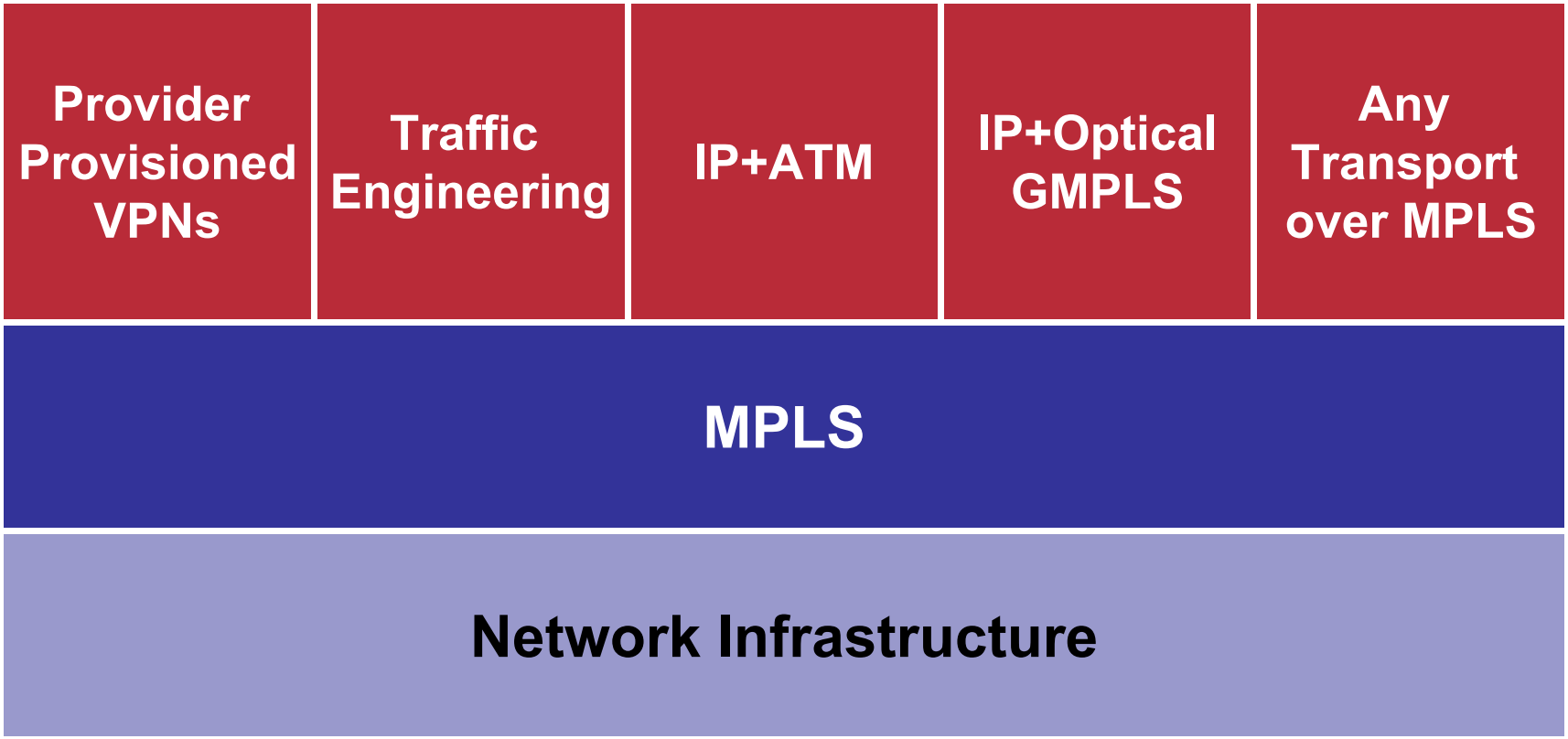
What Is MPLS?

- **Multi Protocol Label Switching**
- **MPLS is an efficient encapsulation mechanism**
- **Uses "labels" appended to packets (IP packets, AAL5 frames) for transport of data**
- **MPLS packets can run on other Layer 2 technologies such as ATM, FR, PPP, POS, Ethernet**
- **Other Layer 2 technologies can be run over an MPLS network**
- **Labels can be used as designators**

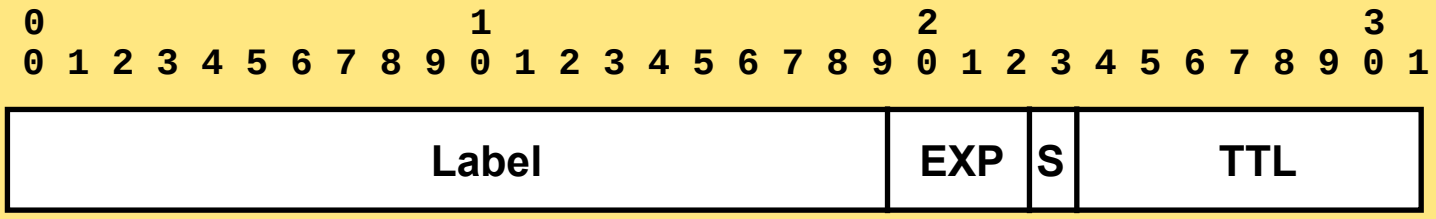
  For example—IP prefixes, ATM VC, or a bandwidth guaranteed path
- **MPLS is a technology for delivery of IP services**

MPLS as a Foundation for Value-Added Services



TECHNOLOGY BASICS

Label Header for Packet Media



Label = 20 Bits
COS/EXP = Class of Service, 3 Bits
S = Bottom of Stack, 1 Bit
TTL = Time to Live, 8 Bits

- Can be used over Ethernet, 802.3, or PPP links
- Uses two new Ethertypes/PPP PIDs
- Contains everything needed at forwarding time
- One word per label

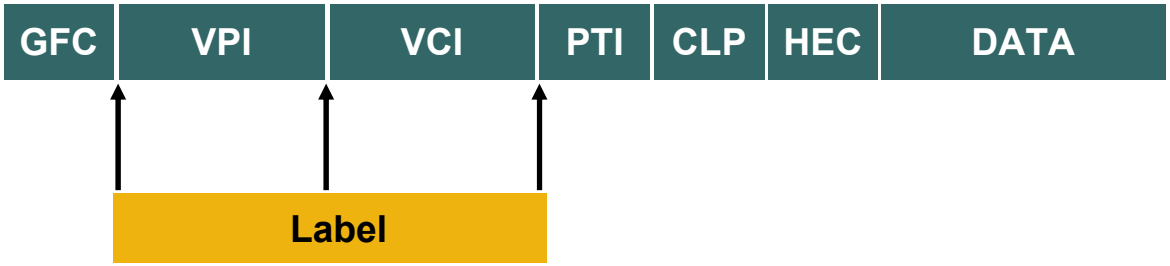
Encapsulations

PPP Header
(Packet over SONET/SDH)

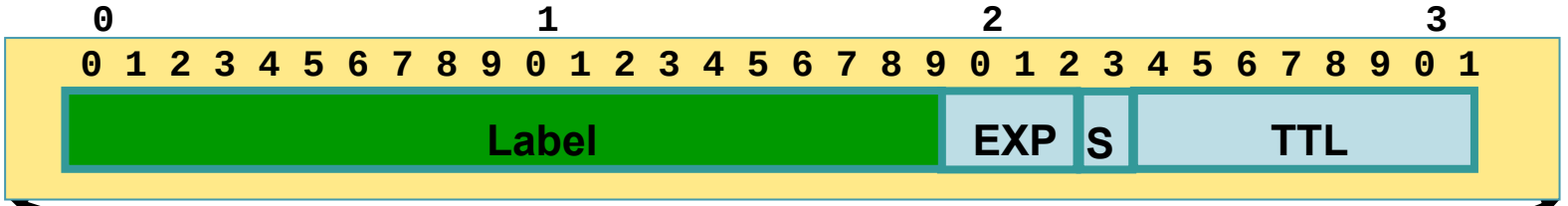
One or More Labels Appended to the Packet

LAN MAC Label Header

ATM MPLS Cell Header



Label Format and Encapsulations



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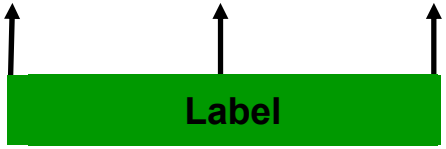


Forwarding Equivalence Class

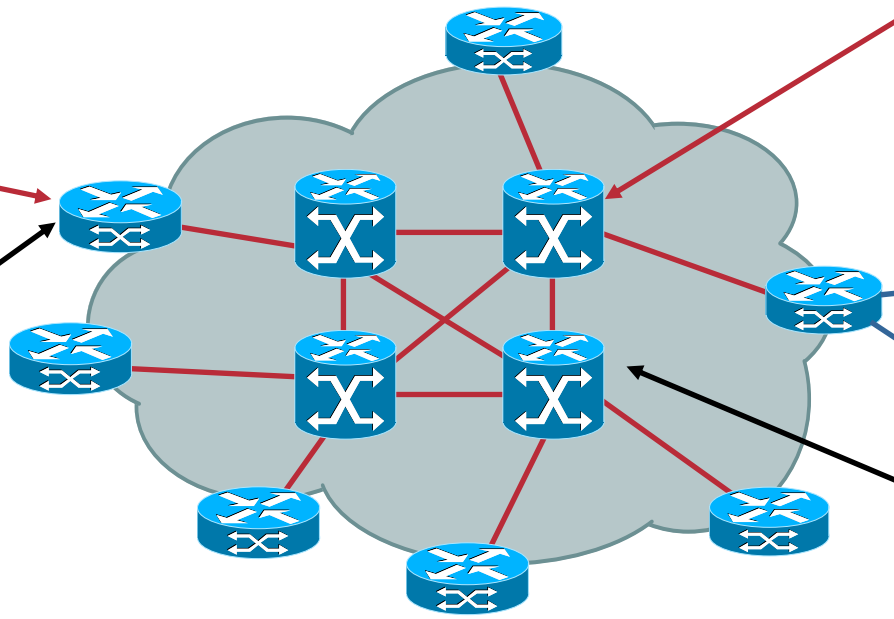
Determines How Packets Are Mapped to LSP

- IP prefix/host address
- Layer 2 circuits (ATM, FR, PPP, HDLC, Ethernet)
- Groups of addresses/sites—VPN x
- A bridge/switch instance—VSI
- Tunnel interface—traffic engineering

MPLS Concepts

At Edge:
- Classify packets
- Label them
- Label imposition

Edge Label Switch Router (ATM Switch or Router)



In Core:
- Forward using labels (as opposed to IP addr)
- Label indicates service class and destination
- Label swapping or switching

At Edge:
- Remove labels and forward packets
- Label disposition

Label Switch Router (LSR)
- Router
- ATM switch + label switch controller

Label Distribution Protocol

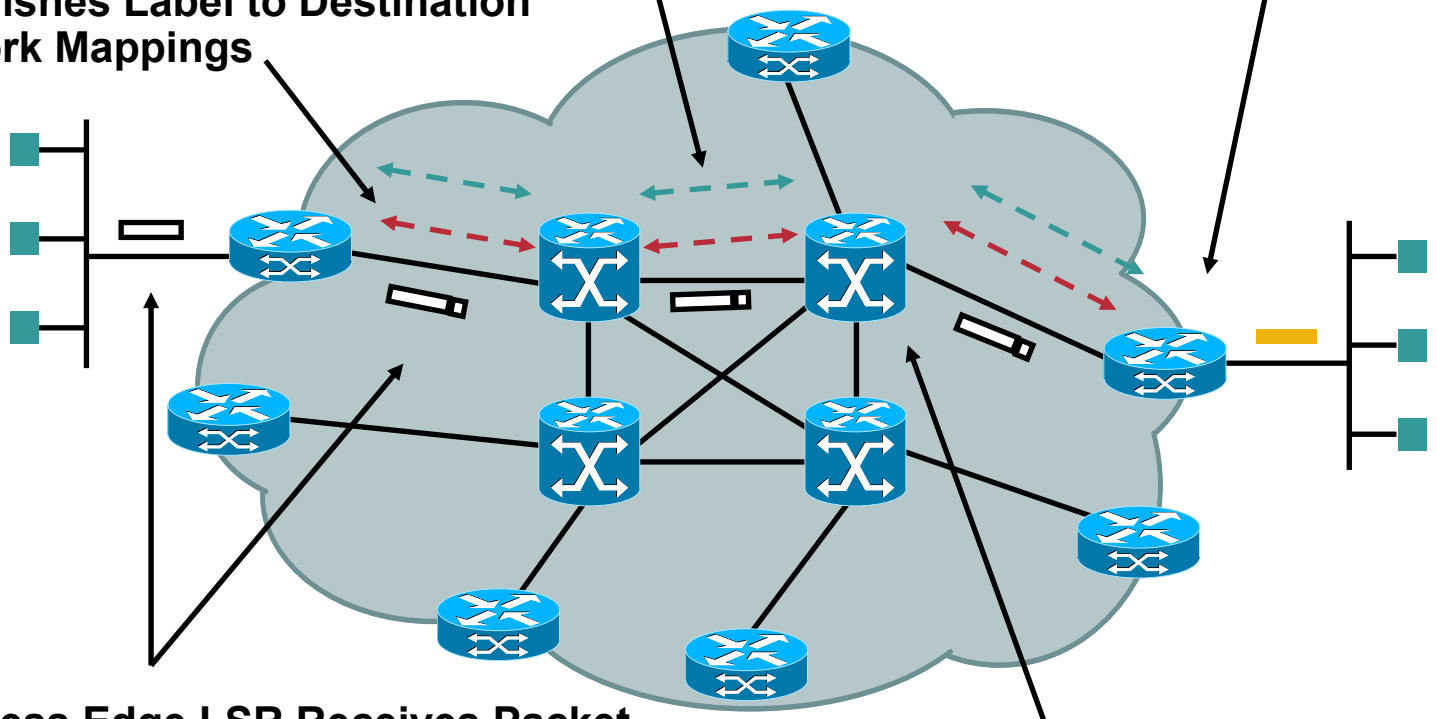
- Create new services via flexible classification
- Provide the ability to setup bandwidth guaranteed paths
- Enable ATM switches to act as routers

MPLS Operation

1a. Existing Routing Protocols (e.g. OSPF, IS-IS) Establish Reachability to Destination Networks

1b. Label Distribution Protocol (LDP) Establishes Label to Destination Network Mappings

4. Edge LSR at Egress Removes Label and Delivers Packet



2. Ingress Edge LSR Receives Packet, Performs Layer 3 Value-Added Services, and "Labels" Packets

3. LSR Switches Packets Using Label Swapping

LABEL DISTRIBUTION IN MPLS NETWORKS

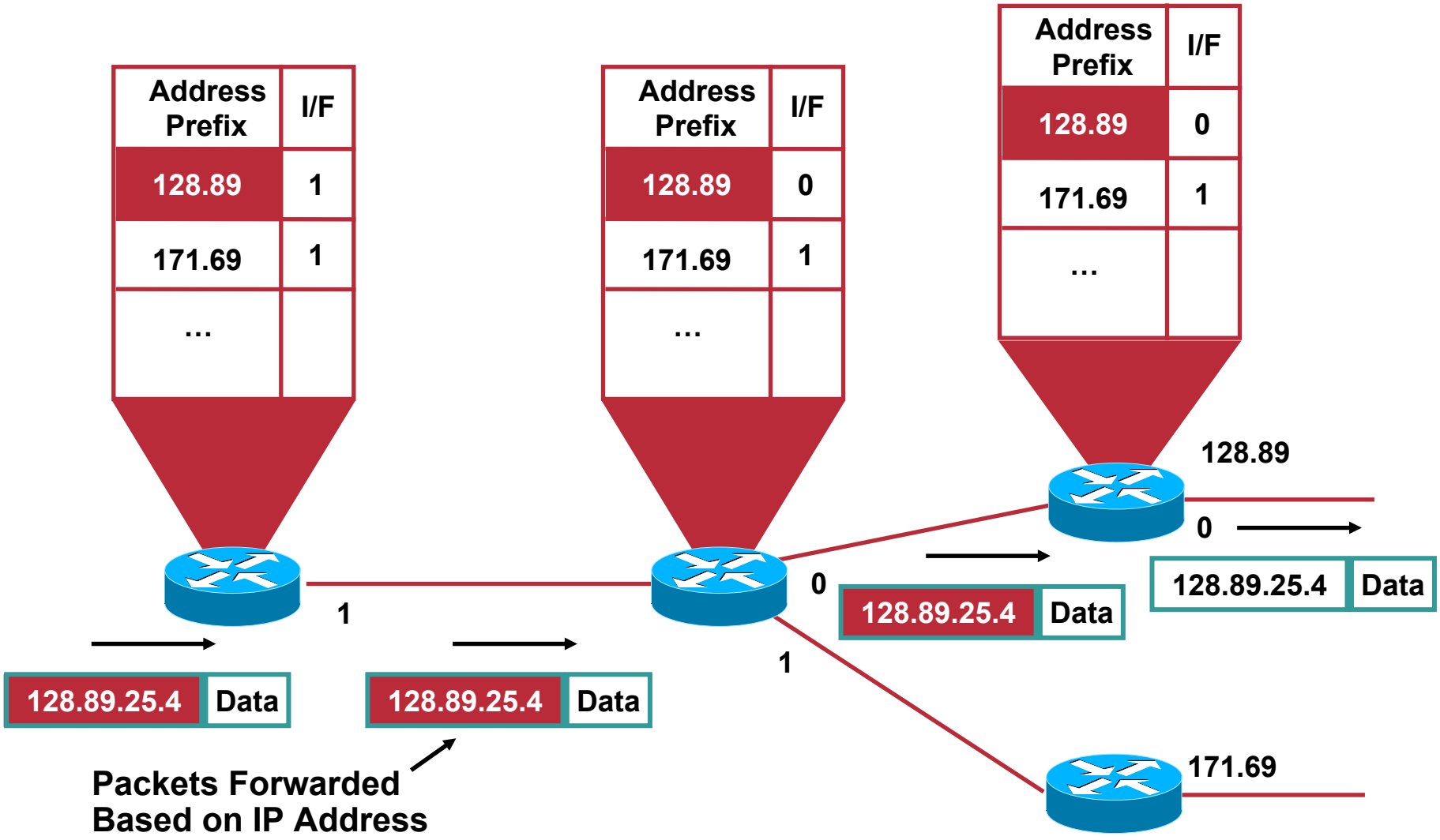
Unicast Routing Protocols

- OSPF, IS-IS, BGP are needed in the network
- They provide reachability
- Label distribution protocols distribute labels for prefixes advertised by unicast routing protocols using
  - Either a dedicated Label Distribution Protocol (LDP)
  - Extending existing protocols like BGP to distribute labels

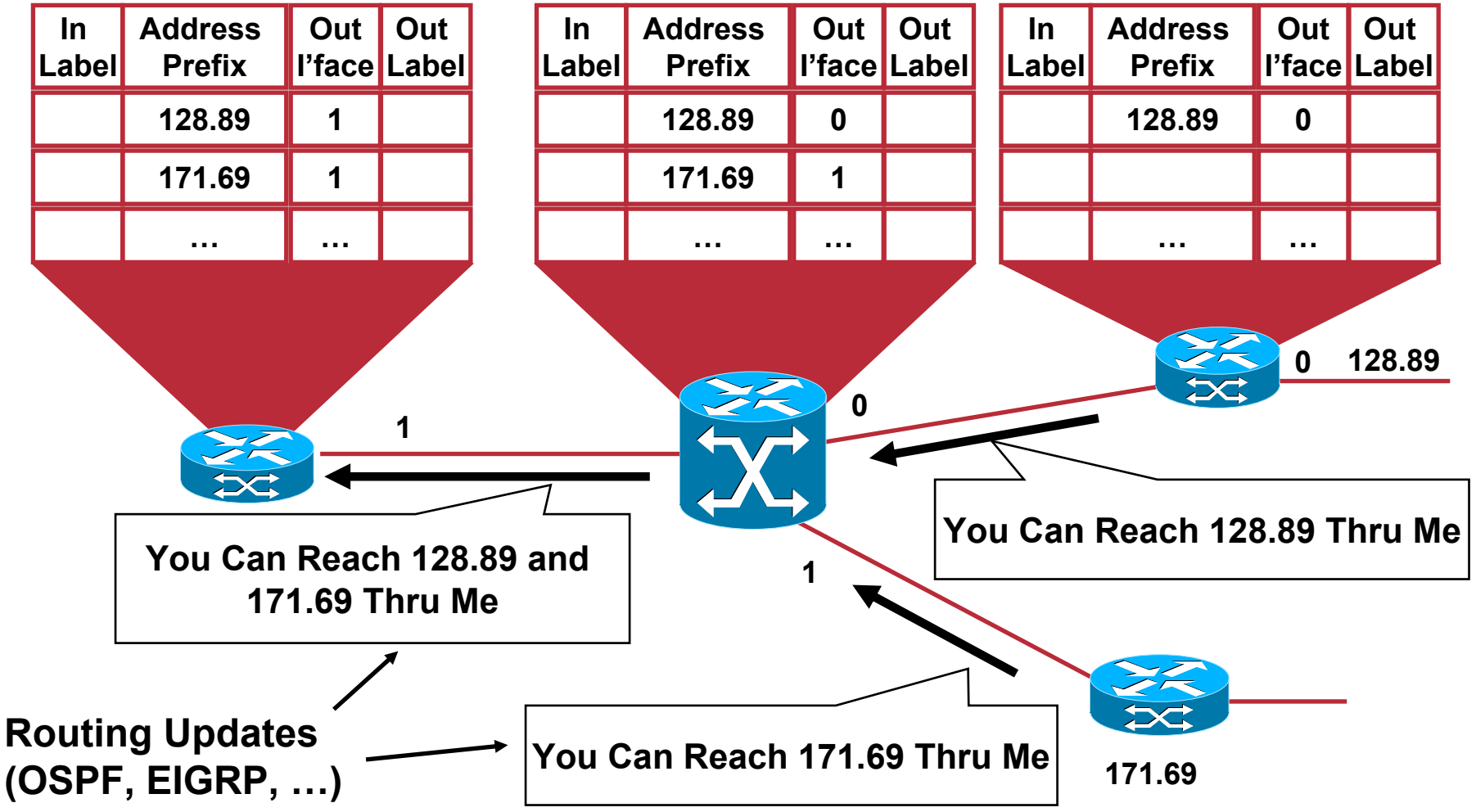
Label Distribution Protocol

- Defined in RFC 3035 and 3036
- Used to distribute labels in a MPLS network
  - Uses a TCP session—multiple sessions require multiple TCP sessions
- Forwarding equivalence class
  - How packets are mapped to LSPs (Label Switched Paths)
- Advertise labels per FEC
  - Reach destination a.b.c.d with label x
- Discovery

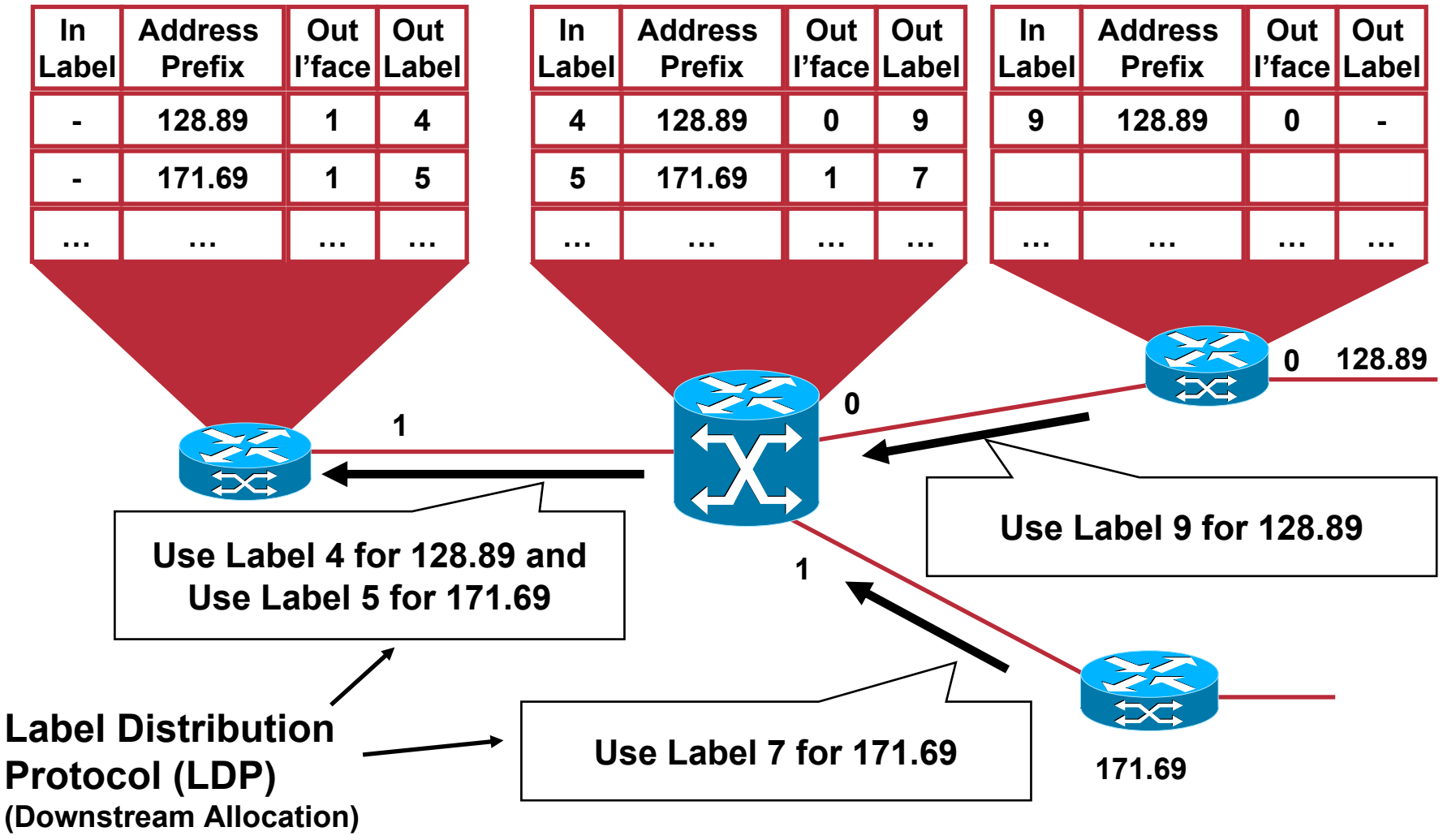
Router Example: Forwarding Packets



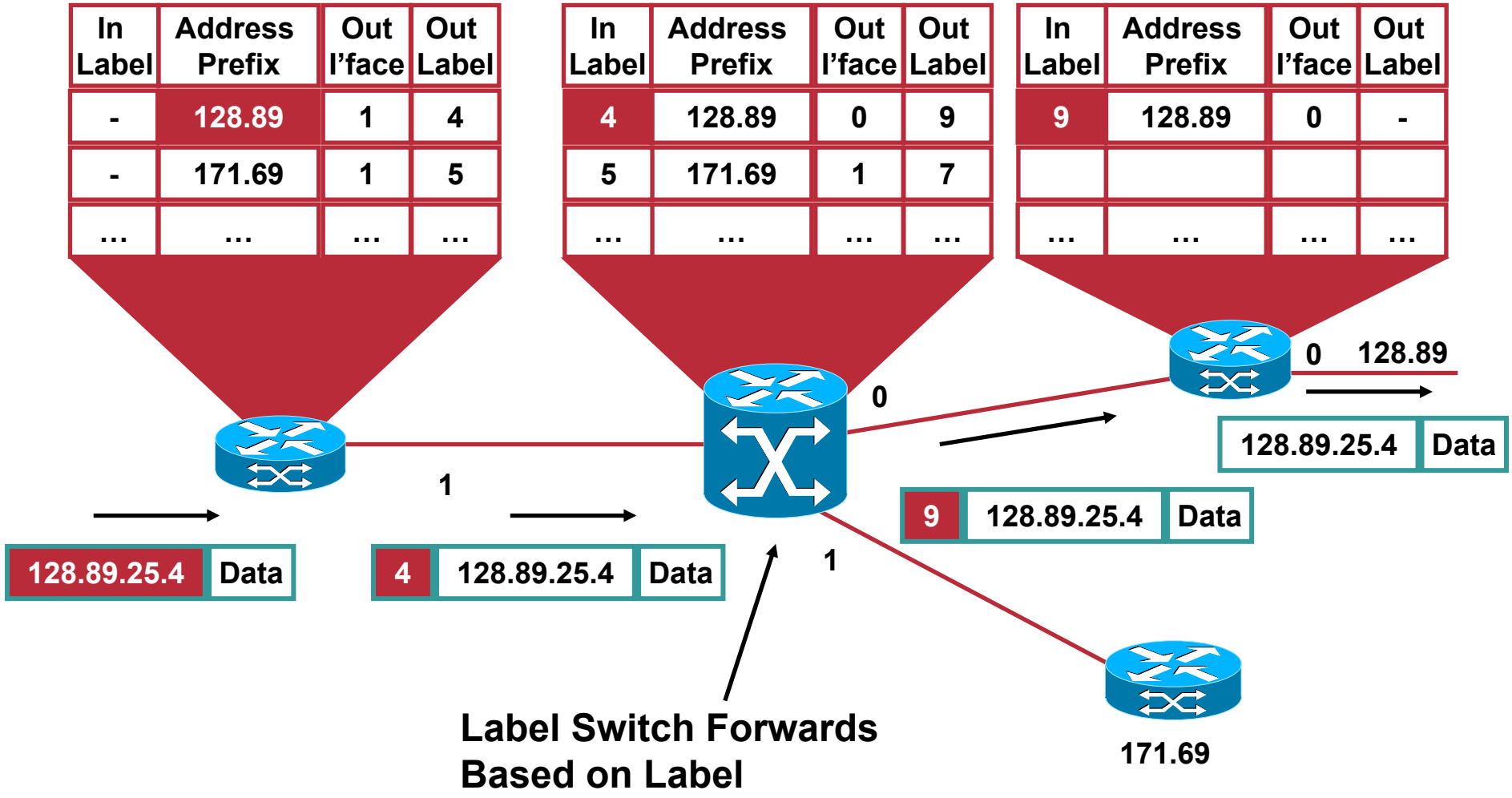
MPLS Example: Routing Information



MPLS Example: Assigning Labels



MPLS Example: Forwarding Packets



Label Distribution Modes

- **Downstream unsolicited**

  Downstream node just advertises labels for prefixes/FEC reachable via that device

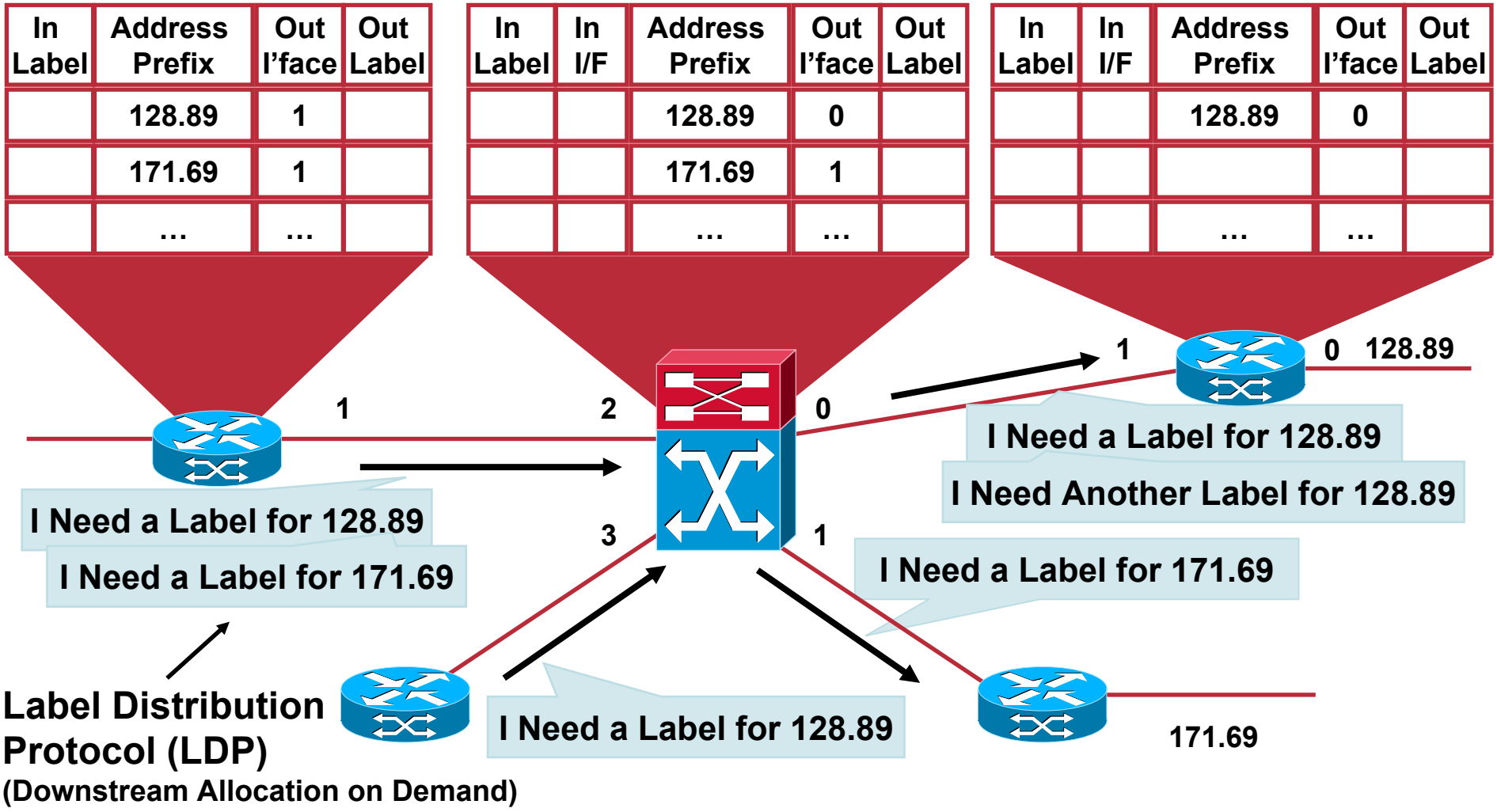
  Previous example

- **Downstream on-demand**

  Upstream node requests a label for a learnt prefix via the downstream node

  Next example—ATM MPLS

ATM MPLS Example: Requesting Labels

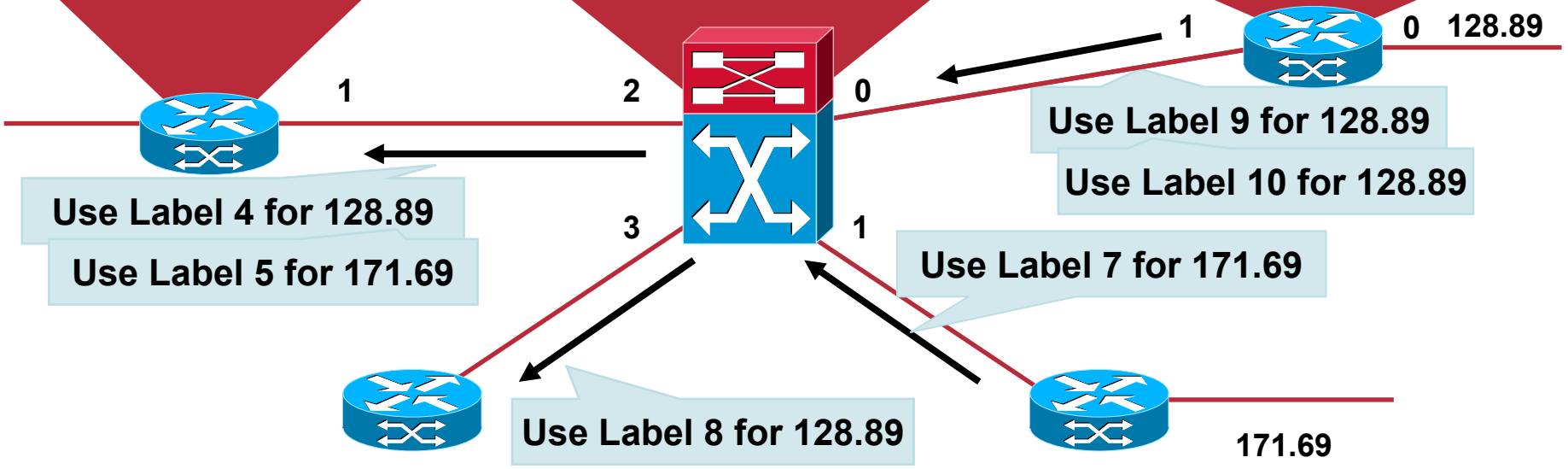


ATM MPLS Example: Assigning Labels

In Label	Address Prefix	Out I'face	Out Label
-	128.89	1	4
-	171.69	1	5
	…	…	

In Label	In I/F	Address Prefix	Out I'face	Out Label
4	2	128.89	0	9
8	3	128.89	0	10
5	2	171.69	1	7

In Label	In I/F	Address Prefix	Out I'face	Out Label
9	1	128.89	0	-
10	1	128.89	0	-
		…	…	



ATM MPLS Example: Packet Forwarding

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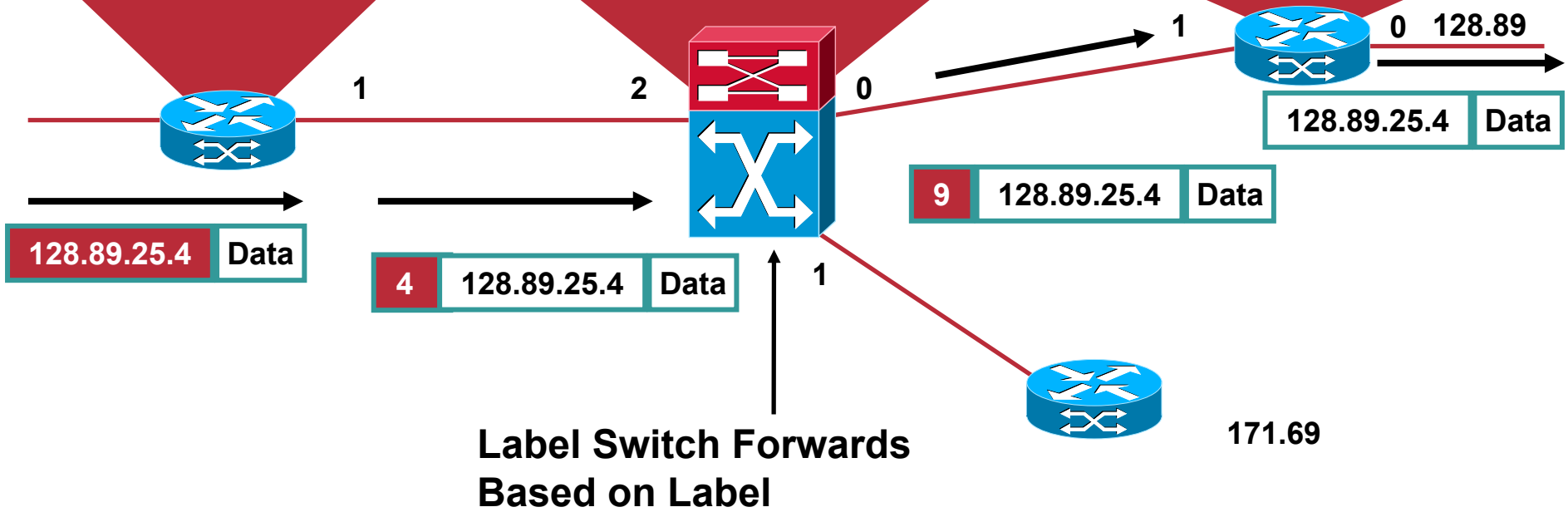
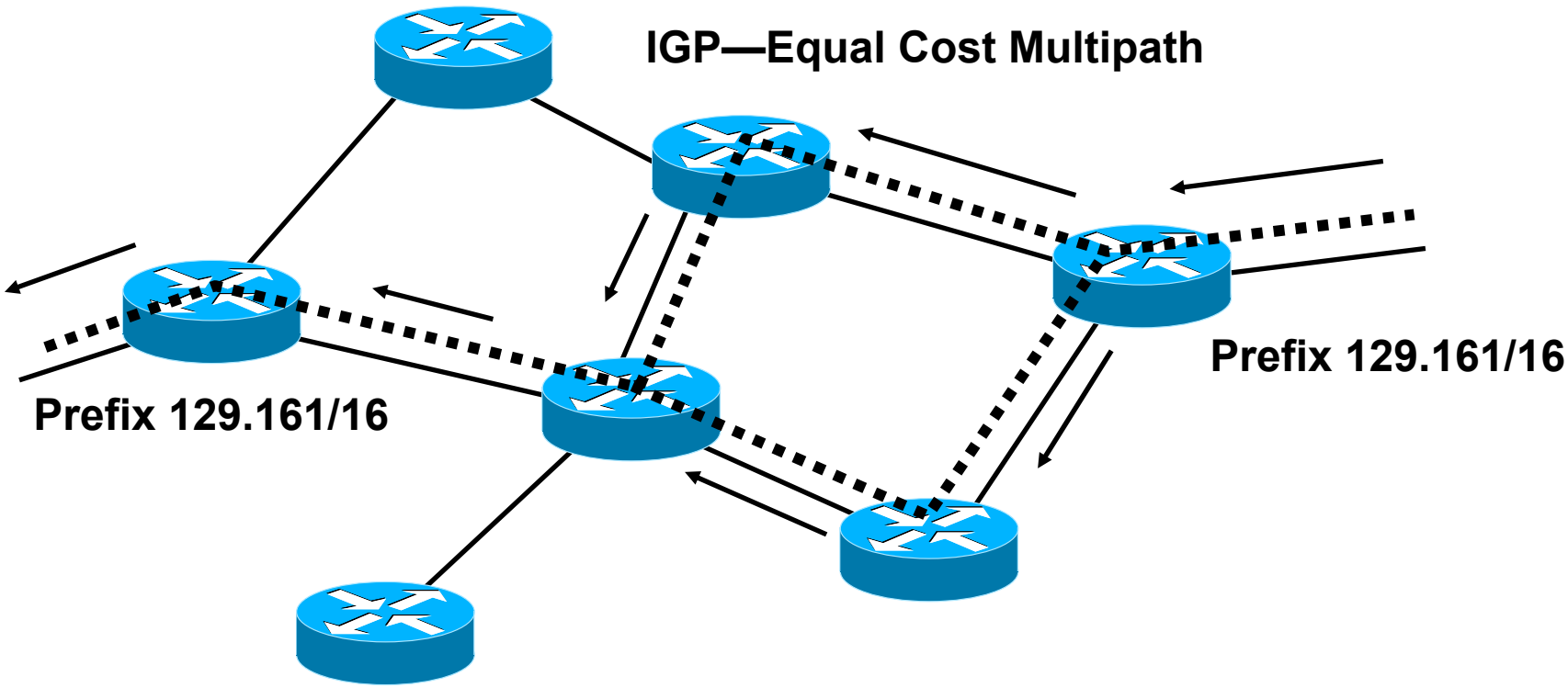


Label Distribution Protocol

Label Merge

- Done by default for packet networks—unique label advertised per FEC
- Requires VC merge for ATM networks

LDP: Label Merge



Labels for Prefix 129.161 Are Advertised Along Both Paths

Label Retention Modes

- In downstream unsolicited mode—label mapping advertisements are received for all routes from all peers
- Liberal label retention

  These mappings are retained regardless of whether the LSR is the next hop for the advertised mapping

  Once labels are allocated to a prefix these labels are retained

  Reaction to routing changes is fast
- Conservative label retention

  Used with DOD mode

  Label mappings are retained only if they are used to forward packets

  Can save some label space—however, reacts slower to changes

Label Allocation Modes

- **Independent mode**
  - **Labels are allocated independently of neighbors' bindings**
  - **As long as the router has routes—it allocates a label irrespective of the neighbor**
- **Ordered mode**
  - **Labels are allocated only after the bindings from neighbors are received**
  - **Takes care of propagation delays in routing changes**

LDP

- **Neighbor discovery**
  - **Discover directly attached neighbors—pt-to-pt links (including Ethernet)**
  - **Establish a session**
  - **Exchange prefix/FEC and label information**
- **Extended neighbor discovery**
  - **Establish peer relationship with another router that is not a neighbor**
  - **Exchange FEC and label information**
  - **May be needed to exchange service labels**

TDP and LDP

- Tag distribution protocol—Cisco proprietary
  - Pre-cursor to LDP
  - Used for Cisco tag switching
- TDP and LDP supported on the same device
  - Per neighbor/link basis
  - Per target basis
- LDP is a superset of TDP
- Uses the same label/TAG
- Has different message formats

Other Label Distribution Protocols: RSVP

- Used in MPLS traffic engineering
- Additions to RSVP signaling protocol
- Leverage the admission control mechanism of RSVP to create an LSP with bandwidth
- Label requests are sent in PATH messages and binding is done with RESV messages
- EXPLICT-ROUTE object defines the path over which setup messages should be routed
- Using RSVP has several advantages