

Layers

application	Firefox, ping, ...
transport	TCP, UDP, ...
network	IP
link	ethernet, WiFi, ...
physical	electrons, photons, ...

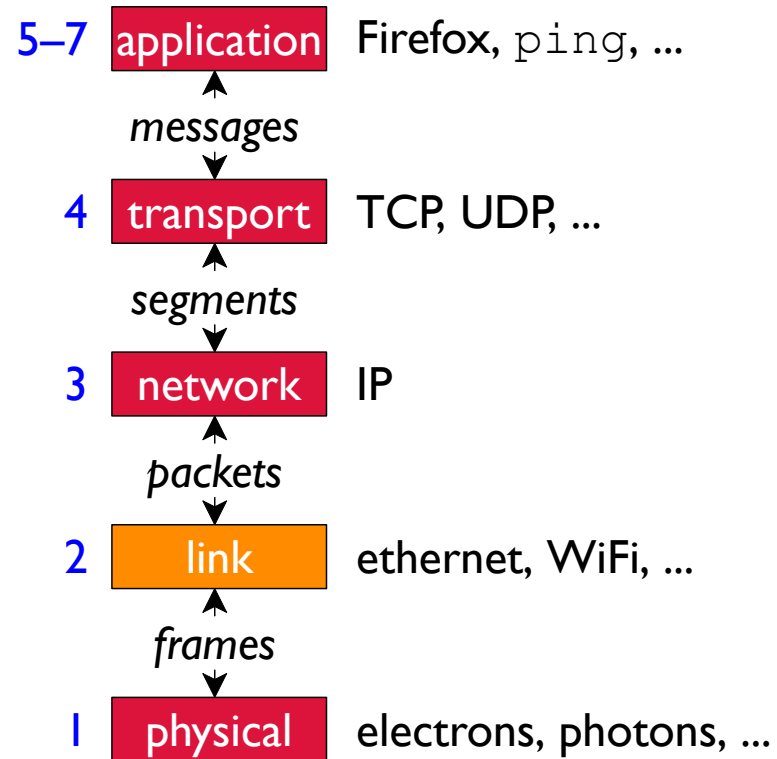
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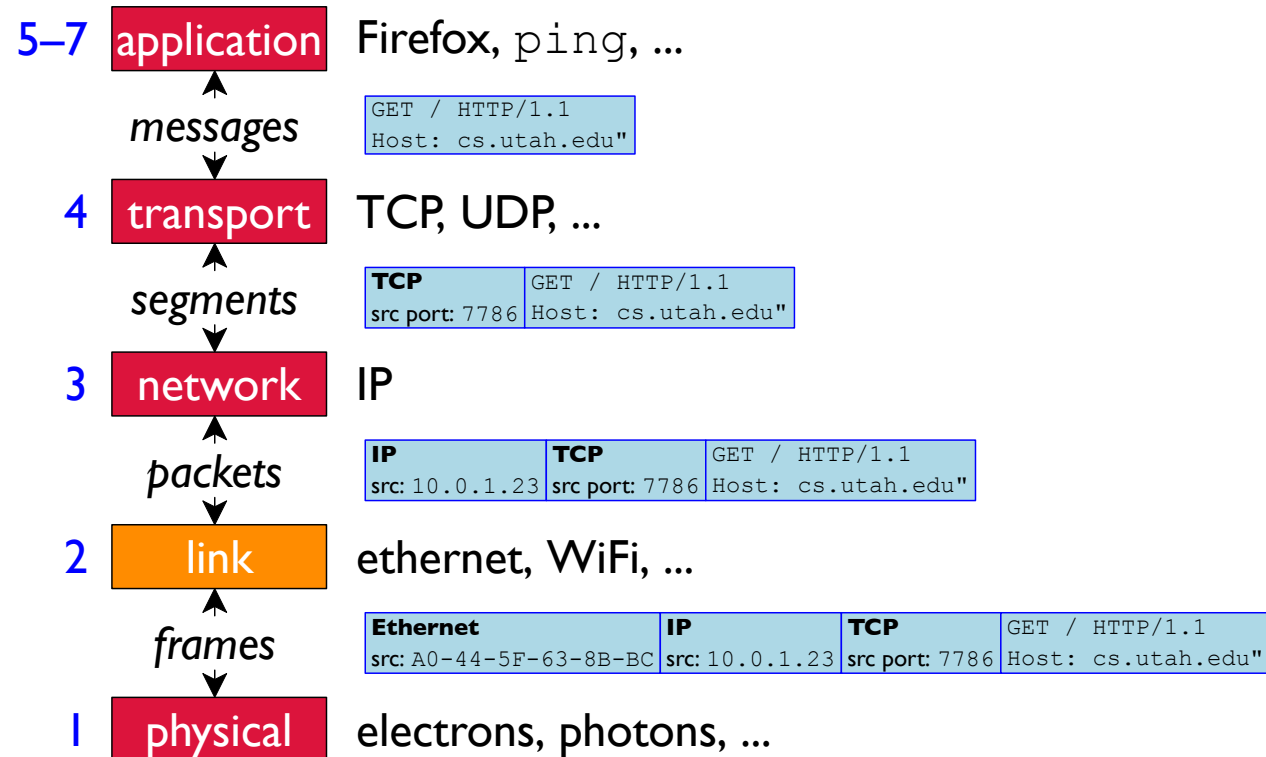
Layers

5–7	application	Firefox, ping, ...
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3	network	IP
2	link	ethernet, WiFi, ...
1	physical	electrons, photons, ...

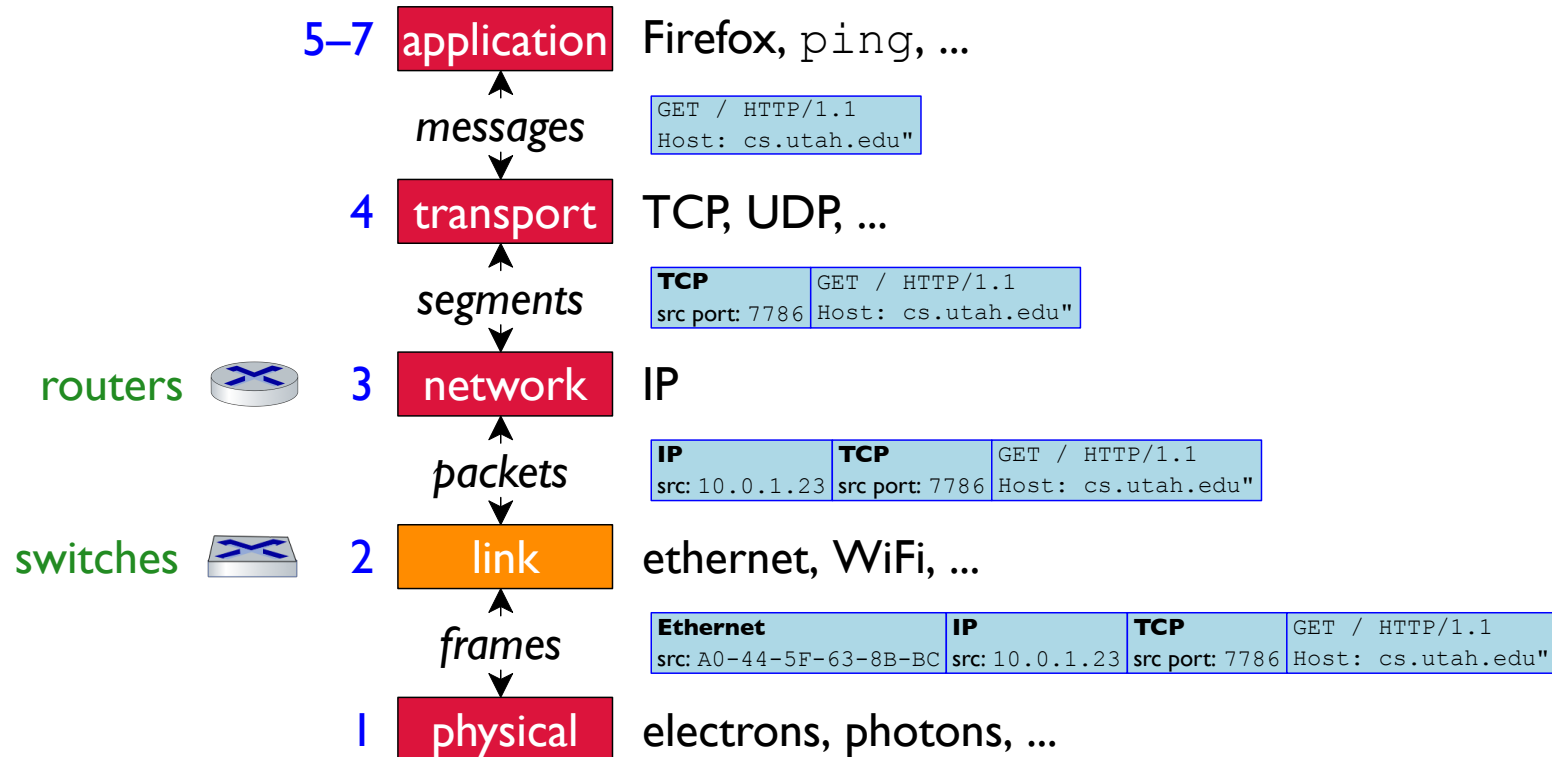
Layers



Layers



Layers



Network vs. Link Addresses

Network addresses as **IP** addresses:

Link addresses as **MAC (medium access control)** addresses:

Network vs. Link Addresses

Network addresses as **IP** addresses:

155.98.69.112 — 32 bits

2607:f8b0:4025::2004 — 128 bits

Link addresses as **MAC (medium access control)** addresses:

A4-CF-99-90-44-DE — 48 bits for Ethernet

Network vs. Link Addresses

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Hierarchical by proximity, to some degree

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Limited structure / hierarchical by manufacturer

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Limited structure / hierarchical by manufacturer

Interface always knows its MAC more like an *identity* than an *address*

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Link addresses as **MAC (medium access control)** addresses:

A4-CF-99-90-44-DE — 48 bits for Ethernet

Limited structure / hierarchical  Phones may randomize identity, though

Interface always knows its MAC more like an *identity* than an *address*

Network vs. Link Addresses

Network addresses as **IP** addresses:

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2607:f8b0:4025::2004 — 128 bits

Hierarchical by proximity, to some degree

Needs to be configured

MAC addresses are shown by `ifconfig`

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Limited structure / hierarchical by manufacturer

Interface always knows its MAC more like an *identity* than an *address*

Address Resolution Protocol (ARP)

Ethernet	IP	TCP	
src: A0-44-5F-63-8B-BC	src: 10.0.1.23	src port: 7786	GET / HTTP/1.1
dest: ???	dest: 141.193.213.10	dest port: 80	Host: cs.utah.edu"

Address Resolution Protocol (ARP)

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In **Local-area network (LAN)** ⇒ need host's MAC

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Link layer analog to network layer **subnet**

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dest: ???	dest: 141.193.213.10	dest port: 80	Host: cs.utah.edu"

Out of LAN $\Rightarrow$ need router's MAC

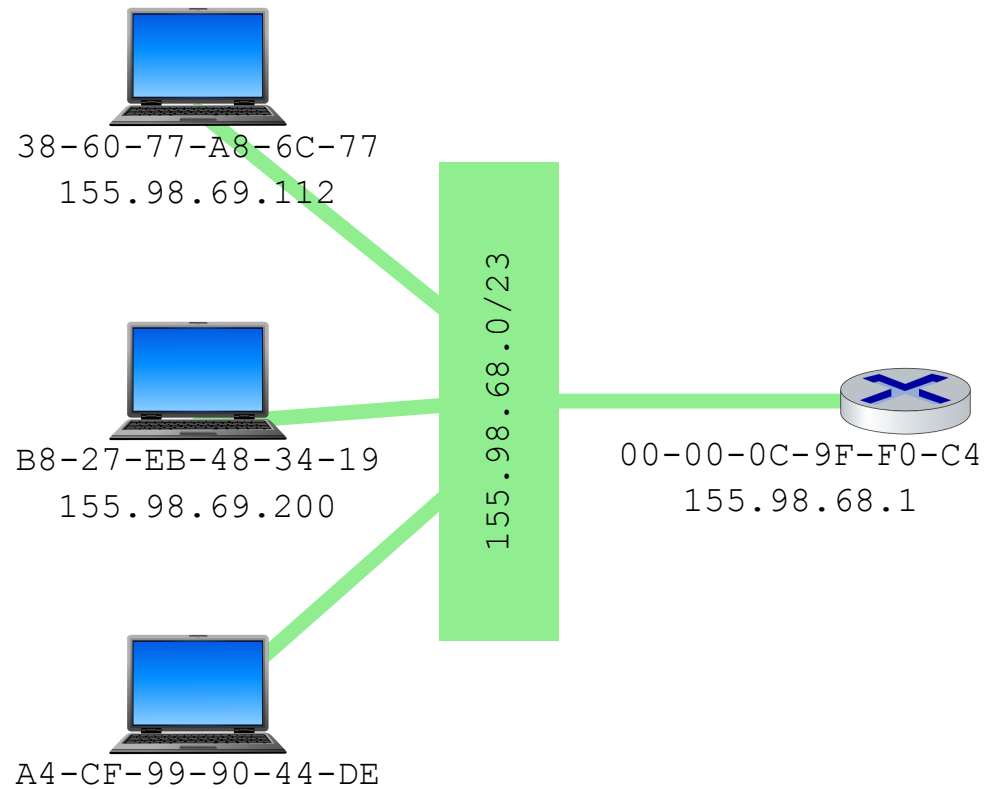
Address Resolution Protocol (ARP)

Ethernet	IP	TCP	
src: A0-44-5F-63-8B-BC	src: 10.0.1.23	src port: 7786	GET / HTTP/1.1
dest: 00-00-0C-9F-F0-C4	dest: 141.193.213.10	dest port: 80	Host: cs.utah.edu"

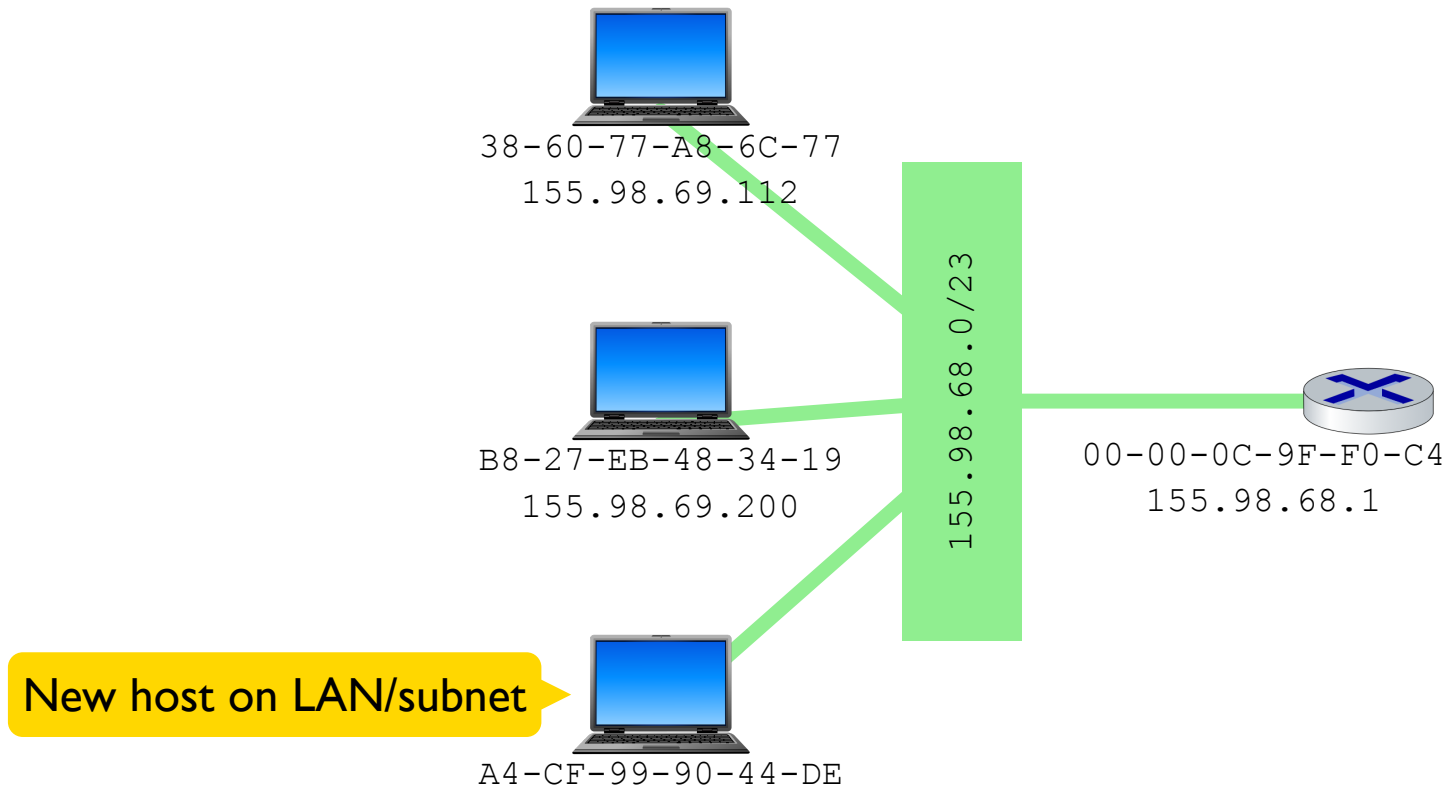
ARP is a LAN protocol to get IP → MAC mappings

Uses FF-FF-FF-FF-FF-FF broadcast address

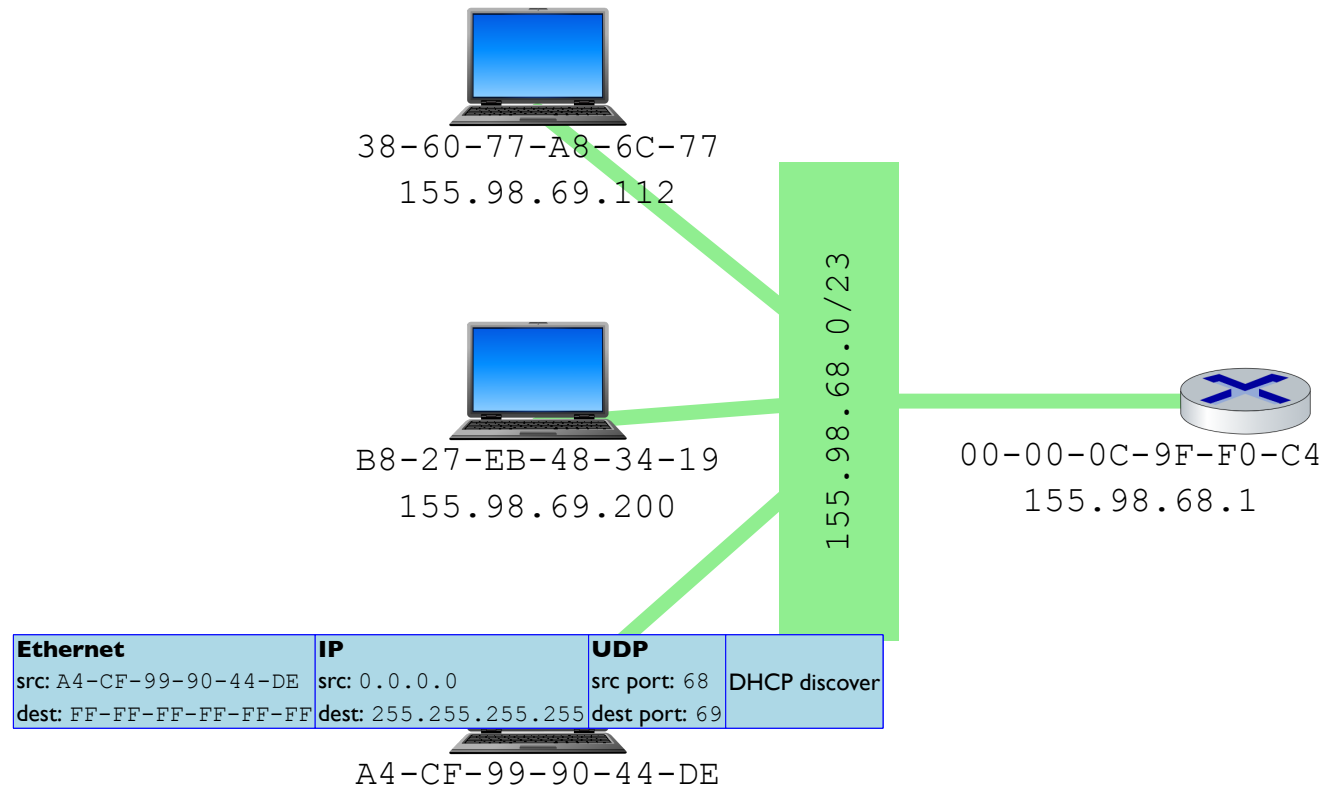
From DHCP to ARP to HTTP



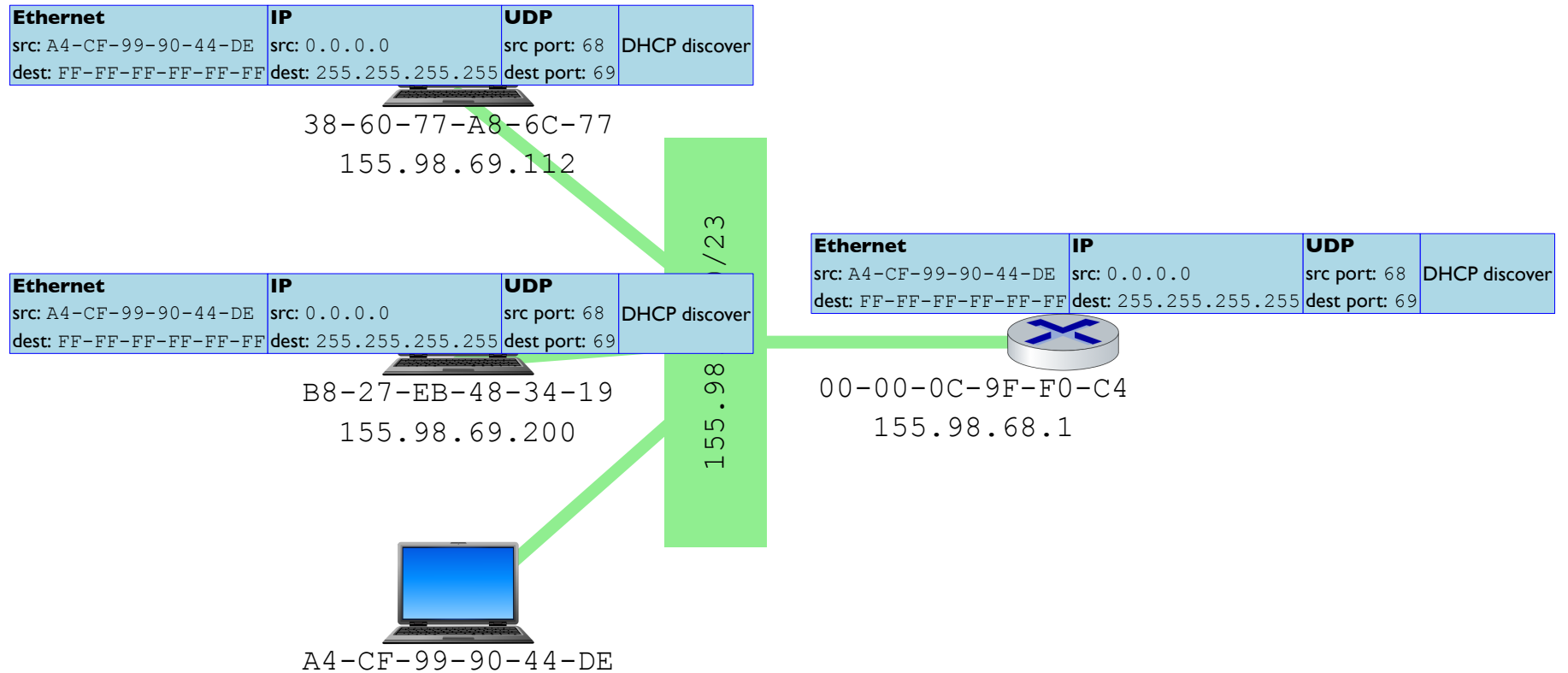
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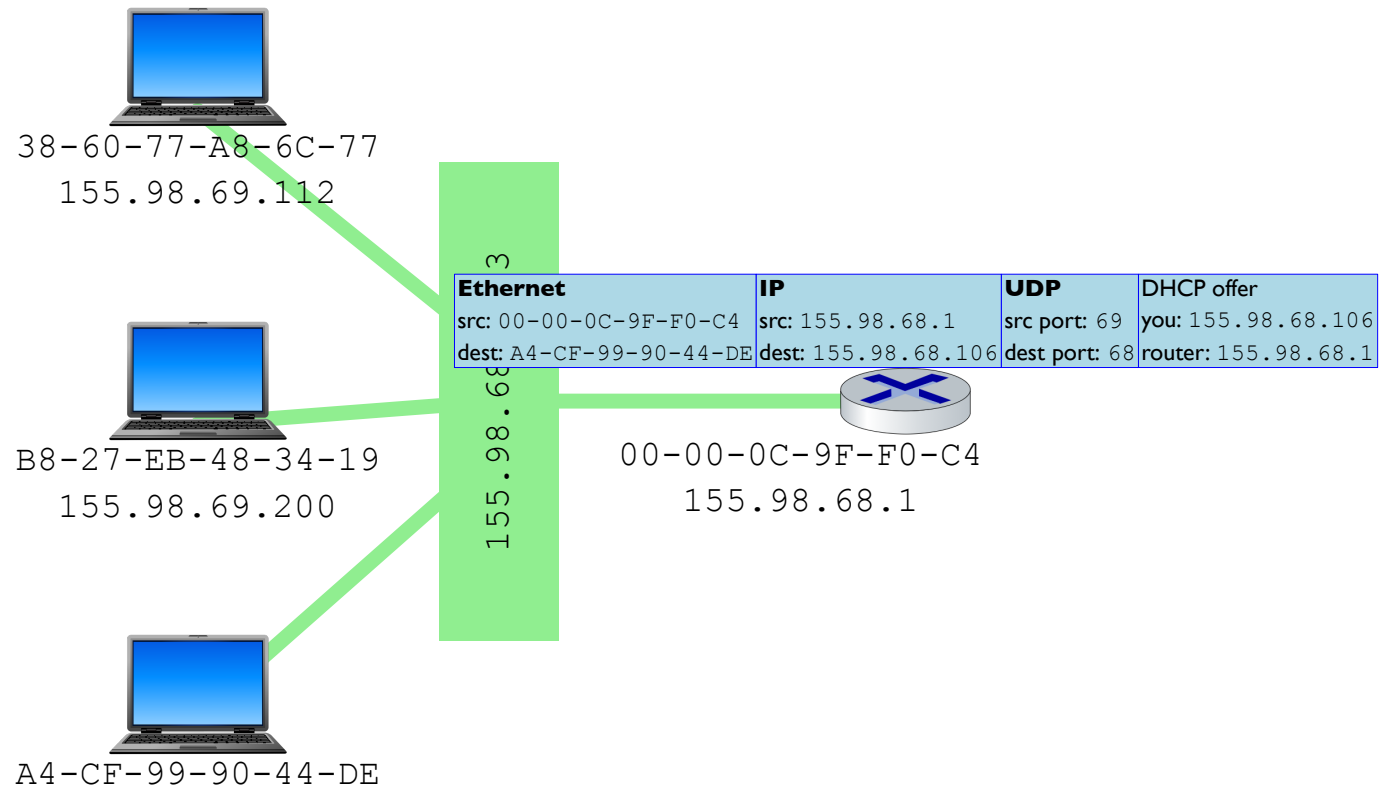
From DHCP to ARP to HTTP



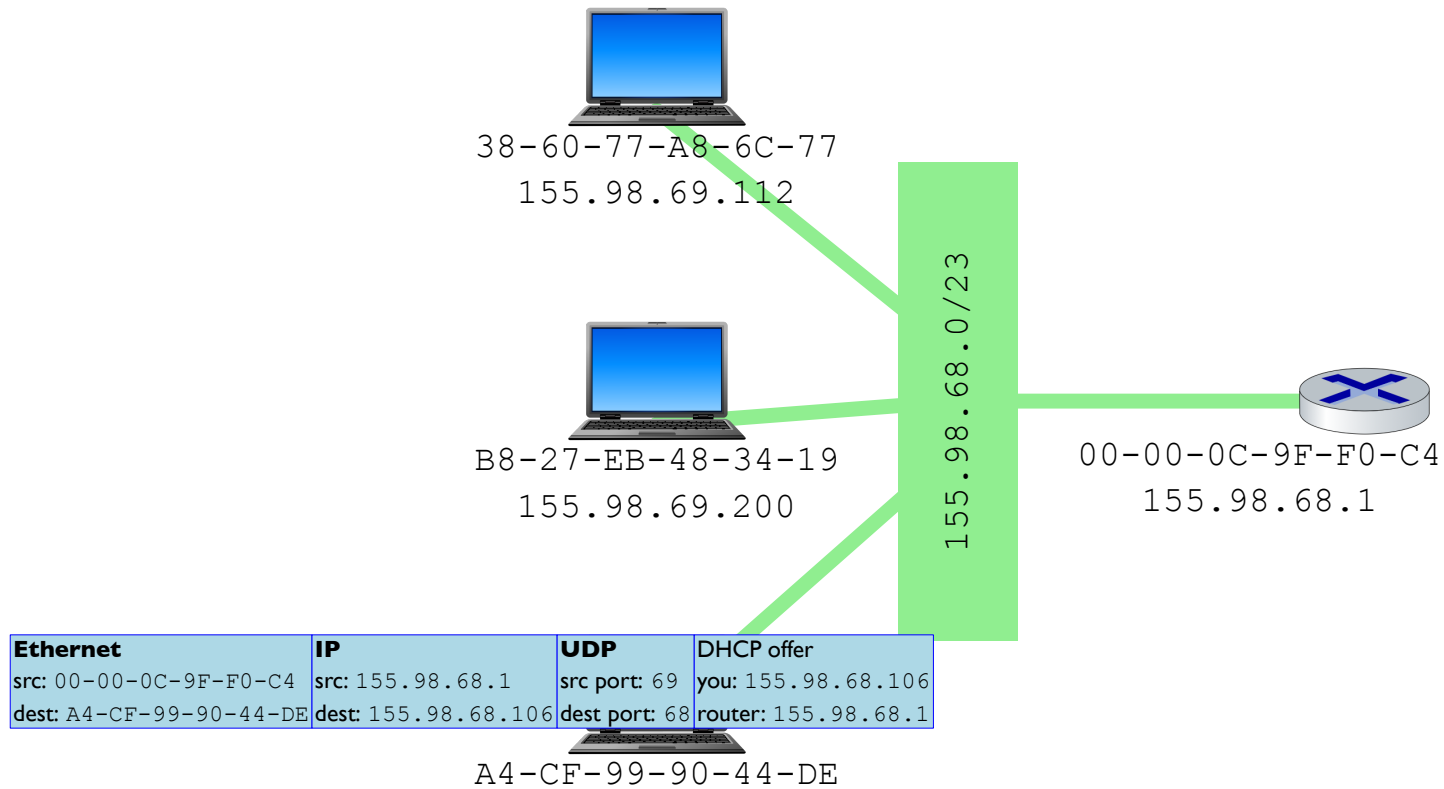
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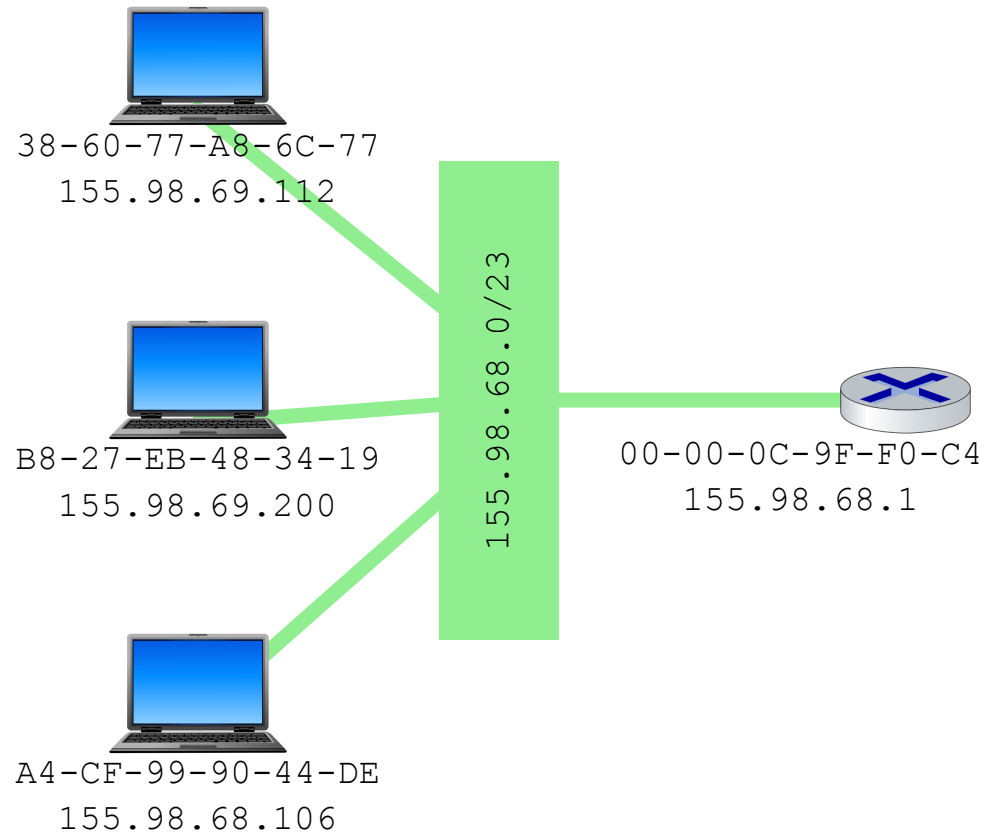
From DHCP to ARP to HTTP



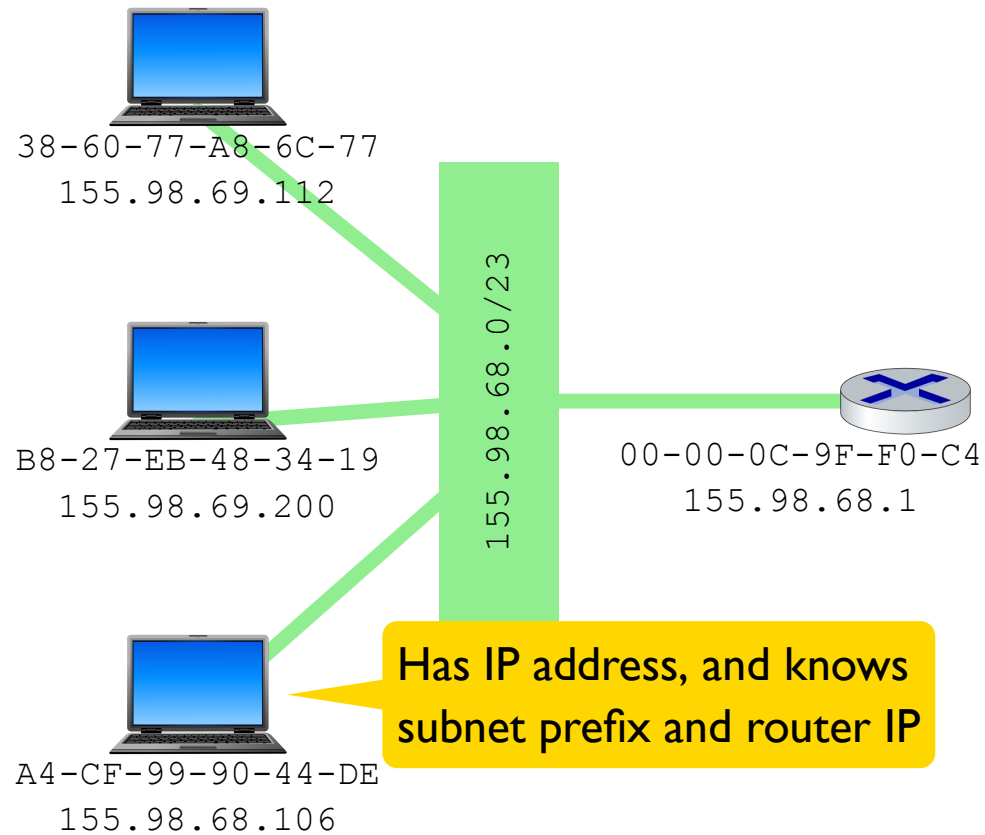
From DHCP to ARP to HTTP



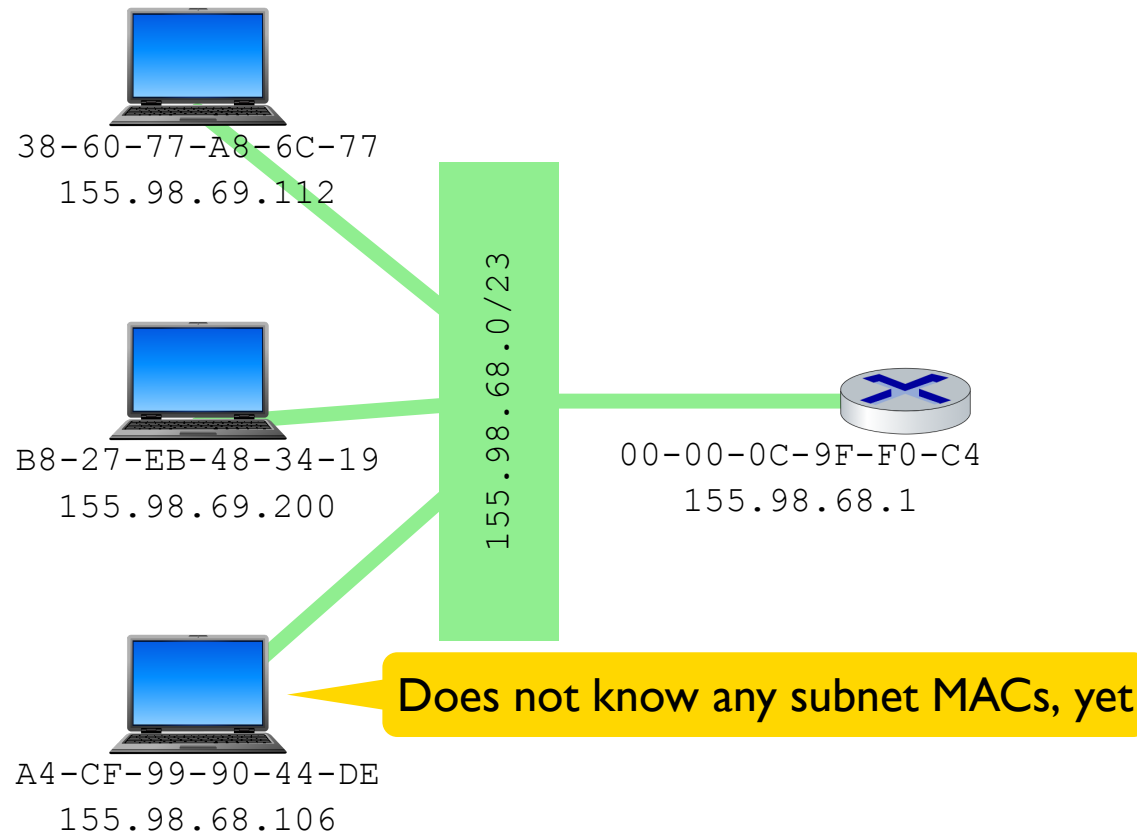
From DHCP to ARP to HTTP



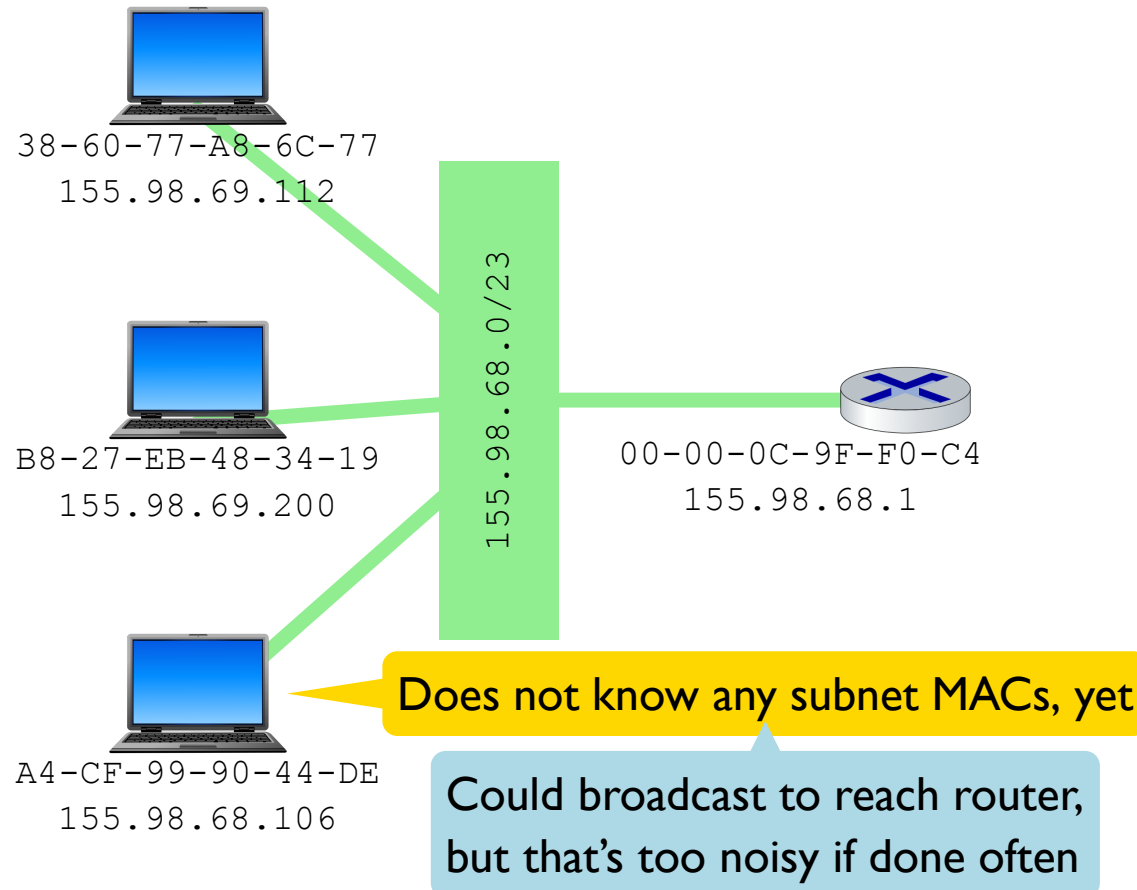
From DHCP to ARP to HTTP



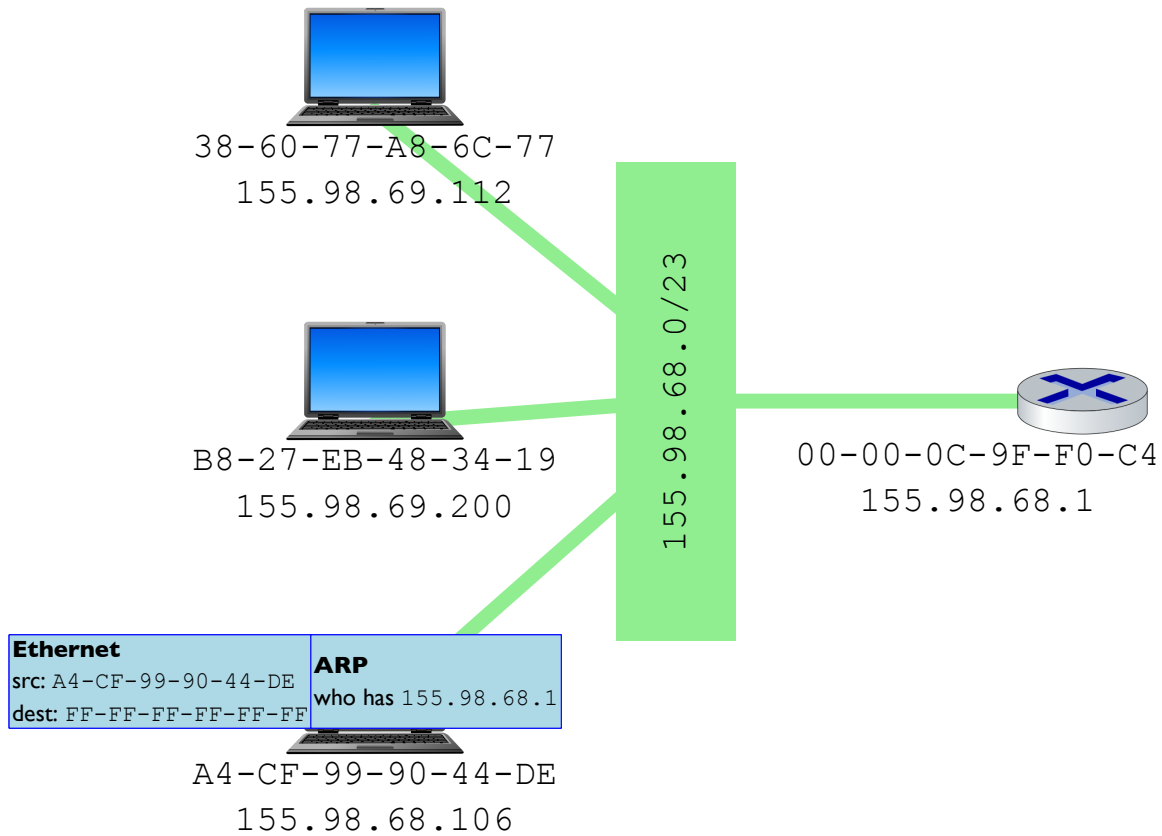
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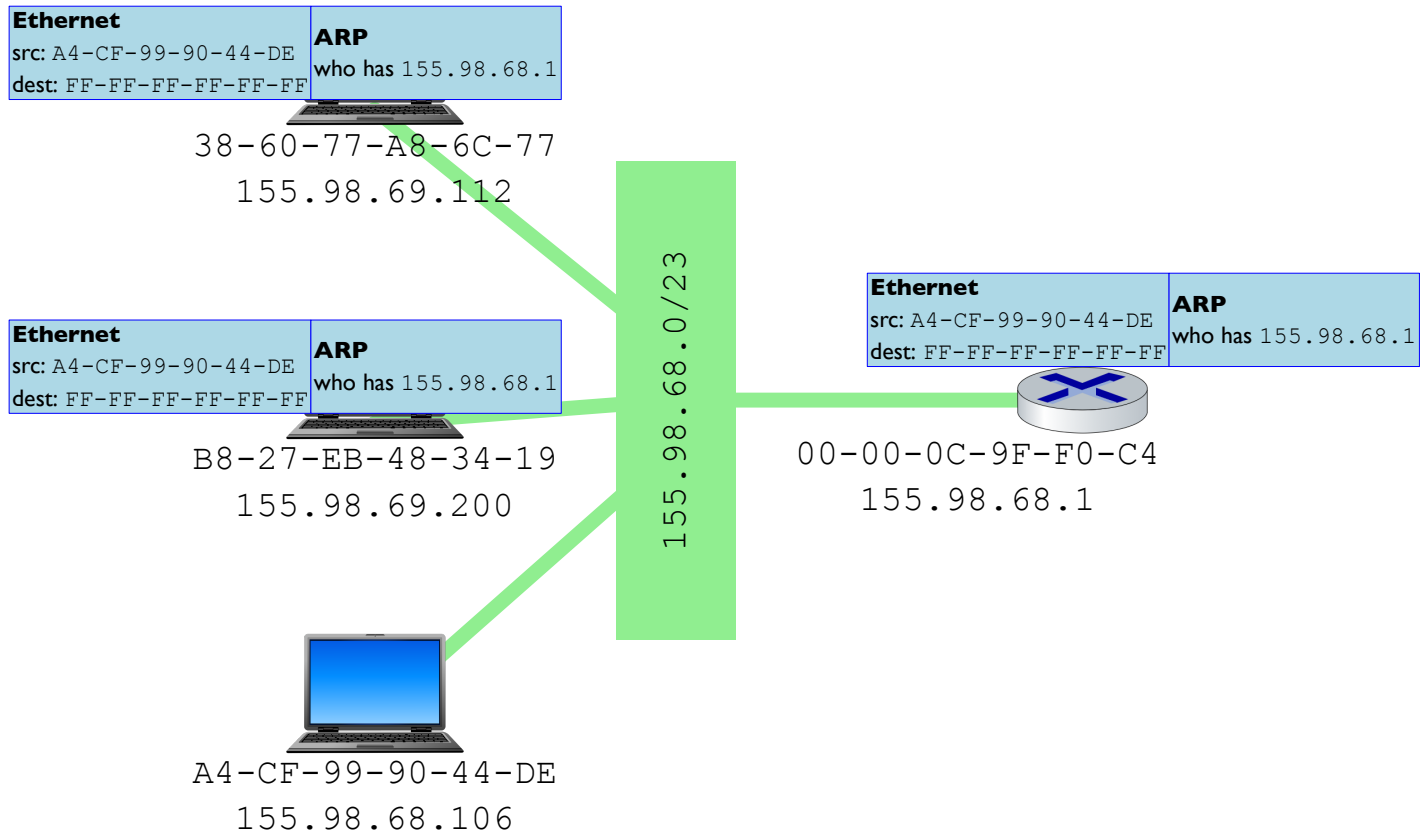
From DHCP to ARP to HTTP



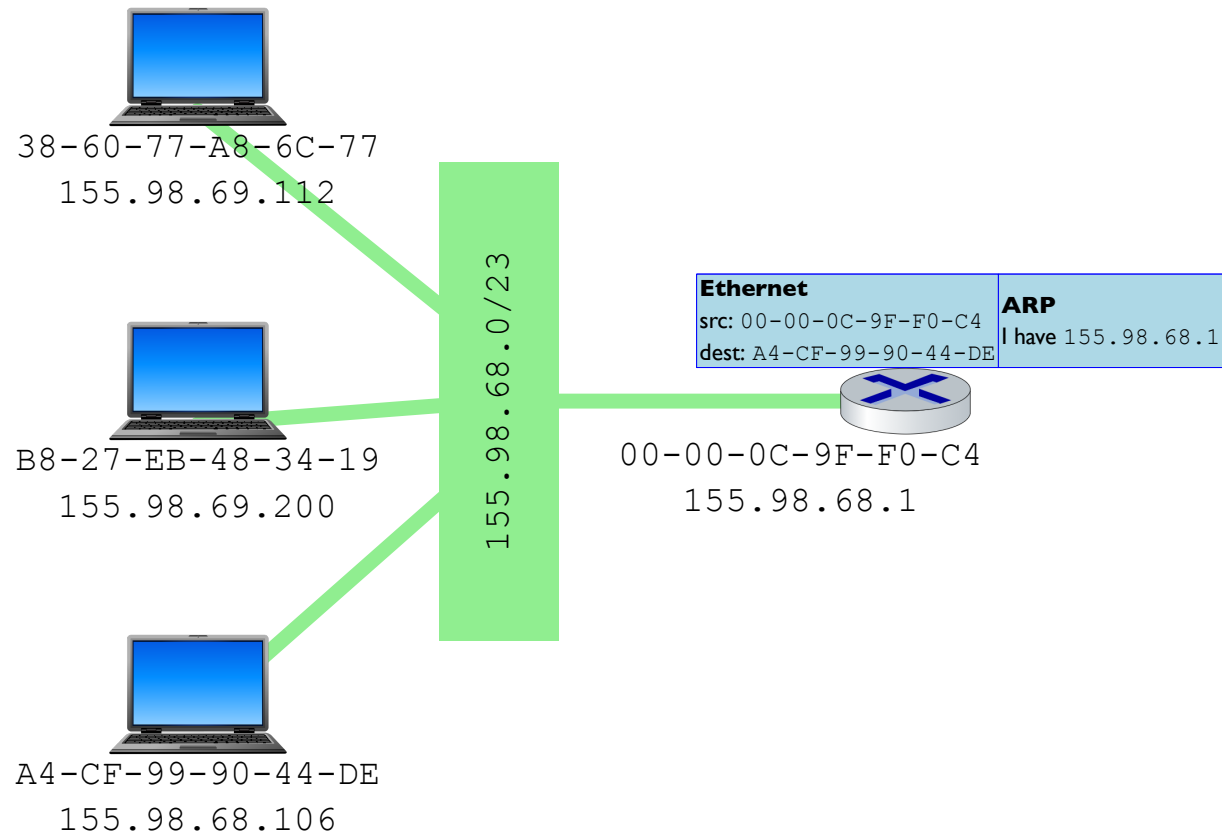
From DHCP to ARP to HTTP



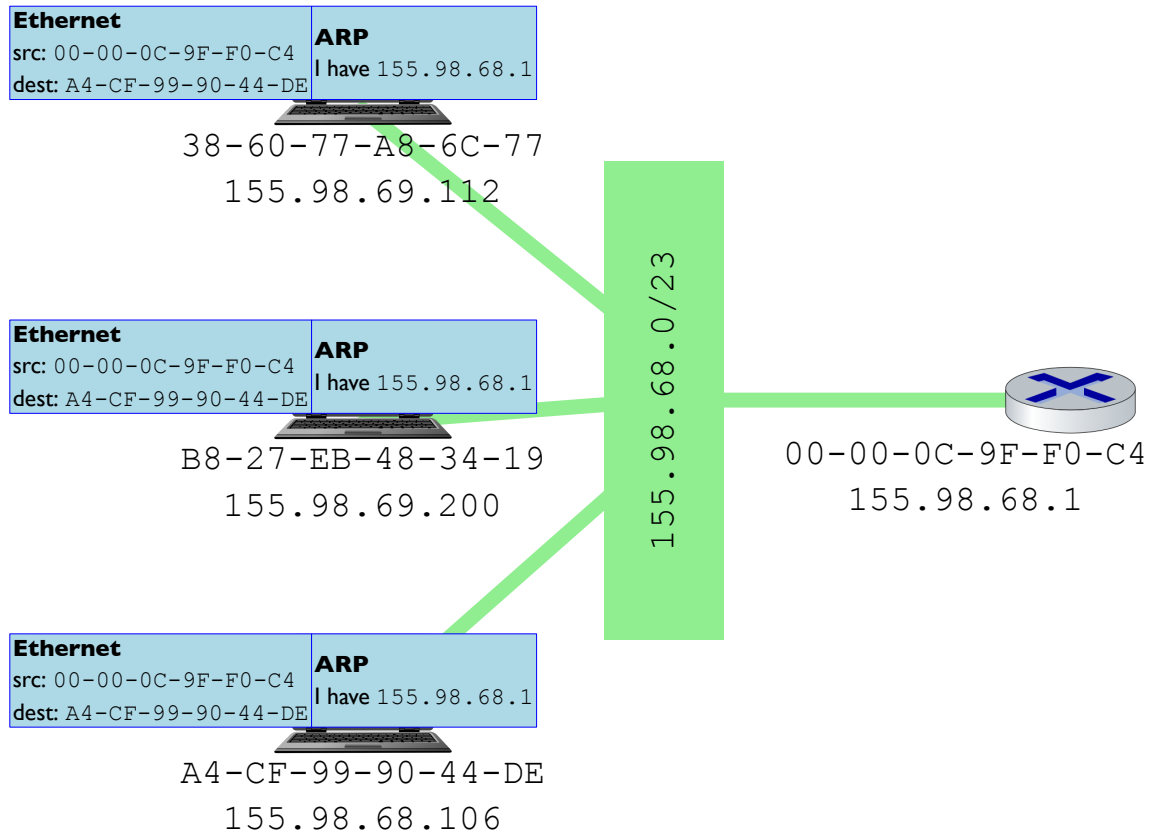
From DHCP to ARP to HTTP



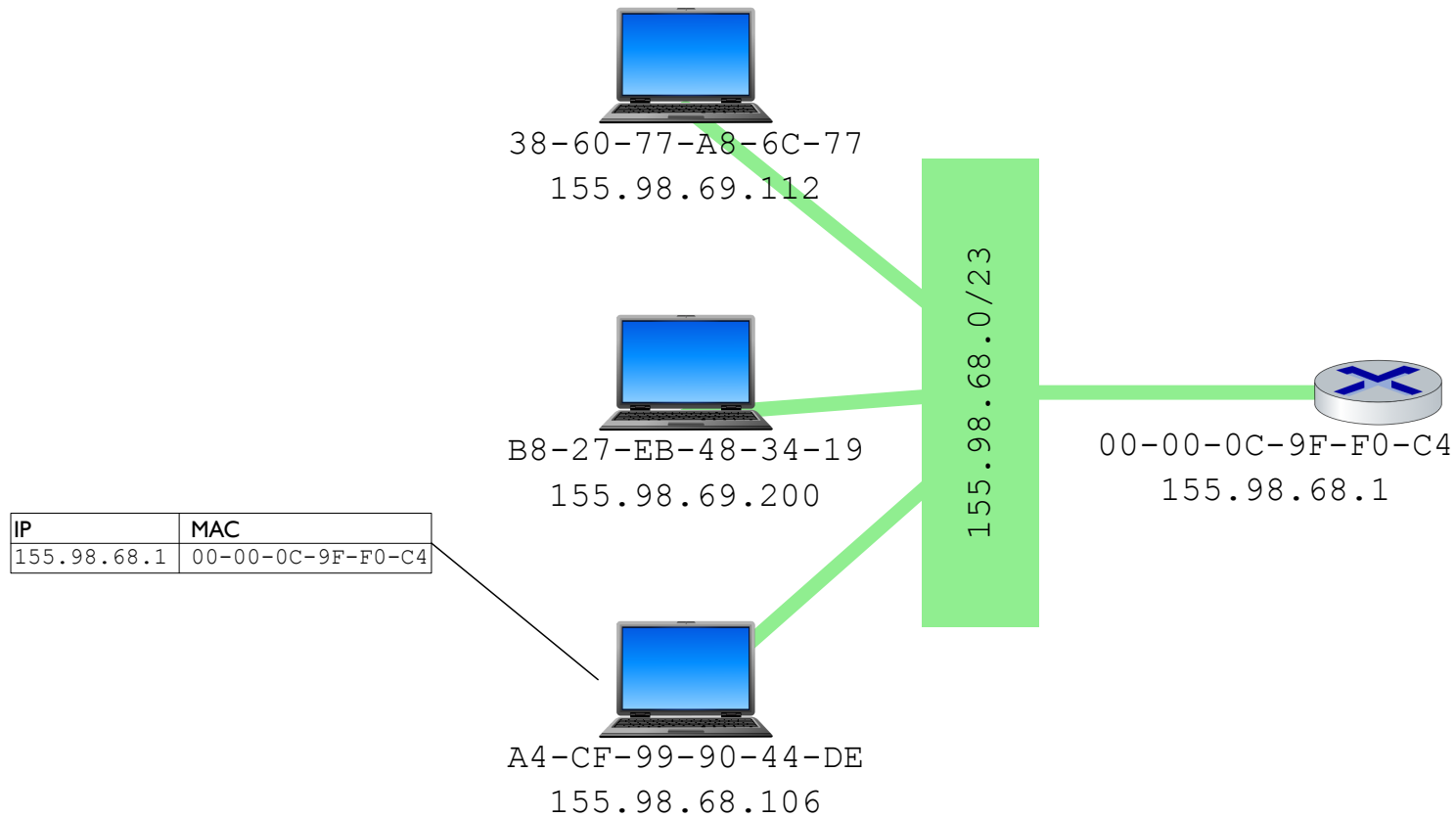
From DHCP to ARP to HTTP



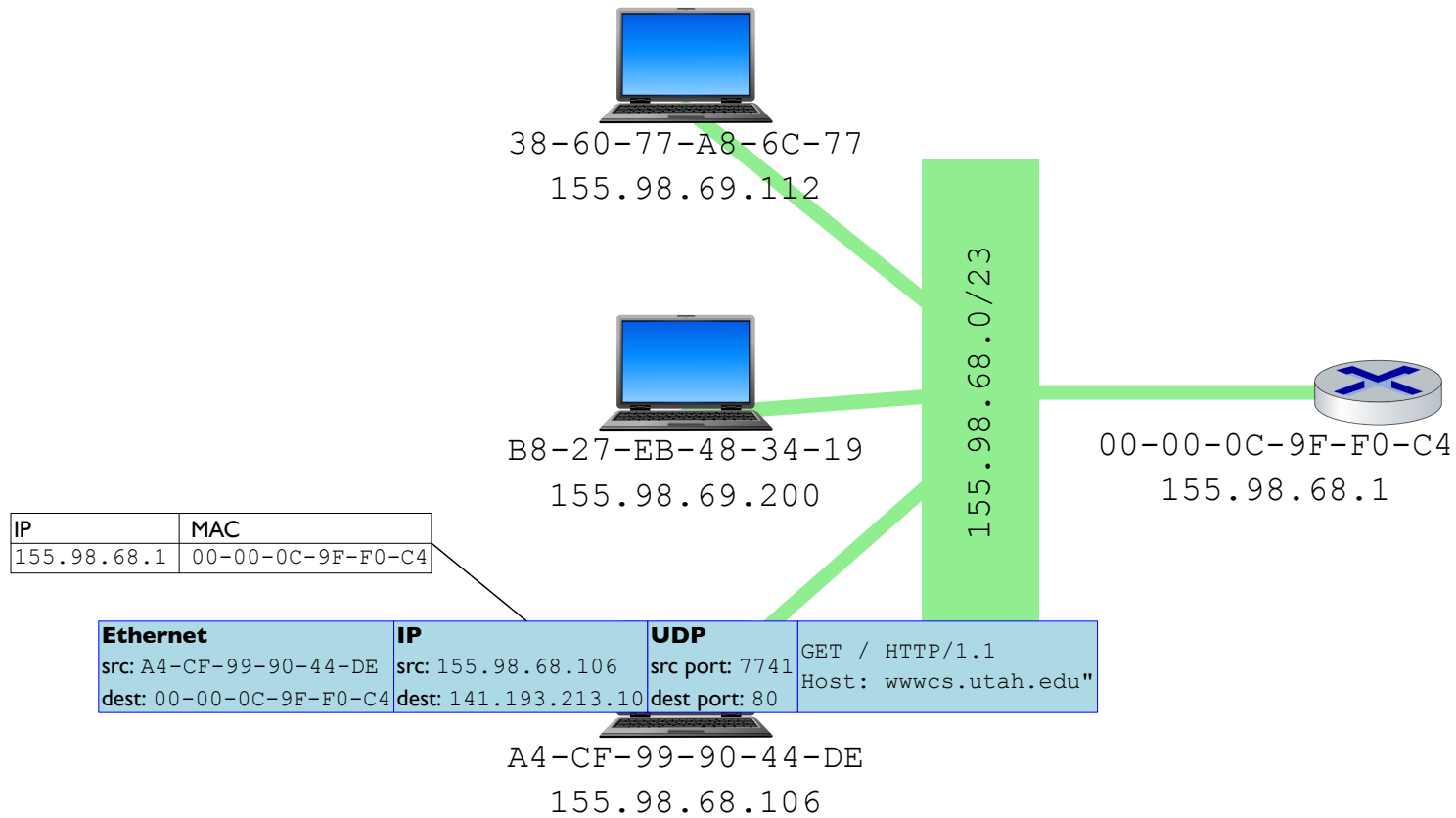
From DHCP to ARP to HTTP



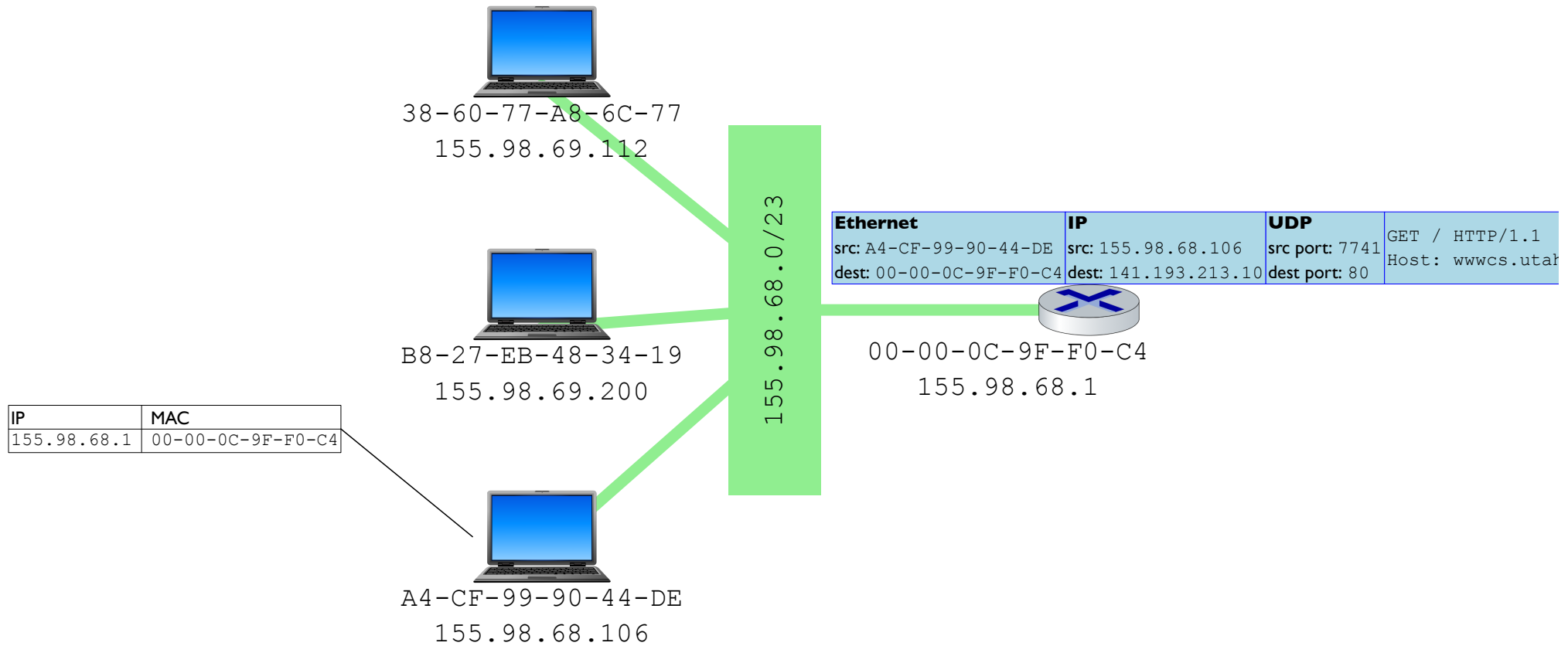
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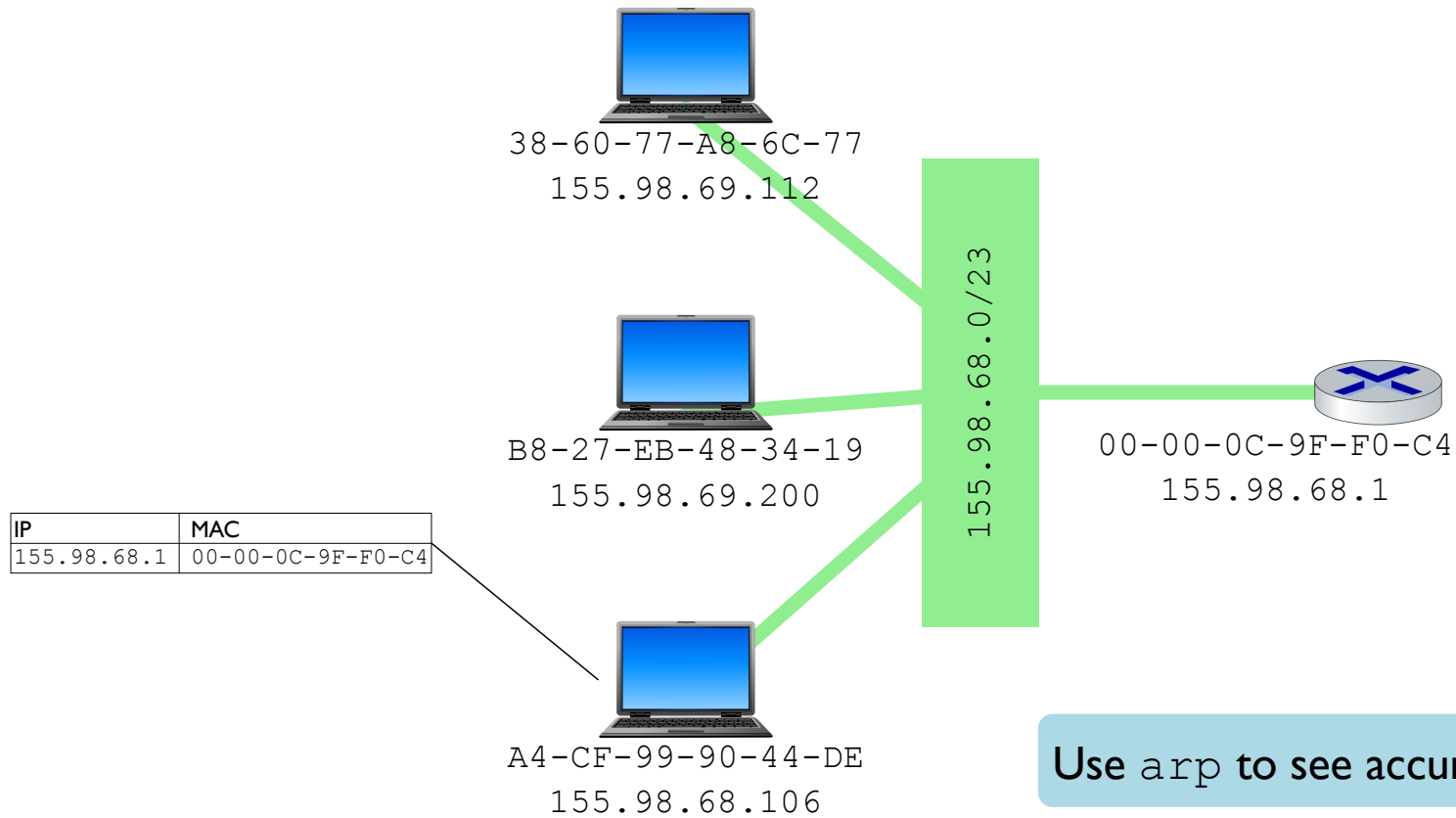
From DHCP to ARP to HTTP



From DHCP to ARP to HTTP



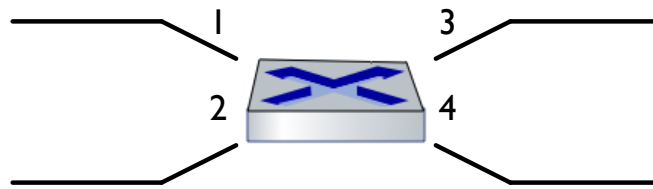
From DHCP to ARP to HTTP



Switches



Switches

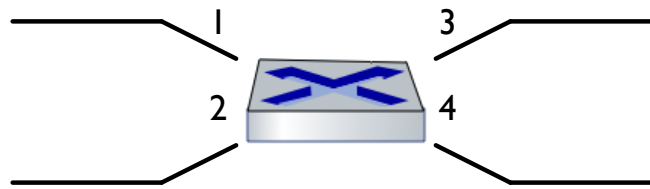


Switches

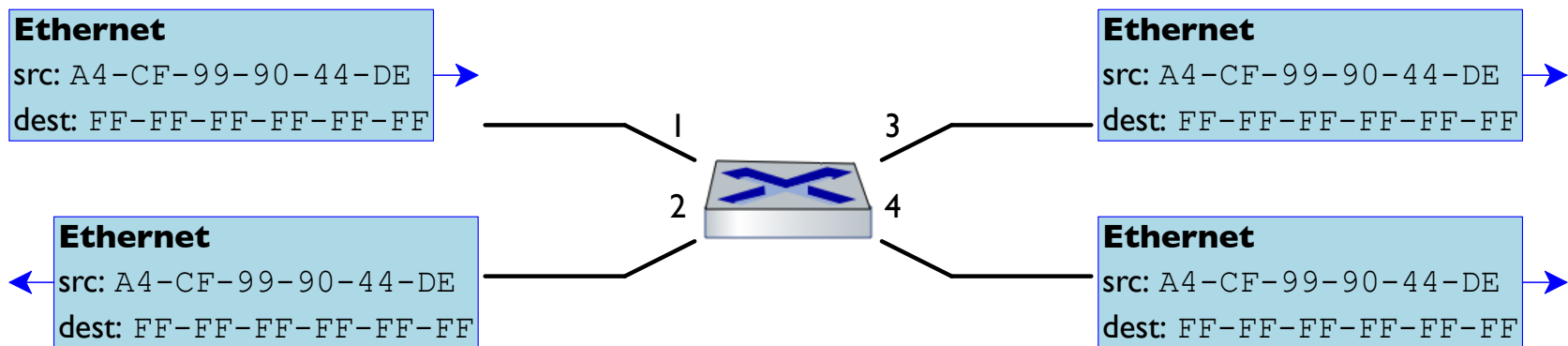
Ethernet

src: A4-CF-99-90-44-DE

dest: FF-FF-FF-FF-FF-FF



Switches

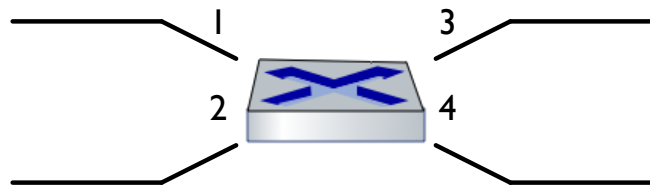


Switches

Ethernet

src: A4-CF-99-90-44-DE

dest: 38-60-77-A8-6C-77

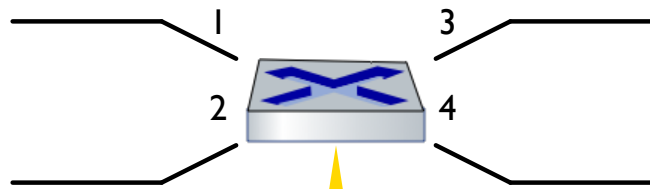


Switches

Ethernet

src: A4-CF-99-90-44-DE

dest: 38-60-77-A8-6C-77



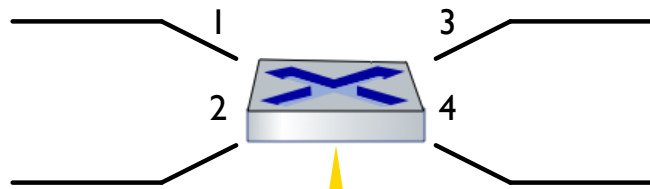
Which link goes to the dest MAC?

Switches

Ethernet

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dest: 38-60-77-A8-6C-77



Which link goes to the dest MAC?

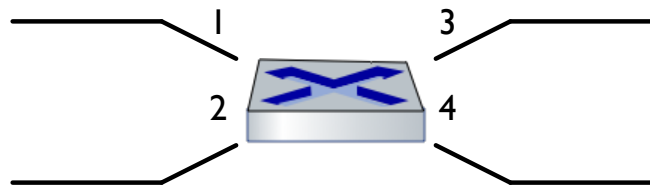
Instead of having to configure a switch,
rely on the fact that some earlier broadcast
was needed for anyone to find another MAC

Switches

Ethernet

src: A4-CF-99-90-44-DE

dest: FF-FF-FF-FF-FF-FF

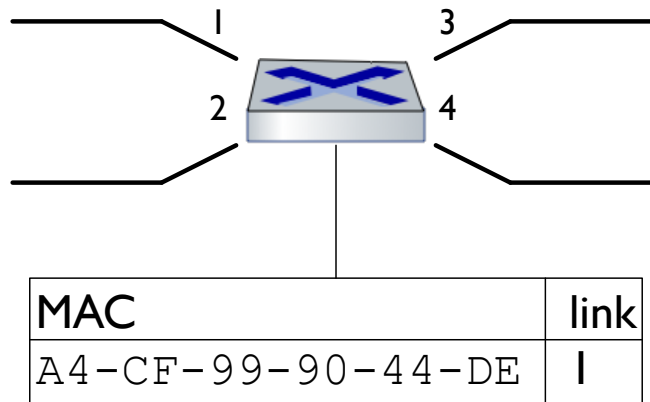


Switches

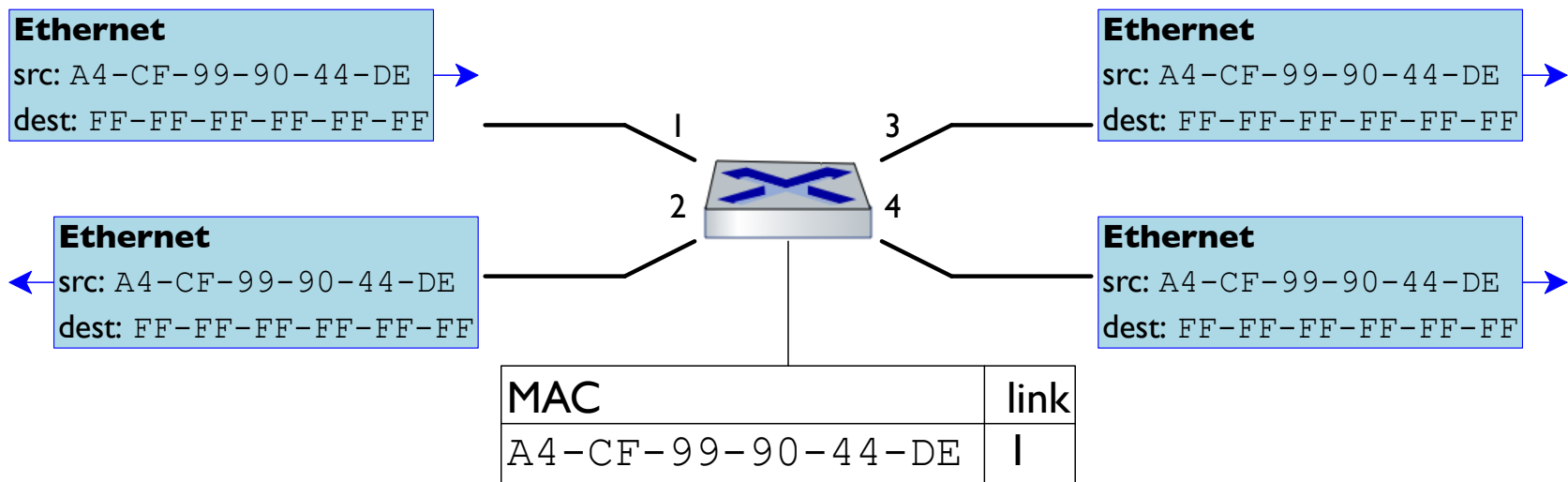
Ethernet

src: A4-CF-99-90-44-DE

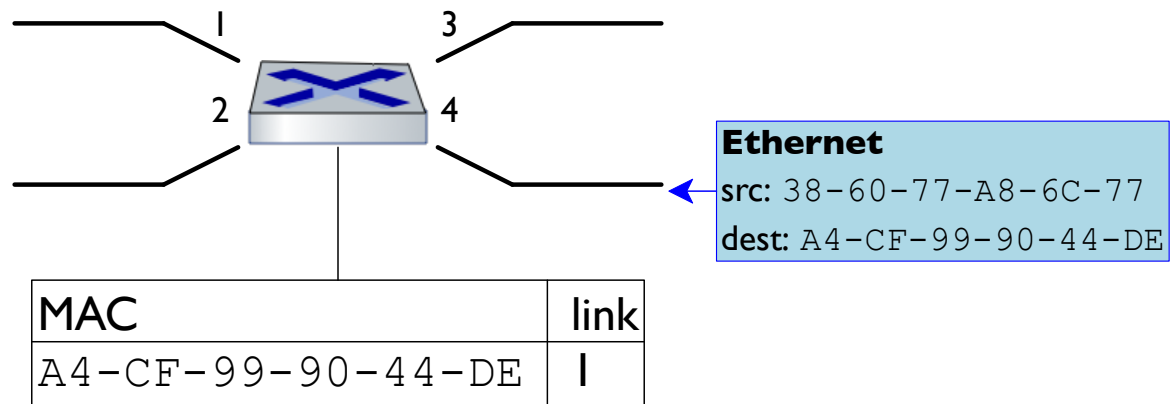
dest: FF-FF-FF-FF-FF-FF



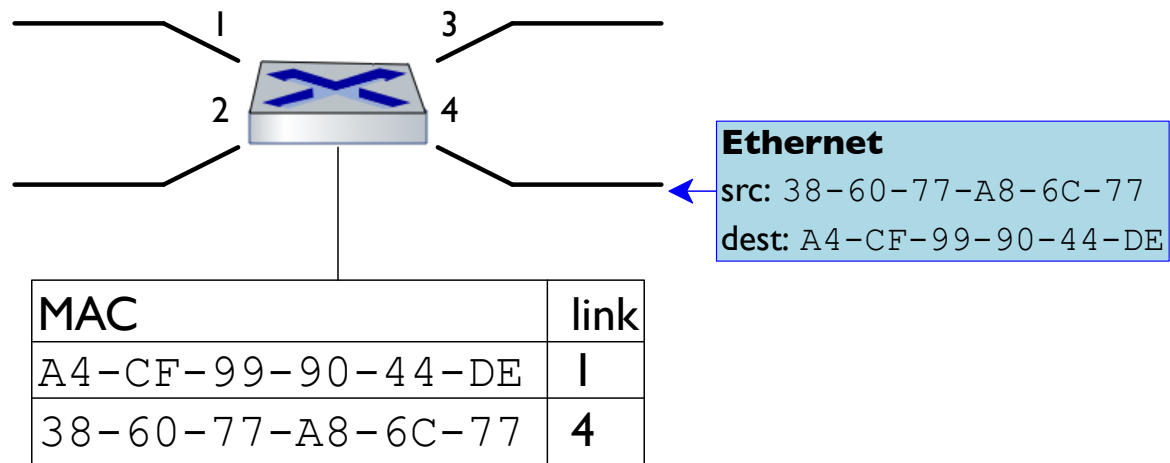
Switches



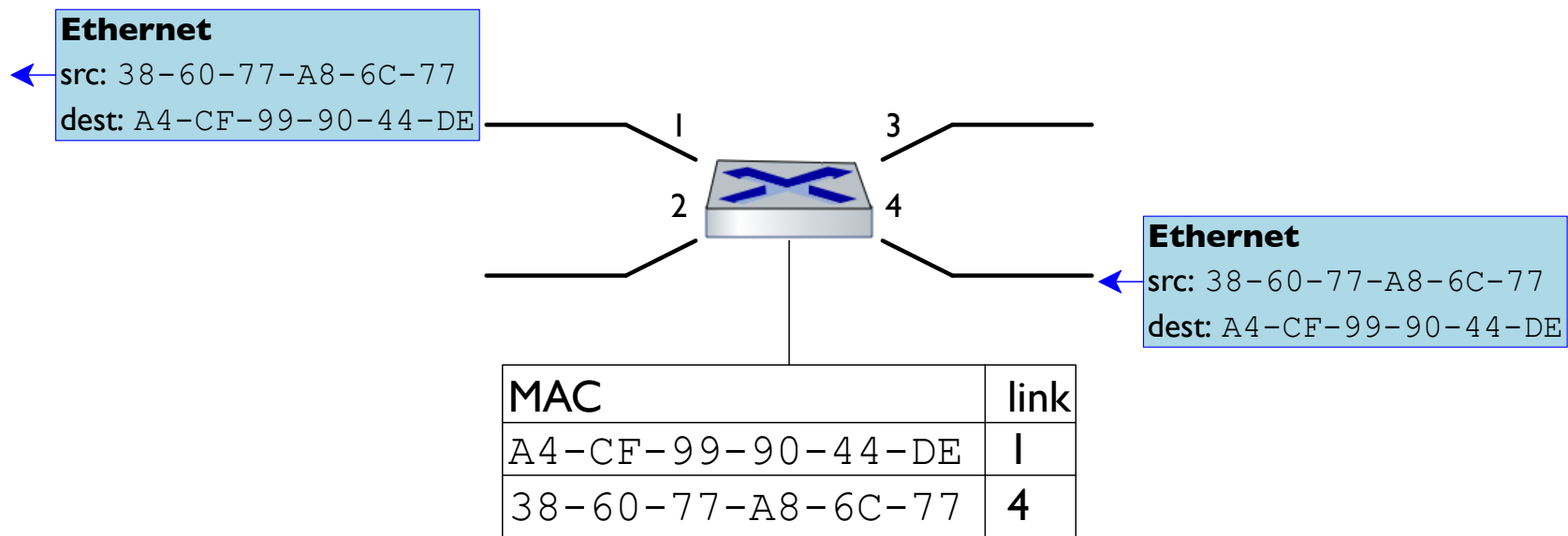
Switches



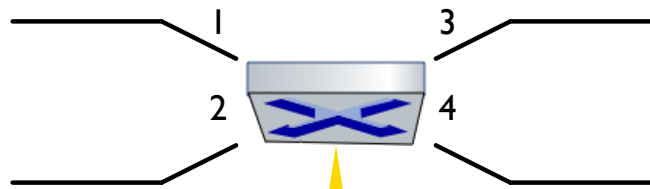
Switches



Switches



Hubs



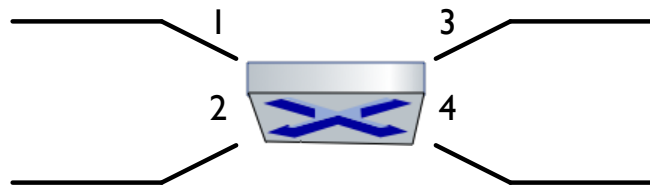
A **hub** is older technology that just broadcasts everything

Hubs

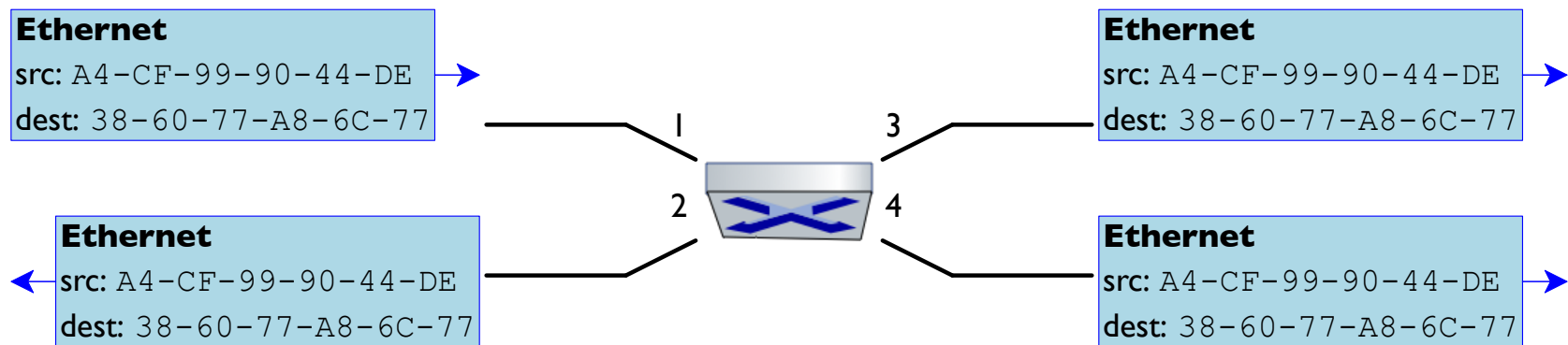
Ethernet

src: A4-CF-99-90-44-DE

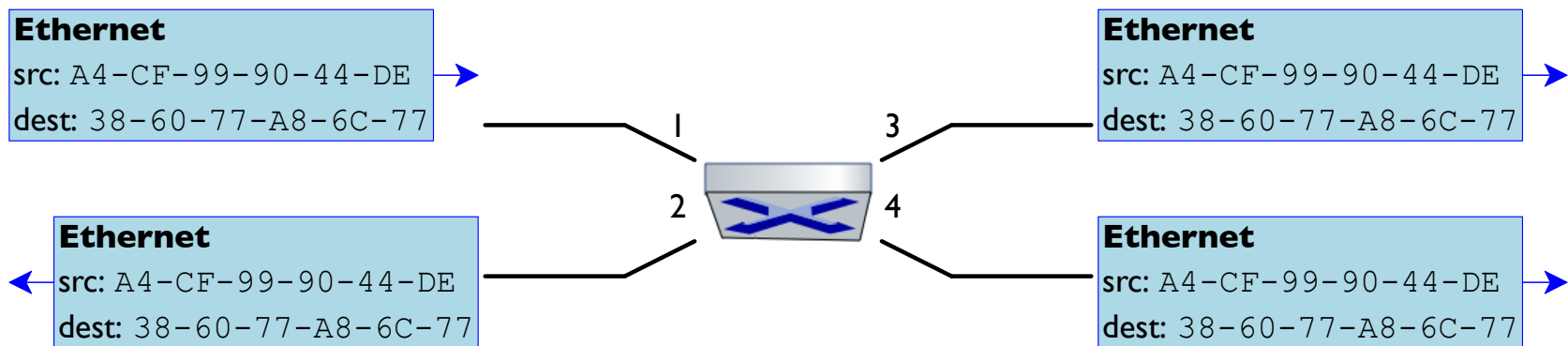
dest: 38-60-77-A8-6C-77



Hubs



Hubs



Switch vs. hub: always choose a switch

Router vs. Switch

Router



Switch



Router vs. Switch

Router



- Must configure

Switch



+ Infers routing

Router vs. Switch

Router



- Must configure
- + Prefix routing

Switch



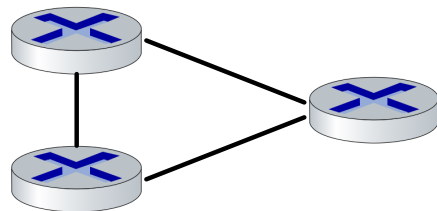
- + Infers routing
- Entry per address

Router vs. Switch

Router



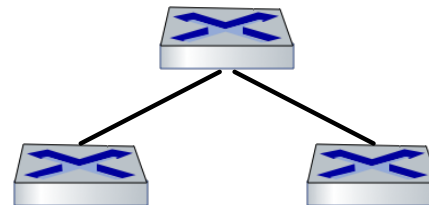
- Must configure
- + Prefix routing
- + Any topology



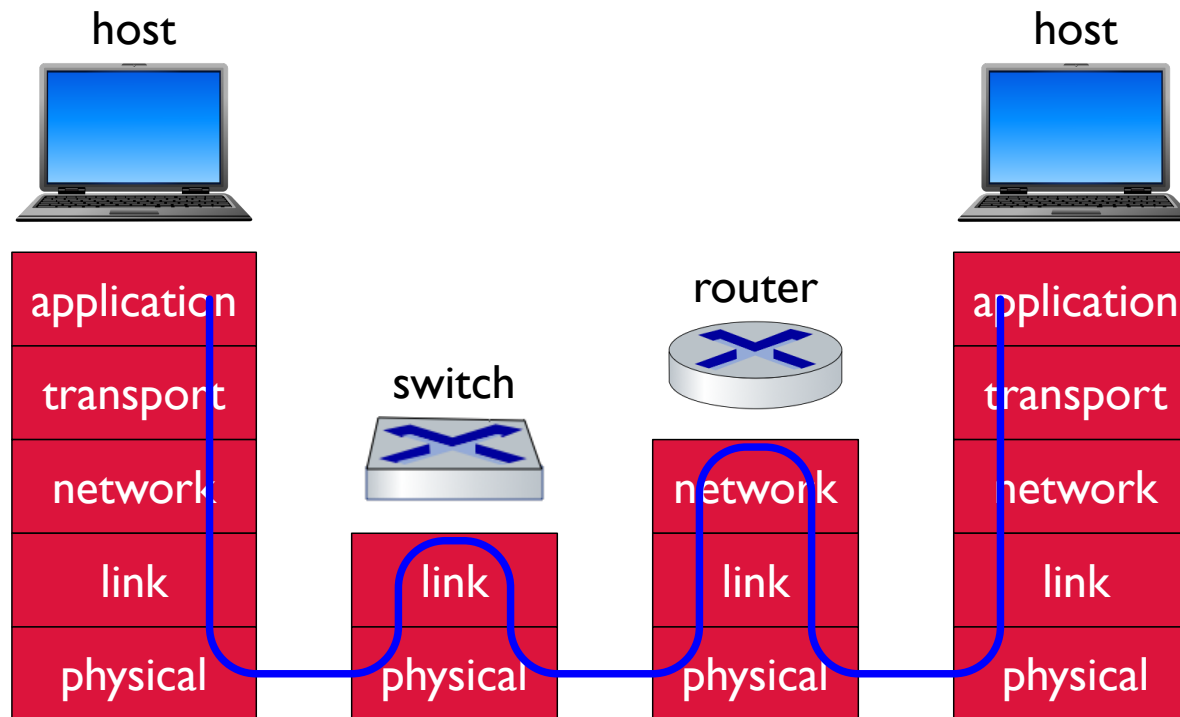
Switch



- + Infers routing
- Entry per address
- Tree topology only



Router vs. Switch



Traditional Data Center Organization



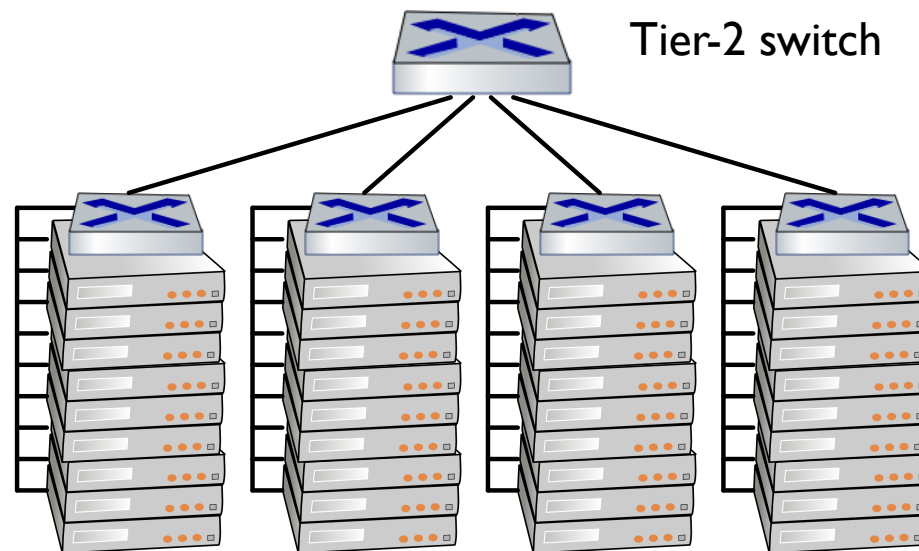
Server rack

Traditional Data Center Organization

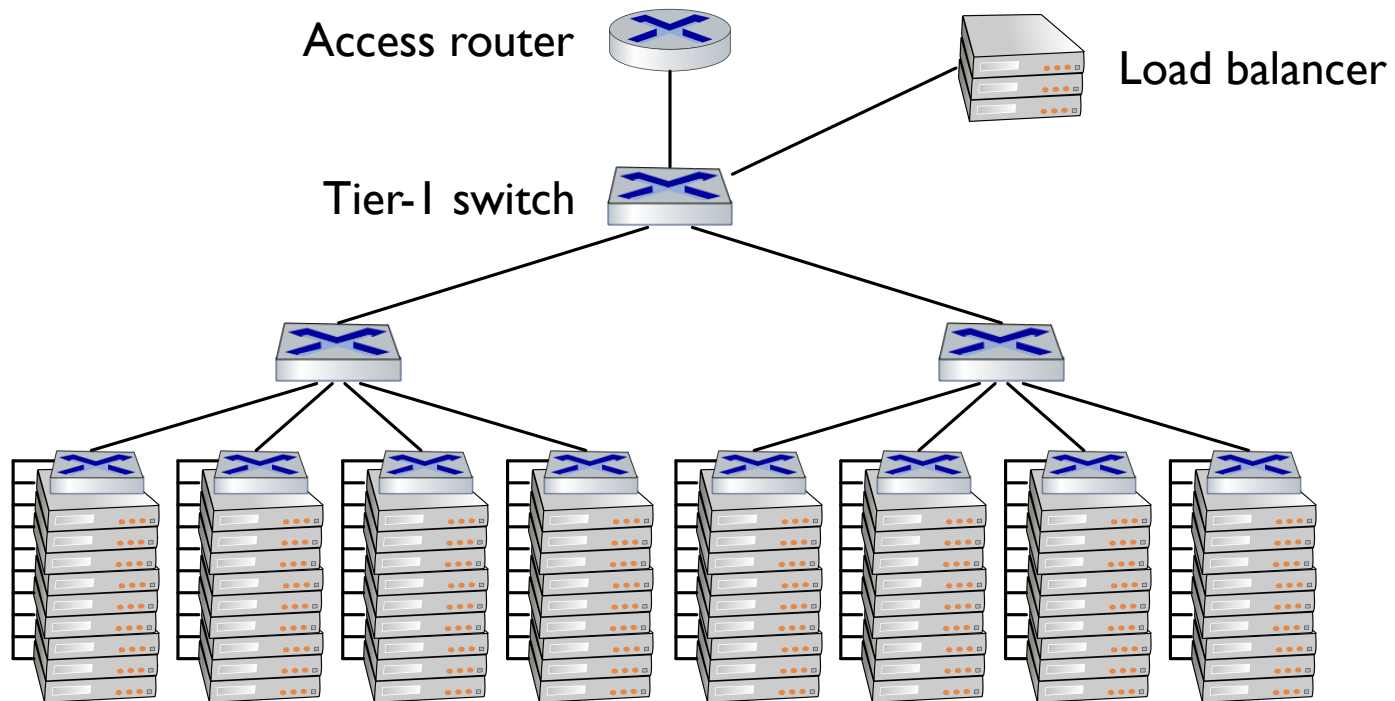


Top of rack (TOR) switch

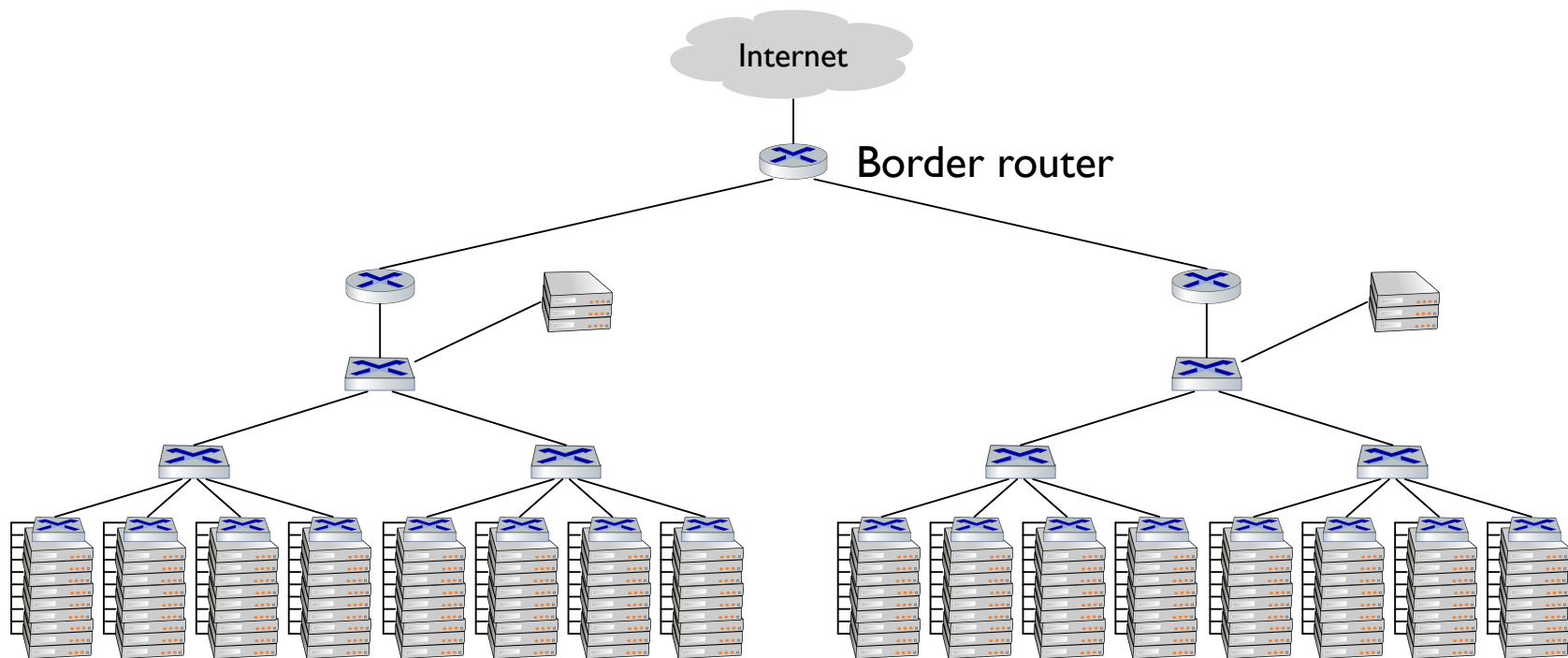
Traditional Data Center Organization



Traditional Data Center Organization



Traditional Data Center Organization



Virtual LAN

Because LAN-level organization has traditionally implied “local,” various tools have built on that concept

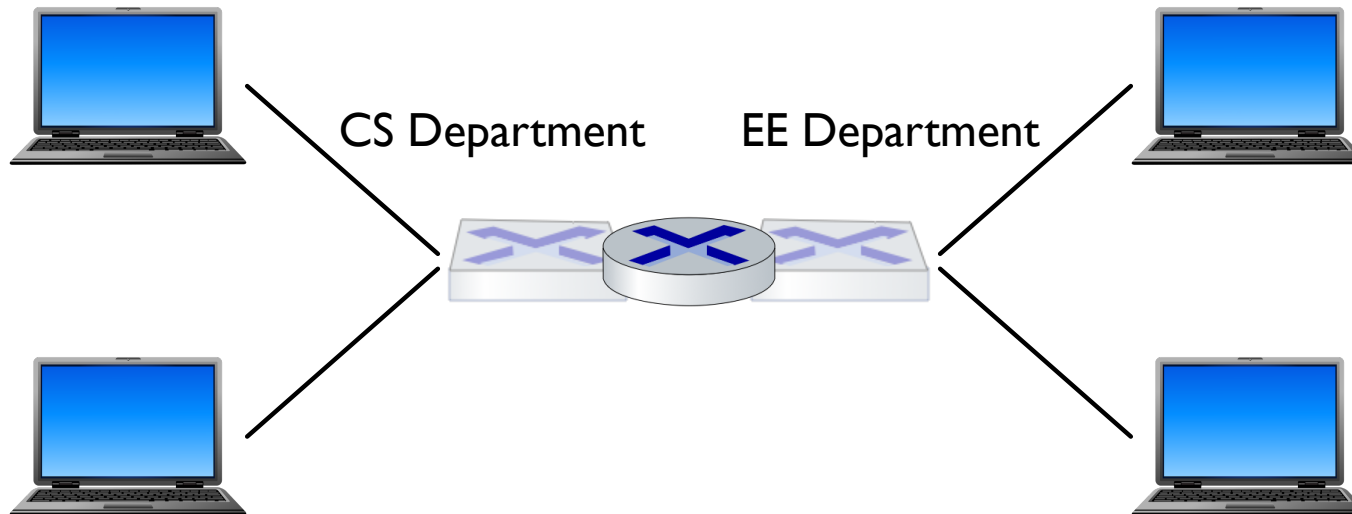
example: a network printer available only within the LAN

Any time a concept like that becomes established, though, eventually is gets *virtualized*

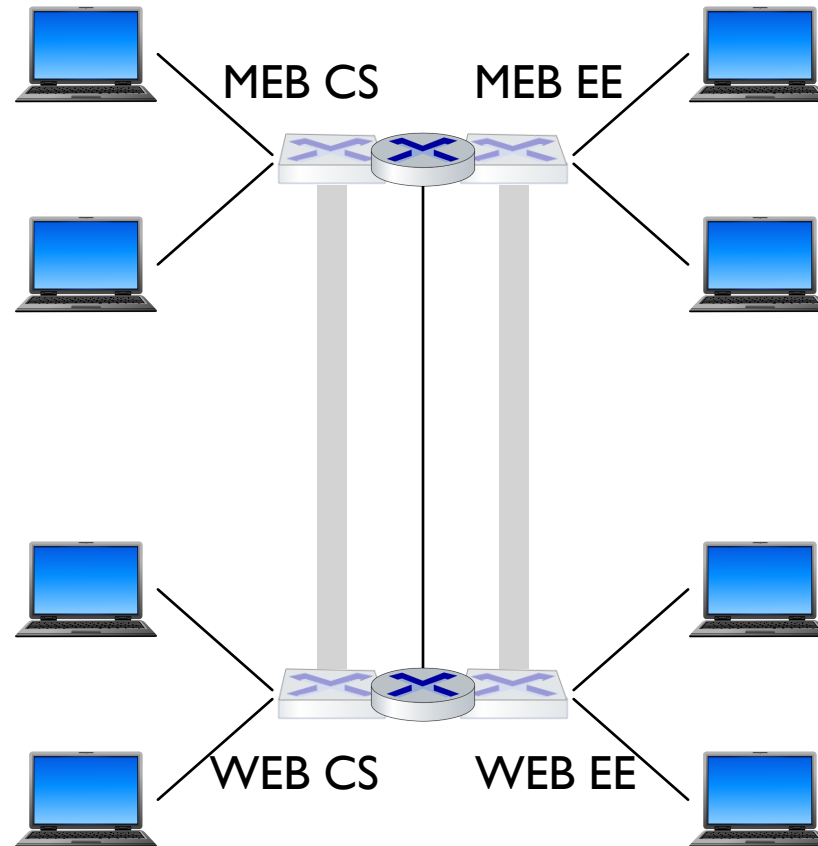
example: splitting an office into two LANs

example: sharing filesystem access across remote locations

Virtual LAN

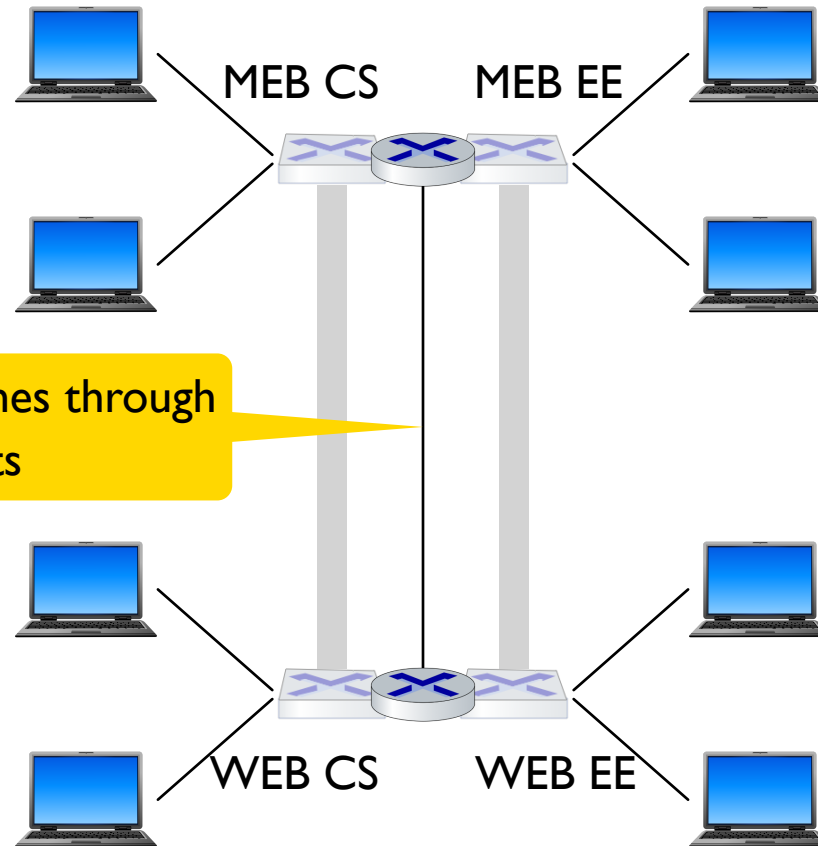


Virtual LAN



Virtual LAN

Tunnel link-layer frames through
network-layer packets



Summary

Network layer: addresses, subnets, and routers

Link layer: **MACs**, **LANs** and **switches**

Link devices configure themselves via **ARP**

Switches configure themselves by observing frames