OLLSCOIL NA hÉIREANN, CORCAIGH
THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER EXAMINATIONS, 2013

B.E. DEGREE (ELECTRICAL and ELECTRONIC)

TELECOMMUNICATIONS

EE4004

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Time allowed: *3 hours*

Answer *five* questions.
All questions carry equal marks.

The use of departmental approved calculators is permitted.

1. (a) Illustrate the data and acknowledgement flow between two computers which are communicating over a dedicated link and which use the "stop and wait" ARQ scheme. From this, derive an expression for the utilization of the link in the case where the link is prone to bit errors. It can be assumed that the only two significant time delays on the link are the propagation delay and the packet (message) holding time.

[*10 marks*]

(b) For a given bit error probability, p, a given line date-rate, R, and a given propagation delay, τ_p, use the expression derived in part (a) of this question to determine the optimum packet size, n, to achieve the maximum line utilization.

[*8 marks*]

(c) For a data link as described in part (a) of this question, the line data rate is 200kbps, the propagation delay is 30ms and the bit error probability is 0.001. Determine the packet size, n, which will provide the maximum utilization on the link.

[*2 marks*]

2. (a) Describe the topology and operation of the four common Local Area Network (LAN) systems. In your description, include a discussion of active and passive bus systems and logical and physical network topology descriptions.

[*10 marks*]

(b) Illustrate the structure of a HDLC (High-level Data Link Control) frame and briefly describe the function of each field of the frame.

[*6 marks*]

(c) Illustrate the command flow between two computers A and B using a High-level Data Link Control protocol, where A instructs the system to set up a connection using the "asynchronous balanced mode" and then shuts down the connection.

[*4 marks*]

3. (a) Illustrate the architecture of a UMTS Radio-Access Network, including the core network and the radio network sub-system, and briefly describe the function of the main blocks.

[*8 marks*]

(b) Illustrate a typical FHSS (Frequency Hopping Spread Spectrum) system (both transmitter and receiver sides) and comment briefly on why FHSS systems have advantages with respect to privacy and immunity from interference.

[*7 marks*]

(c) Illustrate and briefly describe the three most common architectures for wireless networks and specify which architecture is most suitable if the network spans a range of geographic regions.

[*5 marks*]

4. The $M \times M$ channel matrix $\left[P(Y|X)\right]$ for the M-ary uniform channel (MUC) with M input symbols, denoted x_i, $1 \le i \le M$ and M output symbols, denoted y_j, $1 \le j \le M$, is given by: -

$$\left[P(Y|X)\right] = \begin{bmatrix} 1-p & \alpha & \alpha & .. & \alpha \\ \alpha & 1-p & \alpha & .. & \alpha \\ \alpha & \alpha & 1-p & .. & \alpha \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ \alpha & \alpha & .. & \alpha & 1-p \end{bmatrix}$$

where $\alpha = \dfrac{p}{M-1}$ (i.e. all terms on the main diagonal equal $1-p$, all others equal α).

(a) Show that the probability of receiving symbol y_j, $1 \le j \le M$, denoted $P(y_j)$, is given by: -

$$P(y_j) = P(x_j)(1 - M\alpha) + \alpha$$

where $P(x_i)$ denotes the probability of sending symbol x_i, $1 \le i \le M$. [*6 marks*]

(b) Show that the prevarication is given by: -

$$H[Y|X] = -\big((1-p)Log_2[1-p] + p\log_2[\alpha]\big).$$ [*8 marks*]

(c) Show that if the input symbols x_i, $1 \le i \le M$ are equiprobable, then the channel capacity of the MUC is given by: -

$$C_s = \log_2\left[(1-p)^{1-p}\alpha^p M\right]\ b/symbol.$$ [*6 marks*]

5. A baseband digital communications system uses the following signals to represent logic 1 and logic 0: -

$$s_i(t) = \begin{cases} A\sin[\omega t/2] & 0 \le t \le T \quad \text{logic } 1 \\ -A\sin[\omega t/2] & 0 \le t \le T \quad \text{logic } 0 \end{cases}$$

where $\omega = 2\pi/T$ and T denotes the bit signalling interval. The receiver takes a single sample of the received signal during the bit signaling time at $t = \dfrac{T}{2} + \Delta t$ (where Δt represents a clock-induced error in the sampling moment) and compares this sample with a decision threshold D. The communications are affected by zero-mean additive Gaussian noise whose probability density function f_n is given by: -

$$f_n(v) = \frac{e^{\frac{-v^2}{2\sigma^2}}}{\sqrt{2\pi\sigma^2}}$$

where σ^2 denotes the average noise power dissipated in a 1Ω reference resistor.

(a) Show that, to minimize the resulting overall probability of error P_e, the threshold D is given by: -

$$D = \frac{\sigma^2}{2A\sin\left[\omega\frac{T+2\Delta t}{4}\right]}\ln\left[\frac{P_0}{P_1}\right]$$

where P_0 and P_1 respectively denote the probability of sending logic 0 and logic 1.

[*10 marks*]

(b) Show that, if $P_0 > P_1$, then the average probability of error, denoted P_e, is given by: -

$$P_e = \frac{1}{2}\left(1-\left(P_0 erf\left[\frac{D + A\sin\left[\omega\frac{T+2\Delta t}{4}\right]}{\sqrt{2\sigma^2}}\right] + (1-P_0)erf\left[\frac{A\sin\left[\omega\frac{T+2\Delta t}{4}\right] - D}{\sqrt{2\sigma^2}}\right]\right)\right)$$

where: -

$$erf[x] = \frac{2}{\sqrt{\pi}}\int_0^x e^{-y^2}dy.$$

[*10 marks*]

6. (a) Using the Schwarz inequality, which states: -

$$\left|\int_{-\infty}^{\infty} f_1(\omega)f_2(\omega)d\omega\right|^2 \le \int_{-\infty}^{\infty}|f_1(\omega)|^2 d\omega\int_{-\infty}^{\infty}|f_2(\omega)|^2 d\omega,$$

or otherwise, show that the signal to noise ratio (SNR) at the output of a linear filter subject to an input signal $s(t)$, with Fourier transform $S(\omega)$, and input coloured noise with power spectral density $S_{nn}(\omega)$ satisfies: -

$$\left(\frac{S}{N}\right)_o \le \frac{1}{2\pi}\int_{-\infty}^{\infty}\frac{|S(\omega)|^2}{S_{nn}(\omega)}d\omega$$

and state the equation for the matched filter for this coloured noise.

[*10 marks*]

(b) Hence, or otherwise, deduce the maximum attainable SNR if the input noise is additive white Gaussian (AWGN) with a power spectral density of $\eta/2$ W/Hz.

[*3 marks*]

(c) The matched filter for an input signal $s(t)$, with Fourier transform $S(\omega)$, and additive white Gaussian noise (AWGN) with a power spectral density $\eta/2$ W/Hz is implemented in a receiver. The actual noise, however, is coloured with a power spectral density of $S_{nn}(\omega)$ (i.e. the designer designed for white noise but, in practice, coloured noise affects the receiver). Show that, in this case, the SNR, $\left(\frac{S}{N}\right)_o$, is given by: -

$$\left(\frac{S}{N}\right)_o = \frac{2\pi \ \ E^2}{\int_{-\infty}^{\infty} S_{nn}(\omega)\left|S(\omega)\right|^2 d\omega}$$

where E denotes the energy content of $s(t)$ (assuming a 1Ω reference resistor).

[*7 marks*]

7. Given the following table of field elements of $GF(2^5)$: -

0	$\alpha^7 = \alpha^4 + \alpha^2$	$\alpha^{15} = \alpha^4 + \alpha^3 + \alpha^2 + \alpha + 1$	$\alpha^{23} = \alpha^3 + \alpha^2 + \alpha + 1$
1	$\alpha^8 = \alpha^3 + \alpha^2 + 1$	$\alpha^{16} = \alpha^4 + \alpha^3 + \alpha + 1$	$\alpha^{24} = \alpha^4 + \alpha^3 + \alpha^2 + \alpha$
α	$\alpha^9 = \alpha^4 + \alpha^3 + \alpha$	$\alpha^{17} = \alpha^4 + \alpha + 1$	$\alpha^{25} = \alpha^4 + \alpha^3 + 1$
α^2	$\alpha^{10} = \alpha^4 + 1$	$\alpha^{18} = \alpha + 1$	$\alpha^{26} = \alpha^4 + \alpha^2 + \alpha + 1$
α^3	$\alpha^{11} = \alpha^2 + \alpha + 1$	$\alpha^{19} = \alpha^2 + \alpha$	$\alpha^{27} = \alpha^3 + \alpha + 1$
α^4	$\alpha^{12} = \alpha^3 + \alpha^2 + \alpha$	$\alpha^{20} = \alpha^3 + \alpha^2$	$\alpha^{28} = \alpha^4 + \alpha^2 + \alpha$
$\alpha^5 = \alpha^2 + 1$	$\alpha^{13} = \alpha^4 + \alpha^3 + \alpha^2$	$\alpha^{21} = \alpha^4 + \alpha^3$	$\alpha^{29} = \alpha^3 + 1$
$\alpha^6 = \alpha^3 + \alpha$	$\alpha^{14} = \alpha^4 + \alpha^3 + \alpha^2 + 1$	$\alpha^{22} = \alpha^4 + \alpha^2 + 1$	$\alpha^{30} = \alpha^4 + \alpha$

and considering a $(31,21)$ double error correcting primitive BCH code based upon this field:-

(a) Show that: -

(i) The minimal polynomial $m_1(x)$ is given by: -

$$m_1(x) = x^5 + x^2 + 1$$

[*4 marks*]

(ii) The minimal polynomial $m_3(x)$ is given by: -

$$m_3(x) = x^5 + x^4 + x^3 + x^2 + 1$$

[*4 marks*]

(b) Use the syndrome decoding method to correct the received sequence: -

$$v(x) = x^{24} + x^{23} + x^{22} + x^{18} + x^{17} + x^{16} + x^{15} + x^{14} + x^{13} + x^{12} + x^9 + x^8 + x^6 + x^5 + x^2 + x.$$

[*6 marks*]

(c) Use the syndrome decoding method to correct the received sequence: -

$$v(x) = x^{24} + x^{23} + x^{22} + x^{18} + x^{17} + x^{16} + x^{15} + x^{13} + x^{10}$$

and determine the corresponding user information polynomial, denoted $i(x)$.

[*6 marks*]