CARLETON UNIVERSITY

Department of Systems and Computer Engineering

SYSC4700 Telecommunications Engineering Winter 2013

Term Exam Solution Set – 15 February 2013

Duration: 80 minutes

Instructions:

1. **Closed-book exam (no aid-sheet). No cell phones.**
2. **Write answers in the spaces provided on the question sheet.**
3. **If necessary, use both sides of a page.**

Name:

Student Number:

Question	Mark	Max possible mark
1		20
2		32
3		30
Total		82

Question 1 [20 pts] – A/D Conversion and Time-Division Multiplexing

There is a high-speed line which can carry traffic at a rate 5.148 Mbits/sec. A number of analog voice signals will first be digitized and then will be multiplexed on to this high-speed line through TDM (time-division multiplexing). There is no control bits appended during the multiplexing operation.

There are two types of A/D conversion, low quality and high quality, with the below parameters.

- Low-Quality A/D Conversion: Sampling Rate = 6,000 samples/sec
  Quantizer: 64-level

- High-Quality A/D Conversion: Sampling Rate = 18,000 samples/sec
  Quantizer: 2048-level

Let us denote the users whose voice signals go through the low-quality A/D conversion as type-L users, and those whose voice signals go through the high-quality A/D conversion as type-H users.

(a) **[7 pts]** How many type-L users can be multiplexed on to the high-speed carrier?

1 type-L user rate: 6,000 samples/sec x 6 bits/sample = 36 Kbits/sec
No of type-L users: (5.148 Mbits/sec)/(36 Kbits/sec) = 143 users

(b) **[6 pts]** How many type-H users can be multiplexed on to the high-speed carrier?

1 type-H user rate: 18,000 samples/sec x 11 bits/sample = 198 Kbits/sec
No of type-L users: (5.148 Mbits/sec)/(198 Kbits/sec) = 26 users

(c) **[7 pts]** Next, consider the case where a mix of type-L and type-H users will be multiplexed. If there are *n* type-L users and *n* type-H users to be multiplexed, find *n*.

n = (5.148 Mbits/sec)/(36 Kbits/sec + 198 Kbits/sec) = 22

Question 2 [32 marks] – Short Questions

(a) [6 pts] Give two business values for operators that telecom standardization brings.

1) Multiple sources of supply (decrease risk of sole supplier dependencies/lock-in, improve choice at competitive prices).
2) Interoperability e.g. multi-vendor networks, service interop.
3) Assurance that investment in technology should not abruptly change or fail

(b) [6 pts] Give two business values for vendors that telecom standardization brings.

1) Network vendors can sell to all service operators, freed from vendor specific R&D.
2) Reduce customization.
3) Build reputation / customer confidence - strong standards brand
4) Larger markets from wide adoption, greater economies of scale

(c) [4 pts] Write two types of standards bodies.

1) Accredited
2) Treaty-based
3) Partnerships
4) Forums and Consortia
5) Industry Associations
6) Government Advisory Councils
7) Global
8) Regional
9) National

(d) [6 pts] What do the followings acronyms stand for?

1) ITU: International Telecommunication Union
2) IETF: Internet Engineering Task Force

(e) [4 pts] Give two examples for standards development organizations.

ITU, IEEE, ETSI, IETF, …

(f) [6 pts] Give three examples of highest impact telecom standards.

1) Signaling System #7 (SS7)
2) SONET / SDH
3) AMPS: AT&T Bell Labs circa 1984
4) Ethernet: IEEE 802.3 circa 1980
5) TCP / IP
6) X.400
7) X.25

Question 3 [30 marks] – Link Budget

In this question we will determine the maximum achievable transmission rate in the downlink of a cellular wireless network. Here are the specifications of interest:

- Base Station (BS) transmit power: P_{TX} = 0.2 W
- Transmitter (BS) antenna gain: G_{TX} = 7 dB
- Receiver (terminal) antenna gain: G_{RX} = 3 dB
- Quality requirement: SNR > 5 dB
- Receiver noise figure: F = 3.98 = 6 dB
- Ambient temperature: $T = 290^{o}$K
- Boltzmann constant: $k = 1.38\text{x}10^{-23}$ joule/^{o}K
- Path loss (PL): $(4\pi f/c)^2 d^4$, where
    - o Distance between BS and a wireless terminal: d
    - o Speed of light: $c = 3\text{x}10^8$ m/sec.
    - o Carrier frequency: f = 2 GHz
- Maximum spectral efficiency according to Shannon's channel capacity theorem: $\mu_{\max} = \log_2(1+\text{SNR})$ bits/sec/Hz.

Calculate the maximum achievable rate in bits/sec if a wireless terminal is 200 m away from the BS.

[**Help 1**: $P_{noise} = kTBF$ in linear scale.]

[**Help 2**: Note that B (bandwidth) is not given in the question; it is to be calculated.]

[**Help 3**: Some values are given in dB scale, while some others in linear.]

$$SNR_{dB} = 5\,\text{dB} \Rightarrow SNR = 10^{\frac{5}{10}} = 3.16$$

$$\mu_{\max} = \log_2(1+SNR) = 2.06\,\text{bits/sec/Hz}$$

$$R_{\max} = \mu_{\max} B = 2.06B \qquad (1)$$

$$SNR_{dB} = P_{TX} - PL + G_{TX} + G_{RX} - P_{noise} \qquad (2)$$

$$P_{TX} = 10\log_{10}(0.2) = -7\,\text{dBW}$$

$$PL = 10\log_{10}\left[\left(\frac{4\pi f}{c}\right)^2 d^4\right] = 20\log_{10}\left(\frac{4\pi f}{c}\right) + 40\log_{10} d = 130.5\,\text{dB}$$

$$P_{noise} = 10\log_{10}(kTBF) = [-197.98 + 10\log_{10} B]\ \text{dBW}$$

Substitute P_{TX}, P_L, and P_{noise} in (2):

$$5 = -7 - 130.5 + 7 + 3 + 197.98 - 10\log_{10} B$$
$$\rightarrow 10\log_{10} B = 65.48$$
$$\rightarrow B = 3.53\,\text{MHz}$$

Substitute B in (1):

$$R_{\max} = \mu_{\max} B = 2.06 \times 3.53\,\text{MHz} = 7.28\,\text{Mbits/sec}$$