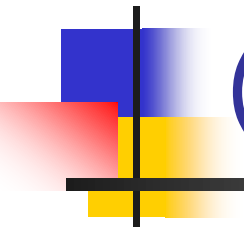

Multiprotocol Label Switching (MPLS)

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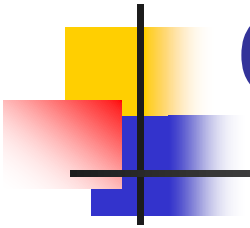
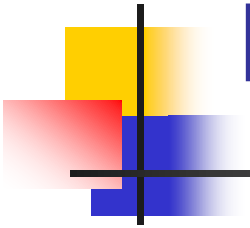


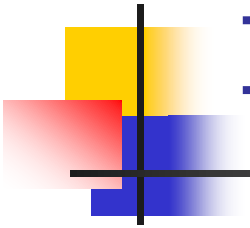
Outline

- Motivation
- MPLS Basics
- Operation
- Protocol Stack Architecture
- Advantages and Disadvantages



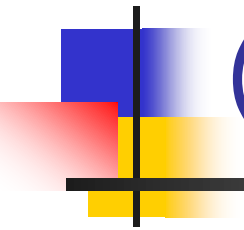
Motivation

- IP
- ATM
- MPLS positioning



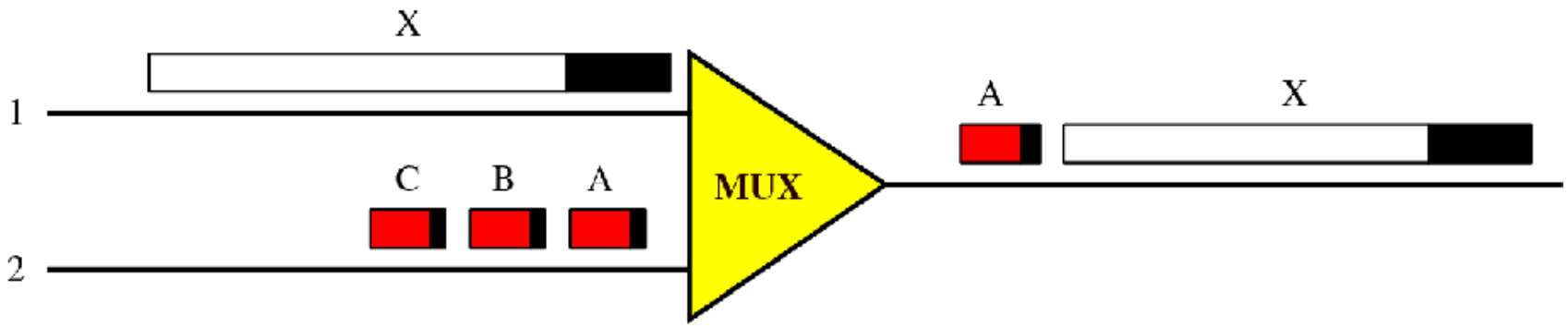
Internet Protocol (IP)

- IP is here and everywhere
- De facto protocol for global Internet
- Disadvantages
  - connectionless (e.g. no QoS)
  - independent forwarding decisions based on IP
  - large IP header (at least 20 bytes)
  - routing in Network Layer (Slower than Switching)
  - Usually shortest path (not concern other metrics)



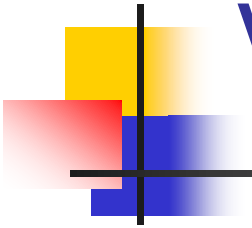
Asynchronous Transfer Mode (ATM)

Packet Sizes in the Network



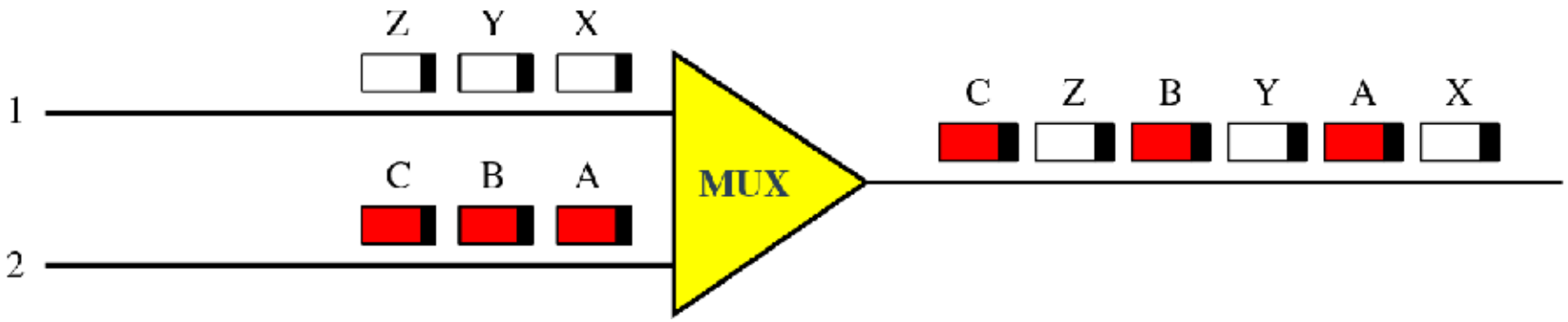
- traffic unpredictable
- Slow and expensive
- Delay variation

Voice Transmission



- If introduce large packet size for voice
  - Cannot tolerate long delay, large jitter
  - Echo problem
    - echo cancellation does not work (long delay)
- To support voice
  - Small packet
  - fixed-size packet
  - Called "**Cell**" → ***ATM cell***

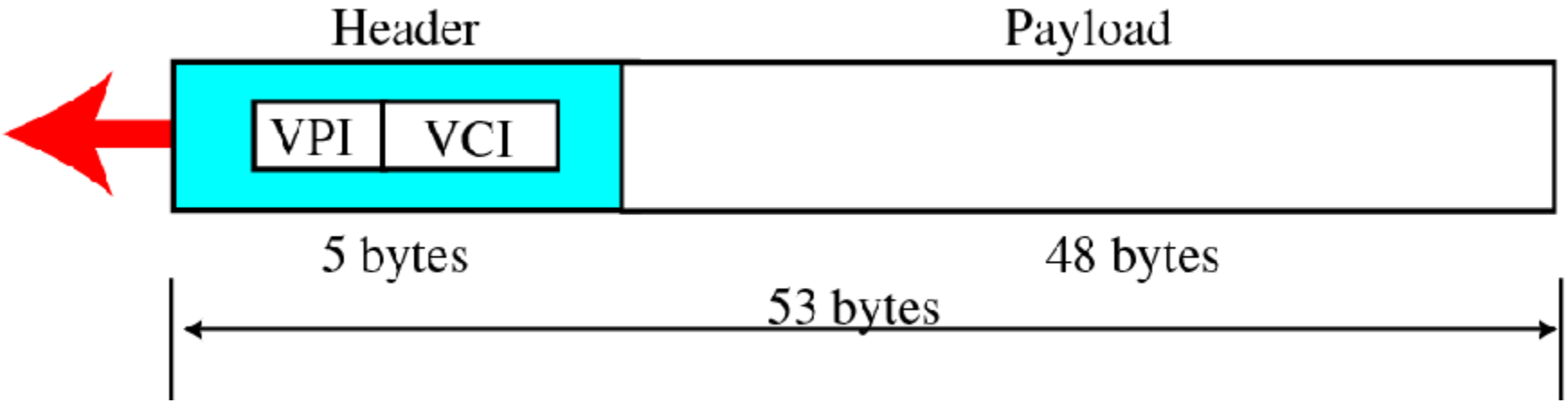
Multiplexing using cells



Advantages of cells

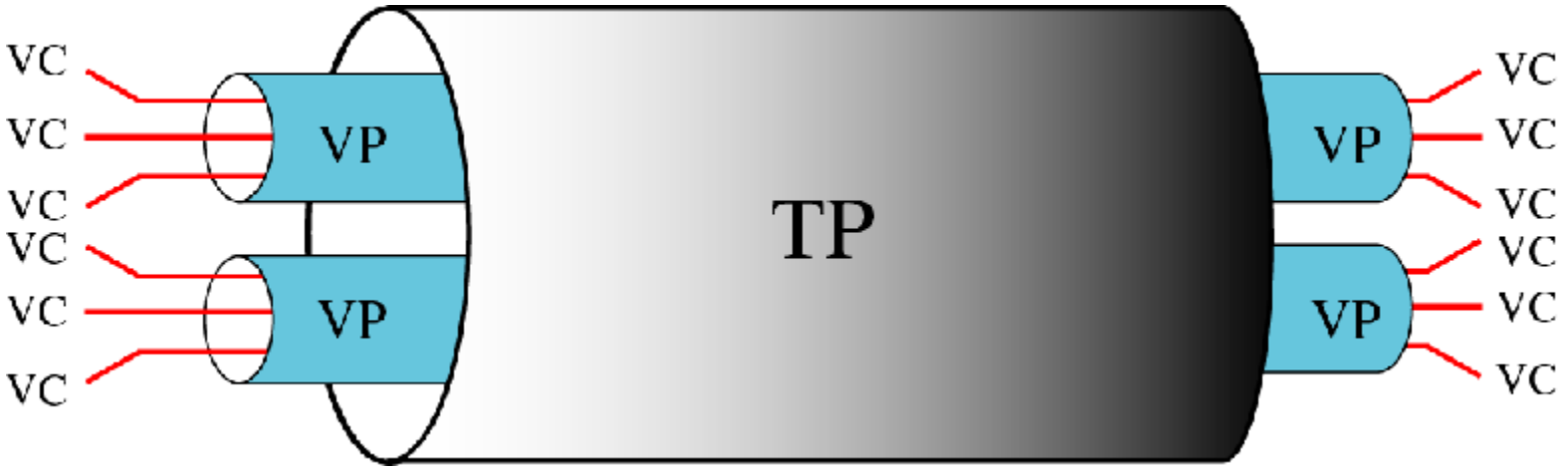
- Fair delay
- high speed and cheap (switching and multiplexing -> HW)

An ATM cell



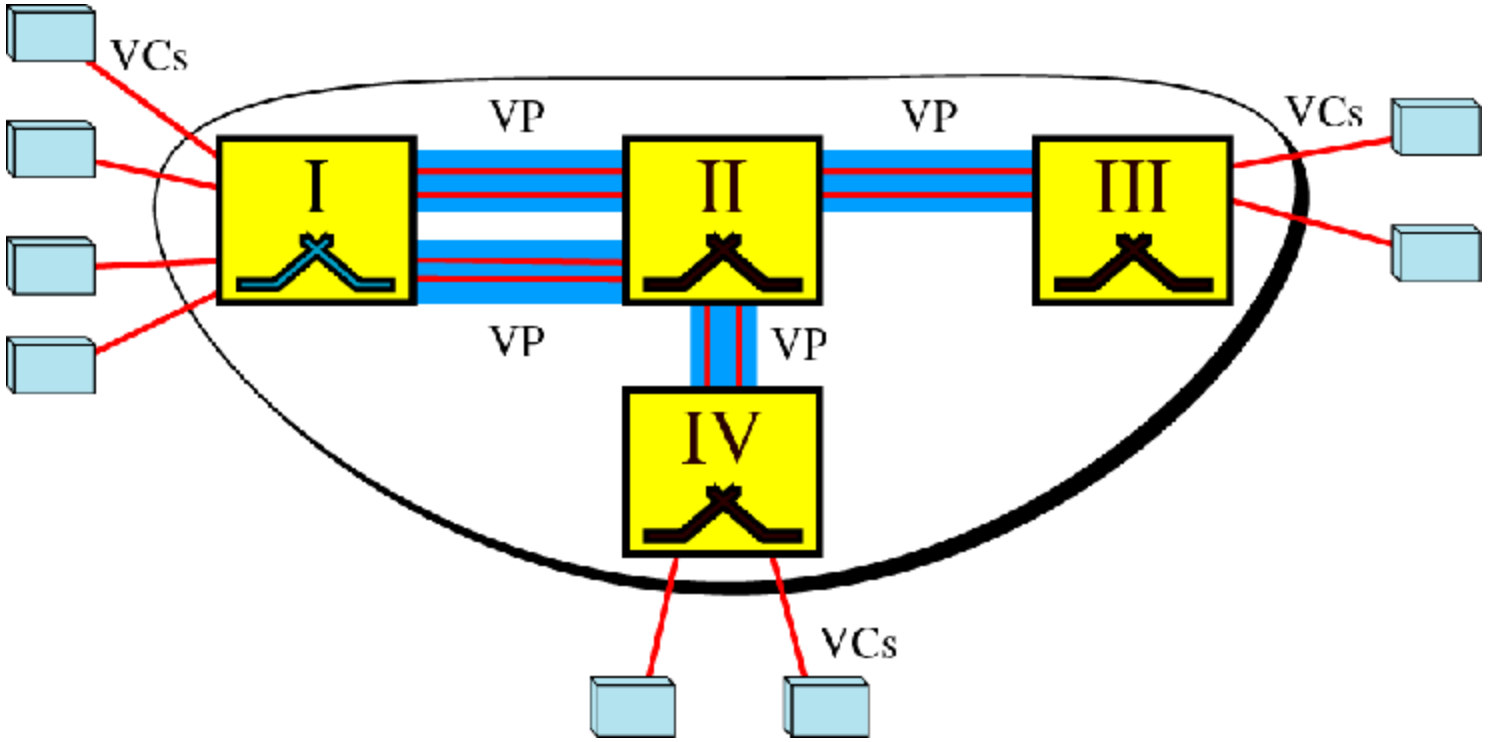
VPI: Virtual Path Identifier
VCI: Virtual Circuit Identifier

TP, VPs, and VCs



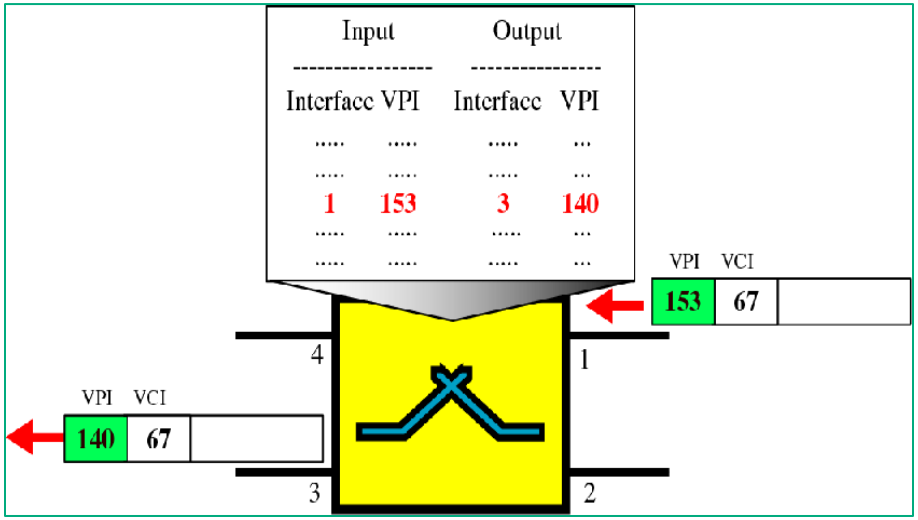
TP: Transmission Path
VP: Virtual Path
VC: Virtual Circuit

Examples of VPs and VCs

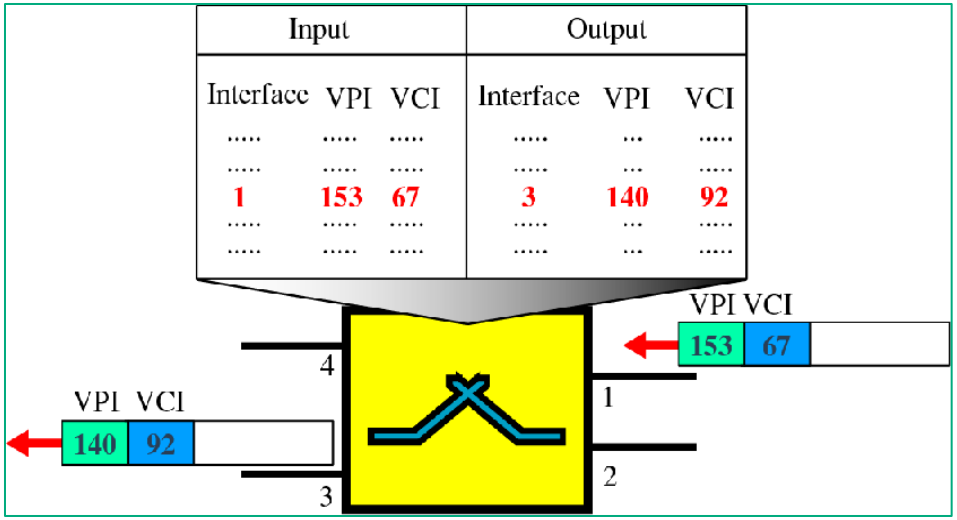


ATM Switching

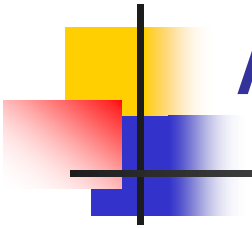
Forwarding Table



VP switch (use only VPI)
* Most switches



VPC switch (use both VPIs and VCIs)
* Boundaries switches

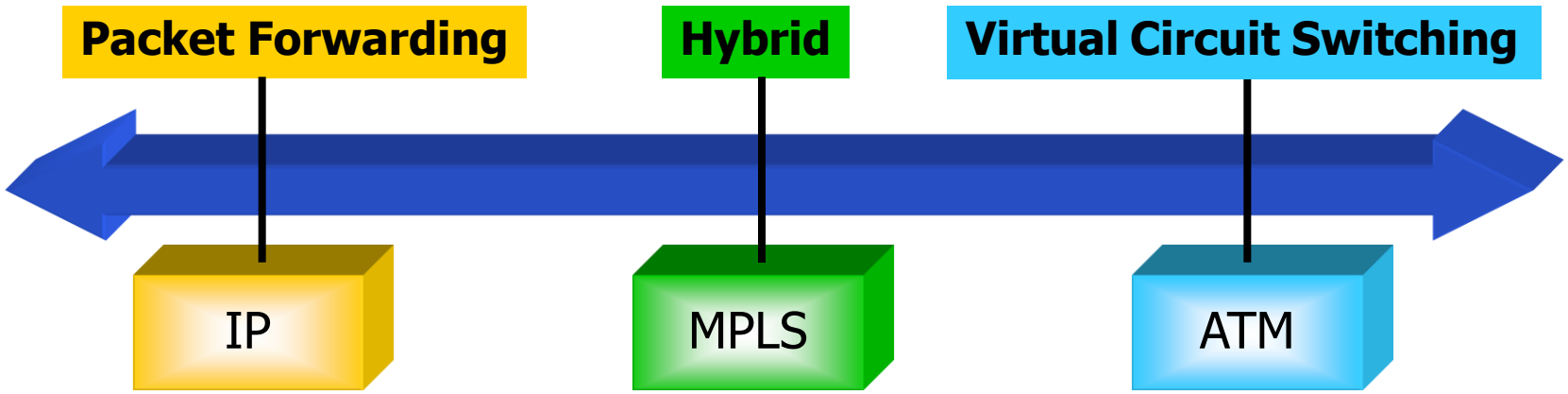


ATM

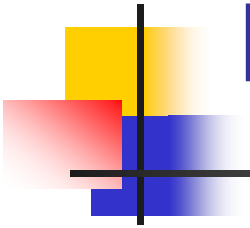
- Connection oriented (Supports QoS)
- Fast packet switching
  - fixed length packets (cells)
- Integration of different traffic types
  - voice, data, video
- Disadvantages
  - Complex
  - Expensive
  - Not widely adopted

MPLS Positioning

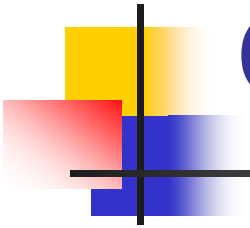
- Combine the forwarding algorithm used in ATM with IP



MPLS Overview



- Switch data according to its **Label (tag)**
  - look up in table
  - determine next hop
  - substitute new label
- Do not pay attention to
  - network and transport protocols
  - → **Multiprotocol**
- Switching for IP and non-IP
- Signaling protocol based on IP

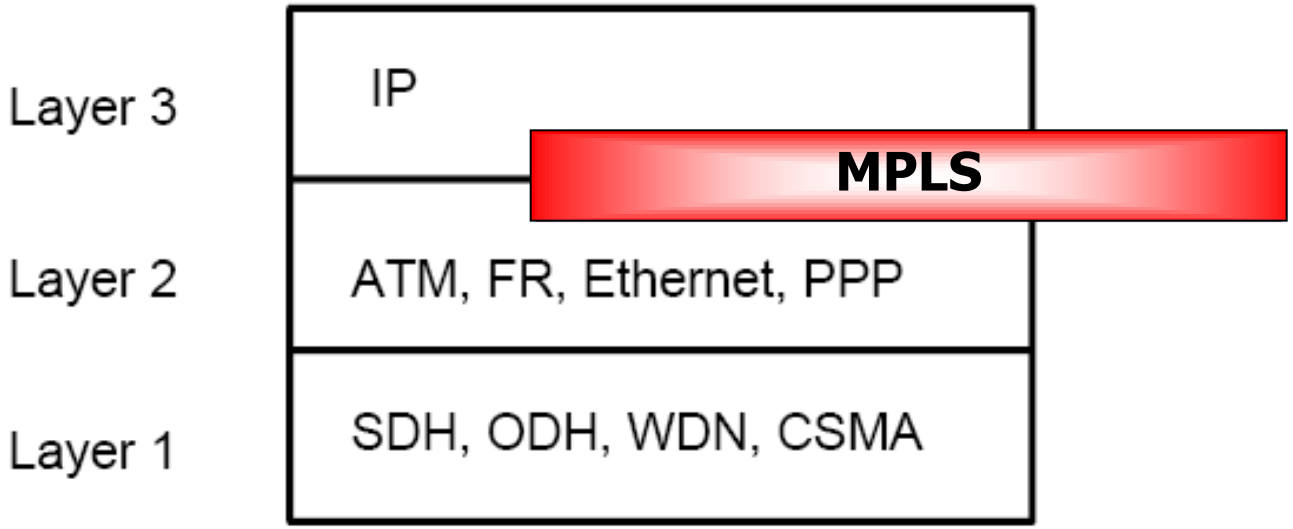


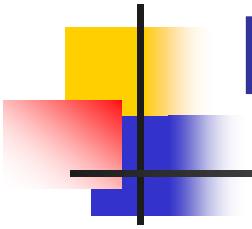
Outline

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

MPLS in the protocol stack

- Between Layer 2 and Layer 3



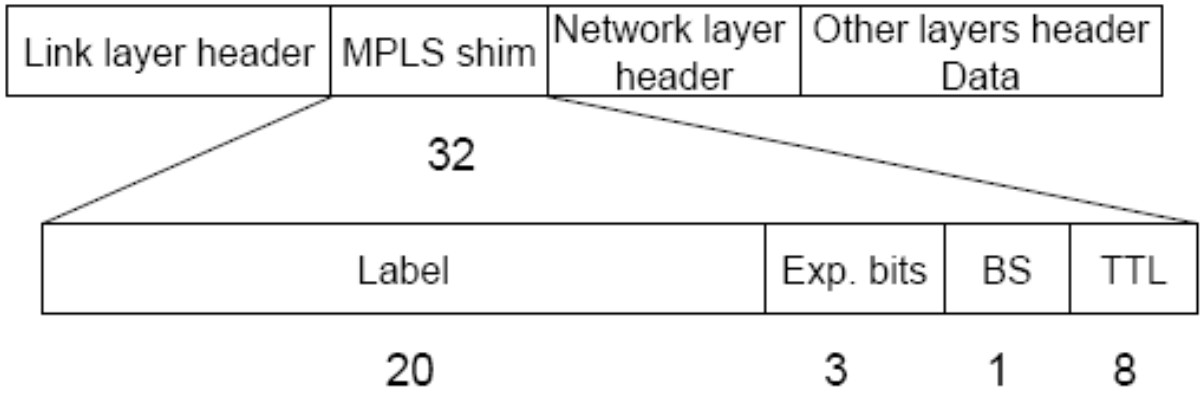


MPLS Characteristics

- Flow Management
- Independent of L2 and L3 protocols
- Maps IP-addresses to fixed length labels
- Interfaces to existing routing protocols (RSVP, OSPF)
- Supports ATM, Frame-Relay and Ethernet

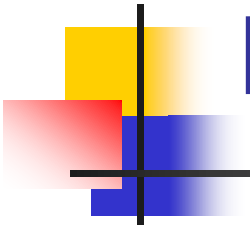
Label

- 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

Shim: A thin, often tapered piece of material, such as wood, stone, or metal, used to fill gaps, make something level, or adjust something to fit properly.
…http://www.thefreedictionary.com/



Label Distribution

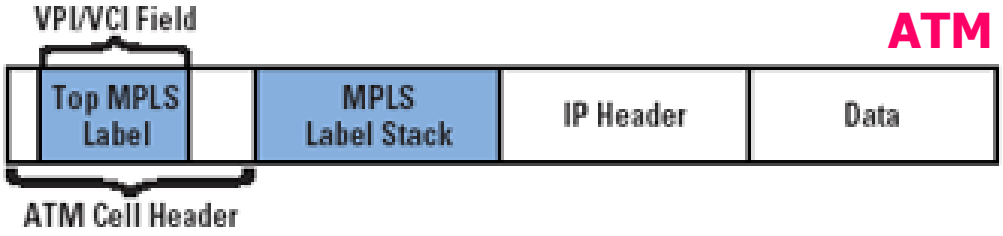
- Not specify a single method for label distribution
- Routing support for label exchange
  - BGP and RSVP can piggyback the label information
- IETF defines signal and management
  - label distribution protocol (LDP)
- Extension of LDP protocol
  - support explicit routing based on QoS

Label Insertion

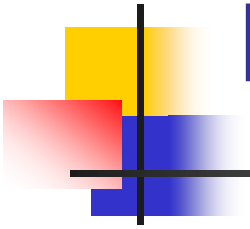
Data Link Frame

IEEE 802 MAC Frame

ATM Cell



Frame Relay Frame



MPLS Terminology

LDP: Label Distribution Protocol

LSP: Label Switched Path

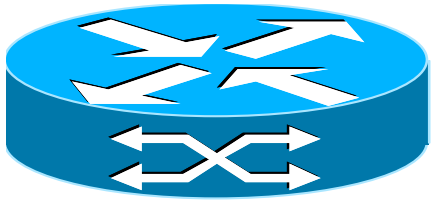
FEC: Forwarding Equivalence Class

LSR: Label Switching Router

LER: Label Edge Router

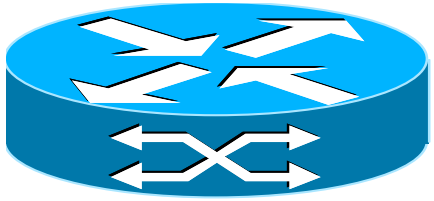
Label Edge Router (LER)

- Edge of an MPLS network
- Assigns and removes packet labels
- Support multiple ports
  - frame relay
  - ATM
  - Ethernet
  - etc.

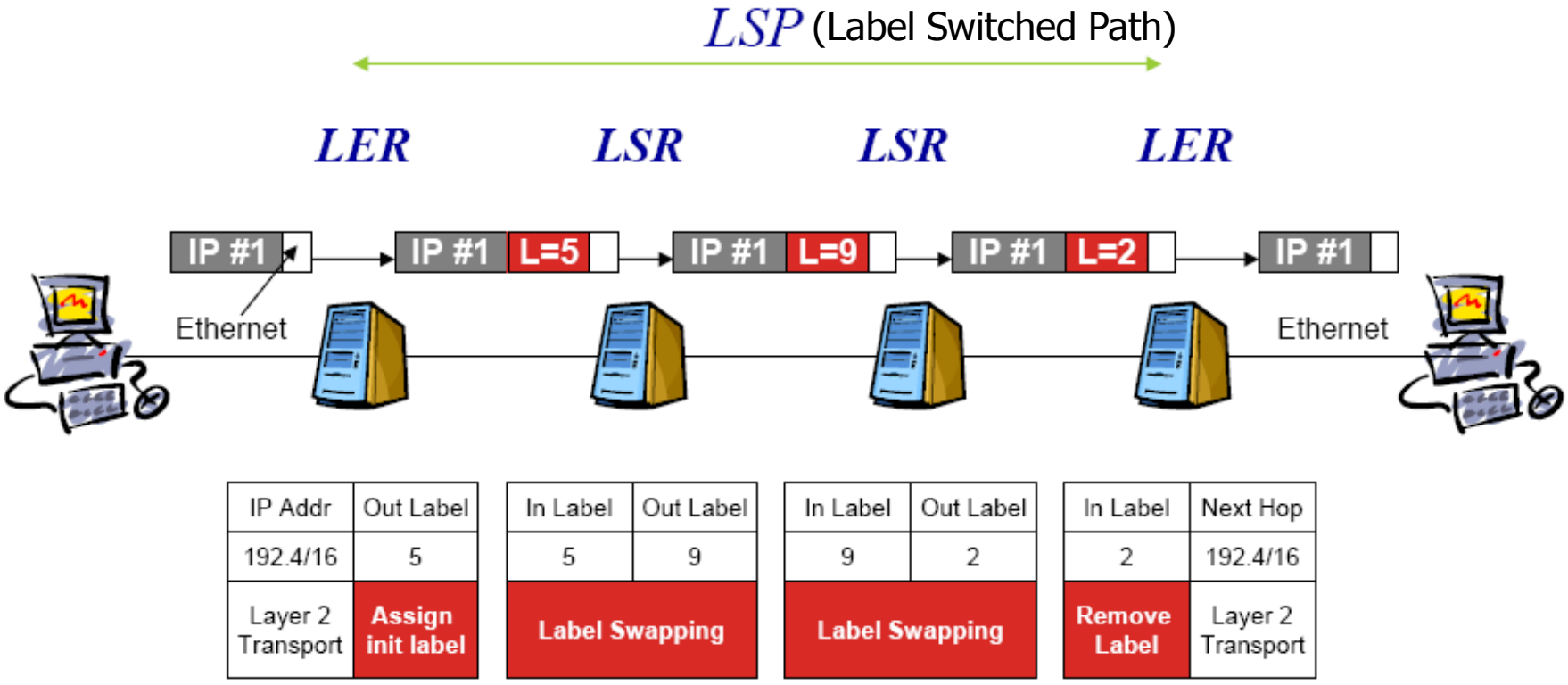


Label Switching Router (LSR)

- High speed router in the core on an MPLS network
- ATM switches can be used as LSR
  - no hardware modification
  - label switching is equivalent to VP and VC switching

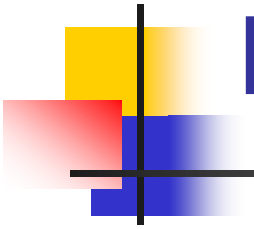


LER and LSR Position



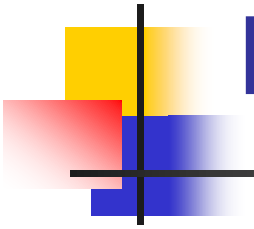
"ROUTE AT EDGE, SWITCH IN CORE"

Forward Equivalence Class (FEC)

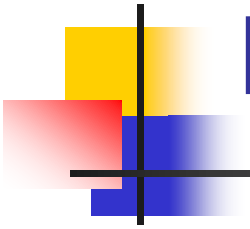


- Represent group of packets
  - share same requirements for their transport
- Packet Assignment
  - assignment to each packet
  - only one time at entry point

Label-Switched Path (LSP)



- A path is established before the data transmission starts
- A path is a representation of a Forward Equivalence Class (FEC)

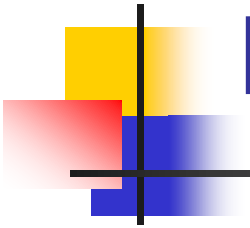


LSP Setup

- Hop-by-hop routing
  - each LSR independently selects next hop for a given FEC
- Explicit routing
  - similar to *source routing* (sender specify the route of the packet)
  - ingress LSR specifies the list of nodes through which the packet traverses
- LSP setup for an FEC is unidirectional
  - return traffic must use another LSP

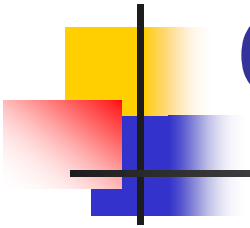
Label Distribution Protocol (LDP)

- Application layer protocol
  - for label binding distribution info to LSRs
  - map FECs to labels (create LSP)
  - LDP sessions are established between LDP peers in the MPLS network (not necessarily adjacent).
  - Sometimes employs OSPF or BGP



LDP message types

- Discovery messages
  - announce/maintain the presence of an LSR
- Session messages
  - establish/maintain/terminate sessions between LDP peers
- Advertisement messages
  - create, change, and delete label mappings for FECs
- Notification messages
  - provide advisory info and signal error information



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- **Operation**
- Protocol Stack Architecture
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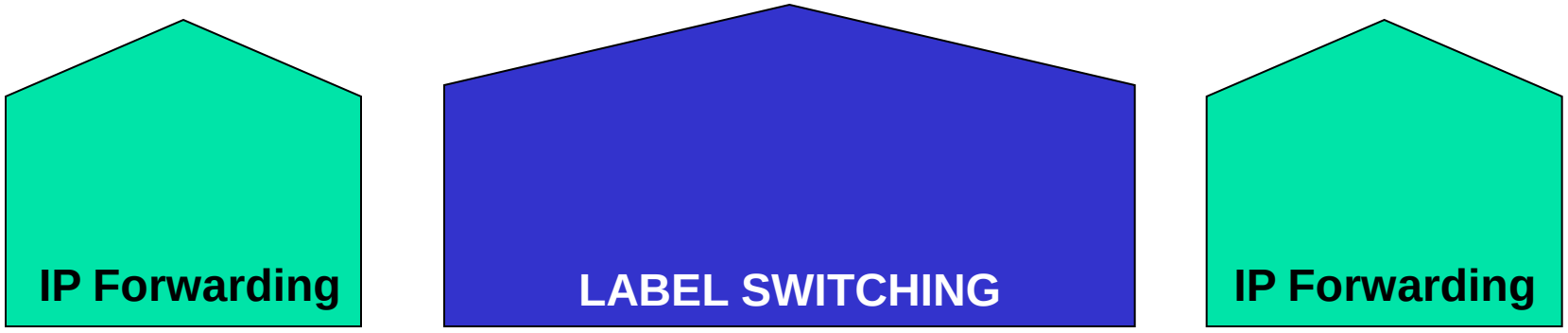
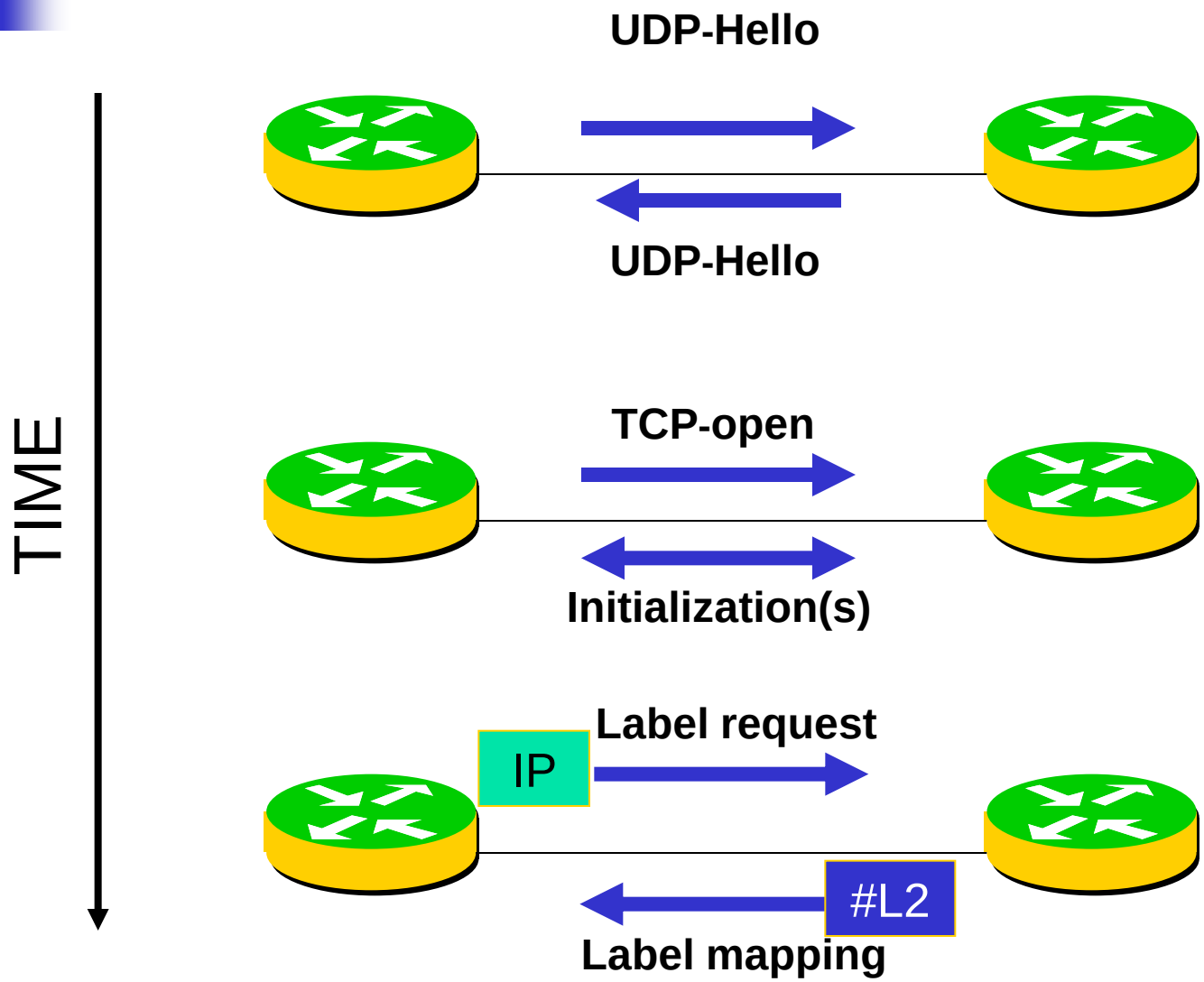
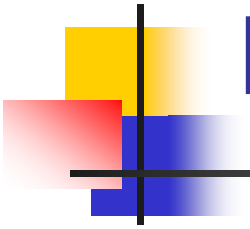
Route at Edge, Switch in Core



MPLS: How does it work?

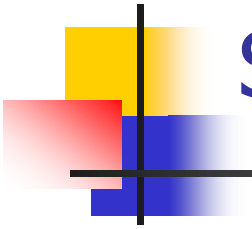




MPLS Operation

- Five Steps
  - label creation and distribution
  - table creation at each router
  - label-switched path creation
  - label insertion/table lookup
  - packet forwarding

Step 1 :Label creation and distribution



- First, routers bind a label to a specific FEC
- Then build their tables
- Using LDP
  - downstream routers initiate the distribution of labels and the label/FEC binding
  - negotiate traffic-related characteristics and MPLS capabilities
- A reliable and ordered transport protocol should be used for the signaling protocol

Step 2: Table creation

- On receipt of label bindings each LSR creates entries in the label information base (LIB)
- Table specifies 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
  - entries are updated whenever renegotiation of label bindings occurs

Example of LIB Table

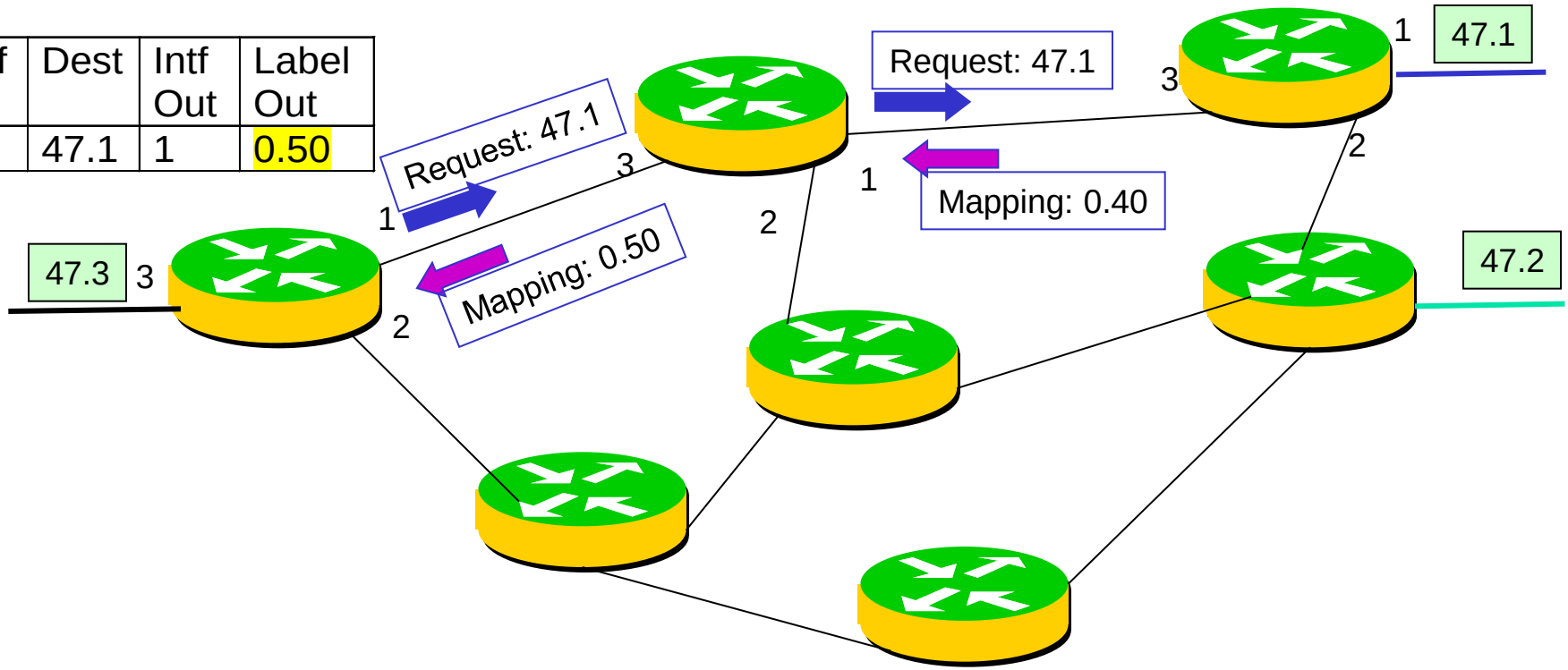
Input Port	Incoming Port Label	Output Port	Outgoing Port Label
1	3	3	6
2	9	1	7

MPLS Label Distribution

Intf In	Label In	Dest	Intf Out	Label Out
3	0.50	47.1	1	0.40

Intf In	Label In	Dest	Intf Out
3	0.40	47.1	1

Intf In	Dest	Intf Out	Label Out
3	47.1	1	0.50

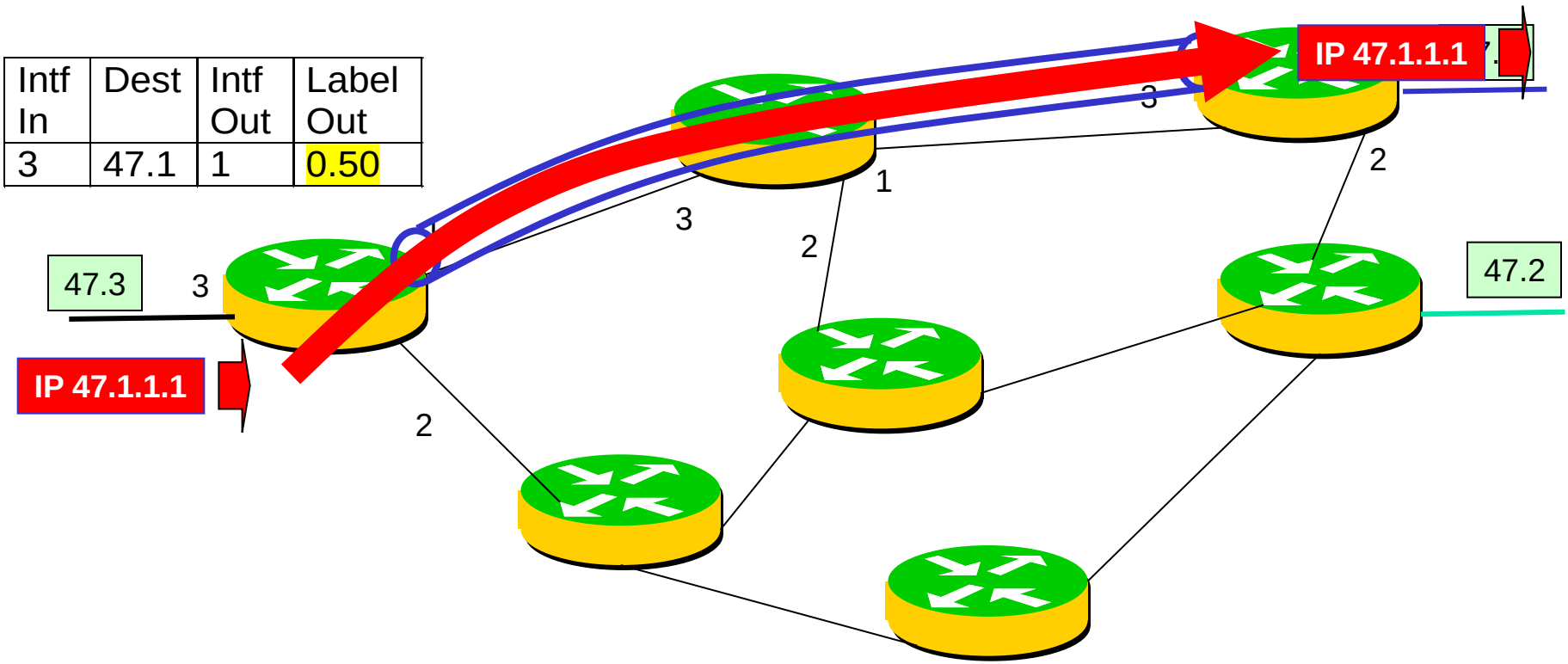


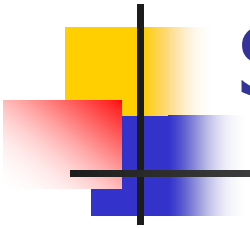
Label Switched Path (LSP)

Intf In	Label In	Dest	Intf Out	Label Out
3	0.50	47.1	1	0.40

Intf In	Label In	Dest	Intf Out
3	0.40	47.1	1

Intf In	Dest	Intf Out	Label Out
3	47.1	1	0.50

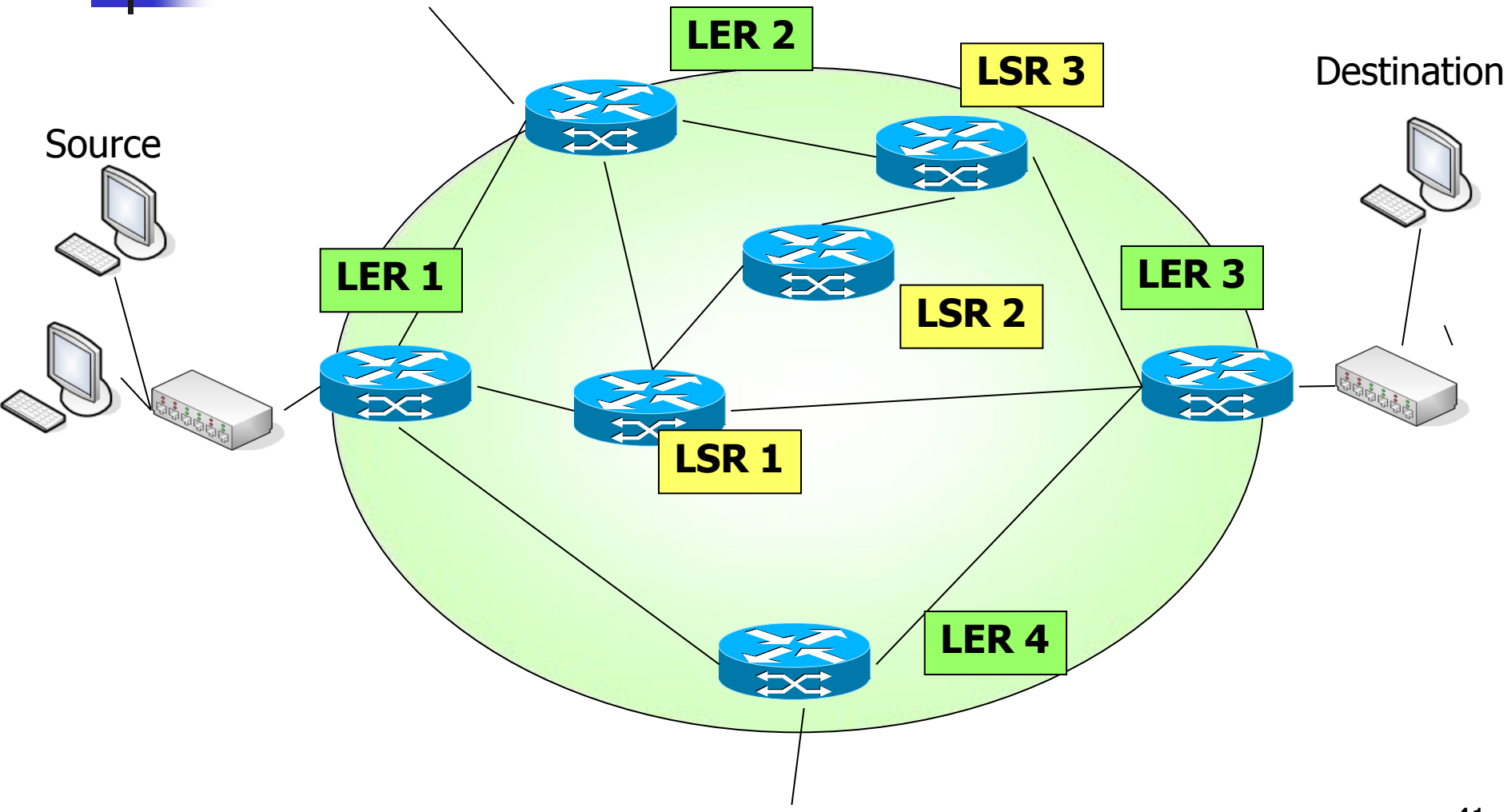




Step 3: Label switched path creation

- LSPs are created in the reverse direction to the creation of entries in the LIBs.

MPLS Example



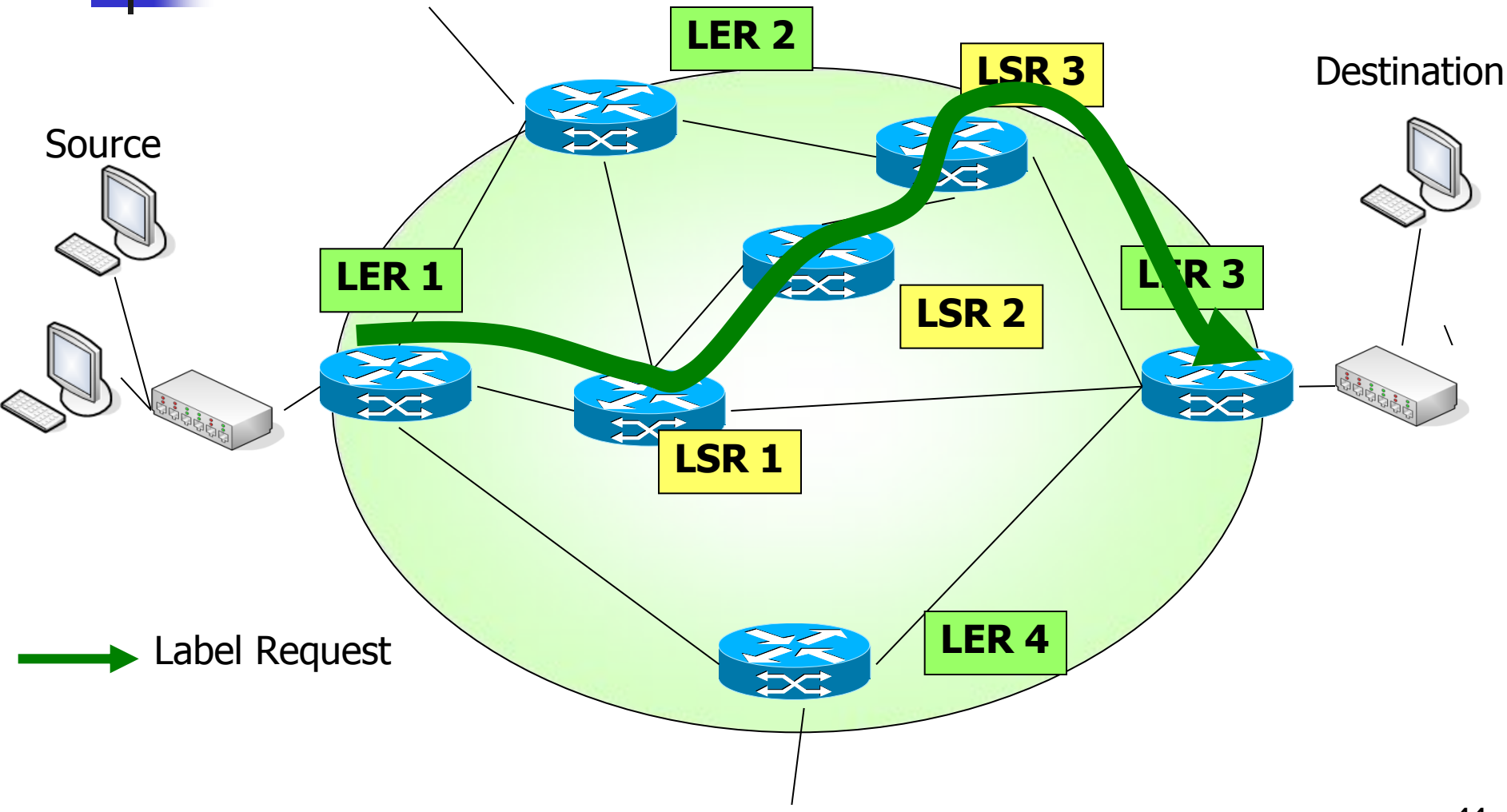
Step 4: Label insertion/table-lookup

- First router (LER1) uses 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 (LER3), the label is removed and the packet is supplied to the destination

Step 5: Packet forwarding

- For first time packet
  - LER1 may not have any labels
  - (In IP) find the longest add match for 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 (green lines)

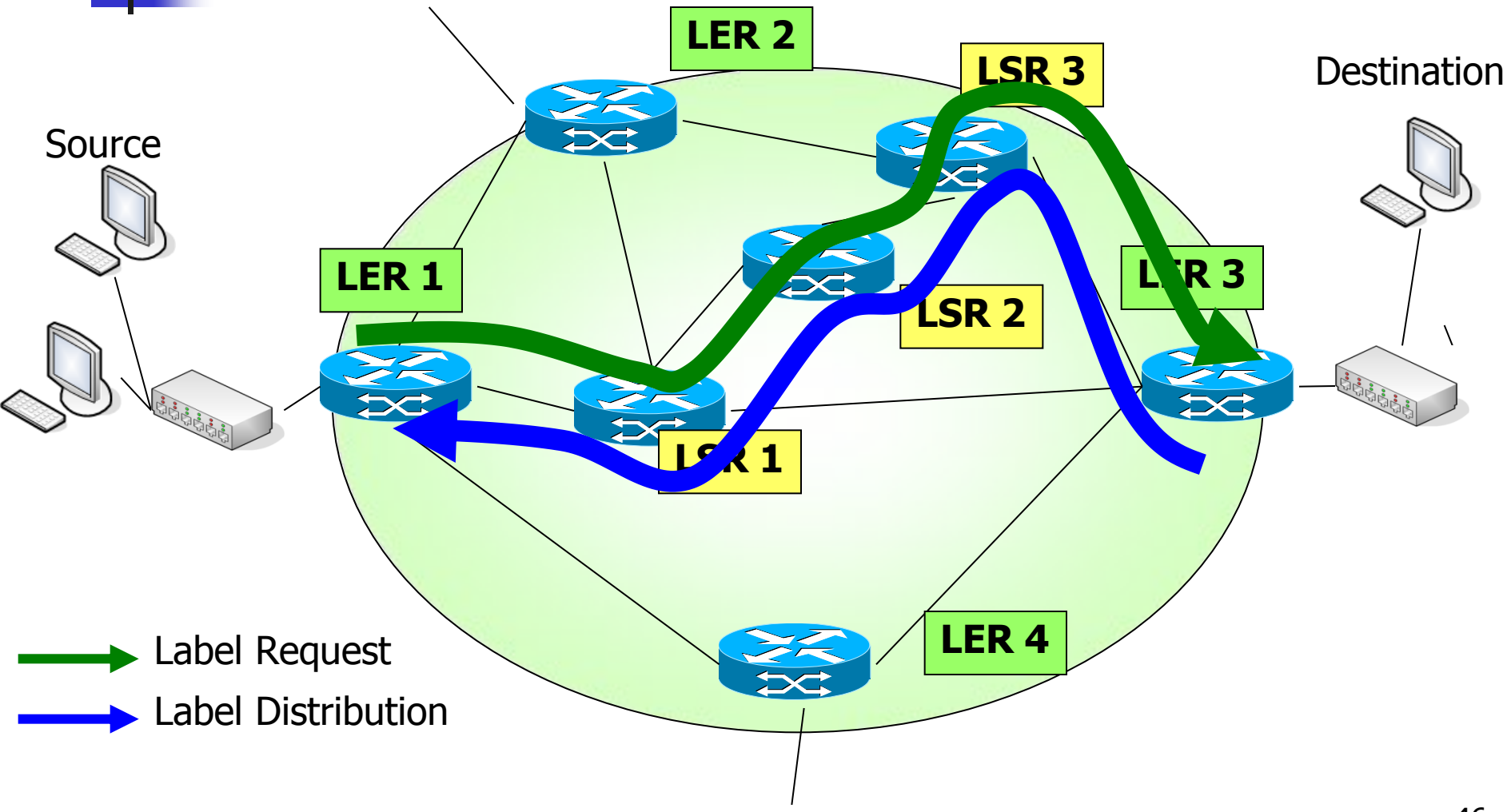
MPLS Operation Example

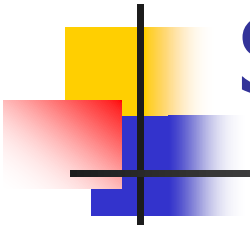


Step 5 (cont.)

- Label downstream (LER3 →LSR→ … → LER1)
- The LSP setup (blue lines) uses LDP or any other signaling protocol.
- LER1 will insert the label and forward the packet to LSR1

MPLS Operation Example

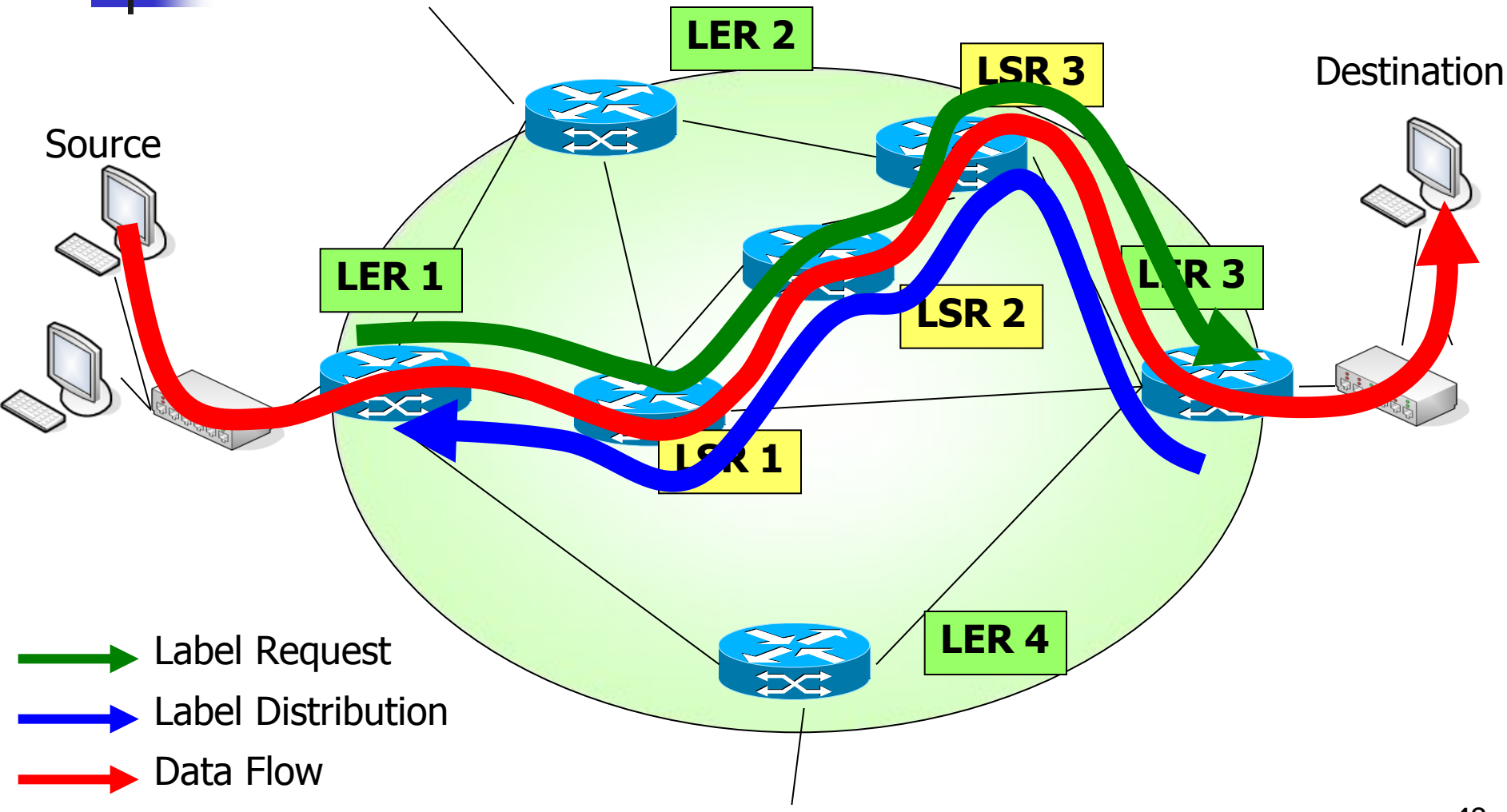




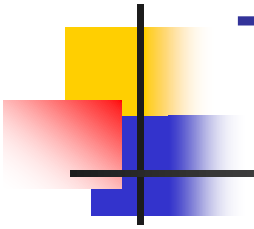
Step 5 (cont.)

- Each subsequent LSR (LSR2,LSR3)
  - examine label in received packet
  - replace it with outgoing label
  - forward it
- When reaches LER4, label is removed
  - leave MPLS domain and deliver to the destination
- Actual data path followed by the packet is the red line

MPLS Operation Example

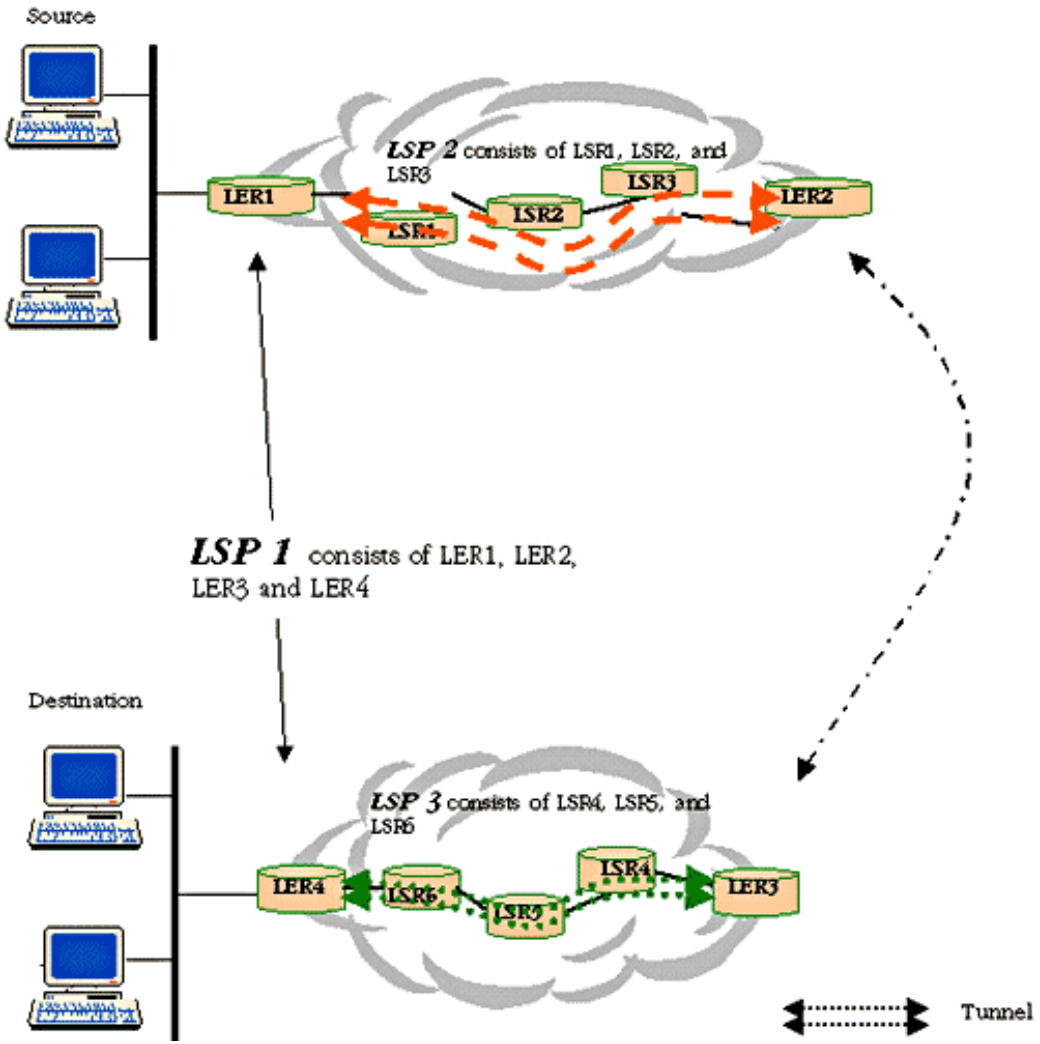


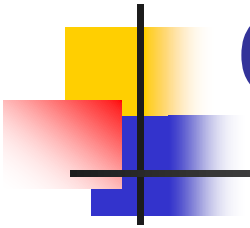
Tunneling in MPLS



- 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.

Tunneling in MPLS

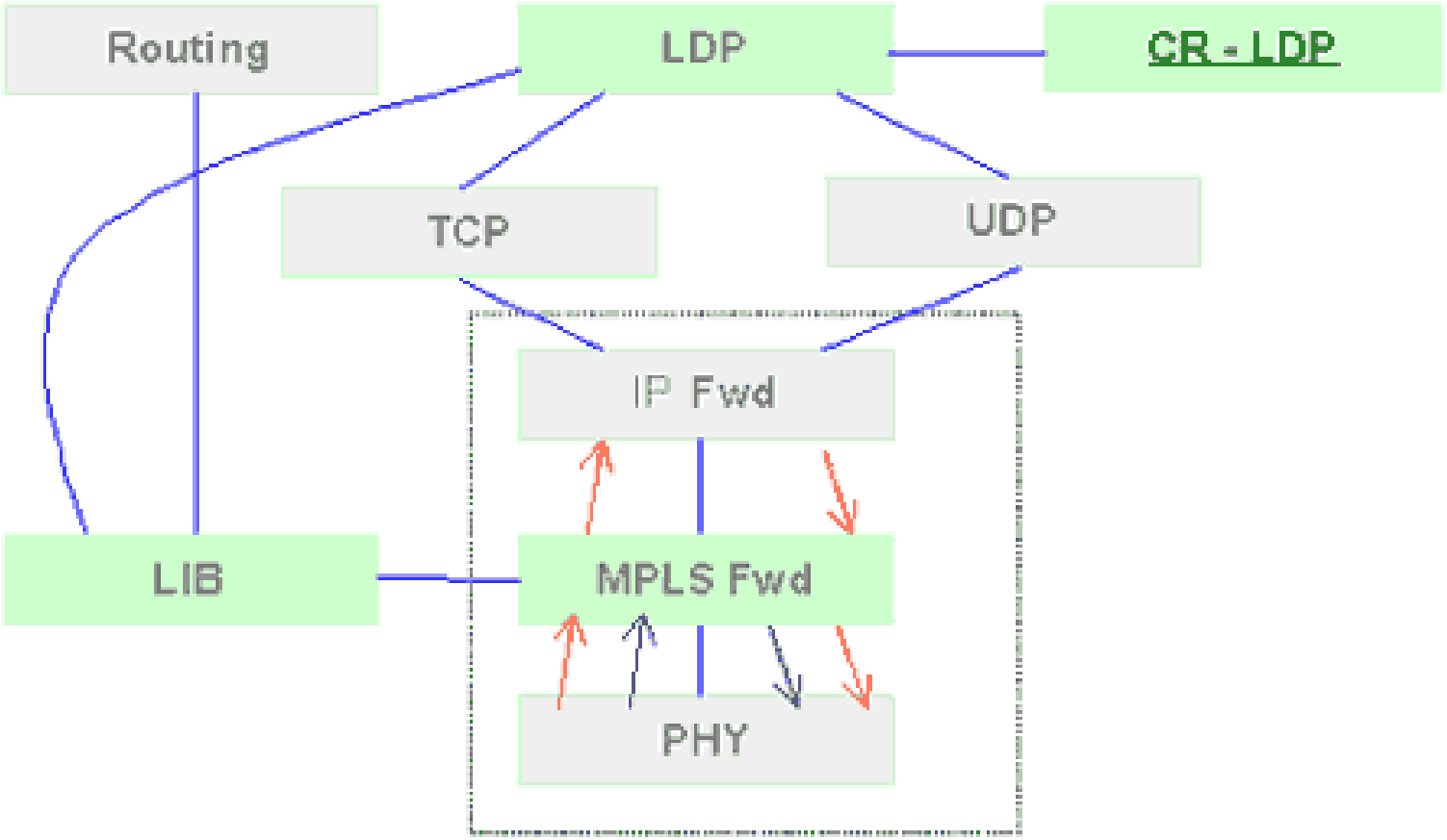


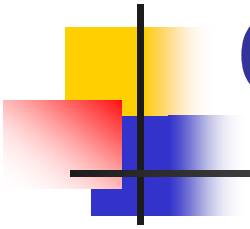


Outline

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

MPLS Protocol Stack Architecture





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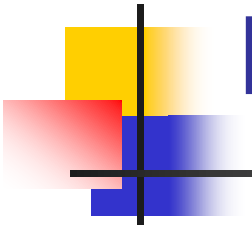
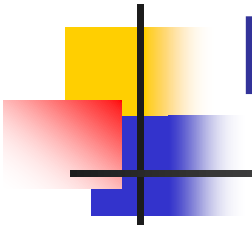


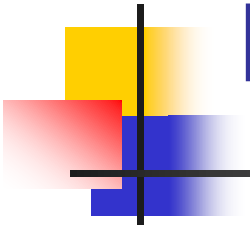
MPLS Advantages

- 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



MPLS Disadvantages

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



References

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- "MPLS Tutorial and Operational Experiences", Peter Ashwood-Smith, Bilel Jamoussi, October, 1999