Communication
Part 2
CS 074 The Digital World
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Outline
• Channels, Signals and Noise
• Channel Coding
• Networks
• Mobile Information Systems

Channels
• A communication channel is a medium by which information can be transmitted from a source to a destination
  — point-to-point
  — broadcast
Signal and Noise

• **Signal** is information of interest, transmitted with a given power
• **Noise** is what may obscure the signal, always present with a given power

• Key Ratio: Signal to Noise Ratio (SNR):

**Signal Power/Noise Power**

Signal to Noise Ratio

• High SNR means clear signal, higher channel capacity

• SNR typically very large so it is usually quantified logarithmically:

\[
\text{One bel} = \log_{10}(S/N)
\]

• A ten-fold increase in SNR increases this quantity by 1 bel
Signal to Noise Ratio

- Loudness usually measured in 10ths of bels, **decibels** (db):
  
  \[
  \text{One db} = \frac{\log_{10}(S/N)}{10}
  \]

- E.g., 90db is a SNR ratio of \(10^9 = 1 \text{ Billion}\)

- E.g., 60db is a SNR ratio of \(10^6 = 1 \text{ Million}\)

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Sound

- Loudness of sound with power X is the ratio of X to the power of the softest audible sound S:
  
  \[
  L(X) = 10 \times \log_{10}(X/S) \text{ db}
  \]

- So
  
  \[
  L(S) = 10 \times \log_{10}(S/S) = 10 \times \log_{10}(1) = 10 \times 0 = 0
  \]

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Sound

- Normal conversation X = 10^6S so L(X) = 60db

- Rock concert X = 10^{11}S so L(X) = 110db or even 120db (hearing loss in a few minutes ...)

- iPods can be 115db, so watch out
Shannon Model of Communication

• Use **digital** representation

• In particular, use **binary**

Sample the Signal, Send the Samples

- Transmitting bits using Amplitude Modulation
• Transmitting bits using Frequency Modulation

Shannon Communication Model

Shannon Communication Model
Sample Communication Channels

- Twisted-pair wires, 10 – 100 Mbs
- Fiber-optics cables, 100 Gbs
- 802.11 Wireless 10 – 100 Mbs

It’s a noisy world ...

- Failure of the physical transmission channel
- How to detect errors
- How to correct errors
- How to minimize errors

Shannon Communication Model

- Analog Signal
- Analog to Digital
- Source Coding
- Channel Coding (Modulation)
- Physical Communication Channel
- Compressed bits with additional error correction information
Shannon Communication Model

Error Detection: Simple Parity
- Protocol: working with even or odd parity. For this example, we choose even.
- Add up the bits. If sum is even, then attach a 0. If the sum is odd, attach a 1.
  \[0001\ 1100 \Rightarrow 1\ 0001\ 1100\]
- Receiver does the same to detect 1-bit errors.

Error Detection: Checksum
- Add up all the data words then, for fixed K, compute
  \[R = N \mod K\]
- Send R along with the data.
- On the receiving end, do the same thing, computing:
  \[R' = N \mod K\]
- If \(R \neq R'\) ERROR! Request a resend.
Error Correction

- Usually error detection leads to a request from the receiver to the sender to resend the data.
- R. W. Hamming: one bit error correction, clever use of parity bits.

Minimizing Errors

- We know that a fundamental advantage of digital representation over analog is that data can be restored
- E.g. if there are only two possibilities for a signal, the problem becomes recognizing which possibility the actual signal more closely resembles
• Bandwidth = the width of a frequency range
  • E.g. the AM band is 530-1700 KHz, for a bandwidth of about
  1200 KHz
  • Within a band, signals (e.g. radio stations) have to be kept a
  certain distance apart to avoid interference (could not have
  stations at both 1030 and 1031 KHz)
  • More bandwidth => more “stations,” “channels,” i.e., more
  channel capacity
  • With more bandwidth it is possible to transmit more
  information

• These four are interrelated
  • Stronger signal (S) => higher channel capacity C
  • More noise (N) => lower C
  • More bandwidth (B) => higher C
  • \[ C = B \log_2 (1+S/N) \]
  • Shannon-Hartley Theorem
  • So channel capacity increases linearly with
     bandwidth but logarithmically with signal-to-noise
     ratio

\[ C = B \log_2 (1+S/N) \]

• Usually noise is uncontrollable
• So to increase channel capacity, the engineer must increase either
  bandwidth or signal power
• Power is a precious resource!
• Use more power in a PC or cell phone => bigger battery, shorter
  battery life, etc.
• With only two signal levels, power usage is minimized
• To achieve a fixed data rate, can use 1000x less power if we can get
  100x more bandwidth!