Announcements

- Reading
  - Chapter 4 (4.1-4.2)
- Project #4 is on the web
  - Note policy about project #3 missing components
- Homework #1
  - Due 11/6/01
    - Chapter 6: 4, 12, 24, 37
- Midterm #2
  - 11/8/01 in class

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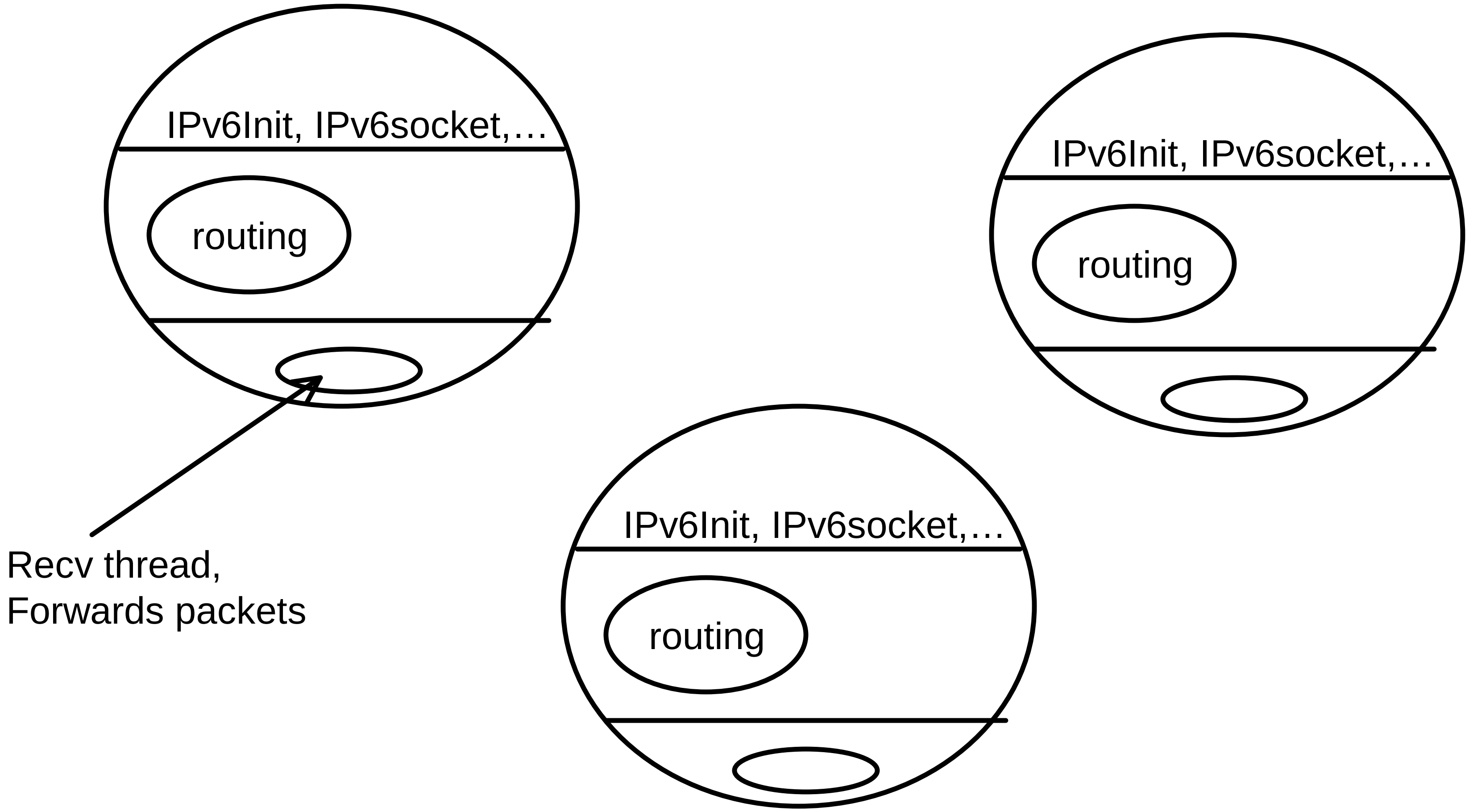
Project #4 Notes



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Transmission: Satellites

- Different Orbits Possible
  - orbit affects many communication properties
- Geosynchronous
  - always over the same spot on the earth
  - 36,000 Km orbit is required
  - only 180 slots possible
  - uses one uplink and one down link frequency
  - large round-trip latencies
- LEO (Low Earth Orbit)
  - each satellite keeps moving into and out of range
    - solution: use a large number of satellites
    - sort of like cells, but the cells are the ones moving
  - lower round-trip latency

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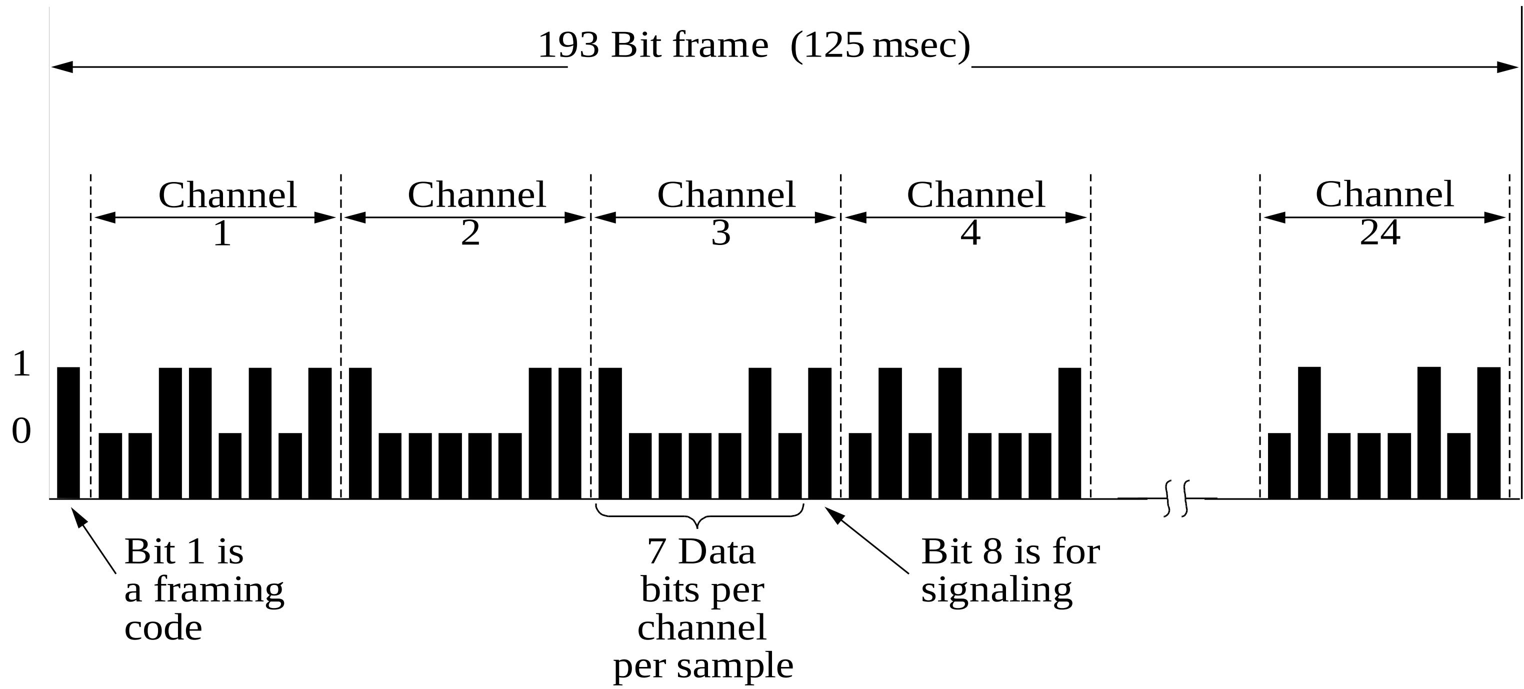
Sending More Than one Signal At Once

- Called multiplexing
  - original goal of Bell was to MUX multiple telegraph signals
- Time Division Multiplexing
  - everyone gets whole bandwidth
  - but only when its their turn



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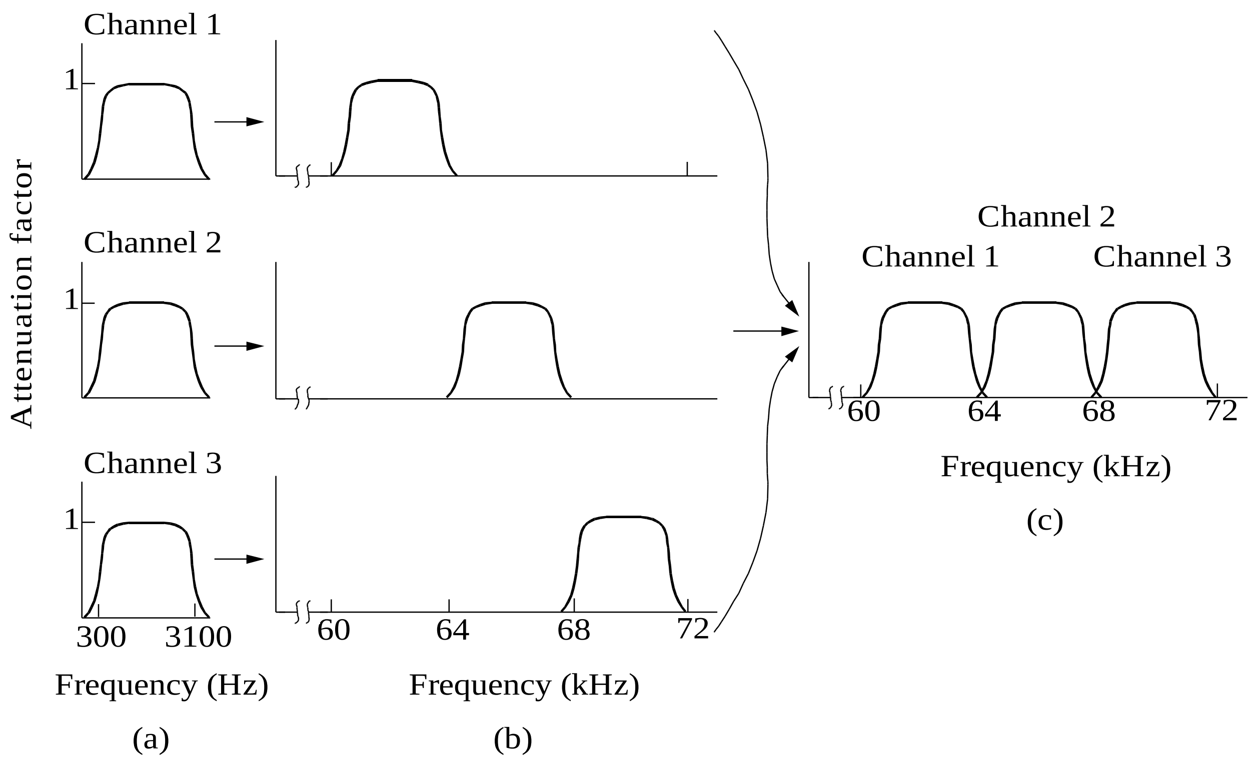
Frequency Division Multiplexing

- Frequency Division
  - everyone gets to talk at once
  - but only in their own frequency



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ATM Switching

- Requirements
  - be able to switch 360,000 cells/sec per input link
  - switch cells with as low a discard rate as possible
  - never reorder the cells on a virtual circuit
- Issues
  - multiple cells destined for the same output at once
    - need to buffer one of them
    - must ensure fairness is maintained
  - head-of-line blocking
    - possible that a blocked output is holding up cells that could be delivered

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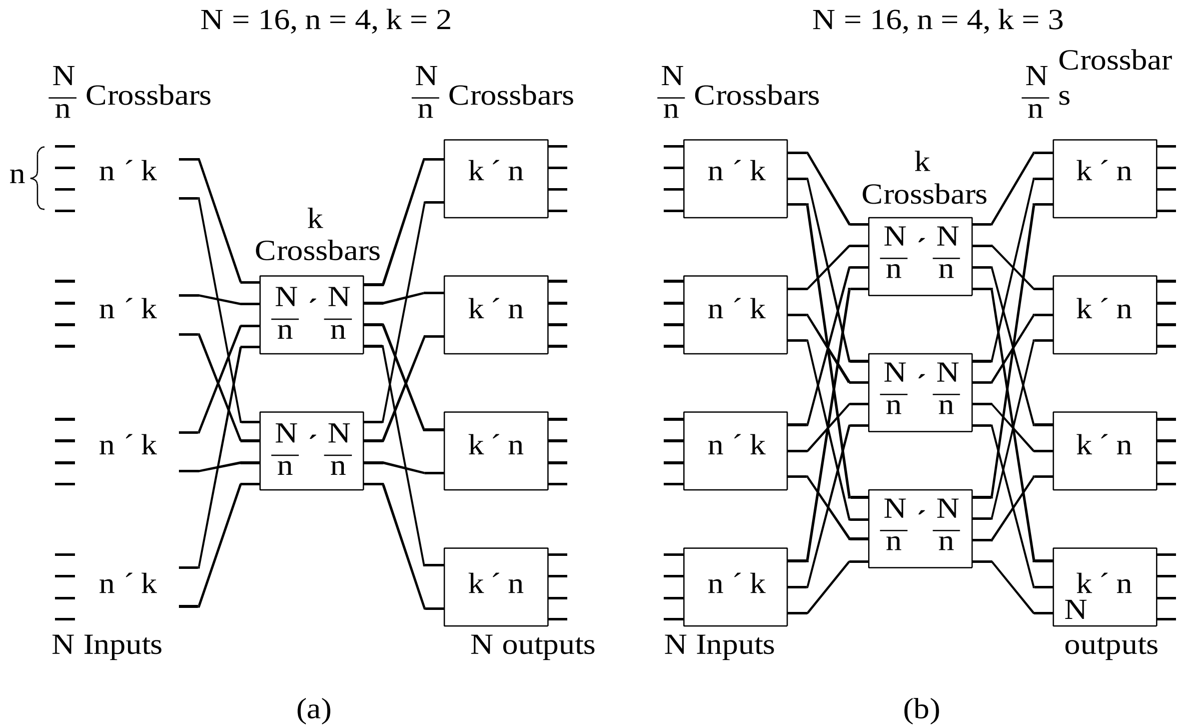
Switching Fabric (space division)

- Cross bars are great, but require $O(n^2)$ wires
- Can use a collection of smaller cross bar switches
  - penalty: a request to connect may **block**



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Batcher-banyan Switching

- Banyan
  - can do a “good” or “poor” job of switching due to collisions
  - if the inputs are sorted, we get performance
- Batcher
  - sorts traffic base on full address of destination
  - compares two colliding packets and uses final destination to select output port
  - requires $O(n\log^2 n)$ nodes (2x2 switching elements)

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Medium Access Layer

- Broadcast Networks
  - share a common resource for communication
    - bus, wire, air, etc.
  - need to coordination access to this resource
- Limits of Static Channel Allocation
  - suitable for constant rate traffic of similar speeds
  - however, bursty traffic results in poor channel utilization
  - consider one queue vs. separate queues for each person
    - n queues with bursty arrival have mean delay n times 1 queue
- Dynamic Allocation
  - only use channel when have something to send
  - need to control access to the channel

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Shared Channel Model

- Station model
  - N independent stations
  - each wants to send λ frames per second
  - a station may not send another frame until the first is sent
- Single Channel Assumption
  - all stations communicate over a single shared channel
- Collisions: two stations attempt to send at once
  - neither transmission succeeds
- Time
  - continuous time: frame transmissions can start anytime
  - discrete time: clock ensures all sends initiate at the start of a slot
- Carrier Sense
  - stations can tell if channel is in use before sending
  - stations must wait to know if channel was in use

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Aloha

- Stations
  - ground based radio stations on islands
- Pure Aloha
  - If send data at will, collisions will happen
  - on collision, wait a random amount of time & try again
  - use standard, fixed size packets
  - what is channel efficiency (assuming Poisson distribution)?
    - S **new** frames per frame time
    - assume G total frames trying to be sent per frame time
    - P_0 = probability of exactly one sender sending
    - $S = G\, P_0$
    - probability of k frames generated during a frame time
      - $Pr[k] = G^k\, e^{-G} / k!$
    - $P_o = e^{-G} e^{-G} = e^{-2G}$, so $S = Ge^{-2G}$

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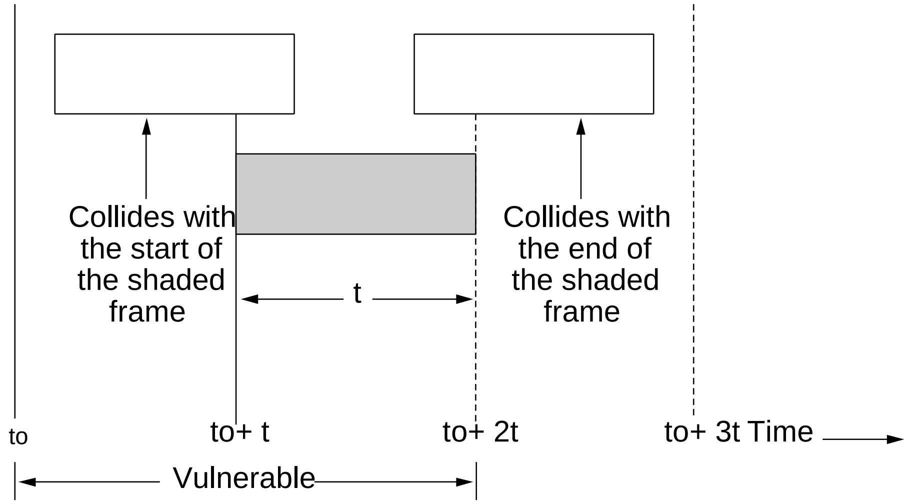
Performance of Aloha



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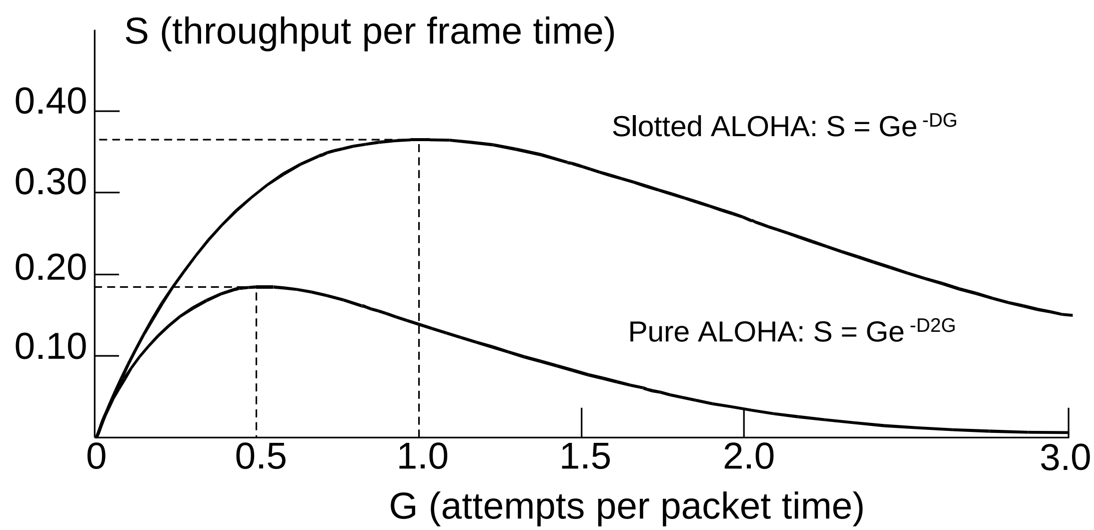

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Aloha (cont.)

- Slotted Aloha
  - Use a central clock
  - Each station only sends at the start of frame
  - Reduces collision window by 1/2
    - $S = G\, e^{-G}$

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