COMP90007 Internet Technologies

Week 4 Workshop

Semester 2, 2020

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 which 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.

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, e.g. there can be an infinite number of signalling levels, this is because there is no noise. This is a neat observation and the level information is not restricted by the question in any way. Shannon specifies a limit on the information rate based on given noise.

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 (i.e. 100).

  - Using Shannon's theorem, we have: B x log(1+S/N)
    = 6MHz x $\log_2(1+100)$ = 6MHz x 6.65 = 39.9Mbps

  Note: Using Nyquist's theorem, we have: 2B x $\log_2$ V

  = 2 * 6MHz x $\log_2$ 4 = 12MHz x 2 = 24Mbps

  The bottleneck is therefore the Nyquist limit, giving a maximum channel capacity of 24Mbps.

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.