Overview

- Finish reliable transmission

- Methods to share physical media: multiple access
  - Fixed partitioning
  - Random access

- Channelizing mechanisms

- Contention-based mechanisms
  - Aloha
  - Ethernet
No. We could use redundancy
  - Send additional data to compensate for lost packets

When is it better not than using retransmission?
  - Broadcast media with lots of receivers
    - If each one ACK/NAK then hard to scale
      - Lots of messages
      - Lots of state
    - Heterogeneous receivers
      - Some receivers can handle 500kbps others 100Mbps
      - E.g., variable quality wireless reception
  - Highly lossy or very long delay channels (e.g., satellite)
Forward Error Correction

- Use **erasure codes** to redundantly encode $k$ data frames into $m > k$ encoded frames
  - Reed Solomon Codes, Tornado codes, Raptor codes, etc.

- Multicast/broadcast encoded frames speculatively

- A receiver can reconstruct message from *any* $k$ frames in the set of $m$ encoded frame
Reliability Summary

- The primary way we achieve reliability over an unreliable channel is **automatic repeat request**
  - Explicitly notify sender of received packets by sending an acknowledgement (ACK)
  - Resend packets that are not ACKed within some timeframe
- We can make this efficient by having many unACKed packets simultaneously in flight
- Sliding Window is the standard technique to manage this process and keep the sender and receiver in sync
  - And limit the amount of data needing to be buffered
- Can use pattern of ACKs to infer losses by making assumptions about packet reordering
Fixed Partitioning

- Need to share media with multiple nodes \((n)\)
  - Multiple *simultaneous* conversations

- A simple solution
  - Divide the channel into multiple, separate channels

- Channels are physically separate
  - Bitrate of the link is split across channels
  - Nodes can only send/receive on their assigned channel

- Several different ways to do it
  - _____ Multiple Access madlibs…
Frequency Division (FDMA)

- Divide bandwidth of $f$ Hz into $n$ channels each with bandwidth $f/n$ Hz
  - Easy to implement, but unused subchannels go idle
  - Used by traditional analog cell phone service, radio, TV

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Time Division (TDMA)

- Divide channel into rounds of $n$ time slots each
  - Assign different hosts to different time slots within a round
  - Unused time slots are idle
  - Used in GSM cell phones & digital cordless phones

- Example with 1-second rounds
  - $n=4$ timeslots (250ms each) per round
Code Division (CDMA)

- Do nothing to physically separate the channels
  - All stations transmit at the same time in the same frequency bands
  - One of so-called spread-spectrum techniques

- Sender modulates their signal on top of unique code
  - Sort of like the way Manchester modulates on top of clock
  - The bit rate of resulting signal much lower than entire channel

- Receiver applies code filter to extract desired sender
  - All other senders seem like noise with respect to signal

- Used in newer digital cellular technologies
Partitioning Visualization

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Problem w/Channel partitioning

- Not terribly well suited for random access usage
  - Why?

- Instead, design schemes for more common situations
  - Not all nodes want to send all the time
  - Don’t have a fixed number of nodes

- Potentially higher throughput for transmissions
  - Active nodes get full channel bandwidth
Aloha

- Designed in 1970 to support wireless data connectivity
  - Between Hawaiian Islands—rough!

- Goal: distributed access control (no central arbitrator)
  - Over a shared broadcast channel

- Aloha protocol in a nutshell:
  - When you have data **send it**
  - If data doesn’t get through (receiver sends acknowledgement) then **retransmit after a random delay**
  - Why not a fixed delay?
Collisions

- Frame sent at $t_0$ collides with frames sent in $[t_0-1, t_0+1]$
  - Assuming unit-length frames
  - Ignores propagation delay

![Diagram showing frame overlaps at different time intervals](image-url)
Slotted Aloha

- Time is divided into equal size slots (frame size)
- Host wanting to transmit starts at start of next slot
  - Retransmit like w/Aloha, but quantize to nearest next slot
- Requires **time synchronization** between hosts

Success (S), Collision (C), Empty (E) slots
Q: What is max fraction slots successful?
A: Suppose $n$ stations have packets to send
  - Each transmits in slot with probability $p$
  - Prob[successful transmission], $S$, is:

$$S = p(1-p)^{(n-1)}$$

- any of $n$ nodes:

$$S = \text{Prob[one transmits]} = np(1-p)^{(n-1)}$$
  (optimal $p$ as $n\to\infty$ = $1/n$)
  $= 1/e = .37$

At best: channel used for useful transmissions 37% of time!
Carrier Sense (CSMA)

- Aloha transmits even if another host is transmitting
  - Thus guaranteeing a collision

- Instead, listen *first* to make sure channel is idle
  - Useful only if channel is frequently idle
  - Why?

- How long to be confident channel is idle?
  - Depends on maximum propagation delay
  - Small (<<1 frame length) for LANs
  - Large (>>1 frame length) for satellites
non-persistent CSMA
- Give up, or send after some random delay
- Problem: may incur larger delay when channel is idle

1-persistent CSMA
- Send as soon as channel is idle
- Problem: blocked senders all try to send at once

P-persistent CSMA
- If idle, send packet with probability $p$; repeat
- Make sure $(p \times n) < 1$
Even with CSMA there can still be collisions. Why?

- If nodes can detect collisions, abort! (CSMA/CD)
  - Requires a minimum frame size ("acquiring the medium")
  - B must continue sending ("jam") until A detects collision

- Requires a full duplex channel
  - Wireless is typically half duplex; need an alternative
For Next Time

- Read 3-3.2 in P&D
- Keep going on the project…