Introduction to Error Control Coding

520.460
Introduction

“If your communication system does not use coding, it’s probably oversized.”

(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]:

• Noise does \textit{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 \textit{Channel Capacity} \( C \).

\textbf{Theorem}: \textit{There exist mappings of increasingly long sequences of information symbols into increasingly long sequences of channel symbols such that:}

\[
\Pr(\text{error}) \to 0
\]

provided that the transmission rate \( R < C \). \hfill \Box

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:

Information Source → Source Encoder → Channel Encoder → Encryption → Modulator → To Channel

Receiver Functions:

From Channel → Demodulator → Decryption → Channel Decoder → Source Decoder → Destination
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
       \( \Pr(\text{error}) vs E/N \)
   (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

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For more information, go to

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