

MPLS Introduction

Multi-Protocol Label Switching

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MPLS Introduction

- **Motivation**
 - MPLS Basics
 - Components and Protocols
 - Operation
 - Protocol Stack Architecture
 - Advantages and Disadvantages
-

Motivation

□ IP

- The first defined and used protocol
- De facto the only protocol for global Internet working

... but there are disadvantages

Motivation (cont.)

□ IP Routing disadvantages

- Connectionless
 - e.g. no QoS
 - Each router has to make independent forwarding decisions based on the IP-address
 - Large IP Header
 - At least 20 bytes
 - Routing in Network Layer
 - Slower than Switching
 - Usually designed to obtain shortest path
 - Do not take into account additional metrics
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Motivation (cont.)

□ ATM

- connection oriented
 - Supports QoS
- fast packet switching with fixed length packets (cells)
- integration of different traffic types (voice, data, video)

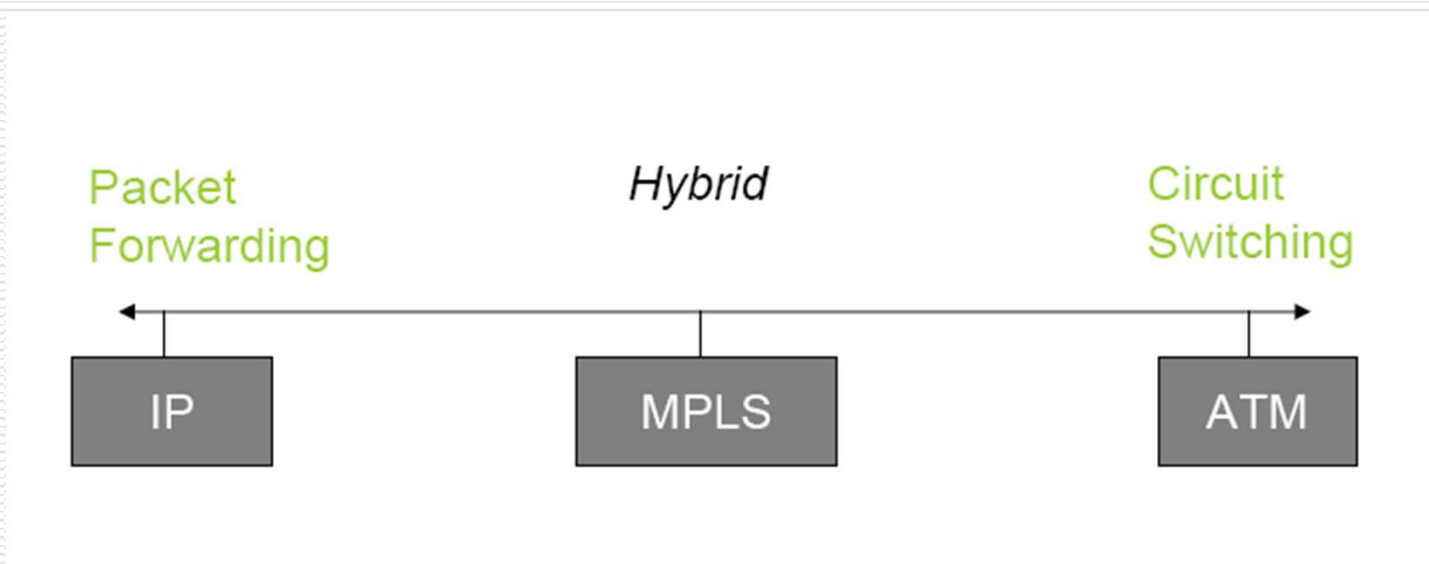
... but there are also disadvantages

Motivation (cont.)

- ATM disadvantages
 - Complex
 - Expensive
 - Not widely adopted
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Motivation (cont.)

- Idea: Combine the forwarding algorithm used in ATM with IP.

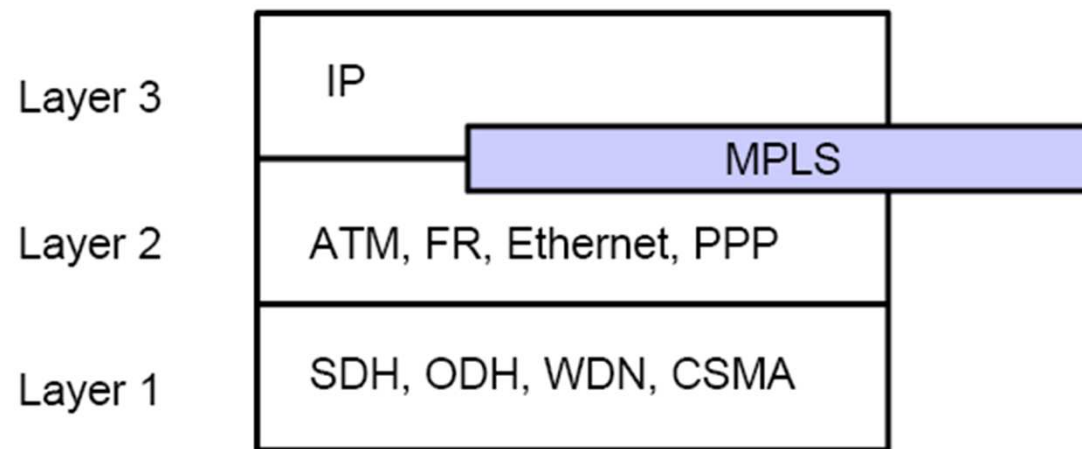


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MPLS Basics

- ❑ Multi Protocol Label Switching is arranged between Layer 2 and Layer 3



MPLS Basics (cont.)

□ MPLS Characteristics

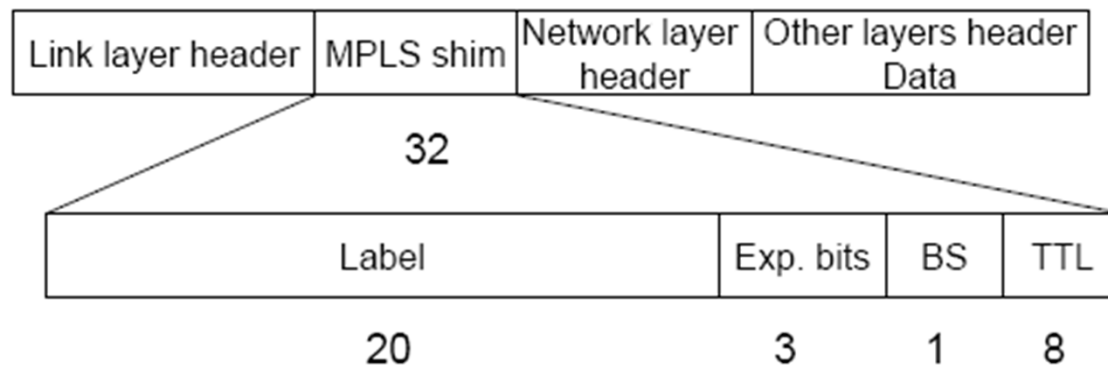
- Mechanisms to manage traffic flows of various granularities (*Flow Management*)
 - Is independent of Layer-2 and Layer-3 protocols
 - Maps IP-addresses to fixed length labels
 - Interfaces to existing routing protocols (RSVP, OSPF)
 - Supports ATM, Frame-Relay and Ethernet
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Label

□ Generic label format



Exp.bits: Experimental Bits, often used for Class of Service

BS: Bottom of Stack bit, is set if no label follows

TTL: Time To Leave, used in the same way like in IP

Label (cont.)

□ Label distribution

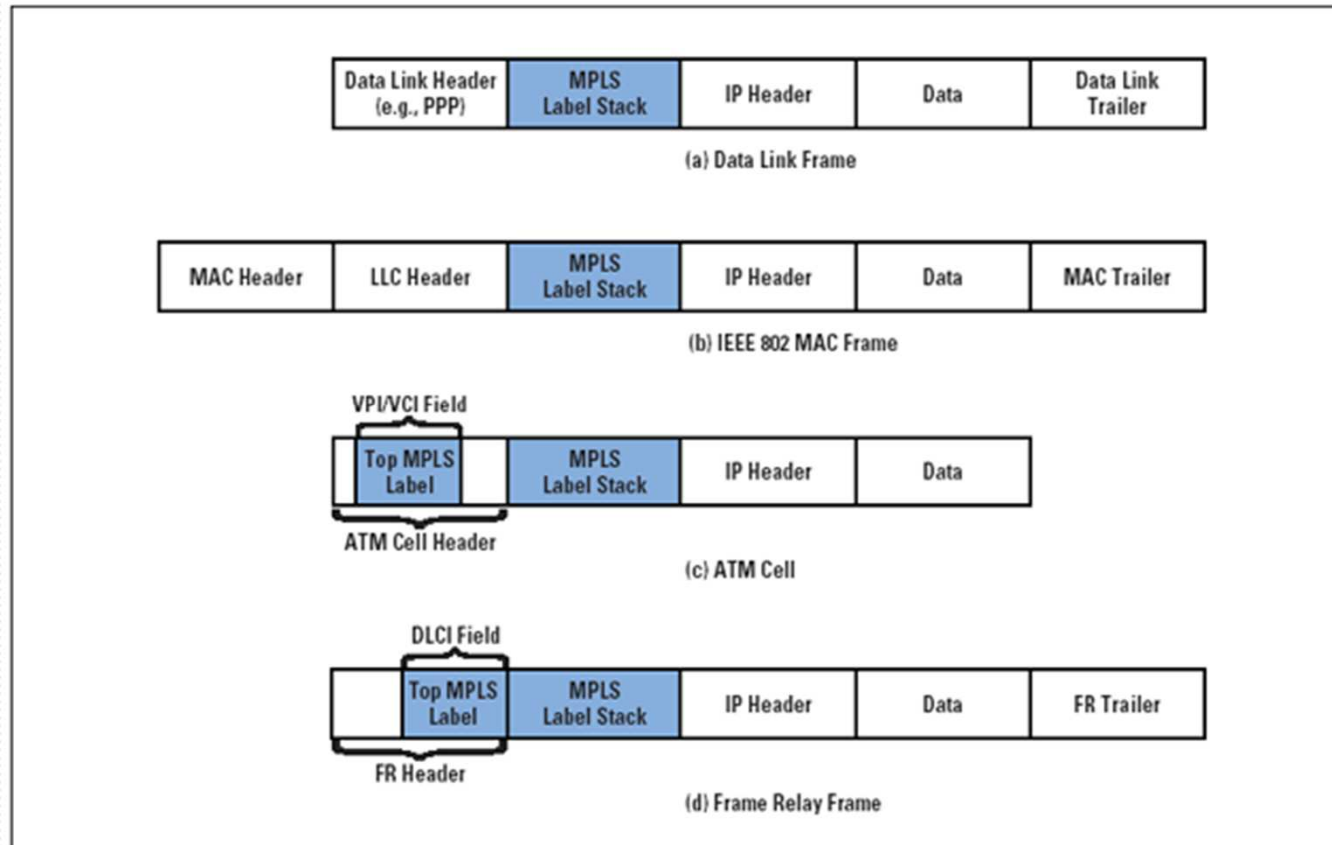
- MPLS does not specify a single method for label distribution
 - BGP has been enhanced to piggyback the label information within the contents of the protocol
 - RSVP has also been extended to support piggybacked exchange of labels.
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Label (cont.)

- IETF has also defined a new protocol known as the label distribution protocol (LDP) for explicit signaling and management
 - Extensions to the base LDP protocol have also been defined to support explicit routing based on QoS requirements.
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Label (cont.)

Figure 4: Position of MPLS Label



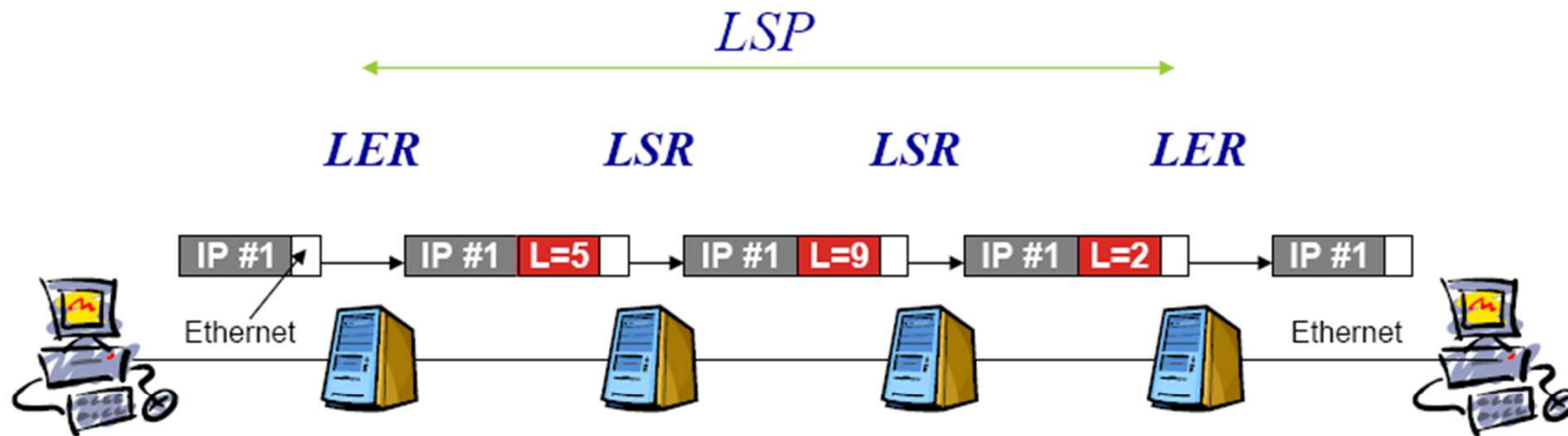
Label Edge Router - LER

- ❑ Resides at the edge of an MPLS network and assigns and removes the labels from the packets.
 - ❑ Support multiple ports connected to dissimilar networks (such as frame relay, ATM, and Ethernet).
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Label Switching Router - LSR

- ❑ Is a high speed router in the core on an MPLS network.
 - ❑ ATM switches can be used as LSRs without changing their hardware. Label switching is equivalent to VP/VC switching.
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Positions of LERs & LSRs



IP Addr	Out Label	In Label	Out Label	In Label	Out Label	In Label	Next Hop
192.4/16	5	5	9	9	2	2	192.4/16
Layer 2 Transport	Assign init label	Label Swapping		Label Swapping		Remove Label	Layer 2 Transport

“ROUTE AT EDGE, SWITCH IN CORE”

Forward Equivalence Class - FEC

- Is a representation of a group of packets that share the same requirements for their transport.
 - The assignment of a particular packet to a particular FEC is done just once (when the packet enters the network).
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Label-Switched Paths - LSPs

- ❑ A path is established before the data transmission starts.
 - ❑ A path is a representation of a FEC.
-

LSP Details

- MPLS provides two options to set up an LSP
 - hop-by-hop routing

Each LSR independently selects the next hop for a given FEC. LSRs support any available routing protocols (OSPF, ATM ...).
 - explicit routing

Is similar to source routing. The ingress LSR specifies the list of nodes through which the packet traverses.
 - The LSP setup for an FEC is unidirectional. The return traffic must take another LSP!
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Label Distribution Protocol - LDP

- An application layer protocol for the distribution of label binding information to LSRs.
 - It is used to map FECs to labels, which, in turn, create LSPs.
 - LDP sessions are established between LDP peers in the MPLS network (not necessarily adjacent).
 - Sometimes employs OSPF or BGP.
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LDP details

- LDP message types:
 - **discovery messages**—announce and maintain the presence of an LSR in a network
 - **session messages**—establish, maintain, and terminate sessions between LDP peers
 - **advertisement messages**—create, change, and delete label mappings for FECs
 - **notification messages**—provide advisory information and signal error information
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Traffic Engineering

- ❑ In MPLS, traffic engineering is inherently provided using explicitly routed paths.
 - ❑ The LSPs are created independently, specifying different paths that are based on user-defined policies. However, this may require extensive operator intervention.
 - ❑ RSVP-TE and CR-LDP are two possible approaches to supply dynamic traffic engineering and QoS in MPLS.
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RSVP-TE

- Request bandwidth and traffic conditions on a defined path.
 - Drawback:
 - Requires regular refreshes
 - Scalability
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CR-LDP

- ❑ Takes into account parameters, such as link characteristics (bandwidth, delay, etc.), hop count, and QoS.
 - ❑ It is entirely possible that a longer (in terms of cost) but less loaded path is selected.
 - ❑ Drawback: It adds more complexity to routing calculations.
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MPLS Operation

- The following steps must be taken for a data packet to travel through an MPLS domain.
 - label creation and distribution
 - table creation at each router
 - label-switched path creation
 - label insertion/table lookup
 - packet forwarding
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Step 1

- Label creation and label distribution
 - Before any traffic begins the routers make the decision to bind a label to a specific FEC and build their tables.
 - In LDP, downstream routers initiate the distribution of labels and the label/FEC binding.
 - In addition, traffic-related characteristics and MPLS capabilities are negotiated using LDP.
 - A reliable and ordered transport protocol should be used for the signaling protocol.
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Step 2

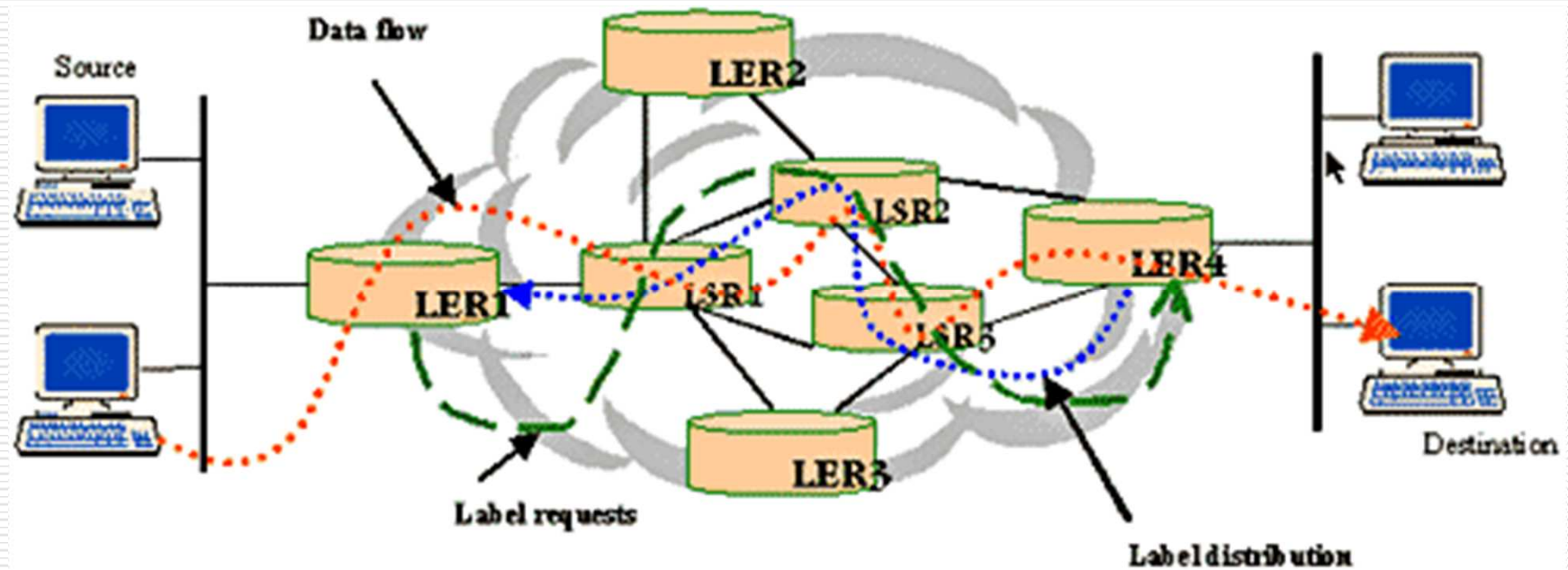
Table creation

- On receipt of label bindings each LSR creates entries in the label information base (LIB).
 - The contents of the table will specify the mapping between a label and an FEC.
 - mapping between the input port and input label table to the output port and output label table.
 - The entries are updated whenever renegotiation of the label bindings occurs.
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Example of LIB Table

Input Port	Incoming Port Label	Output Port	Outgoing Port Label
1	3	3	6
2	9	1	7

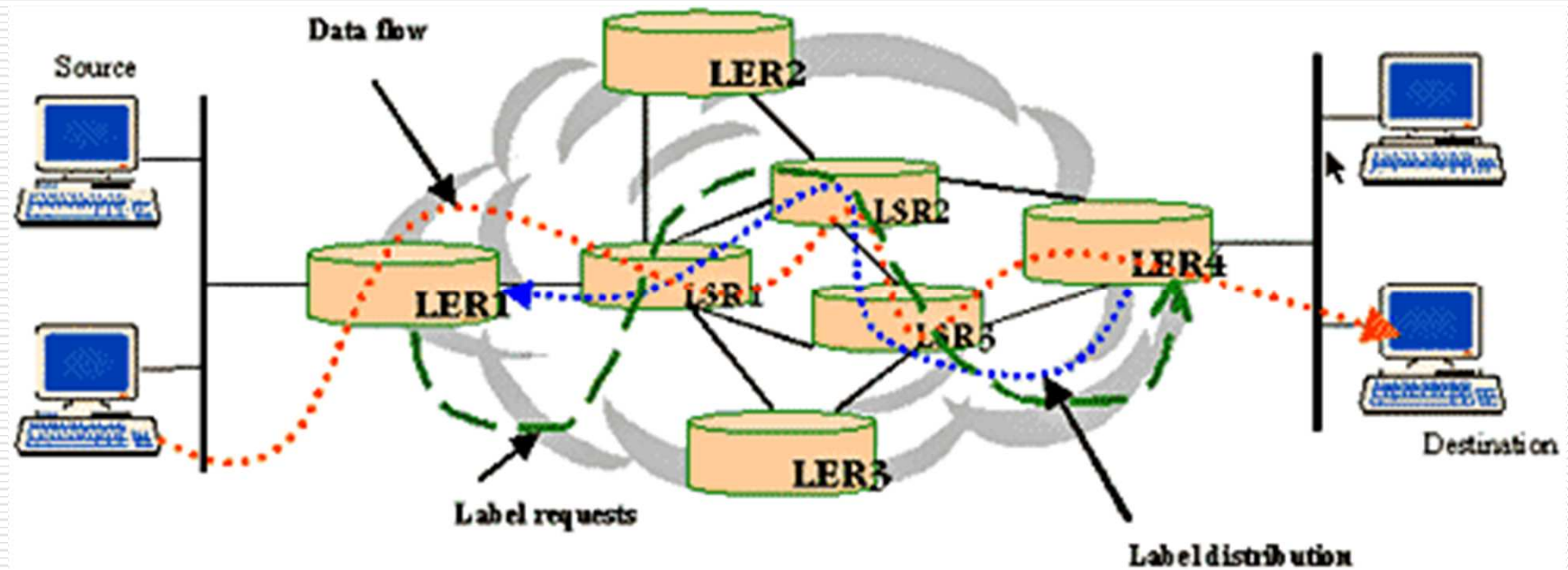
MPLS Operation Example



Step 3

- Label switched path creation
 - The LSPs are created in the reverse direction to the creation of entries in the LIBs.
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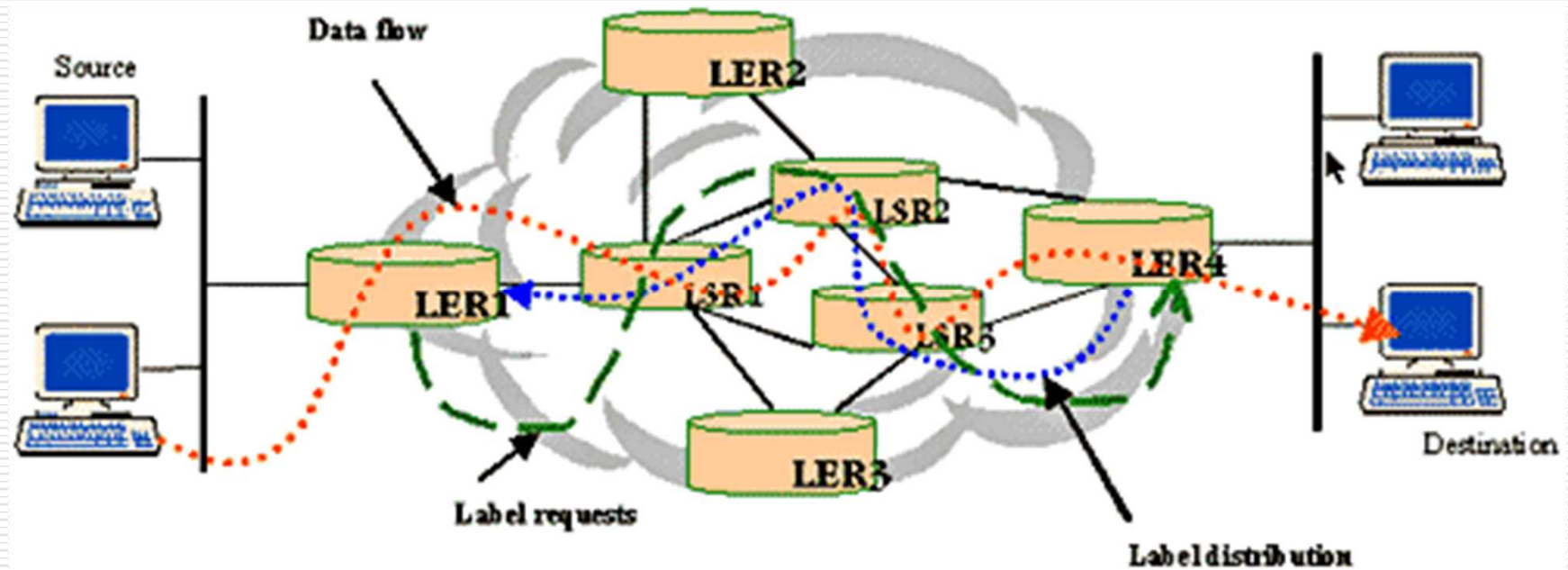
MPLS Operation Example



Step 4

- Label insertion/table-lookup
 - The first router (LER1) uses the LIB table to find the next hop and request a label for the specific FEC.
 - Subsequent routers just use the label to find the next hop.
 - Once the packet reaches the egress LSR (LER4), the label is removed and the packet is supplied to the destination.
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MPLS Operation Example



Step 5

□ Packet forwarding

- LER1 may not have any labels for this packet as it is the first occurrence of this request. In an IP network, it will find the longest address match to find the next hop. Let LSR1 be the next hop for LER1.
 - LER1 will initiate a label request toward LSR1.
 - This request will propagate through the network as indicated by the broken green lines.
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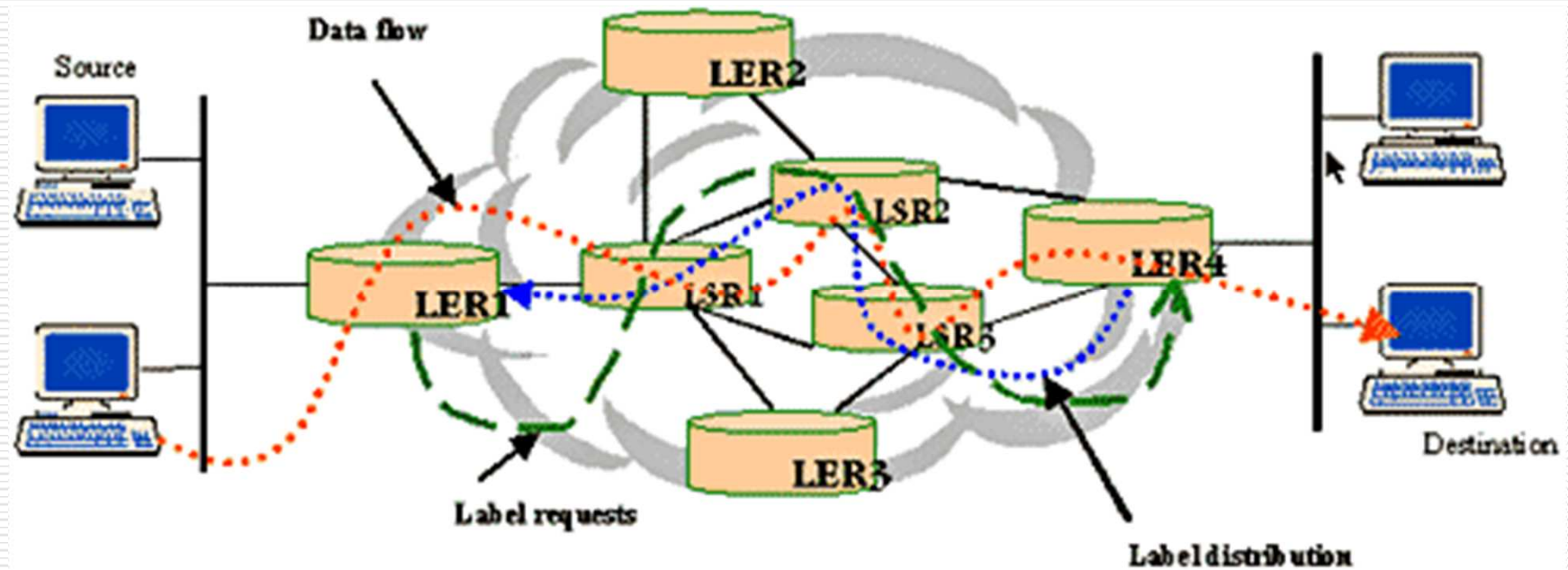
Step 5 (cont.)

- Each intermediary router will receive a label from its downstream router starting from LER2 and going upstream till LER1. The LSP setup is indicated by the broken blue lines using LDP or any other signaling protocol. If traffic engineering is required, CR-LDP will be used in determining the actual path setup to ensure the QoS/CoS requirements are complied with.
 - LER1 will insert the label and forward the packet to LSR1.
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Step 5 (cont.)

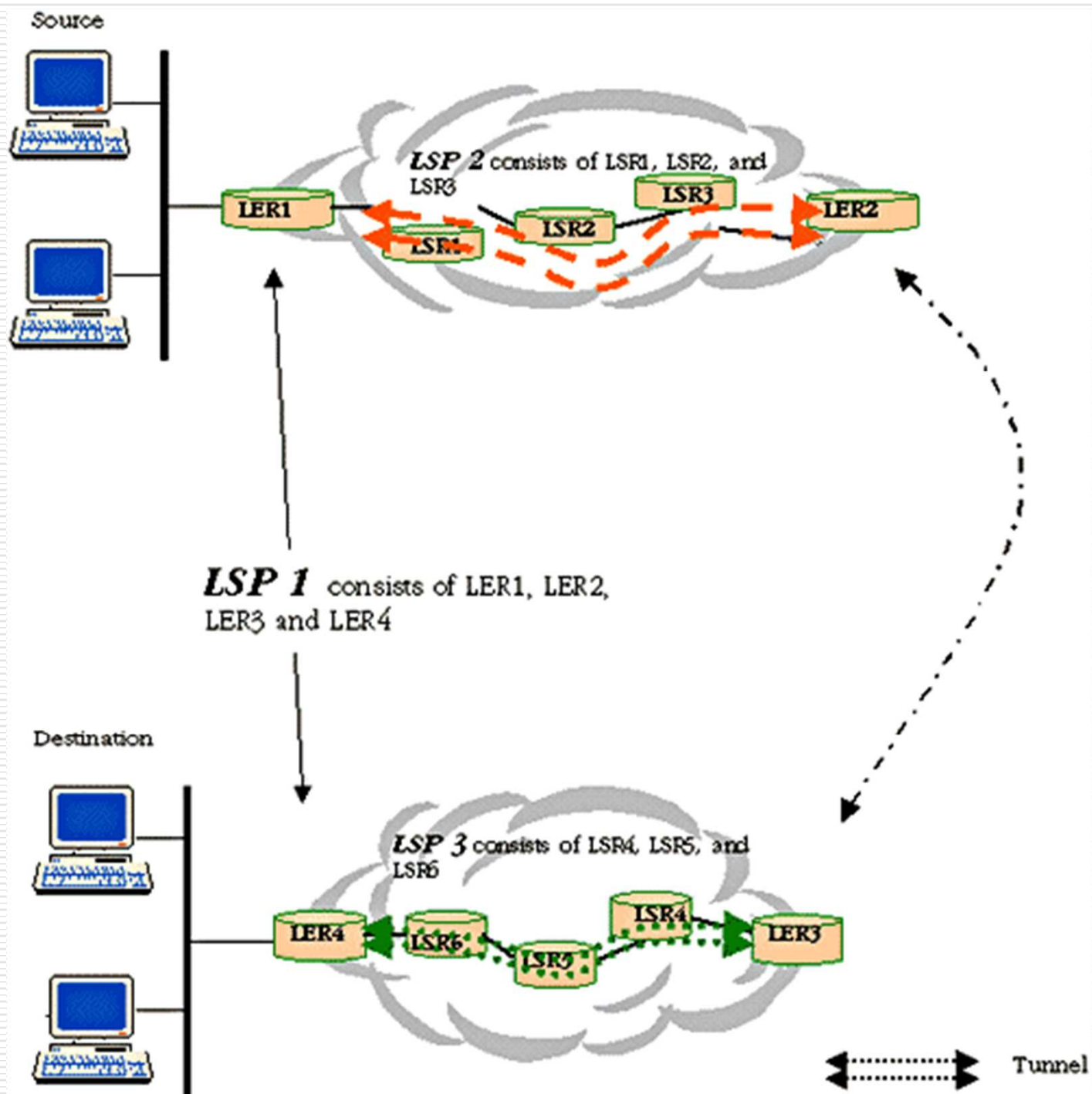
- Each subsequent LSR, i.e., LSR2 and LSR3, will examine the label in the received packet, replace it with the outgoing label and forward it.
 - When the packet reaches LER4, it will remove the label because the packet is departing from an MPLS domain and deliver it to the destination.
 - The actual data path followed by the packet is indicated by the broken red lines.
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MPLS Operation Example



Tunneling in MPLS

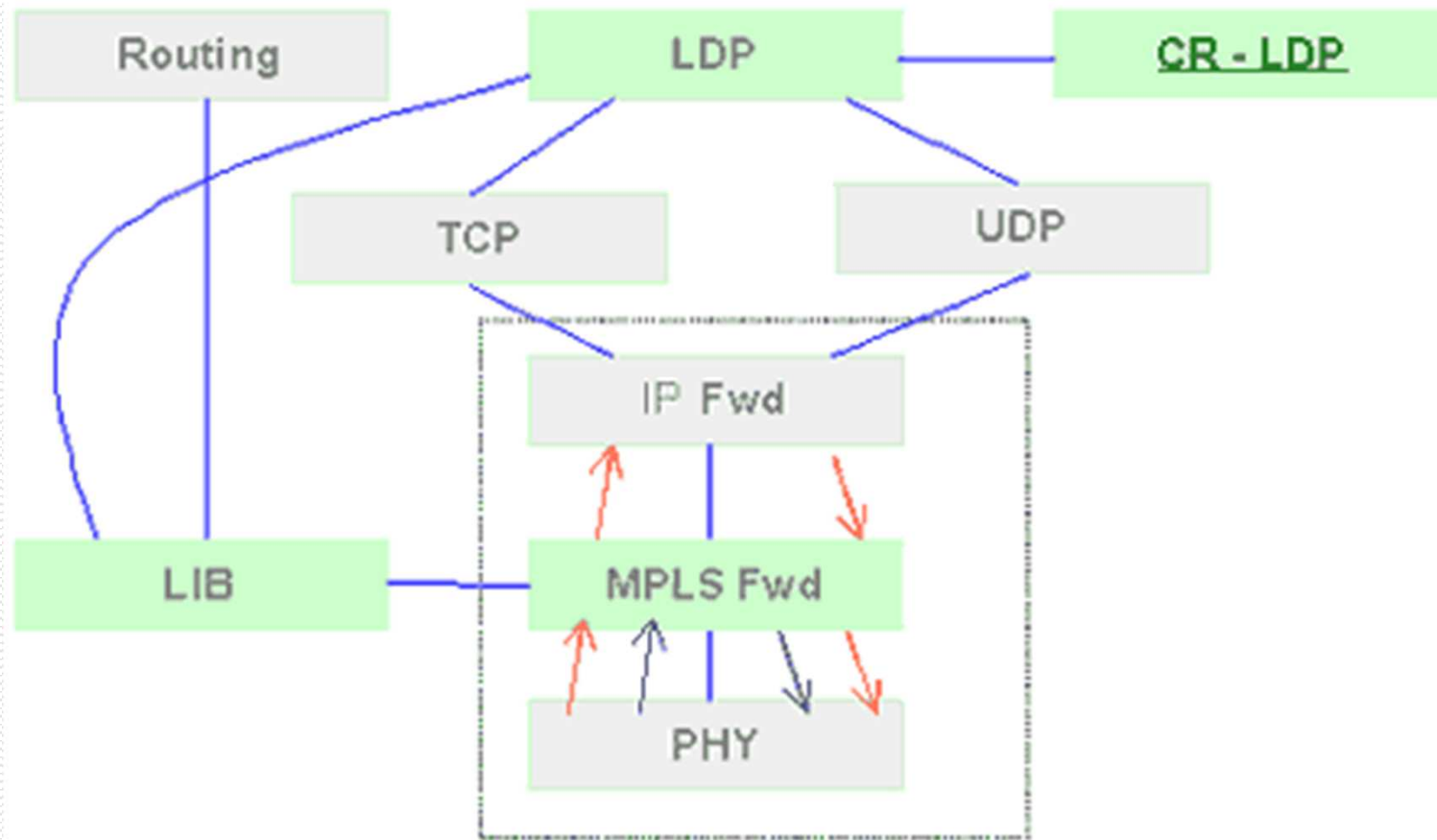
- Control the entire path of a packet without explicitly specifying the intermediate routers.
 - Creating tunnels through the intermediary routers that can span multiple segments.
 - MPLS based VPNs.
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MPLS Protocol Stack Architecture



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MPLS Advantages

- ❑ Improves packet-forwarding performance in the network
 - ❑ Supports QoS and CoS for service differentiation
 - ❑ Supports network scalability
 - ❑ Integrates IP and ATM in the network
 - ❑ Builds interoperable networks
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MPLS Disadvantages

- ❑ An additional layer is added
 - ❑ The router has to understand MPLS
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