

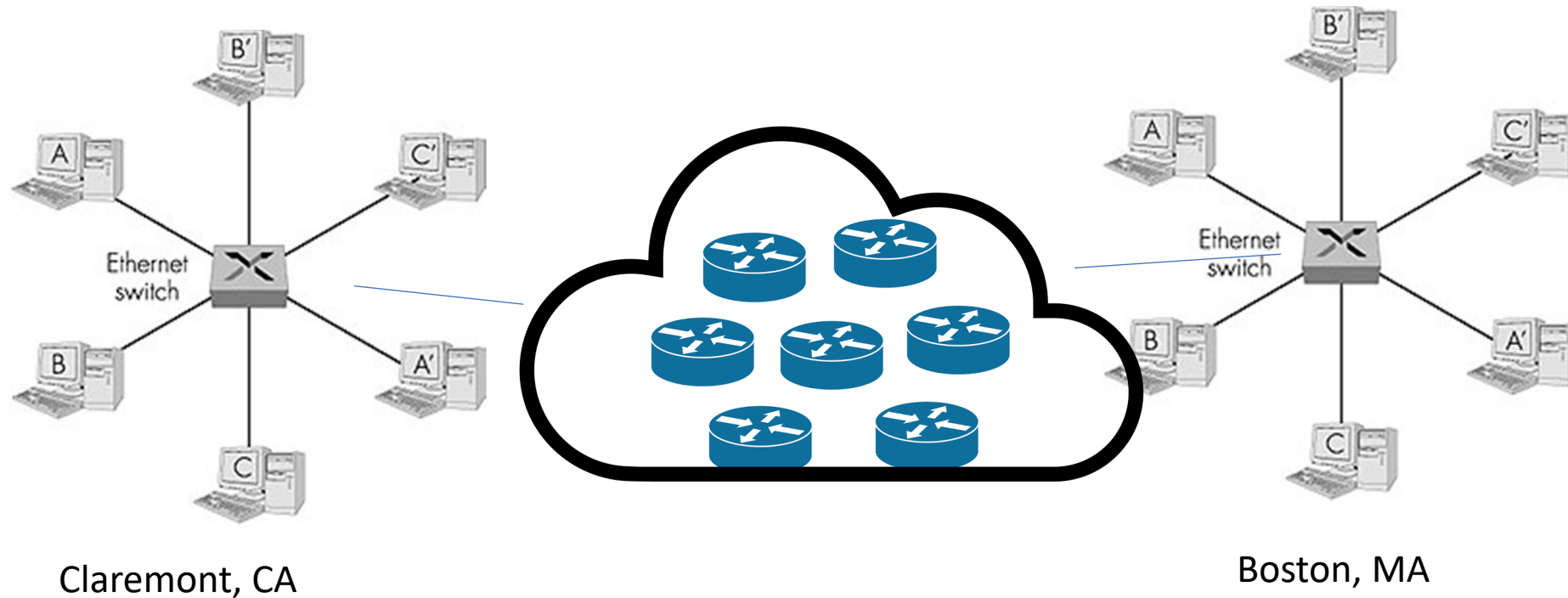
CS 181AG
Lecture 4

Intro to Network Layer (IP)

Arthi Padmanabhan
Sep 12, 2022

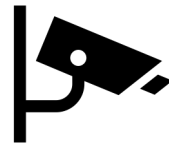
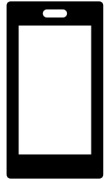
Reminder: Internet is a Network of Networks

- Last time: how do we extend a local network to reach more hosts?
- This time: how do *different* networks reach each other?



Host

- Any device connected to the internet

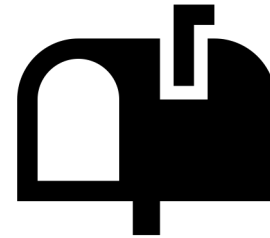
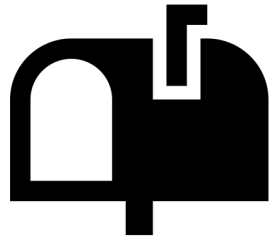


Standardized Communication

- To communicate within a network, every network need not use the same protocol (i.e., LAN 1 could use Ethernet while LAN 2 uses token ring)
- To communicate between networks, we need *routing*

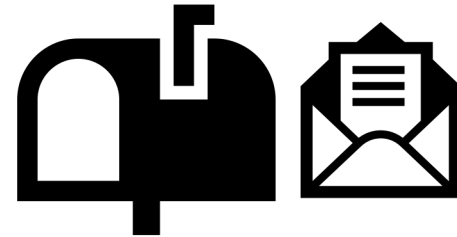
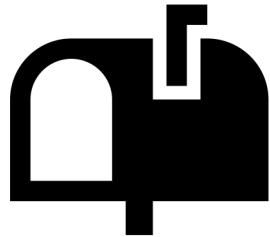
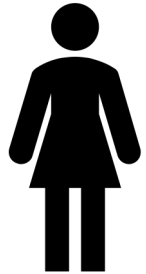
IP Addresses

- Your mailing address on the internet



IP Addresses

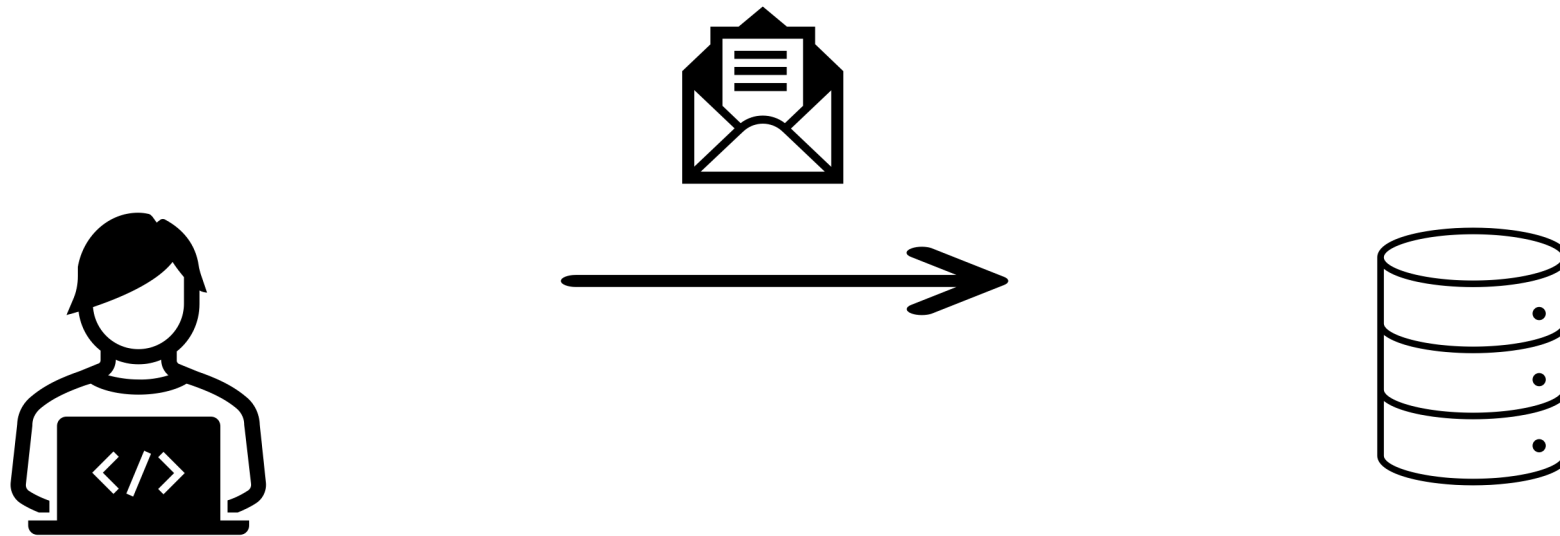
- Your mailing address on the internet



Packet Headers Contain src and dst

Source address (src): YouTube server IP address

Destination address (dst): your computer's IP address



Form of an IP address

- 192.16.1.3
- 32-bit binary, separated into 8-bit chunks
- 4,294,967,296 addresses – is this enough?

IP Address Hierarchy

Harvey Mudd College



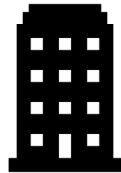
10.0.x.x

Computer Science



10.0.10.x

Physics



10.0.20.x

Math



10.0.30.x

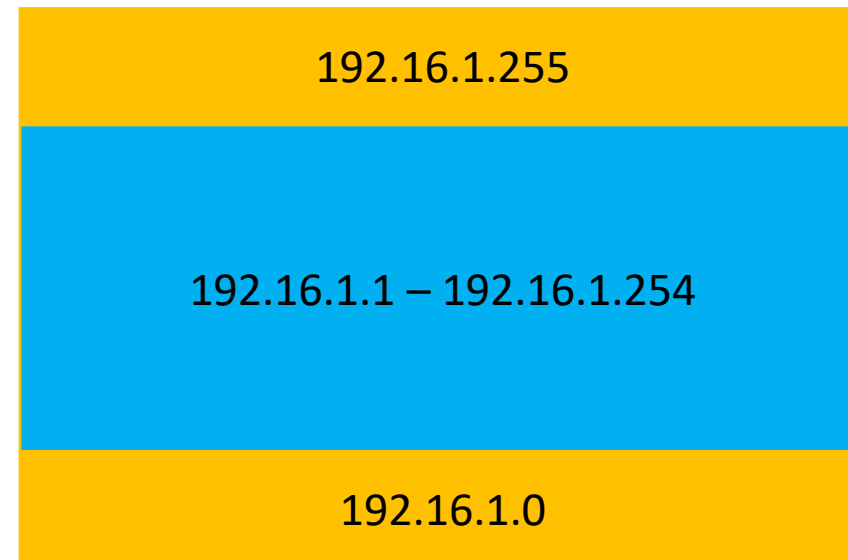
10.0.30.1?

IP addresses in a network

- 192.16.1.x
- Lowest address on network?
 - 192.16.1.0: Network Address
- Highest address on network?
 - 192.16.1.255: Broadcast Address
- Hosts can be everything in between (but not including) network and broadcast
 - This network host range is $192.16.1.1 - 192.16.1.254 = 254$ hosts

IP address notation

- 192.16.1.x could be written as 192.16.1.0/24
 - Means the first 24 bits are the network and the last 8 are the host
- Subnet mask: 255.255.255.0



Practice Question

- Are 192.16.1.0/16 and 192.16.3.40/16 in the same network?
- Are 192.16.1.0/24 and 192.16.3.40/24 in the same network?

How IP Addresses are Assigned

- IANA (Internet Assigned Numbers Authority) gives out IP address ranges
- Originally, they used "classful" addressing:
 - Class A: \8 -> ex/ city
 - Class B: \16 -> ex/ universities, office buildings
 - Class C: \24 -> ex/ home
- 127 was a class A address that meant "home" – how your computer connects to any servers running locally

IP Address Assignment

- Eventually, more flexibility was needed because they ran out of class B addresses
- Now subnet mask need not be only 8, 16, or 24
- This is a valid network: 192.16.1.240/28
 - Network Address?
 - Broadcast Address?
 - Host range?
 - Number of hosts?

Practice Problems

- Write network, broadcast, host range, and number of hosts:
- 200.10.154.252/30
- 210.10.1.16/4
- 100.5.10.0/14

How IP Addresses are Assigned

- Dynamic: assign a new IP address each time a host connects

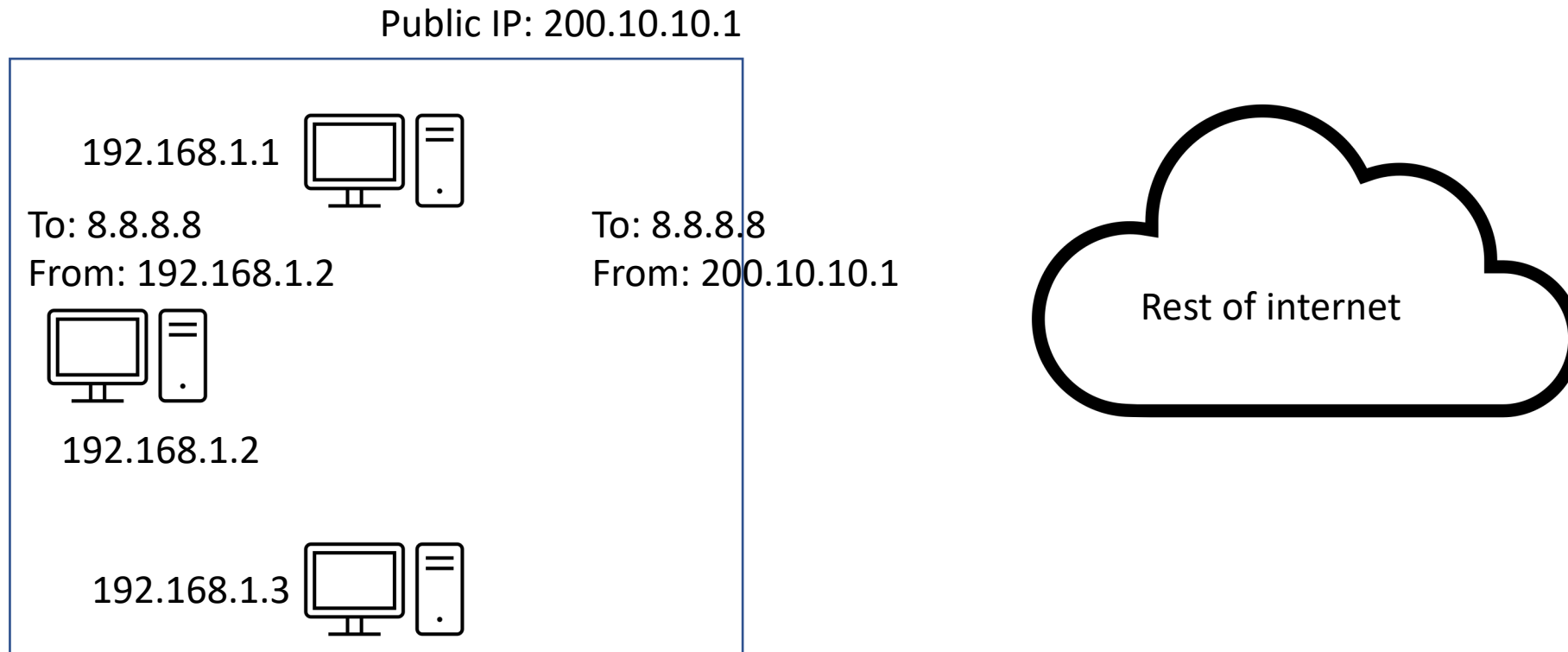


- Static: ex/ wired connection at workstation

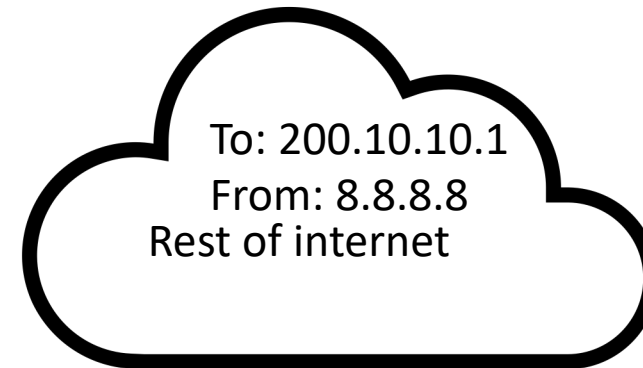
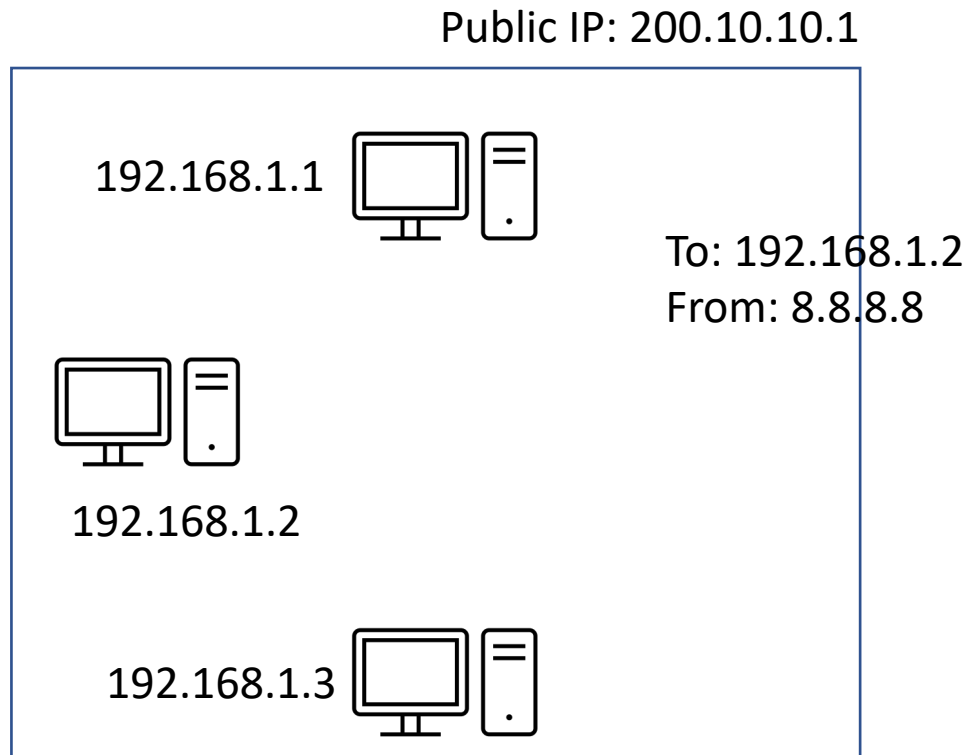


Not Enough IP Addresses?

- Use private IP addresses within a network and a single public IP outside

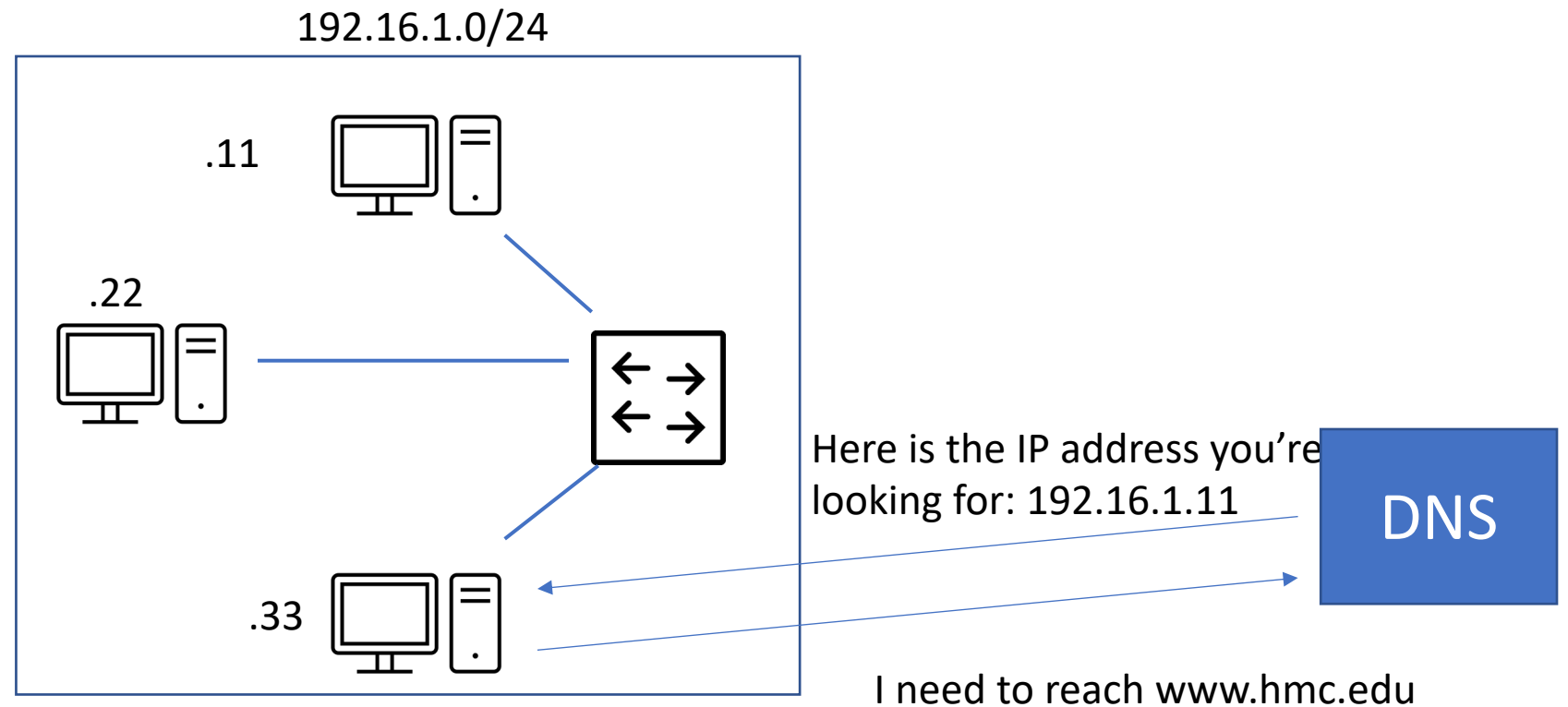


Not Enough IP Addresses?



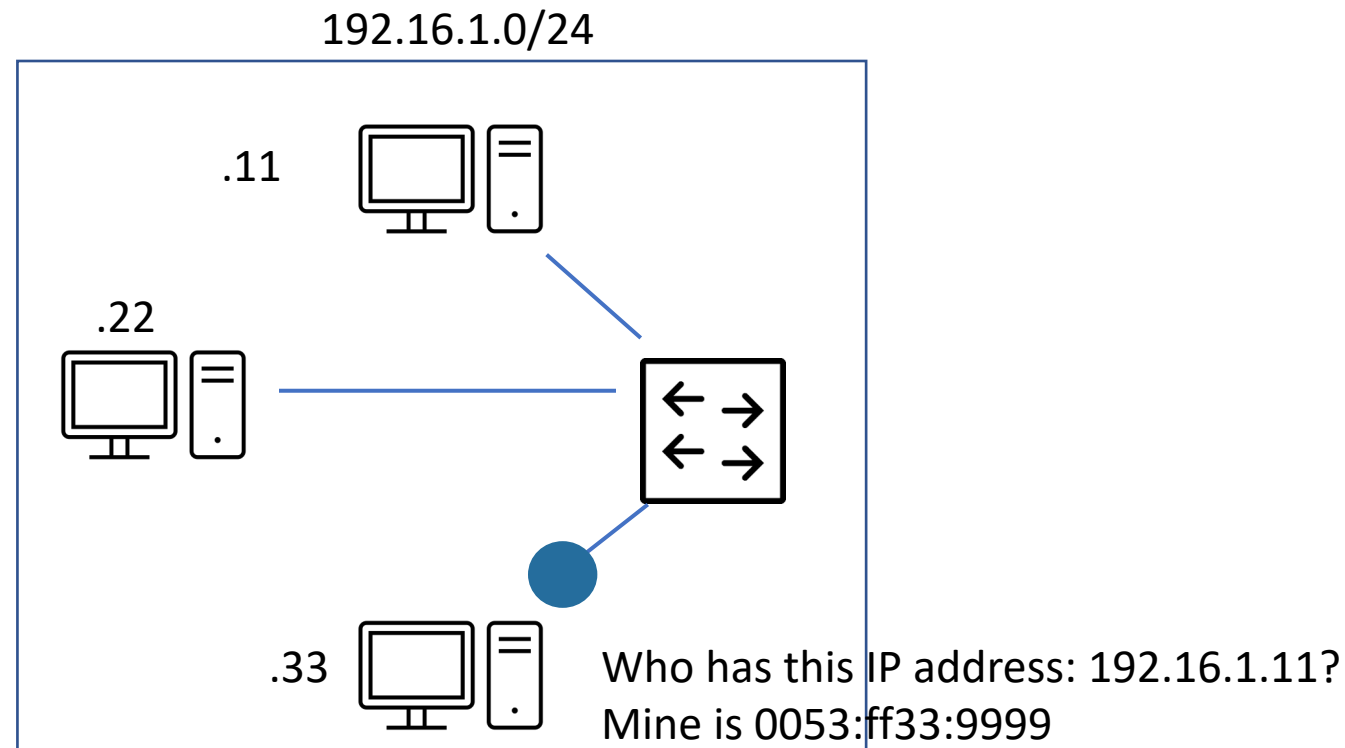
IP Addresses to MAC address?

- Address Resolution Protocol -> map from IP address (known) to MAC address (unknown)



IP Addresses to MAC address?

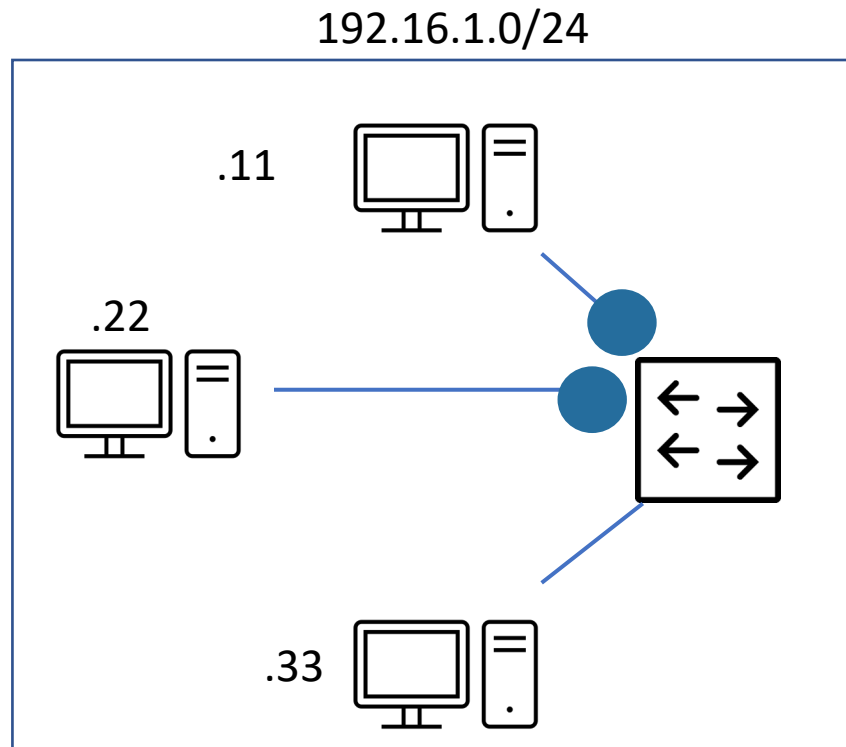
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DNS

IP Addresses to MAC address?

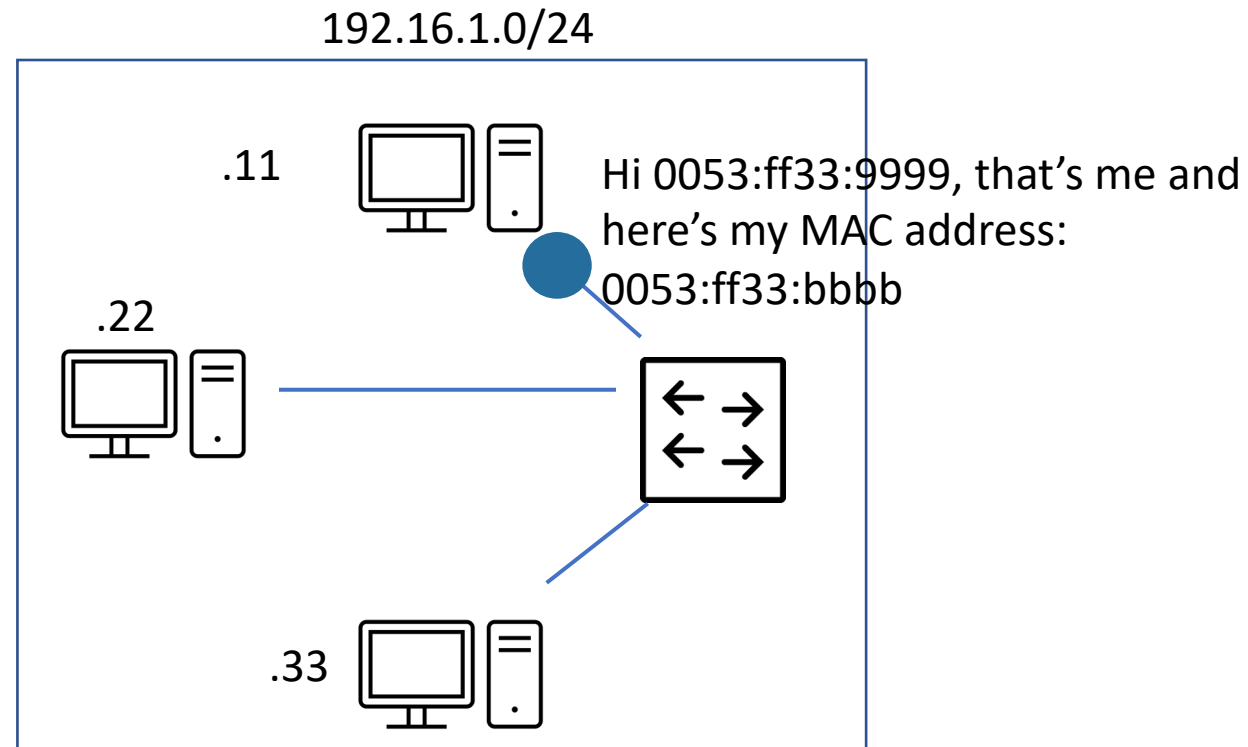
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DNS

IP Addresses to MAC address?

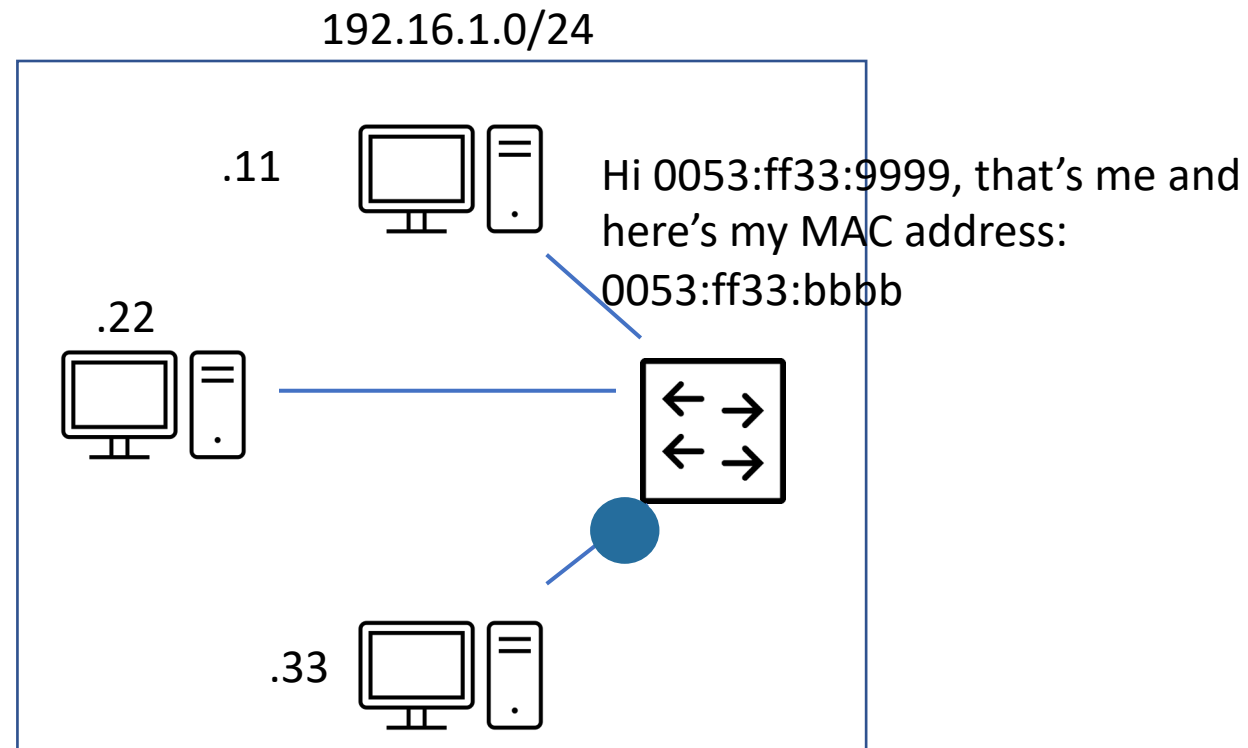
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DNS

IP Addresses to MAC address?

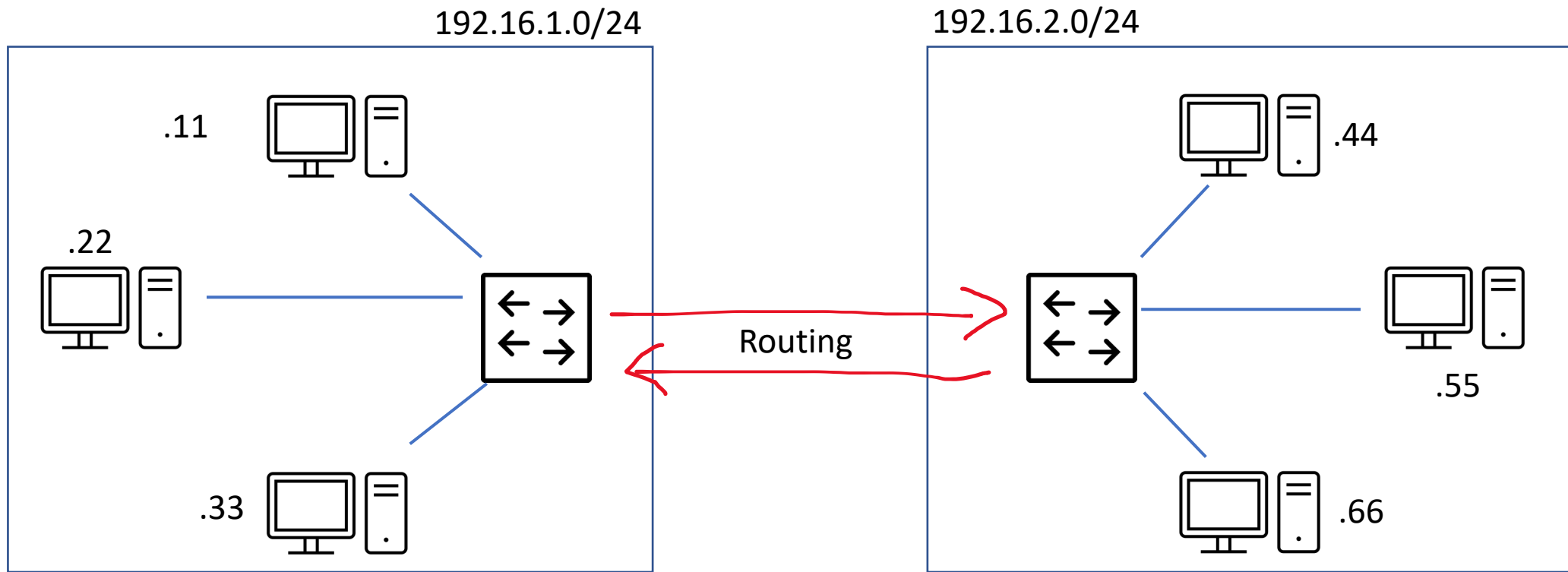
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DNS

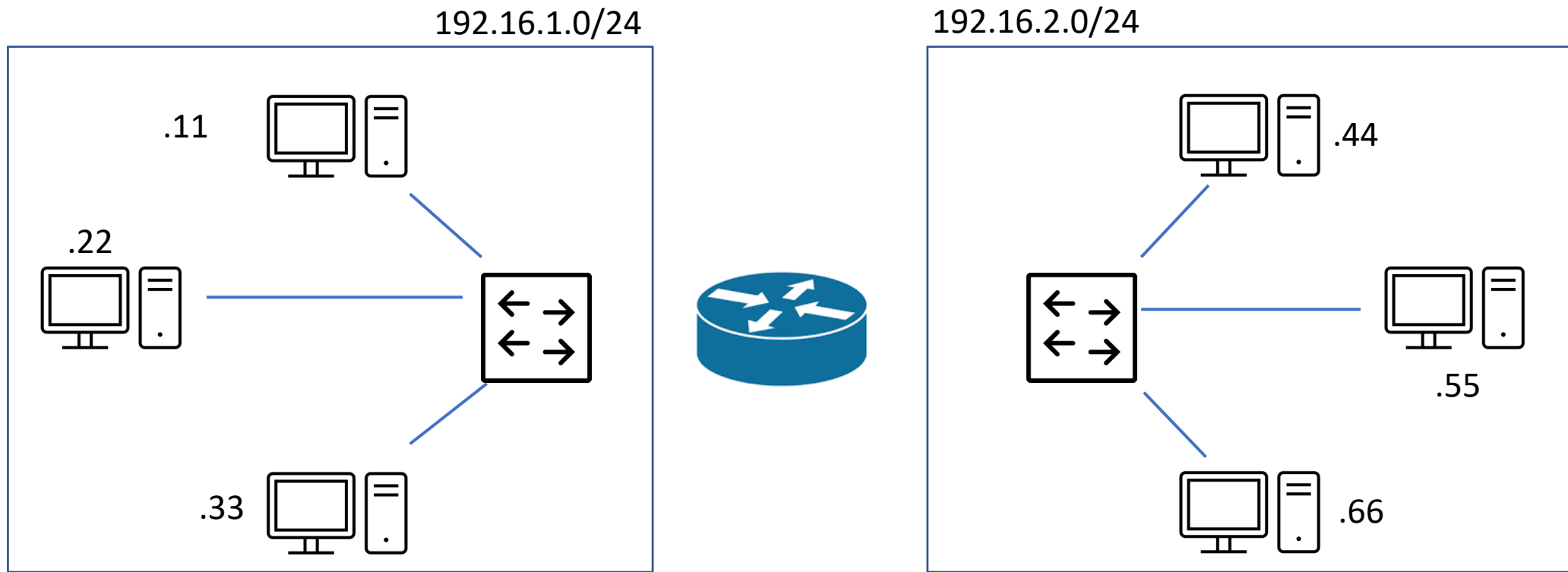
Routing

- For moving packets between networks (as opposed to switches that move packets within networks)



Routers

- For moving packets between networks (as opposed to switches that move packets within networks)
- Router: Device that forward packets based on IP addresses



Forwarding Information Base

- Adding each individual IP address does not scale!

| IP Address | Where to Send |
|-------------|---------------|
| 192.16.1.11 | Router 2 |
| 192.16.1.12 | Router 2 |
| 192.16.1.13 | Router 2 |

Forwarding Information Base

| IP Prefix | Where to Send |
|---------------|---------------|
| 192.16.1.0/24 | Router 2 |
| | |
| | |

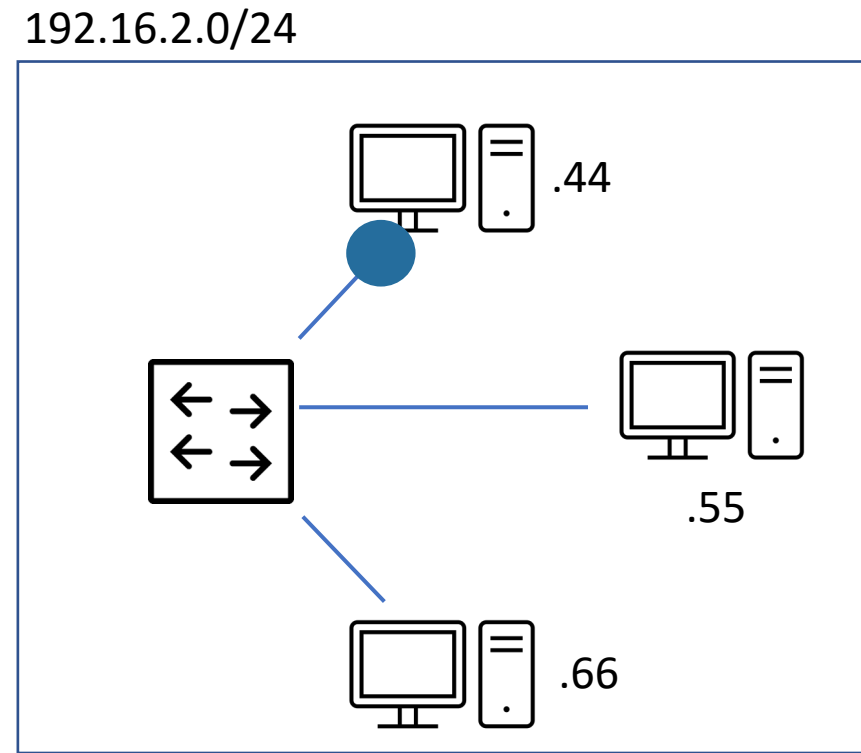
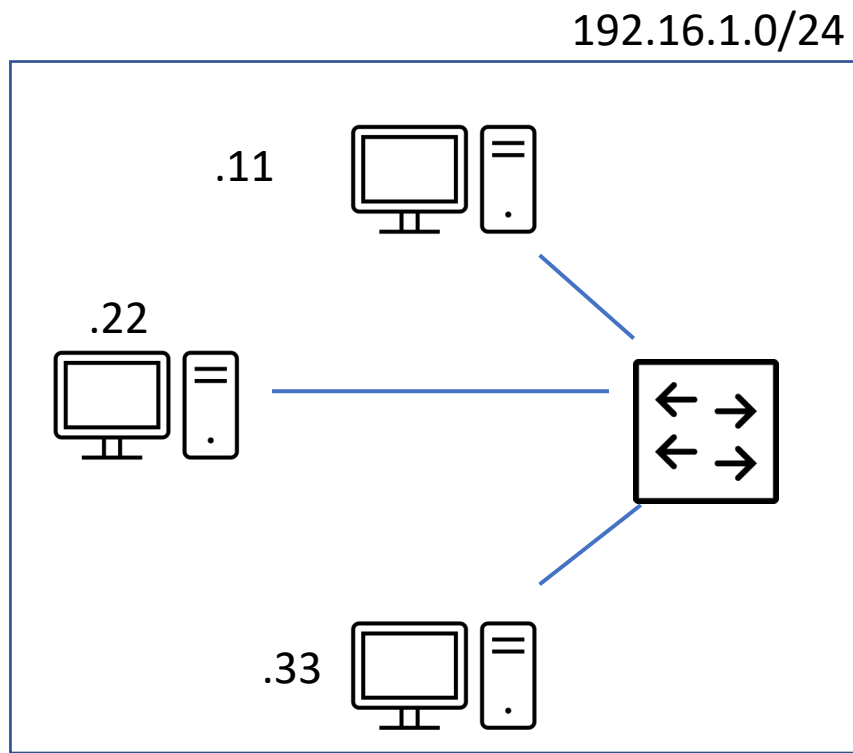
Forwarding Information Base

| IP Prefix | Where to Send |
|---------------|---------------|
| 192.16.1.0/24 | Router 2 |
| 192.16.1.15 | Router 3 |
| 192.16.1.19 | Router 1 |

- What if an address matches multiple prefixes?
- “All flights to the US go through Boston except those going to CA – then go through LA”
- -> Choose the longest matching prefix

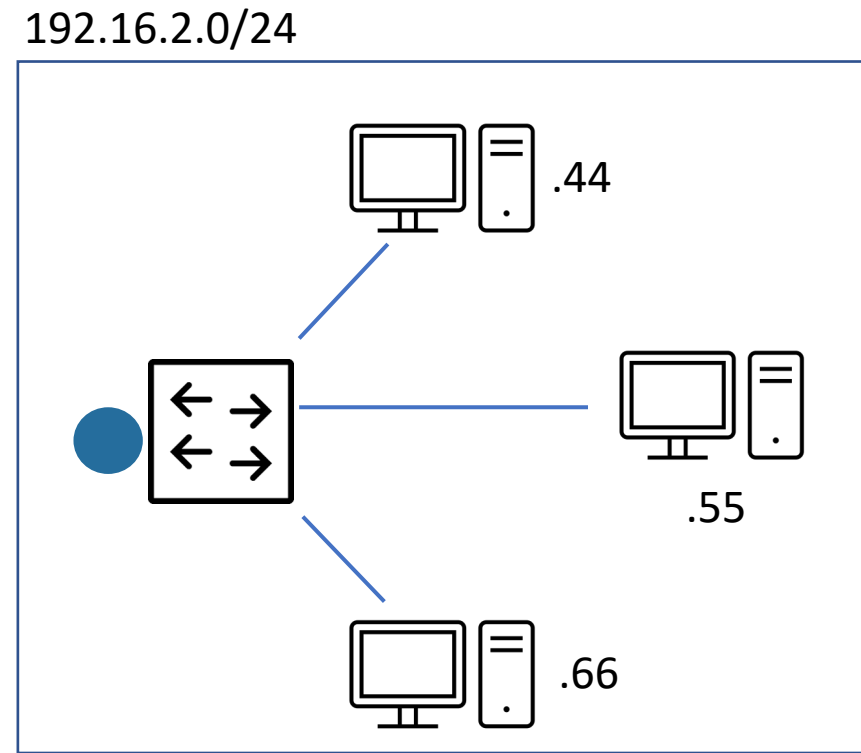
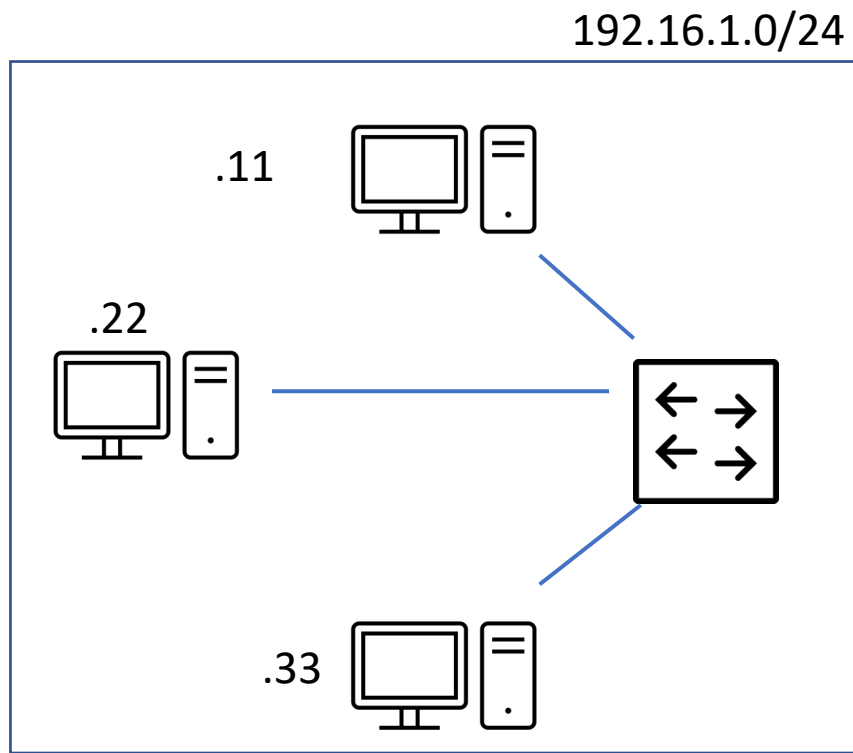
Routing Example

src: 192.16.2.44
dst: 192.16.1.33



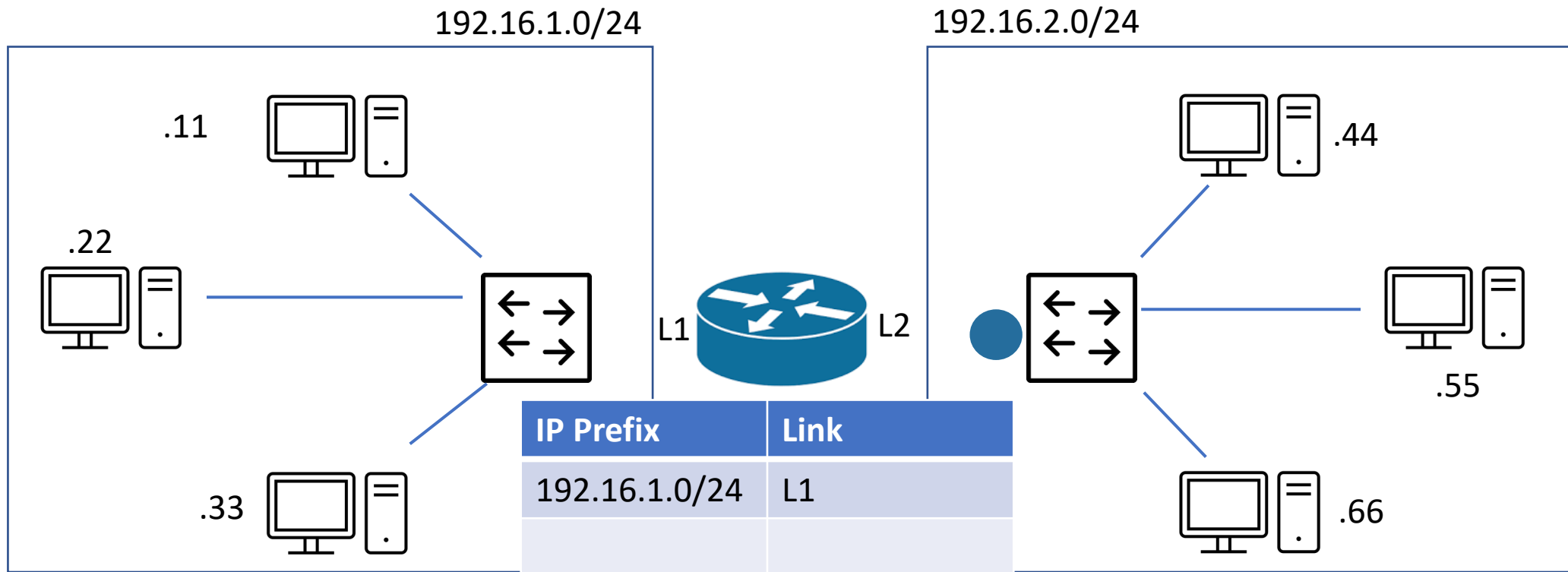
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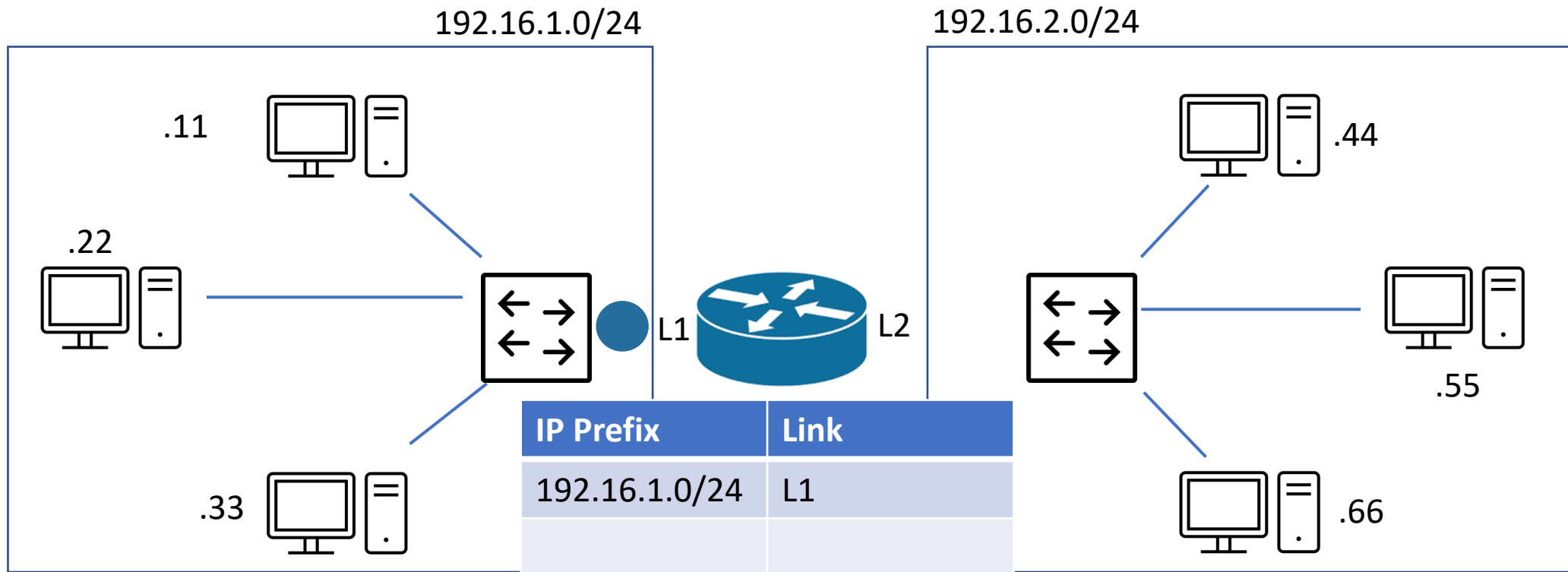
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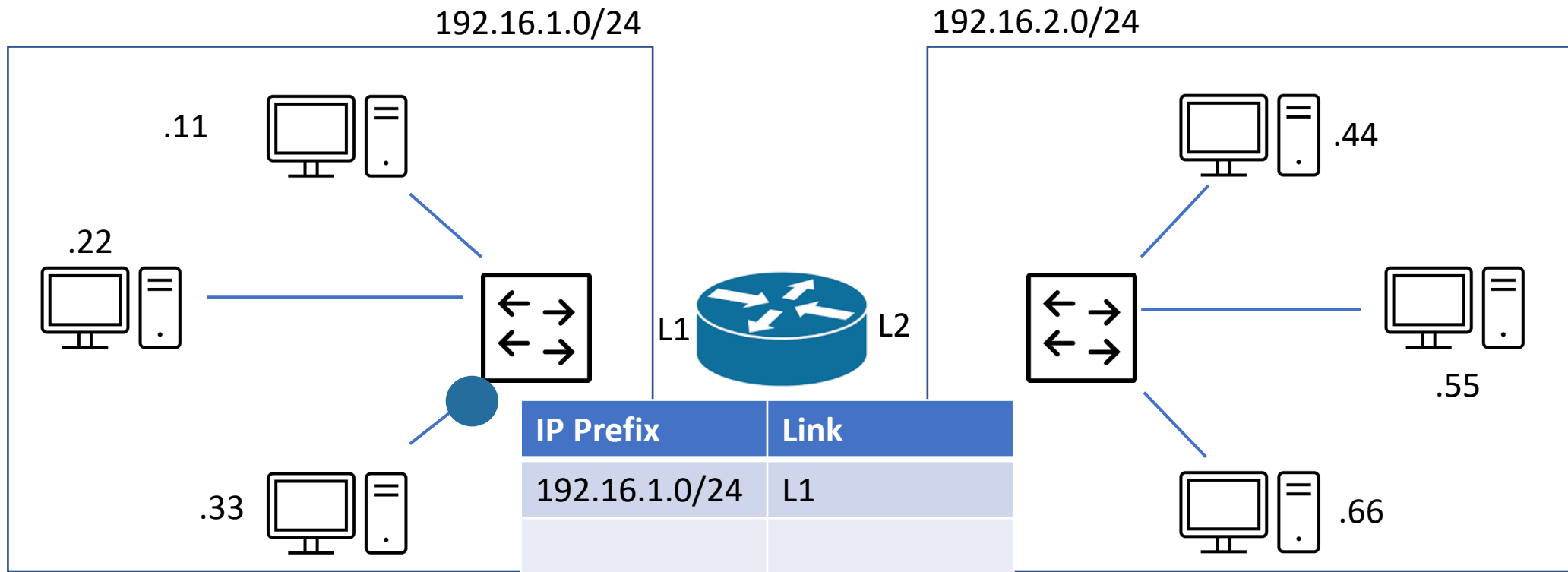
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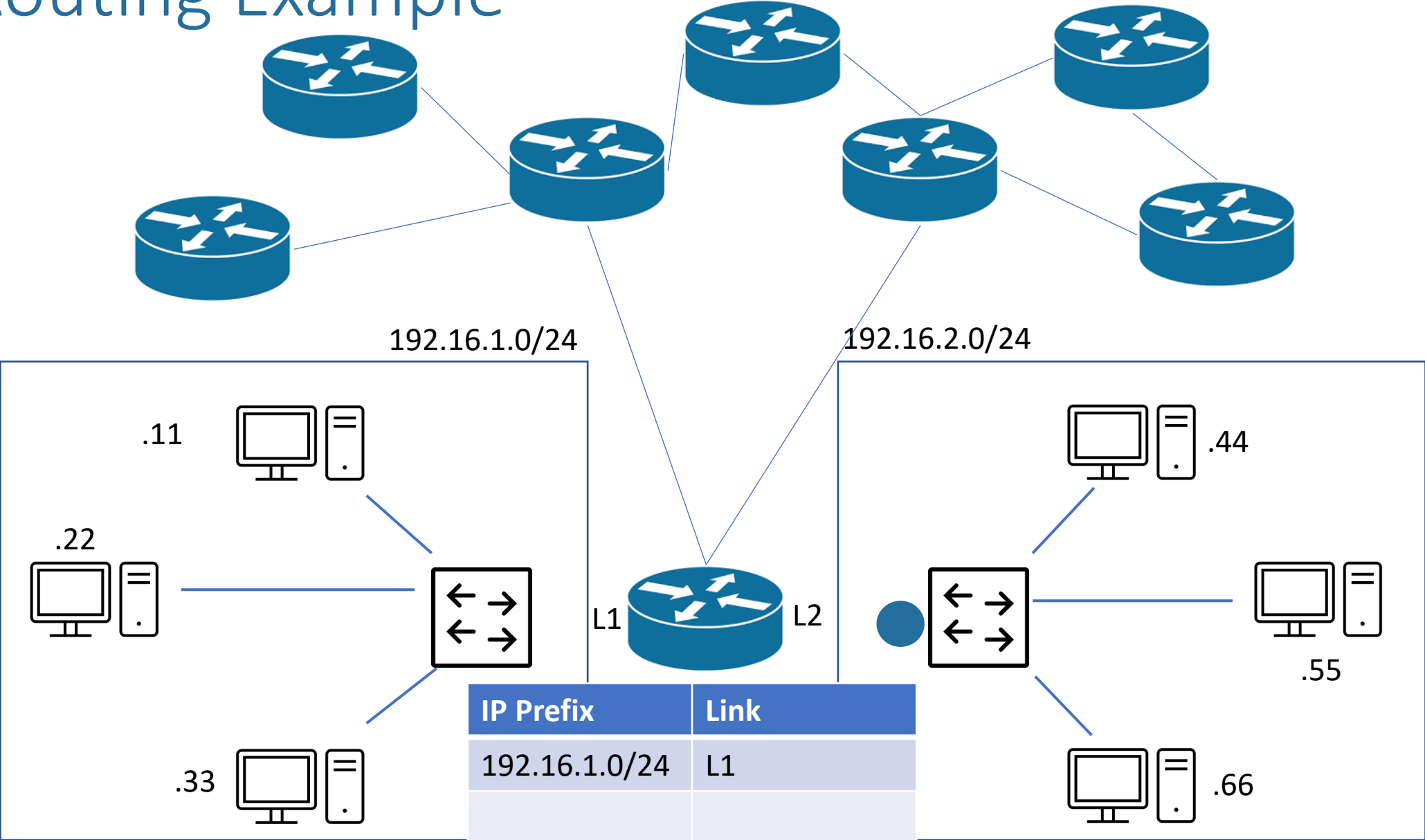


Routing Example

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Routing Example



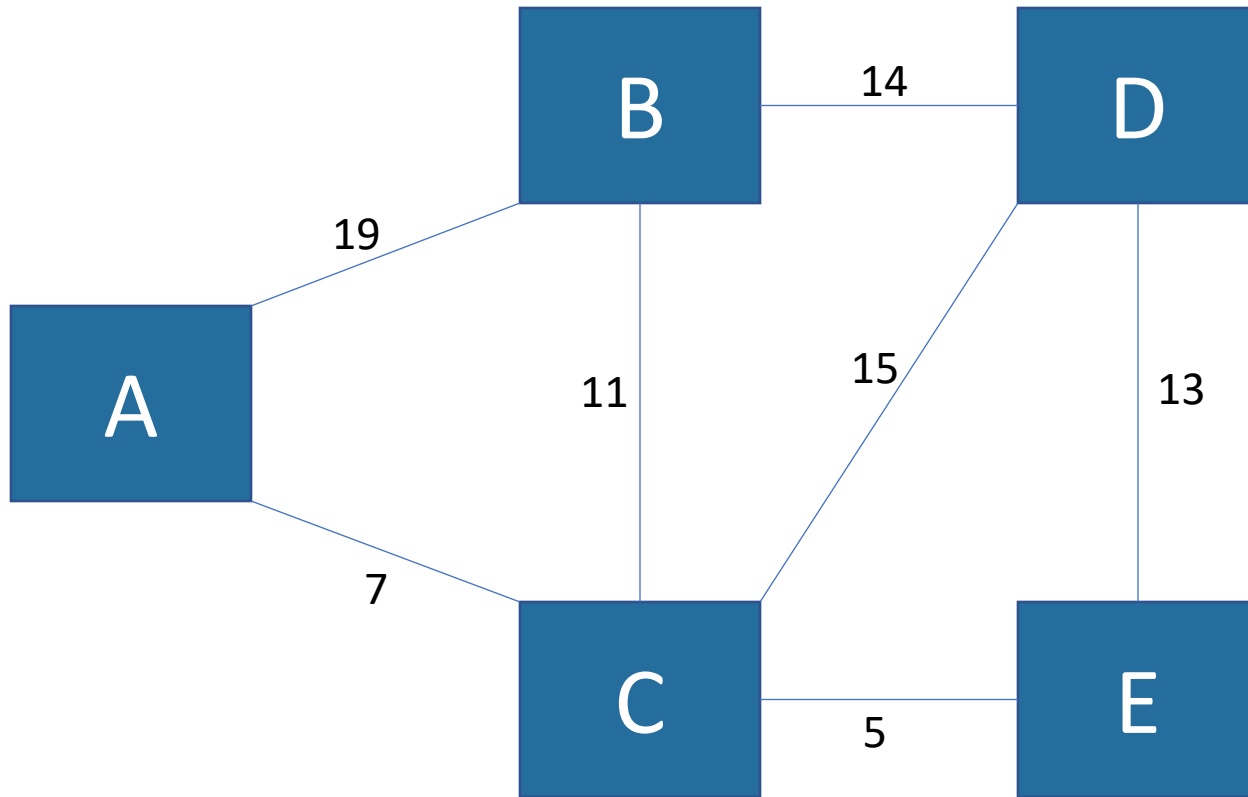
Guts of a Router

- Forwarding plane:
 - How do we *efficiently* look up the FIB and forward packets?
- Control plane:
 - How do we populate the FIB?
 - Many algorithms – we'll cover some (OSPF, BGP)

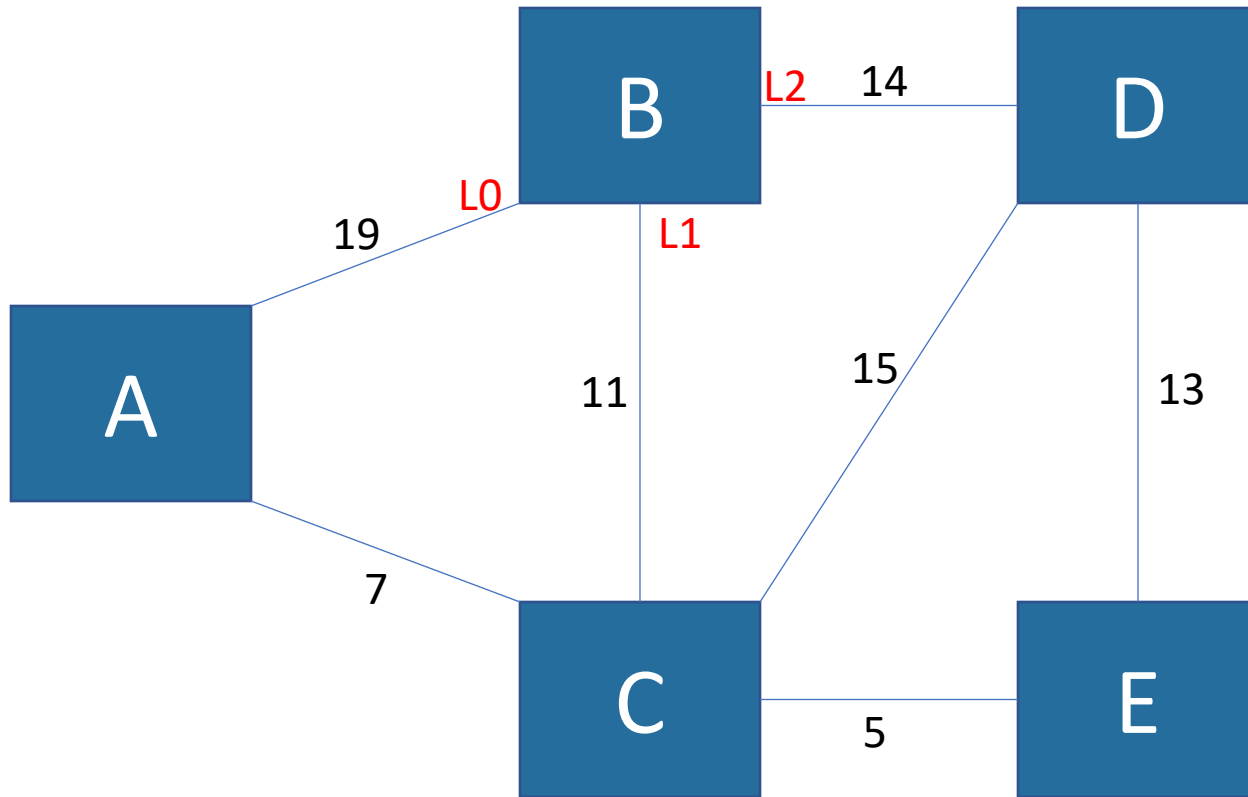
Guts of a Router

- Forwarding plane:
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Example Topology



Example Topology



B's FIB

| Dst | Link | Cost |
|-----|------|------|
| | | |
| | | |
| | | |
| | | |
| | | |

Routing Game

- You will receive a card that says “You are X” and on the back; “your connections are X: *cost* and Z: *cost*”
- Find the lowest cost path from src to dst
- You may not leave your seat
- You may talk to your neighbors or the room

Routing Protocol Categories

- Distance-Vector: each node “advertises” the routes through it to its neighbors
- Link-State: each node builds the whole topology in its knowledge base