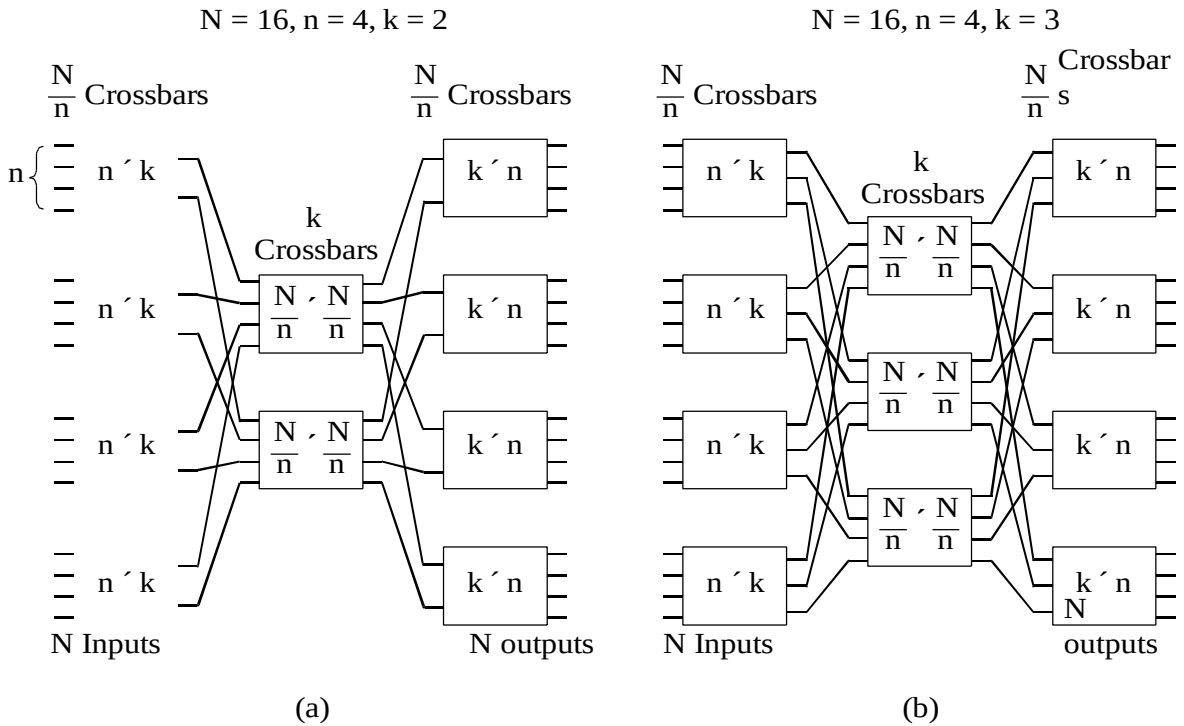
Announcements

- Reading
  - Today: Chapter 4 (4.2.1 to 4.2.6)

Switching Fabric (space division)

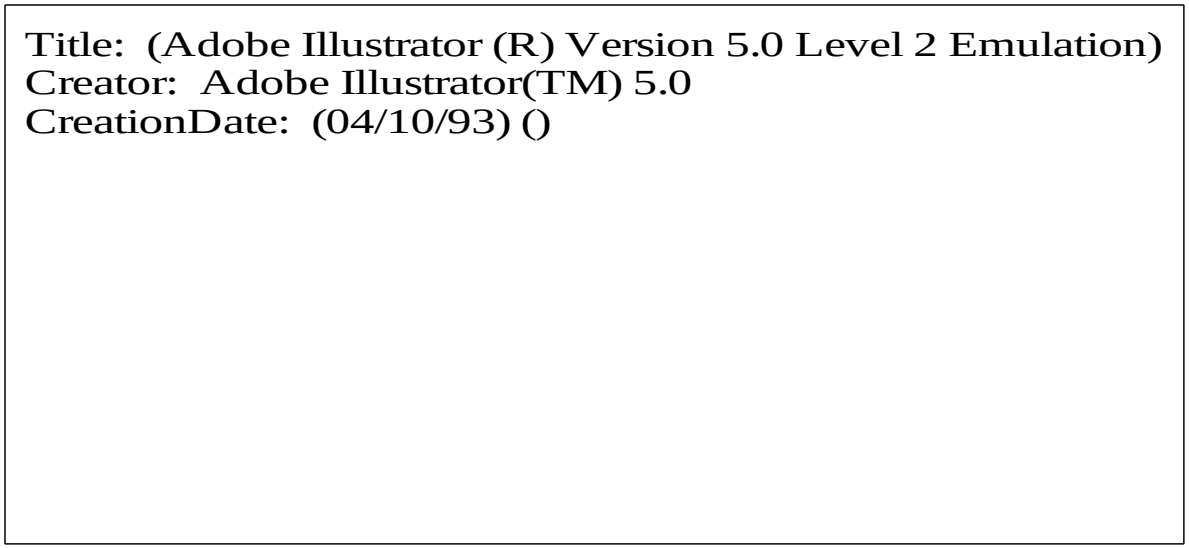
- Cross bars are great, but require $O(n^2)$ wires
- Can use a collection of smaller cross bar switches
  - penalty: a request to connect may **block**



From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.

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)



From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.

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

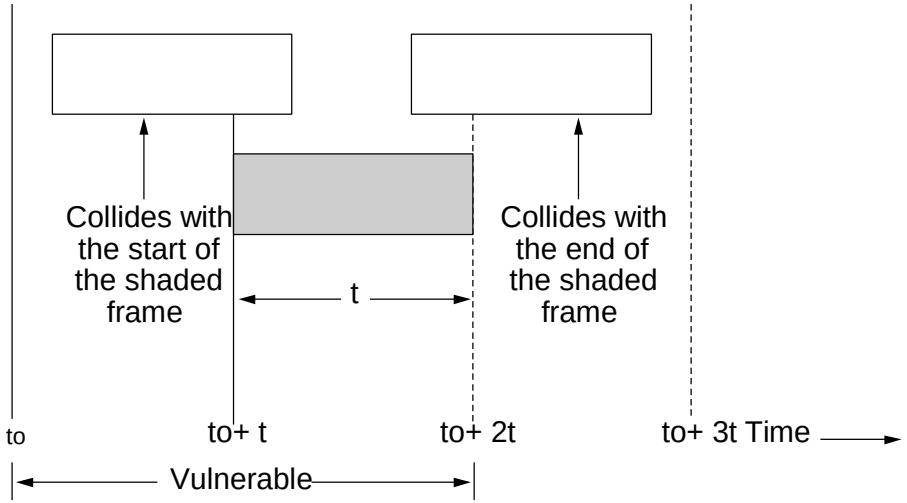
Shared Channel Model

- 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

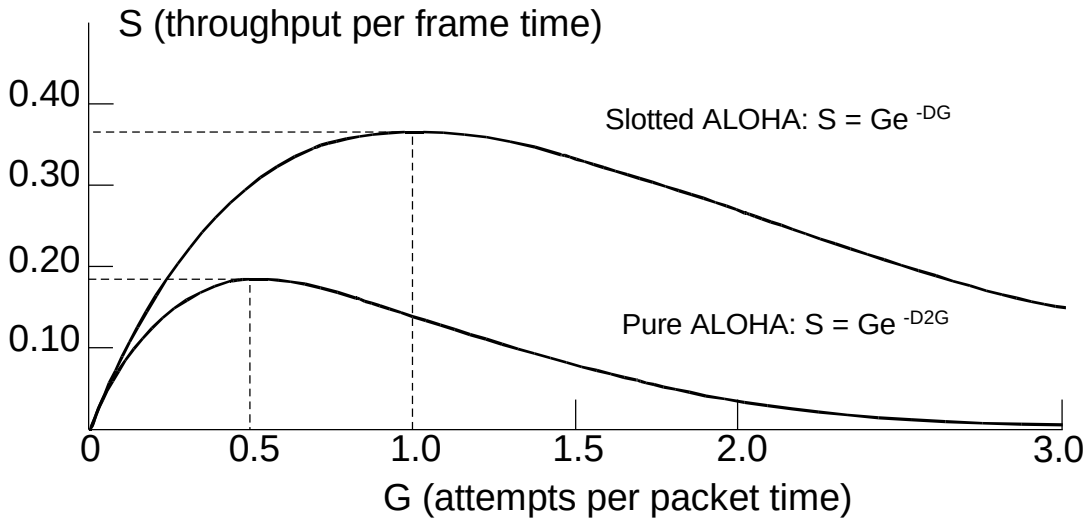
Aloha

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

Performance of Aloha



From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.



From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.

Aloha (cont.)

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

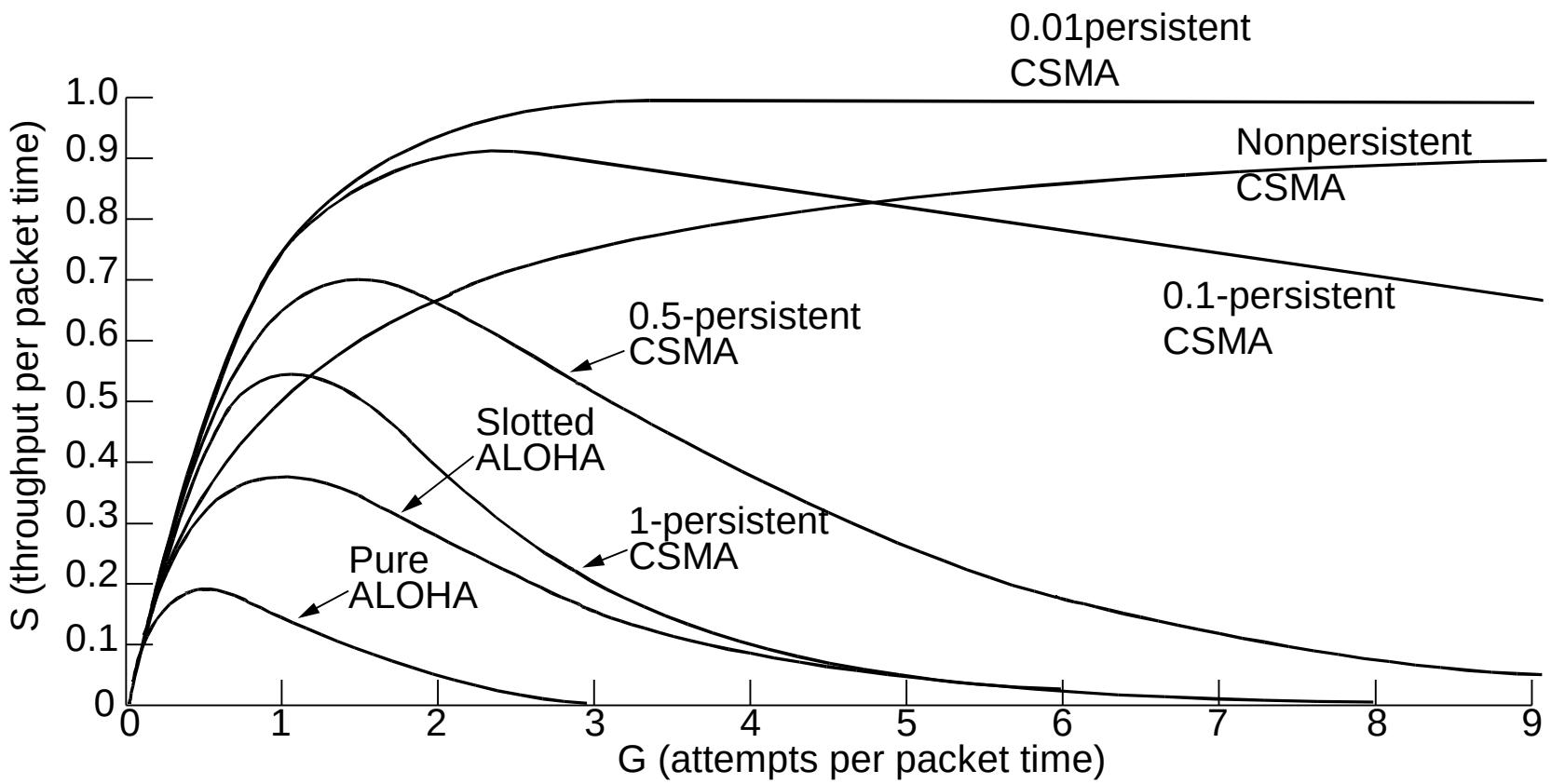
Carrier Sense Multiple Access

- look before you leap!
  - don't send if someone else is sending
- collisions are still possible
  - propagation delay induces uncertainty into sensing
  - possible two hosts both start sending at the same time
- persistence: when to send after detecing channel in use
  - 1-persistent
    - as soon as the channel is free, starting sending
  - nonpersistent CSMA
    - if channel is sensed busy, wait a random time and try again
  - p-persistent CSMA
    - if slot is idle send with probability p, else wait for next idle slot

Carrier Sense Multiple Access

- look before you leap!
  - don't send if someone else is sending
- collisions are still possible
  - propagation delay induces uncertainty into sensing
  - possible two hosts both start sending at the same time
- persistence: when to send after detecting channel in use
  - 1-persistent
    - as soon as the channel is free, starting sending
  - nonpersistent CSMA
    - if channel is sensed busy, wait a random time and try again
  - p-persistent CSMA
    - if slot is idle send with probability p, else wait for next idle slot

Impact of Carrier Sense



From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.

Collision Detection

- If a sender senses a collision
  - stop sending at once
  - apply random backoff
- "contention" period
  - after contention period, there will be no collision
  - send for for 2τ (max propagation delay)
    - need 2τ since might be a collision at far end at $\tau-\varepsilon$