The Link Layer

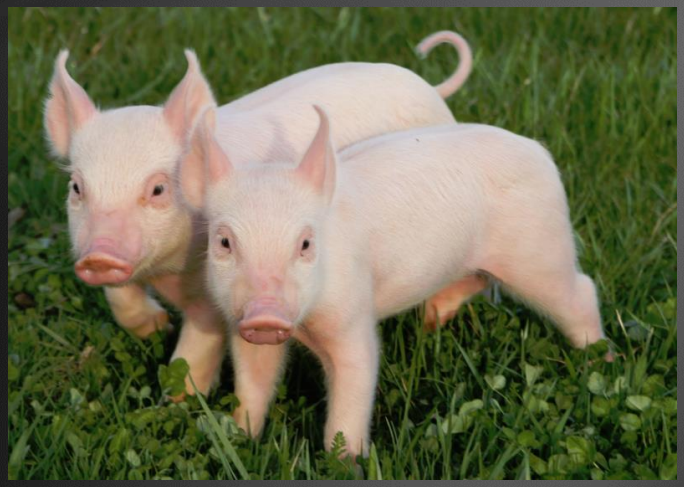
CSE 461 Section: The Last One (!!!!!!111)

A Joke

- Worst thing
- Traceroute packet
- Network engineer

Error Detection/Correction

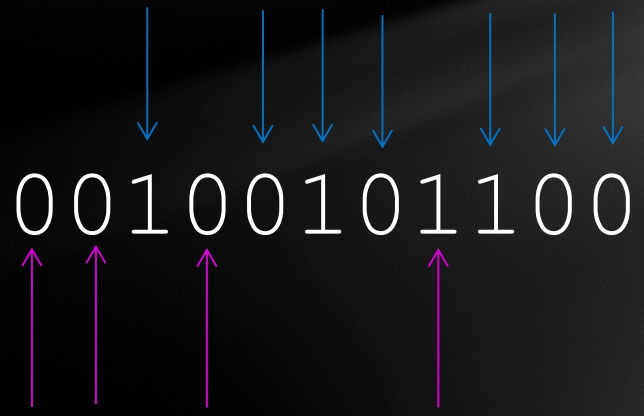
- We want to know when there are errors in communication
  - Parity bits can tell us this, to a certain extent
  - But they have drawbacks
  - You need detect multiple parity bits to detect multiple errors
- Correcting errors would be even better, though! Why?
  - It'd save lots of time
- What are some ways we can correct errors?
  - Send data multiple times; take most frequently occurring bit for a given place
  - Send longer symbols (e.g., 11111 instead of 1)
  - Send data with a payload that's a function of the payload
    - Like parity bits, but we need something smarter



Hamming Codes

- Originally created by Bell Labs engineer Richard Hamming to save time on punchcard reading errors
- Hamming codes now used for network communications as well as hard drive RAIDs

All other bits are message bits



Bits in 1, 2, 4, 8, etc. positions are parity bits

Hamming Codes

- An extension of bit parity, where parity check bits are in "powers of two" positions
  - `Bit string: 0  0  1  0  0  1  0  1  1  0  1`
    `Bit number: 1  2  3  4  5  6  7  8  9  10 11`
    `Par/msg:    p  p  m  p  m  m  m  p  m  m  m`
- Each data bit is checked (with even parity) by check bits that make up its "power of two" sum
- Let's look at how data bit 7 is checked
  - What's 7 in binary?
    - 00111
  - Which bits are 1? What powers of 2 does each correspond to?
    - 4, 2 and 1
  - This means the message bit in bit 7 is added to the sums for parity bits 1, 2 and 4

Hamming Codes

- All parity bits are calculated like this: binary addition of the
  message bits they check, with no carry
- Possible to detect single-bit and double-bit errors
- Possible to recover from single-bit errors
- See Hamming lecture (will be linked on calendar) for more details

Hamming Distance

- Hamming distance: minimum number of bit flips necessary to change one string into another
- Examples:
  - What's the Hamming distance between:
    - 10001 and 10000
    - 00111 and 00000
    - 10100 and 01011
- Hamming distance can also describe a general way of coding data

- Imagine system where possible "symbols" are 1111, 0000, 0011, and 1100
- In this system, what's the Hamming distance?
  - 2
- What about system consisting of codes 00000 and 11111?
  - 5

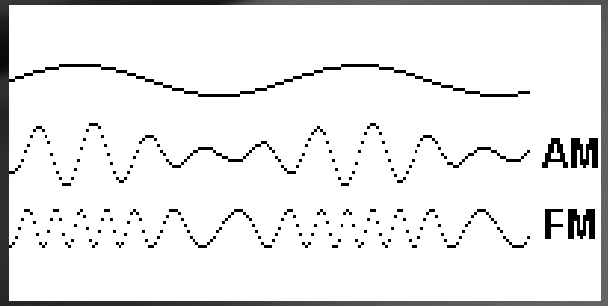
In this way, Hamming distance describes robustness to noise

Frequency & Bandwidth

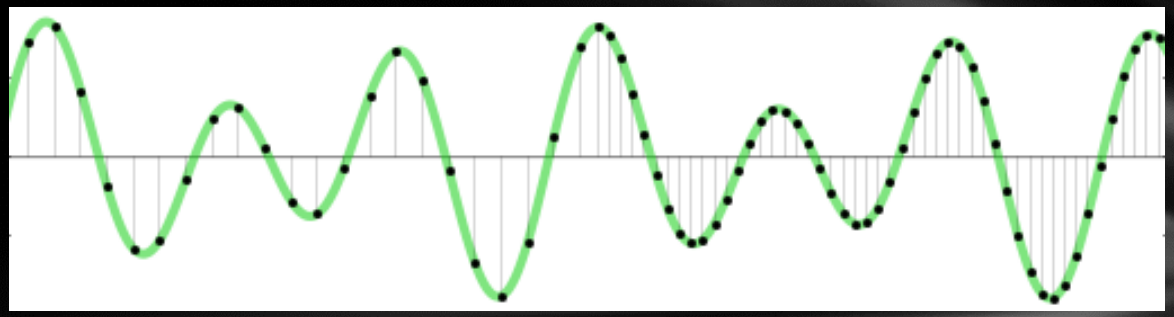
- Frequency: rate of an oscillation
- Bandwidth: measures the width of a range of frequencies
- Bandwidth = $freq_{upper}$ - $freq_{lower}$
- Human hearing bandwidth: ~20kHz (20kHz - 20 Hz)
- "Bandwidth" and "bitrate" are often used interchangeably; this is a different definition
- **Bonus Question**: what's the frequency range and bandwidth of 802.11 b/g?
  - 2.4 GHz to 2.5 GHz; 100 MHz

Shannon's Theorem

- Also called "noisy-channel coding theorem"
- Tells about maximum bitrate in the presence of noise
- Max. bitrate = bandwidth * $\log_2(1 + \text{signal/noise})$
- $C = B \log_2(1 + S/N)$
- Intuitive understanding
  - Sending signal over a wave with amplitude modulation
  - As the wave changes, each amplitude can correspond to a different symbol
  - Less noise means we can detect symbols more precisely!
- What are the implications of this?
  - More power -> higher data rate
  - More bandwidth -> higher data rate
  - This is why companies fight so much (pay so much) for spectra!



Nyquist Rate



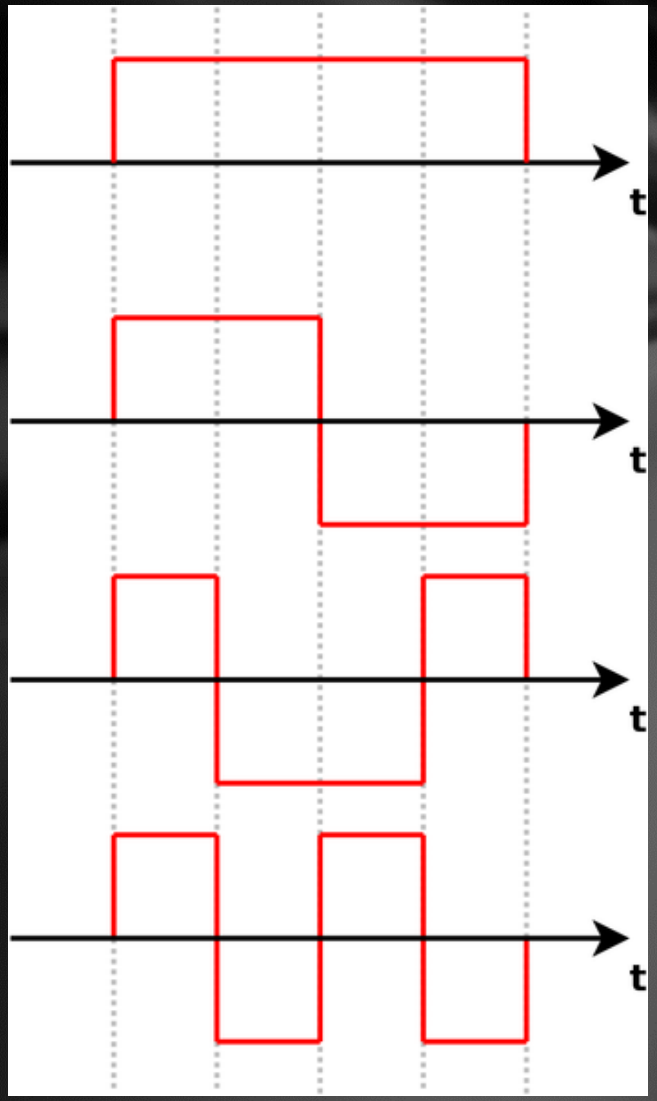
- To recover a waveform, the sampling rate must be at least two times the highest frequency
- Telephone sampling rate is 8kHz; what are the implications of this?
- What sampling rate would be required to recover all frequencies audible by humans? (Up to 20kHz)
  - 40KHz
  - Audio CDs use 44.1kHz sampling rates for this reason

Code Division Multiplexing (1)

- All stations send at the same time, with same frequencies
- Each station has a unique chip sequence, all orthogonal to each other
- E.g., (1,1,1,1) ⊥ (1,1,-1,-1) ⊥ (1,-1,1,-1)
- Each of these is a symbol: a station sends its sequence for 1, and the negation of that sequence for 0
- Receiver decodes signal by taking the dot product of the received signal with the chip sequence for each station

Code Division Multiplexing (2)

- Signals on the right are all orthogonal (including each one's negation)
- If added on top of each other, they're always separable with the method on the previous slide
- Quick example on the board



Network Programming in Action: Nat Stories

- Worked at Nintendo from 2005 to 2007, then from 2010 to 2013
- Helped game developers with programming issues, hardware and API questions, and bug troubleshooting
- Basically a TA for game developers!
- The first time, focused on graphics and gameplay
- The second time, focused on network features

Network Programming in Action: Nat Stories

- Lots of network features on Nintendo platforms (and most game platforms)
  - Nintendo Wii had:
    - 802.11 Wi-Fi and Ethernet via USB
    - Online multiplayer and matchmaking framework (Nintendo Wi-Fi Connection)
    - Online rankings
    - User-specific data storage servers
    - User-to-user and Nintendo-to-user messaging system (WiiConnect24)
    - Ad-hoc communication with Nintendo DS
      - Uploading game executables to a DS for "Download Play"
    - Marketplace: Wii Shop Channel
    - Parental Control system and user relationships via "Friend Codes"
  - Other consoles, like Nintendo 3DS, had many more network-related features

Network Programming in Action: Nat Stories

- Helped developers optimize protocols for sending/receiving gameplay data
- Wrote FAQs and whitepapers about network communication
- Helped developers figure out if their implementations met all of the official Nintendo guideline
- Helped design and improve proposed network features for new consoles
- Answered lots of e-mails like this:

Hi :

1. use wii develop machine connect to a router .
2. cutoff router power
3. Open router power,
4. Wii try to connect router
5. Always fail. And error code 51031.

How to solve it ?

Network Programming in Action: Nat Stories

- Networking is used lots in video games
- Performance-heavy area where new application-level protocols are designed all the time
- Really awesome industry to get into if you want to work with networking, graphics, or design tools
- Let me know if you want industry contacts!

Reminder

Make sure you fill out course evaluations!!