Chapter 5  Data Encoding

Data Transmission

• Digital data, digital signal
  • Analog data, digital signal: e.g., voice, and video are often digitized to use digital transmission facilities. (e.g. PCM)
  • Digital data, analog signal: for trans. media (e.g. optical fiber, unguided media) only propagate analog signal. (e.g. ASK, FSK, PSK)
  • Analog data, analog signal: to shift the bandwidth of baseband signal into another portion of spectrum.

Digital Data, Digital Signal

• Digital signal: Discrete, discontinuous voltage pulses; each pulse is a signal element; Binary data encoded into signal elements
  ➢ Unipolar: All signal elements have same sign
  ➢ Polar: One logic state represented by positive voltage the other by negative voltage
• Data rate: Rate of data transmission in bits per second (bps)
• Duration or length of a bit: Time taken for transmitter to emit the bit
• Modulation rate: Rate at which the signal level changes
  ➢ Measured in baud = signal elements/sec (e.g. pulse/sec)

Performance Metrics of Encoding Schemes

• Signal Spectrum
  ➢ Lack of high frequencies reduces required bandwidth
  ➢ Lack of dc component allows ac coupling via transformer, providing isolation
  ➢ Good scheme concentrate power in the middle of the bandwidth
• Clocking: Synchronizing transmitter and receiver
  ➢ External clock
  ➢ Sync mechanism based on signal
• Error detection: Can be built in to signal encoding
• Signal interference and noise immunity: Some codes are better than others
• Cost and complexity
  ➢ Higher signal rate (& thus data rate) lead to higher costs
  ➢ Some codes require signal rate greater than data rate

DDDS Encoding Schemes

• Nonreturn to Zero (NRZ):
  ➢ Nonreturn to Zero-Level (NRZ-L)
  ➢ Nonreturn to Zero Inverted (NRZI)
• Multilevel Binary: (reading assignment)
  ➢ Bipolar –AMI (Alternate Mark Inversion)
  ➢ Pseudoternary
• Biphase:
  ➢ Manchester
  ➢ Differential Manchester
• Scrambling Techniques: (reading assignment)
  ➢ B8ZS
  ➢ HDB3
Nonreturn to Zero-Level (NRZ-L)
- Two different voltages for 0 and 1 bits
- Voltage constant during bit interval
  - no transition i.e. no return to zero voltage
- e.g. Absence of voltage for zero, constant positive voltage for one
- More often, negative voltage for one value and positive for the other

Bits
- 0 0 1 0 1 1 1 0 1 0 0 0 0 1 0

NRZ-L
Clock
Manchester

Nonreturn to Zero Inverted
- Constant voltage pulse for duration of bit
- Data encoded as presence or absence of signal transition at the beginning of bit time
- Transition (low to high or high to low) denotes a binary 1
- No transition denotes binary 0
- An example of differential encoding

NRZ-L
0 1 0 0 1 1 0 0 0 1 1

NRZI

NRZ pros and cons
- Pros: Easy to engineer; Make good use of bandwidth
- Cons: Lack of synchronization capability (e.g. successive 0s)
- Used for magnetic recording
- Not often used for signal transmission

-> Differential Encoding
- Data represented by changes rather than levels
- More reliable detection of transition rather than level
- e.g., Manchester Code

Biphase Coding
- Manchester
  - Transition in middle of each bit period
  - Transition serves as clock and data
  - Low to high represents one
  - High to low represents zero
  - XOR of clock and NRZL
  - Used by IEEE 802.3 (for baseband coaxil cable & twisted-pair CSMA/CD bus LANs)
- Differential Manchester
  - Midbit transition is clocking only
  - Transition at start of a bit period represents zero
  - No transition at start of a bit period represents one
  - Note: this is a differential encoding scheme
  - Used by IEEE 802.5 (token ring LAN)
Biphase Pros and Cons

- **Con**
  - At least one transition per bit time and possibly two
  - Maximum modulation rate is twice of NRZ
  - Requires more bandwidth

- **Pros**
  - Synchronization on mid bit transition (self clocking)
  - Error detection: Absence of expected transition

Digital Data, Analog Signal

- Use Public telephone system: 300Hz to 3400Hz
  - Use modem (modulator-demodulator)

- Amplitude shift keying (ASK):
  - Values represented by different amplitudes of carrier
  - Usually, one amplitude is zero, i.e. presence and absence of carrier is used
  - Used over optical fiber

- Frequency shift keying (FSK)
  - Values represented by different frequencies (near carrier)
  - Used for high frequency radio trans. (3 to 30 MHZ)
  - Even used for higher frequency on LANs using co-ax

- Phase shift keying (PK)
  - Phase of carrier signal is shifted to represent data

Modulation Techniques

- Digitization
  - Conversion of analog data into digital data
  - Digital data can then be transmitted using NRZ-L
  - Digital data can then be transmitted using code other than NRZ-L
  - Digital data can then be converted to analog signal
  - Analog to digital conversion done using a codec
    - Pulse code modulation
    - Delta modulation

Analog Data, Digital Signal
Pulse Code Modulation (PCM)

- If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all the information of the original signal (Sampling Theory)
- Voice data limited to below 4000Hz
- Require 8000 sample per second
- Each sample assigned digital value
- 4 bit system gives 16 levels
- Quantized
- 8 bit sample gives 256 levels
- Quality comparable with analog transmission
- 8000 samples per second of 8 bits each gives 64kbps

Analog Data, Analog Signals

- Why modulate analog signals?
  - Higher frequency can give more efficient transmission
  - Permits frequency division multiplexing (chapter 8)
- Types of modulation
  - Amplitude
  - Frequency
  - Phase

Analog Modulation

- Analog or digital data
- Using analog signal
- Spread data over wide bandwidth
- Makes jamming and interception harder
- Frequency hoping
  - Signal broadcast over seemingly random series of frequencies
- Direct Sequence
  - Each bit is represented by multiple bits in transmitted signal
  - Chipping code

Spread Spectrum