Module 1 - 1

Introducing Basic MPLS Concepts

Drawbacks of Traditional IP Routing

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- 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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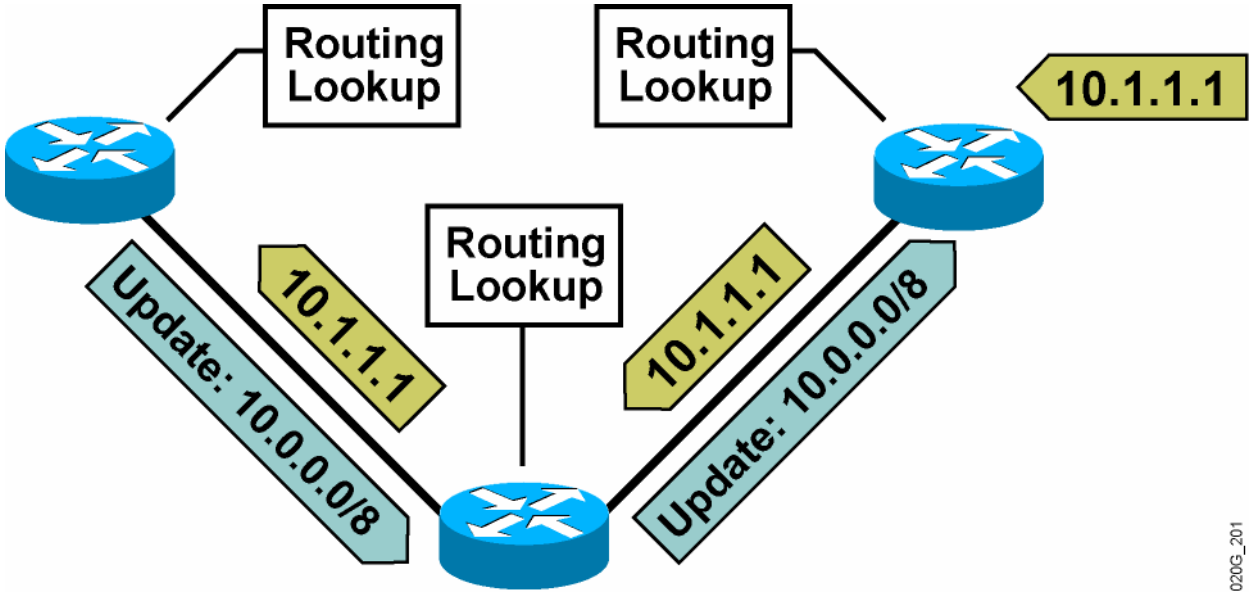

- Every router may need full Internet routing information (more than 100,000 routes).
- Destination-based routing lookup is needed on every hop.

Drawbacks of Traditional IP Routing: IP over ATM

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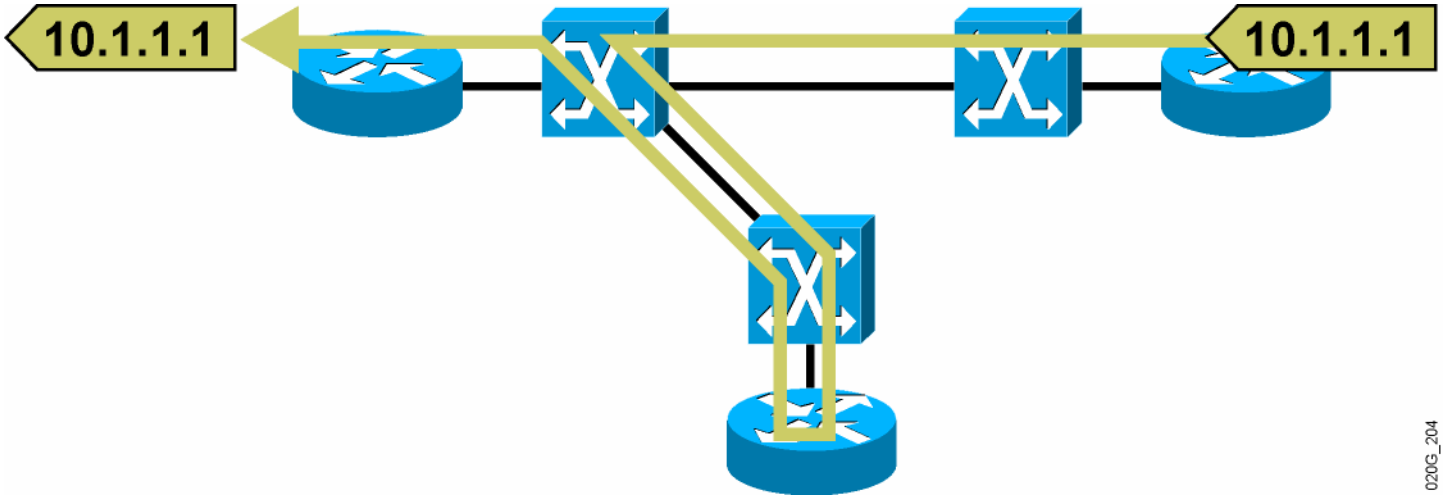

- Layer 2 devices have no knowledge of Layer 3 routing information—virtual circuits must be manually established.
- Layer 2 topology may be different from Layer 3 topology, resulting in suboptimal paths and link use.
- Even if the two topologies overlap, the hub-and-spoke topology is usually used because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

Drawbacks of Traditional IP Routing: Traffic Engineering

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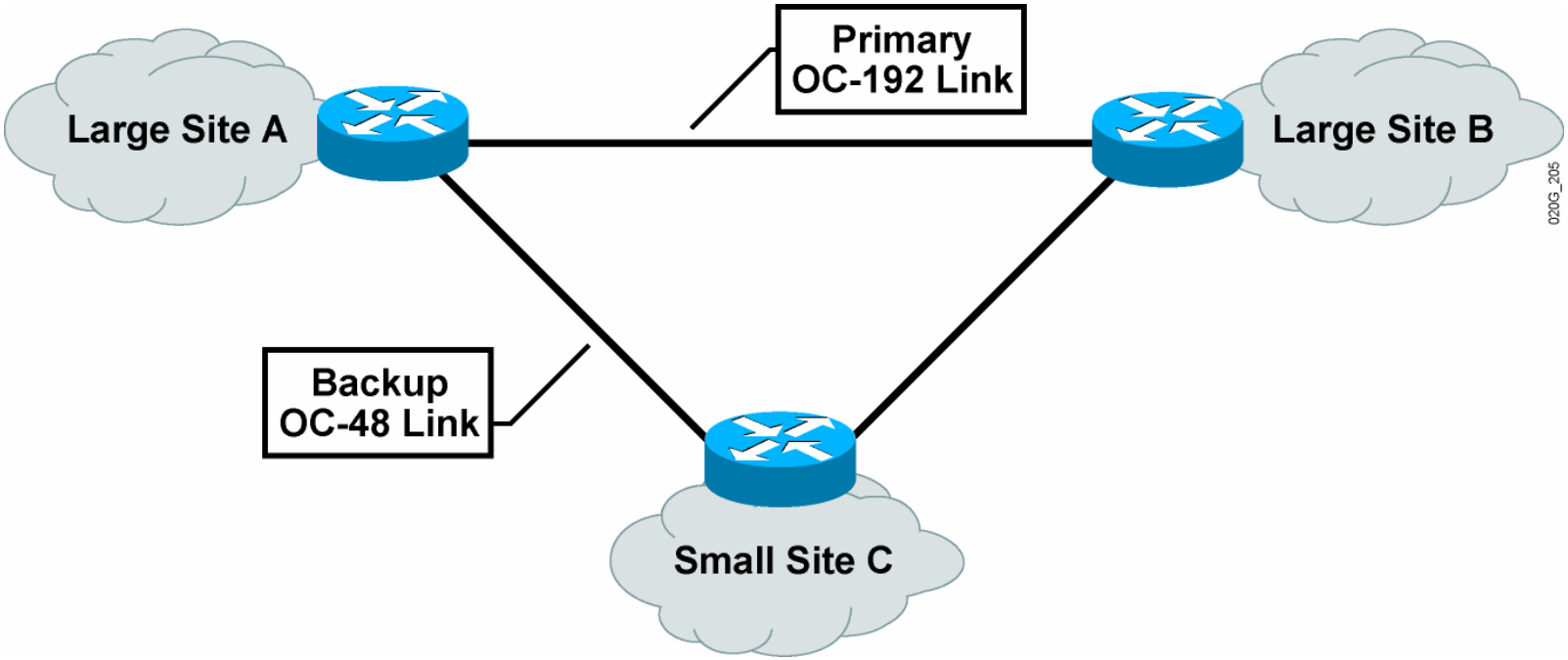

- Most traffic goes between large sites A and B, and uses only the primary link.
- Destination-based routing does not provide any mechanism for load balancing across unequal paths.
- Policy-based routing can be used to forward packets based on other parameters, but this is not a scalable solution.

Basic MPLS Concepts

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- 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

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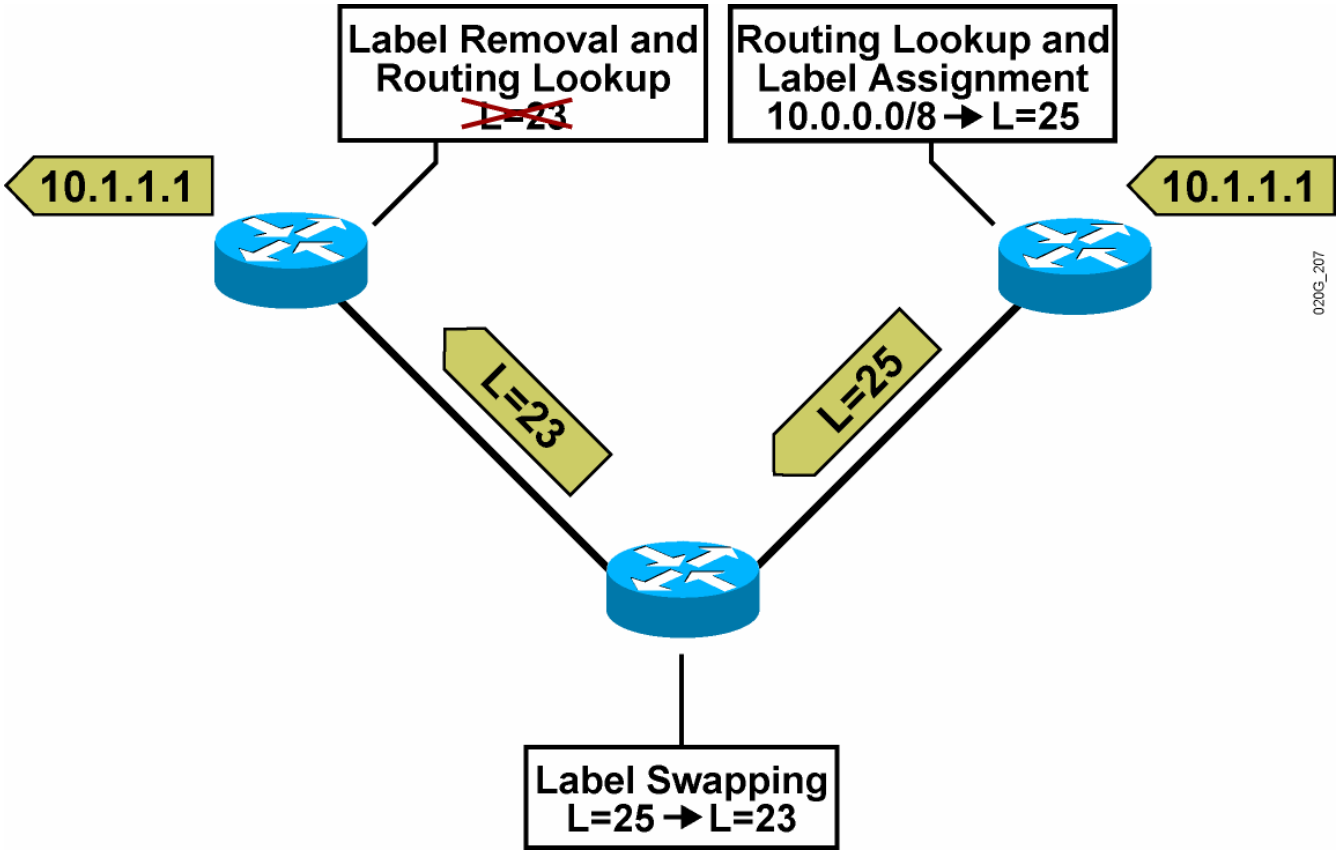

- Only edge routers must perform a routing lookup.
- Core routers switch packets based on simple label lookups and swap labels.

MPLS vs. IP over ATM

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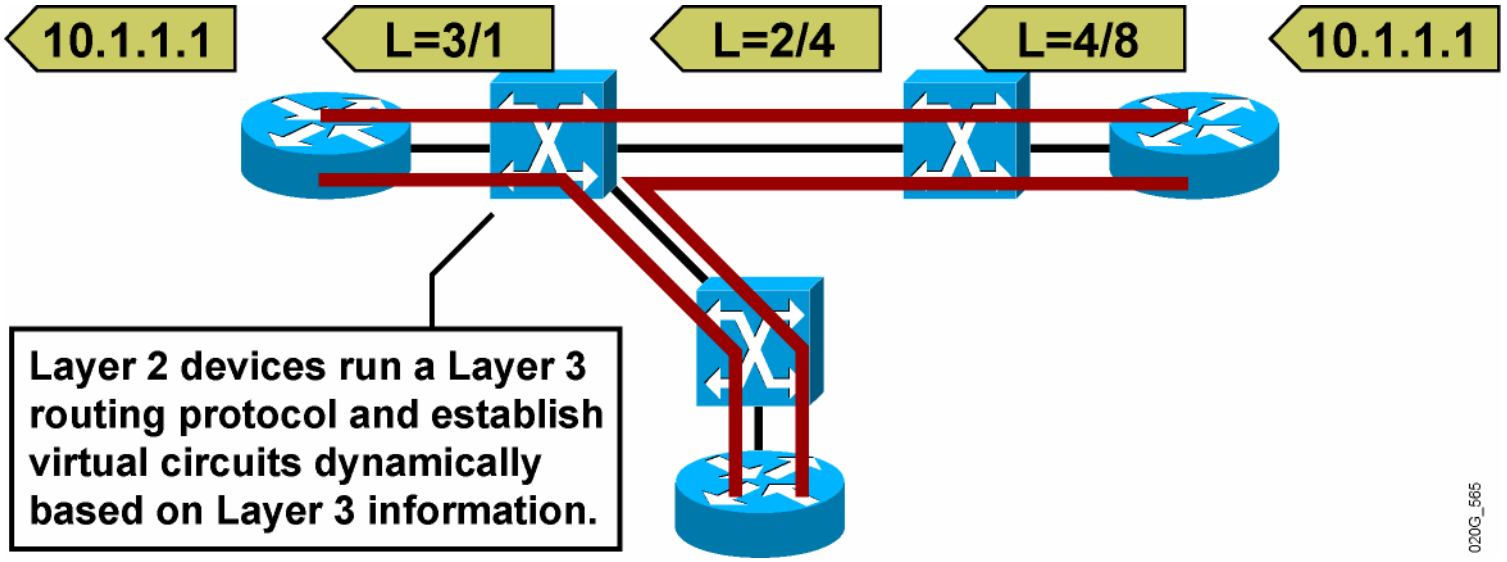
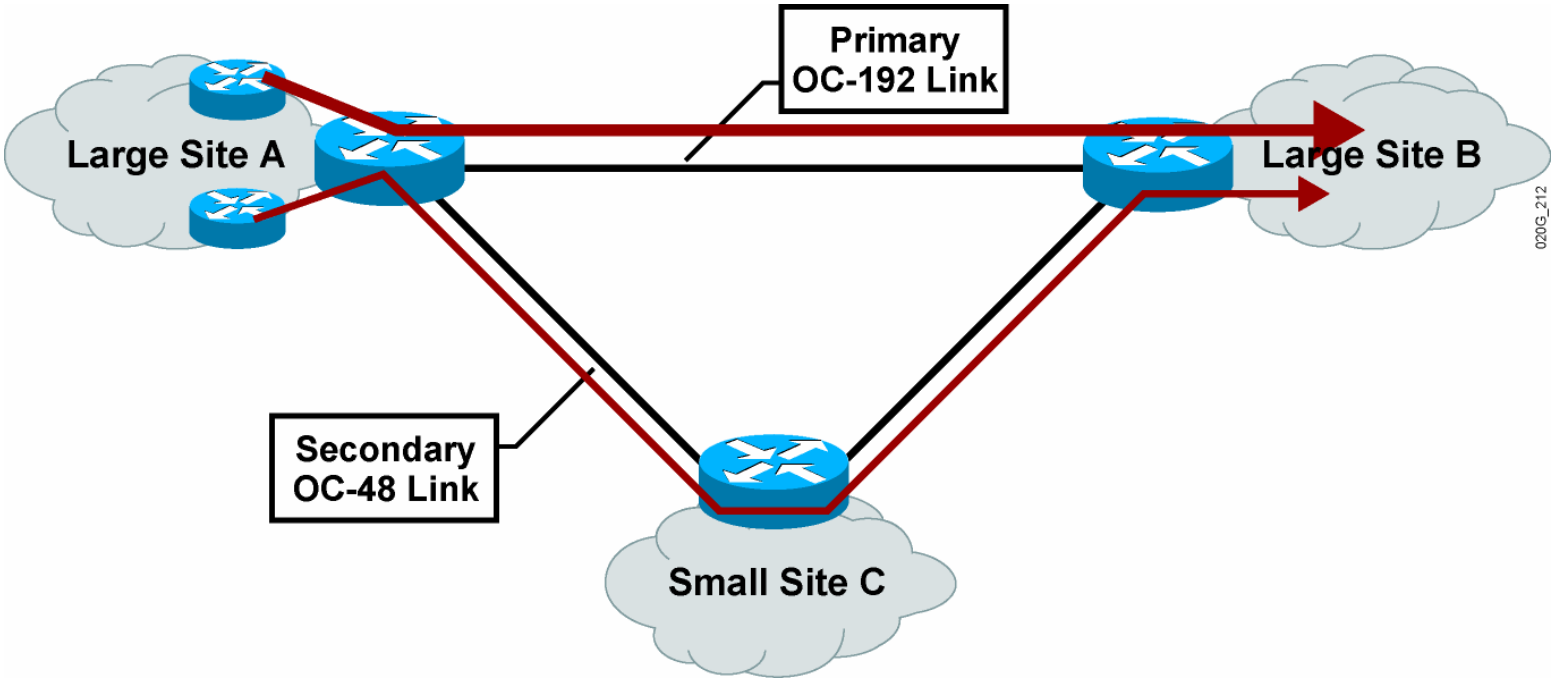


- Layer 2 devices are IP-aware and run a routing protocol.
- There is no need to manually establish virtual circuits.
- MPLS provides a virtual full mesh topology.

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 Architecture

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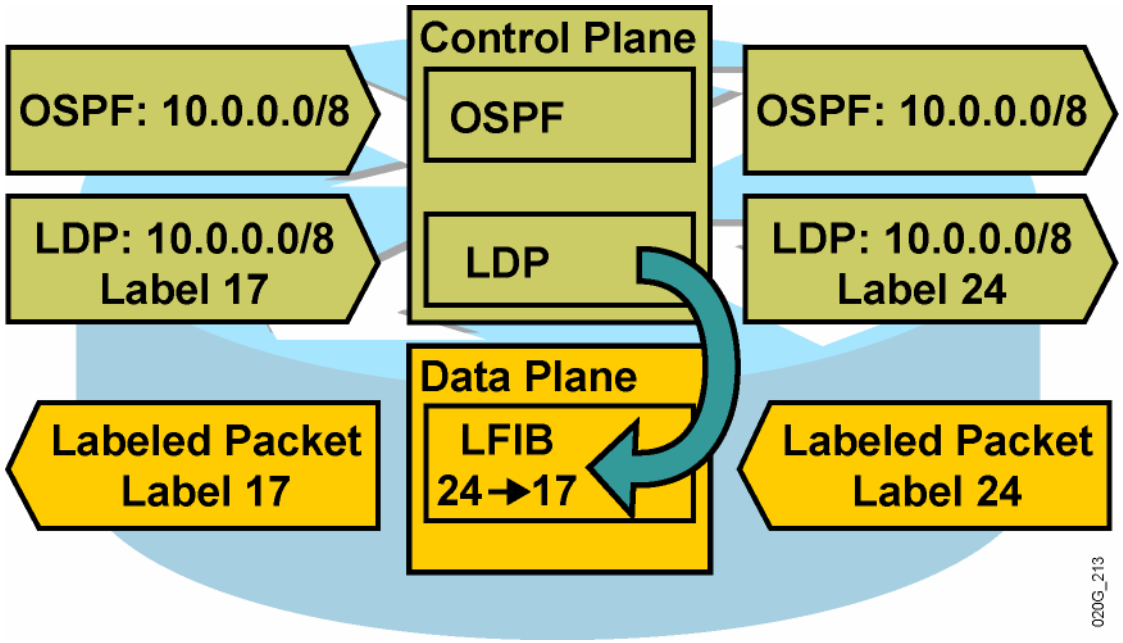
MPLS has two major components:

- **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

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- 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

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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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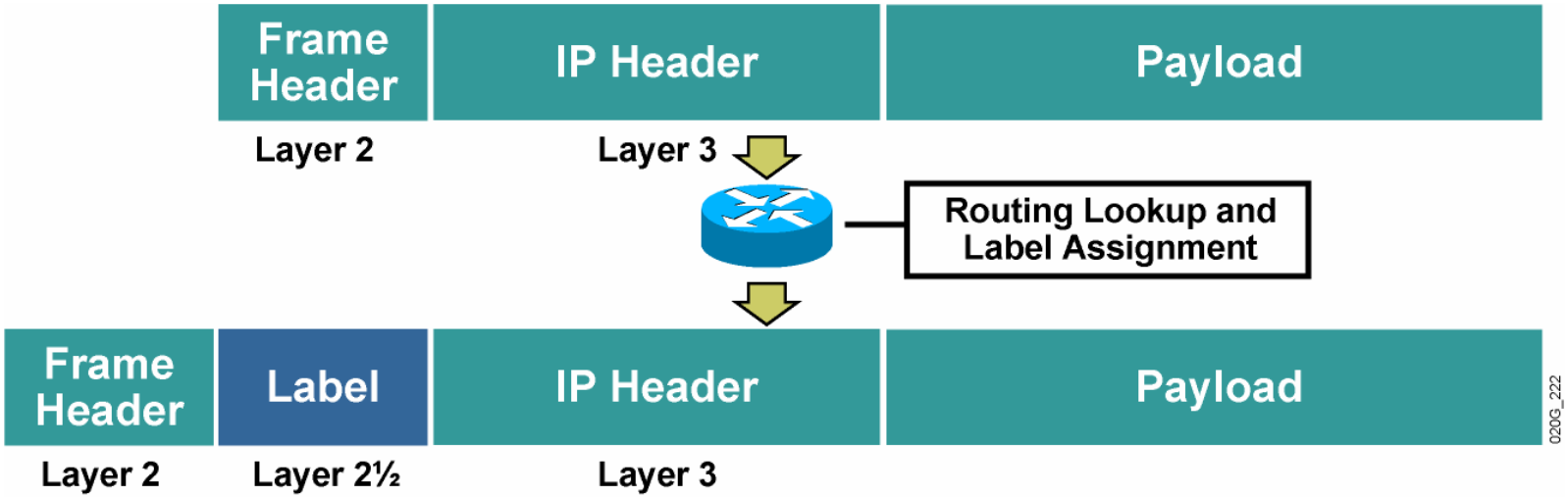

Label Switch Routers

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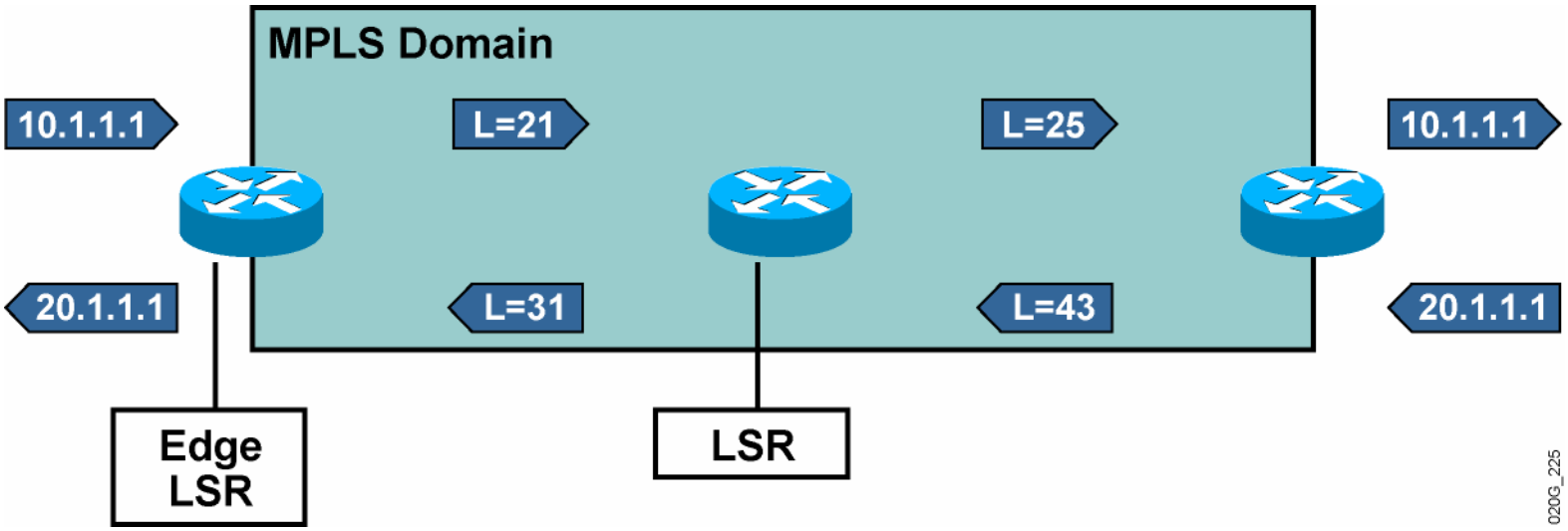

- **LSR primarily forwards labeled packets (label swapping).**
- **Edge LSR primarily labels IP packets and forwards them into the MPLS domain, or removes labels and forwards IP packets out of the MPLS domain.**

Label Switch Routers: Architecture of LSRs

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- 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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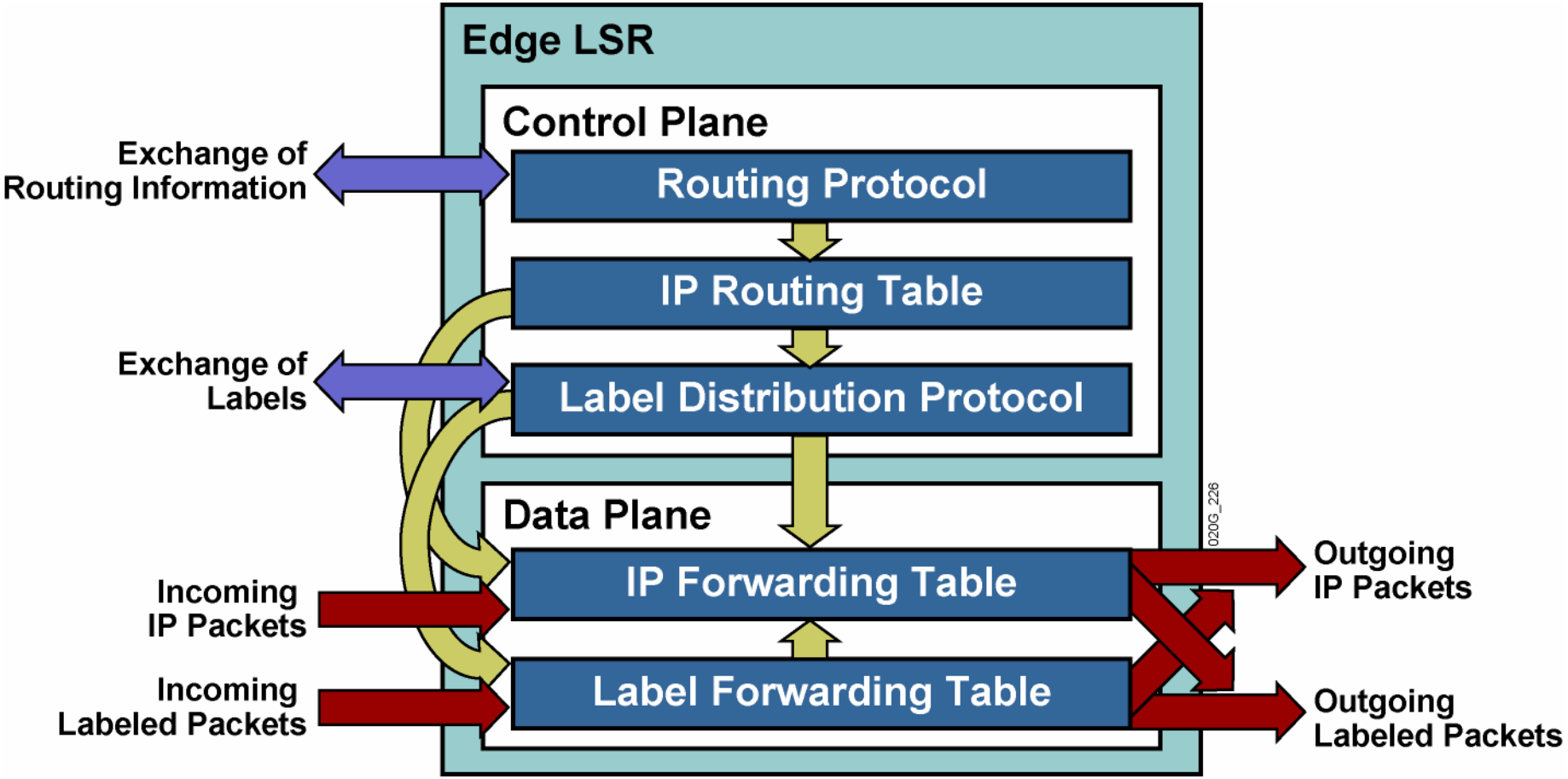

Module 1 - 2

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

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- 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

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- 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

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- 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

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- 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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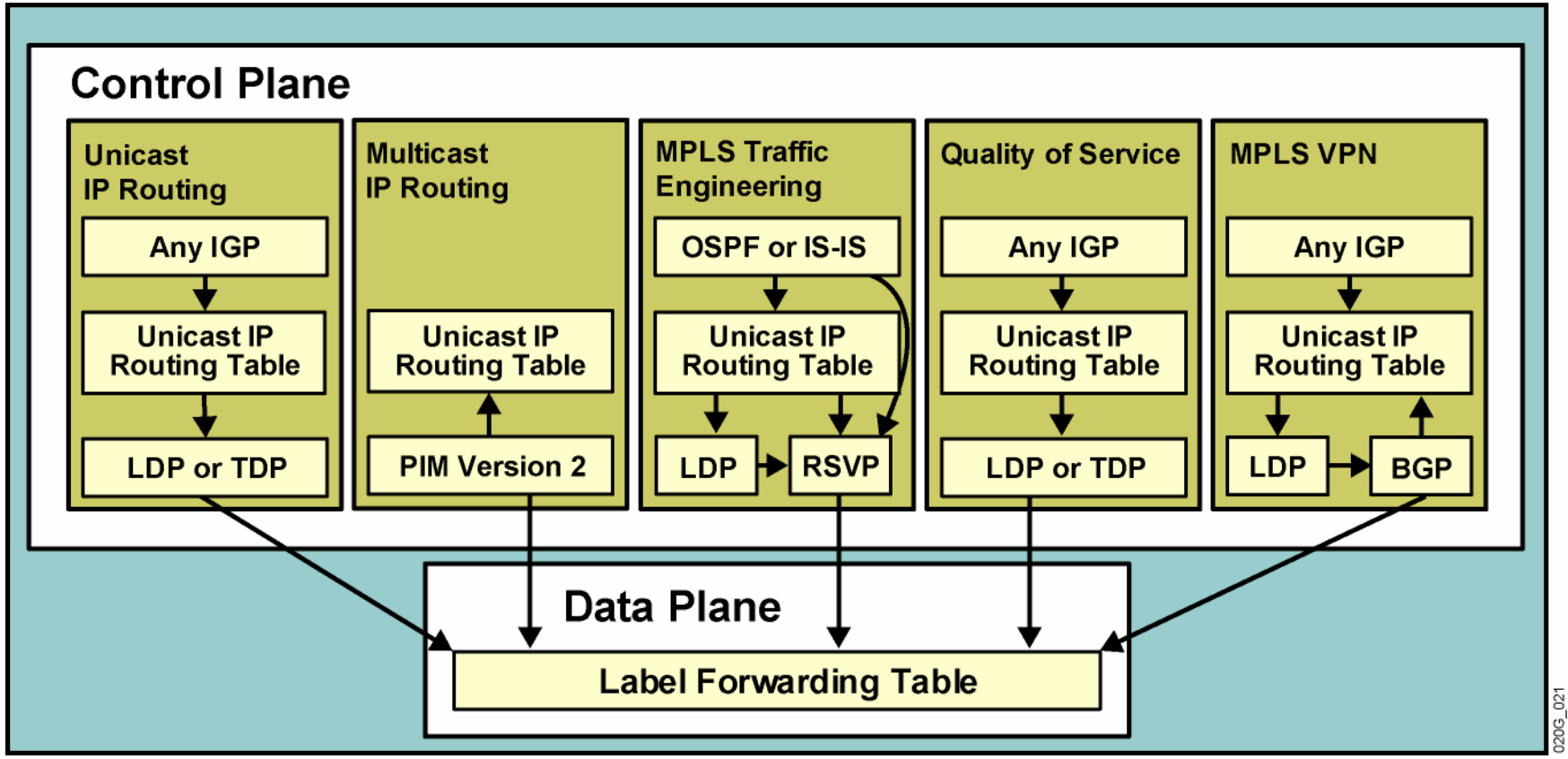

Module 1 - 3

Introducing MPLS Labels and Label Stack

MPLS Labels

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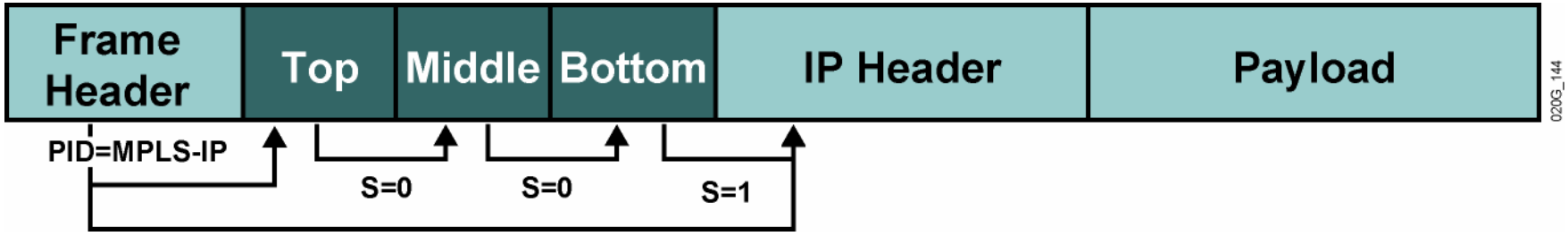
- Labels are inserted between the Layer 2 (frame) header and the Layer 3 (packet) header.
- There can be more than one label (label stack).
- The bottom-of-stack bit indicates if the label is the last label in the label stack.
- The TTL field is used to prevent the indefinite looping of packets.
- Experimental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

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- 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

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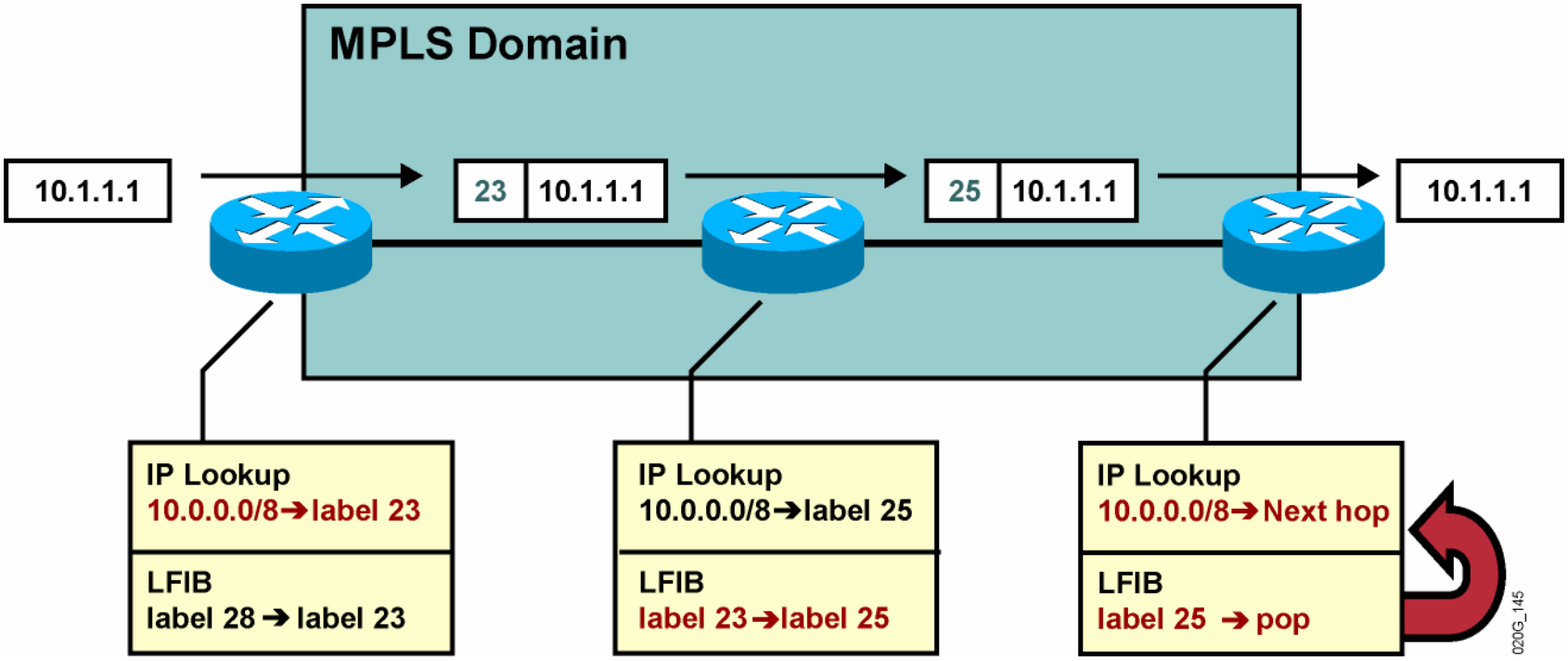

- On ingress, a label is assigned and imposed by the IP routing process.
- LSRs in the core swap labels based on the contents of the label forwarding table.
- On egress, the label is removed and a routing lookup is used to forward the packet.

Module 1 - 4

Introducing MPLS VPN Routing Model

MPLS VPN Routing Requirements

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- 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

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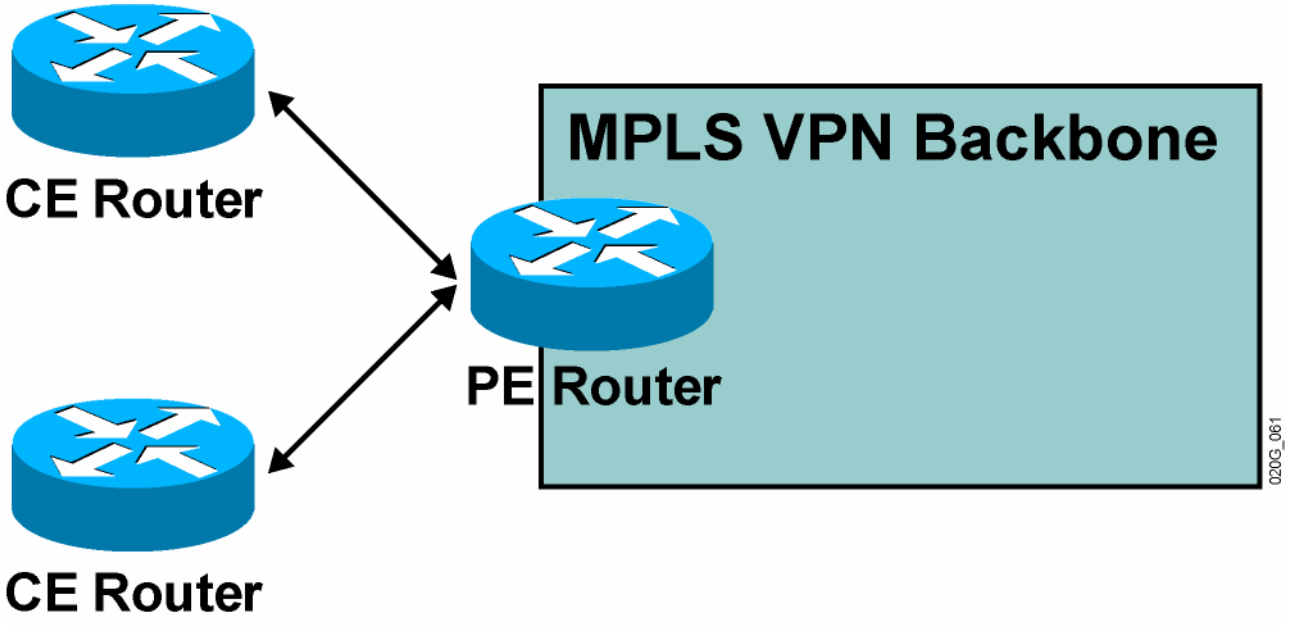

- The CE routers run standard IP routing software and exchange routing updates with the PE router.
  - EBGP, OSPF, RIPv2, EIGRP, and static routes are supported.

MPLS VPN Routing: Overall Customer Perspective

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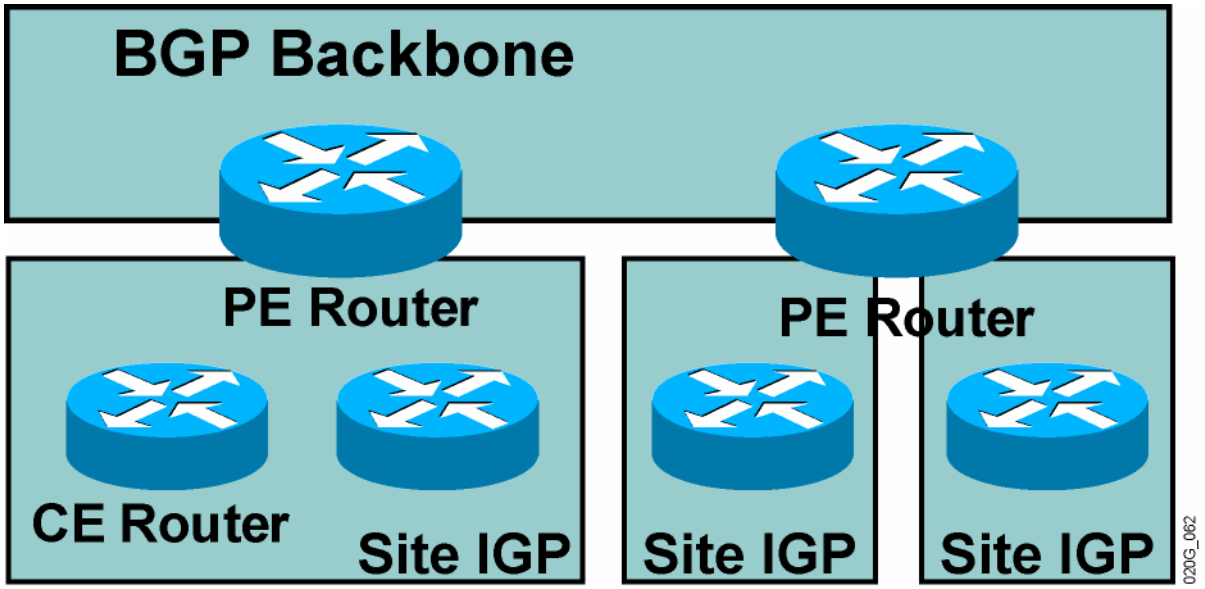
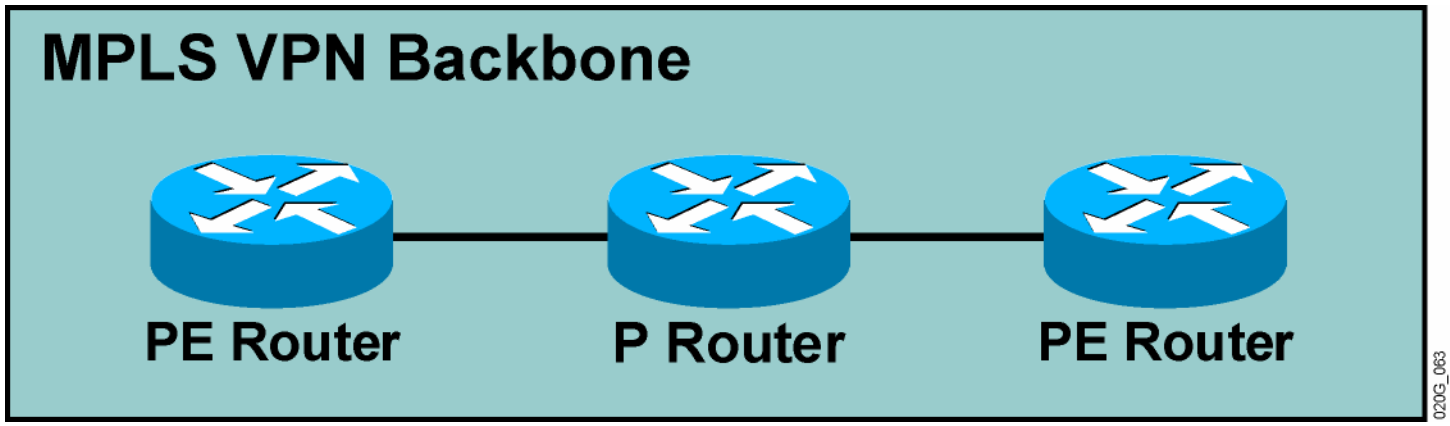


- To the customer, the PE routers appear as core routers connected via a BGP backbone.
- The usual BGP and IGP design rules apply.
- The P routers are hidden from the customer.

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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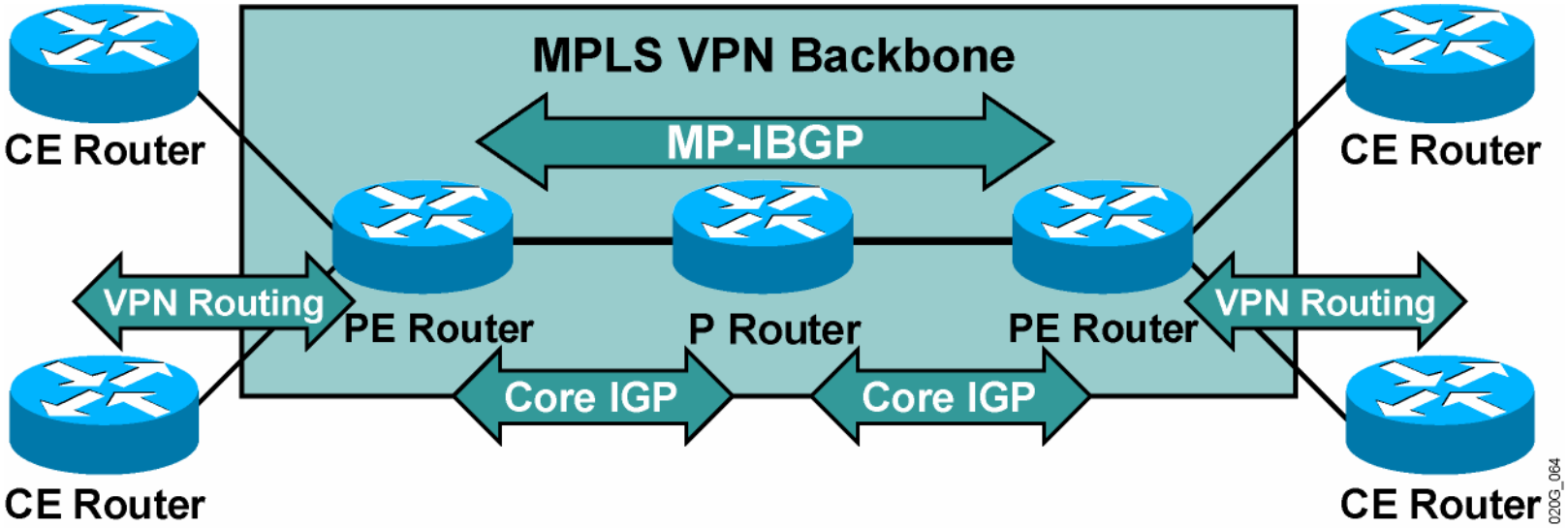

PE routers:

- 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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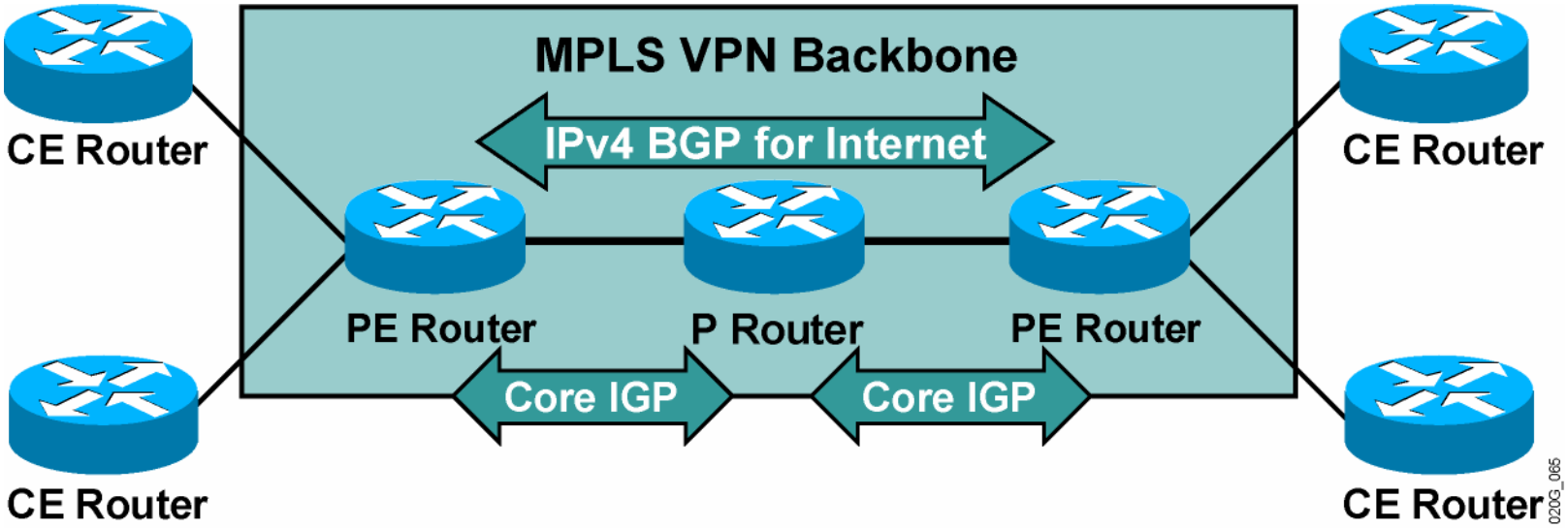
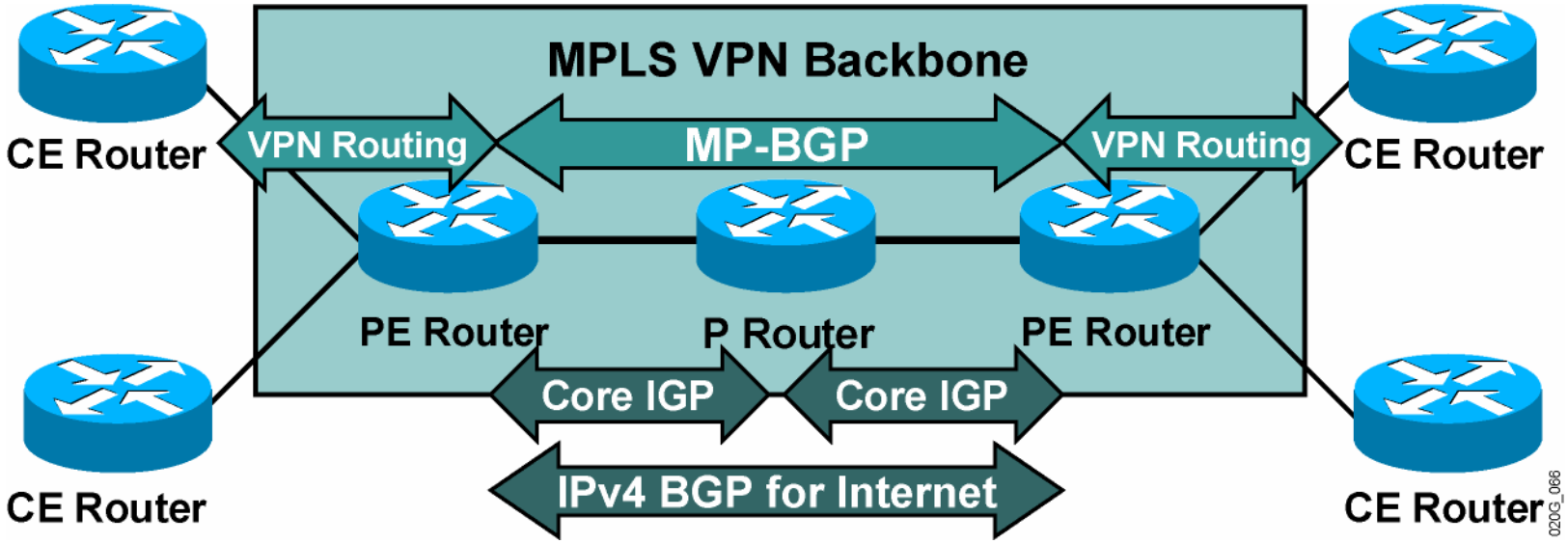


PE routers can run standard IPv4 BGP in the global routing table:

- **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



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.

Module 1 - 5

Forwarding MPLS VPN Packets

VPN Label Propagation

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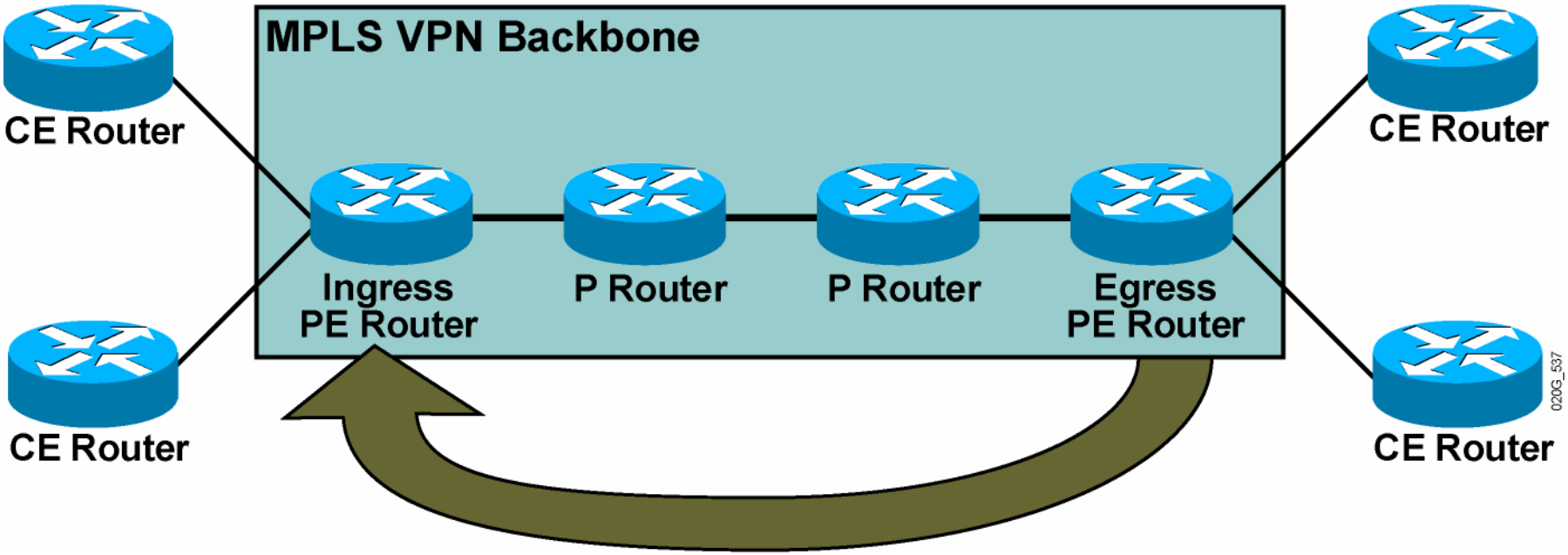
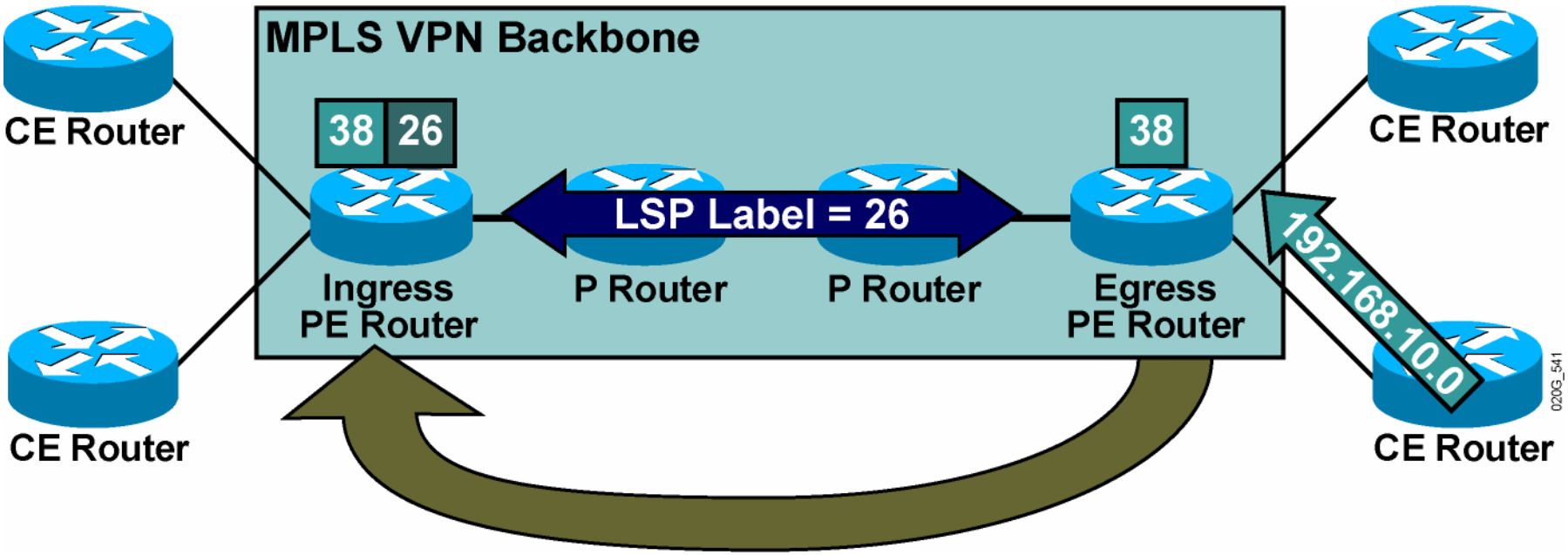


Labels are propagated in MP-BGP VPNv4 routing updates.

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

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- 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

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- 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.