Introduction to Error Control Coding

520.460

Introduction

"If your communication system does not use coding, it's probably overdesigned."

(E. Berlekamp)

Error Control Coding

- What is coding?
  - *mapping of messages...resistance to noise*
- Why is coding used in digital communication systems and elsewhere? (...*elsewhere?*)
  - *because it works...*
- Why does coding work?
  - *Shannon's 1948 surprise...*
- How does coding work?
  - *focus of most of this course*
- How well does coding work?

Digital Communication

The Problem: *to deliver* **information** *over* **noisy** *channels at an acceptable* **rate** *and* **reliability**.

One Solution: *Increase the transmitted* **energy** *per* **symbol** *to render the noise negligible and ineffective.*

Another Solution: *Add* **redundancy** *to the transmitted information so that transmitted errors can be* **detected** *and* **corrected.**

Why does Coding Work?

Claude Shannon [1948]:[a]

- Noise does *not* place an inescapable limit on the probability of error or on the transmission rate.
- Characteristics of the channel (noise level, bandwidth, signal power) determine precisely the *Channel Capacity* C.

Theorem: *There exist mappings of increasingly long sequences of information symbols into increasingly long sequences of channel symbols such that:*

$$\Pr(error) \to 0$$

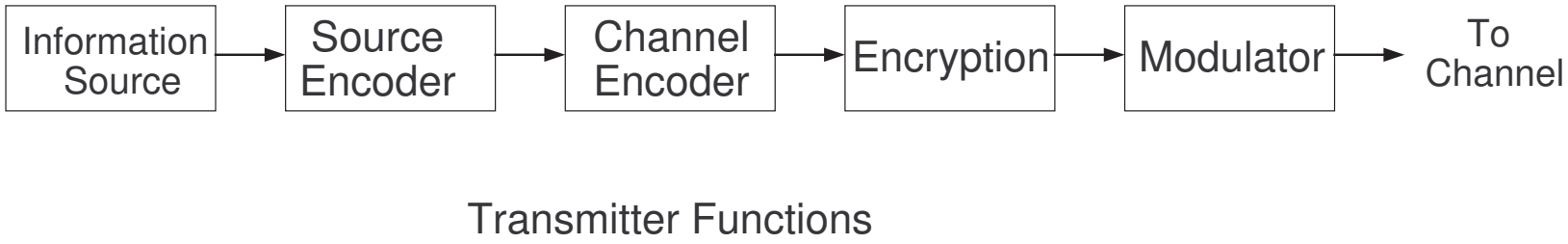
provided that the transmission rate $R < C$. □

[a]Shannon, C.E., "A Mathematical Theory of Communication," *Bell System Technical Journal*, v27, pp 379-423, 623-656 (1948).

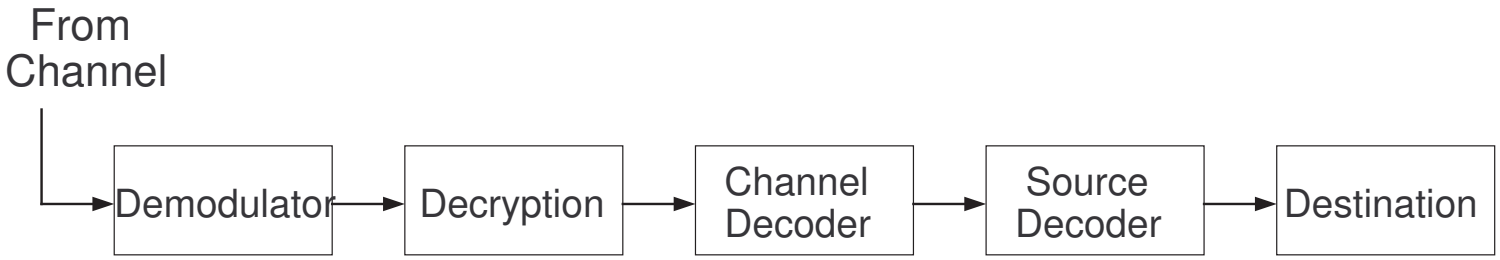
Notes:

- theorem has been proved rigorously in several ways;
- all proofs are *non-constructive*;
- 55 (since 1948, perhaps earlier) years of research into codes and decoders;
- recent systems are *very close* to achieving capacity on the Gaussian channel.
- *Information Theory* addresses channel capacity and related considerations (520.447).
- electronic mass storage media achieves storage densities beyond what is possible without coding.

A Digital Communication System



Transmitter Functions



Receiver Functions

General Objectives of Coding

1. detection and correction of errors introduced in the channel
2. efficient transmission of data
   (a) lower transmitter power than without coding
   ($\Pr(error)$ vs E/N)
   (b) more efficient use of bandwidth (bps/Hz)
3. low complexity encoding and decoding schemes (time, memory, chip area).

Assignment: Think of (or envision) up to three (3) uses of coding (or decoding or both) that are outside of electronic communication and computer data storage.

The Study of Digital Communication at JHU

Sample MSEE Program without Thesis

Basic Communications (401)

Error Control Coding (460)

Digital Communications I (465)

Digital Multimedia Coding & Processing (443)

Random Signal Analysis (651)

Information Theory (447)

Digital Communications II (466)

Optical Communications (619)

Sem. in Error Control Coding (766)

Sem. on Optical Commun. (753)

For more information, go to

http://www.ece.jhu.edu/~cooper/new_page_1.htm