COMP90007 Internet Technologies

Week 4 Workshop

Semester 2, 2019

Suggested solutions

Question 1 (Sampling)

- Consider a telephone signal that is bandwidth limited to 4 kHz.
  - (a) At what rate should you sample the signal so that you can completely reconstruct the signal?
    min. sampling rate = 2 × 4000 = 8 kHz = 8000 samples/s
  - (b) If each sample of the signal is to be encoded at 256 levels, how many bits/symbol are required for each sample?
    256 possible values per sample requires $\log_2(256) = 8$ bits/sample
  - (c) What is the minimum bit rate required to transmit this signal?
    8 bits/sample × 8000 samples/s = 64 kbps

- **Note:** This is a direct application of the Sampling Theorem and forms the basics of the application of the theorem, i.e. without considering data rates.

Question 2 (Sampling)

- Is the Sampling theorem true for optical fibre or only for copper wire?

  - The Sampling theorem is a property of mathematics and has nothing to do with technology.

  - The Sampling theorem states that if you have a function whose Fourier spectrum (frequency domain representation) does not contain any frequency components (sines or cosines) above *f*, then by sampling at a frequency of *2f*, you capture all the information there is. The Sampling theorem is independent of the transmission medium.

  - **Note**: You do not need to know the Fourier transform, law, etc.

Question 3 (Max Data Rate)

- Given a noiseless 4 kHz channel, what is the maximum data rate of the communications channel?
  - A noiseless channel can carry an arbitrarily large amount of information, no matter how many levels of signals to use (i.e. there can be an infinite number of signalling levels because there is no noise)
  - Just use many levels of signals, so that each symbol can carry many bits. Assume a 4 kHz channel, the baud rate is 8k symbols/sec. If each symbol can represent 16 bits data, the channel can send 128 kbps. If each symbol can represent 1024 bits, the channel can send 8.2 Mbps.
  - The key word here is “noiseless.” With a normal noisy 4 kHz channel, Shannon specifies a limit on the information rate on the channel known as its *capacity*.

Question 4 (Max Data Rate)

- The bandwidth of a television video stream is 6 MHz. How many bits/sec are sent if four-level digital signals are used? Assume a noiseless channel.

  - The maximum baud rate is 12 symbols/sec
  - Four levels of signalling provide: log2 4 = 2 bits/symbol
  - Hence, the total data rate is: 12 million symbols/s × 2 bits/symbol = 24 Mbps

Question 4 (Max Data Rate)

- The bandwidth of a television video stream is 6 MHz. How many bits/sec are sent if four-level digital signals are used? Now assume a S/N of 20db.

  - Using Shannon's theorem, we have: B x log(1+S/N)
    = 6MHz x log(1+100) = 6MHz x 6.65 = 39.9Mbps

Question 5

The following character encoding is used in a data link protocol:

A:	01000111	B:	11100011
FLAG:	01111110	ESC:	11100000

Show the bit sequence transmitted (in binary) for the four-character frame payload *A B ESC FLAG,* when each of the following framing methods are used:

(a) Character count

(b) Flag bytes with byte stuffing

(c) Starting and ending flag bytes, with bit stuffing

Answer:

1. 00000101 01000111 11100011 11100000 01111110
   5 A B 'ESC' 'FLAG'
2. 01111110 01000111 11100011 11100000 11100000 11100000 01111110 01111110
   FLAG A B ESC 'ESC' ESC 'FLAG' FLAG
3. 01111110 01000111 11**0**100011 111**0**00000 011111**0**10 01111110
   FLAG A B 'ESC' 'FLAG' FLAG

Question 6

The following data fragment occurs in the middle of a data stream for which the byte-stuffing algorithm as described in the lecture is used:

A B ESC C ESC FLAG FLAG D.

What is the output after stuffing?

Answer:
After stuffing we get:
A B ESC ESC C ESC ESC ESC FLAG ESC FLAG D.