Bangladesh Army University of Engineering & Technology

CSE-3215
Data Communication

Lecture-15

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DATA RATE LIMITS

A very important consideration in data communications is how fast we can send data, in bits per second, over a channel. Data rate depends on three factors:

1. The bandwidth available
2. The level of the signals we use
3. The quality of the channel (the level of noise)

Topics to be discussed in this section:

For Noiseless Channel: Nyquist Bit Rate

For Noisy Channel: Shannon Capacity

Nyquist Sampling Rate

The minimum rate at which a signal can be sampled without introducing errors, which is twice the highest frequency present in the signal.

Formula:

Nyquist bit rate = 2 x Bandwidth (Hz) x No. of bits per level

Shannon Capacity

Shannon capacity describes the capacity of a noisy channel. The formula is:

$C = B \log_2 (1+SNR)$

Where,

C = Capacity of channel,

B = Bandwidth in Hz,

SNR = Signal to Noise ratio (Average power of received signal ÷ Average power of noise)

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Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The Data Rate of the noiseless channel (Nyquist bit rate) can be calculated as

$$\boxed{\text{BitRate} = 2 \times 3000 \times \log_2 2 = 6000 \text{ bps}}$$

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Consider the same noiseless channel transmitting a signal with four signal levels (for each level, we send 2 bits). The Nyquist bit rate can be calculated as

$$\boxed{\text{BitRate} = 2 \times 3000 \times \log_2 4 = 12{,}000 \text{ bps}}$$

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We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

Solution

We can use the Nyquist formula as shown:

$$265{,}000 = 2 \times 20{,}000 \times \log_2 L$$

$$\log_2 L = 6.625 \qquad L = 2^{6.625} = 98.7 \text{ levels}$$

Since this result is neither an integer nor a power of 2, we need to either increase the number of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.

Note: Number of levels here can be 98 or 99 also, but a power of 2 is more acceptable.

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Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

$$\boxed{C = B \log_2 (1 + \text{SNR}) = B \log_2 (1 + 0) = B \log_2 1 = B \times 0 = 0}$$

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

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We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$\boxed{\begin{aligned} C &= B \log_2 (1 + \text{SNR}) = 3000 \log_2 (1 + 3162) = 3000 \log_2 3163 \\ &= 3000 \times 11.62 = 34{,}860 \text{ bps} \end{aligned}}$$

This means that the highest bit rate for a telephone line is 34.860 kbps.

If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

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The signal-to-noise ratio is often given in decibels. Assume that SNR_{dB} = 36 and the channel bandwidth is 2 MHz. The theoretical channel capacity can be calculated as:

$$SNR_{dB} = 10 \log_{10} SNR \rightarrow SNR = 10^{SNR_{dB}/10} \rightarrow SNR = 10^{3.6} = 3981$$

$$C = B \log_2 (1 + SNR) = 2 \times 10^6 \times \log_2 3982 = 24 \text{ Mbps}$$

That's all for today

Thank You