Lecture 2

- What is a network made of?
- How is it shared?
- How do we evaluate a network?

Phone company

```
Home PC --> [ DSL modem ] --> Phoneline --> [ Central Office:
DSLAM --> Switch] --> ...
                |-> telephone
|-> telephone network
```

Digital Subscriber Line (DSL)

- Twisted pair copper
- 3 separate channels
    - downstream data channel
    - upstream data channel
    - 2-way phone channel
- up to 25 Mbps downstream
- up to 2.5 Mbps upstream

Why phone lines?

- They are everywhere

Cable company

```
Home PC --> [ cable modem ] --> copper ---> O --> fiber --> [
Cable head end: CMTS --> Switch] --> ...
```

Cable

- Coaxial copper & fiber
- up to 42.8 Mbps downstream
- up to 30.7 Mbps upstream
- Shared network

University net

```
Workstation --> Ethernet cable ---> "local" switch --> aggregate
switch" --> ...
```

How is it shared?

- How do we scale a network to many end-systems?
- Switched networks enable efficient scaling!
- Two approaches to sharing
    - Reservation
    - On-demand
- Switching on-demand exploits **statistical multiplexing** better than reservations
    - Sharing using the statistics of demand

    - Good for bursty traffic (average << peak demand)
    - Similar to insurance, with the same failure mode

Statistical multiplexing is a recurrent theme in computer science

- Phone network rather than dedicated lines
    - ancient history
- Packet switching rather than circuits
    - today's lecture
- Cloud computing
    - shared vs. dedicated machines

Two approaches to sharing

Packet Switching

- Packets treated on demand
- Admission control: **per packet**

Circuit Switching

- Resources reserved per active "connection"
- Admission control: **per connection**

A hybrid: virtual circuits

- Emulating "circuit" switching with packets… check textbook!

Circuit Switching

```
Reservation establishes a "circuit" within a switch
```

1. **src** sends a reservation request to **dst**
2. Switches "establish a circuit"
3. **src** starts sending data
4. **src** sends a teardown circuit message

Many kinds of "circuits"

- Time division multiplexing (**TDM**)
    - Divide time in **time slots**
    - Separate time slots per circuit
- Frequency division multiplexing (**FDM**)
    - Divide frequency spectrum in **frequency bands**
    - Separate frequency band per circuit

Timing in Circuit Switching

1. Circuit establishment
2. Data transfer
3. Circuit teardown

Inefficiencies in Circuit Switching

- Case 1: Multiple data transfers with standby periods in-between with no data transmission
    - Unused circuit
- Case 2: Really small data transfer
    - Circuit establishment and teardown takes more time than data

        transfer, too much work for such a little transmission

- Circuit switching doesn't "route around trouble" if a switch fails

Evaluation of Circuit Switching

- Pros
    - Predictable performance
    - Simple/fast switching (once circuit established)
- Cons
    - Complexity of circuits setup/teardown
    - Inefficient when traffic is bursty
    - Circuit setup adds delay
    - Switch fails -> its circuit(s) fails

Packet Switching

- Each packet contains destination (**dst**)
- Each packet treated independently
- With buffers to absorb transient overloads

Evaluation of Packet Switching

- Pros
    - Efficient use of network resources
    - Simpler to implement
    - Robust: can "route around trouble"
- Cons
    - Unpredictable performance
    - Requires buffer management and congestion control