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:** Kevin Dackow
- **UTA**: Wyatt Maleta
- **GradTA**: Yuan Gao
- **GradTA**: Zeling Feng
- **How to reach us: Piazza**

  https://piazza.com/brown/fall2019/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

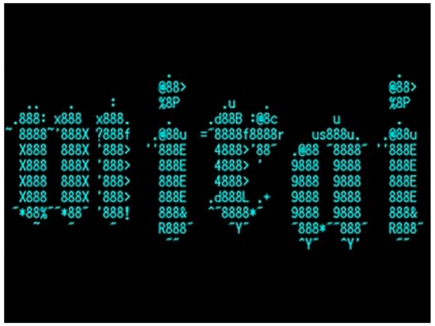
- **What is a network?**
  - System of lines/channels that interconnect
  - *E.g.*, railroad, highway, plumbing, postal, telephone, social, computer
- **Computer Network**
  - Moves information
  - Nodes: general-purpose computers (most nodes)
  - Links: wires, fiber optics, EM spectrum, composite…

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*, …

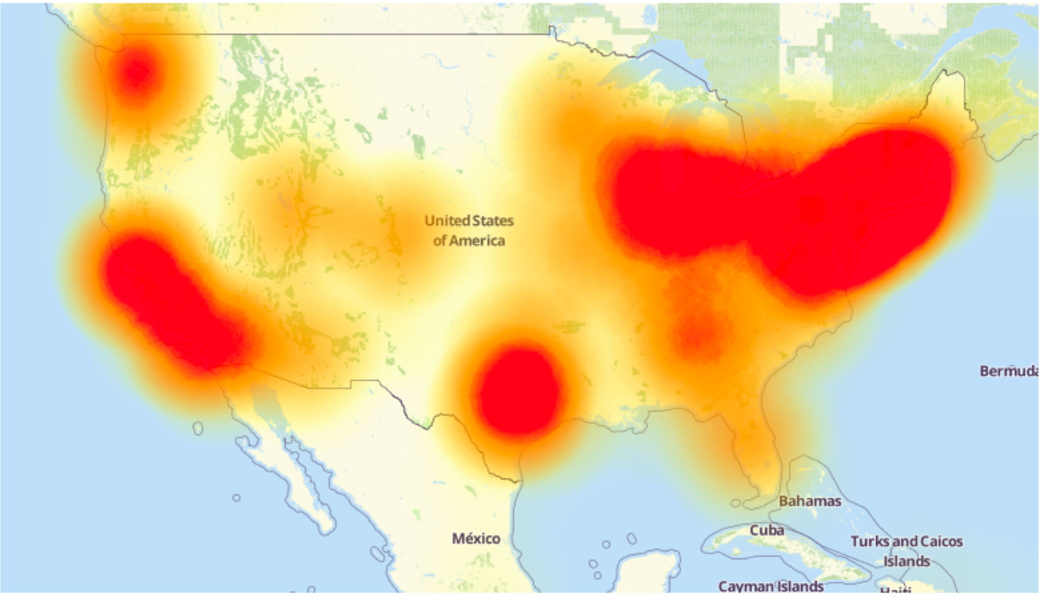
Examples of Innovation / Disruption

- **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

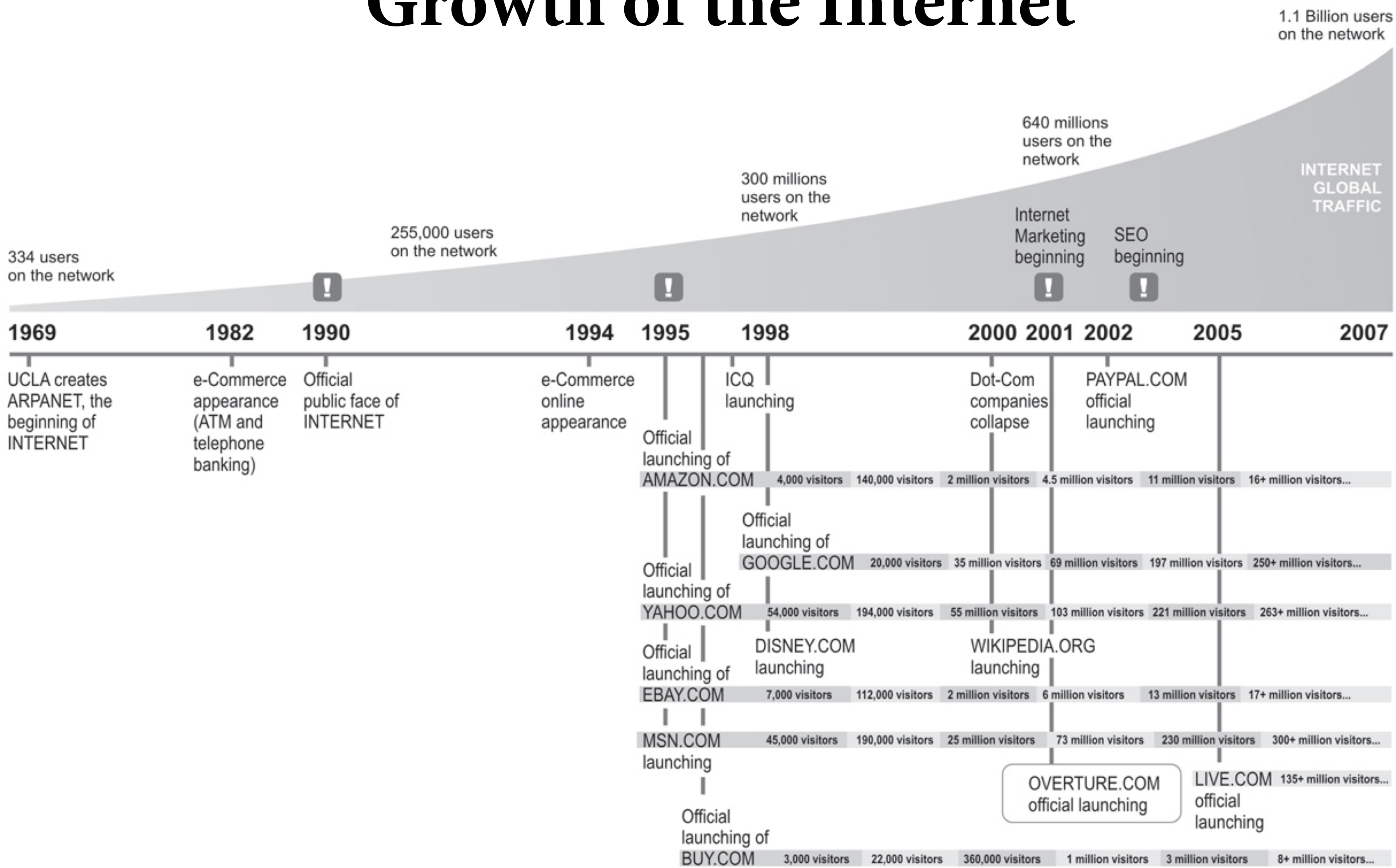


Mirai (Oct 2016)

- **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

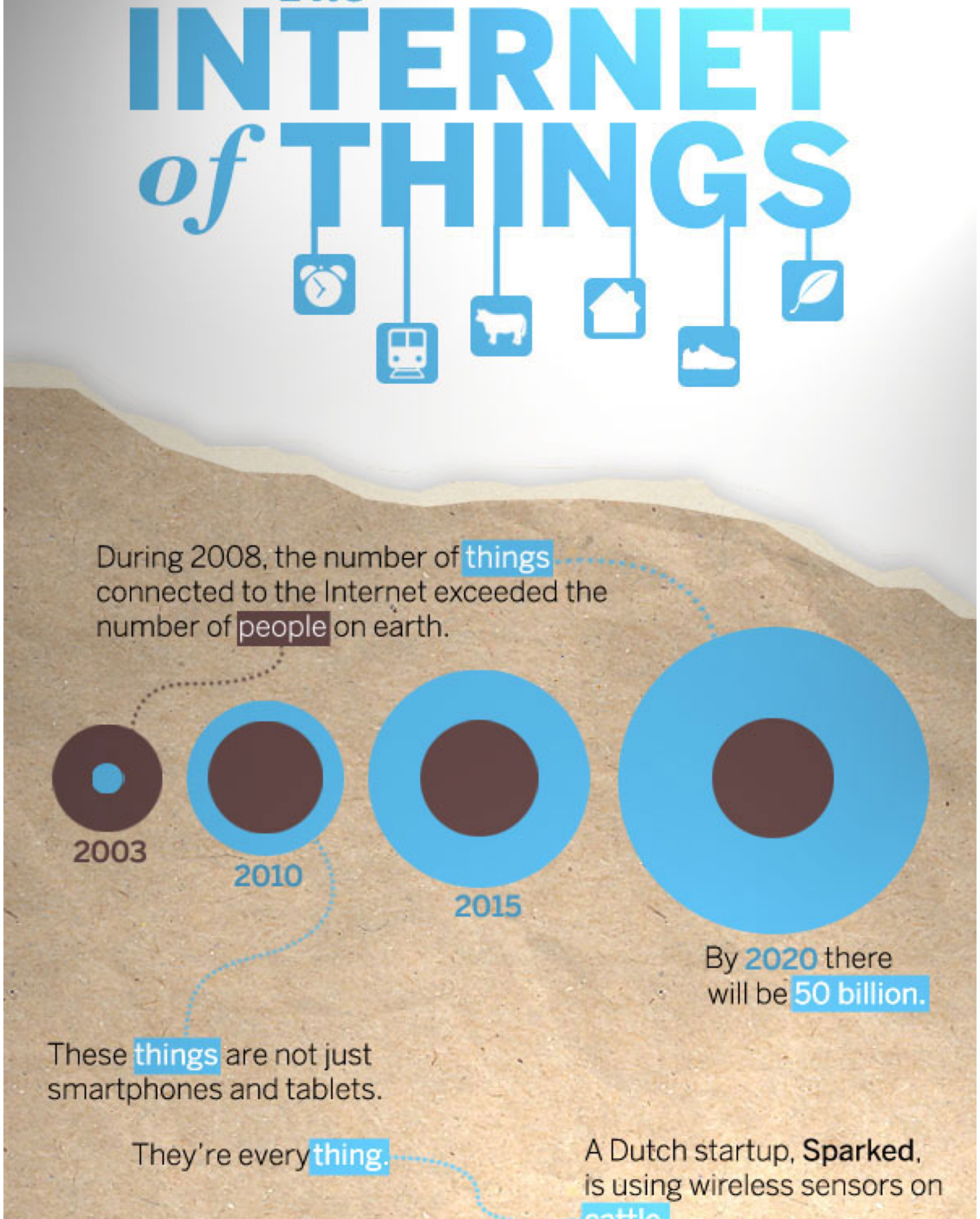
Growth of the Internet

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 ~ 3.3×10^{21} bytes
73% will be wireless

Source: CISCO



Source: Cisco

Source: Facebook

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

Why should you take this course?

Basic

Human

Needs

Maslow's
Hierarchy of Needs
(1943)

Source: hard to track meme on the Internet

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!**

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, works for all**
  - Mediation, Error correction, encryption, …
- **How to do this at scale**
  - Planetary scale (or beyond)

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…

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

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**

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, multi-threading, and byte packing…

Administrivia

- **All assignments will be on the course page**
  http://www.cs.brown.edu/courses/cs168/f19
- **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
  - Handouts, due dates, programming resources, *etc…*
  - *Subject to change* (reload before checking assignments)

Waitlist

https://tinyurl.com/168wl

HW0

http://cs.brown.edu/courses/csci1680/f19/hw0.html

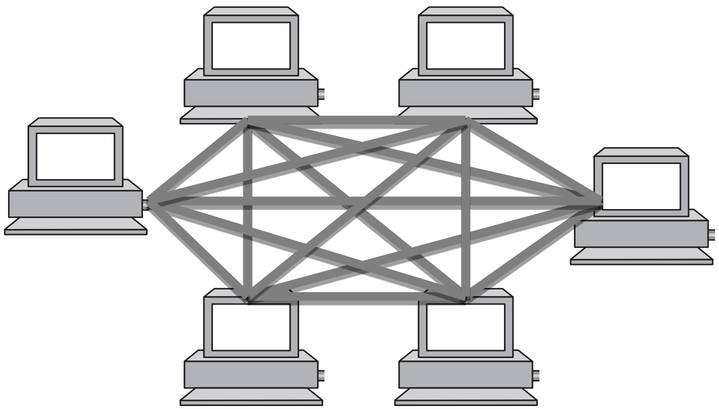
Stretch

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

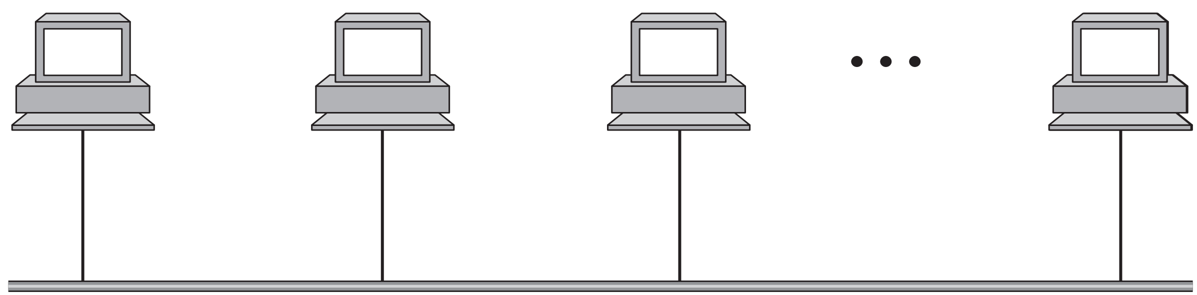
Building Blocks

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

How to connect more nodes?

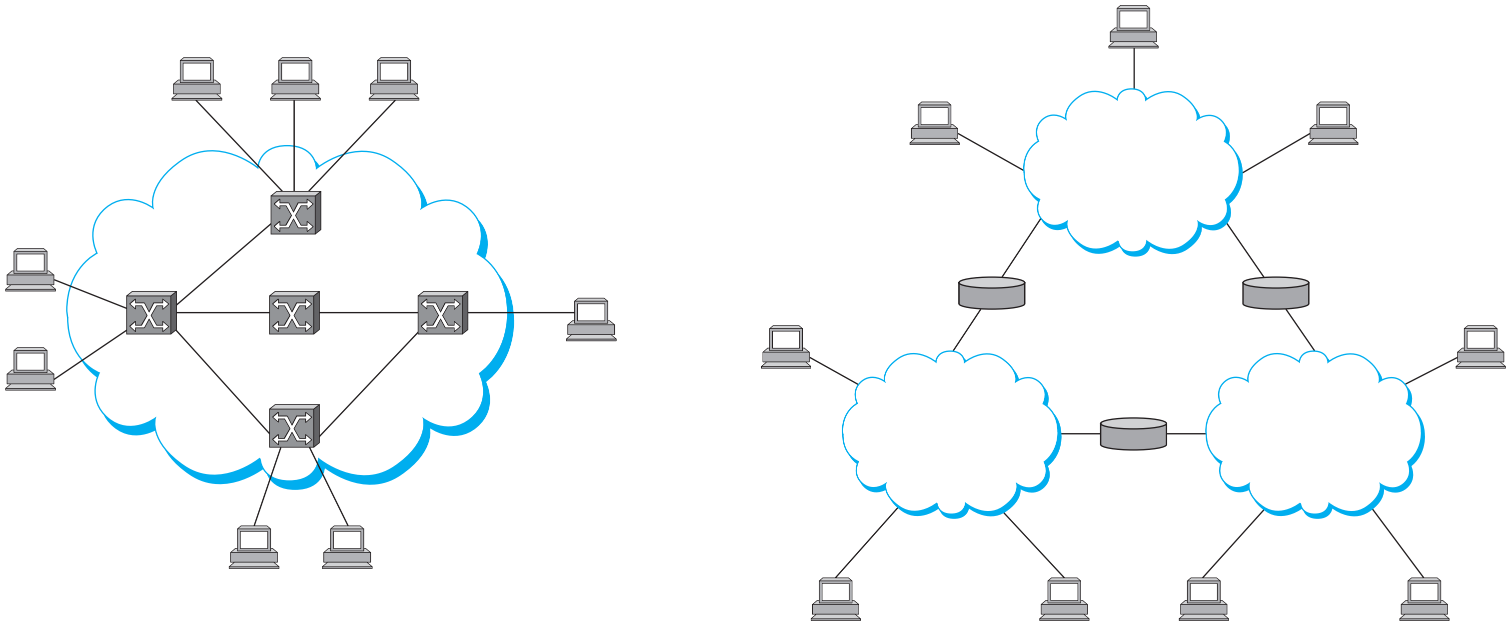


Multiple wires



Shared medium

From Links to Networks



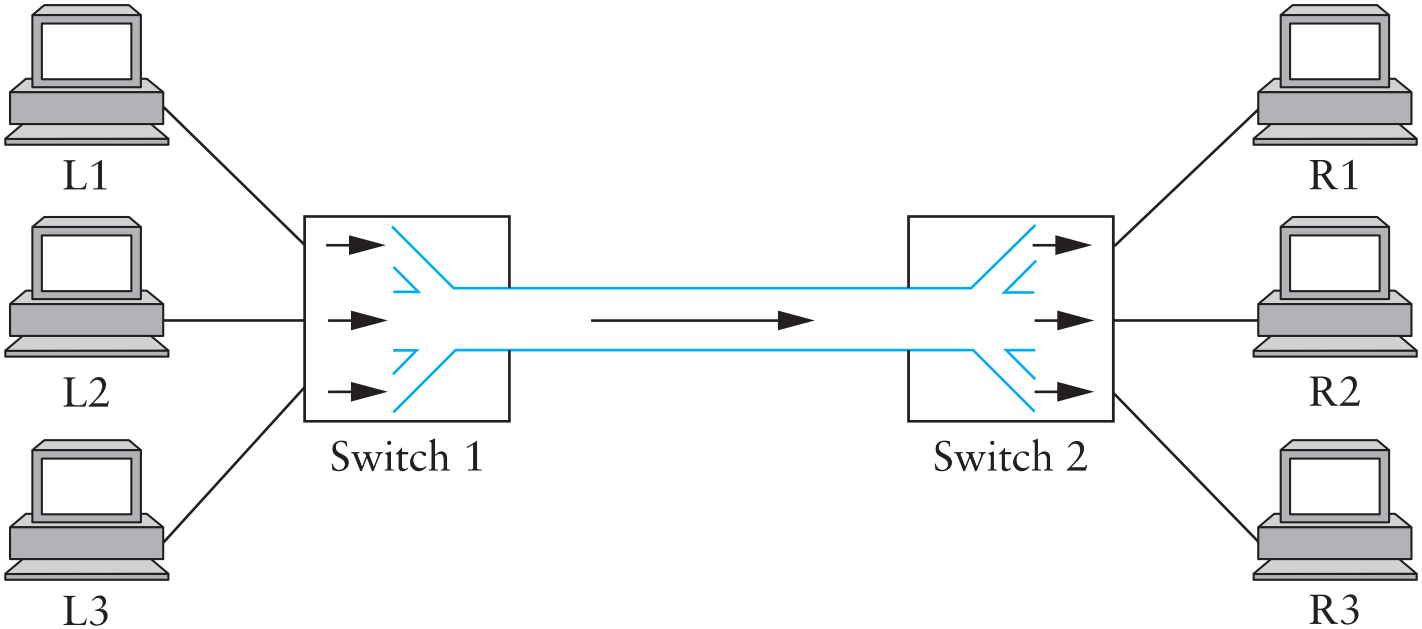
- **To scale to more nodes, use *switching***
  - Nodes can connect to multiple other nodes
  - Recursively, one node can connect to multiple networks

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

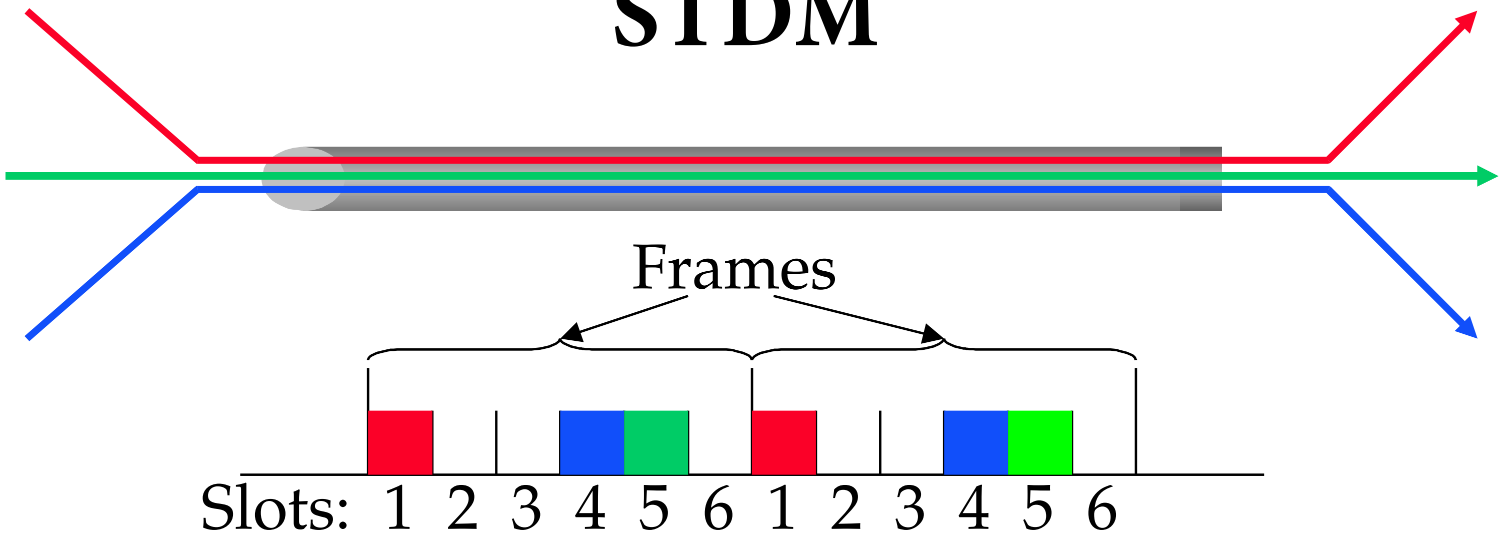
Analogy: circuit switching reserves the highway for a cross-country trip. Packet switching interleaves everyone's cars.

Multiplexing



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

STDM

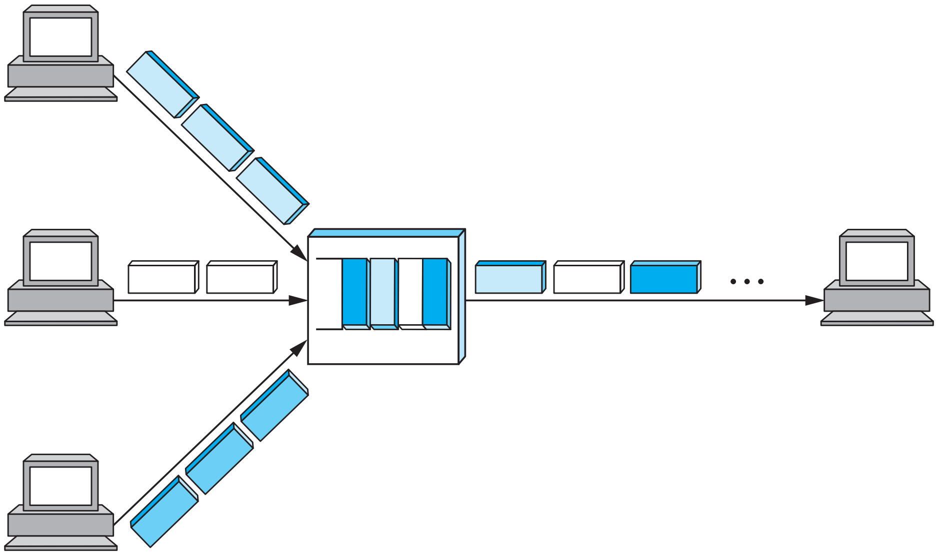


- **Synchronous time-division multiplexing**
  - Divide time into equal-sized quanta, round robin
  - Illusion of direct link for switched circuit net
  - But wastes capacity if not enough flows
  - Also doesn't degrade gracefully when more flows than slots

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.