Networks

Hari Balakrishnan (hari@mit.edu)

6.02 Spring 2009

Lecture #17

April 8, 2009

- Sharing, a fundamental problem
- Switches: circuit and packet switching
- Queues to absorb traffic bursts
- Understanding delays

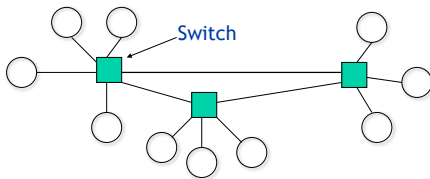Note: Lecture notes on course web site

---

From Links to Networks

So far, we've learned about tools to help us communicate over a *point-to-point link*

Modulation + channel coding = physical layer

Your Network Here!

Switches Orchestrate Link Sharing

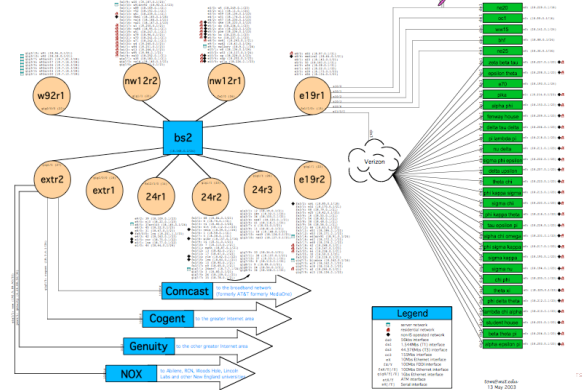- **A *switch* is a computing device that allows many concurrent communications to share the network**

Switch

This structure is called a *network topology*

MIT Campus Network

Topology Overview

An early "switched" network: The optical telegraph
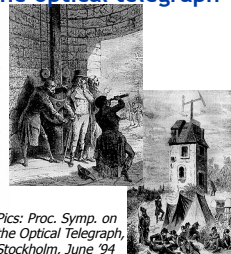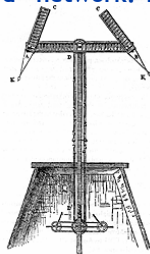
Pics: Proc. Symp. on the Optical Telegraph, Stockholm, June '94

- Chappe (1763-1805), "defense contractor"; 1st msg successfully sent in 1794
- Napoleon in power (1799): "Paris is quiet, and the good citizens are content."
- 1814: Extends from Paris to Belgium & Italy
- 1840: 4000 miles, 556 stations, 8 main lines, 11 sublines, each hop ~10 km
- Many modern techniques: framing, codes, redundant relays, message acks, priority messages, error notification, primitive encryption!

Mechanical Telephone Switch

Almon Brown Strowger (1839 - 1902)

- 1889: Invents the "girl-less, cuss-less" telephone system

And switches today…

Alcatel 7670 RSP

802.11 access point

TX8

Juniper TX8/T640

Avici TSR

Lucent 5ESS telephone switch

Cisco GSR 12416
6ft x 2ft x 1.5ft
4.2 kW power
160 Gb/s cap.

Circuit Switching

- First establish a *circuit* between end points
  - E.g., done when you dial a phone number
  - Message propagates from caller toward callee, establishing some state in each switch

- Then, ends send data ("talk") to each other

- After call, *tear down* (close) circuit
  - Remove state

Caller — Callee

(1) Establish
(2) DATA — Communicate
(3) Tear down

Example: Time Division Multiplexing

Switch

Time-slots

frames =0 1 2 3 4 5 0 1 2 3 4 5

- Divide time into *N* frame times, each frame belonging to a different conversation (color)
- At most *N* concurrent conversations share link
- Setup: Allocate time-slot to conversation
- Add entry to table mapping (inlink,time-slot) to (outlink,time_slot)
- Forwarding step at switch: consult table
- When does this approach (not) work?

A Different Approach: Packet Switching

- Data is sent in **packets**
- Each packet contains *control* information in a *header*
  - Destination address
  - Source address
  - Other stuff

Host 1   switch 1   switch 2   Host 2

| Header | Data |

- Switch forwards each packet by looking up dest addr in a *forwarding table*
  - Receive, lookup, **store in queue** (if link busy), forward

- No reservation of time slot: different communications can get different rates

Packet 1
Packet 2
Packet 3

Why Packet Switching Works: Statistical Multiplexing ("Statmux")

1 sender
2 senders
4 senders
8 senders
16 senders
32 senders
64 senders
128 senders
256 senders

Understanding Little's Law

- Mean no. in queue = rate * mean delay
- N = rate * delay

n(t) = # pkts at time t in queue

0   T   t

- See notes for details