# CSCI-1680 - Computer Networks

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**http://www.cs.brown.edu/courses/cs168**

Based partly on lecture notes by David Mazières, Phil Levis, John Jannotti, Peterson & Davie

# Cast

- **Instructor: Rodrigo Fonseca (rfonseca)**
- **HTA:** Yunheng Mong
- **Grad TA**: Nick DeMarinis
- **Grad TA:** Michael Markovitch
- **How to reach us: Piazza**

https://piazza.com/brown/fall2018/csci1680

# Overview

- **Goal: learn concepts underlying networks**
  - How do networks work? What can one do with them?
  - Gain a basic understanding of the Internet
  - Gain experience writing *protocols*
  - Tools to understand new protocols and applications

***"From 2 communicating machines to the entire Internet"***

# But why should you care?

- **Networks have mostly disappeared...**
  - By being everywhere!

- **But**
  - Almost all applications are (partly) cloud-based
  - There are important tradeoffs when using networked systems
    - From your ISP choice to satellite communications to high performance computing, …
  - What to do when they fail?

# Networks

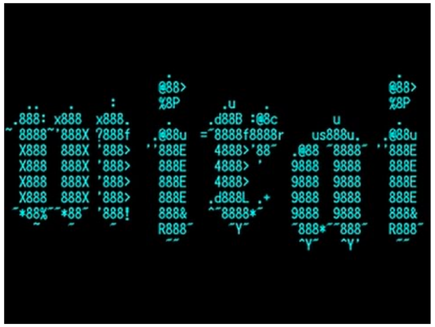
- **What is a network?**
  - System of lines/channels that interconnect
  - *E.g.*, railroad, highway, plumbing, postal, telephone, social, computer
- **Computer Network**
  - Moves information
  - Nodes: general-purpose computers (most nodes)
  - Links: wires, fiber optics, EM spectrum, composite…

# Why are computer networks cooler?

- **Many nodes are general-purpose computers**
- **Very easy to innovate and develop new uses of the network: *you* can program the nodes**
- **Contrast with the ossified Telephone network:**
  - Can't program most phones
  - Intelligence in the network, control by parties vested in the *status quo*, …

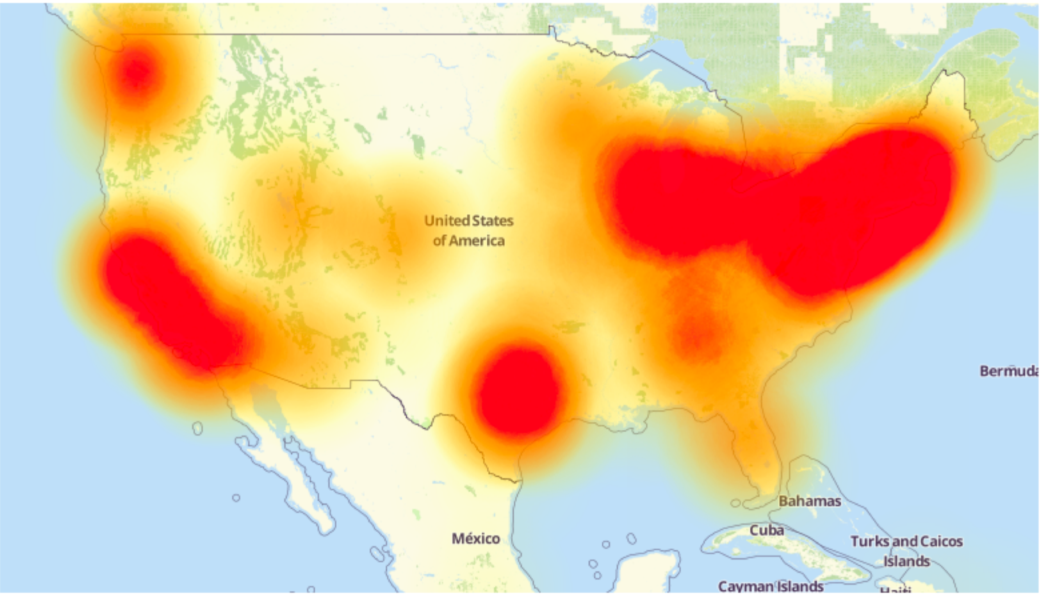
# Examples of Innovation / Disruption

- **WhatsApp: as of Jan 2016, reached 1B monthly active users in 7 years**
  - 57 engineers by then!
- **Uber disrupted transportation**
  - Connectivity allowed a global dispatch service
- **Mirai Botnet (!)**
  - ~50,000 IoT Devices (cameras, DVRs, routers)
  - 100s of Gbps attacks in late 2016

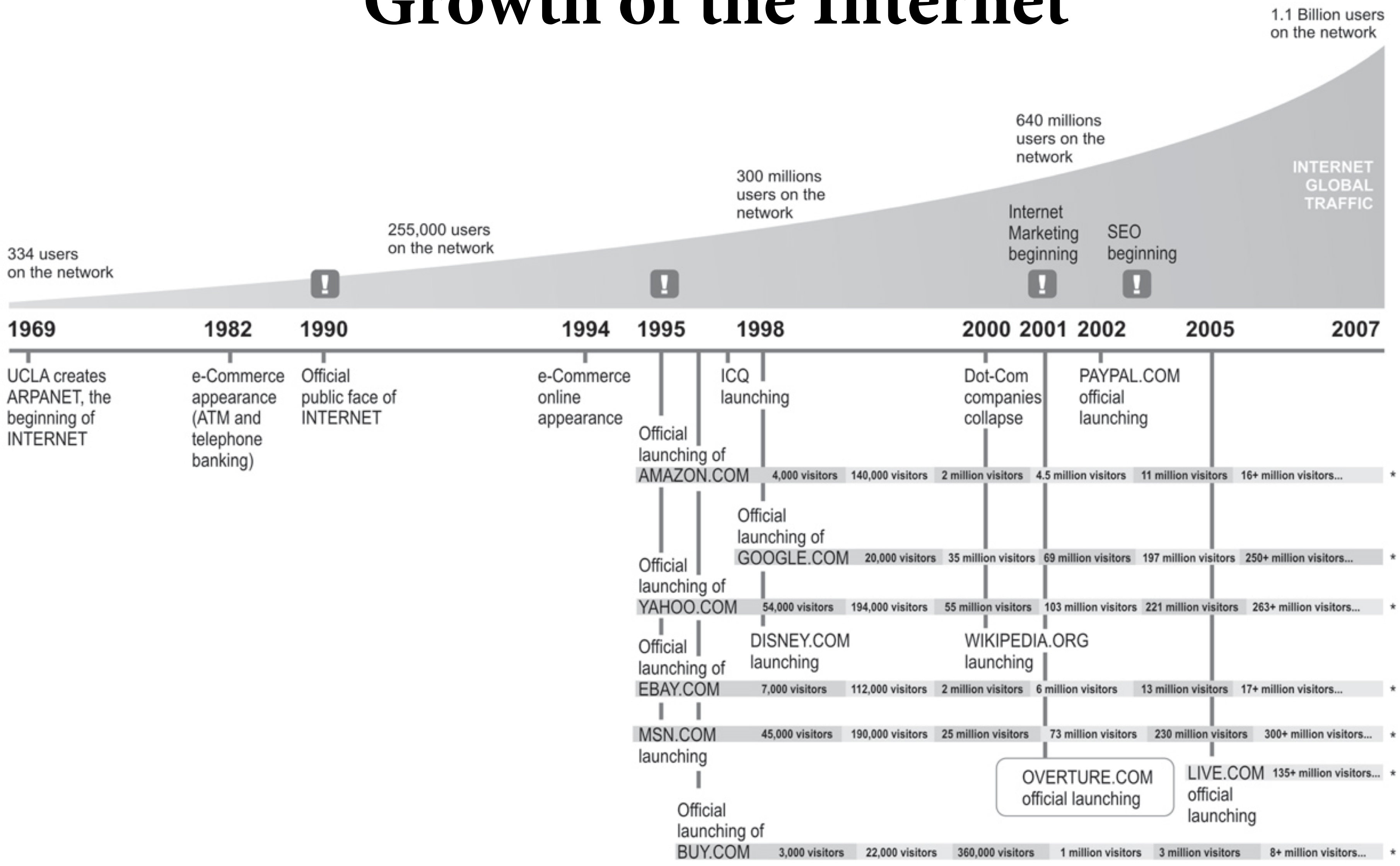


# Mirai (Oct 2016)

- **DVRs, Home Routers, Cameras disrupted DYN**
  - DNS provider for Twitter, Netflix, Reddit, others



# Growth of the Internet



* User traffic calculation per day

Source: Miguel Angel Todaro

kilo mega giga tera peta exa zetta

# Growth of the Internet

| Year | Global Internet Traffic |
|---|---|
| 1992 | 100 GB per day |
| 1997 | 100 GB per hour |
| 2002 | 100 GB per second |
| 2007 | 2,000 GB per second |
| 2016 | 26,600 GB per second |
| 2021 | 105,800 GB per second |

By 2021:

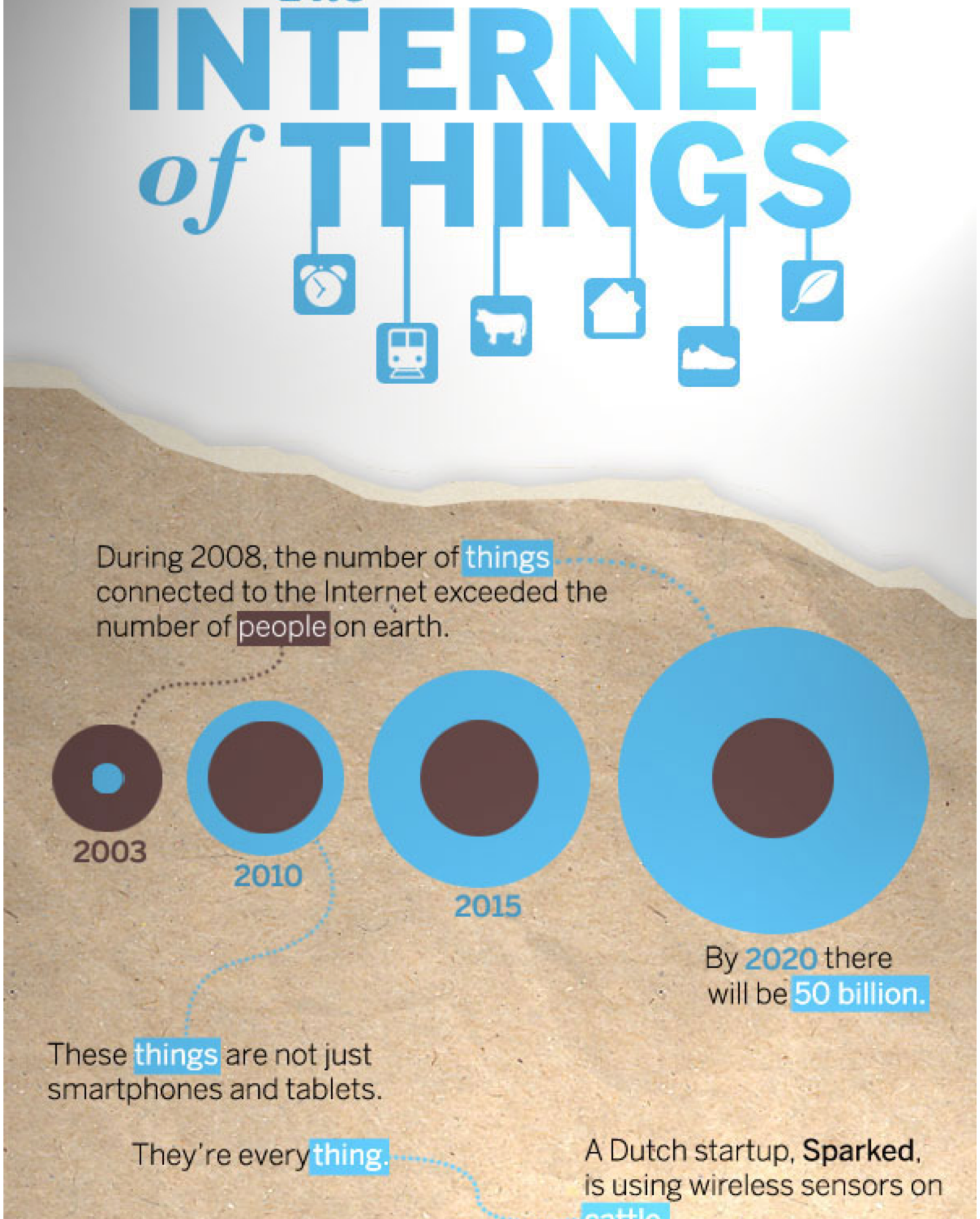
4.6B users

27 Billion devices (3.5 per capita)

3.3 Zettabytes ~ 3.3x$10^{21}$ bytes

73% will be wireless

Source: CISCO



# INTERNET of THINGS

During 2008, the number of things connected to the Internet exceeded the number of people on earth.

By 2020 there will be 50 billion.

These things are not just smartphones and tablets.

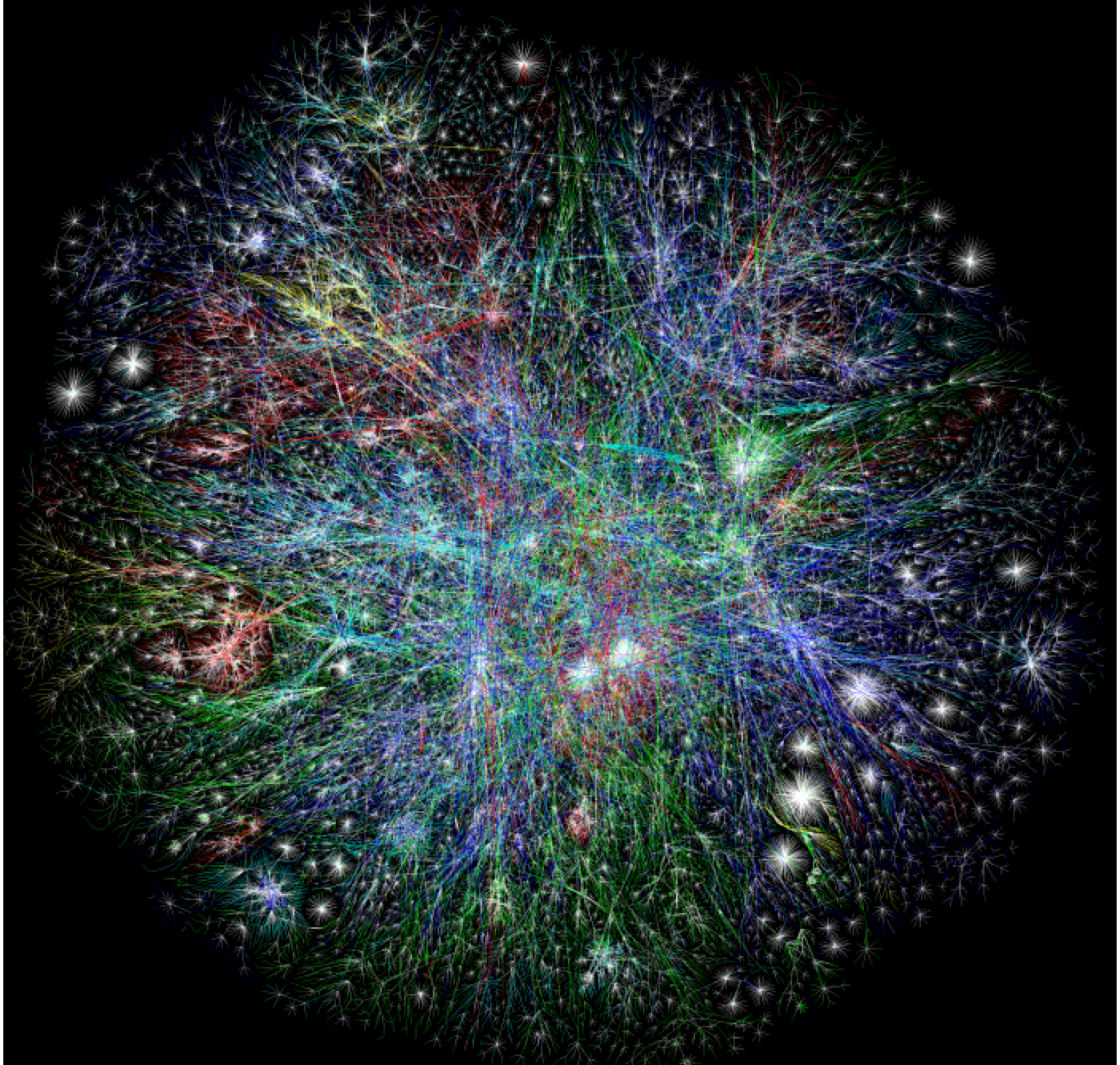
They're everything.

A Dutch startup, **Sparked**, is using wireless sensors on cattle

Source: Cisco

facebook
December 2010

Source: Facebook



Traceroute map of the Internet, ~5 million edges, circa 2003. opte.org

# Why should you take this course?

- **Impact**
  - Social, economic, political, educational, …
  - Why should you care about NetNeutrality?
  - What does it mean to run out of IP addresses?
  - How could Egypt shut down the Internet internally?
  - How could Pakistan shut down Youtube *globally*?
- **Continuously changing and evolving**
  - Incredible complexity
  - Any *fact* you learn will be inevitably out of date
  - Learn general underlying *principles*
- **Learn to program the network**
- **Networks are cool!**

# Roadmap

- **Assignments: learn by implementing**
  - Warm up: Snowcast, a networked music server
    - Get a feel for how applications use the network
- **Build knowledge from the ground up**
  - Link individual nodes
  - Local networks with multiple nodes
  - IP: Connect hosts across several networks
  - Transport: Connect processes on different hosts
  - Applications
- **A few cross-cutting issues**
  - Security, multimedia, overlay networks, P2P…

# Recurring Themes

- **How to find who to talk to**
  - Addresses and names, discovery, routing
- **Decide *how* to talk to them**
  - Encodings, Protocols
- **Make sure communication is correct, only among intended parties**
  - Error correction, encryption, …
- **How to do this at scale**
  - Planetary scale (or beyond)

# Mechanics

- **Content:**
  - Lecture slides are the authoritative content
  - Only what we cover in class will be tested
- **Tools:**
  - Discussions: **Piazza**
  - HW submission/grading + exam grading: **Gradescope**
  - Project development and submission: **Github**
  - Sign up for these (see HW0)
- **Groups**
  - Snowcast is individual, other projects in pairs

# Prerequisites

- **CSCI-0330 (or equivalent).**
  - We assume basic OS concepts (kernel/user, threads/processes, I/O, scheduling)
- **Low-level programming  or be willing to learn quickly**
  - threads, locking, explicit memory management, …
- **We allow any* language**
  - No high-level networking APIs, though (unless you write them yourself)
  - You will be bit twiddling and byte packing…

# Administrivia

- **All assignments will be on the course page**
  http://www.cs.brown.edu/courses/cs168/f17
- **Texts (not required):**
  - Peterson and Davie, Computer Networks - A Systems Approach, 4th or 5th editions *or*
  - Kurose and Ross, ‘Computer Networking: A Top-Down Approach (6th or 7th editions)
- **You are responsible to check the web page and piazza!**
  - All announcements will be there
  - Textbook chapters corresponding to lectures: read them before class
  - Handouts, due dates, programming resources, *etc…*
  - *Subject to change* (reload before checking assignments)

# What do you do?

- **“Written” component**
  - Exams: Midterm (15%) and Final (25%)
  - Homework: 3 written assignments (15%)
    - Short answer and design questions
- **4 Programming Projects (45%)**
  - Snowcast: streaming music server
  - IP, as an overlay, on top of UDP
  - TCP, on top of *your* IP
  - Final (short, fun, to be decided)
- **Must pass two components individually**

# HW0

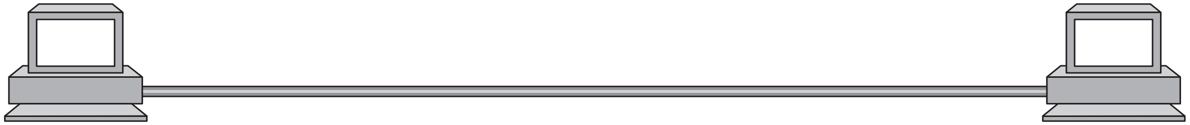
https://cs.brown.edu/courses/cs168/f18/hw0.html

# Stretch

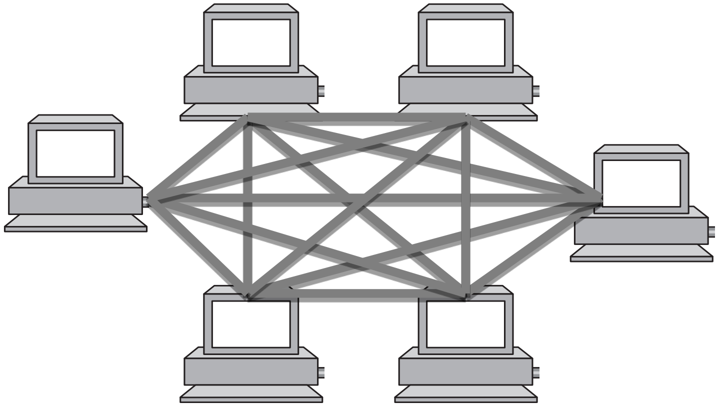
- (and I won’t look if you are shopping and want to flee)

# Building Blocks

- Nodes: Computers (hosts), dedicated routers, …
- Links: Coax, twisted pair, fiber, radio, …

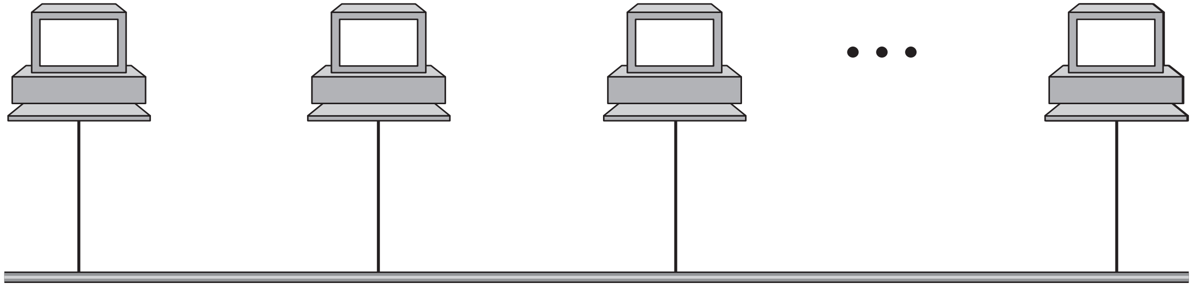


# How to connect more nodes?

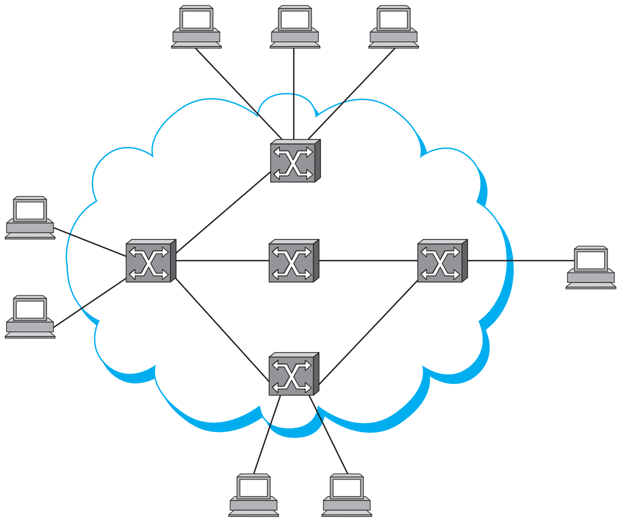


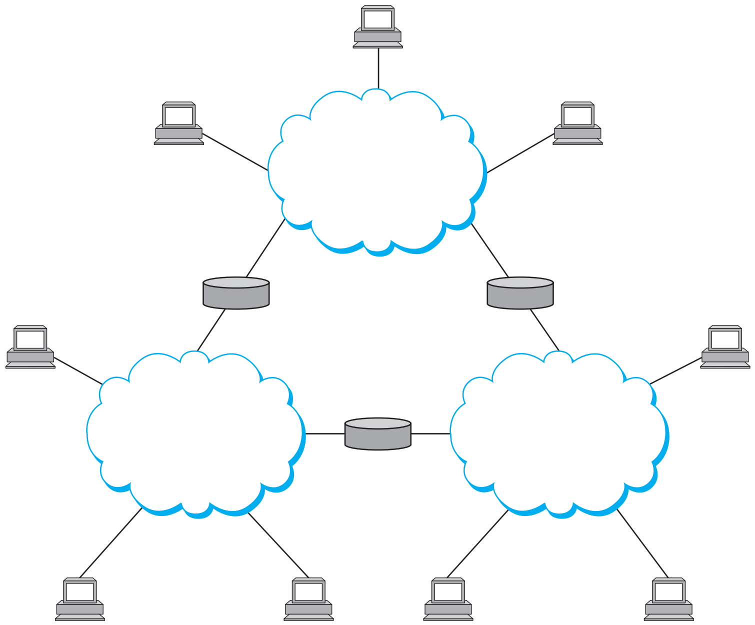
Multiple wires

Shared medium



# From Links to Networks





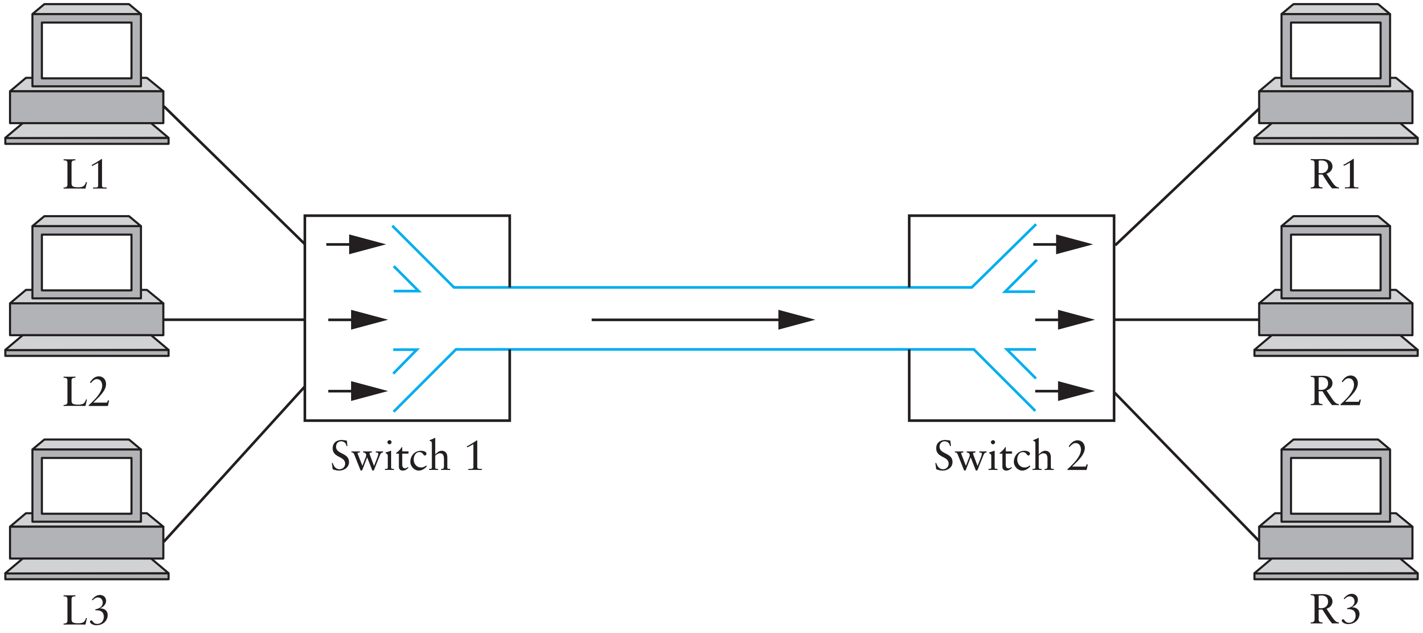
- **To scale to more nodes, use *switching***
  - Nodes can connect to multiple other nodes
  - Recursively, one node can connect to multiple networks

# Switching Strategies

- **Circuit Switching – virtual link between two nodes**
  - Set up circuit (*e.g.* dialing, signaling) – may fail: busy
  - Transfer data at known rate
  - Tear down circuit
- **Packet Switching**
  - Forward bounded-size messages.
  - Each message can have different senders/receivers
  - Focus of this course

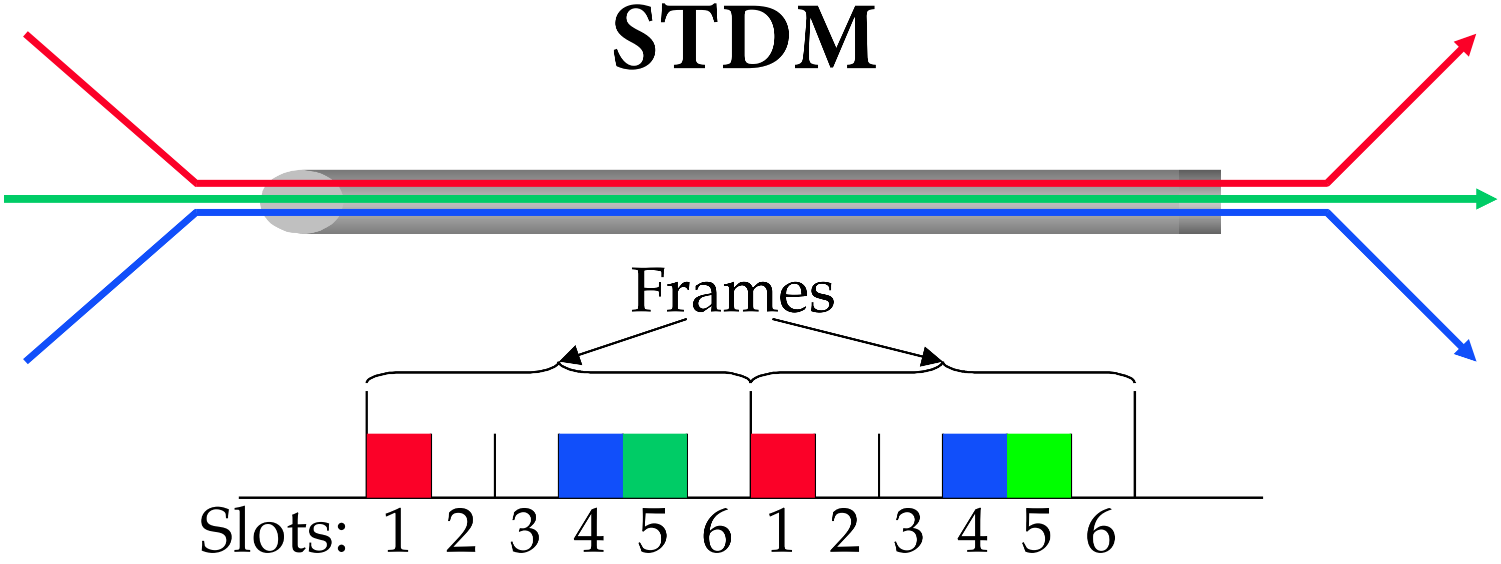
Analogy: circuit switching reserves the highway for a cross-country trip. Packet switching interleaves everyone's cars.

# Multiplexing



- **What to do when multiple flows must share a link?**

# STDM

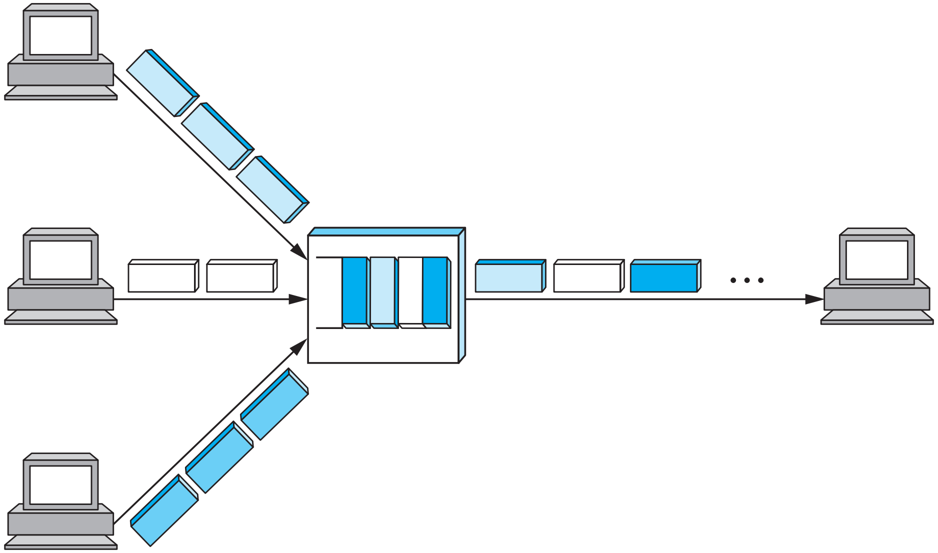


- **Synchronous time-division multiplexing**
  - Divide time into equal-sized quanta, round robin
  - Illusion of direct link for switched circuit net
  - But wastes capacity if not enough flows
  - Also doesn’t degrade gracefully when more flows than slots

# FDM

- **Frequency-division multiplexing: allocates a frequency band for each flow**
  - Same as TV channels and radio stations
- **Similar drawbacks to STDM**
  - Wastes bandwidth if someone not sending
  - Can run out of spectrum

# Statistical Multiplexing



- **Idea: like STDM but with no pre-determined time slots (or order!)**
- **Maximizes link utilization**
  - Link is never idle if there are packets to send

# Statistical Multiplexing

- **Cons:**
  - Hard to guarantee fairness
  - Unpredictable queuing delays
  - Packets may take different paths
- **Yet…**
  - This is the main model used on the Internet
- **Think of running a restaurant**
  - For a fixed set of people that go there every day
  - Or on a busy corner of Manhattan
    - When would you take reservations?

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# Coming Up

- **Snowcast: start TODAY!**
- **Next class:**
  - More on layering
  - How to use the network from the application: sockets
- **Then…**
  - We start moving up the network stack, starting from how two computers can talk to each other.