Internet

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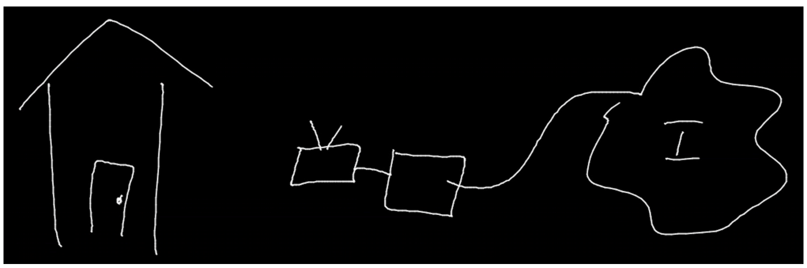
Introduction (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=0m10s)

- We use the internet on a daily basis and have constant access and connectivity
- Home network

  - Cable modem, DSL modem, or FIOS device
    - Connects to the internet
    - Pay monthly for an ISP (Internet Service Provider)
      - Verizon, Comcast, etc.
    - Could have built in wireless connectivity for your devices
      - May need an additional home router
        - Devices connect to a router via cables or wifi

IP (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=2m13s)

- Every computer on the internet has an IP (Internet Protocol) address
  - Of the form #.#.#.#
    - Four numbers separated by dots of the values 0-255
    - Other IP address formats exist today as well
  - Like postal addresses, they uniquely identify computers on the internet

        - Any device connected to the internet has an IP address
            - Allows other computers to talk to it
- ISPs assign a IP address to your computer (router)
    - Used to be physically configured
    - DHCP (Dynamic Host Configuration Protocol)
        - Software that ISPs provides to allow your computer to request an IP address
        - DHCP servers respond with a specific IP address for your Home
    - Multiple devices can connect to your home network
        - The home router supports DHCP and assigns IP addresses to your devices

DNS (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=6m43s)

- We access websites using domain names (Facebook.com, Google.com, etc.), but it turns out that these sites too have IP addresses
- DNS (Domain Name System) servers convert domain names into IP addresses

Packets (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=8m21s)

- Computers communicate by sending packets, which are like virtual envelopes sent between computers
    - Ultimately still 0s and 1s
- As an analogy, suppose we want to find a cat image on the internet
- So, we send a request to a server, say Google, like “get cat.jpg”
    - We place this request in an envelope
- On the envelope, we list out IP as the return address
- However, for the recipient of the request, we don’t know the IP address for Google
    - Have to rely on DNS
    - Send a request to our ISPs DNS server for Google’s IP address
        - If the ISP’s DNS server doesn’t know a website’s IP address, it has been configured to ask another DNS server
        - There exist root servers that know where to look to for an IP address if it exists

- After sending the request off, we'll get a response ms later

- The cat will be sent back in one or more packets
  - If the cat image is too large for a single envelope, sending it in one packet could take up internet traffic
  - To solve this, Google will divide the cat image into smaller fragments
    - Put the fragments into different envelopes
    - Write information on the envelopes
      - Return address: Google's IP address
      - Delivery address: Our IP address
      - List the number of packets on each envelope (1 of 4, 2 of 4, etc.)

TCP/IP (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=14m15s)

- IP goes beyond addresses
  - Set of conventions computers and servers follow to allow intercommunication
- Fragmentation like in the envelope example are supported by IP
  - If missing a packet, you can logically infer which packet you're missing based on the ones received
    - However, IP doesn't tell computers what to do in this case
- TCP (Transmission Control Protocol) ensures packets can get to their destination
  - Commonly used with IP (TCP/IP)
  - Supports sequence numbers that help data get to its destination
    - When missing a packet, a computer can make a request for the missing packet
    - The computer will put packets together to get a whole file
  - Also includes conventions for requesting services (port identifiers)
    - To make sure Google knows we're requesting a webpage and not an email or other service

Ports (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=18m14s)

- Per TCP, the world has standardized numbers that represent different services
- If 5.6.7.8 is Google's IP address, 5.6.7.8;80 (port 80) lets use know that we want a webpage
  - 80 means http (hypertext transfer protocol)
    - The language that web servers speak
  - Google will send the request to their web server via http
- Many websites use secure connections with SSL or HTTPS, which uses the port 443
- Email uses port 25
- Other ports exist as well

Protocols (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=19m53s)

- Protocols are just sets of rules
  - Humans use these all the time, such as the protocol for meeting people: handshakes
- When a request is made to Google for an image, HTTP tells Google how to respond appropriately

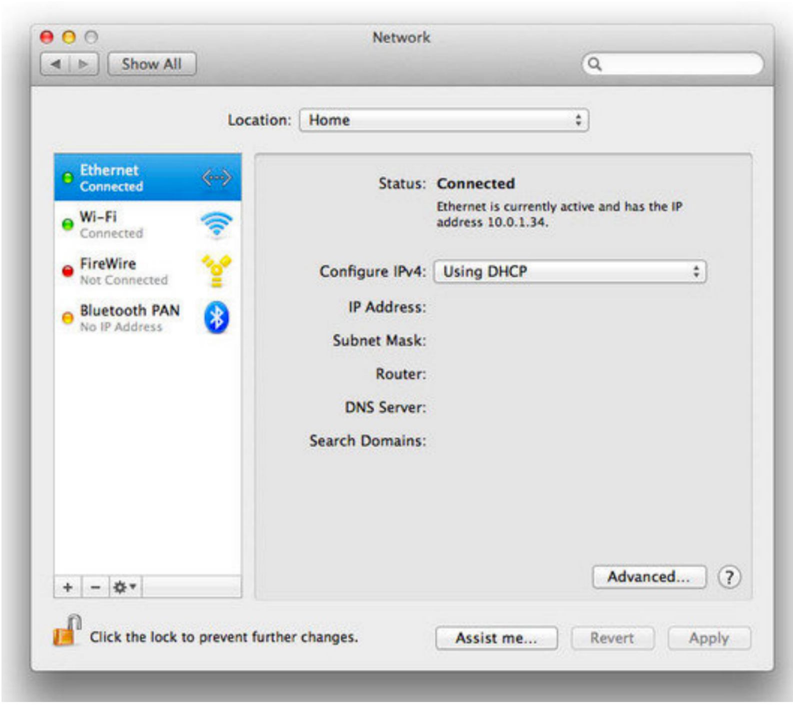
UDP (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=21m12s)

- User Datagram Protocol
  - Doesn't guarantee delivery
  - Used for video conferencing such as FaceTime
    - Packets can be dropped for the sake of keeping the conversation flowing
  - Used anytime you want to keep data coming without waiting for a buffer to fill

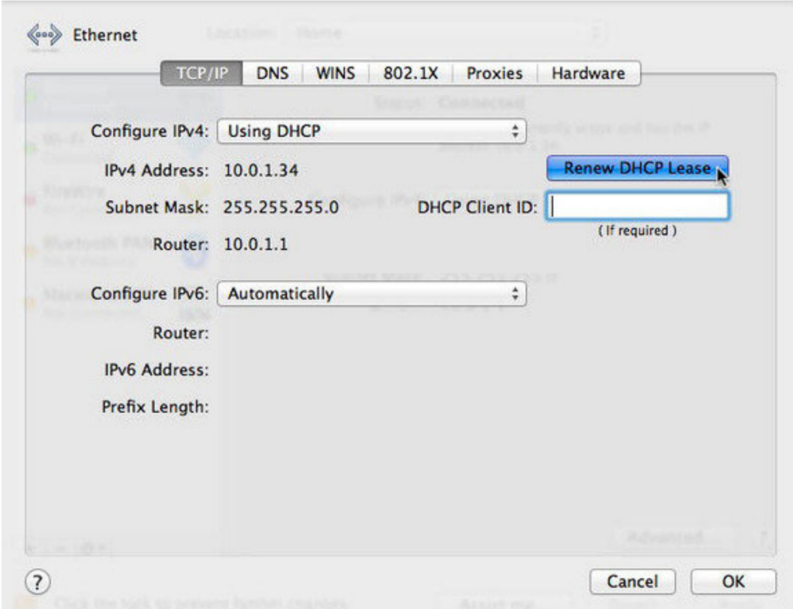
IPs in More Detail (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?

t=23m28s)

- IP addresses are limited
  - In the format #.#.#.#, each number is 8 bits, so 32 bits total
    - This yields 2^{32} or about 4 billion possible addresses
      - We're running out of addresses for all computers
  - Current version of addresses is IPv4
  - Moving towards IPv6
    - Uses 128 bits, yielding 2^{128} possible addresses
- How do you find your IP address?
- On a Mac, go to system preferences an poke around a bit

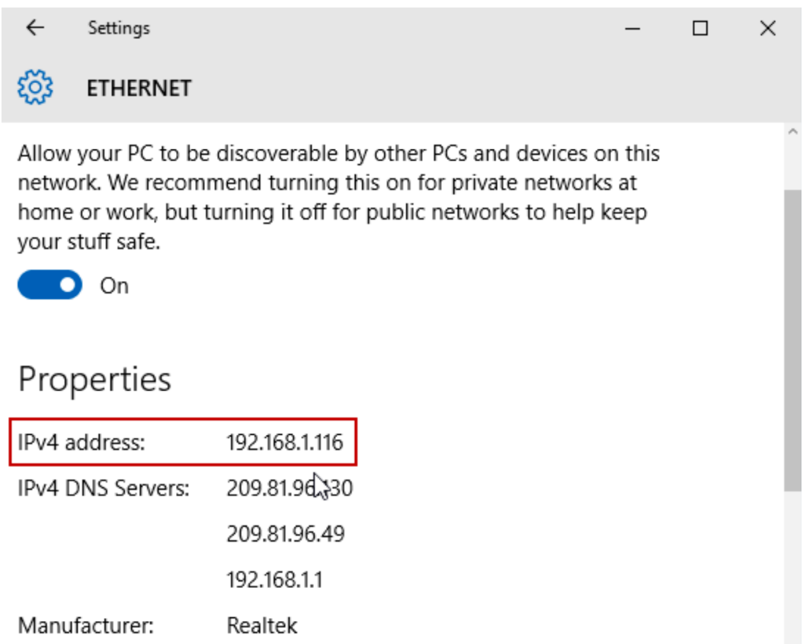


- Private addresses exist
  - 10.#.#.#, 192.168.#.#, or 172.16.#.#
  - Only with special configuration can someone talk to your computer
  - Your personal device is not a server, so people should not need to access them directly
    - Your device needs to request data from servers
  - Even email is stored on a server such as Gmail and your device makes a request to that server to access that email
- Looking at advanced settings...



- Subnet mask is used to decide if another computer is on the same network
- Router (aka Gateway) has its own address
  - Routs data in different directions

- On windows:

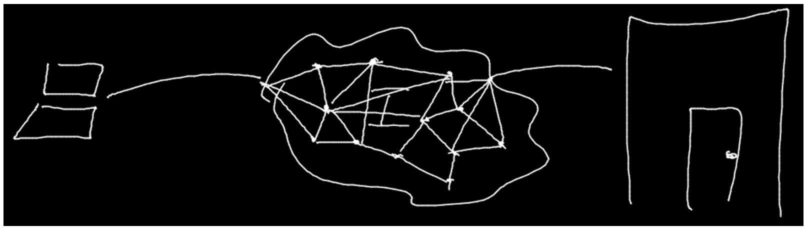


  - Shows DNS servers as well

Routers (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=27m6s)

- Routers have bunches if wires coming and going out of them

    - They have a big table with IP addresses and where data should be routed to get to that destination
        - Often, the data is routed to some next router
- Routers purpose is to send data in the direction of a destination
    - The next router will send it to another until it reaches a destination



- The internet is a network of networks (with their own routers)
    - Often multiple ways to go from A to B
        - Based in US Military logic to prevent downtime if a particular router goes down
        - When multiple packets are sent, like cat.jpg from Google, they can each take a different path, still getting to their destination eventually
            - Sometimes the internet is busy and the quickest path changes

Traceroute (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=32m31s)

- How long does it take for this process of data transfer to take on the internet?
- Traceroute is a program that sends packets to each router on a path to a destination, reporting the time it takes to reach that router
- From Sanders Theatre to Google.com:
    - 1-2: A few unnamed routers at Harvard
    - 3-4: More Harvard routers
    - 5-6: Level3 is a ISP
    - 7+: The routers are denying the request
- From Sanders Theatre to Berkeley.edu

```
traceroute to www.berkeley.edu (128.32.203.137), 30 hops max, 40 byte packets
 1  10.243.16.161 (10.243.16.161)  0.333 ms
 2  10.240.144.33 (10.240.144.33)  0.517 ms
 3  core-ne-gw-vl408.fas.harvard.edu (140.247.2.33)  0.676 ms
 4  bdrgw1-te-4-7-core.net.harvard.edu (128.103.0.146)  1.314 ms
 5  18.254.32.5 (18.254.32.5)  1.637 ms
 6  i2-re-nox1sumgw1.nox.org (192.5.89.18)  14.017 ms
 7  et-3-0-0.4079.sdn-sw.eqch.net.internet2.edu (162.252.70.113)  22.988 ms
 8  et-5-3-0.4079.rtsw.chic.net.internet2.edu (162.252.70.114)  23.451 ms
 9  et-5-3-0.4079.rtsw.chic.net.internet2.edu (162.252.70.114)  23.217 ms
10  et-8-0-0.4079.sdn-sw.denv.net.internet2.edu (162.252.70.10)  44.928 ms
11  et-8-0-0.4079.sdn-sw.denv.net.internet2.edu (162.252.70.10)  44.836 ms
12  et-7-0-0.4079.sdn-sw.lasv.net.internet2.edu (162.252.70.30)  61.950 ms
13  et-7-0-0.4079.sdn-sw.lasv.net.internet2.edu (162.252.70.30)  61.859 ms
14  et-4-1-0.4079.rtsw.losa.net.internet2.edu (162.252.70.29)  66.695 ms
15  hpr-svl-hpr3--lax-hpr3-100ge.cenic.net (137.164.25.74)  78.135 ms
16  hpr-ucb--svl-hpr-10g.cenic.net (137.164.27.133)  80.391 ms
17  t1-3.inr-201-sut.berkeley.edu (128.32.0.65)  79.948 ms
18  e3-48.inr-310-ewdc.berkeley.edu (128.32.0.97)  80.265 ms
19  calweb-farm-prod.ist.berkeley.edu (128.32.203.137)  80.162 ms
```

- 6: Northern Crossroads
- 7-14: A fast connection
  - 8-9: Chicago
  - 10-11: Denver
  - 12-13: Las Vegas
  - 14: Los Angeles
- 19 is where it arrives at Berkeley in 80 ms!

- From Sanders Theatre to MIT.edu

```
$ traceroute www.mit.edu
traceroute to www.mit.edu (104.91.71.143), 30 hops max, 40 byte packets
 1  10.243.16.161 (10.243.16.161)  0.413 ms
 2  10.240.144.33 (10.240.144.33)  9.888 ms
```

  - 6-7: Goes to New York connectivity
  - 8: MIT's website is outsourced to Akamai's NYC servers
- From Sanders Theatre to CNN.jp
  - 9-10 jumps from Seattle to Osaka past an ocean!
    - Using undersea cabling

Undersea Cabling (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=40m56s)

- David shows a video about undersea cables

Cable Modem Demo (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=43m5s)

- David examines a home cable modem, focusing on its ports
  - Coaxial cable to plug into the wall
  - Phone jacks (RJ11) as many services are bundled together these days
  - Four jacks for ethernet cables (RJ45)
    - Devices can plug into these for internet connectivity
  - This modem has wifi support built in

Network Switch Demo (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=46m27s)

- David examines a network switch
  - A device that you can plug into your router to allow more connections for all your other devices

Home Router Demo (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=47m48s)

- David examines a home router
- Home routers can have wifi, firewall, and switching capabilities

Network Cable Demo (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=48m54s)

- David cuts open a network ethernet cable to examine its inner workings
- Inside a network cable are 8 wires of different colors
  - Some are for transmitting data, others for receiving data
  - Others still are for insulation and cancellation of interference

Closing Thoughts and Homework (https://video.cs50.net/cscie1a/2017/fall/lectures/internet?t=50m24s)

- For homework, find a device that looks like a modem or router and take a look at the connectors on the back of it
    - If brave, play around with unplugging cables
        - Note: Your internet may go down in the process, but can be easily restarted with the cables properly reconnected!
    - If you have a spare ethernet cable, take a look inside yourself
        - These are a bit harder to put back together!