
- **The label distribution protocol binds labels to networks learned via a routing protocol.**

MPLS TE

- **MPLS TE requires OSPF or IS-IS with extensions for MPLS TE as the IGP.**
- **OSPF and IS-IS with extensions hold the entire topology in their databases.**
- **OSPF and IS-IS should also have some additional information about network resources and constraints.**
- **RSVP** is used to establish TE tunnels and to propagate labels.

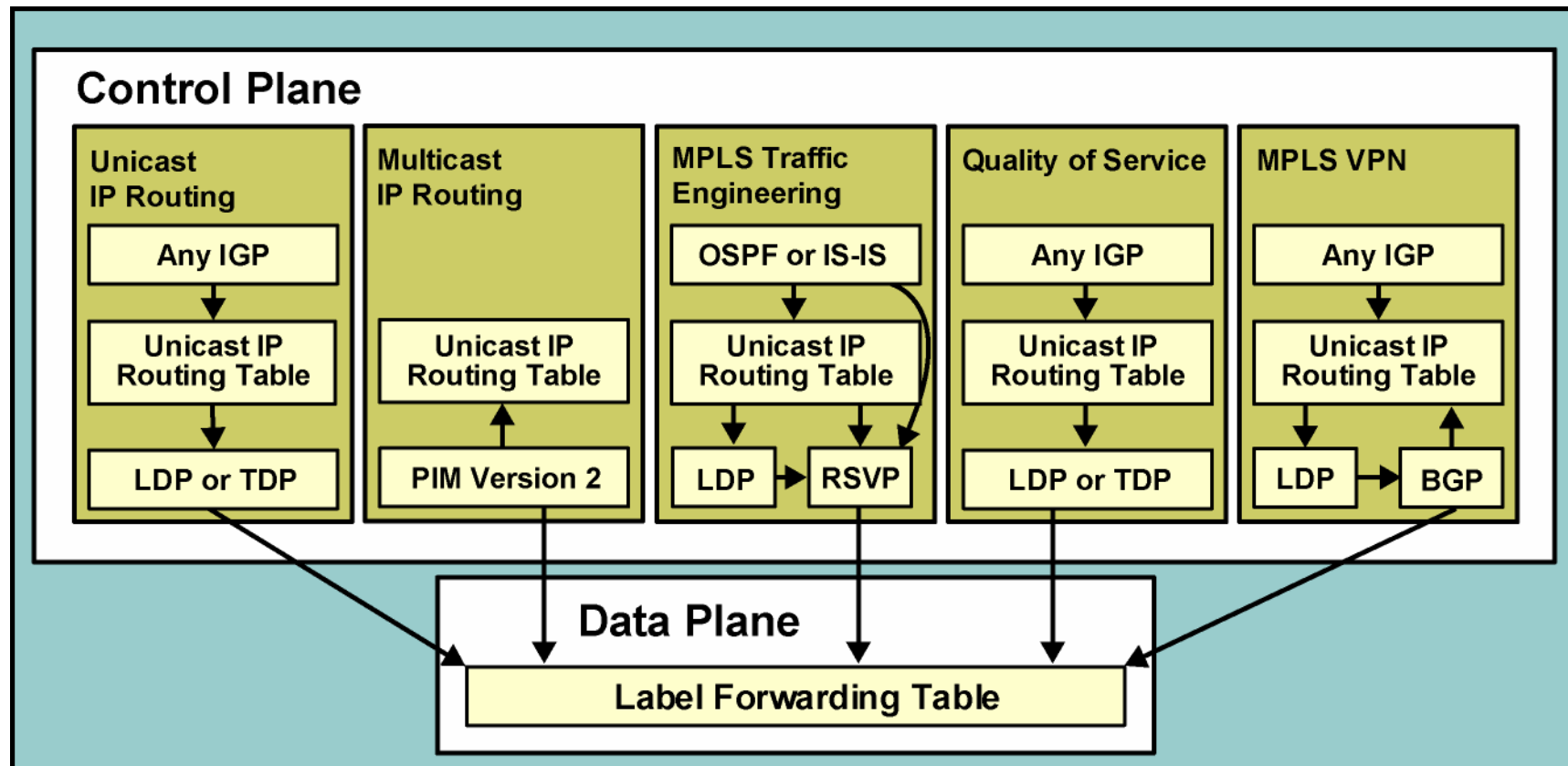
Quality of Service

- **Differentiated QoS is an extension to unicast IP routing that provides differentiated services.**
- **Extensions to LDP are used to propagate different labels for different classes.**

Virtual Private Networks

- **Networks are learned via an IGP (OSPF, EBGP, EIGRP, Routing Information Protocol version 2, or static) from a customer or via BGP from other internal routers.**
- **Labels are propagated via MP-BGP.**
- **Two labels are used:**
 - **The top label points to the egress router (assigned through LDP).**
 - **The second label identifies the outgoing interface on the egress router or a routing table where a routing lookup is performed.**
- **FEC is equal to a VPN site descriptor or VPN routing table.**

Interactions Between MPLS Applications



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Module 1 - 3

Introducing MPLS Labels and Label Stack



MPLS Labels

- Labels are inserted between the Layer 2 (frame) header and the Layer 3 (packet) header.
- There can be more than one label (label stack).
- The **bottom-of-stack** bit indicates if the label is the last label in the label stack.
- The TTL field is used to prevent the indefinite looping of packets.
- **Experimental bits** are usually used to carry the IP precedence value.

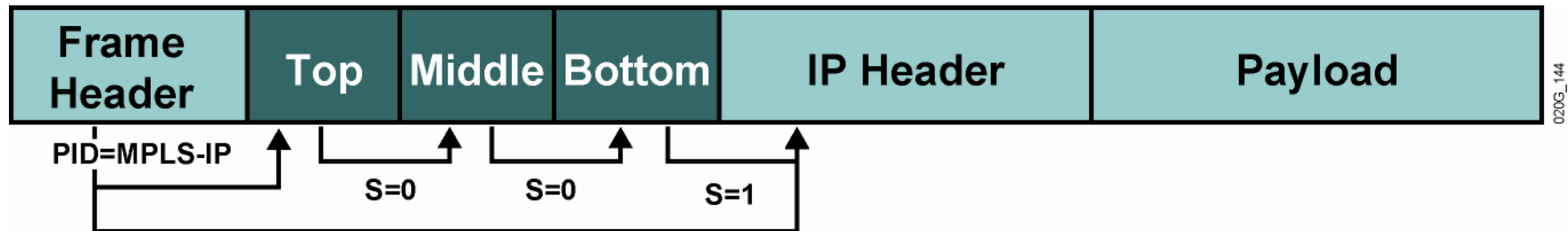
MPLS Label Format



MPLS uses a 32-bit label field that contains the following information:

- **20-bit label (a number)**
- **3-bit experimental field (usually used to carry IP precedence value)**
- **1-bit bottom-of-stack indicator (indicates whether this is the last label before the IP header)**
- **8-bit TTL (equal to the TTL in the IP header)**

MPLS Label Stack

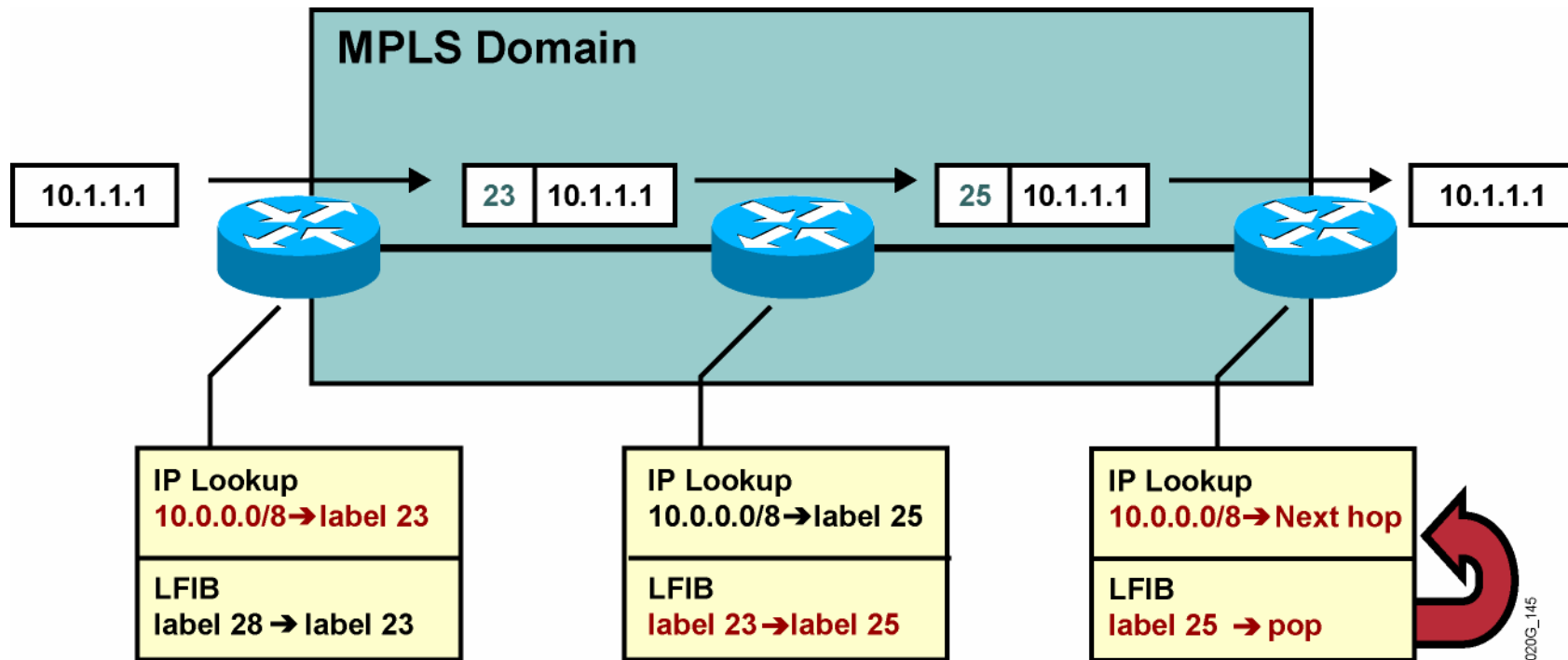


- The protocol identifier in a Layer 2 header specifies that the payload starts with a label (labels) and is followed by an IP header.
- The bottom-of-stack bit indicates whether the next header is another label or a Layer 3 header.
- The receiving router uses the top label only.

MPLS Forwarding

- **An LSR can perform the following functions:**
 - **Insert (impose) a label or a stack of labels on ingress**
 - **Swap a label with a next-hop label or a stack of labels in the core**
 - **Remove (pop) a label on egress**

MPLS Forwarding: Frame Mode



- On ingress, a label is assigned and imposed by the IP routing process.
- LSRs in the core swap labels based on the contents of the label forwarding table.
- On egress, the label is removed and a routing lookup is used to forward the packet.

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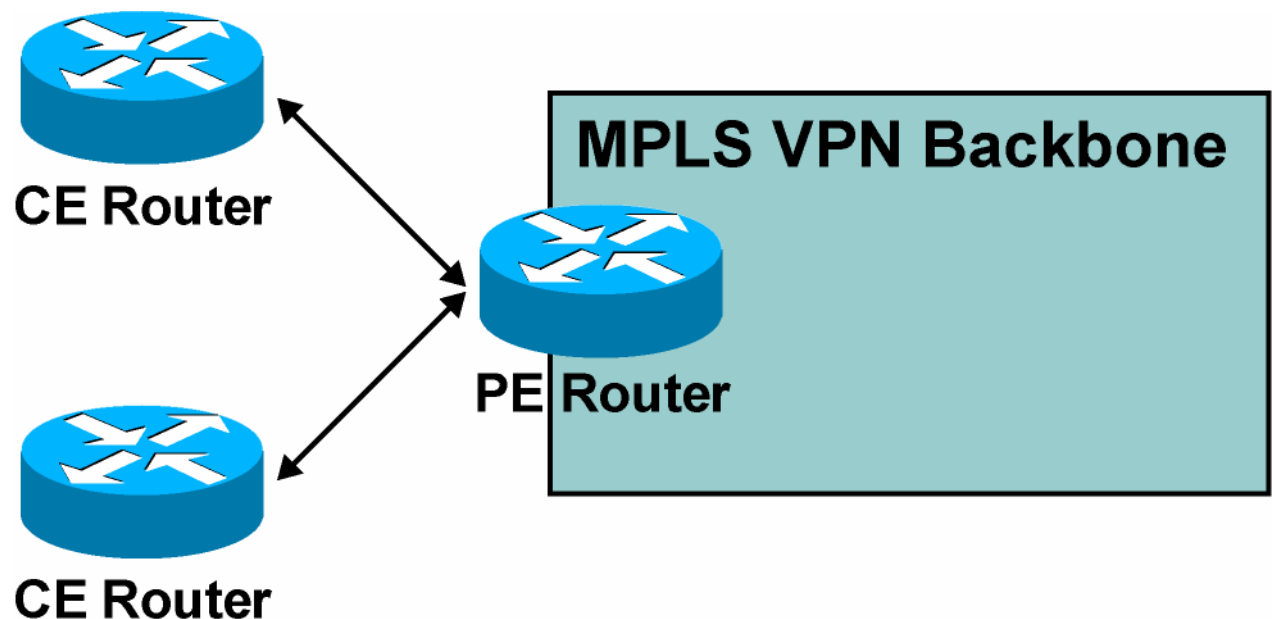
Introducing MPLS VPN Routing Model



MPLS VPN Routing Requirements

- **CE routers have to run standard IP routing software.**
- **PE routers have to support MPLS VPN services and Internet routing.**
- **P routers have no VPN routes.**

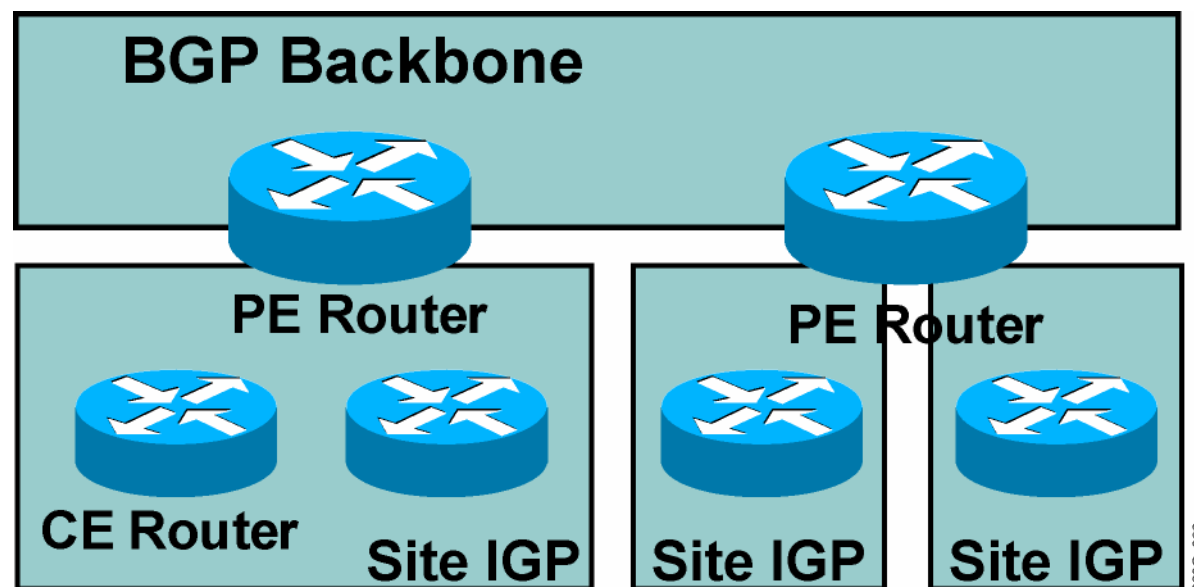
MPLS VPN Routing: CE Router Perspective



- The CE routers run standard IP routing software and exchange routing updates with the PE router.
 - EBGP, OSPF, RIPv2, EIGRP, and static routes are supported.

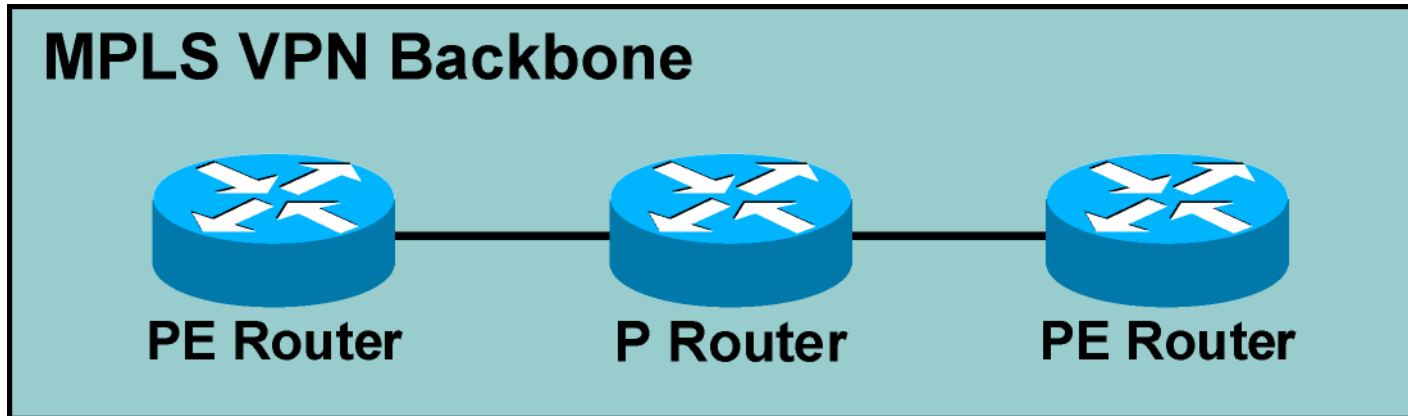
MPLS VPN Routing: Overall Customer Perspective

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- To the customer, the PE routers appear as core routers connected via a BGP backbone.
- The usual BGP and IGP design rules apply.
- The P routers are hidden from the customer.

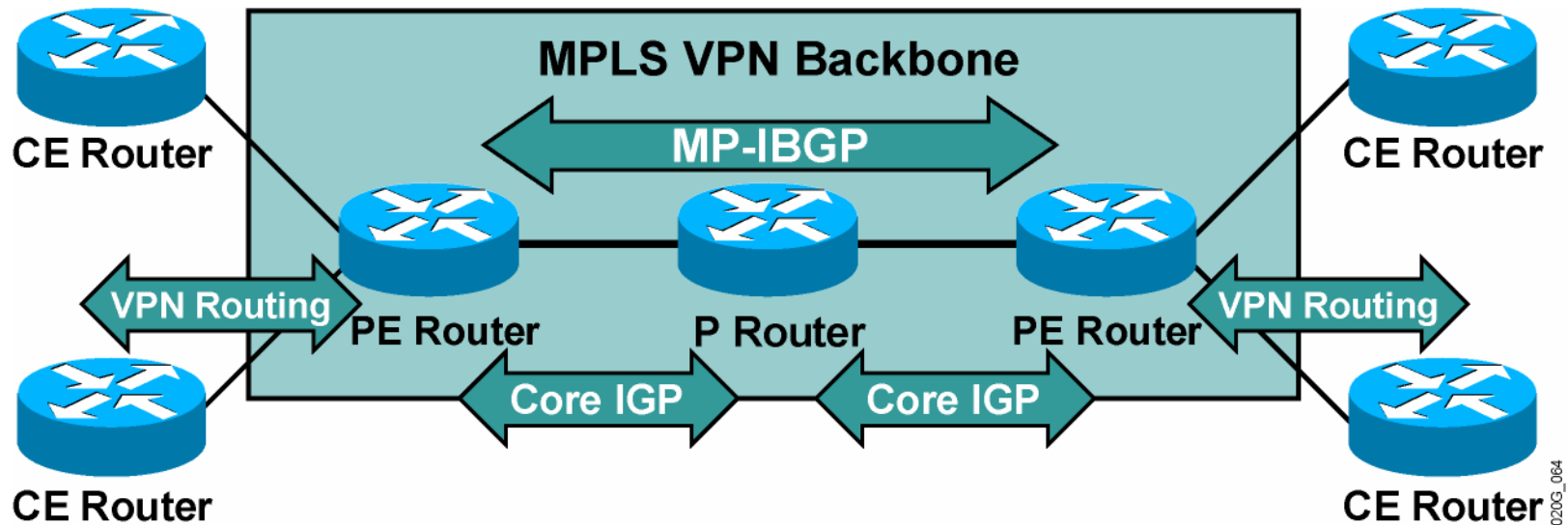
MPLS VPN Routing: P Router Perspective



- **P routers do not participate in MPLS VPN routing and do not carry VPN routes.**
- **P routers run backbone IGP with the PE routers and exchange information about global subnetworks (core links and loopbacks).**

MPLS VPN Routing: PE Router Perspective

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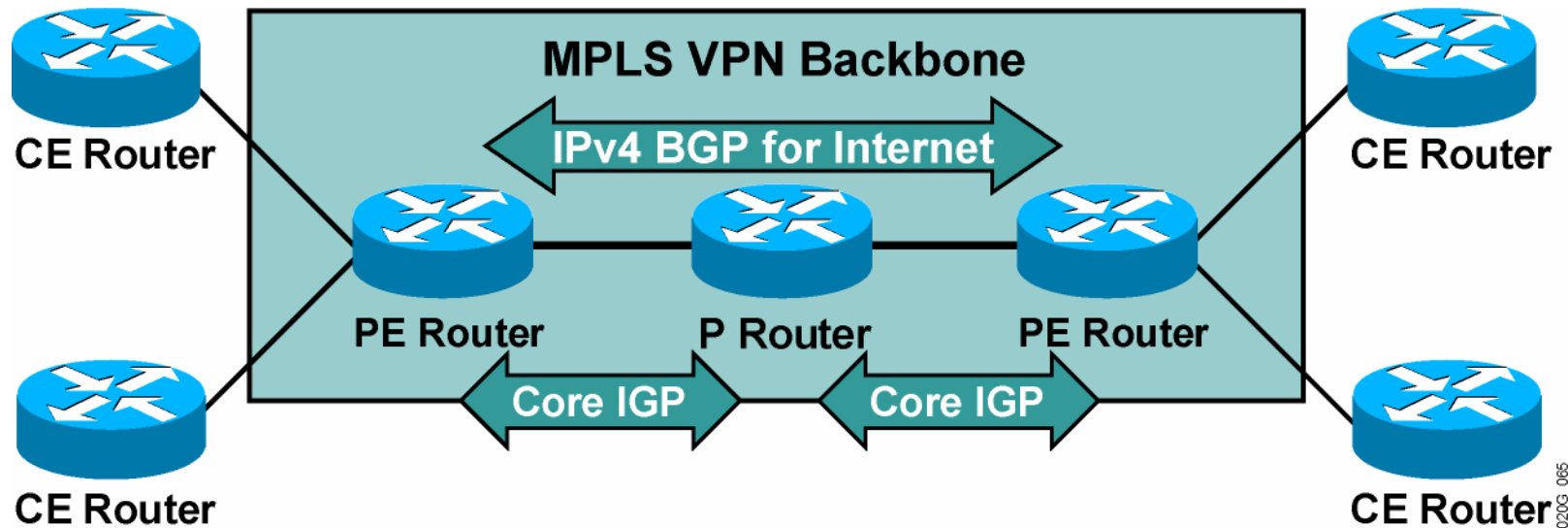


PE routers:

- Exchange VPN routes with CE routers via per-VPN routing protocols
- Exchange core routes with P routers and PE routers via core IGP
- Exchange VPNv4 routes with other PE routers via MP-IBGP sessions

Support for Existing Internet Routing

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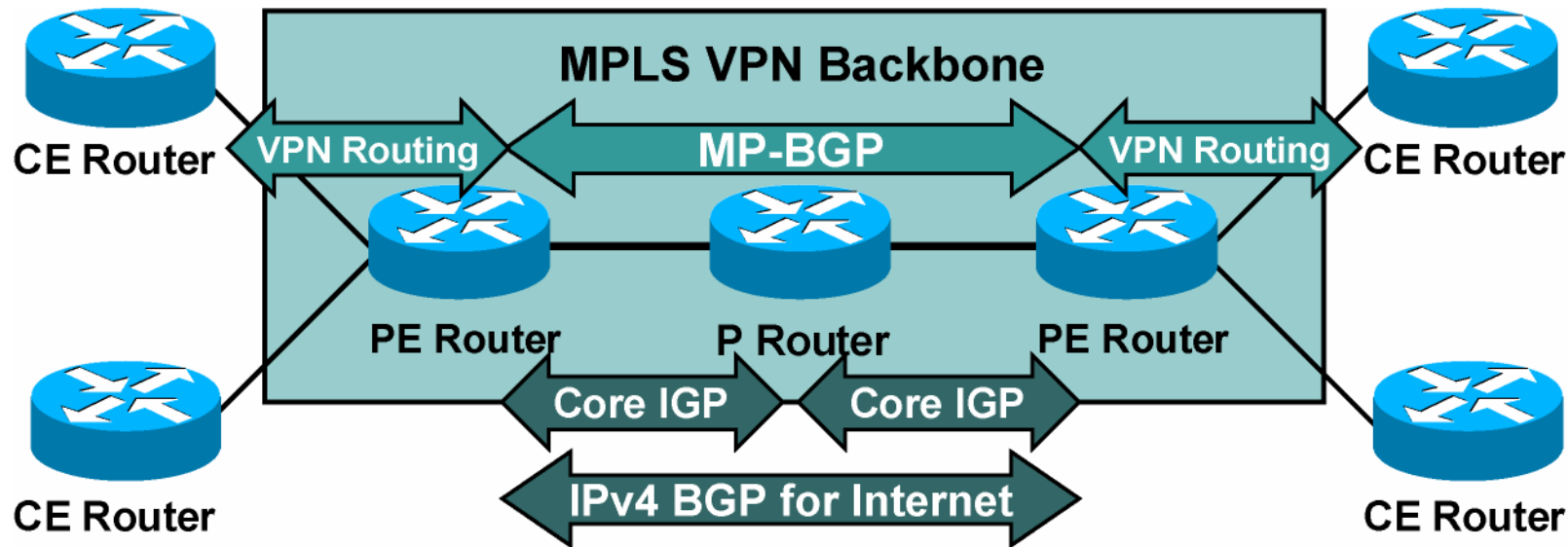


PE routers can run standard IPv4 BGP in the global routing table:

- PE routers exchange Internet routes with other PE routers.
- CE routers do not participate in Internet routing.
- P routers do not need to participate in Internet routing.

Routing Tables on PE Routers

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PE routers contain a number of routing tables:

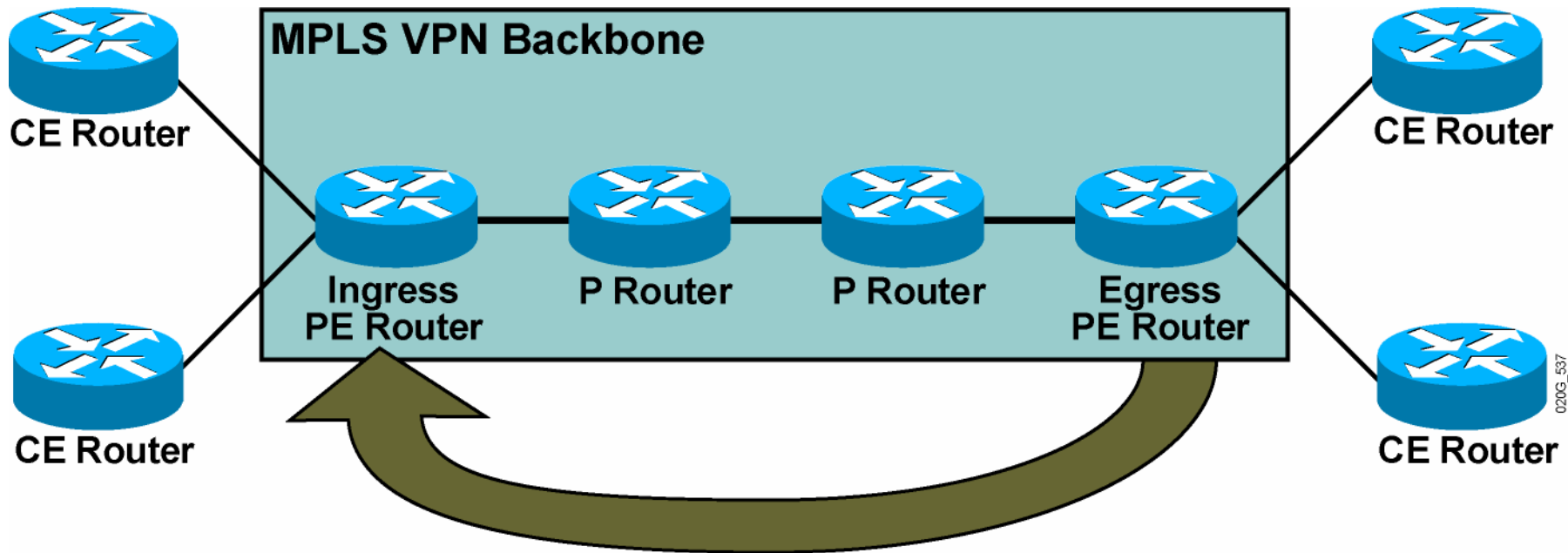
- The **global routing table** contains core routes (filled with core IGP) and Internet routes (filled with IPv4 BGP).
- The **VRF tables** contains routes for sites of identical routing requirements from local (IPv4 VPN) and remote (VPNv4 via MP-BGP) CE routers.

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Forwarding MPLS VPN Packets

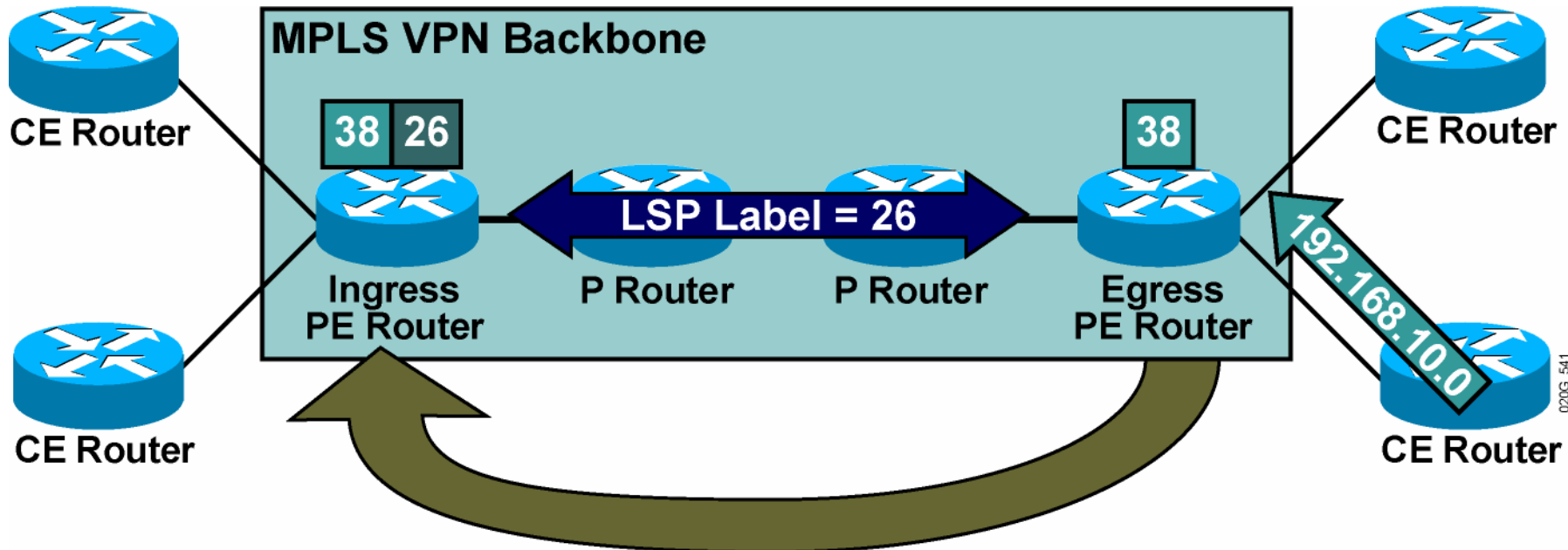


VPN Label Propagation



Labels are propagated in MP-BGP VPNv4 routing updates.

VPN Label Propagation (Cont.)



- Step 1:** A VPN label is assigned to every VPN route by the egress PE router.
- Step 2:** The VPN label is advertised to all other PE routers in an MP-BGP update.
- Step 3:** A label stack is built in the VFR table.

MPLS VPNs and Packet Forwarding

- **The VPN label is understood only by the egress PE router.**
- **An end-to-end LSP tunnel is required between the ingress and egress PE routers.**

Summary

- **PE routers forward packets across the MPLS VPN backbone using label stacking.**
- **The last P router in the LSP tunnel pops the LDP label, and the PE router receives a labeled packet that contains only the VPN label.**
- **Labels are propagated between PE routers using MP-BGP.**