CARLETON UNIVERSITY

Department of Systems and Computer Engineering

SYSC 4700 **Telecommunications Engineering** **Winter 2007**

Assignment 1 with Solutions

Posting date: Saturday, January 27, 2007
Due date: 4:00 pm, Tuesday, February 6, 2007 (in box outside ME 4438)

Question 1 [10 points]

Consider an upcoming xDSL standard as an access technology over the copper telephone lines (i.e., last-mile access). Here are some relevant specifications:

- This standard uses the DMT (discrete multitone modulation) technology with 4 KHz tones (i.e., channels).
- There is 1 KHz guard band between neighboring tones.
- The downstream portion uses the spectrum band between 2.000 MHz and 7.119 MHz.
- Spectral efficiency is 9 bits/sec/Hz.

(a) [6 points] Find the downstream rate in bits/sec (assuming the pulse shape that yields the highest spectral efficiency).

There are a total of (7119+1-2000)/5 = 1024 channels. Each channel can carry a rate of R_c = 4000 Hz x 9 bits/sec/Hz = 36 Kbits/sec. Therefore, the total downstream rate is R_T = 1024 x 36 Kbits/sec = 36.864 Mbits/sec.

(b) [4 points] Find the minimum required SNR at the user modem to facilitate this system using the Shannon channel capacity formula.

W/R (spectral efficiency) is given to be 9 bits/sec/Hz. Therefore, the minimum required SNR (found by the Shannon channel capacity formula) is

$\log_2(1+SNR) = 9 \rightarrow SNR = 511 = 27.08$ dB

Question 2 [10 marks]

Consider a high-quality analog-to-digital converter (ADC) for voice signals with the following specifications:

- The ADC captures the detail in the voice signal up to 13 KHz.
- 2048 levels are used for quantization.

Next, consider a time-division multiplexing scheme (TDM) which combines the digital output from 20 users whose analog data is digitized through the above described ADC scheme. A TDM frame consists of samples from 20 users plus three bits for synchronization purposes.

(a) [6 points] Find the line speed (in bits/sec) to carry this TDM traffic.

Sampling rate: 26 Ksamples/sec (according to Nyquist Theorem)
2048 quantization levels → $\log_2 2048 = 11$ bits/sample

Frame length: (20 users x 1sample/user x 11 bits/sample) + 3 snch bits = 223 bits
Frame duration: 1/26,000 sec.
→ *Line speed: 223 bits in 1/26,000 sec = 5.798 Mbits/sec*

(b) [4 points] Assuming that M-ary QAM modulation is used, find M if the line has 1.2 MHz of bandwidth (indicate what pulse shape you assumed in this design).

Since there is modulation, clearly we have bandpass transmission.
Synch pulses are the most bandwidth efficient pulses with $\mu = 1$ symbol/sec/Hz.
→ *Maximum symbol rate: $R_s = 1.2$ MHz x 1 symbol/sec/Hz = 1.2 Msymbols/sec*

ceil(5.798 Mbits/sec / 1.2 Msymbols/sec) = 5 bits/symbol → $2^5 = 32$ levels
→ *32-QAM has to be used.*

Note that if rectangular pulses with $\mu = 0.5$ symbols/sec/Hz are used, then R_s will be 600 Ksymbols/sec, which will necessitate 10 bits/symbol; in that case, 1024-QAM has to be used.