

CS 725/825 & IT 725

Lecture 4

Networking Fundamentals

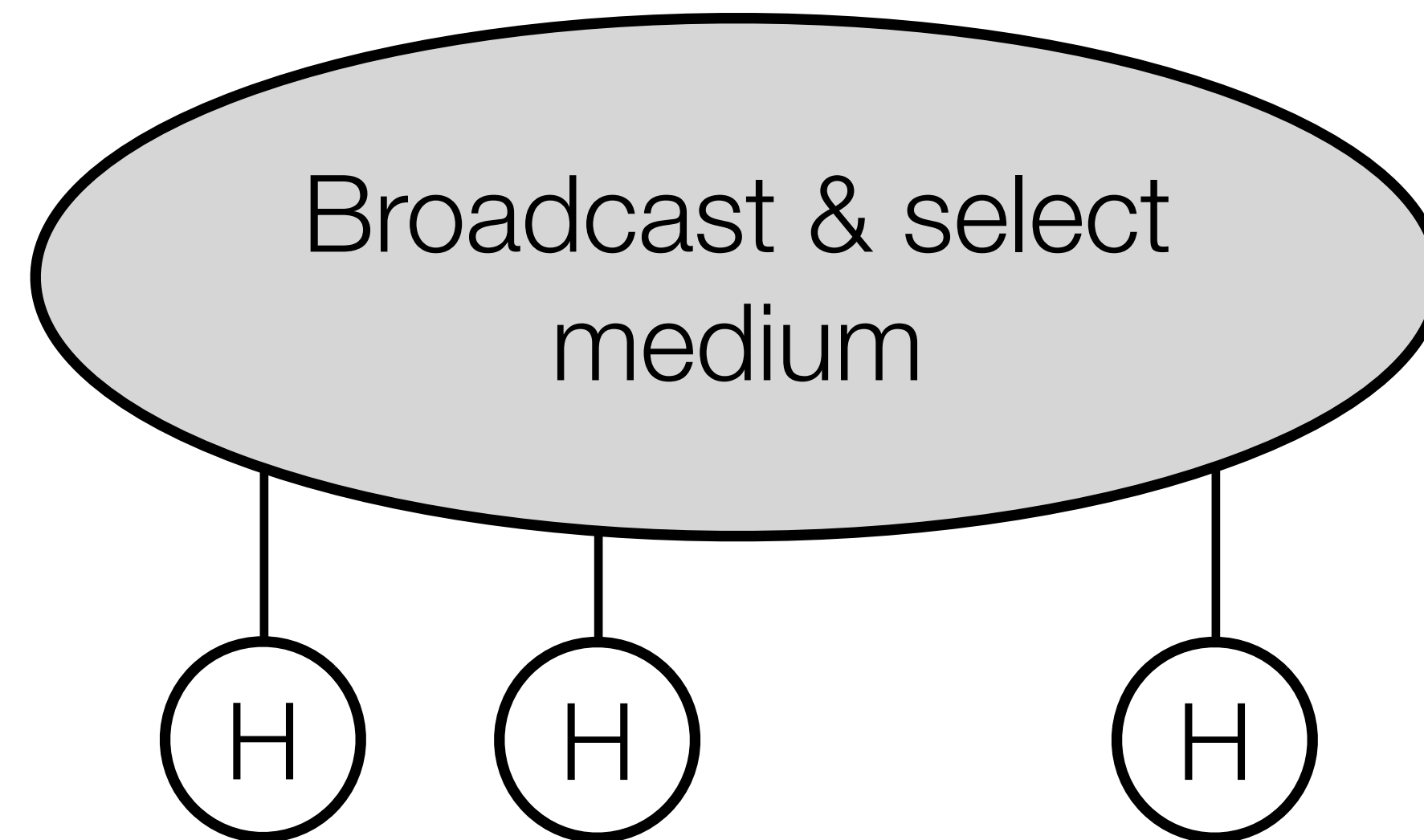
September 8, 2025

Store and Forward

- ▶ Intermediate nodes **receive**, **store**, and **forward** packets
 - storing and retransmission adds **fixed delay**
- ▶ **Output conflict** - multiple packets waiting to be forwarded on the same output
 - queues/buffers used to store packets waiting transmission
 - queuing adds **variable delay**
 - potential for **packet loss** due to buffer overflow

A bit of history...

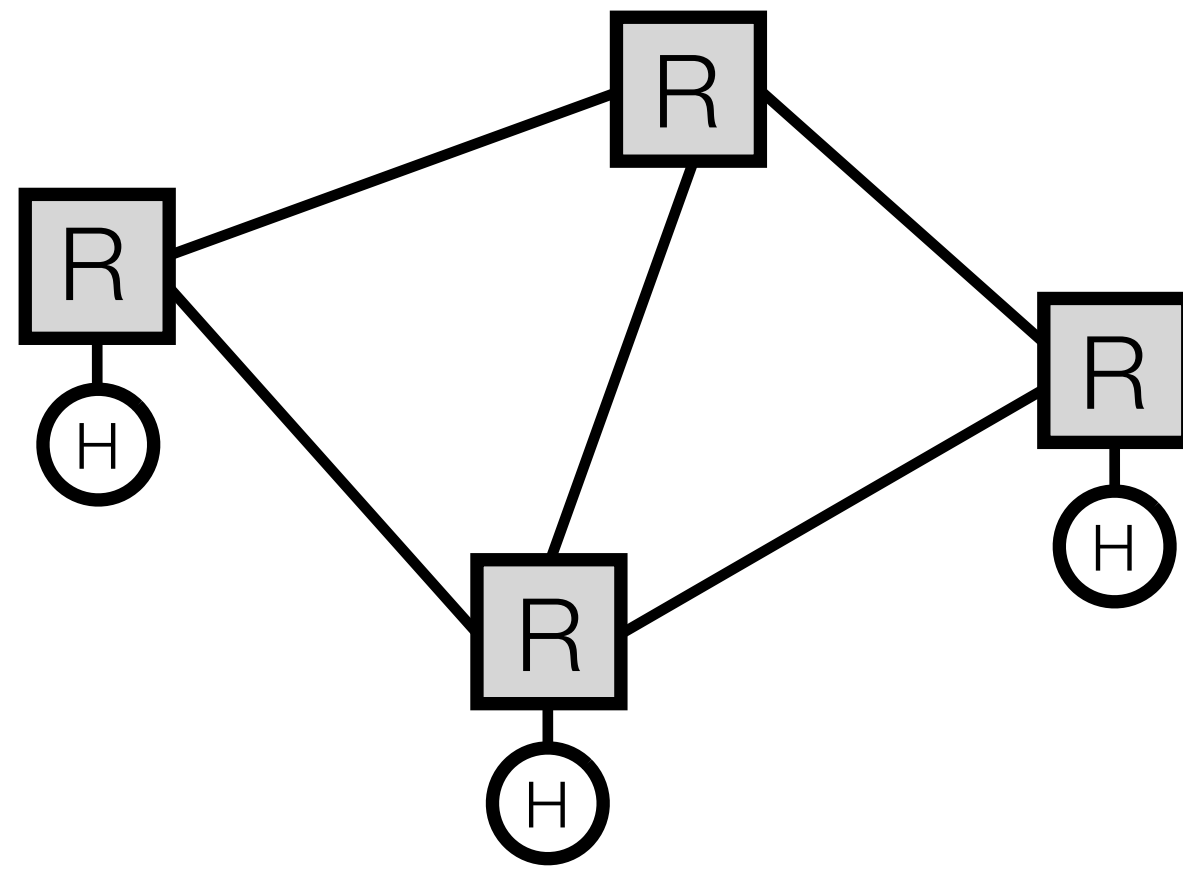
- ▶ **Local area networks** (late 80's, early 90's)
 - (then) based on broadcast & select medium



- (today) a network of Ethernet (L2) switches

Comparison

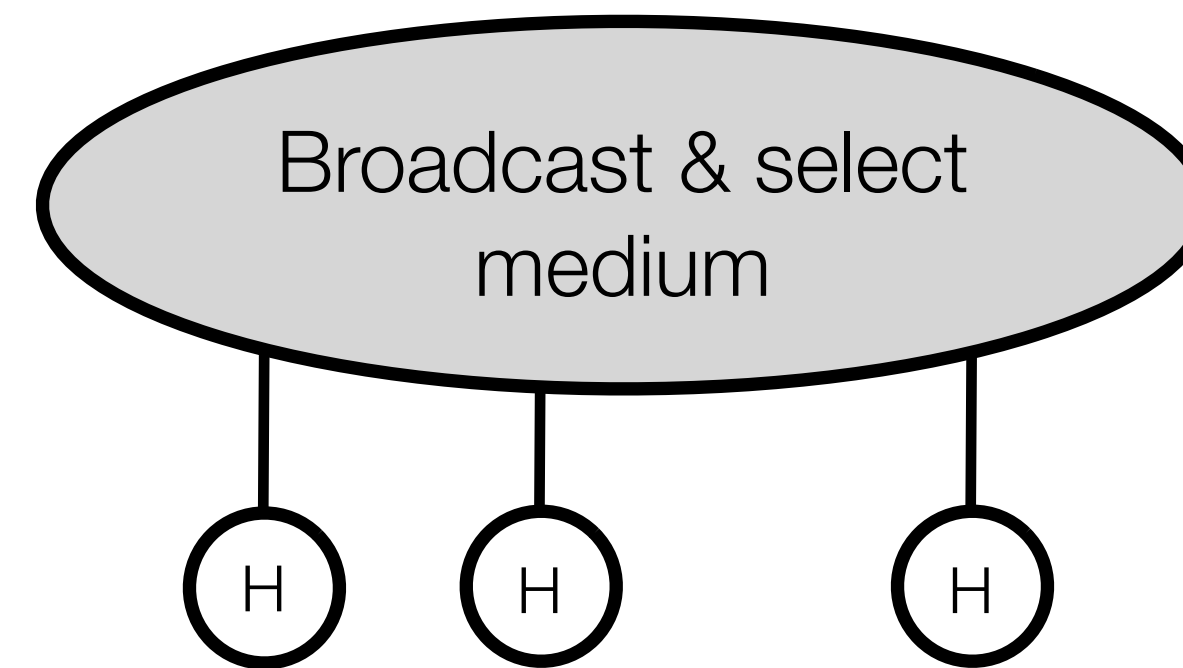
► Routed networks



- topology driven by geography
- long distances (high latency)
- need for scalability
- location-related addresses
- routing

➡ **Network Layer (L3)**

► Broadcast & select

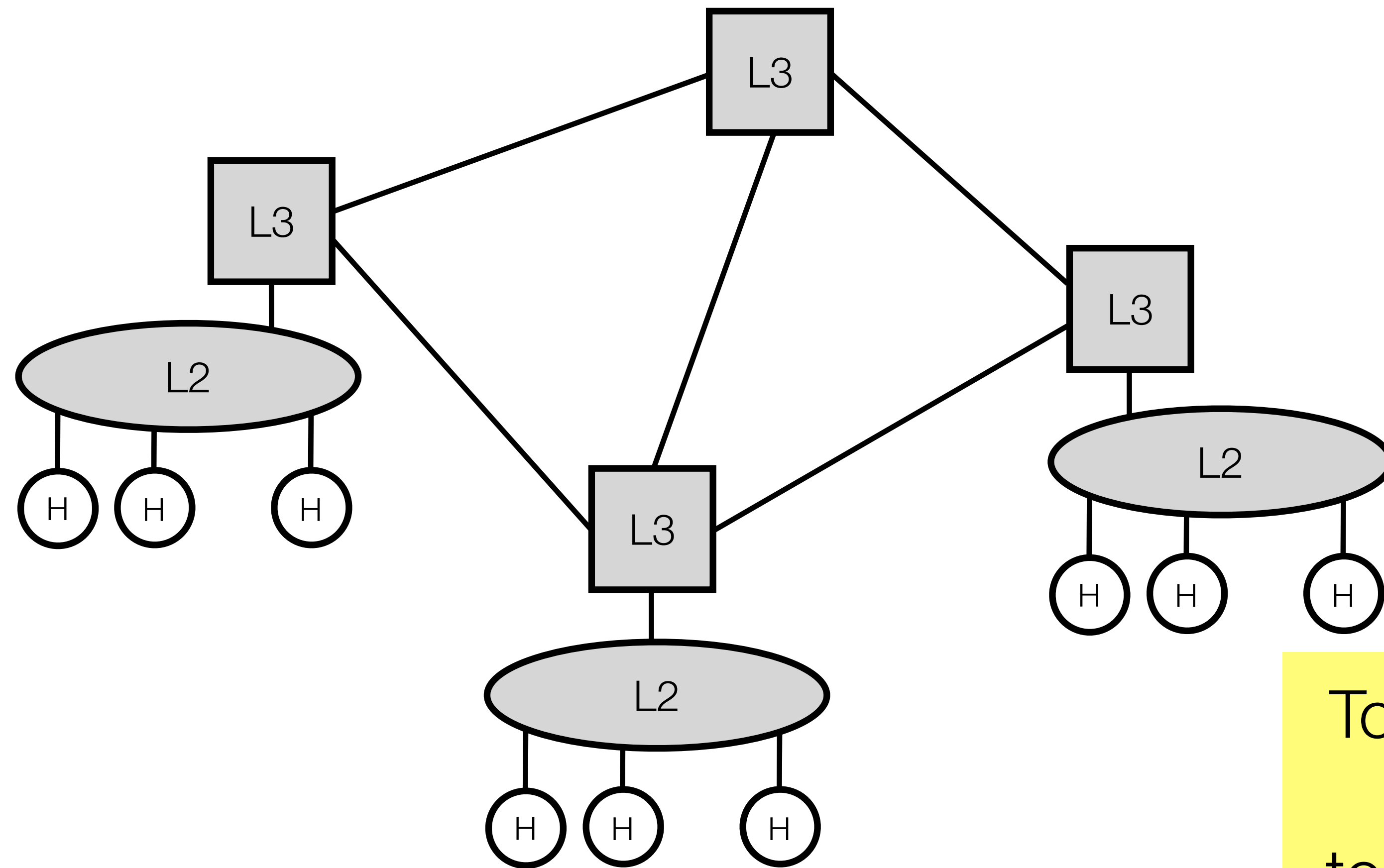


- everyone connected to everyone
- short distances (low latency)
- lesser need for scalability
- arbitrary addresses
- address discovery

➡ **Link Layer (L2)**

Today

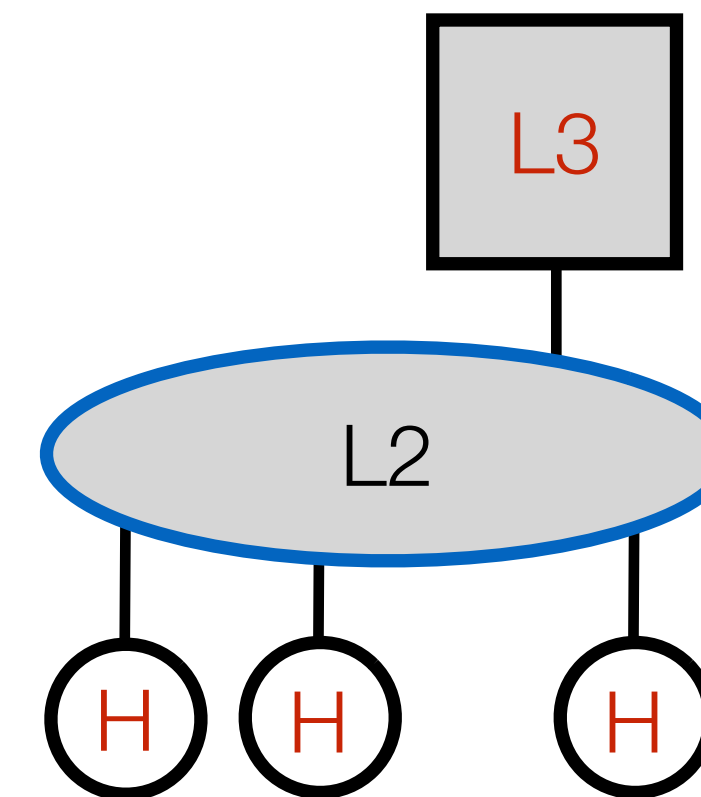
Internet - a network to **INTER**connect **NET**works



Today, L2 switching and L3 routing are often mixed together in devices capable of processing multiple layers

Networking Basics

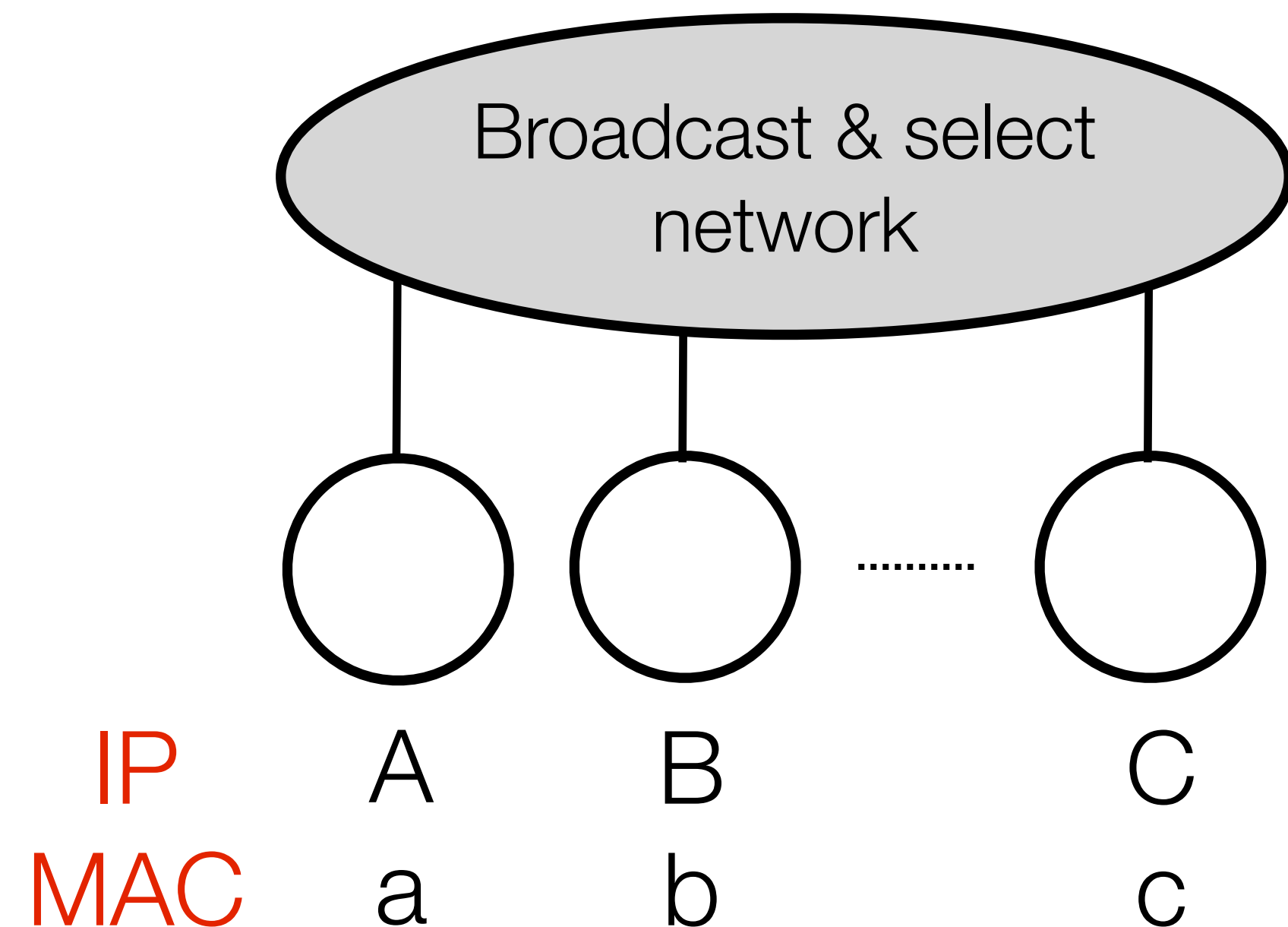
- ▶ **Goals:** IP/MAC addresses, fundamental protocols, subnetting, basics of routing/switching
- ▶ **Assumptions:**
 - packet switched network
 - nodes attached to a **L2 broadcast-and-select network**
 - each **node** “has” a 6-byte MAC and a 4-byte IP addresses



Address Resolution

- **Problem:** Find MAC address of a node with a given IP address

A has a packet with IP destination address B, A needs B's MAC address to deliver the packet



- **Solution:** ARP - Address Resolution Protocol

ARP

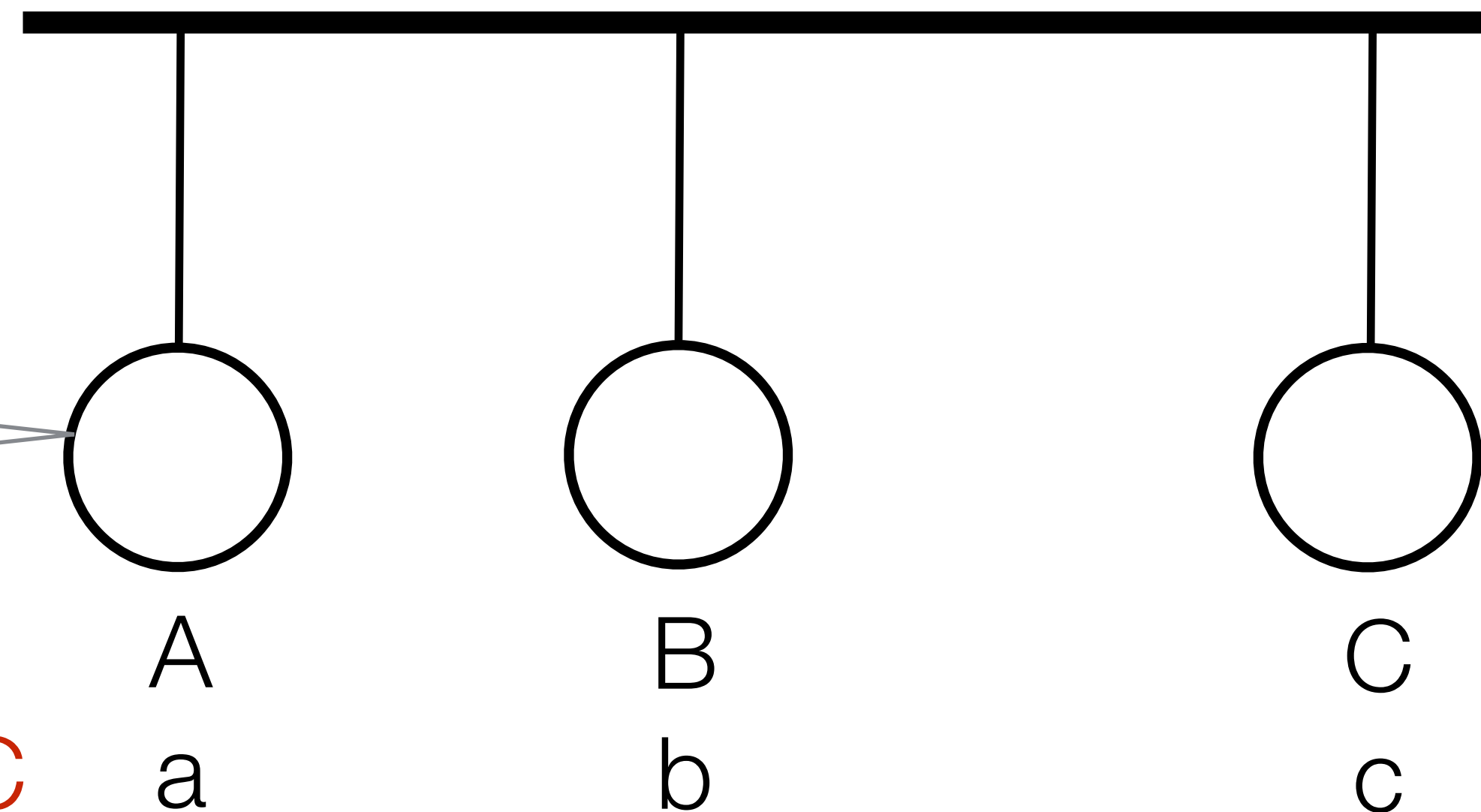
A has a packet with IP destination address B, A needs B's MAC address to deliver the packet

Broadcast and Select medium

Who has IP = B?

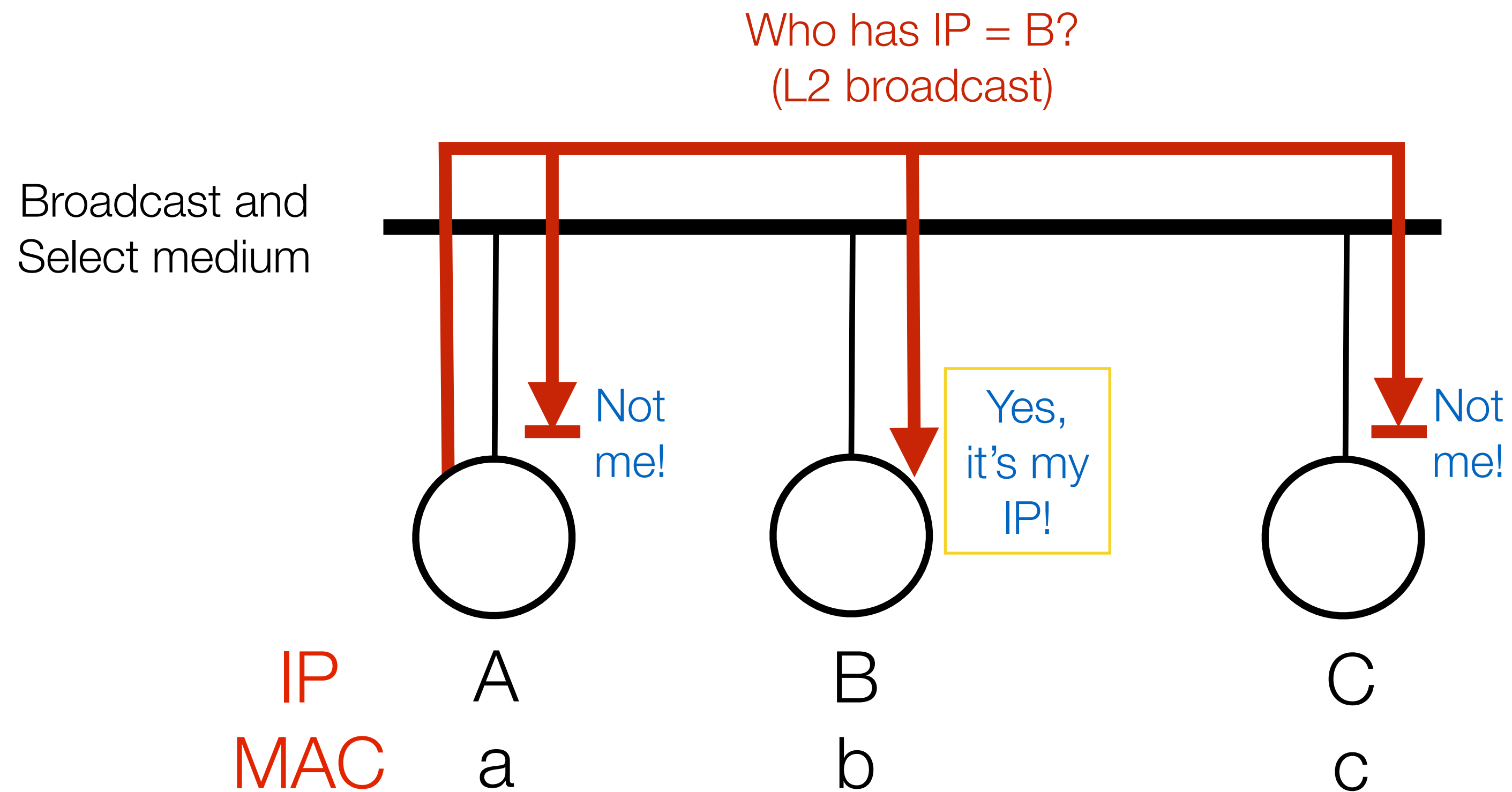
	MAC	IP	
SRC	a	A	
DST	?	B	

IP
MAC

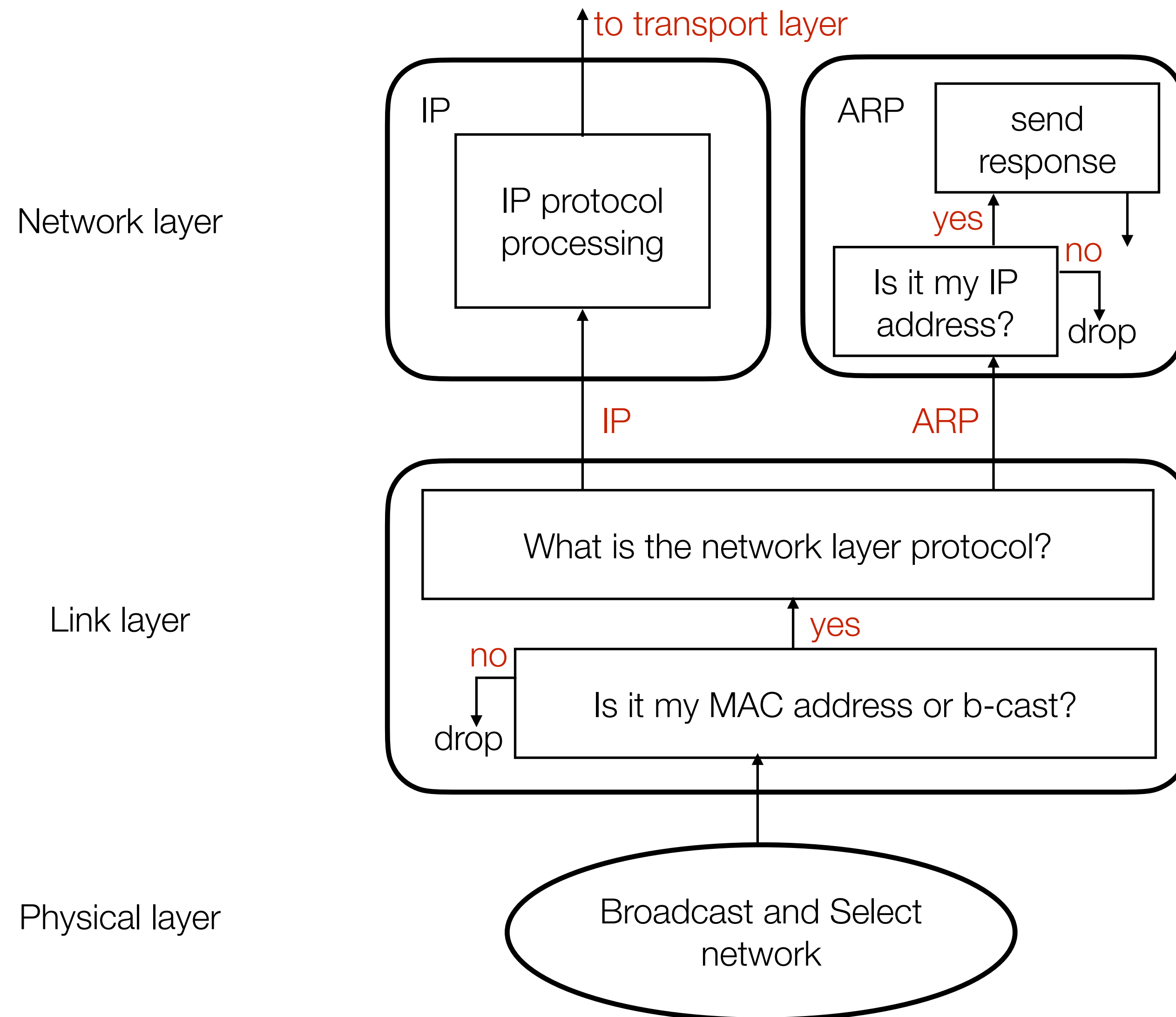


ARP

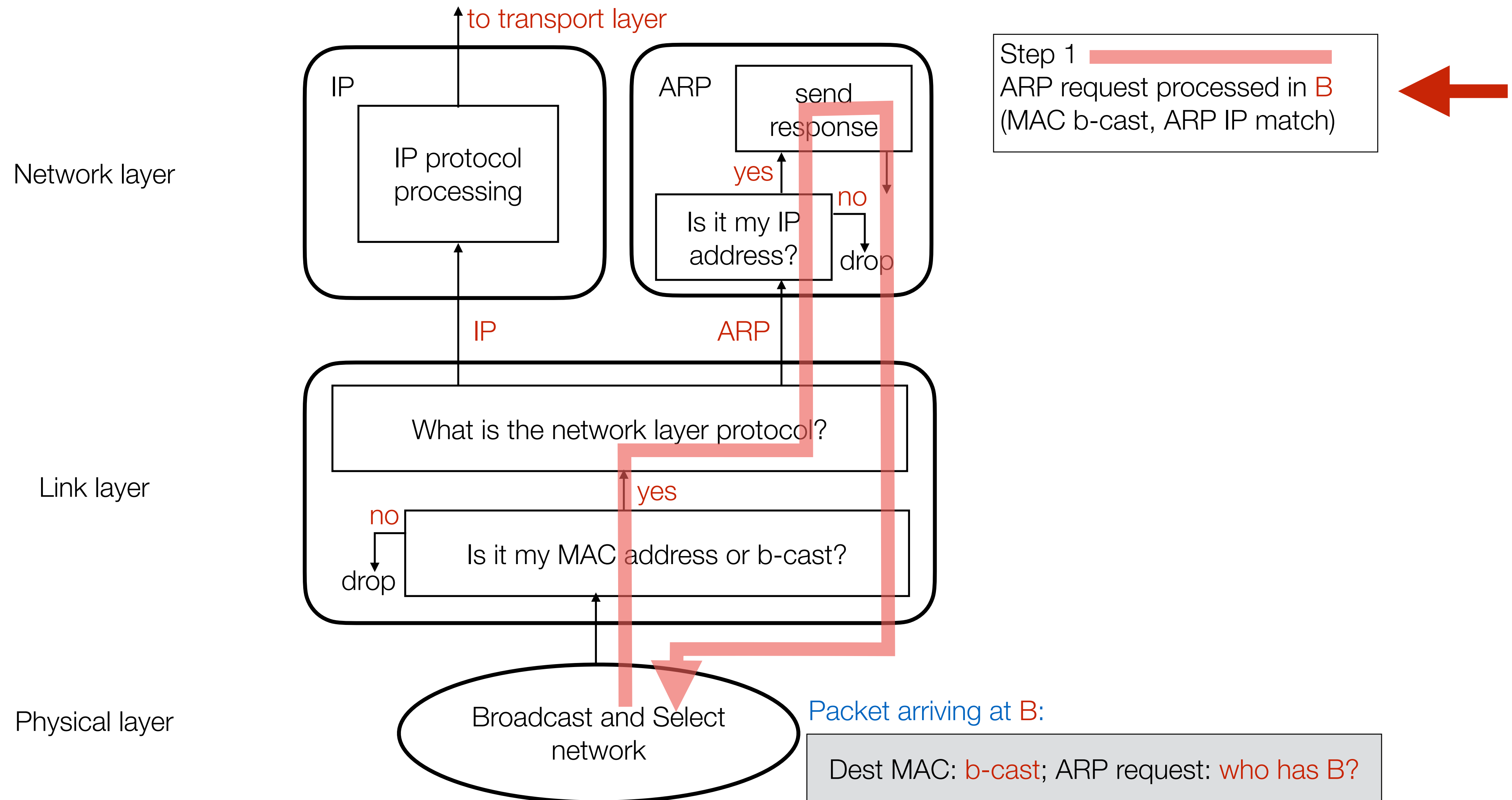
- **Step 1:** “Who has ...” **broadcasted** to everyone by A



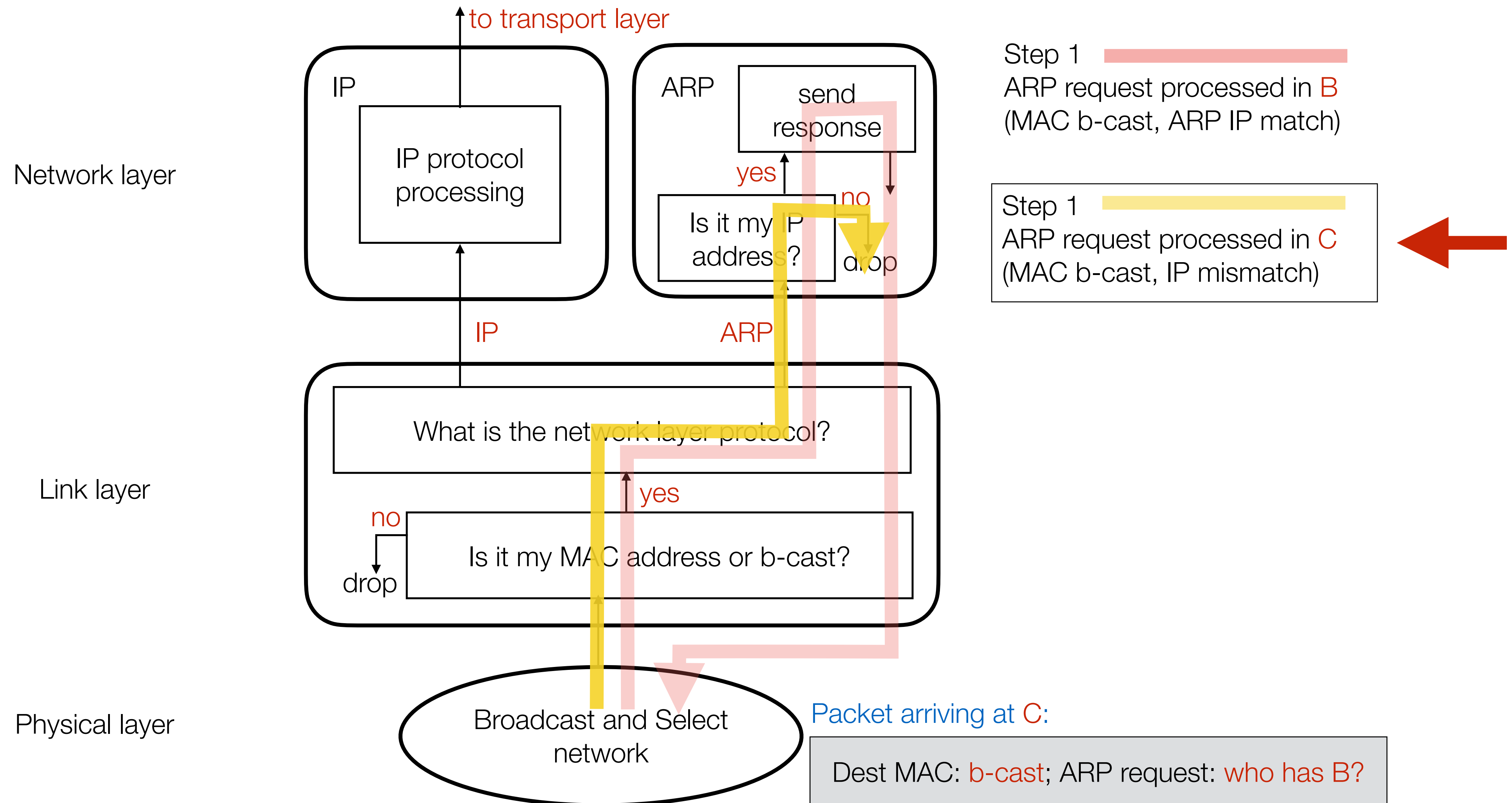
ARP packet processing



ARP packet processing

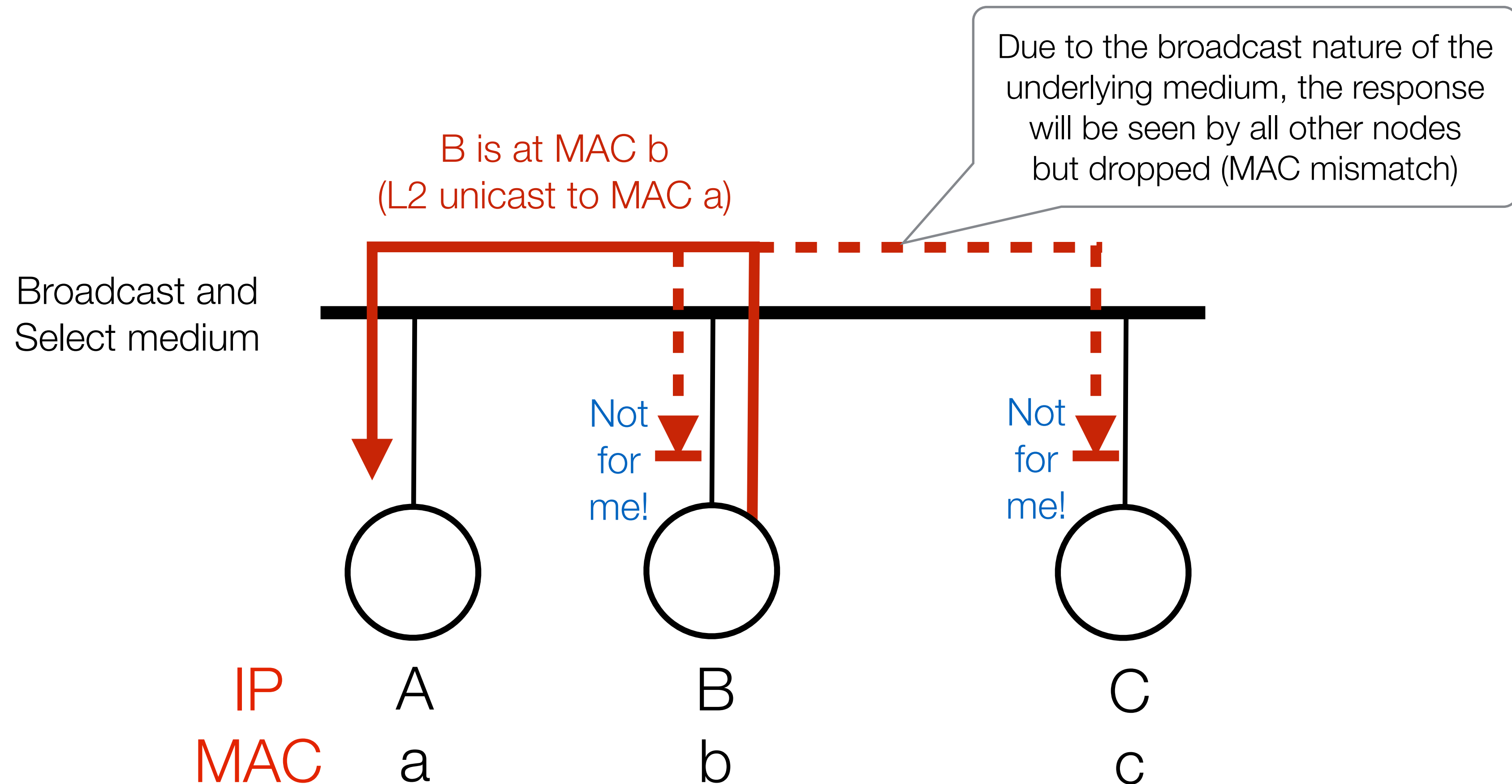


ARP packet processing

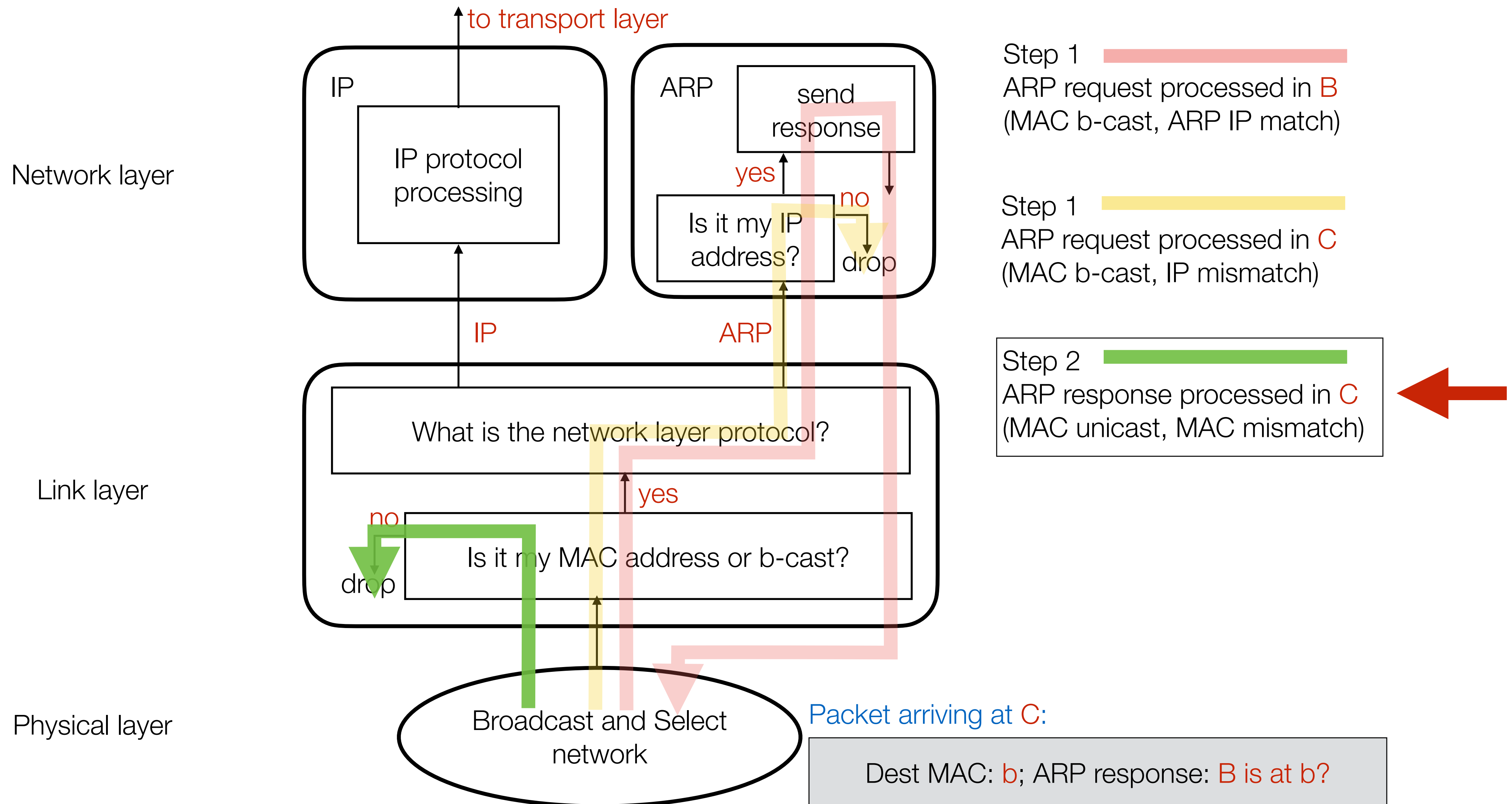


ARP

- Step 2: B sends L2 unicast response to A (MAC a)

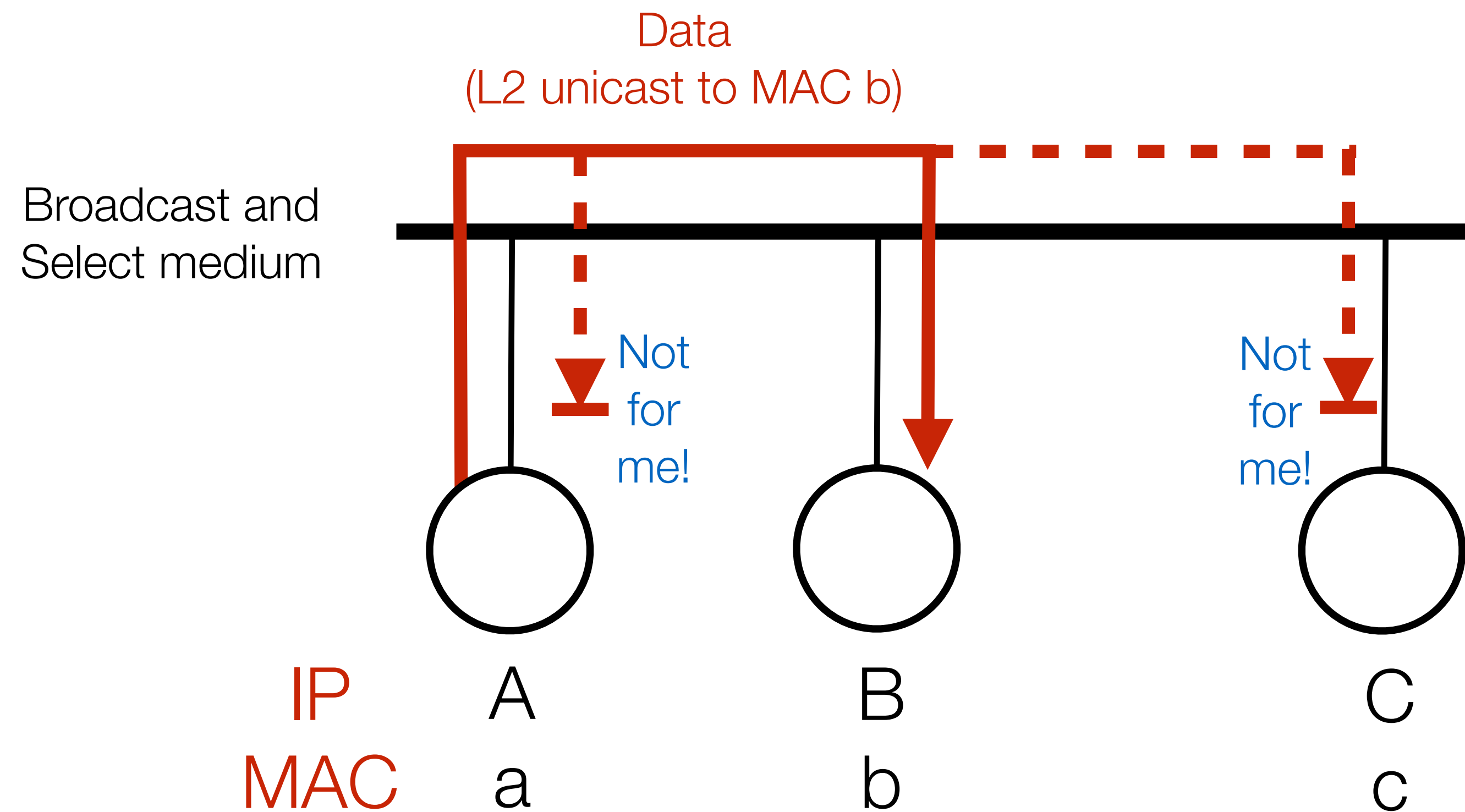


ARP packet processing

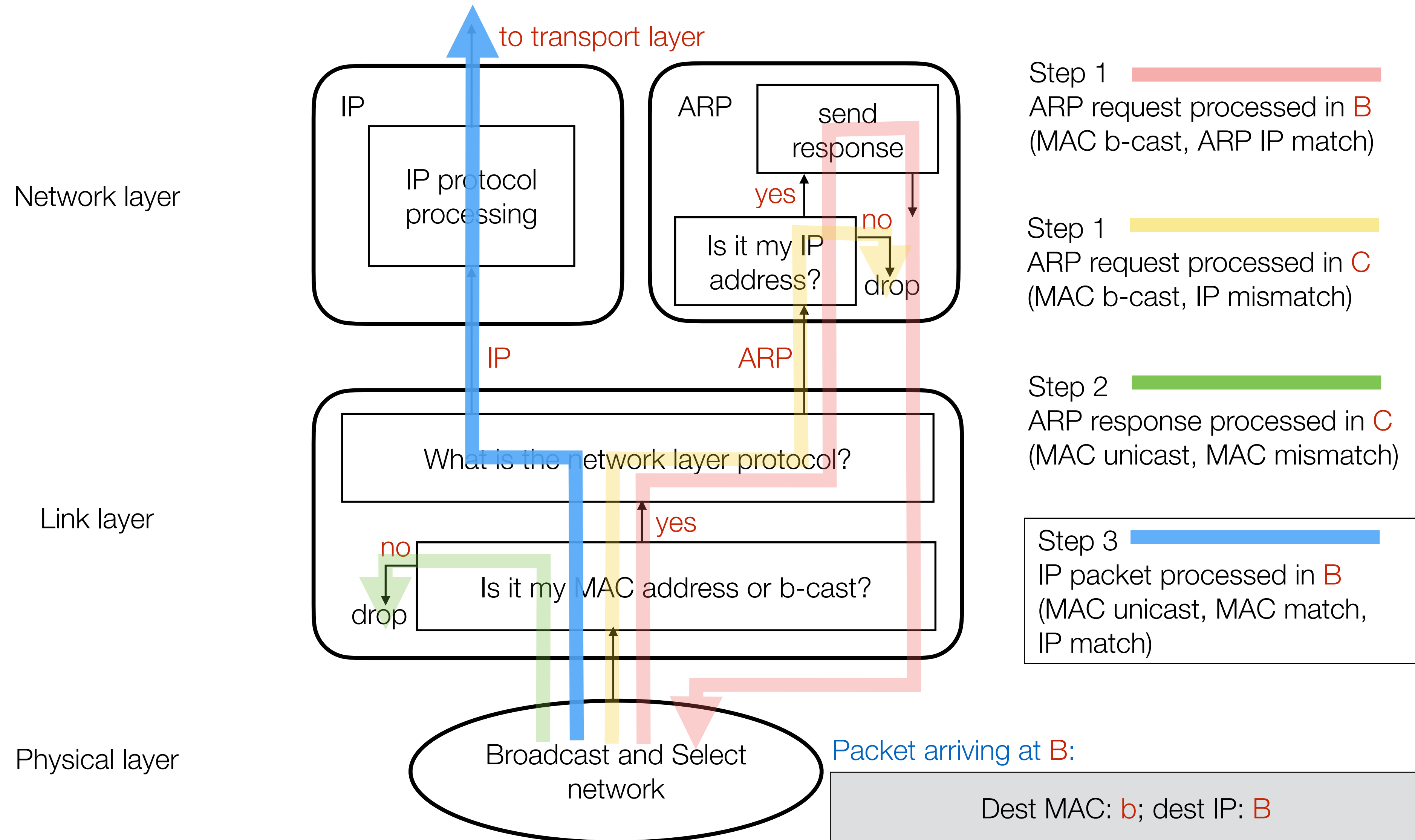


ARP

- Step 3: A sends data using L2 unicast to MAC b

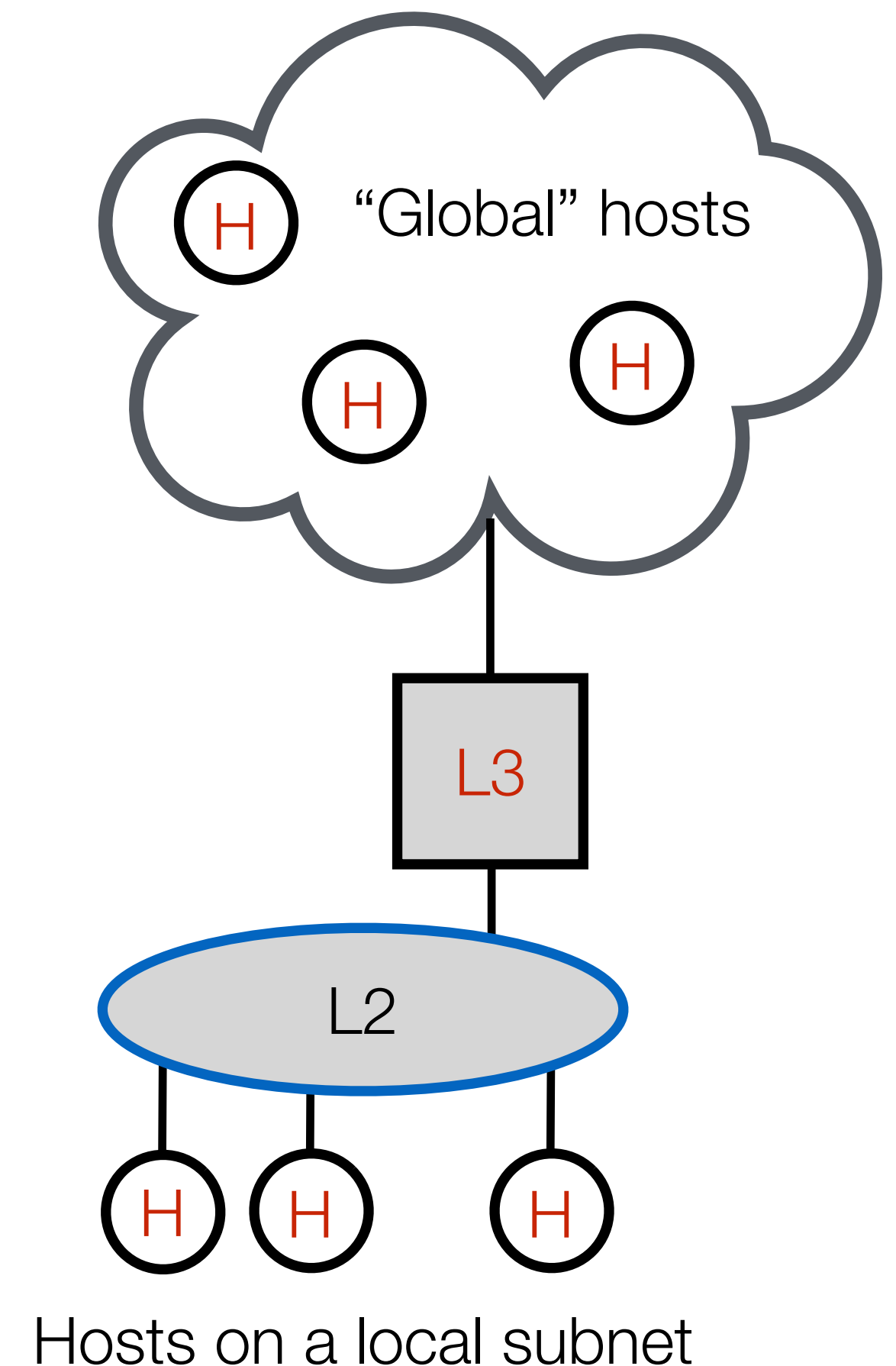


ARP packet processing



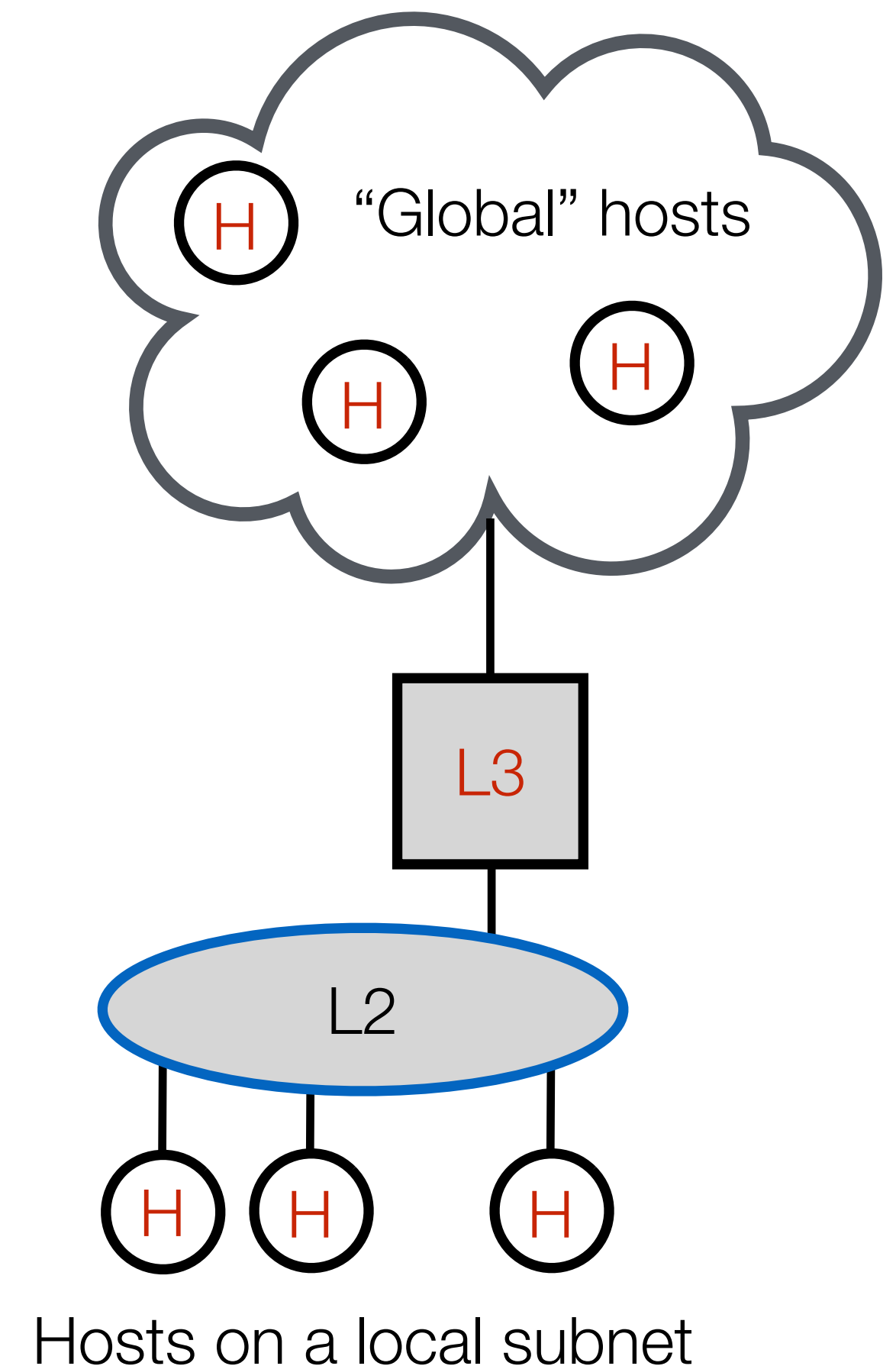
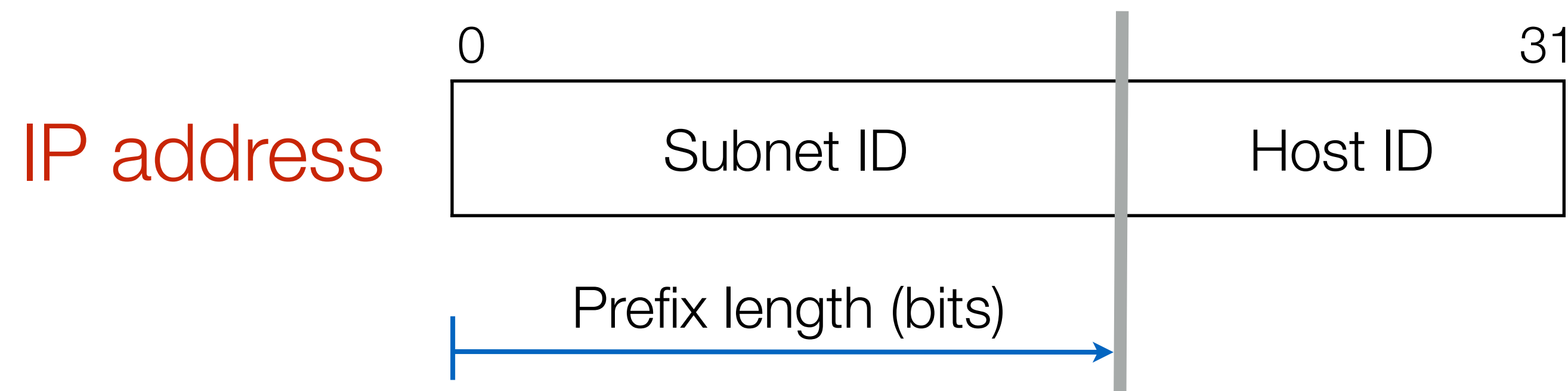
Subnetting

- ▶ **Problem:** deciding whether an IP address belongs to a specific **subset** of IP addresses
- ▶ **Solution:** nodes on a subnet (and only those) have IP addresses within a specific **range**



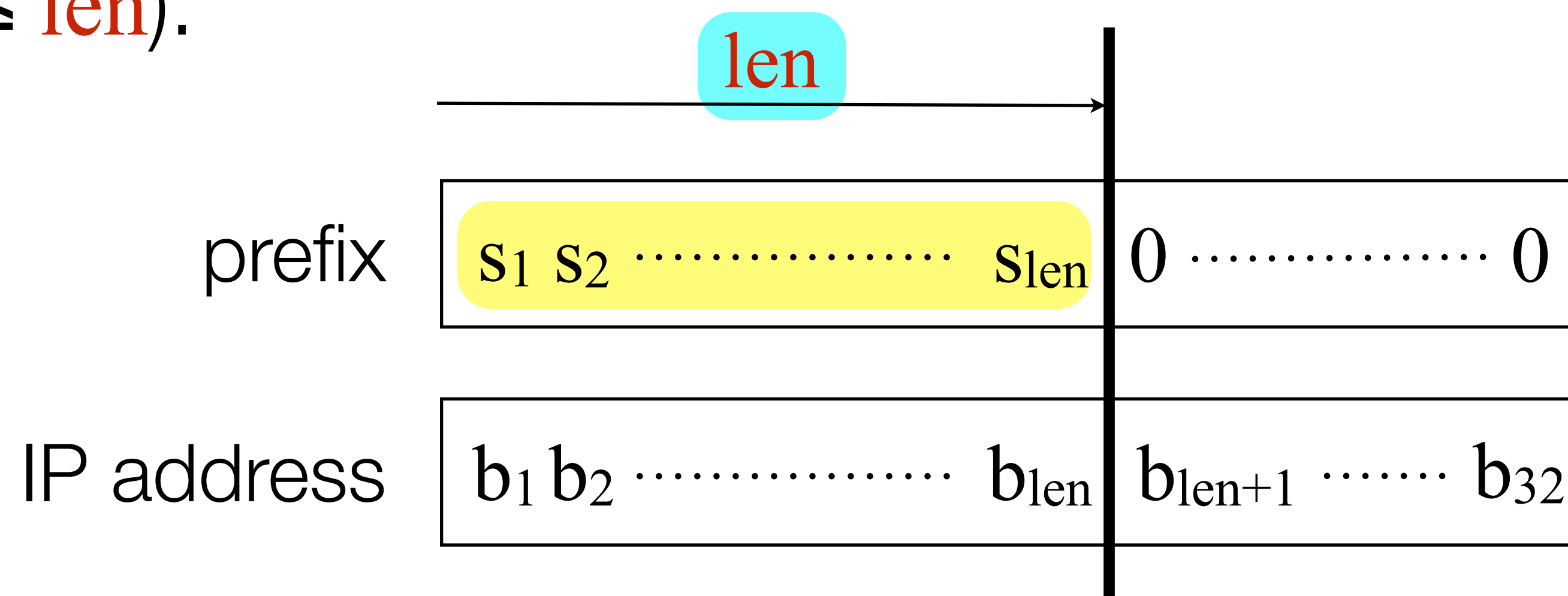
Subnetting

- ▶ **Problem:** deciding whether an IP address belongs to a specific **subset** of IP addresses
- ▶ **Solution:** nodes on a subnet (and only those) have IP addresses within a specific **range**
- ▶ Simplifying HW implementation: **subnets** (ranges of IP addresses that can be placed only in a specific, constrained way):



IP Prefix

- ▶ specifies a range of consecutive IP addresses
- ▶ consists of a *subnet id* and a *length* (*len*)
e.g., 132.177.4.0/22
- ▶ An IP address belongs to a range specified by a prefix if its first *len* bits are equal to those in the *subnet id* ($s_i = b_i$ for all $i \leq \text{len}$):



Example questions

- ▶ Range of 132.177.4.0/24?
132.177.4.0 → 132.177.4.255
- ▶ Prefix for range 132.177.0.0 → 132.177.255.255?
132.177.0.0/16

Example questions

- ▶ Range of 132.177.4.0/26?
132.177.4.0 → 132.177.4.63
- ▶ Prefix for range 132.177.2.192 → 132.177.2.223?
132.177.2.192/27

Combining prefixes

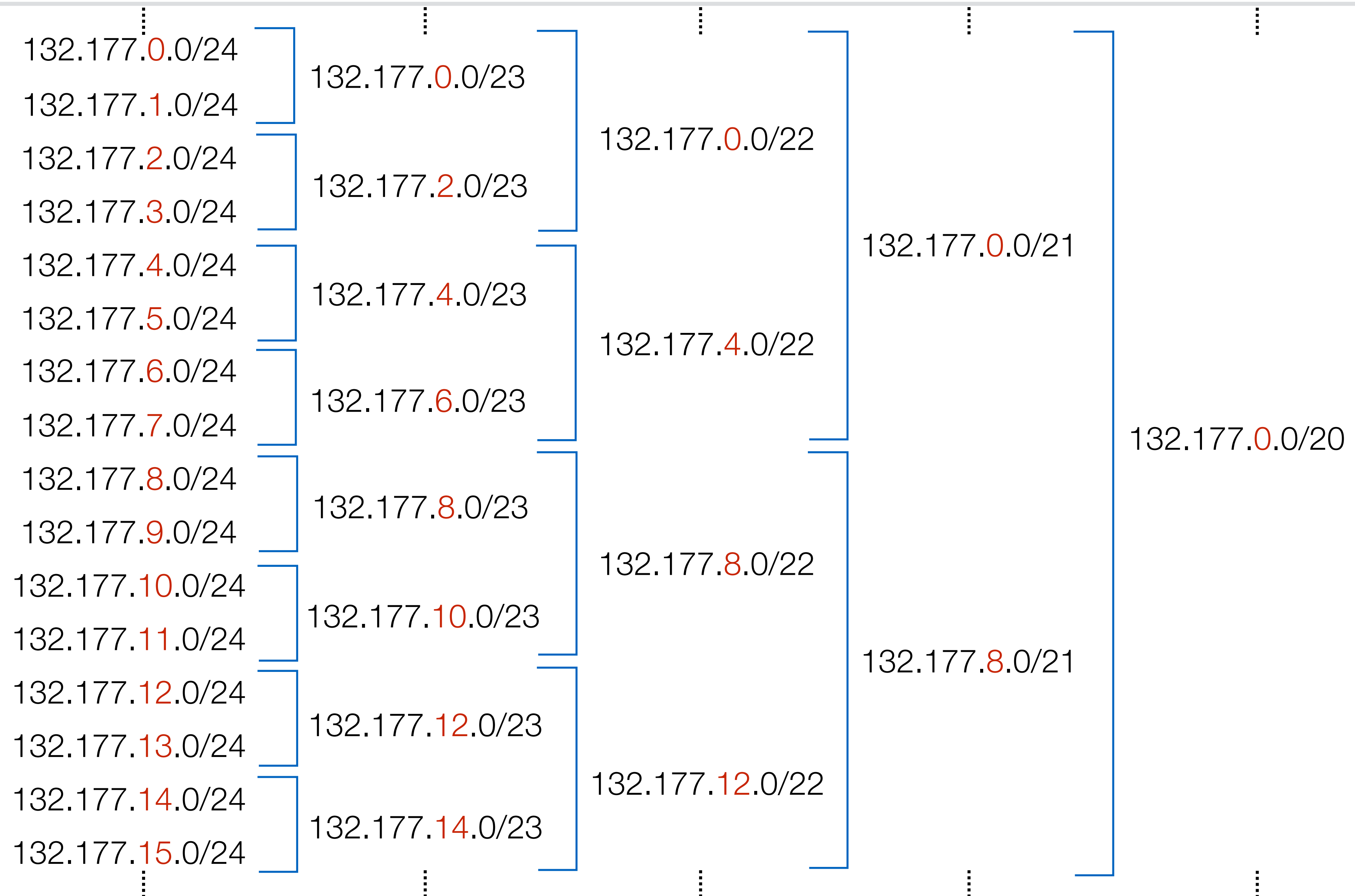
132.177.0.0/24

132.177.1.0/24

132.177.0.0/23

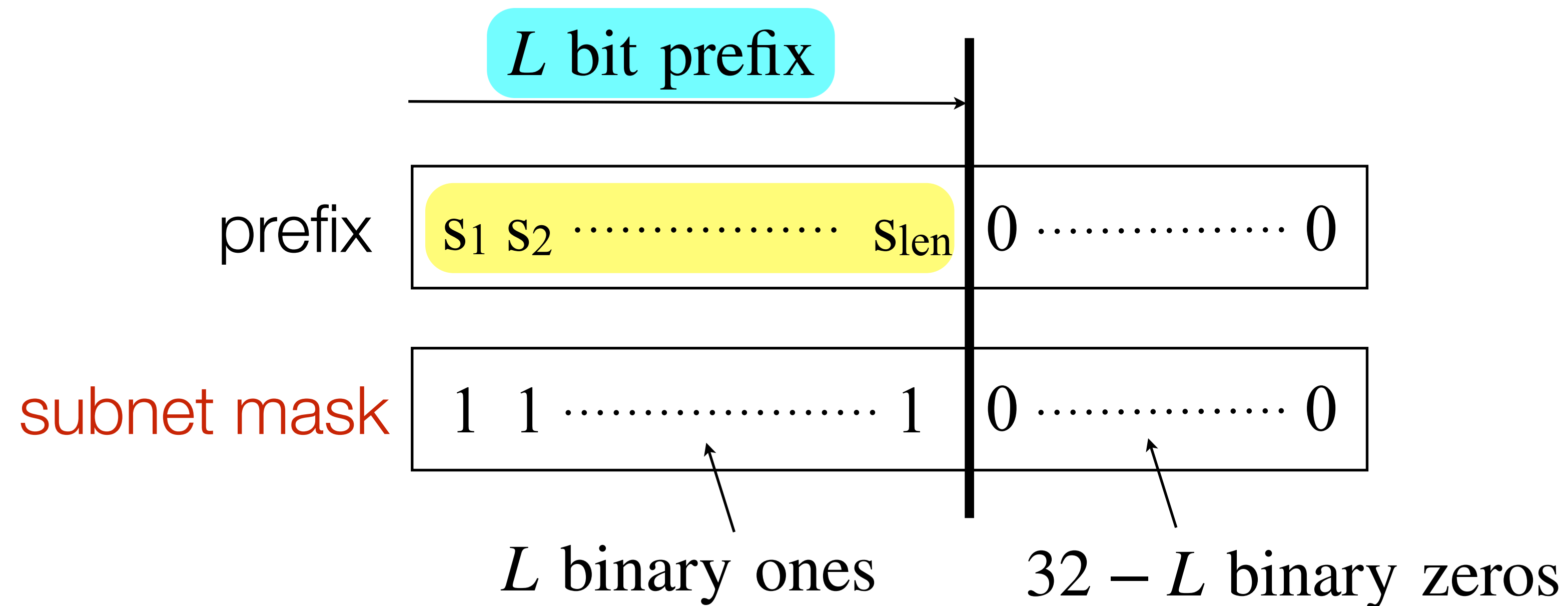
Range 132.177.0.0 - 132.177.1.255

Combining prefixes



Subnet Mask

- ▶ Another way to specify **prefix length**
- ▶ A 32 bit, IP address-like value whose binary representation has binary ones in bits corresponding to the subnet id bits.



Subnet Mask Representation

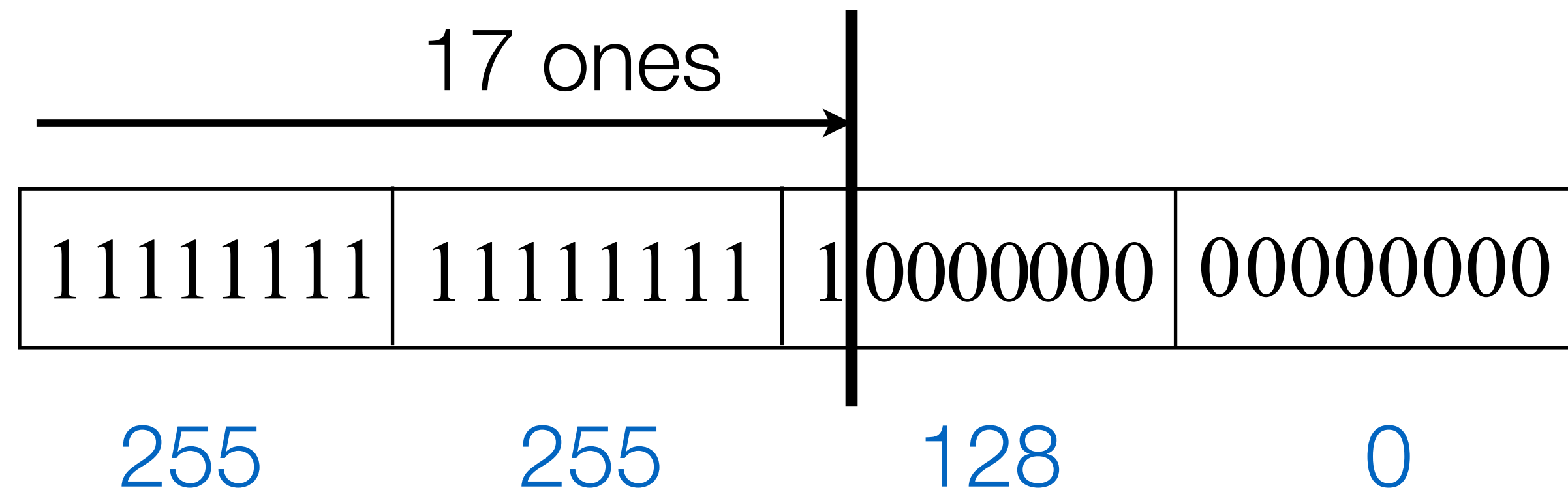
- ▶ Typically represented using *decimal dotted notation*:
255.255.0.0
- ▶ Subnet length and subnet mask (netmask) are for all practical purposes equivalent:

132.177.4.0 with netmask 255.255.255.0

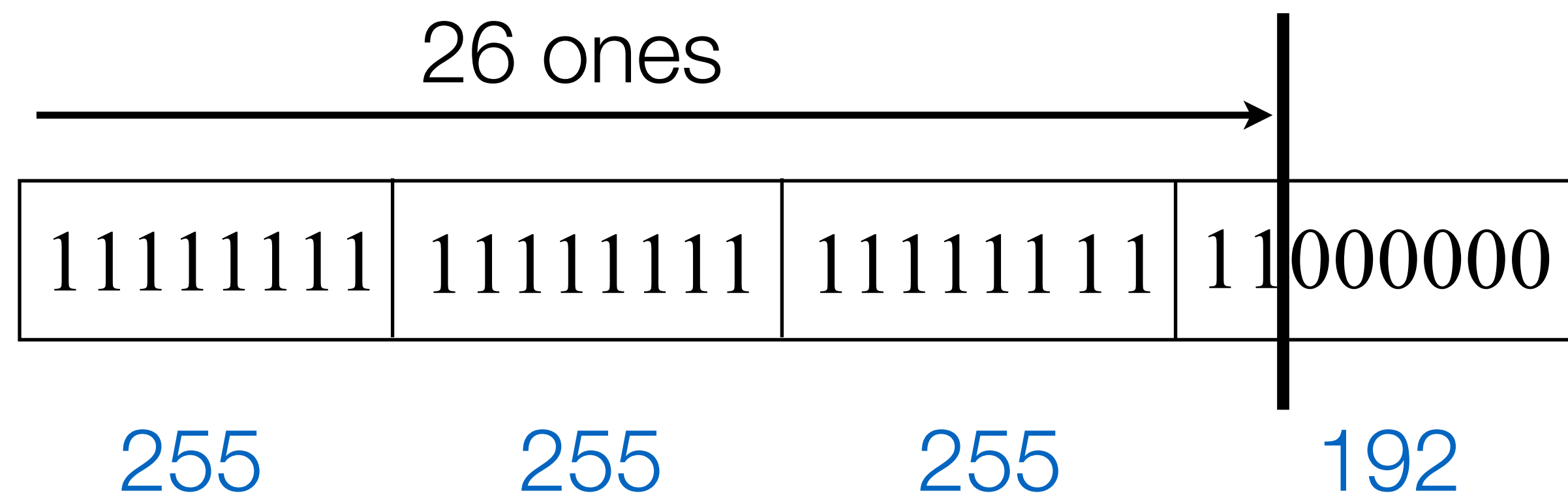
is equivalent to 132.177.4.0 /24

Example questions

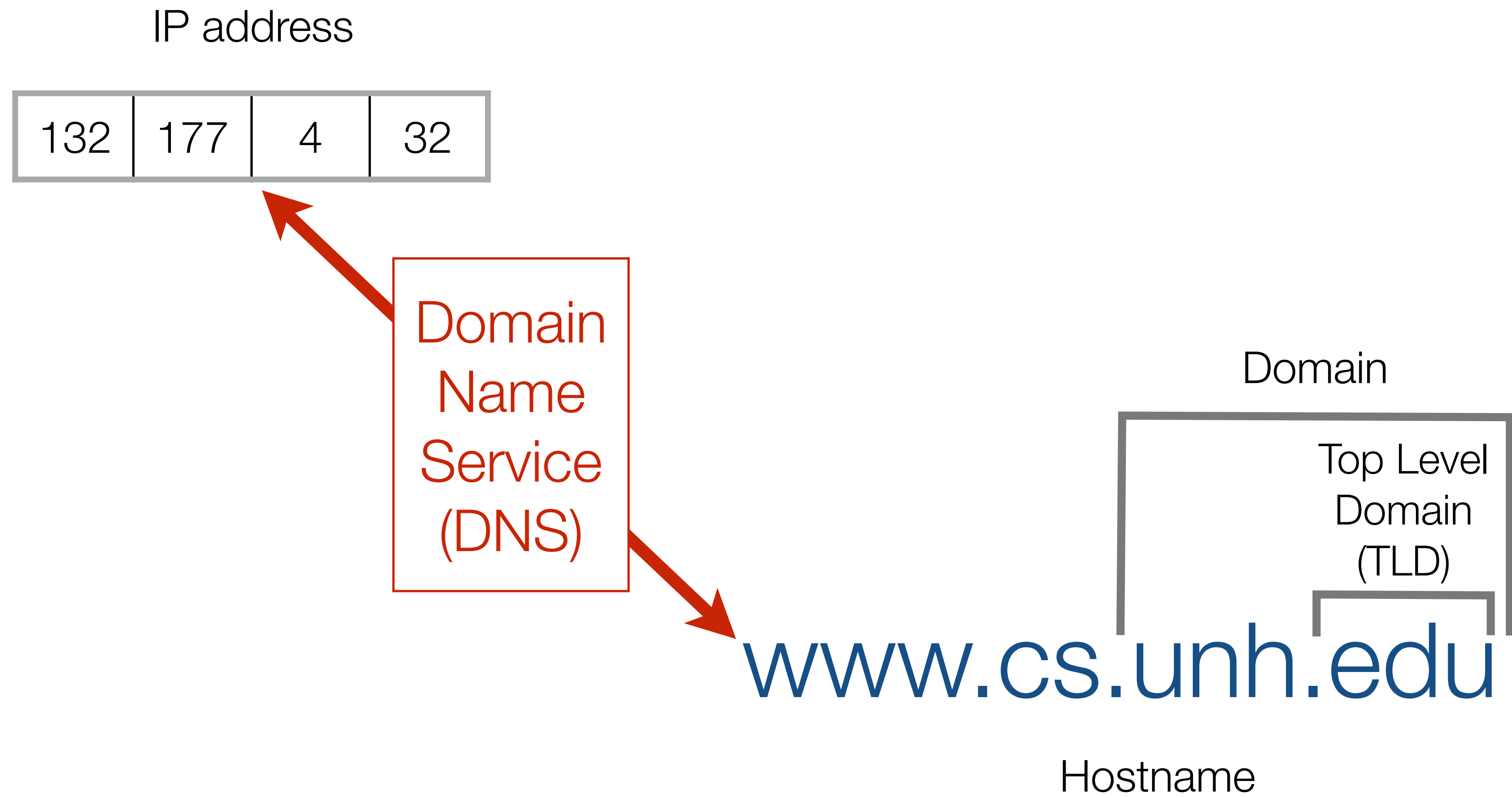
- Subnet mask for prefix length /17?



- Prefix length for subnet mask 255.255.255.192?



Domain Name Service



Domain Name Service

- ▶ Mapping between hostnames and IP addresses:
 - one-to-one, one-to-many, many-to-one, or many-to-many?
 - mapping in both directions
- ▶ Possible solutions:
 - centralized database
 - fully distributed database