Lecture 1: Intro & Overview

- Fundamental Problems in Information Theory
- Course Overview
- Logistics

Fundamental Problems in IT

- Q1: Is there a limit to how much data can be compressed?

- Q2: At what rates is reliable communication possible over a noisy channel?

Question 1

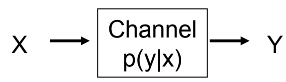
- Q1: Is there a limit to how much data can be compressed?
- A: $\boxed{H(X)\ \text{bits/symbol}}$
- For binary source, H(X) = true information, 1-H(X) = redundancy

Question 2

- Q2: At what rates is reliable communication possible over a noisy channel?
- A: $$\boxed{C = \max_{p(x)} I(X;Y)}$$
- At any rate R < C, reliable communication is possible

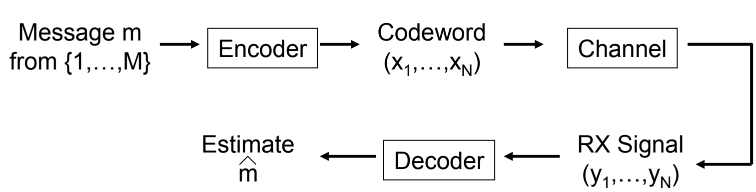
Channel Definition

- Channel: Probabilistic relationship between input X and output Y: p(y|x)



- Use channel multiple times (discrete-time)
  - Each use might correspond to a symbol period

Communication System

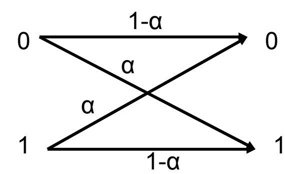


$$\textbf{Rate (R)} = \frac{\log_2 M}{N} = \frac{\#\text{ of info bits in message}}{\#\text{ of channel uses}} = \text{bits/use}$$

$$\textbf{Block error rate} = P(e) = P(\hat{m} \neq m)$$

Example Channel

Binary Symmetric Channel with cross-over probability α<1/2



$$\mathbf{p(y = x) = 1 - \alpha, \quad p(y \neq x) = \alpha}$$

Encoder/Decoder Design

- Encoder: Choose M (# of codewords) length N binary codewords
- Decoder: Given length N received vector, choose message m that TX most likely sent

Limits of Communication

- What is highest rate (for any N) of reliable communication, i.e. what is best any encoder/decoder can do?

- Zero-error capacity: Reliable <-> P(e) =0
  - For BSC, zero error capacity is zero because P(e) > 0 for any code
  - Generally very difficult problem
  - Not so interesting from practical/engineering standpoint

Channel Capacity

- Shannon's Formulation:

  What is highest rate such that P(e) -> 0 as N goes to infinity?

- A: $$\boxed{C = \max_{p(x)} I(X;Y)}$$

- For any R < C, there exist encoders/decoders for all N with P(e) -> 0 as N grows large
- For any R > C, P(e) -> 1 as N grows large

Source Channel Separation

Source → Compressor (Source Coding) → Encoder (Channel Coding) → Channel

Remove Redundancy (Q1)

Add "intelligent" Redundancy (Q2)

- Optimal to do source and channel coding separately for single TX, single RX channel
- Can reliably transmit any source with

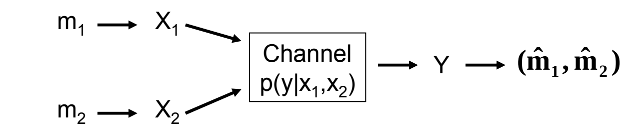
$$H(X) < C$$

Course Overview

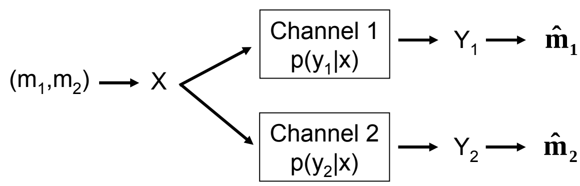
- Information Theory Basics
  - H(X), I(X;Y), AEP,…
- Single User Gaussian Channels
  - AWGN: $Y = X + N$
  - Fading
  - MIMO
  - Freq-selective

Course Overview

- Multiple-access Channel

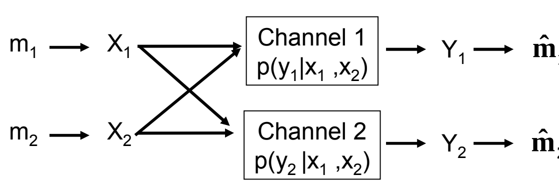


- Broadcast Channel

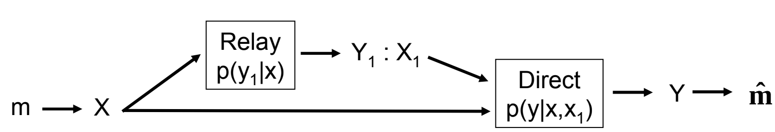


Course Overview

- Interference Channel



- Relay Channel

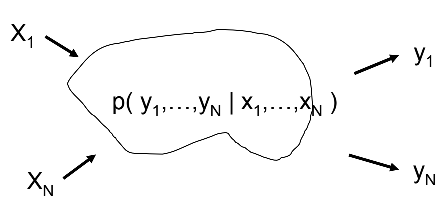


Course Overview

- Rate Distortion Theory
  - Maximum compression such that reconstruction not perfect but meets distortion criteria (lossy source coding)

Course Overview

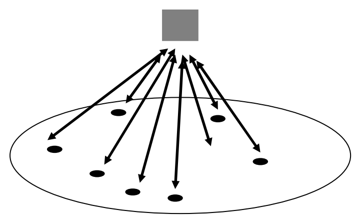
- Capacity of general (ad-hoc) multi TX/multi RX networks



- Includes relaying, routing, etc.

Course Overview

- Sensor Networks: Distributed Estimation/Detection, CEO Problem, Joint Source/Channel Coding



Course Overview

- Network Coding: Perform coding at routers instead of just multiplexing to increase performance and add robustness

Logistics

- Text: No required text, but info theory book is highly recommended (Cover & Thomas)
- Prerequisite: EE5581 or equivalent
- Homework: Approximately weekly for first half of course, ~7 total
- Midterm exam in middle of course
- Research Project: In-depth study, or original research topic
- Grading: 35% HW, 25% Midterm, 40% Project