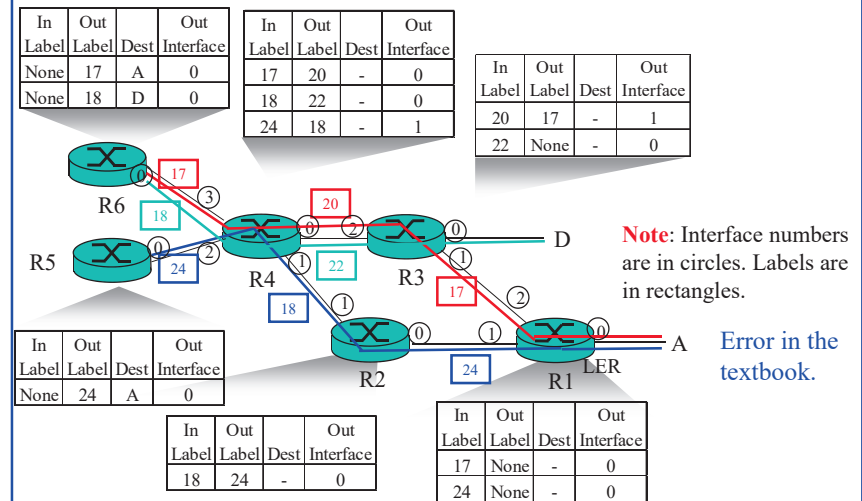# Address Resolution Protocol

- ❑ Problem: Given an IP address find the MAC address
- ❑ Solution: Address Resolution Protocol (ARP)
- ❑ The host broadcasts a request (Dest MAC=FFFFFFFF): "What is the MAC address of 127.123.115.08?"
- ❑ The host whose IP address is 127.123.115.08 replies back: "The MAC address for 127.123.115.08 is 8A:5F:3C:23:45:56$_{16}$"
- ❑ Nodes cache the MAC-IP mapping in a "ARP table" You can list ARP table using "arp –a" command
- ❑ Frame Format: Hardware (HW): 0x0001 = Ethernet,
  - ❑ Protocol (Prot): 0x0800 = IP,
  - ❑ Operation: 1 = Request, 2=Response

HW Type	Prot Type	HW Addr Length	Prot Addr Length	Oper- ation	Sender HW Addr	Sender Prot Addr	Target HW Addr	Target Prot Addr
16b	16b	8b	8b	16b	48b	32b	48b	32b

MPLS Forwarding Tables

In Label	Out Label	Dest	Out Interface
None	17	A	0
None	18	D	0

In Label	Out Label	Dest	Out Interface
17	20	-	0
18	22	-	0
24	18	-	1

In Label	Out Label	Dest	Out Interface
20	17	-	1
22	None	-	0

In Label	Out Label	Dest	Out Interface
None	24	A	0

In Label	Out Label	Dest	Out Interface
18	24	-	0

In Label	Out Label	Dest	Out Interface
17	None	-	0
24	None	-	0

Note: Interface numbers are in circles. Labels are in rectangles.

Error in the textbook.

MPLS Label Switched Paths (LSPs)

- ❑ Label switched paths (LSPs) are set up before use. ⇒ Connection oriented
- ❑ During set up each router tells the previous router what label it should put on the frames of that LSP.
- ❑ The label is actually an index in the MPLS forwarding table.
- ❑ Indexing in MPLS table is much faster than searching in IP tables.
- ❑ Although speed was one reason for using MPLS but the main reason is that the bandwidth can be reserved along the path.
- ❑ Labels are local. The same label number may be used by different routers for different LSPs.
- ❑ The label number changes along various links of the same LSP.
- ❑ Labels are 20-bit long ⇒ 2^{20}-1 Labels. Labels 0-15 are reserved.


Label Edge Routers (LERs)

- ❑ Routers connected to non-MPLS routers or nodes or routers of other MPLS domains are called Label Edge Routers (**LERs**)
- ❑ LERs add labels to frames coming from non-MPLS nodes or remove their labels if forwarding to non-MPLS nodes or other domains.
- ❑ The labels added by LERs **may be** based on destination address along with other considerations, such as source address, QoS, etc.
- ❑ Other LSRs forward based solely on the label and the interface the frame came in. They **do not** look at the destination address field.

MPLS versus IP Paths

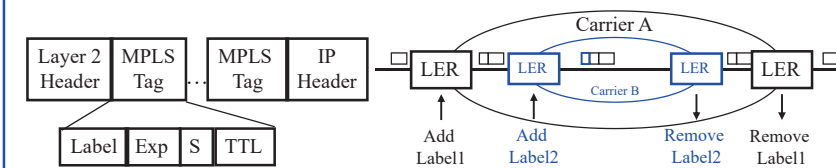entry router (R4) can use *different* MPLS routes to A based, e.g., on source address
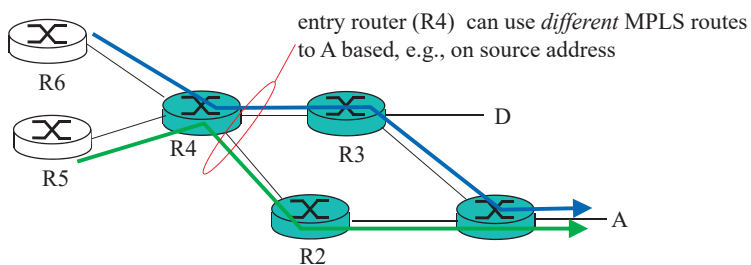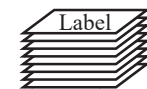

- ❑ **IP Routing**: Path determined by destination address alone
- ❑ **MPLS Routing**: Path can be based on source and destination address, flow type, …
  - ❑ **Fast reroute**: Precompute backup routes in case of link failure

IP-only router

MPLS and IP router
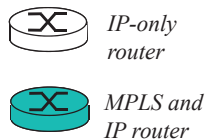
MPLS Label Format

- ❑ MPLS label is inserted after layer 2 header but before layer 3 header ⇒ MPLS is Layer 2.5
  - ➤ 20 bit label
  - ➤ 3 bit Experimental: Class of Service
  - ➤ 1 bit end-of-stack. A packet may have a stack of labels to allow carrier nesting.
- ❑ TTL field is decremented for all forwarded packets.
  When adding label TTL field from IP header is copied to the MPLS tag.
  When removing label TTL field from MPLS tag is copied to IP Header.
- ❑ MPLS Signaling:
  - ➤ OSPF has been extended to help prepare label tables
  - ➤ There are several other "*Label Distribution Protocols*"

Label

Layer 2 Header	MPLS Tag	…	MPLS Tag	IP Header

Label	Exp	S	TTL
20b	3b	1b	8b

Carrier A

LER — LER — LER — LER

Carrier B

Add Label1   Add Label2   Remove Label2   Remove Label1

MPLS: Review

1. Multiprotocol Label Switching (MPLS) allows virtual circuits called "Label Switched Paths (LSPs)" in IP
2. Each packet has a Layer 2.5 MPLS tag which includes a 20-bit label
3. Label switching routers (LSRs) forward based on input interface and the label
4. Label table is prepared by a "Label Distribution Protocol." OSPF is one example of a LDP.
5. MPLS tags can be stacked to allow network nesting

Ref: Section 6.5

Homework 6C

- ❑ Consider the MPLS network shown in "MPLS Forwarding Tables" slide. Suppose that we want to perform traffic engineering so that packets from R6 destined for A are switched to A via R6-R4-R2-R1 and packets from R5 destined for A are switched via R5-R4-R3-R1. Show the updated MPLS table in R4 that would make this possible. For simplicity, use the same label values as shown currently. Only LSP paths change and the table at Router R4.