Lecture 1

Office hours 4:30 - 5:30 Thursday in 413 Soda Hall

What is Networking about?

- **End-system**: A device that uses the internet to communicate
    - E.g. linux server, windows PC, MAC laptop, iPad, smartphone, car navigator, heart pacemaker
- **Switch**: Helps the end-system communicate
- **Link**: Connects end-systems to switches and switches to other switches
- **Internet Service Provider (ISP)**:
    - E.g. Cable company, phone company, university net
- **Packet**: A set of formatted bits
- **Path**: The sequence of links and switches through which packets travel from their origin to their destination
- **Protocol**: A set of rules on how to communicate

A few defining characteristics of the Internet

A federated system

- The Internet interconnects different networks (> 18,000 ISPs)
- One common protocol – the "Internet Protocol (IP)" - between users and the network and between networks
- Interoperability is the Internet's most important goal
- Leads to a constant tussle between business and technical factors
    - competing ISPs must cooperate to serve their customers
    - practical realities of incentives, economics and real-world trust determine physical topology and path selection
    - a common protocol is great for interoperability … but complicates innovation

Tremendous scale

Enormous diversity and dynamic range

- Communication latency: microsends to seconds (10^6)
- Bandwidth: 1KBits / second to 100 Gigabits/second (10^7)
- Packet loss: 0–90%
- Technology: optical, wireless, satellite, copper
- Endpoint devices, sensors, cell phones, datacenters
- Applications: Skype, live video, gaming, remote medicine
- Users: the governing, governed, operators, selfish, **malicious**, naive, savvy, embarrassed, paranoid, …

Constant Evolution

Asynchronous Operation

- Fundamental constraint: speed of light

Prone to Failure

- To send a message, all components along a path must function correctly
    - Software, modem, wireless access point, firewall, links, network interface cards, switches, …
    - Including **human operators**

An Engineered System

- Constrained by limits of available technology
    - Link bandwidths
    - Switch port counts
    - Bit error rates
    - Cost

What do we know?

- The early Internet pioneers came up with a solution that was successful beyond all imagining
- Several enduring **architectural principles and practices** emerged from their work
- But it is just one design

- And numerous cracks have emerged over time
    - want to diagnose problems but federation hides inner workings
    - want to block unwanted traffic but the network doesn't authenticate
    - cant optimize for different applications or customers
    - upgrading protocols is deeply painful
    - As have new requirements
        - COMPLETE

Architectural principles

- Decentralization [lectures: all]
- Packets [lecture 2]
- Statistical multiplexing [lecture 2]
- Best effort service [lecture 3]
- The "end to end" design principle [lectures 8+]
- "Layered" decomposition [lectures: all]
- IP as "narrow waist" interface [lecture 8]

Summary

- The Internet offers us a lesson on how to reason through the design of a complex system
    - What are our goals and constraints?
    - What's the right prioritization of goals?

    - How do we decompose a problem?
    - Who does what? How?
    - What are the tradeoffs between design options?
- In short: a lesson in how to **architect** a system

Network Architecture

- More about thinking rigorously than doing rigorous math
- More about understanding tradeoffs than running benchmarks
- More about practicality than optimality
- **Done right, can be a powerful thing**

What CS168 will teach me

- **How** the Internet works
- **Why** it works the way it does
- How to **reason** through a complicated (networking) design problem

Workload

- Three projects
- Three homeworks
- One midterm
- Final