COMP90007 Internet Technologies

Week 4 Workshop

Semester 2, 2021

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 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/sec = 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 is independent of the transmission medium. 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.

Question 3 (Max Data Rate)

- Given a noiseless 4 kHz channel, what is the maximum data rate of the communication 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 level.

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 M symbols/sec
Four levels of signalling provide: $\log_2 4 = 2$ bits/symbol
Hence, the total data rate is: 12 M symbols/sec × 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)

$= 6\text{MHz} \times \log_2(1+100) = 6\text{MHz} \times 6.65 = 39.9\text{Mbps}$

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

$= 2 * 6\text{MHz} \times \log_2 4 = 12\text{MHz} \times 2 = 24\text{Mbps}$

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

Question 5 (Framing)

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 110100011 111000000 011111010 01111110
     FLAG       A        B        'ESC'     'FLAG'     FLAG
```

Question 6 (Framing)

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.