CARLETON UNIVERSITY

Department of Systems and Computer Engineering

SYSC4700 Telecommunications Engineering Winter 2007

Term Exam – 15 February 2007

SOLUTIONS

Instructions:

1. **Closed-book exam (no aid-sheet). Use of non-programmable, non-communicating calculators is permitted.**
2. **Write answers in the spaces provided on the question sheet.**
3. **If necessary, use both sides of a page.**
4. **Write legibly, and state any assumptions that you make.**

Name:

Student Number:

Question	Mark	Max possible mark
1		25
2		25
3		13
Total		63

Question 1 [25 marks] – Link Budget for a 3G Cell

In this question we will determine the maximum transmission rate in the downlink of a cell in a 3G cellular network. Here are the specifications of interest:

- BS transmit power: P_{TX} = 20 dBW
- Transmitter (BS) antenna gain: G_{TX} = 17 dB
- Receiver (terminal) antenna gain: G_{RX} = 0 dB
- Quality requirement: SNR > 4 dB
- Carrier frequency: f = 3 GHz
- Receiver noise figure: F = 7 dB
- Ambient temperature: $T = 290^{o}$K
- Boltzmann constant: $k = 1.38 \times 10^{-23}$ joule/^{o}K
- Path loss (PL): $(4\pi d/\lambda)^{3.5}$, where
    - Distance between BS and a terminal: d
    - Carrier wavelength: λ
- Cell radius: 1 km
- Spectral efficiency at the cell edge: μ = 0.5 bits/sec/Hz

It is clear that the lowest SNR in the cell will be experienced at the cell edge (i.e., whenever a terminal is 1 km away from the BS) due to the fact that the highest PL will occur at the cell edge.

The service provider has the goal of maintaining the QoS (i.e., SNR > 4 dB) at the cell edge (i.e., d = 1 km). Find the maximum transmission rate, R bits/sec, that can be supported at the edge of this cell.

Solution:

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d} \right)^{3.5}$$

$$P_R\ [dBW] = P_T\ [dBW] + G_T + G_R - 35 \log\left(\frac{4\pi d_m}{\lambda} \right)$$

$$= 20 + 17 + 0 - 35 \log\left(\frac{4\pi d_m f}{c} \right)$$

$$= 37 - 35 \log\left(\frac{4\pi \times 10^3 \times 3 \times 10^9}{3 \times 10^8} \right) = -141.47 \ \ dBW$$

$$P_R - P_N = SNR$$

$$-141.47\ [dBW] - P_N[dBW] > 4\ \ dB \Rightarrow P_N < -145.47\ [dBW]$$

$$10 \log KT + F\ [dB] + 10 \log B < -145.47\ [dBW]$$

$$10 \log B < -145.47 - 10 \log\left(1.38 \times 10^{-23} \times 290\right) - 7\ [dB]$$

$$B < 141.41\ \ KHz \qquad \frac{R_b}{B} = 0.5 bits/\sec/Hz$$

$$R_b < 70.71\ \ Kbps$$

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Question 2 [25 marks] – Short Questions

(a) [8 marks] Write each of the following acronyms in open form (no need for explaining them):

- ITU: International Telecommunication Union
- VoIP: Voice over Internet Protocol
- XDSL: x Digital Subscriber Loop/Line
- FTTx: Fiber To The x
- XPON: x Passive Optical Network
- ATM: Asynchronous Transfer Mode
- SIP: Session Initiation Protocol
- WCDMA: Wideband Code Division Multiple Access

(b) [4 marks] What is the difference between TDM (time-division multiplexing) and TDMA (time-division multiple access)?

Time division: Time slots constitute the channel. Signals (i.e., users) are separated in time.

TDM (time-division multiplexing): Multiple time-separated signals originate from a common location (such from a Base Station).

TDMA (time-division multiple access): Multiple time-separated signals originate from different locations, but they are all destined to a common information sink (such as the uplink traffic in a cell).

(c) [4 marks] Give two examples of 2G cellular standards and two examples of 3G cellular standards.

2G: GSM, IS-95, DAMPS, CDPD
3G: UMTS, WCDMA, CDMA2000, EVDO, EVDV, HSDPA, HSUPA

(d) [4 marks] Give three reasons why mobile communication system standards are important.

- Compatibility enables users to stay connected Minimum number of devices for needs.
- Competing and co-operating service providers.
- Minimum number of devices for needs.
- Essential due to scarce radio spectrum resources
- Common and consistent solutions essential to end user experience.
- Lowering device cost due to mass production.

(e) [5 marks] What is triple-play and what is its significance?

High speed Internet + TV (video on demand or broadcast) + Telephone (voice): on one broadband connection.
- Commercial trend.
- Not designed for interoperability.
- Uses shared network such as cable or DSL.
- Has to achieve different Quality of Service requirements for each service.

Question 3 [13 Marks] – Transmission Rate and Bandwidth

- A 1.544 Mbits/sec DS1 system is transmitted through a wireless channel.
- 64-QAM modulation is used; the carrier frequency is 3.6 GHz.

(a) **[3 marks]** What is the signaling pulse shape that will result in minimum bandwidth consumption?

The synch pulse.

(b) **[3 marks]** What is the spectral efficiency, μ, in bits/sec/Hz if the pulse shape determined in Part (a) is used?

Since synch pulse is assumed:

$$\mu = \log_2(64)\,(bits/symbol) \times 1\,(symbol/\sec/Hz) = 6\,bits/\sec/Hz$$

(c) **[7 marks]** With the spectral efficiency obtained in Part (b), calculate the bandwidth required for this transmission. Identify the cutoff frequencies of the transmission band (i.e., if the transmission bandwidth is from f_1 Hz to f_2 Hz, find f_1 and f_2).

$$W = \frac{R}{\mu} = \frac{1.544 Mbits/\sec}{6} = 0.25733\,MHz$$

$$f_1 = 3600 - \frac{W}{2} = 3599.87133\,MHz$$

$$f_1 = 3600 + \frac{W}{2} = 3600.12867\,MHz$$