Computer Communication Networks I

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Lecture 2

What happens when a signal is applied to the channel?

- Assume the bandwidth of the signal is W_s
- Assume that the bandwidth of the channel is W_c
- If the bandwidth of the signal is larger than the bandwidth of the channel (that is: $W_s > W_c$) – then output signal will not contain all of the frequencies of the input signal.
- In other words, channel bandwidth determines the bandwidth of the signals that can pass through the channel.
- Suppose we increase the signaling speed -> pulses become narrower (higher signal bandwidth)
- The bandwidth of a channel places a limit on the rate at which we can send pulses through the channel.

A very important result

If the channel has bandwidth of W, then the narrowest pulse that can be transmitted through the channel has duration of 1/2W seconds.

Therefore, the maximum rate at which pulses can be transmitted through the channel is given by

$$r_{max} = 2W \text{ pulses/second}$$

This rate is called the Nyquist rate.

The term baud rate is also used to denote the signaling rate in pulses/second.

Multilevel transmission

- We can transmit binary information by sending a pulse with amplitude +A (denote 1) and –A (denote 0).
- We can increase the bit rate by sending more levels.
- Example: {-A – A/3 +A/3 +A} to denote {00, 01, 10, 11}
- This is called multilevel transmission.

Important

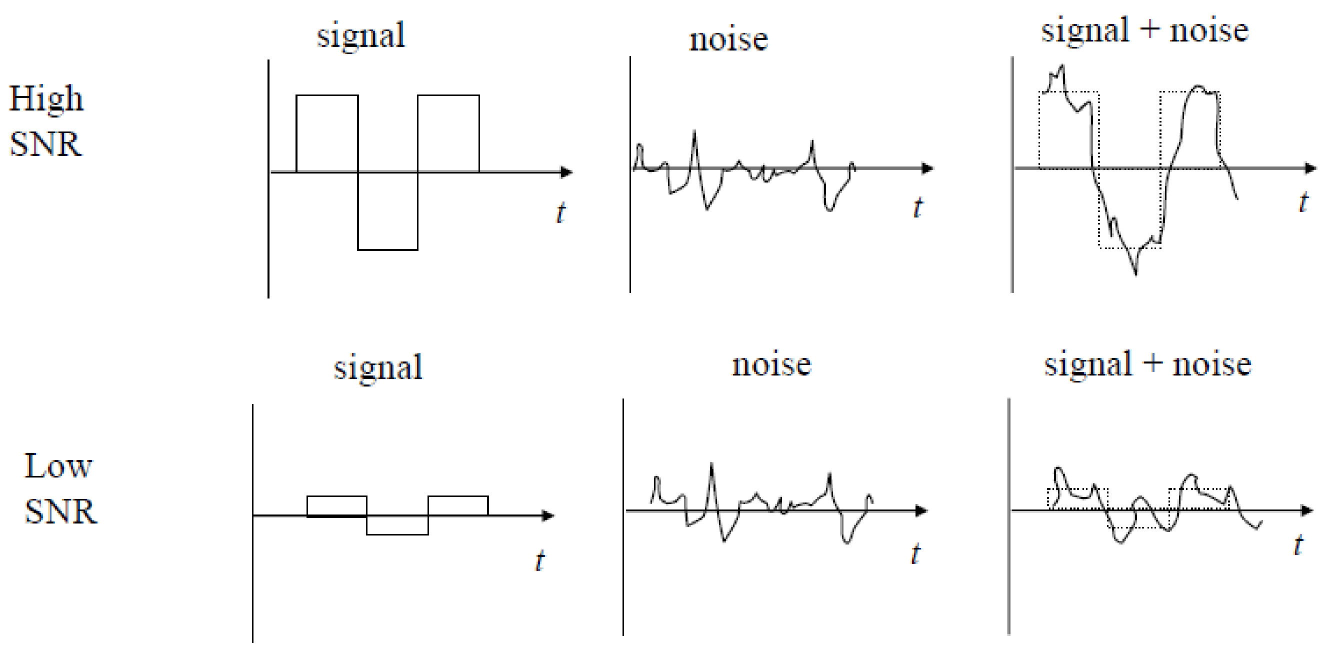
- If we use multilevel transmission with $M=2^m$ amplitude levels, we can transmit at a bit rate of R=2W pulses/second x m bits/pulse = 2Wm bits/second.

Signal-to-noise ratio (SNR)

- Noise is a major problem encountered in all communication systems.
- Noise consists of extra signals added to the transmitted signal at the input to the transmitter.
- The signal-to-noise ratio measures the relative amplitudes of the signal and the noise. It is normally stated in dB (decibels)

$$\text{SNR} = \frac{\text{Average signal power}}{\text{Average noise power}}$$

$$\text{SNR (dB)} = 10 \cdot \log_{10}(\text{SNR})$$



Signal-to-noise ratio

Channel Capacity

- The channel capacity of a transmission system is the maximum rate at which bits can be transferred reliably.
- Claude Shannon derived an expression for the channel capacity of an ideal low-pass channel.
- Reliable transmission of data rates above the capacity is not possible.

- The Shannon channel capacity is given by the following formula:

$$C = W \log_2 (1 + SNR) \text{ bits/second}$$

Example

Consider a telephone channel with W=3.4 kHz and SNR = 40 dB.

First convert the dB in SNR into SNR (linear)

SNR = 40 dB

$40 = 10*\log_{10}(SNR)$

SNR = 10,000

The channel capacity is given by

$$C = 3400*\log_2(1+10{,}000)$$
$$= 45{,}200 \text{ bits/second}$$

Data encoding techniques

Analog and Digital Transmissions

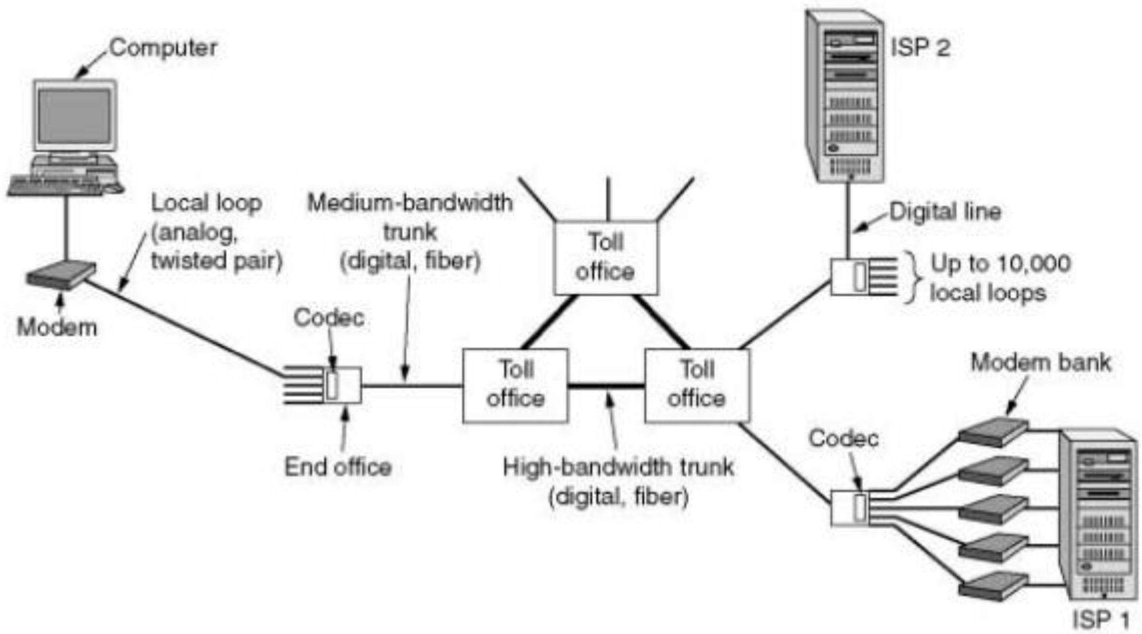


Figure: Use of both analog and digital transmissions for a computer to computer call.

Data Encoding Techniques

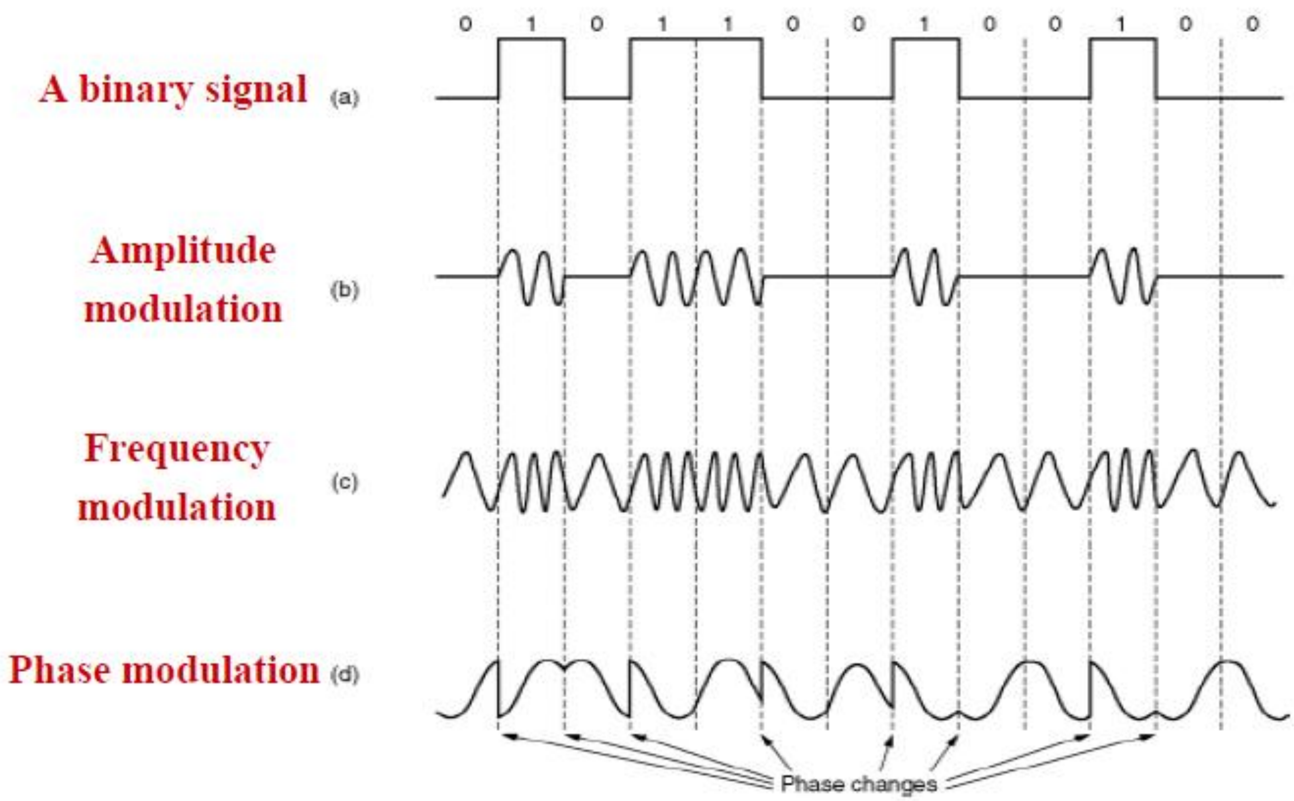
- Digital Data, Analog Signals [modem]
- Digital Data, Digital Signals [wired LAN]
- Analog Data, Digital Signals [codec]

Digital Data, Analog Signals

• Basis for analog signaling is a continuous, constant-frequency signal known as the carrier frequency.

• Digital data is encoded by modulating one of the three characteristics of the carrier:

1. Amplitude
2. Frequency
3. Phase or some combination of these.



Modems

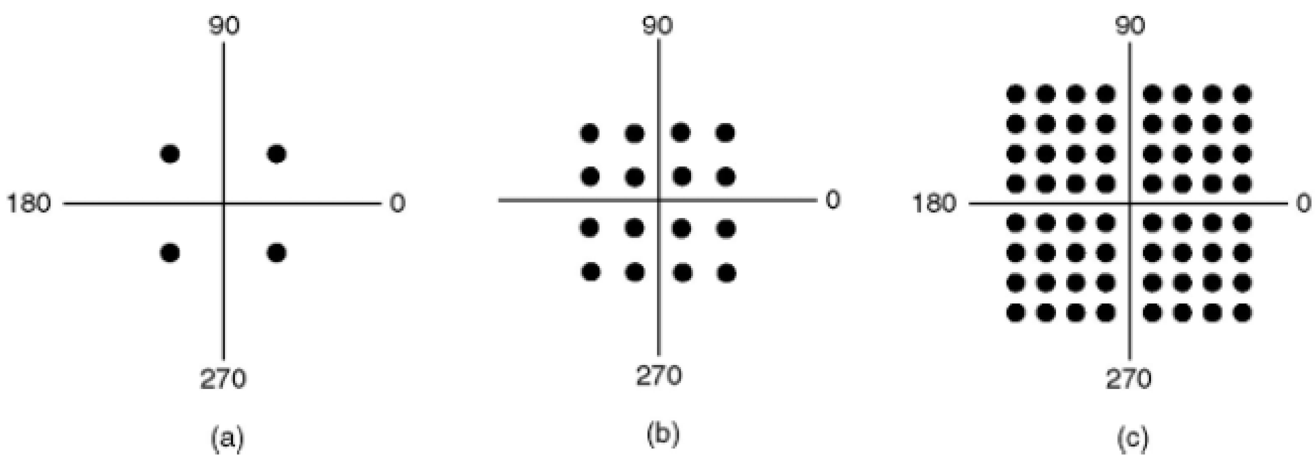
• All advanced modems use a combination of modulation techniques to transmit multiple bits per baud.

• Multiple amplitude and multiple phase shifts are combined to transmit several bits per symbol.

• QPSK (Quadrature Phase Shift Keying) uses multiple phase shifts per symbol.

• Modems actually use Quadrature Amplitude Modulation (QAM).

• These concepts are explained using constellation points where a point determines a specific amplitude and phase.



(a) QPSK. (b) QAM-16. (c) QAM-64.

Figure: Constellation diagrams

Digital data, Digital signals

Line Coding

- Line coding is the method used for converting a binary information sequence into a digital signal in a digital communication system.

  Uses of line coding

- In systems such as wireless local area networks (WLANs) an important design consideration is the need to recover the bit timing information.

- Also many systems do not pass the DC (zero frequency) and low-frequency content.

- Some line coding methods have error detection capabilities.

- Some line coding methods are good against noise

NRZ (Non-Return-to-Zero) Codes

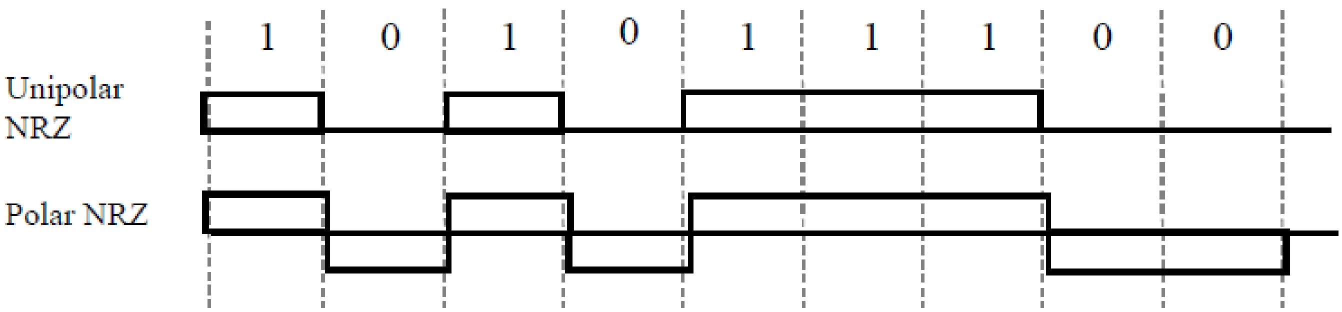
- Uses two different voltage levels (one positive and one negative) as the signal elements for the two binary digits.

NRZ-L (Non-Return-to-Zero-Level)

- The voltage is constant during the bit interval.

- Binary 1 is transmitted by sending a +A/2 and binary 0 is transmitted by sending a –A/2.

- More efficient than NRZ code in terms of the average transmitted power.

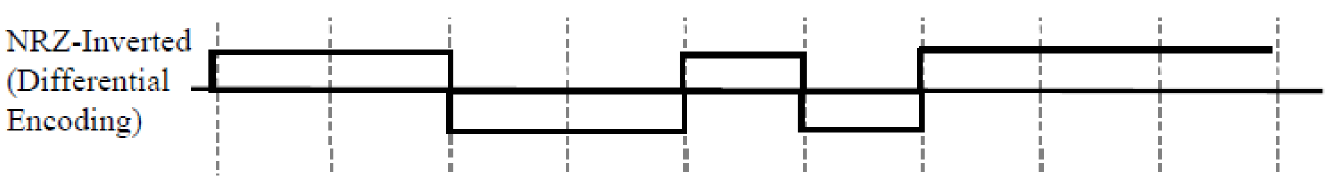


NRZ-I (Non-Return-to-Zero-Inverted)

- The two level NRZ-I signal has a transition at a clock boundary if the bit being transmitted is a logical 1, and does not have a transition if the bit being transmitted is a logical 0.

- NRZ-I is a differential encoding (i.e., the signal is decoded by comparing the polarity of adjacent signal elements.)

Example: 1 0 1 0 1 1 1 0 0



Bi-Polar encoding

- Bi-Polar encoding method was developed to produce a spectrum that is more suitable to channels that do not pass low frequencies.

- In this method binary 0s are mapped into 0 voltage, and therefore makes no contribution to the digital signals.

- Consecutive ones are alternatively mapped into +A/2 and –A/2.

Manchester encoding

• There is **always** a mid-bit transition (which is used as a clocking mechanism)

Encoding Rule

- Zero (0) is represented by low-to-high
- One (1) is represented by high-to-low

Differential Manchester encoding

- The clock half-period always begins with a transition from low to high or from high to low.

- The data half-period makes a transition for one value and no transition for the other value.

- One version of the code makes a transition for 0 and no transition for 1 in the data half-period;

- The other version makes a transition for 1 and no transition for 0.

Example: 1 0 1 0 1 1 1 0 0