FIT9137
Introduction to Computer Architecture and Networks

Week 9: Network & Transport Layers

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Learning Outcomes

- Apply TCP/IP protocols in a network
- Appropriately use and employ routing and addressing
- Investigate how applications communicate over the internet using TCP/IP
- Appropriately use and employ static & dynamic routing

Consultations

- There are multiple consultations sessions per week, both online and on campus.
- https://learning.monash.edu/course/view.php?id=34622&section=5
- Good for: clarify your questions about the contents, get further assessment feedback from your marker, ...

Network Layer:

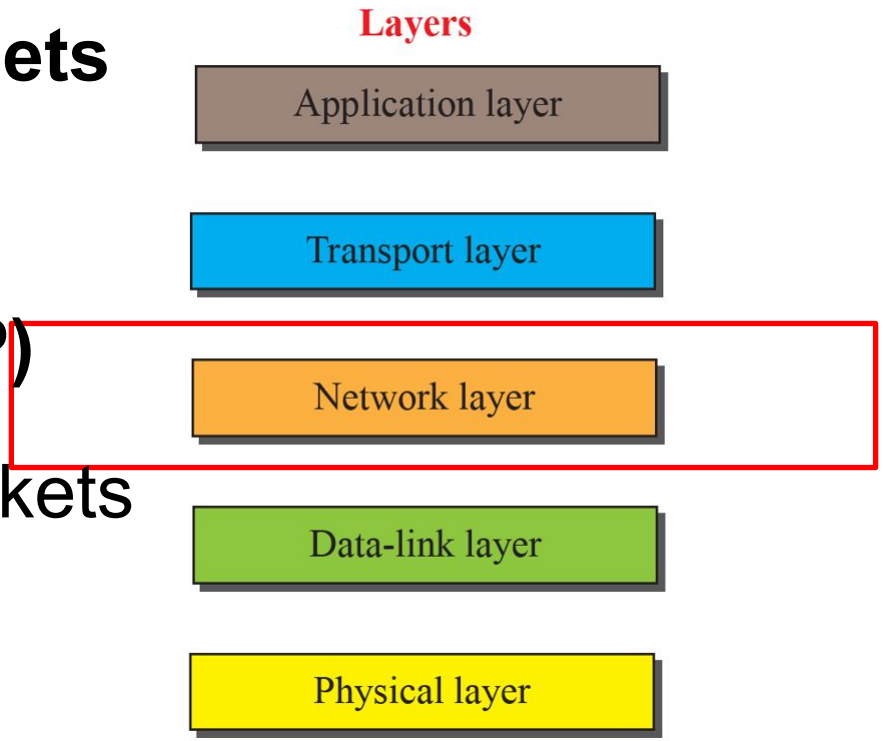
Addressing, Networks & Subnets

Address Resolution

Dynamic IP addressing (DHCP)

addressing and **routing** of packets

connecting different networks

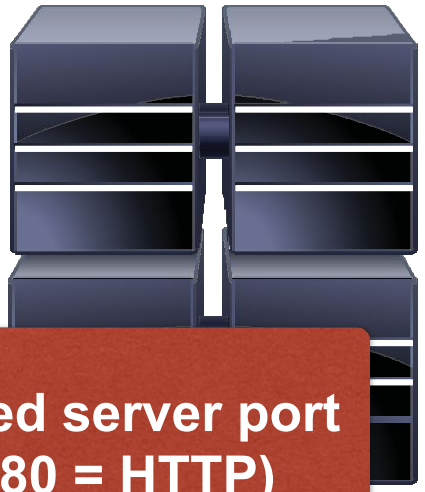


Addressing

Addressing applications

http://www.google.com.au

216.58.220.99:80



Random client port, one per connection

Fixed server port (80 = HTTP)

130.194.77.37:57017

130.194.77.37:57018

130.194.77.37:57019

130.194.11.146:25

smtp.monash.edu

Fixed server port (25 = SMTP)

111.119.8.38:80

http://www.nasa.gov

One address per

Application Layer

- URL (e.g. http://www.csse.monash.edu)

Transport Layer (TCP)

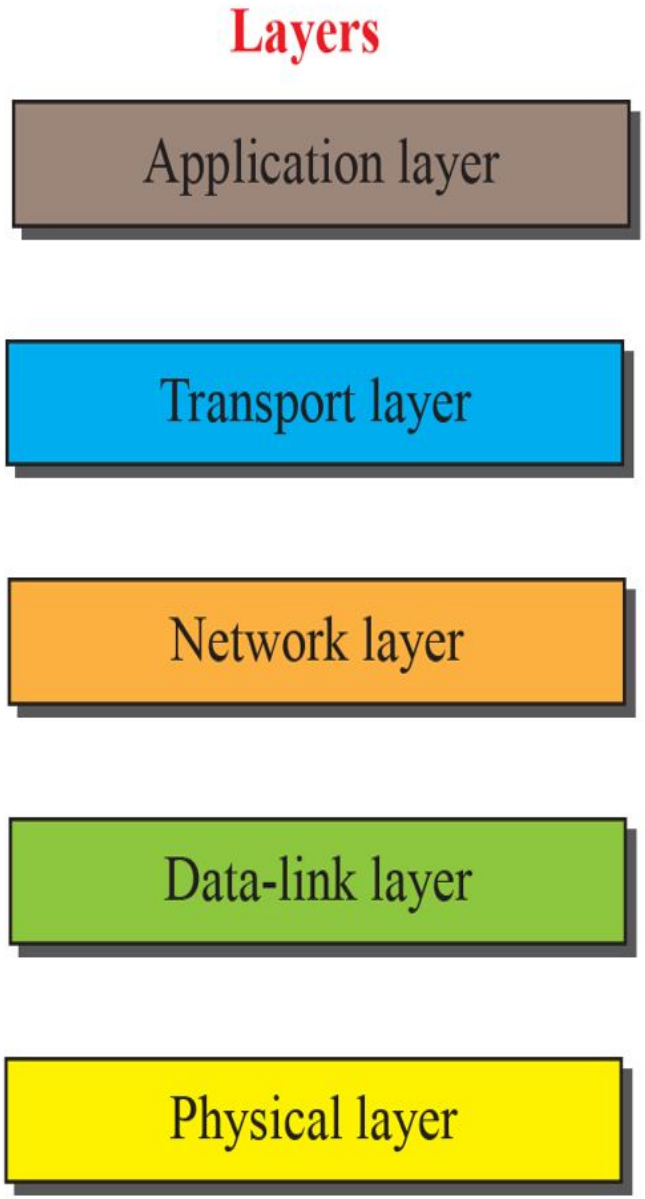
- Port number (e.g. 80 for HTTP)
- identifies the application that handles a message

Network Layer (IP)

- IP address (e.g. 130.194.66.43)
- used for identifying devices across networks

Data Link Layer (Ethernet)

- MAC address (e.g. 00:23:ae:e7:52:85)
- used for sending frames in a LAN



Where to get an address?

DNS entries

- ICANN/Registrars manage top-level and second-level domains
- Network admins manage DNS for their assigned domains

Port numbers

- IANA maintains official list of port numbers

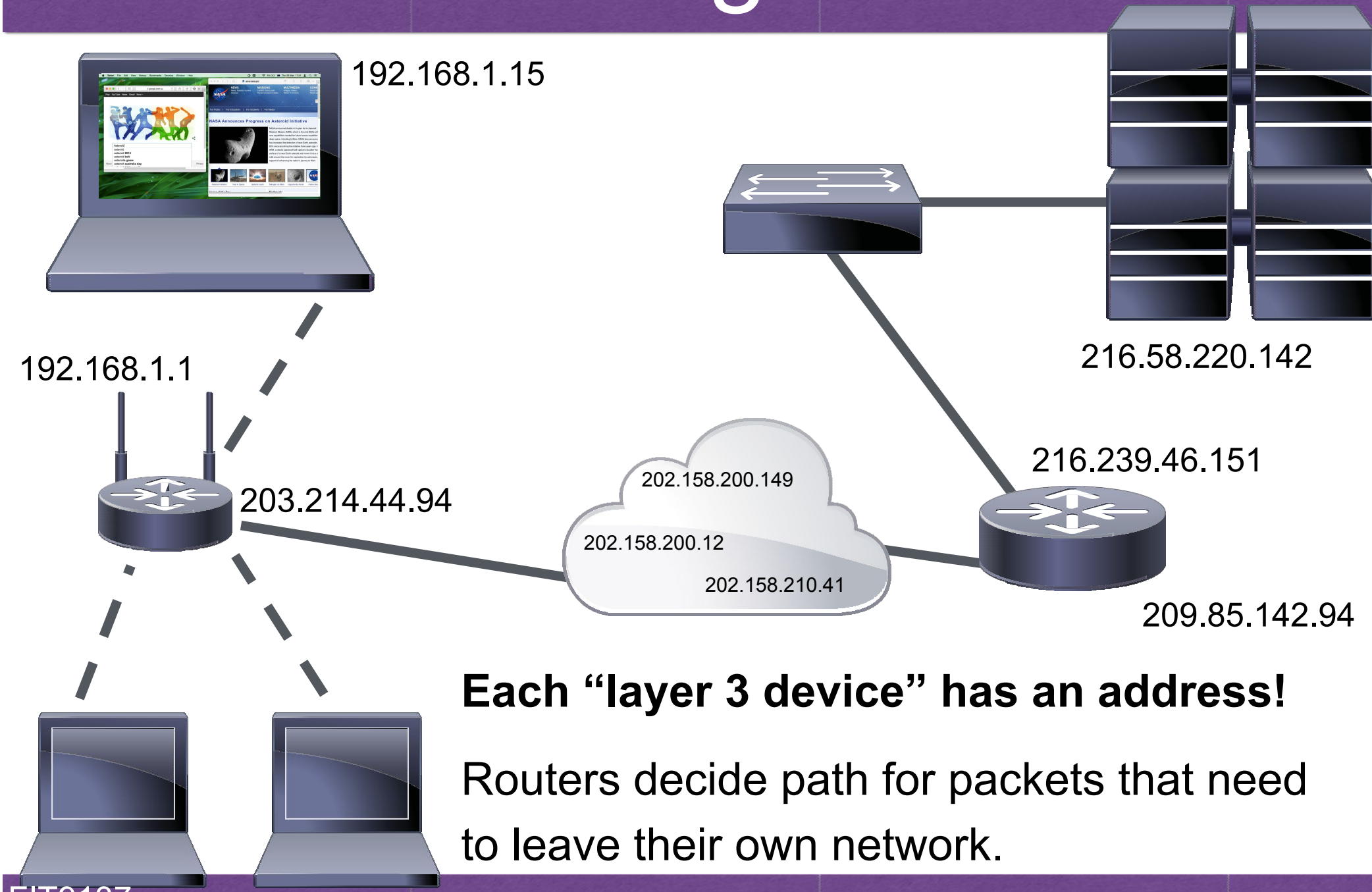
IP addresses

- IANA and Regional Internet Registries (RIR) allocate blocks of addresses, local registries redistribute to customers.
- Network admins configure (static or dynamic) addresses in their assigned block

MAC addresses

- Unique addresses allocated by hardware manufacturers

Addressing devices



Each "layer 3 device" has an address!

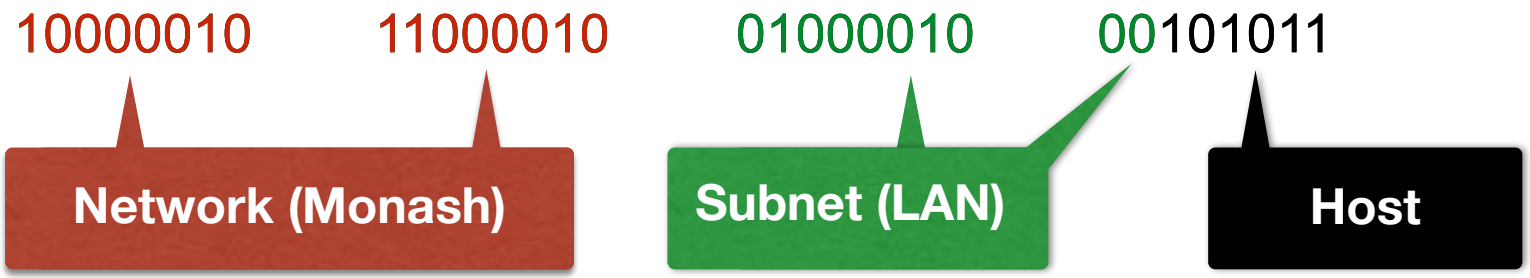
Routers decide path for packets that need to leave their own network.

IP version 4

32 bit addresses

Written using “dotted decimal” notation

Example: 130.194.66.43



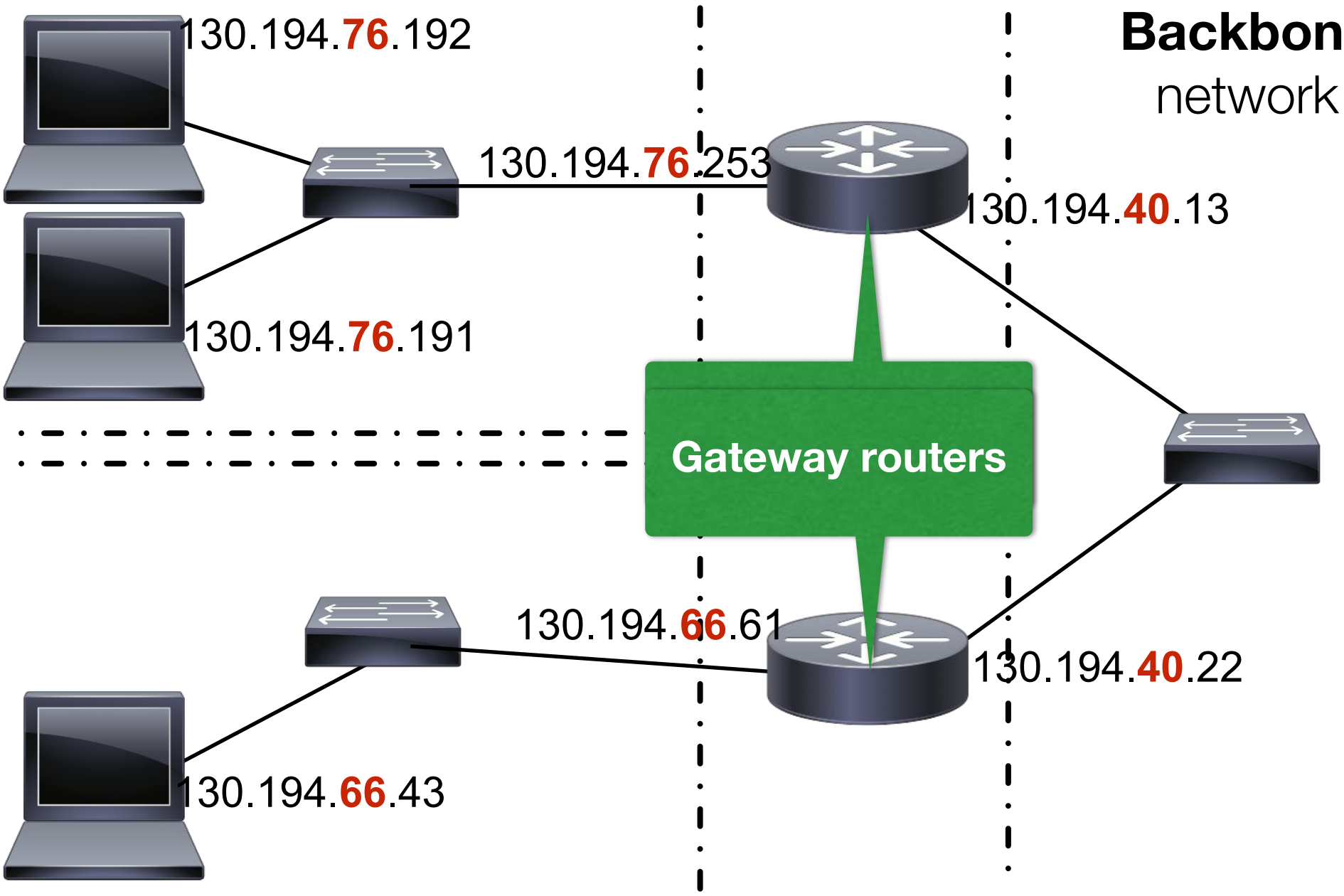
Hierarchy used for routing

You can immediately see if a destination address is in the same subnet!

Subnet **mask**: **255.255.255.192 or /26**

no. of bits in network + subnet

Subnets


130.194.76.192
130.194.76.253
130.194.40.13
Backbone
network
130.194.76.191
Gateway routers
130.194.66.61
130.194.40.22
130.194.66.43

Address resolution

Assume we browse to http://www.google.com.au

- We know client use random tcp port & server uses destination port 80 for http
- We have to translate www.google.com.au into an IP address: 216.58.220.99 (domain name resolution)
- We send a request through the Internet to that IP address
- The router in the destination LAN of 216.58.220.99 needs to know the MAC address for 216.58.220.99 to deliver the frame (MAC address resolution)

This is known as Name resolution or address resolution.

Address resolution: Application Layer

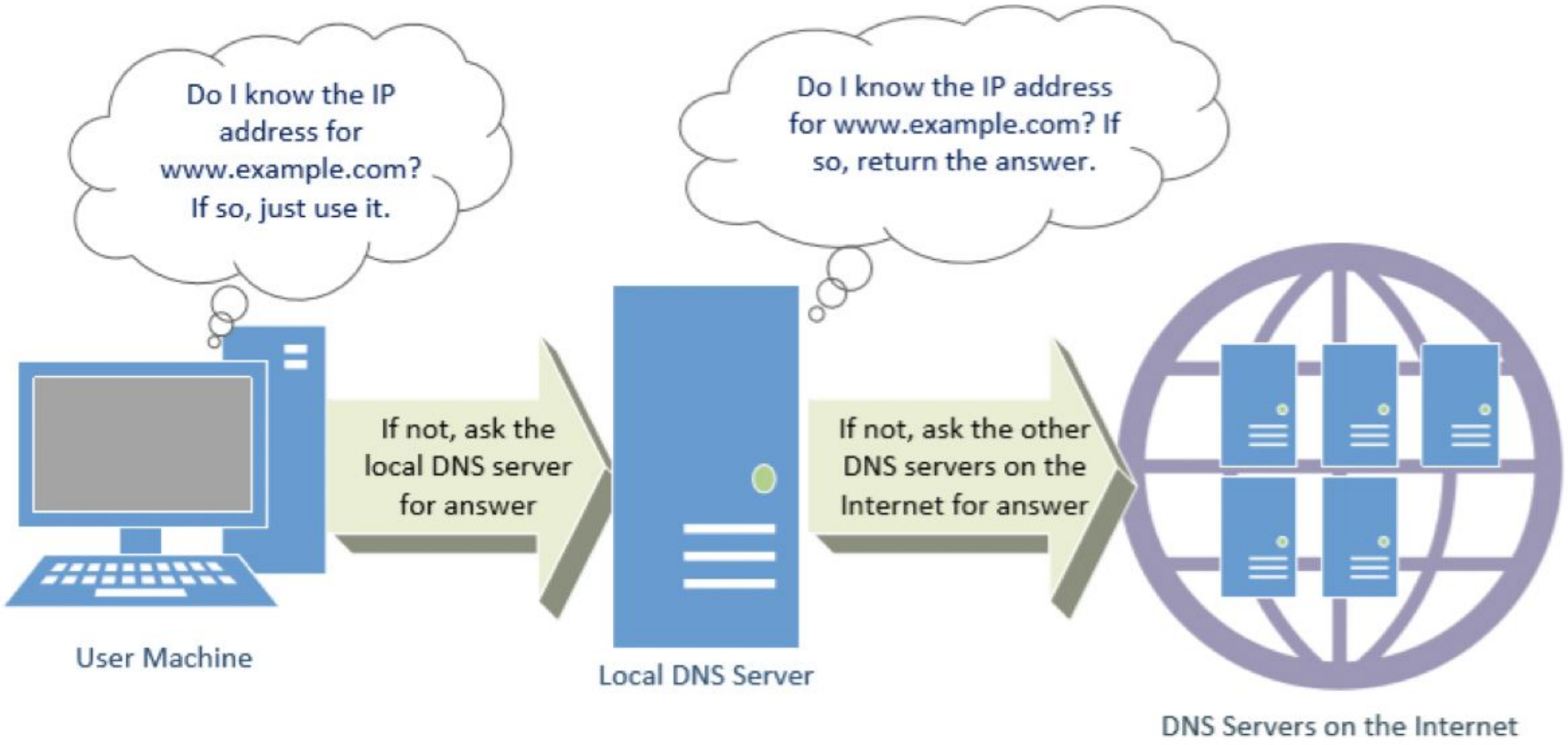
DNS (Domain Name System)

- Application layer protocol for address resolution
- Client sends request to DNS server to get IP address registered for a name

DNS Servers

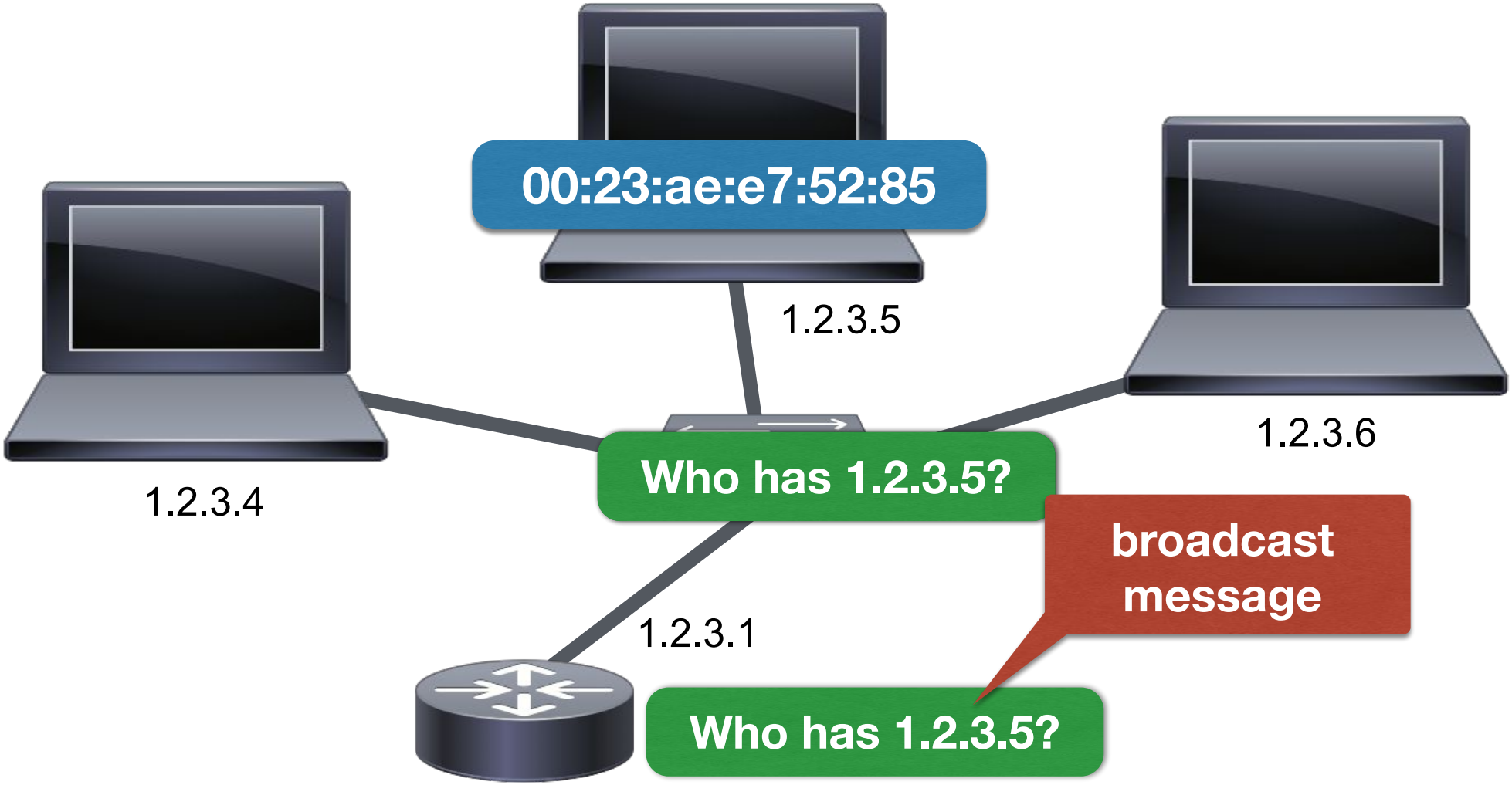
- Implement a **distributed database** of names
- Are organised in a **hierarchy** reflecting the **structure** of the domain names

DNS Query


Do I know the IP address for www.example.com? If so, just use it.
Do I know the IP address for www.example.com? If so, return the answer.
If not, ask the local DNS server for answer
If not, ask the other DNS servers on the Internet for answer
User Machine
Local DNS Server
DNS Servers on the Internet

Address resolution: Data Link Layer

- How to find the MAC address for an IP address:



Address Resolution Protocol (ARP)

Arp /? command for ARP MAC address to IP_Address resolution

PollEv Question: Subnetting

In Network layer Addressing, Internet Protocol Version (IPv4) addresses, Classful addressing is replaced with:

A. Classless addressing

B. Classful addressing new version

C. Classful advertising

D. Classless broadcast

PollEv Question: ARP

Address Resolution Protocol (ARP) request is sent as a broadcast message, the reply is:

A. Unicast message

B. Broadcast message

C. Multicast message

D. Generated locally

Activity A

Configuring IP addresses

Every device on the network needs an IP address

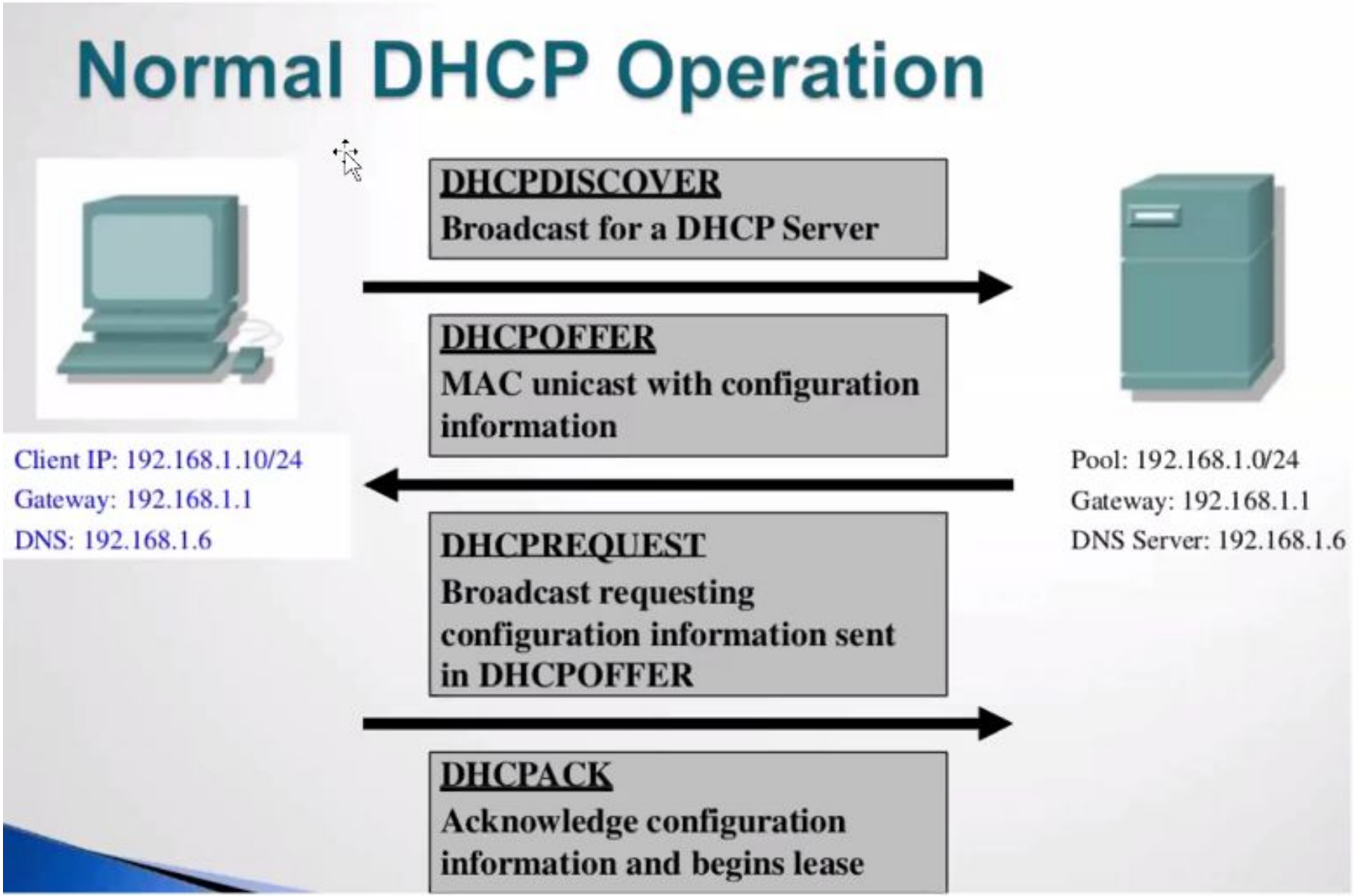
- Doesn't change for servers and routers, so configure statically
- Probably doesn't need to change for workstations, but configuring is time consuming
- Infeasible to allocate statically for mobile devices

Dynamic Addressing IPv4

Dynamic Host Configuration Protocol (DHCP)

- Send broadcast to DHCP server to get an address and subnet mask
- Addresses are only *leased* for a limited time
- Makes efficient use of limited IPv4 address space (since only computers currently connected to the network get an address)
- Much easier for admins to manage than static addresses

Activity B: DHCP



PollEv Question: DHCP

The DHCP (Dynamic Host Configuration Protocol) server _____

A. Maintains a database of available IP addresses
B. Maintains the information about client configuration parameters
C. Grants an IP address when receives a request from a client
D. All of the above

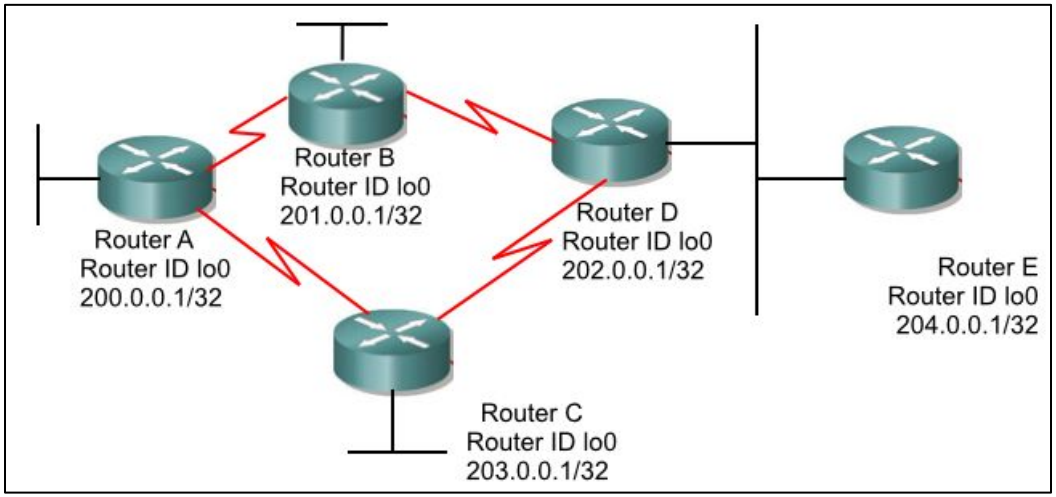
Activity B

The Network Layer:
Routing

Routers

Routers connect networks

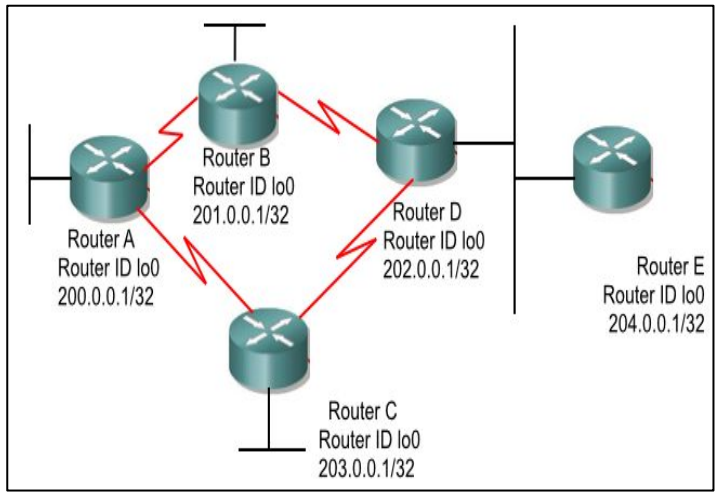
- Internet is a network of networks!
- Most important piece of Internet infrastructure



A router is a layer 3 device

- one IP address per **interface**, i.e. typically per subnet it is connected to
- Clients send packets to routers **if destination is outside their own subnet**
- Routers use IP address to determine over **where the packet is sent next**

Routing



For each incoming packet, the router

- looks at the packet's **destination IP address**
- consults the **routing table:**
  to which other router should I send a packet for this destination, or can I deliver it directly?
- if destination not in table: send to **default gateway**
- if no default gateway configured: **packet can't be routed and is dropped**

Types of decentralised routing

Static routing : Activity C

- Network manager prepares **fixed routing tables**
- Manually updated when the network changes
- Used in simple networks that don't change a lot

Dynamic routing :

- Routers **exchange information** to build routing tables **dynamically**
- Initial tables can be set up by network managers

Dynamic routing algorithms

Distance vector

Exchange information about **distance to destination**, choose **shortest route**

- **EIGRP** (Enhanced Interior Gateway Routing Protocol)
- **RIP** (Routing Information Protocol)
- **BGP** (Border Gateway Protocol)

Link state

Exchange information about **quality of links**, choose **fastest route**

- **OSPF** (Open Shortest Path First)

Routing Information Protocol (RIP)

Distance = hop count

- Max. hop count 15
- Avoids loops

Only used in small networks

- At most 15 hops
- Updates transmit whole routing table
- Can be slow to converge

Link-state routing protocols

Routers exchange information about connectivity

- not just routing table (best routes) but **all** the network it knows about
- use a **metric/Cost** (usually link speed) to describe the **quality** of each connection.

Each router creates a topological map

- a map of the **entire network**
- each router can **independently** compute best route to every subnet using a **shortest path first** algorithm

PollEv Question: Routing

A _____ routing table contains information entered manually.

A. static
B. dynamic
C. hierarchical
D. none of these options

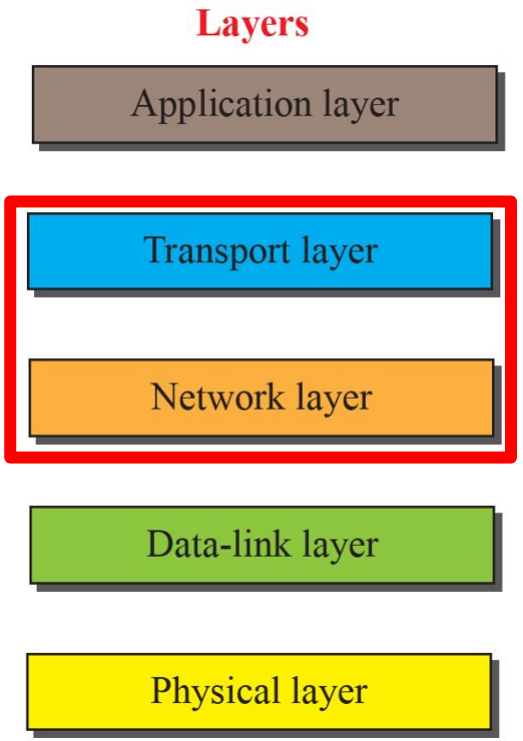
Activity C
Network Routing - Static Routing

The Transport Layer:
TCP / UDP

Network & Transport Layers

Network Layer:

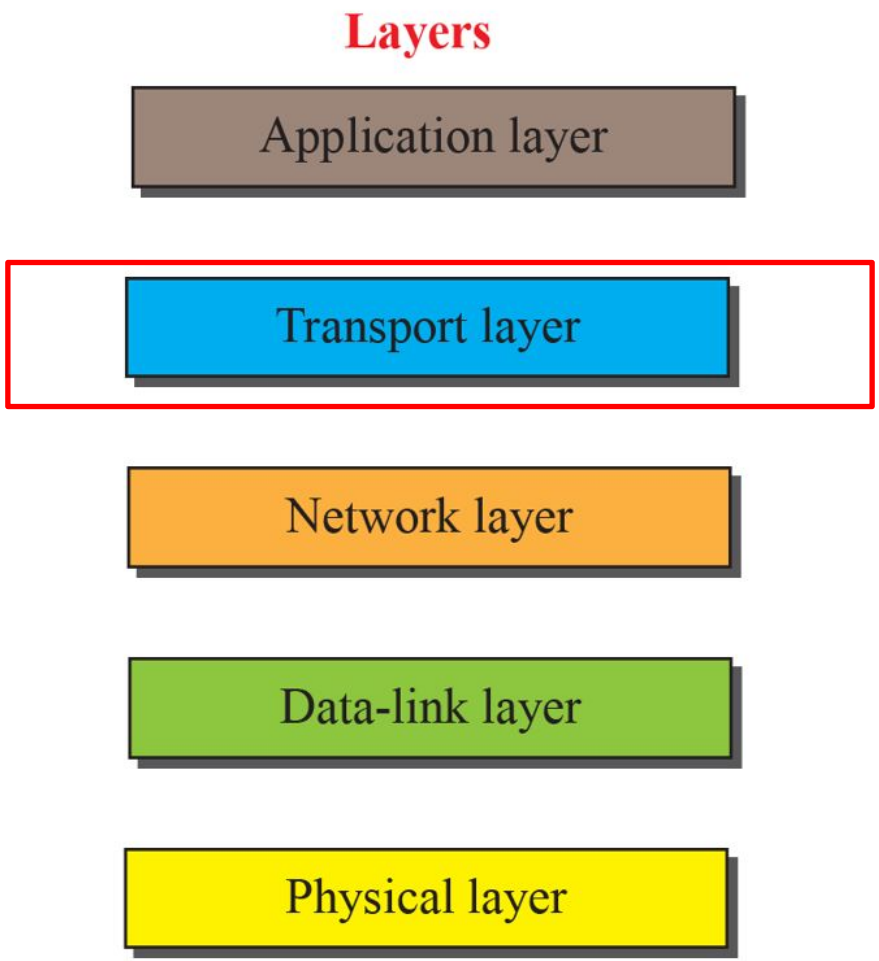
- **addressing** and **routing** of packets
- connecting different networks



Transport Layer:

- establish **end-to-end channel**
- **reliable** communication (segmenting + ARQ)
- **addressing** of individual **applications**

TCP: A reliable end-to-end channel



Transmission Control Protocol (TCP)

Connection-oriented

- A **virtual circuit** is established between two devices
- To the application it always looks like a **point-to-point full duplex** connection
- Messages split into **segments** for transmission

Reliable

- Errors are **detected** and **corrected**
- Segments are re-assembled in the **correct order**

TCP

TCP implements segmentation

- large application layer messages are split into segments

How fast to send segments?

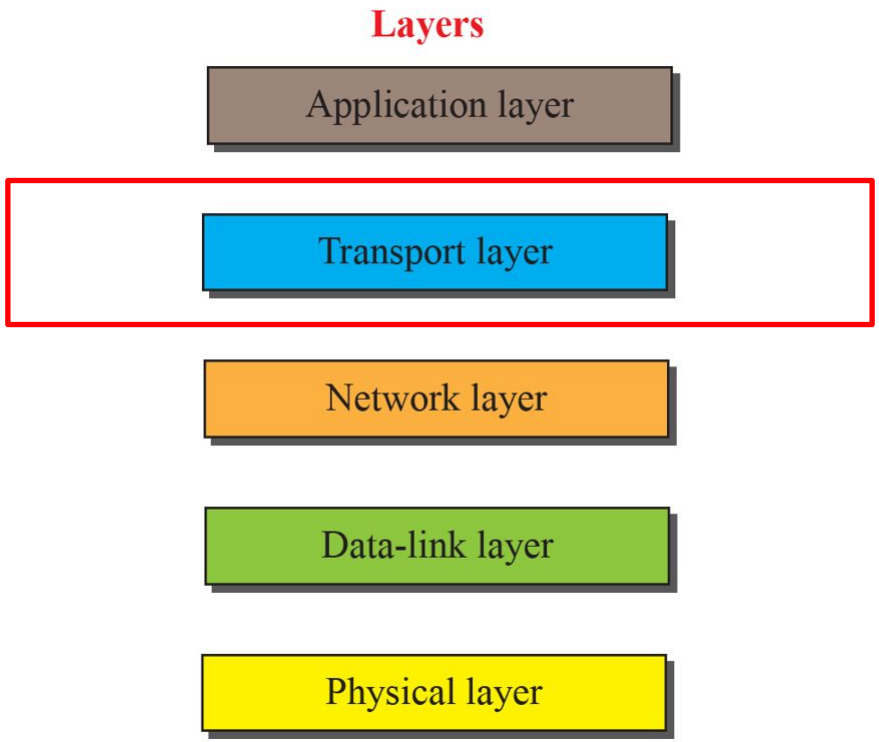
- Sending too many at once may overload receiver or intermediate path with lower bandwidth

How to decide the segment size?

- Sending too large segments requires IP to **fragment**
- Large segments also increase errors

UDP:

connectionless, unreliable transport



User Datagram Protocol (UDP)

Connectionless

- Each packet ("datagram") sent individually
- No virtual circuit
- No acknowledgement of receipt (unreliable)

Small header

- 8 bytes (compared to 20 bytes for TCP)

Use cases

- Applications that send very small messages (e.g., DNS, DHCP, Zoom etc.)
- Applications where loss of segments is acceptable, e.g. streaming video