THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Tamaki Campus

COMPSCI.314.S2.T. Data Communications Fundamentals

Assignment 1: Signals, Codes, Compression, Integrity, Skype, and Powerline Communications

Posted: 27 July 2007
Due: 11.59 pm, Saturday 11 August 2007

This assignment is worth **100 marks** representing **5%** of your total mark.

Questions

Solve the following problems (present each solution in detail):

1. (*4 marks*) a) Distinguish between a digital and analog signal. b) What components describe an analog signal?

   Solution: a) The value of a digital signal is fixed for a short time before changing to another value. Analog signal values vary continuously.

   b) Amplitude, frequency, and phase shift.

2. (*6 marks*) People often casually refer to a 'high-speed connection'. Strictly speaking, this is technically incorrect. Name and describe three factors affecting a connection's performance that have an impact on the user's perception of 'connection speed'.

   Solution:

   - Bandwidth describes how much data can be sent over the network; it is limited to the poorest link.
   - Latency is the elapse time for a single byte (or packet) to travel from one host to another. There are propagation, transmission and processing delays. Latency is cumulative.
   - Errors appear due to interference, busy routers, link fails, noise under the third point. Errors are cumulative.

3. (*10 marks*) a) Define a signal's period and frequency. b) How are they related? c) Suppose the period is 10 nanoseconds, what is its frequency?

   Solution: a) A signal's frequency is the number of cycles through which the signal can oscillate in a second. The period of a signal is the time required by the signal to complete one cycle.

   b) The frequency (f) and period (p) are related as follows:

$$f = \frac{1}{p}.$$

c) As $p = 10 \times 10^{-9} = 10^{-8}$ s per cycle, using the above formula we calculate the frequency f by

$$f = \frac{1}{p} = \frac{1}{10^{-8}} = 10^{8} = 100 \text{ MHz}.$$

4. (*10 marks*) Using a Baudot code, how can we tell a digit from a letter? Illustrate your answer by computing the Baudot code of the string G564FSDH6.

Solution: The Baudot code uses the extra information

11111 (shift down) and **11011** (shift up)

to determine how to interpret a 5-bit code. Upon receiving a shift down, the receiver decodes all codes as letters till a shift up is received, and so on. The Baudot code of the string G564FSDH6 is (shift down and shift up are in bold):

11111-11010-**11011**-10000-10101-01010-**11111**-01101-00101-01001-10100-**11011**-10101

5. (*30 marks*) a) Define the notion of prefix code. b) Give an example of prefix code and an example of non-prefix code; justify your answers. c) Using the algorithm in Kraft's theorem construct a prefix code whose codewords have exactly the lengths $5, 2, 1, 3$. d) Is the prefix code constructed at c) unique (justify your answer)? e) Is your solution for c) extendable, i.e. can you add a new codeword without violating the prefix property?

Solution: a) A prefix code is a code in which no codeword is a (proper) prefix of any other codeword in the set.

b) ASCII is a prefix code because it is a 7-bit code. No codeword can be a prefix of any other codeword because no codeword is any longer or shorter than 7.

The code $\{0, 01, 001, 0001\}$ is not prefix (but the code $\{01, 001, 0001\}$ is prefix).

c) Using the algorithm in Kraft's theorem, we arrange the lengths in increasing order, $1, 2, 3, 5$, and we get the prefix code: $\{0, 10, 110, 11100\}$ which satisfies the requirements: $|11100| = 5, |10| = 2, |0| = 1, |110| = 3$.

d) No, for example, replacing 0 with 1 and 1 with 0 we get a prefix code satisfying the requirements in c), $\{1, 01, 001, 00011\}$.

e) Yes, for example we can add the codeword 11111.

6. (*10 marks*) a) What is the signal-to-noise ratio (S/N)? b) How can we use S/N to distinguish a clear signal from a less clear one?

Solution: a) The signal-to-noise ratio is the ration S/N, where S is the signal power and N is the noise power.

b) A large signal-to-noise ratio indicates a clear signal, while a small signal-to-noise ratio means a less clear signal.

7. (*20 marks*) a) State Shannon's theorem. b) Assume the maximum bandwidth of a medium is 6000 Hz. According to Shannon's theorem, what is the maximum bit rate if the signal-to-noise ratio is 40 dB? You are allowed to approximate where this is appropriate.

Solution: a) Shannon's theorem states that in a noisy transmission,

$$\text{bit rate} \;=\; \text{bandwidth} \;\times \log_2(1 + S/N).$$

b) Using Shannon's theorem, the signal-to-noise ratio is

$$40\,\text{dB} = 4\,\text{B} = \log_{10}\frac{S}{N},$$

hence

$$\frac{S}{N} = 10^4.$$

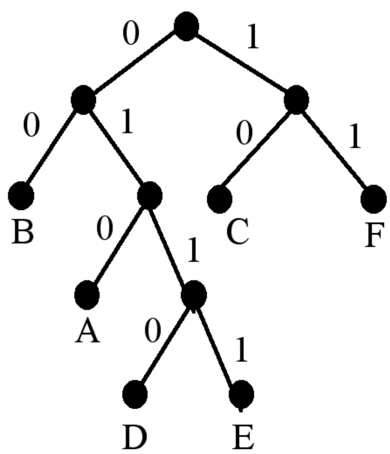
Therefore, the bit rate is

$$6000 \times \log_2(1 + 10^4) = 6000 \times \log_2(10001) \approx 6000 \times 13.288 = 79{,}700 \text{ b/s}.$$

8. (*10 marks*) Devise a Huffman tree and the corresponding codewords for letters whose frequency of occurrence is in the following table:

Letter	Frequency
A	15%
B	25%
C	20%
D	10%
E	10%
F	20%

Solution: Using the Huffmann tree



we obtain the following code: A: 010; B: 00; C: 10; D: 0110; E: 0111; F: 11.