Digital Stewards

Presented by Seattle Community Network

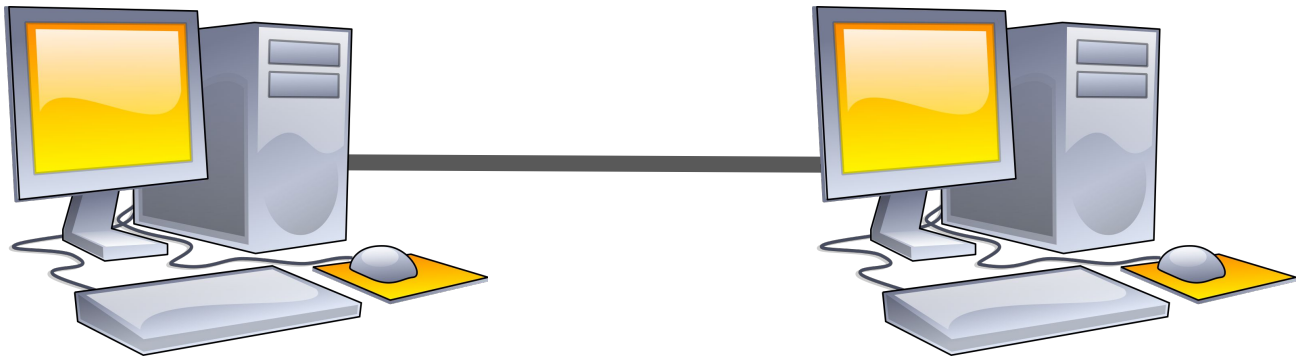
Agenda for Today: Alphabet soup

1. The Internet...
    a. Physical components
2. ...and how it works
    a. Protocols for sending data

This is the core of networking!!
We are in it now

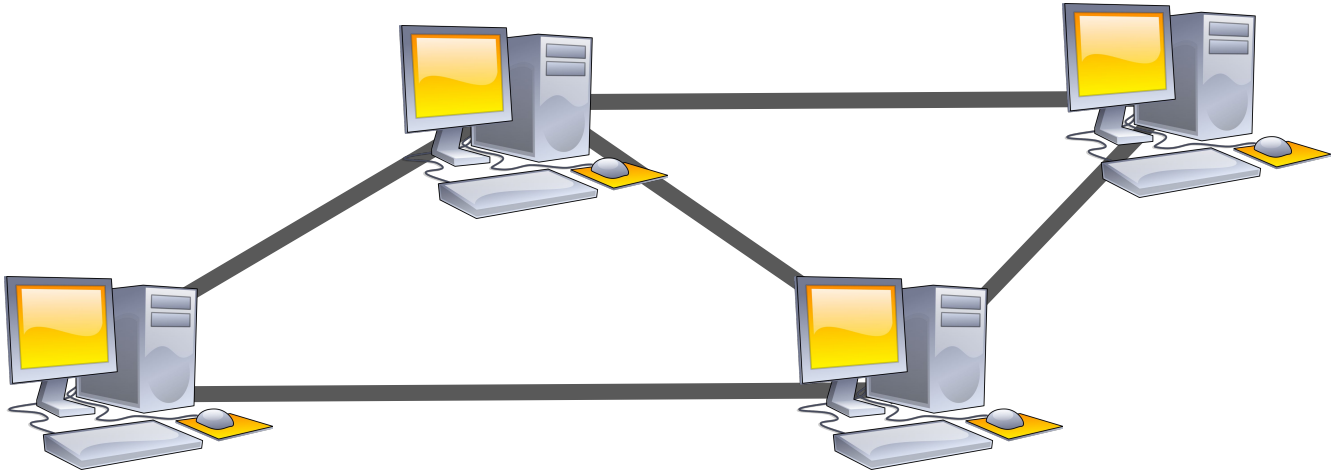
The Internet

What is a “network”?



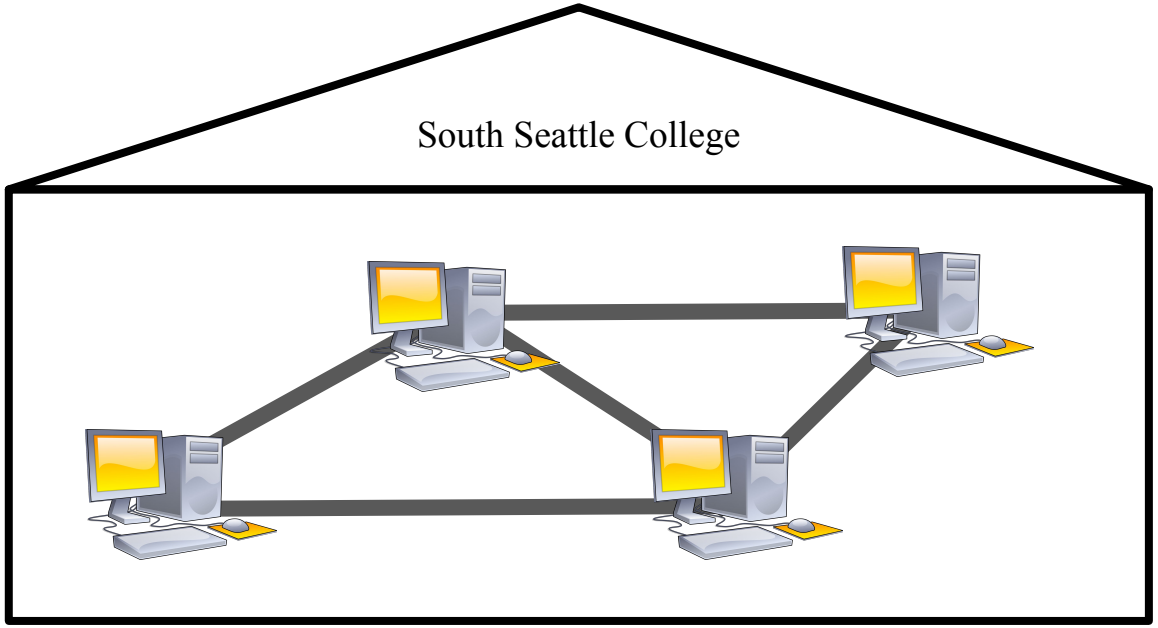
A **network** is a **connection between devices** that allows them to **communicate** and send information to each other.

What is a “network”?



A network can be very big or very small.

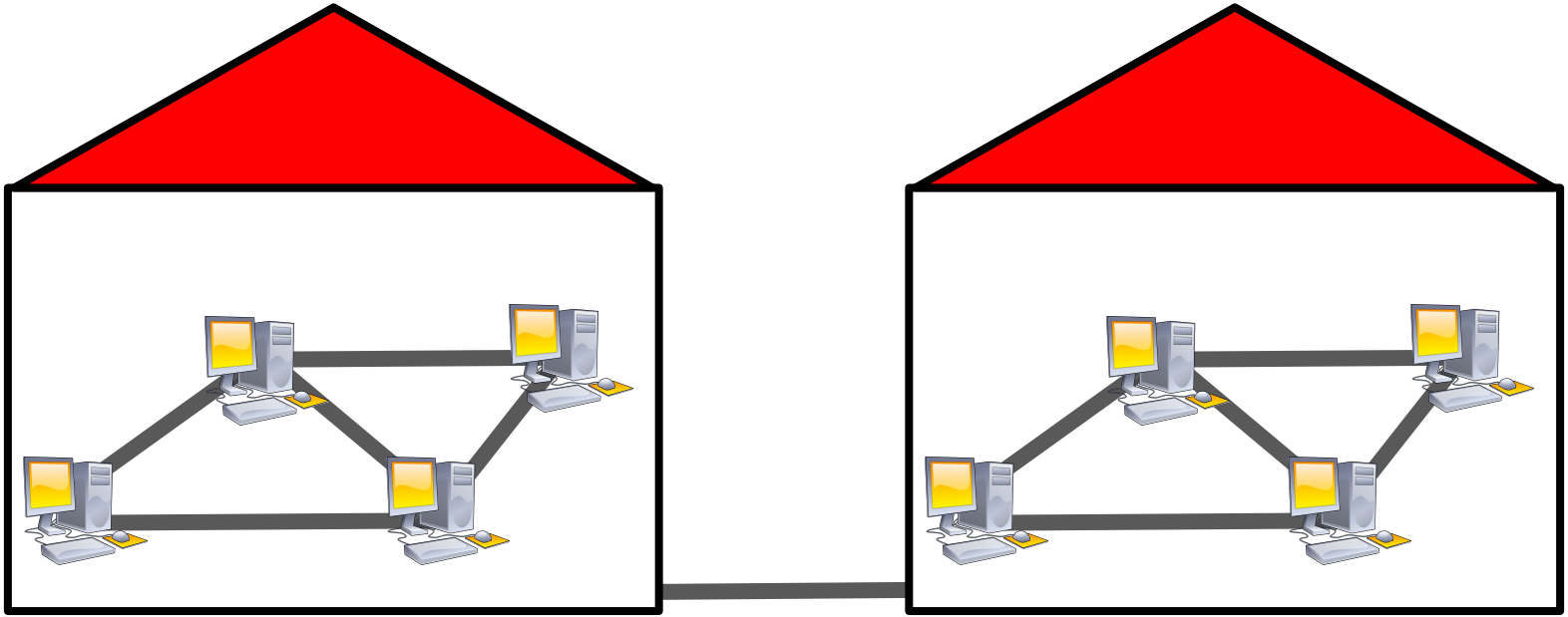
What is a “network”?



A network can be used in a school building so computers can send information to each other without having to use the Internet.

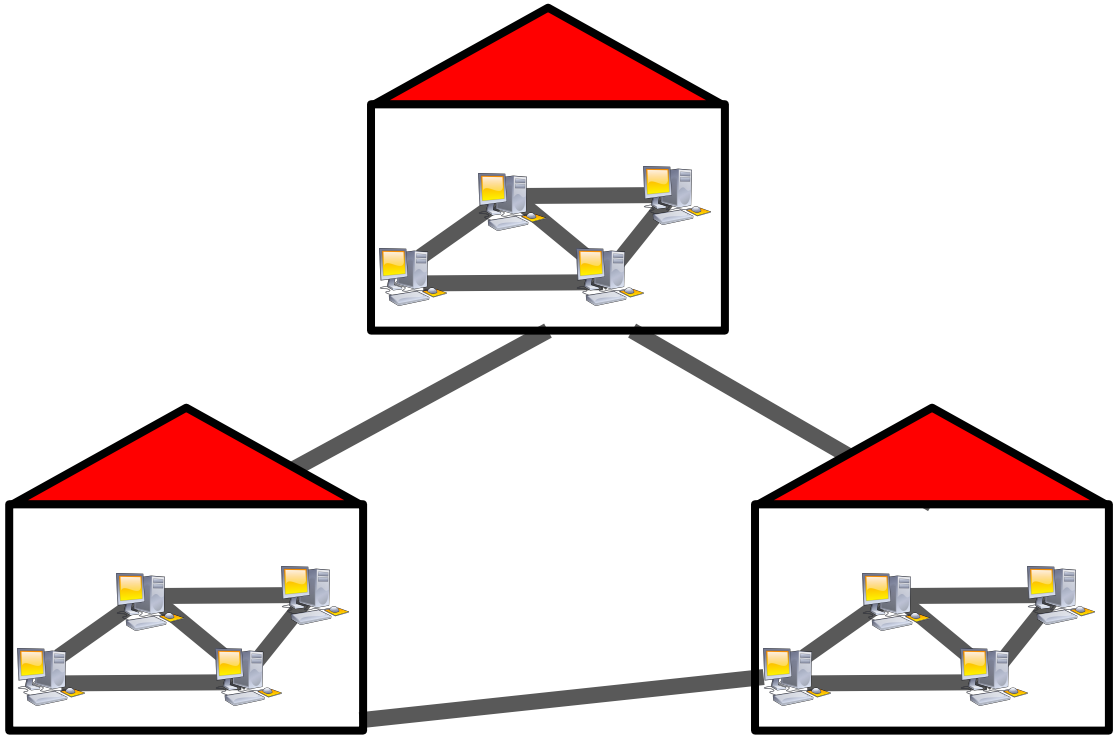
For example: school staff can share private school administration files to each other safely!

What is an “internetwork”?



A “internetwork” is what you get when you connect “networks” together.
“inter” means between

What is an “internetwork”?



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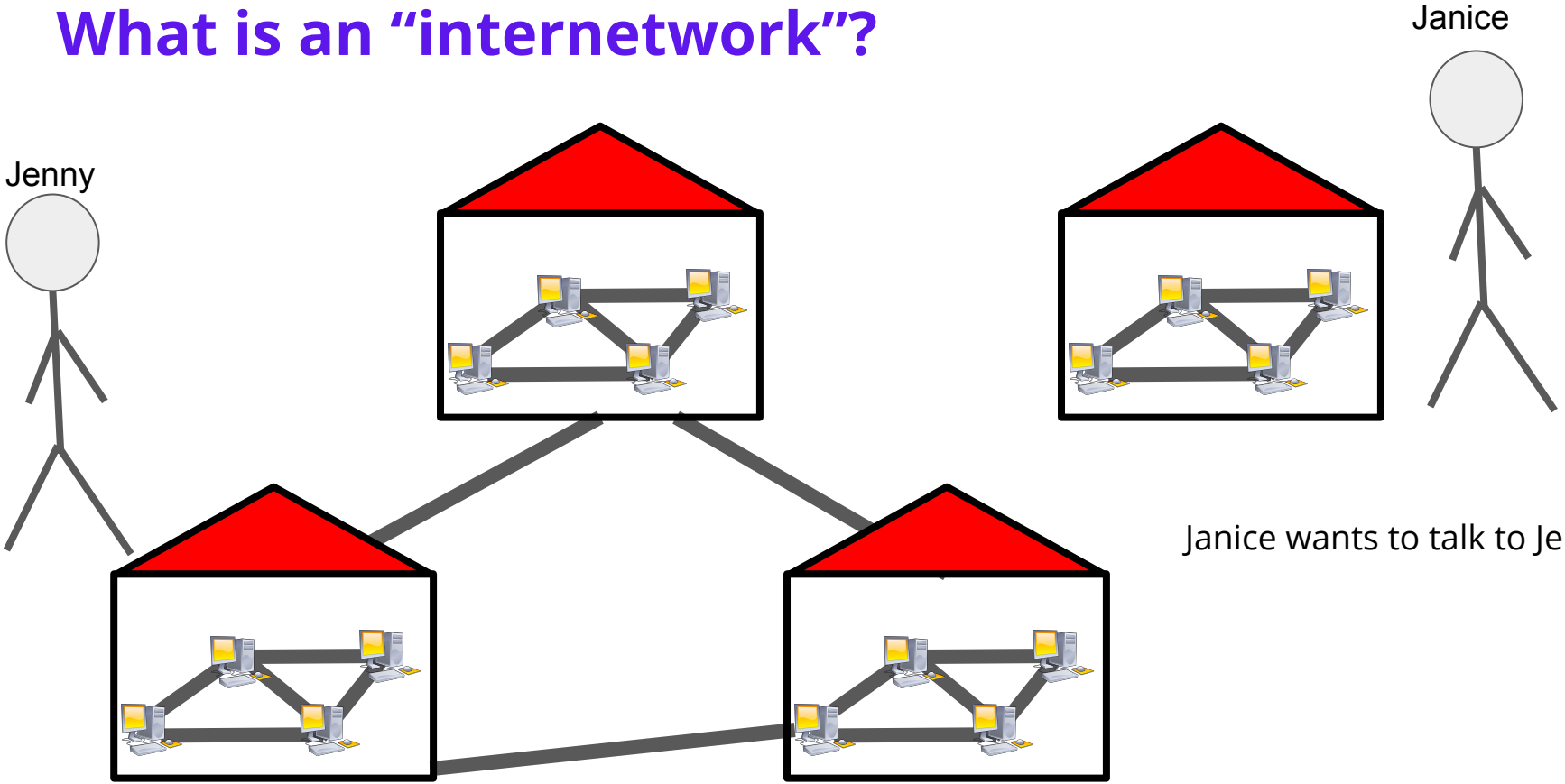
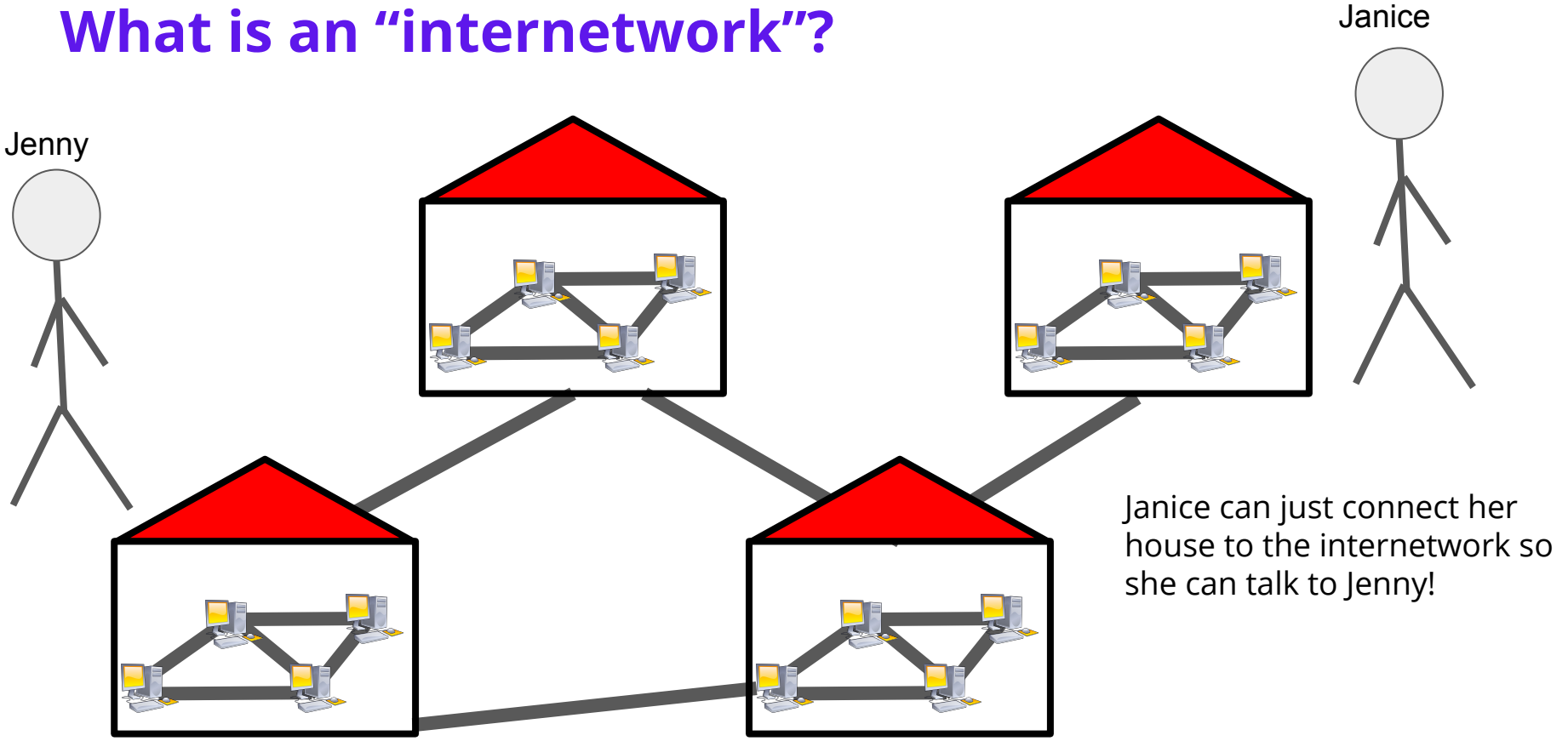


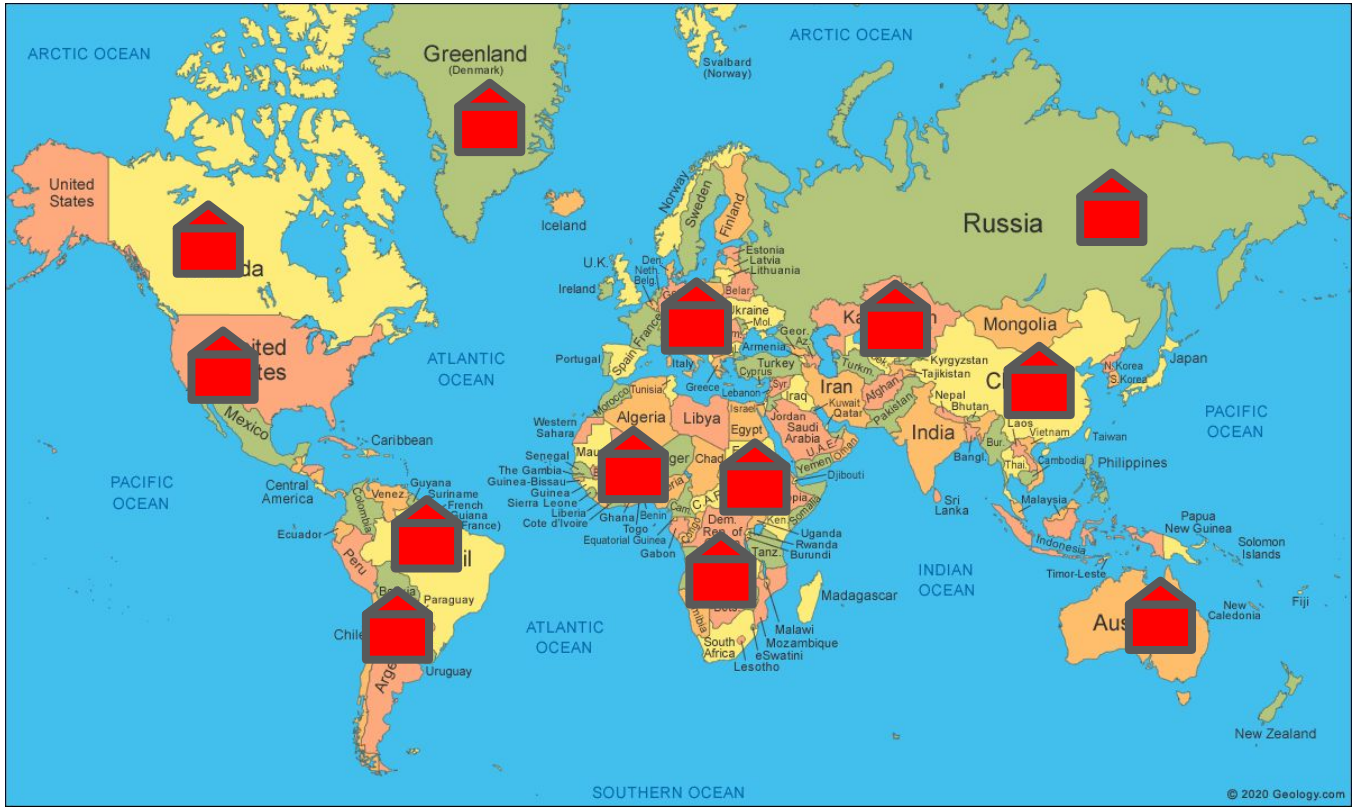
Janice wants to talk to Jenny...

What is an “internetwork”?



Janice can just connect her house to the internetwork so she can talk to Jenny!

What is an “internetwork”?

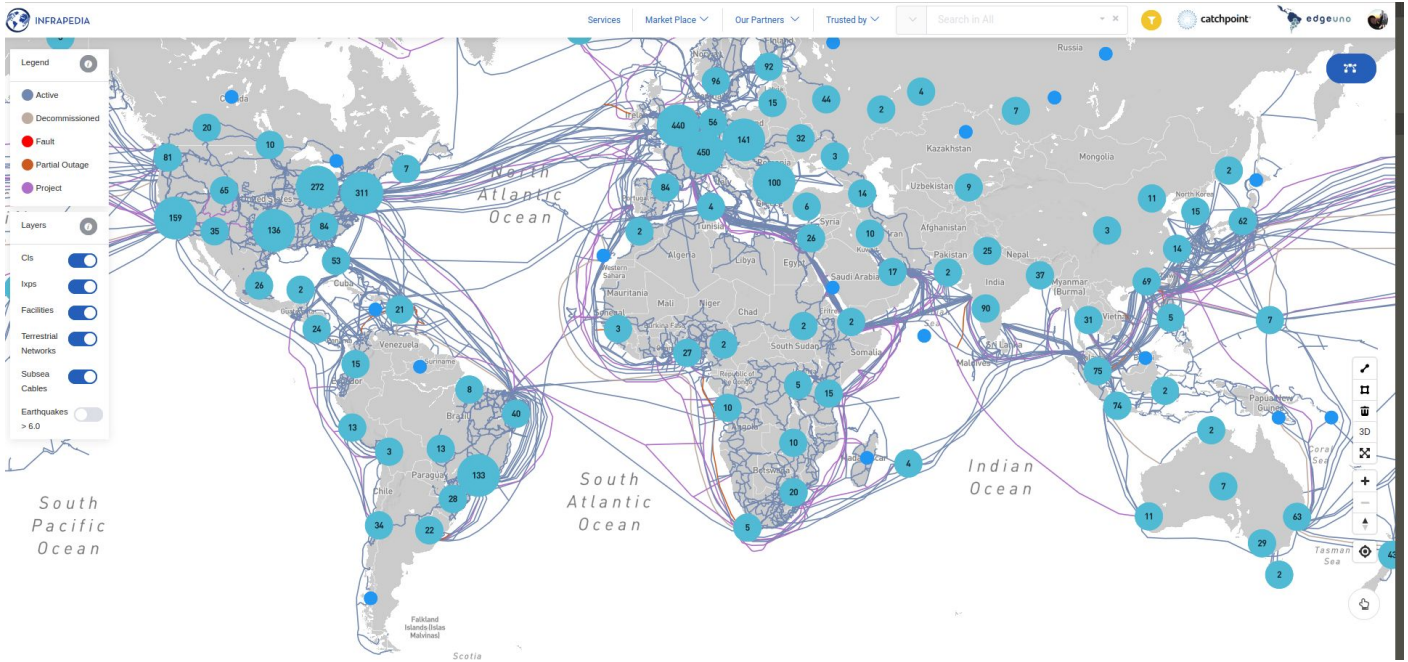


Summary

1. A **network** is a connection that **allows devices to communicate**.
2. A **internetwork** is what you get when you connect **networks** together.
3. The term **internetwork** can be shortened to **internet.**
4. The biggest **internet** in the world is called **The Internet** (with a capital I).

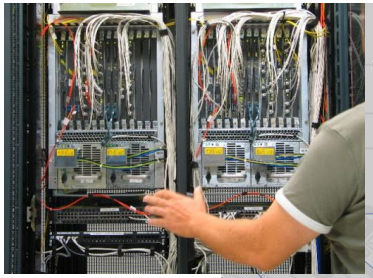
The Internet is Physical

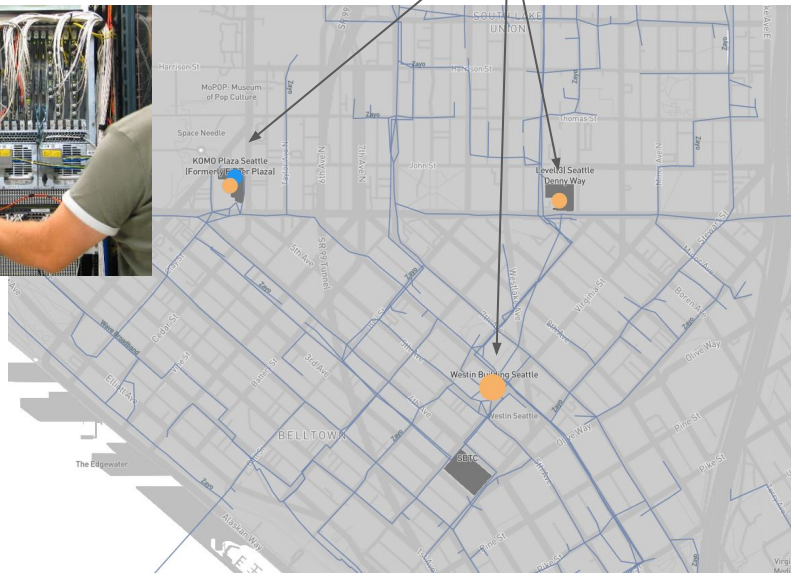
- The Internet: A really big global computer network (infrapedia map)



The Internet is Physical

- At the center: really big “**core routers**” living in data centers and **IXPs**





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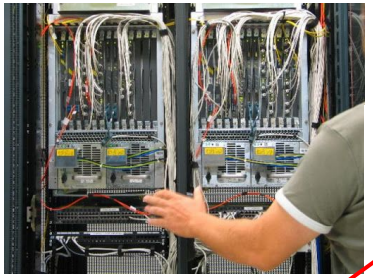

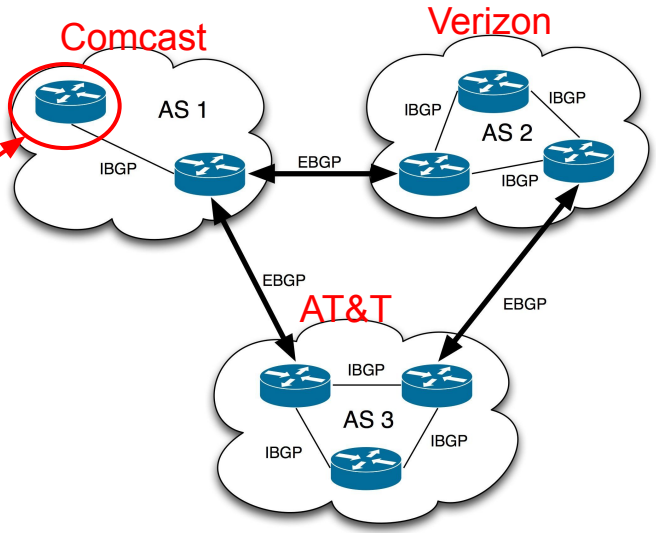

Router

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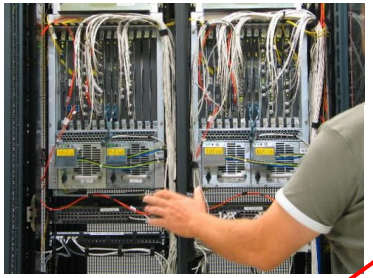
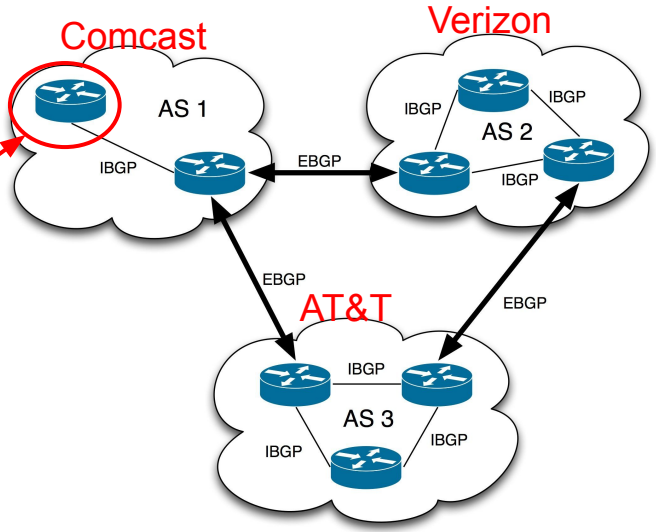


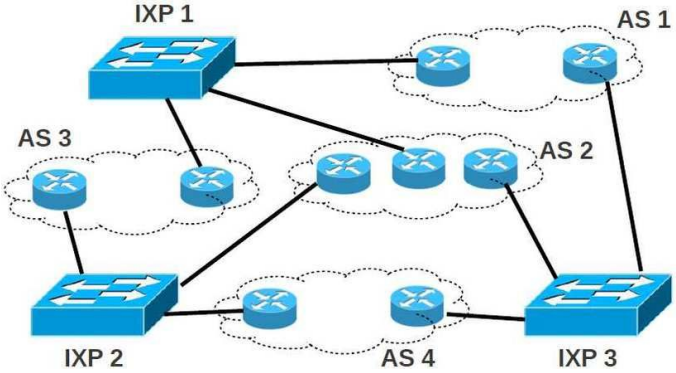
Router

"**Autonomous System**" (AS): basically an Internet Service Provider (like Comcast, CenturyLink, Verizon, AT&T)



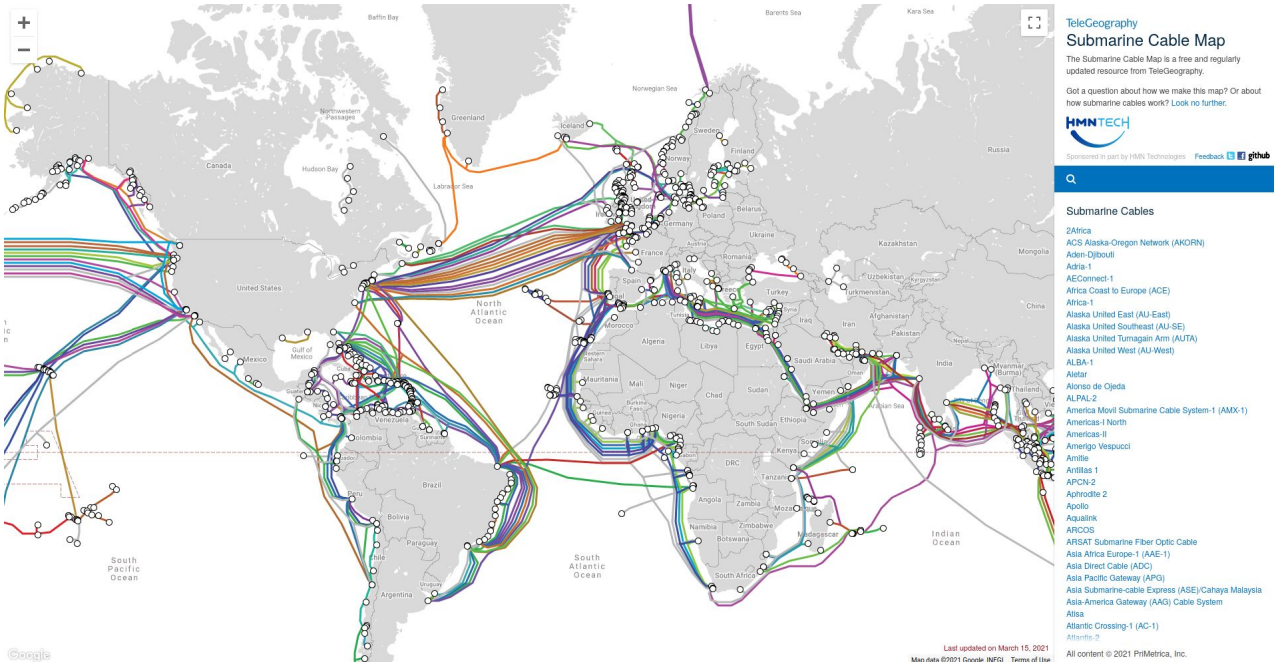
The Internet is Physical

- Core routers of different networks “**peer**” at **Internet eXchange Points**



The Internet is Physical

- **Undersea/submarine cables** connect IXPs/data centers internationally



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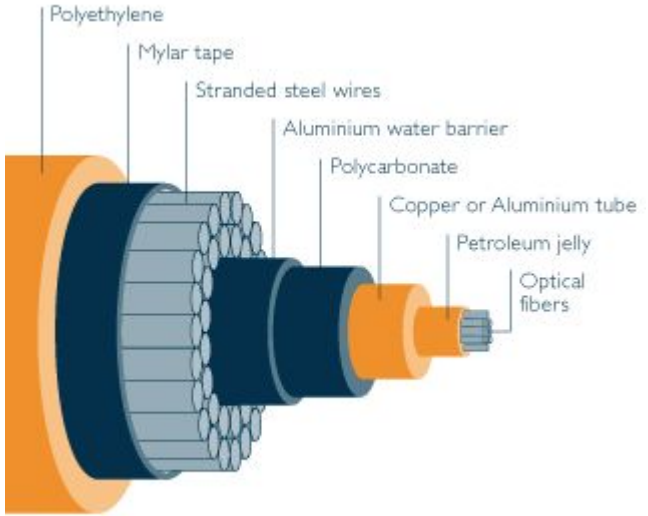
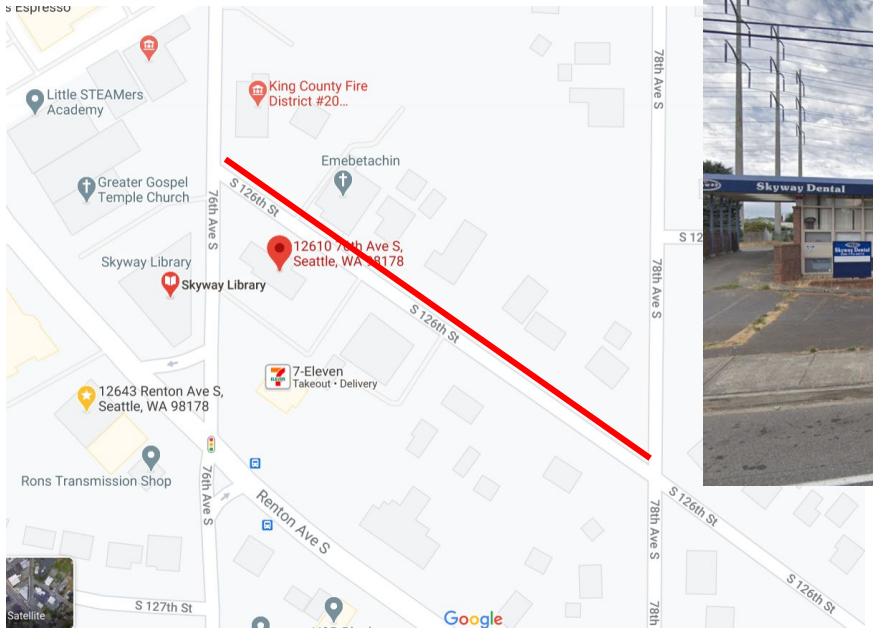


The Internet is Physical

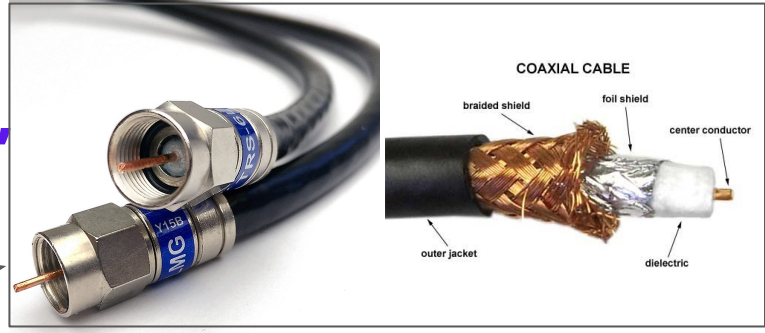
Skyway high-speed Internet?



CenturyLink

Terminology: “Access Networks”

(What end-user devices use to access the Internet)



- Terrestrial networks:
  - **Coaxial cable** (Cable)- electrical signals through copper
  - **Telephone lines** (Digital Subscriber Line or DSL)- electrical signals through copper
  - **Fiber**- light as a signal through glass
    - Bundled fiber (including shared fiber and “dark” fiber)
    - Fiber to the home (FTTH)/Fiber to the premises
    - Very low **latency** (delay to receive data)
  - **Wireless/Cellular**: radio waves through air
    - Towers with broadcast antennas

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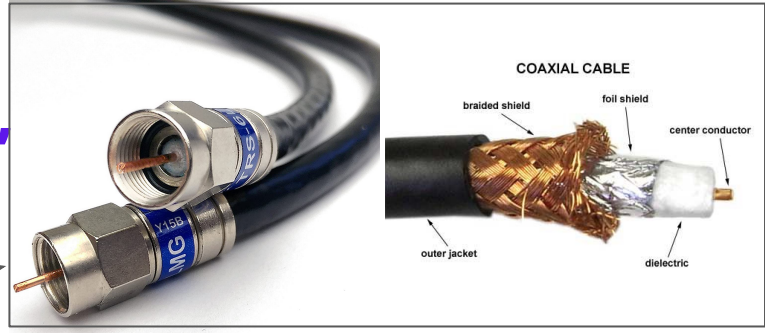

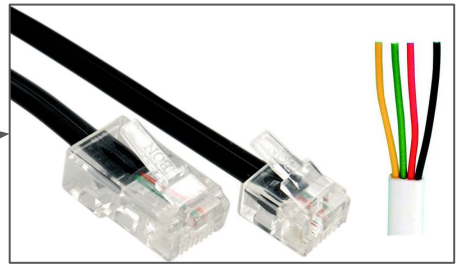

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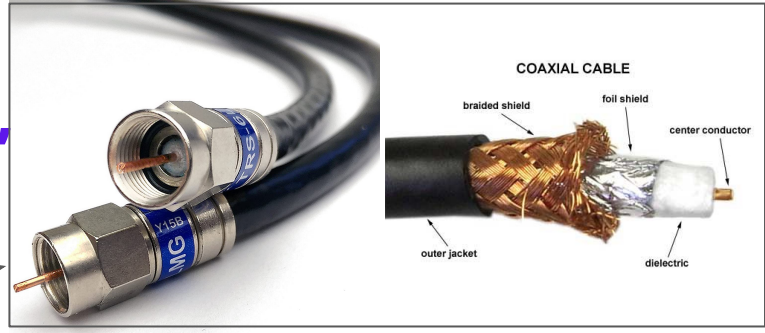

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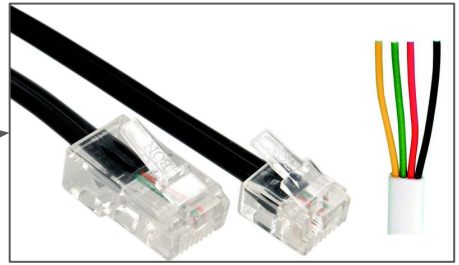

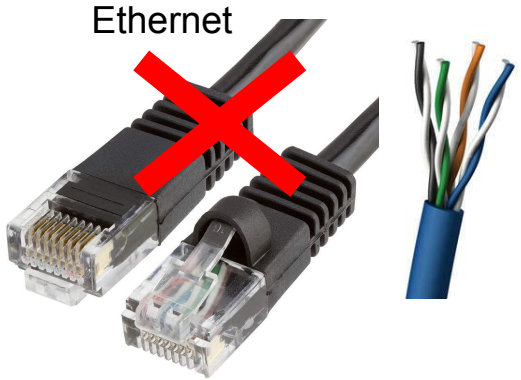

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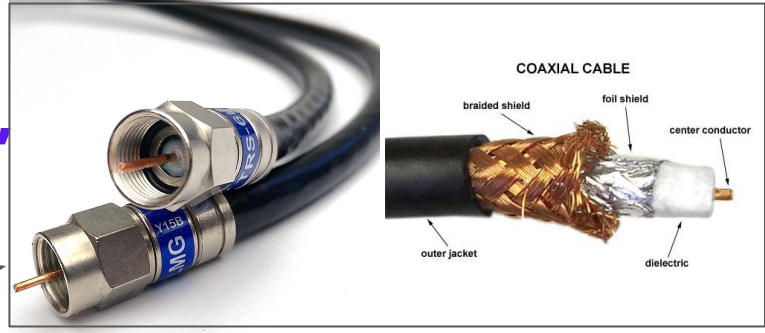

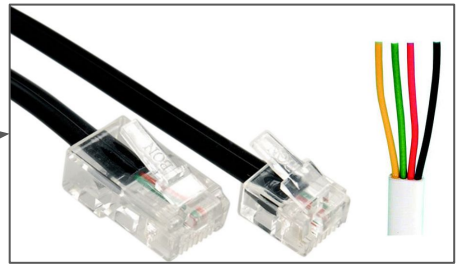

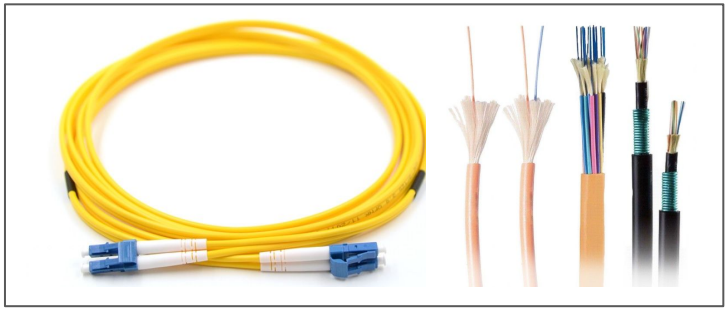

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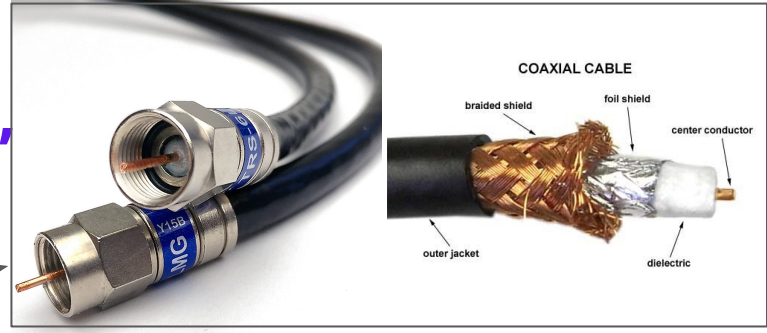
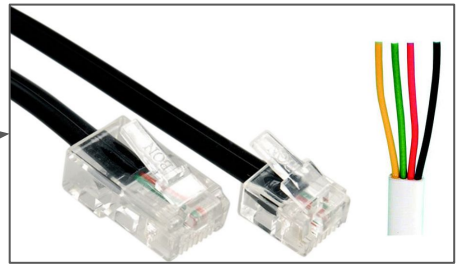
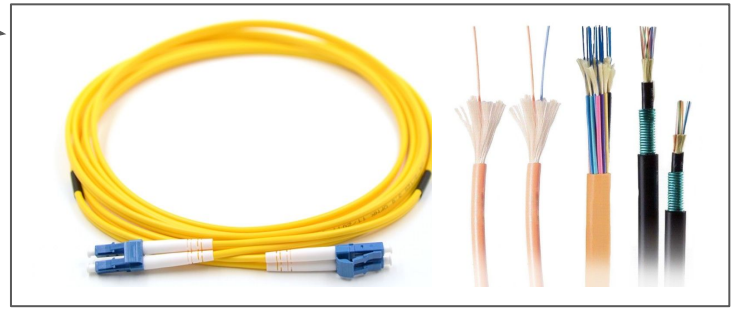


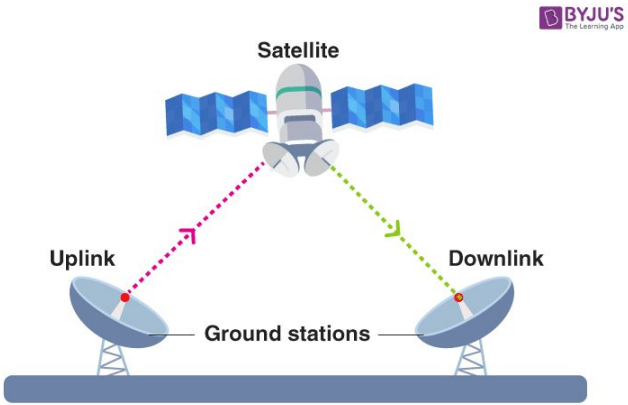




Terminology: “Access Networks”

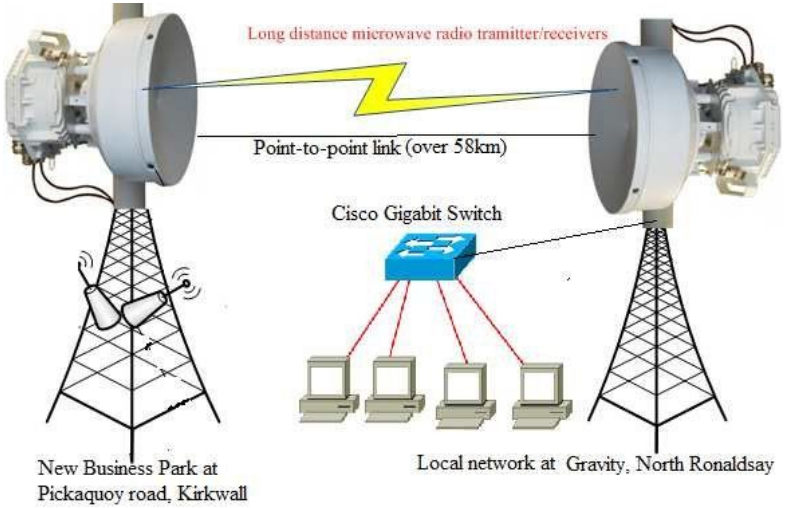
(What end-user devices use to access the Internet)

- **Satellite:** using radio waves through air
  - Satellites in space (relay waves around curved earth)
  - “Ground stations” send to and receive from satellites
  - Very high latency (99-22,000 miles above earth)



Terminology: “Backhaul”

Whatever connects the “access network” back to a bigger network*



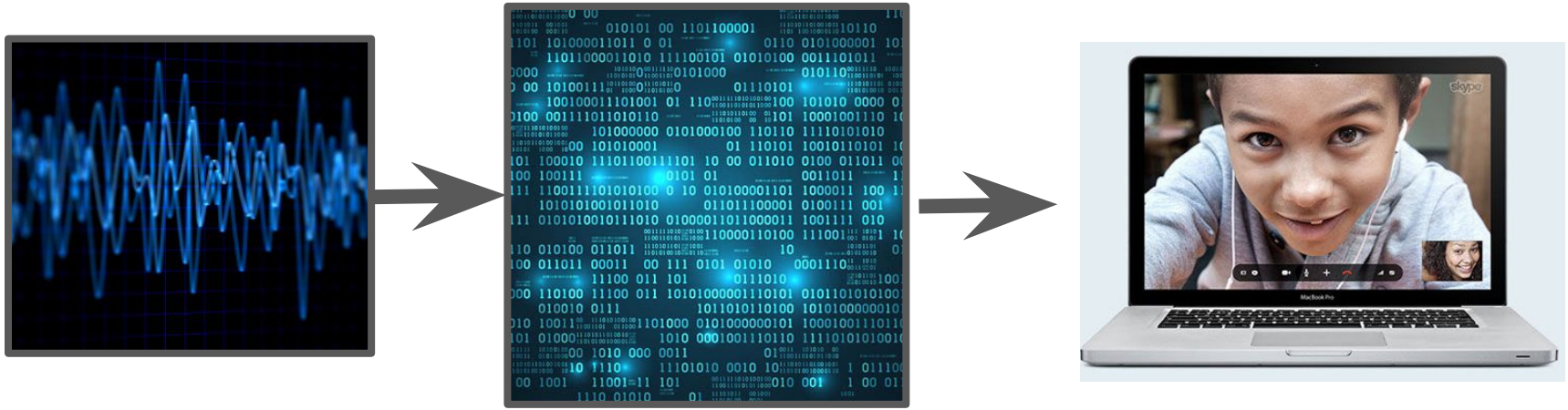
“Microwave” backhaul antennas

* Even the backhaul has a backhaul until it reaches a top-level core router

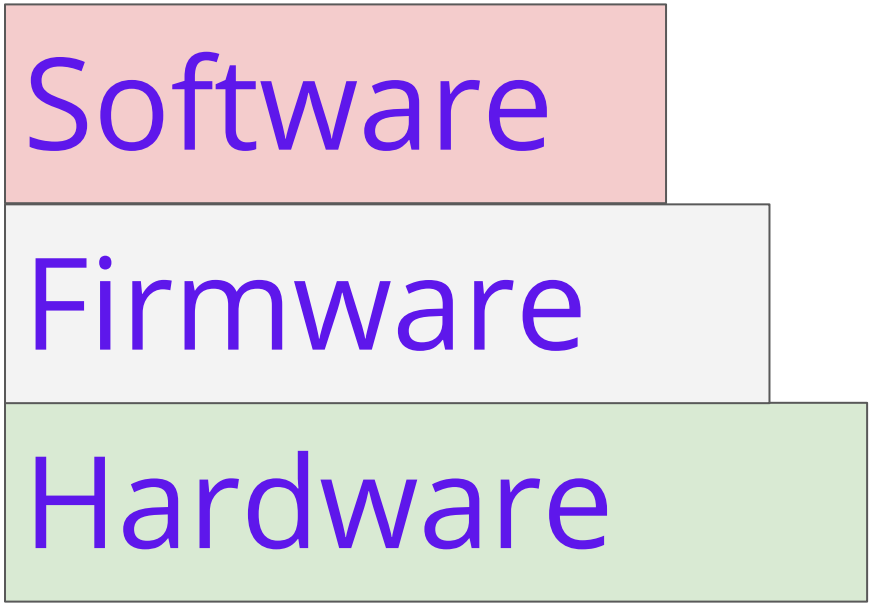
How it works

We’re trying to send some data

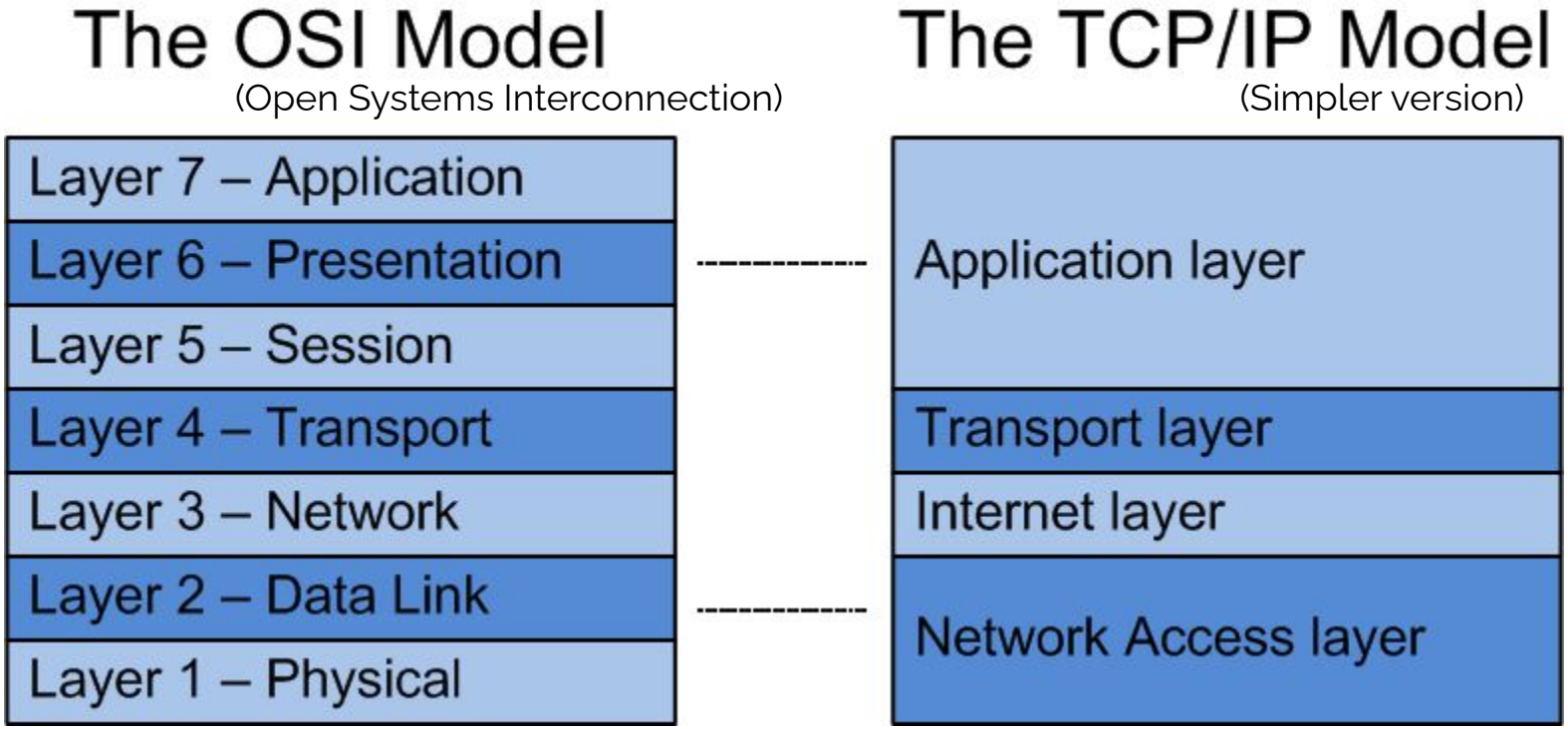
- How do we translate from **physical radio waves** to **computer applications** and the other way around?
- Task: Send message from Computer A to Computer B using the Internet



Layers of abstraction



Network Layers



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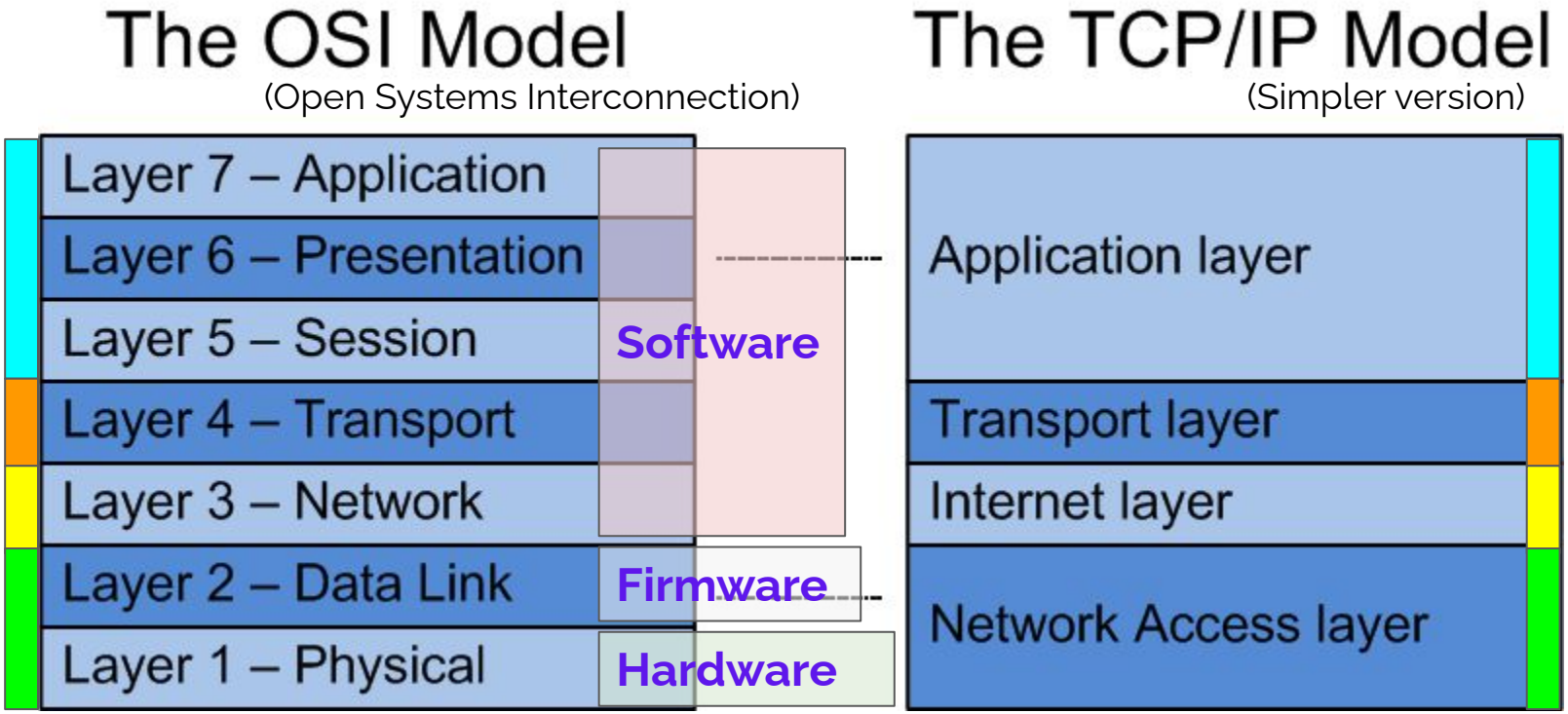

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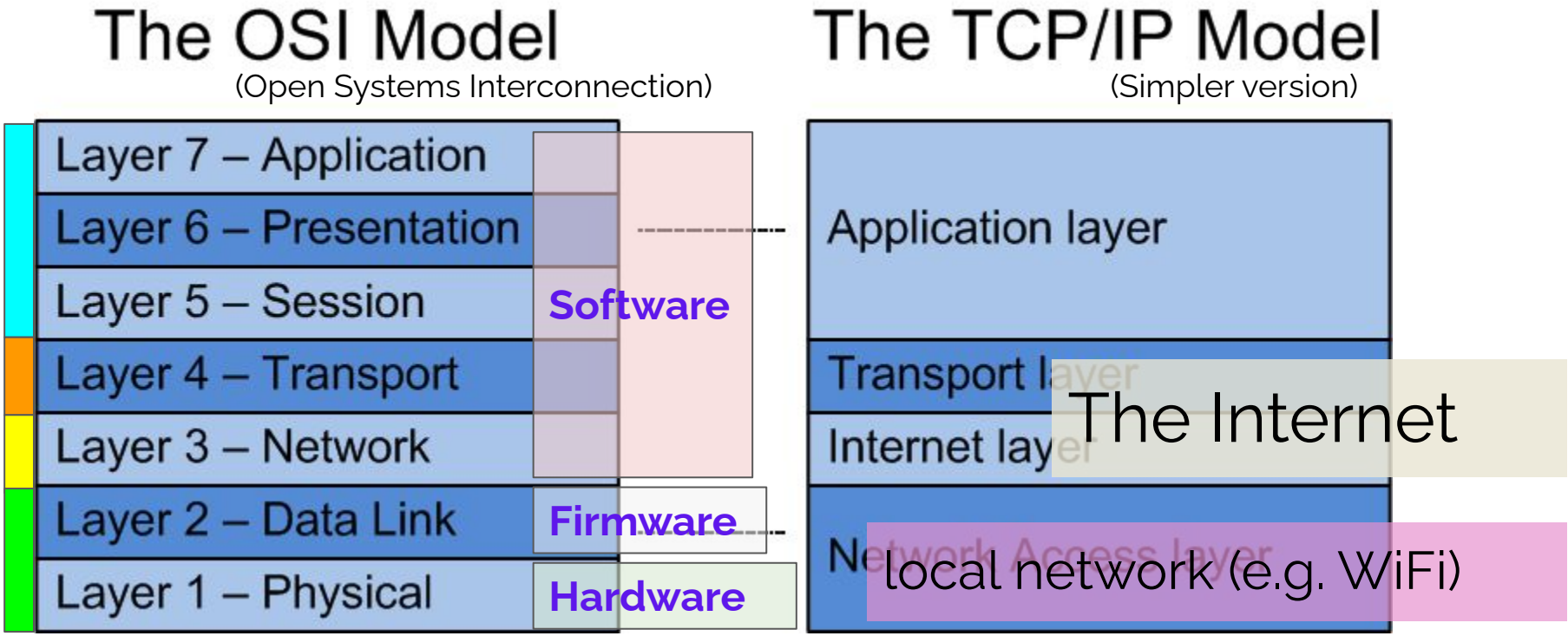
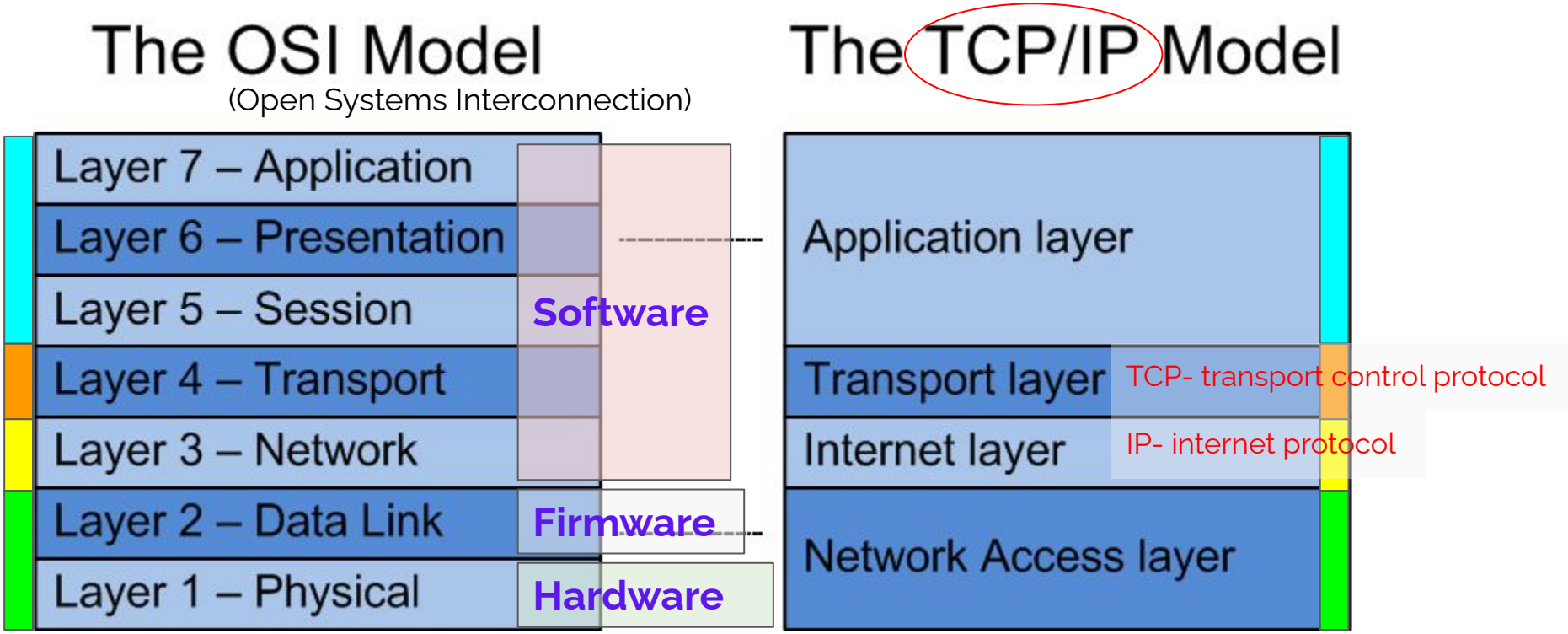


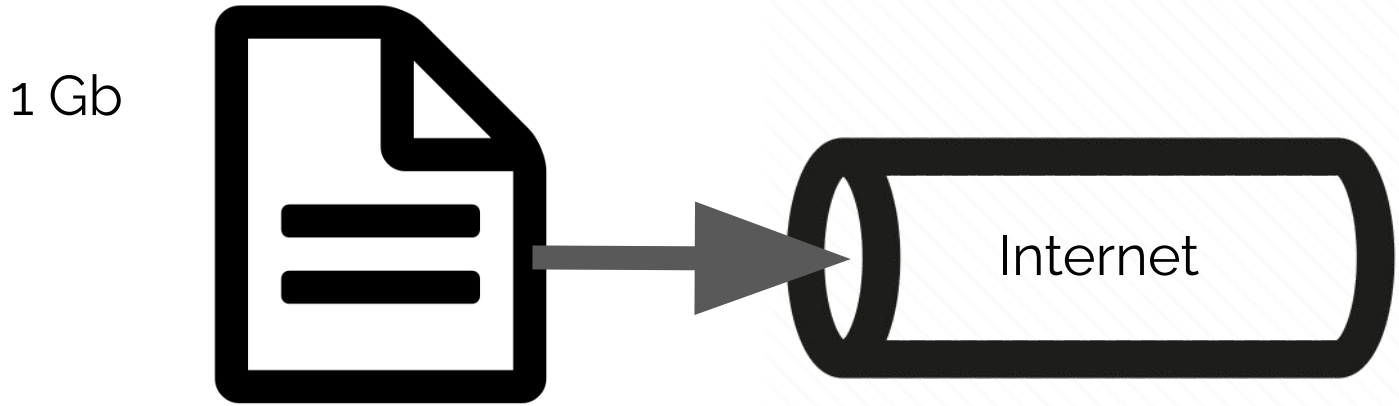
Network Layers

(these are communication "protocols")



Concept: Packet Routing

- You have a large file to send (1 Gigabyte)
- Internet connection for your street is 1 Megabyte per second



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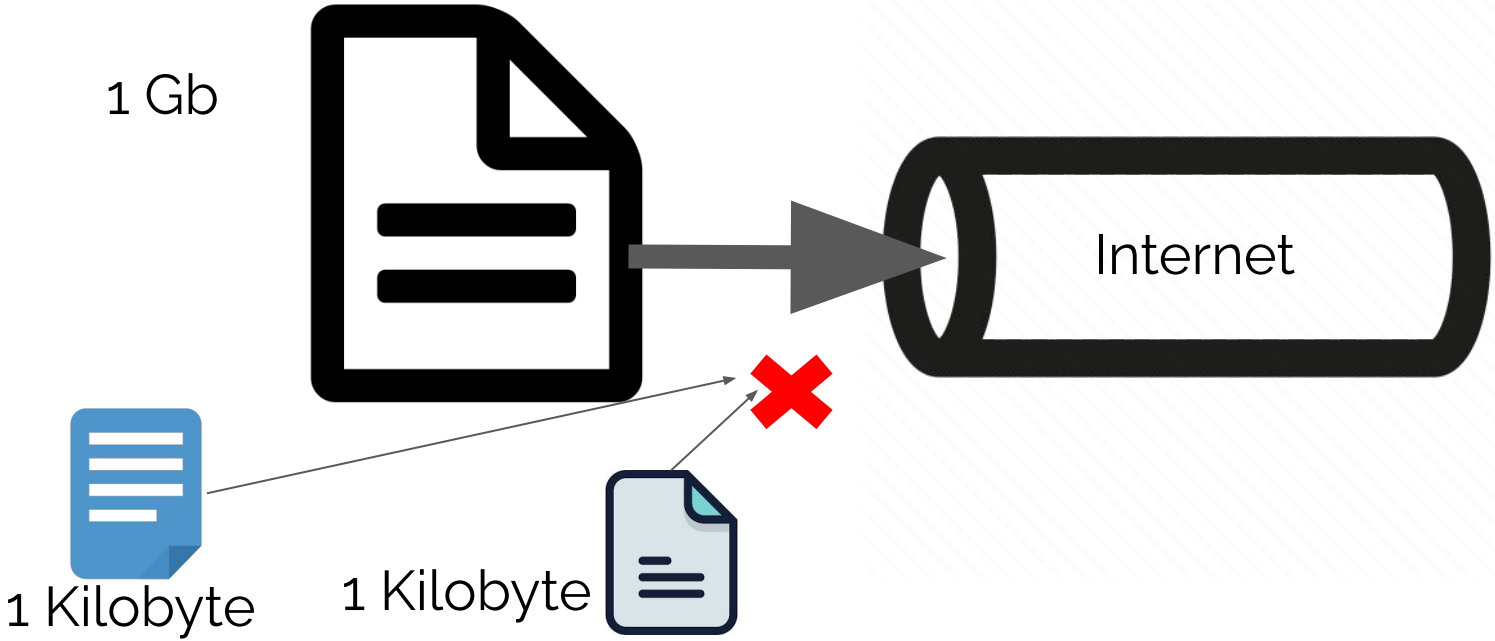
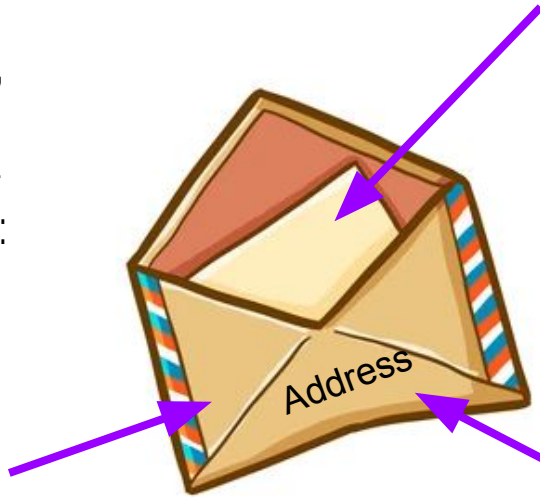


Concept: Packet Routing

- Break data up into small pieces called "**packets**"- e.g. 1 Kb or so
  - For **routing** to the correct address: Attach a "**header**" with routing information so routers in between know where to send it.
  - **Reassembled** into a file at the **destination**.
- **Note:** destinations are physical or virtual **network modems/ "cards"** (hardware and firmware), identified by a globally unique **MAC address**: e.g. `e4:a4:71:30:81:44`
  Network cards are also called "**interfaces**"



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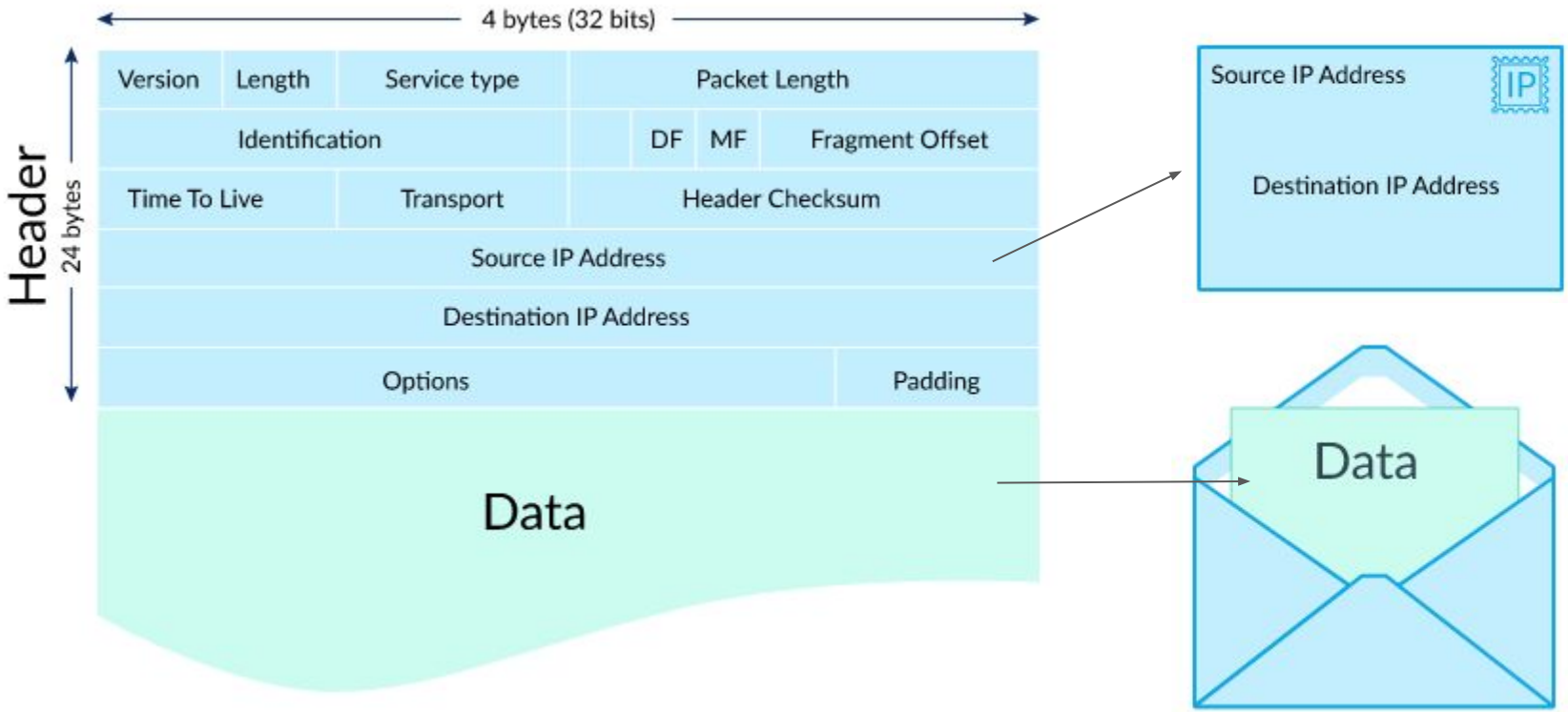
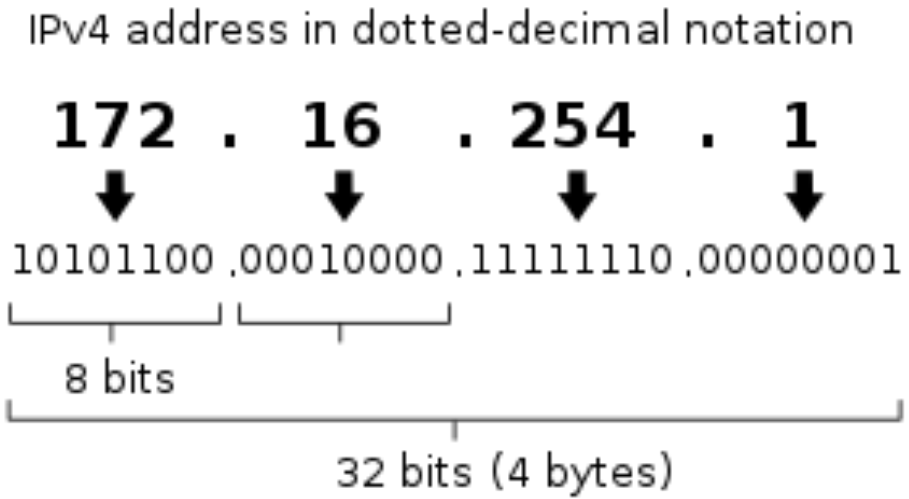


Internet Protocol (IP) Addressing

- There are Internet Protocols version 4 and 6 being used
- IPv4 is more common:



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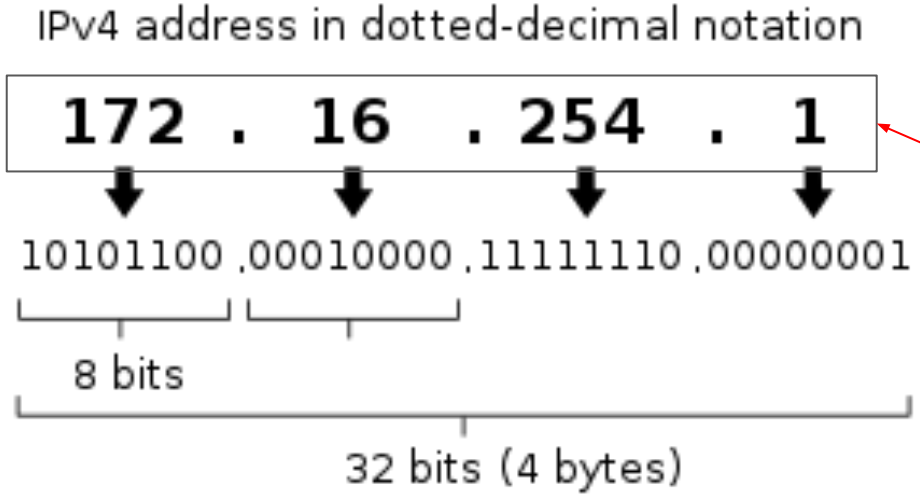

We are going to assign an address to **every single computer** on the Internet with a combination of just 4 numbers.

Note!! Data sizes

1 bit = 0 or 1 (smallest unit of information in a computer)

1 “byte” = 8 “bits”

1000 “bytes” = 1 Kilobyte (Kb)

1000 Kb = 1 Megabyte (Mb)

1000 Mb = 1 Gigabyte (Gb)

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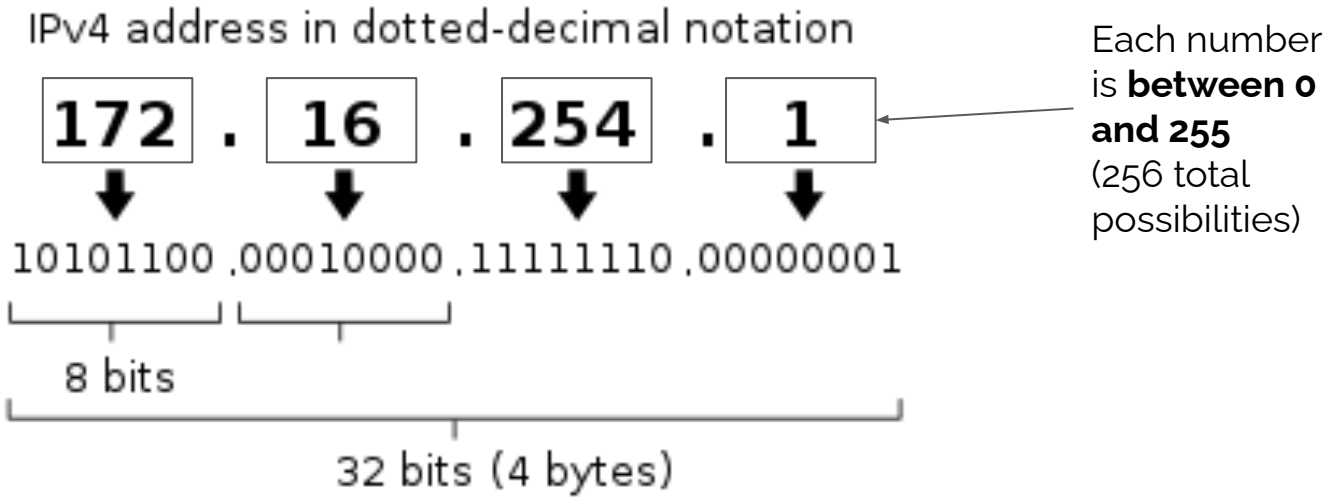

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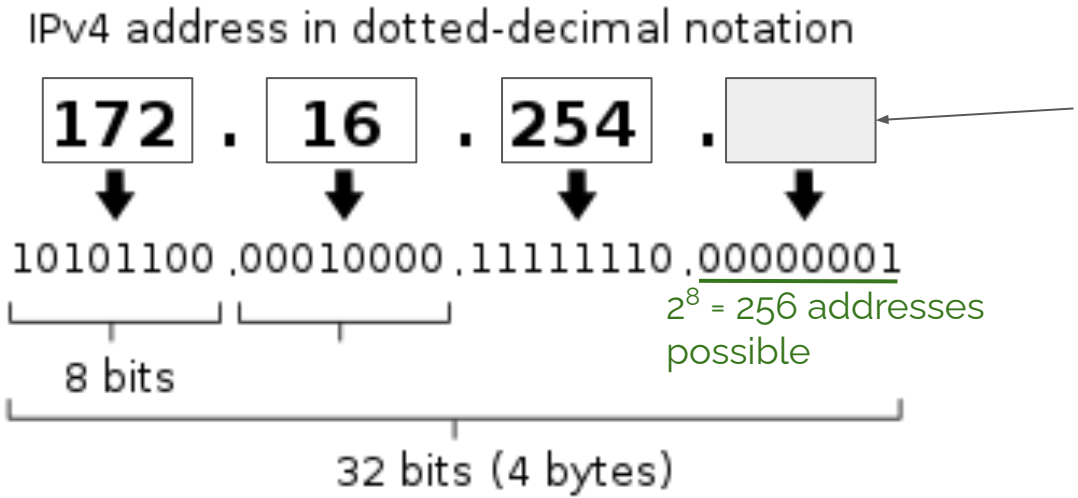
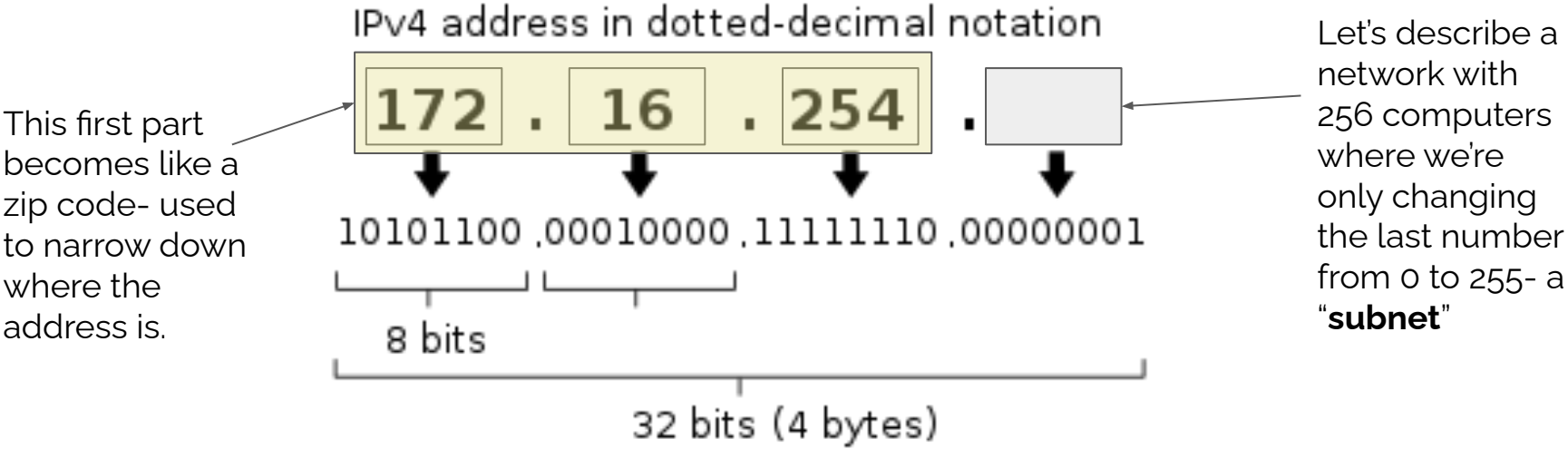


Let's describe a network with 256 computers where we're only changing the last number from 0 to 255- a "**subnet**"

Internet Protocol (IP) Addressing

- There are Internet Protocols version 4 and 6 being used
- IPv4 is more common:



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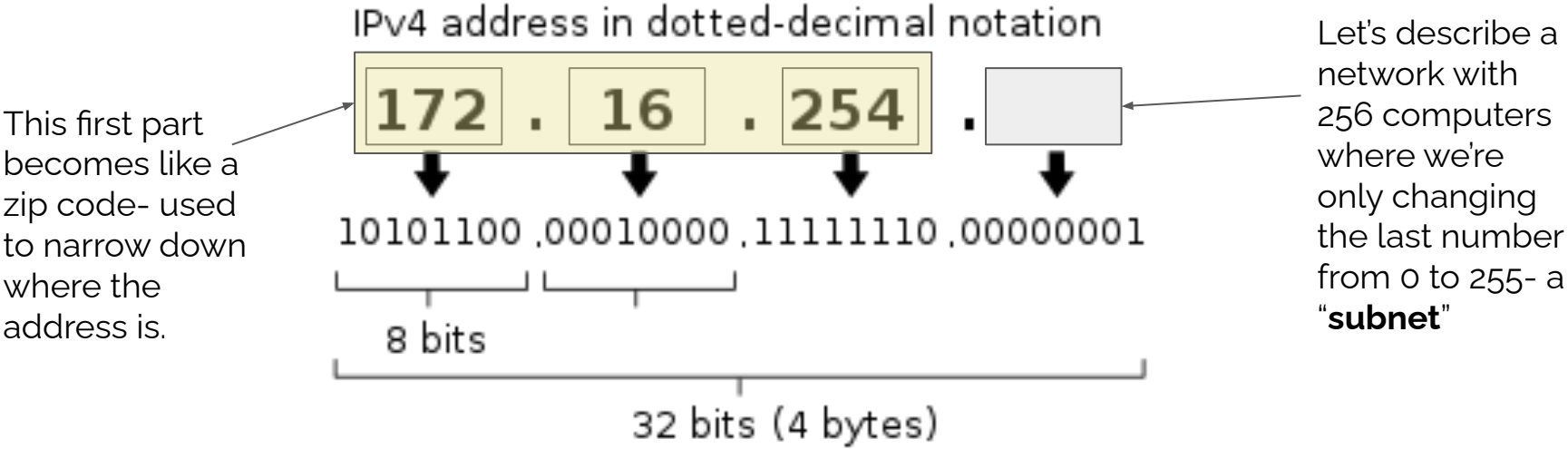

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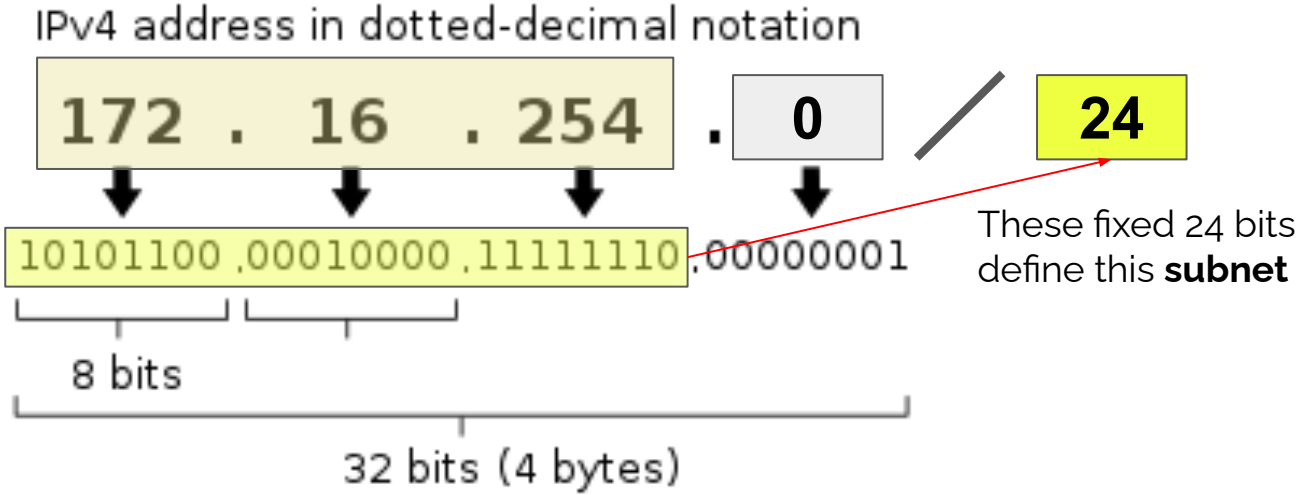

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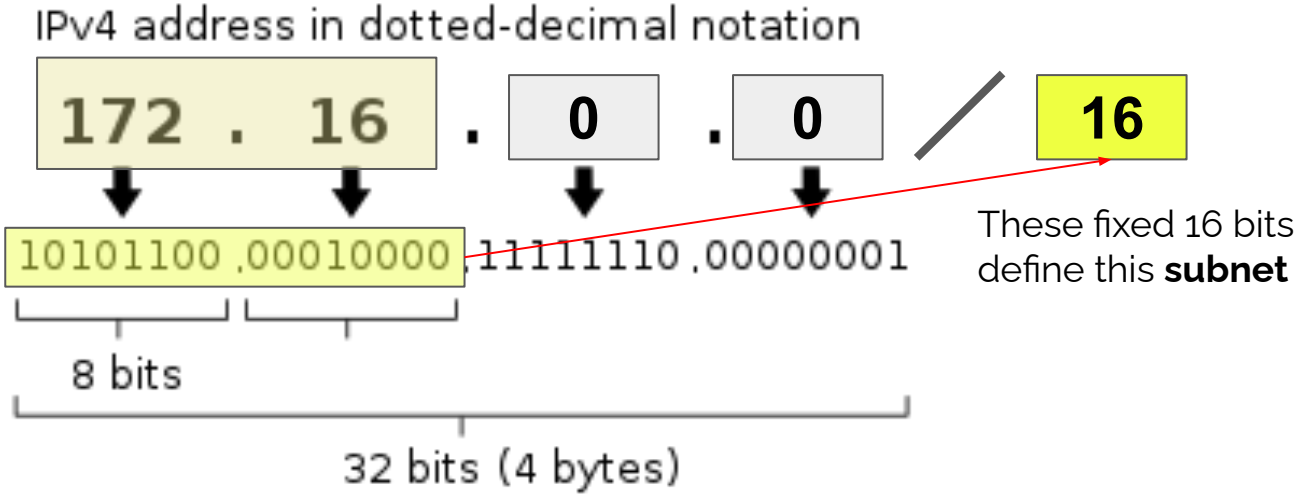

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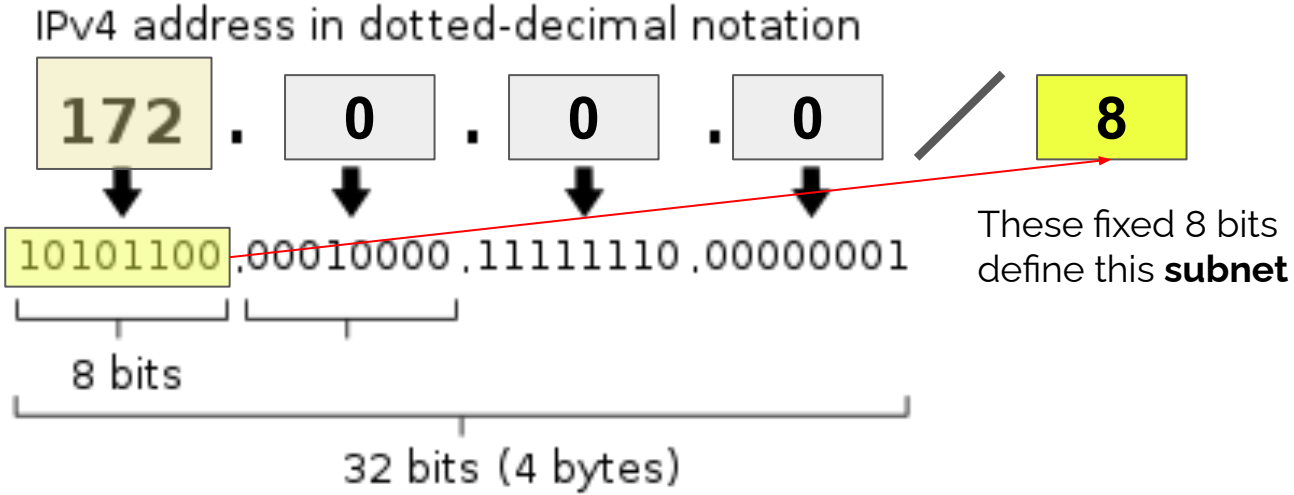

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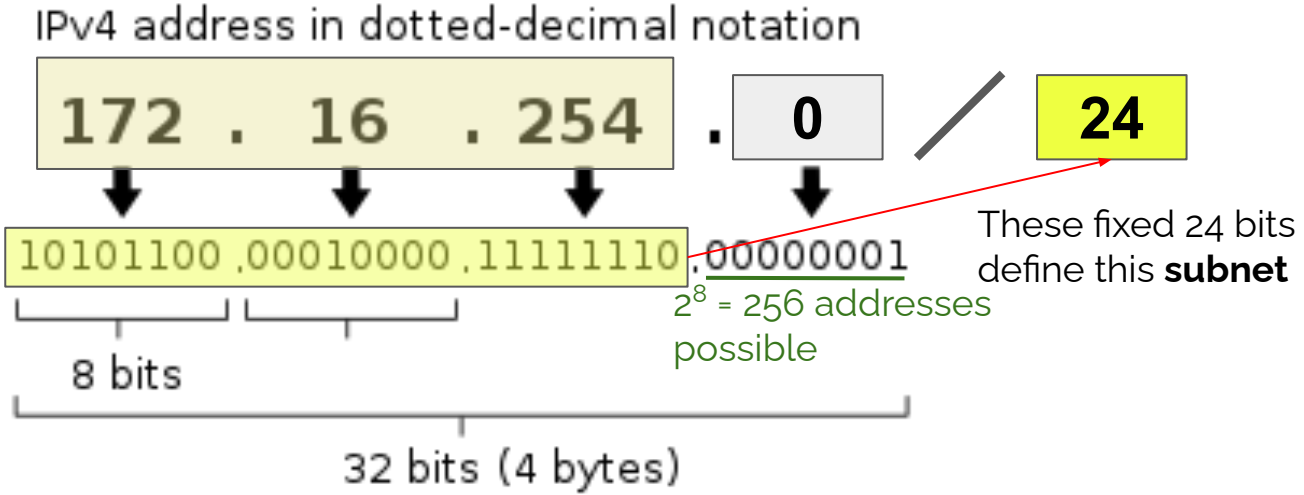

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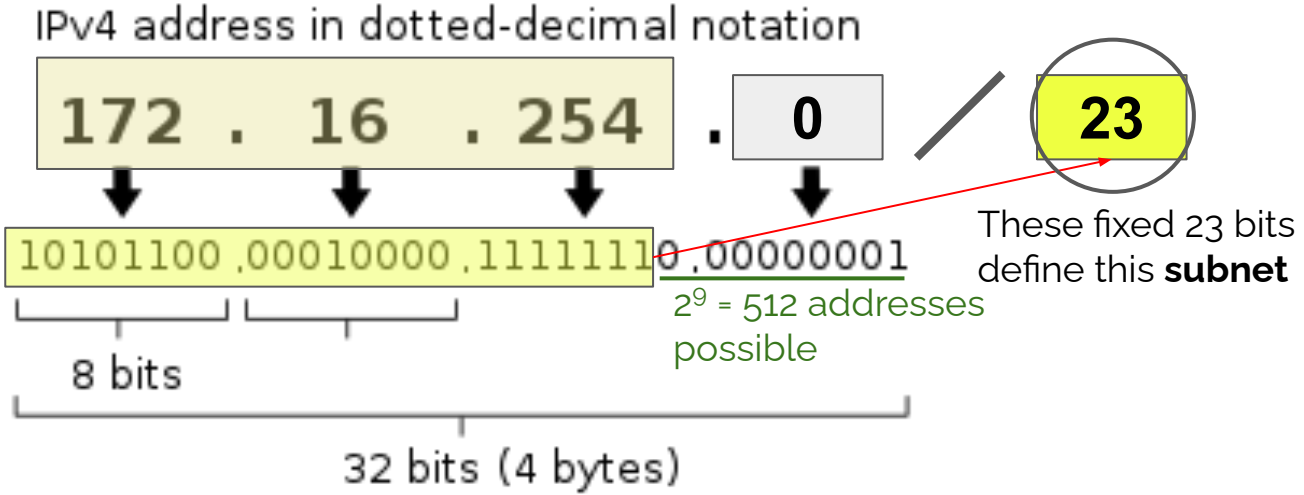

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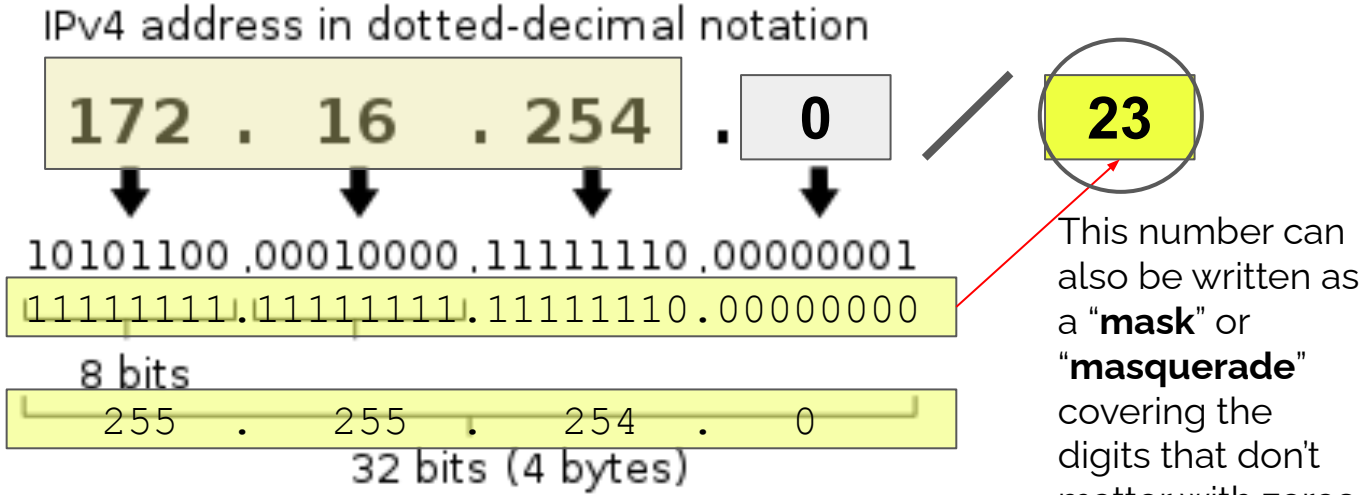
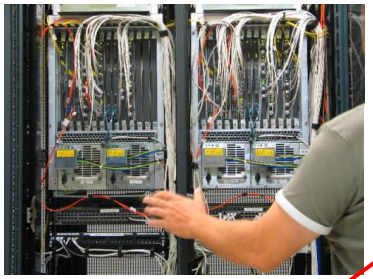
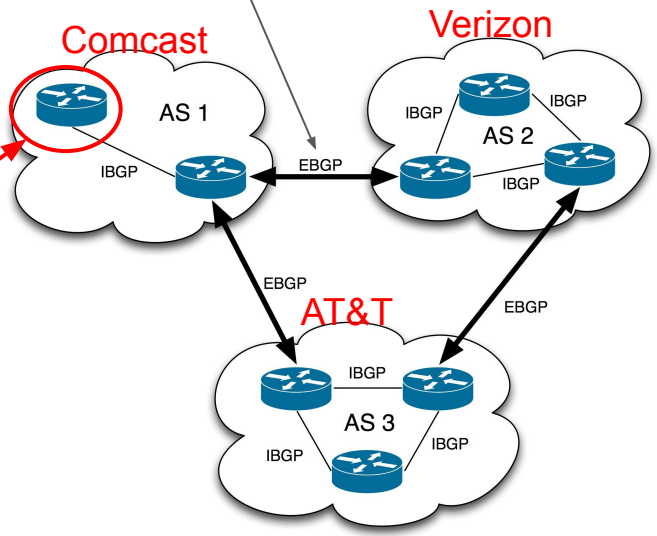


CIDR notation is used a lot



Router

Each ISP network has its own IP address block, which is a **subnet** of the total IP address space. It **advertises these addresses to other networks** via the Border Gateway Protocol (BGP).



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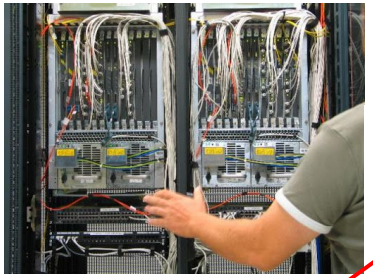

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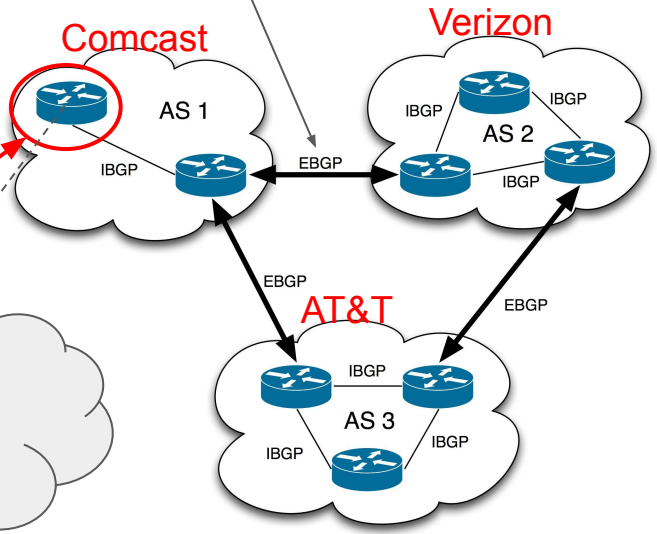
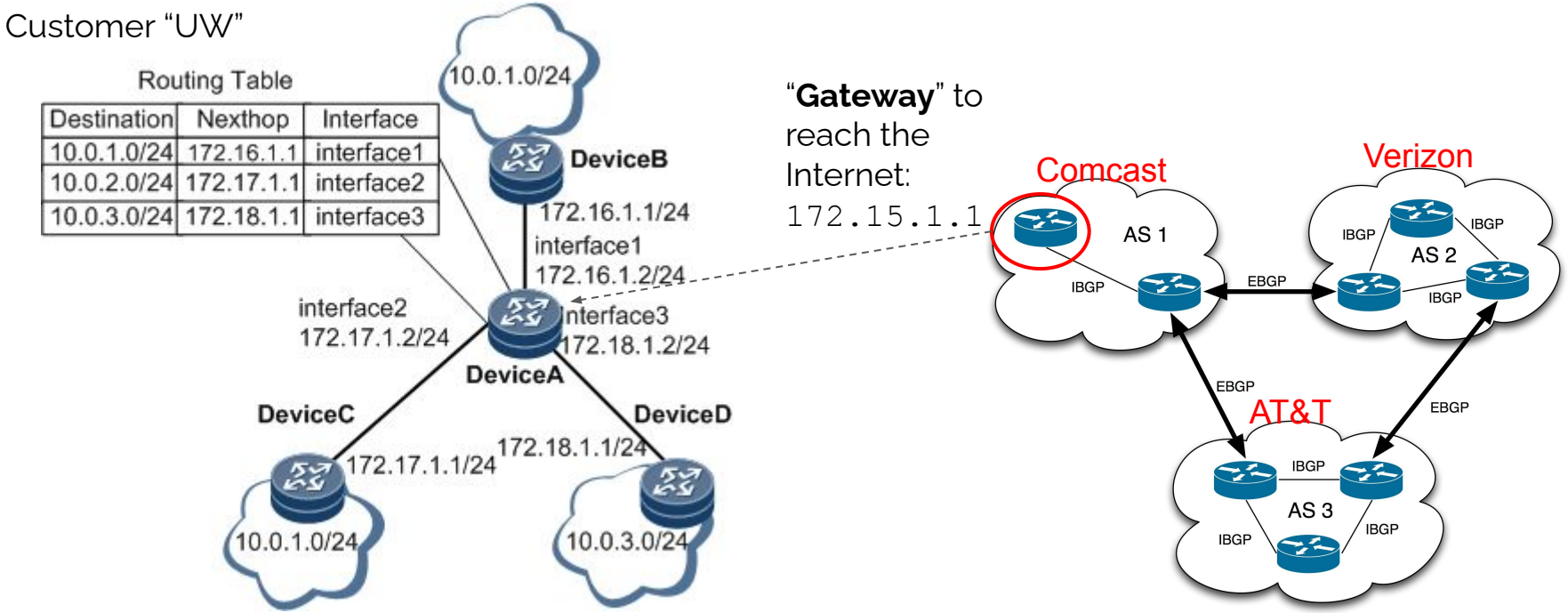


Routing

Each router has a **routing table** where it stores the "next hop" for different subnets.



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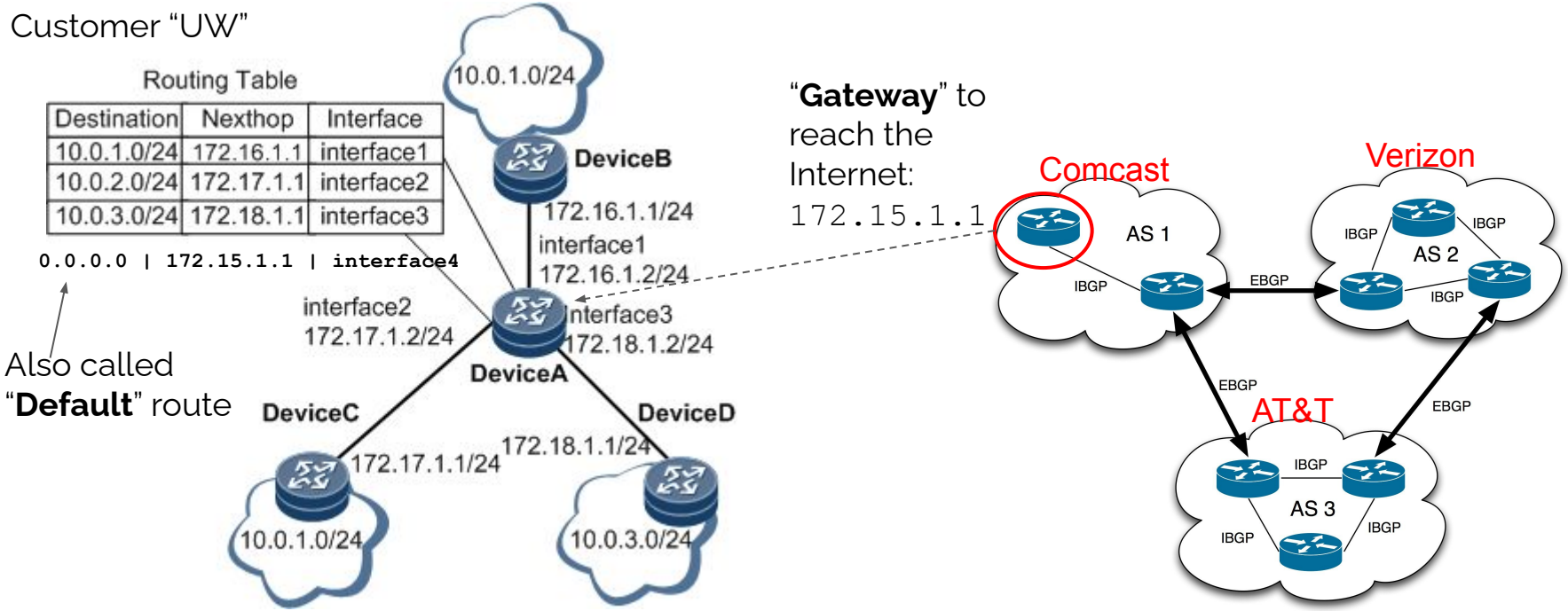


Network Address Translation (NAT)

- Problem with IPv4 addresses:
  - 32-bits long → 2^{32} addresses → 4,294,967,296 addresses
- 4 billion isn't enough!!!
- Can distribute to **large networks**, but not enough for **every single device.**
- Solution:
  - Give each network an address, and let the network figure out how to send data to individual devices

Network Address Translation (NAT) - An Analogy

Like sending mail to an office in a huge building

- We only put down the person's name and the address of the building
- The people who work there distribute the mail

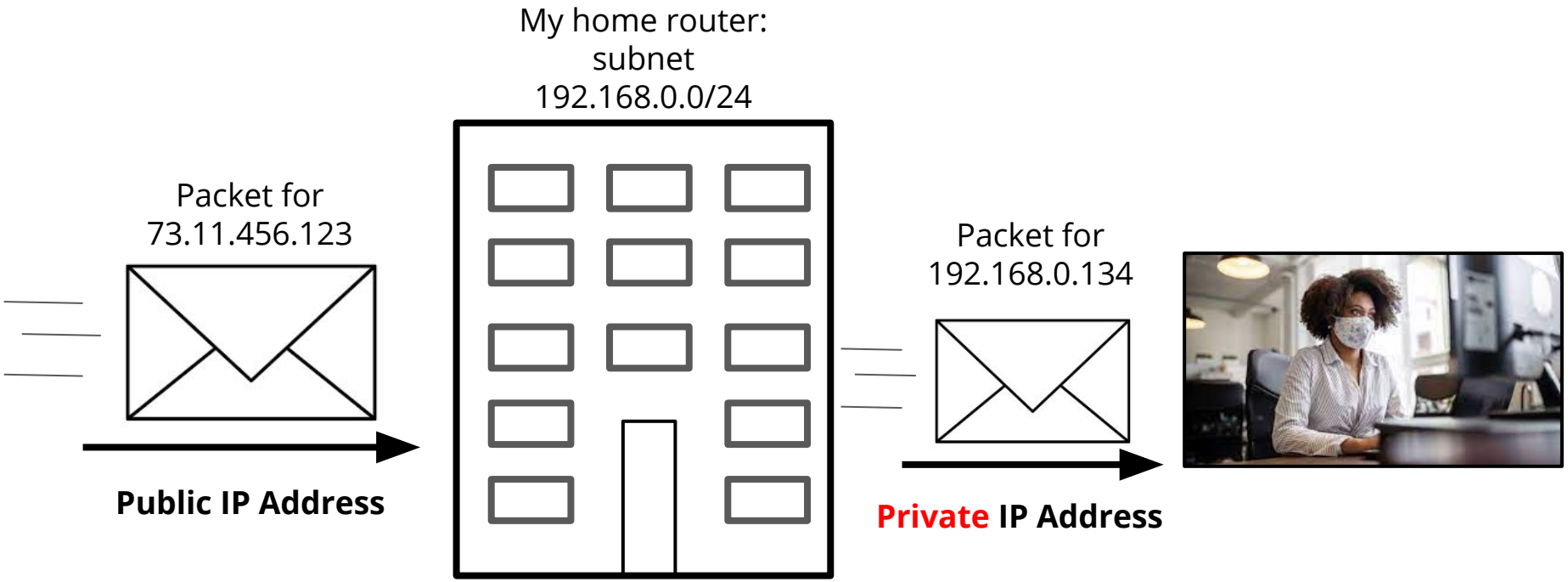
Esther Jang

185 E Stevens Way NE

Seattle, WA 98195

Room CSE1-678

Network Address Translation (NAT)



Network Address Translation (NAT)

- **Private IP address spaces**: (Use these wherever/whenever you want!)
  - **`10.0.0.0/8`** (`10.0.0.0 - 10.255.255.255`)
  - **`172.16.0.0/12`** (`172.0.0.0 - 172.16.255.255`)
  - **`192.168.0.0/16`** (`192.168.0.0 - 192.168.255.255`)
- These are **not publicly routable**. No Internet router (beyond your home router on your local network) will forward this traffic.

Network Address Translation (NAT)

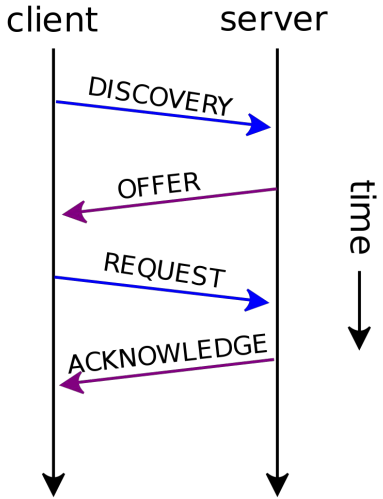
Note:

- IPv6 (we're transitioning) does not use NAT!
- IPv6 addresses have 128 bits and look like this:

  `2001:0db8:0000:0000:0000:ff00:0042:8329`
- Written in hexadecimal with digits 0-15 (0-9 and then A-F)

Dynamic Host Control Protocol (DHCP)

- A service (computer program) run by an access point (e.g. **your home router**)
- **Gives a device on its network an IP address** in a particular subnet that you define in the router
  - Usually private IPs from your home router
  - May also be public IPs, e.g. given from your ISP's network to your home router
- Your device asks for an IP address and the router gives you a "lease" for an address that **expires after a particular time**
  - ISP may refresh your public IP address every 8 hours or every few days, though it often stays the same even with a new lease

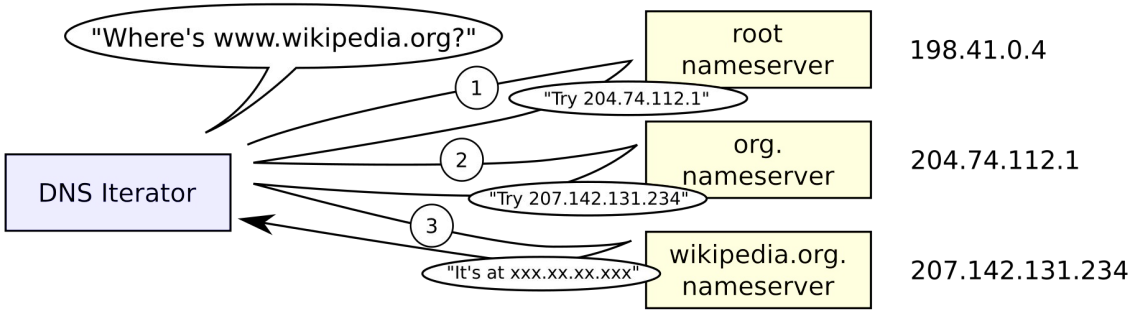


Static IP Assignment

- **Static IP Assignment**- when your IP address stays the same for your device over time (vs. Dynamic when it doesn't)
- Any network device can **assign itself an IP address**! Don't have to ask for it. But if the routers you're going through don't know the routes for it, you will not be able to send or receive using that address. (Like telling USPS the wrong mail address.)
- If you assign yourself an IP address on the **same subnet** as another device (according to its routing rules), you can usually talk to it without setting up any routing.
    - Due to the Address Resolution Protocol (ARP) which discovers local network

Domain Name Service (DNS)

- “Address book/phone book” service to look up URLs’ IP addresses
  - E.g. “Where is facebook.com?” → `157.240.3.35`
- Specific servers on the Internet serve DNS queries
  - Google: `8.8.8.8`
  - CloudFlare: `1.1.1.1`
  - Easy way to check Internet connectivity- if you can successfully reach these IP addresses
- Redirecting someone’s DNS service can result in hacking!



Assignment 4 preview

DNS Experiment

Go to your web browser and go to this website:

`54.214.77.106`

DNS Experiment

Go to your web browser and go to this website:

`54.214.77.106`

Your web browser is programmed to recognize and “resolve” IP addresses directly, to access websites served at those IP addresses.

Ping Experiment

- The “ping” program sends a small “hello” packet containing no data to check connectivity.

Go to your terminal and execute the following command:

```
ping uw.edu
```

What happens?

(Hint: use Ctrl-C to stop the running program.)

What about this one?

```
ping google.com
```

Why are the results different?

If there’s time…

The Internet is still the Wild West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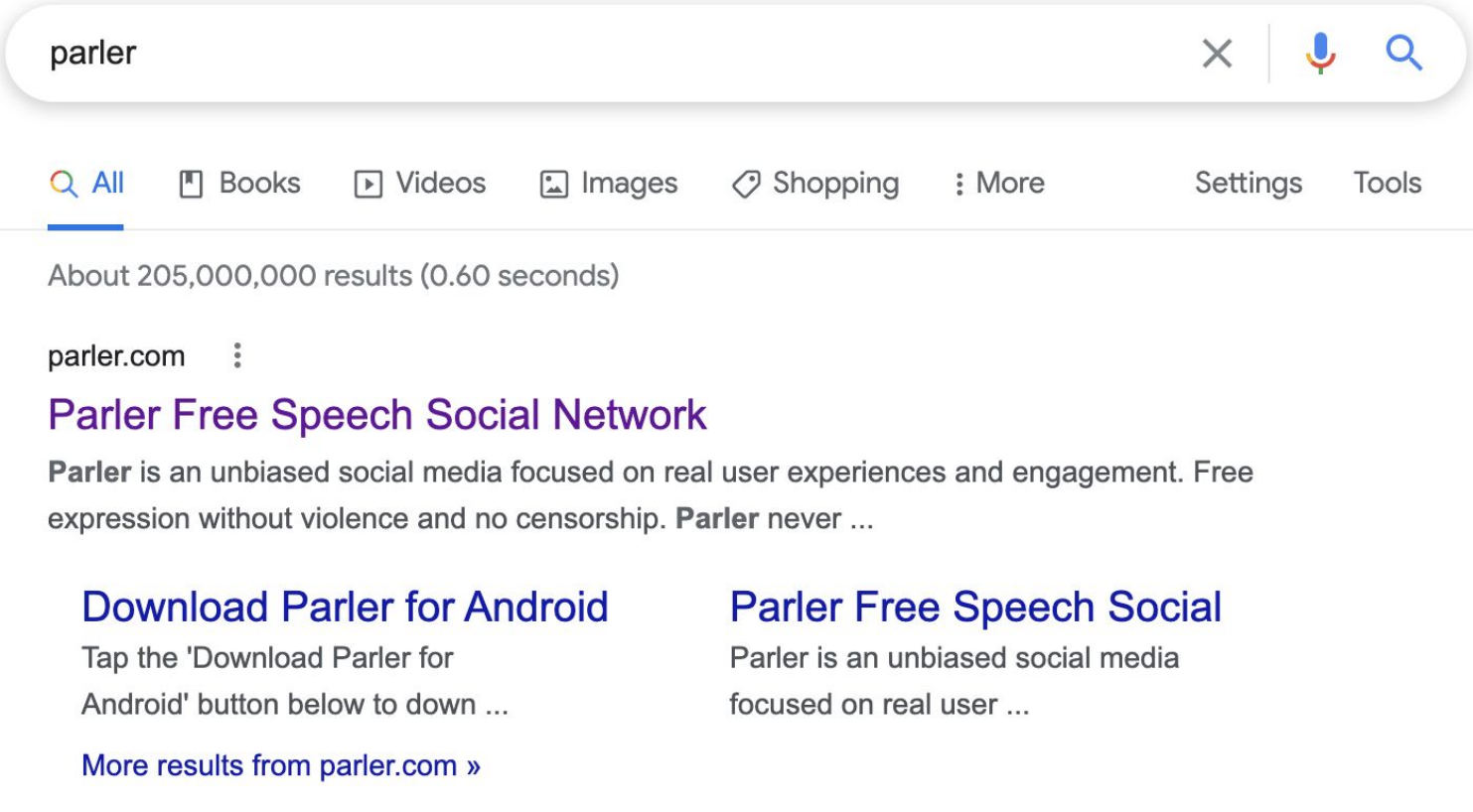
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Videos
Images
Shopping
More
Settings
Tools
About 205,000,000 results (0.60 seconds)
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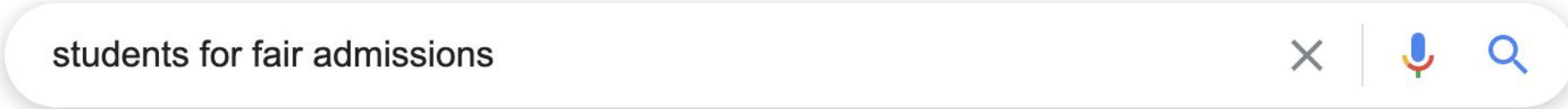

About 61,200,000 results (0.51 seconds)

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Students for Fair Admissions

Students for Fair Admissions is a nonprofit membership group of more than 20,000 students, parents, and others who believe that racial classifications and ...

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How do we send packets between devices?

- **Two main ways to send data packets: TCP and UDP**
  - Analogy: USPS First Class Mail vs USPS Priority Mail
  - There are different rules for what happens to your data
    - e.g. What happens if you lose my package???
    - e.g. Will you tell me if my package got lost?
- **TCP - Transport Control Protocol**
  - If packets get lost, it resends it until success
  - Slower
  - Used for: Email, logging into a server
- **UDP - User Datagram Protocol**
  - Allows packets to get lost
  - Faster
  - Used for: Zoom call, video games

How do we send data between devices over the Internet?

- Break up my data into smaller pieces and send them!
  - Why?
- I also need to make sure my data has a target address
  - Why?