ECEN 455 - Digital Communications

Introduction

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Communications Theory

- **Data Transmission**
  - "The transfer of information from one place to another."
- **Communications Theory**
  - "The study and statement of the principles and methods by which information is conveyed."
- Historically this was done by courier, a chain of bonfires, semaphores, and Morse code over wires.
- In recent times, this means sending a stream of bits or bytes from one location to another using any number of technologies:
  - Copper wire, optical fiber, laser, radio, or infra-red light.

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The Big Question

Why do I need to know this?

Philosophy of Learning for Engineering

- "Engineering Maturity" is not a simple thing to define or achieve
  - One develops the basic concepts (e.g., mathematics, physics, linear systems) in introductory classes
  - And a few more advanced topics in senior level classes
  - Maturity occurs when one can follow new topics in engineering on their own by filling in the gaps
- For some of you
  - This class will be central to your future work as engineers
- For others
  - It will add only to the breadth of your engineering knowledge

Who Are You?

1. Name
2. City and state where you grew up? (if many, pick your favorite)
3. Favorite hobby or sport

History of Communications

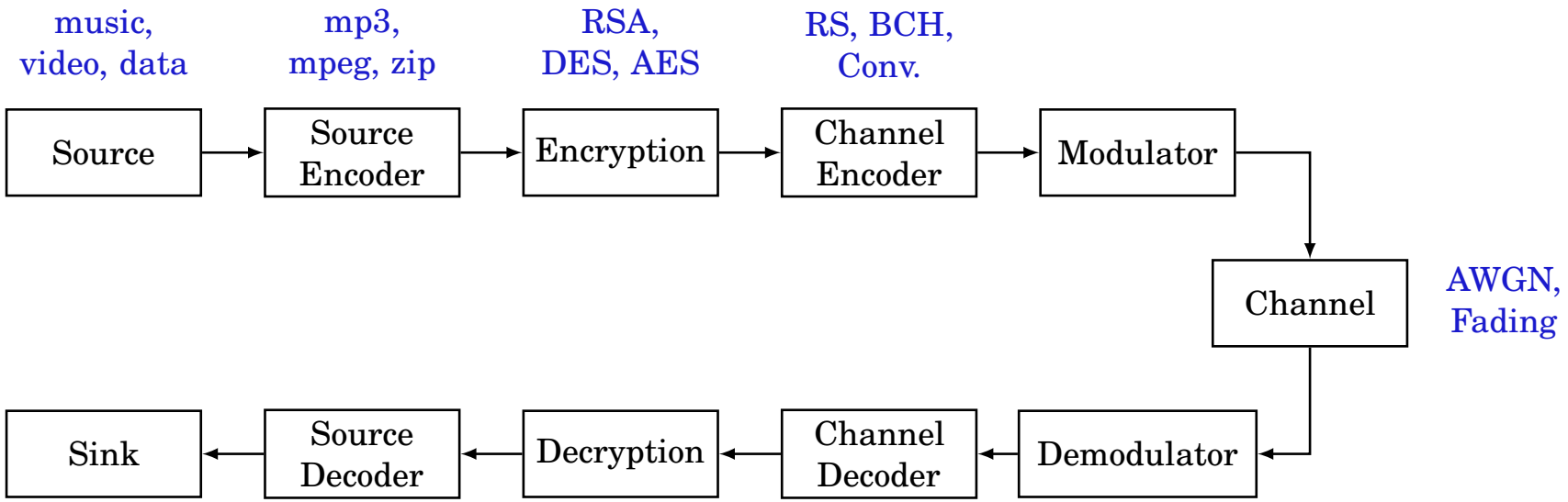
- Early History
  - 150 : Roman empire smoke signal network covers 4500km
  - 1794: Mechanical optical telegraph network across Europe
  - 1844: Commercial electric telegraph service begins
  - 1901: Marconi transmits a radio signal across the Atlantic
- Modern Era
  - 1948: Claude Shannon introduces information theory
  - 1959: First moon bounce (analog) “satellite” communications
  - 1965: Prototype communication satellites (analog relay)
  - 1969: First message sent over ARPANET (precursor to internet)
  - 1973: US Telephone switches start digital PCM transmission
  - 1990: First digital cellular phone call
  - 1995: Qualcomm’s IS-95 CDMA cellular standard ratified
  - 1999: Wi-Fi standard 802.11b ratified by the IEEE

Applications

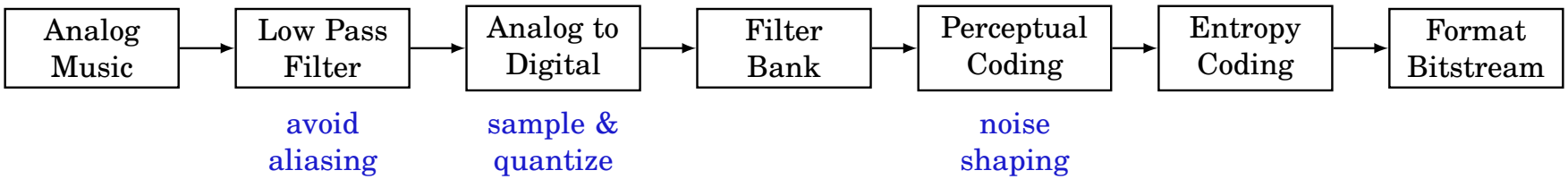
- Many devices are explicit (or implicit) communication systems
  - Compact Discs and DVDs
  - Cell Phones
  - Hard Disk Drives
  - The Internet
  - The Random Access Memory (RAM) in your computer
  - Microprocessor Bus Connections

Introduction to Digital Communications

Communications Block Diagram



MP3 Source Encoder Block Diagram



Terminology

Message: The information to be sent from transmitter to receiver. May be analog or digital (e.g., voice, video, data).

Source Encoder: Generates digital bit stream from an analog or digital source. Lossless coding allows exact reconstruction while lossy coding allows reconstruction with some distortion.

Channel Encoder: Insert redundant bits into message stream to allow for the correction of errors.

Channel Decoder: Attempts to correct errors made by the demodulator using redundancy in the transmitted stream.

Modulator: Converts digital information into a sequence of pulses with characteristics suitable for transmission over the channel.

Demodulator: Estimates digital information from corrupted version of transmitted signal.

Encryption: Scrambles a digital message for security purposes based on a key.

Decryption: Unscrambles a digital message using the encryption key.

Digital vs. Analog Communications

Digital

- Transmits signals from a finite alphabet.
- Can remove effects of noise induced by channel through error correction.
- Analog signals must be digitized.
- Easy to encrypt (for security).
- Better compression techniques.
- Often requires a larger channel bandwidth than analog unless sophisticated compression is used.
- Many different multiplexing techniques available.

Analog

- Transmits signals from an uncountably infinite alphabet.
- Can never remove all noise induced by a channel.
- Can send analog signals.
- Difficult to encrypt.
- Difficult to compress.
- Analog messages generally require a small transmission bandwidth.
- Multiplexing must be done almost exclusively by frequency division.

Probability Theory

- Is a fundamental building block in communication theory
- It also has a bad reputation
  - As difficult to learn and filled with “trick” problems

Famous Story

- In the September 9, 1990 issue of Parade magazine, Marilyn vos Savant (famous for her high IQ) answered this question:

  - *"Suppose you're on a game show, and you're given the choice of three doors. Behind one door is a car, behind the others, goats. You pick a door, say number 1, and the host, who knows what's behind the doors, opens another door, say number 3, which has a goat. He says to you, "Do you want to pick door number 2?" Is it to your advantage to switch your choice of doors?"*

    – Craig. F. Whitaker Columbia, MD

- The letter describes a choice made by contestants on the 1970's game show Let's Make a Deal (hosted by Monty Hall and Carol Merrill)

The Monty Hall Problem

- Marilyn answered that the contestant *should switch*. However, she soon received a pile of letters (many from mathematicians) telling her that she was wrong. The "Monty Hall Problem", as it was named, generated many hours of discussion.

- Yet it is an elementary problem with an elementary solution.
  - Why was there so much confusion?
  - Most people believe they have an *intuitive* grasp of probability
    - ★ On the other hand, few people believe they can factor large integers in the their head!

Intuition vs. Reason and Experiment

- Everyone who has studied probability at length can name a some problems in which their intuition led them astray – often embarrassingly so.
- The best way to avoid errors is to distrust informal arguments and rely instead on a rigorous, systematic approach.
  - **Do the Experiment!**
    - `http://montyhallgame.shawnolson.net/`
    - "I must admit I doubted you until my fifth grade math class proved you right. All I can say is WOW!"

      – John Witt, Westside Elementary River Falls, Wisconsin