OLLSCOIL NA hÉIREANN, CORCAIGH

THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH

UNIVERSITY COLLEGE, CORK

SUMMER EXAMINATIONS, 2010

B.E. DEGREE (ELECTRICAL & ELECTRONIC)

TELECOMMUNICATIONS

EE4004

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Time allowed: *3 hours*

Answer *five* questions.

The use of log tables and a departmental approved non-programmable calculator is permitted.

Q.1. (a) Illustrate a simple wide area network (WAN) consisting of a collection of switches and links and using this diagram describe the functions (5 or more) that are needed for the network to successfully interconnect many users.

[*10 marks*]

(b) Using diagrams as appropriate describe the operation of circuit switching and packet switching in wide area networks (WANs) and outline the advantages and disadvantages of each method.

[*10 marks*]

Q.2. (a) Describe the topology and operation of 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) For local area networks (LANs) describe the following:

(i) The operation of the CSMA/CD MAC protocol.

[6 *marks*]

(ii) The topology and operation of Switch-Based LANs including the main advantage of this approach.

[*4 marks*]

Q.3. (a) Using diagrams as appropriate describe the following aspects of a public telephone system in Europe:

(i) The interface used at the telephone exchange for a voice connection giving rise to the commonly specified data-rate associated with one voice call.

[7 *marks*]

(ii) The first level of multiplexing used in European trunk lines giving rise to the trunk data rate commonly referred to as the E1 rate.

[4 *marks*]

(b) (i) Illustrate the format of an ATM cell and briefly describe the function of each field in the cell.

[3 *marks*]

(ii) Describe how the cell boundaries are identified in an ATM system.

[*3 marks*]

(iii) Draw a state diagram to illustrate how synchronization is achieved at an ATM network node.

[*3 marks*]

Q.4 Given that the $M \times M$ channel matrix $\left[P\left(Y|X\right)\right]$ 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: -

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

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

(a) 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) $H[Y|X] = -((1-p)Log_2[1-p] + p\log_2[\alpha])$.

[8 *marks*]

(c) If the input symbols x_i, $1 \le i \le M$ are equiprobable, show that 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*]

Q.5 A baseband digital communications system uses the following signals to represent its three symbols, respectively denoted x_1, x_2 and x_3: -

$$s_i(t) = \begin{cases} -A & 0 \le t \le T \quad symbol\ x_1 \\ 0 & 0 \le t \le T \quad symbol\ x_2 \\ A & 0 \le t \le T \quad symbol\ x_3, \end{cases}$$

where T denotes the bit signalling interval. The communications are affected by additive white Gaussian noise (AWGN) whose probability density function (pdf) $f_n(v)$

is given by: -

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

The receiver takes a single sample, z, of the received signal during the bit signalling time and makes the detection decision according to the rule: -

$$decision = \begin{cases} symbol\ x_1 & if\ \ z \le -\tau \\ symbol\ x_2 & if\ \ -\tau < z < \tau \\ symbol\ x_3 & if\ \ z \ge \tau \end{cases}$$

where the threshold τ satisfies $0 < \tau < A$.

(a) Show that, having sent symbol x_2, the probability of error, denoted P_{e,x_2}, is given by

$$P_{e,x_2} = 1 - erf\left[\frac{\tau}{\sigma\sqrt{2}}\right],$$

where: -

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

[8 *marks*]

(b) Show the overall average probability of error, P_e, is given by: -

$$P_e = erf\left[\frac{A-\tau}{\sigma\sqrt{2}}\right]\left(\frac{P(x_2)}{2} - \frac{1}{2}\right) - erf\left[\frac{\tau}{\sigma\sqrt{2}}\right]P(x_2) + \frac{1}{2}\left(1 + P(x_2)\right)$$

where $P(x_2)$ denotes the probability of sending symbol x_2.

[12 *marks*]

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

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

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: -

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

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 (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 affected the receiver). Show that, in this case, the SNR, $\left(\frac{S}{N}\right)_o$, is given by: -

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

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

[7 *marks*]

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

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	$\alpha^{12} = \alpha^3 + \alpha^2 + \alpha$	$\alpha^{20} = \alpha^3 + \alpha^2$	$\alpha^{28} = \alpha^4 + \alpha^2 + \alpha$
$\alpha^5 = \alpha^2 + 1$	$\alpha^{13} = \alpha^4 + \alpha^3 + \alpha^2$	$\alpha^{21} = \alpha^4 + \alpha^3$	$\alpha^{29} = \alpha^3 + 1$
$\alpha^6 = \alpha^3 + \alpha$	$\alpha^{14} = \alpha^4 + \alpha^3 + \alpha^2 + 1$	$\alpha^{22} = \alpha^4 + \alpha^2 + 1$	$\alpha^{30} = \alpha^4 + \alpha$

(a) Show that the generator polynomial for the $(31,21)$ double error correcting primitive BCH code based upon this field, denoted $g(x)$, is given by: -

$$g(x) = x^{10} + x^9 + x^8 + x^6 + x^5 + x^3 + 1.$$

[10 *marks*]

(b) If the received data, denoted $v(x)$, is given by: -

$$v(x) = x^{29} + x^{28} + x^{26} + x^{25} + x^{23} + x^{19} + x^{18} + x^{11} + x^7 + x^6,$$

use the syndrome decoding method and the error location polynomial: -

$$x^2 + S_1 x + \frac{S_1^3 + S_3}{S_1} = 0$$

to find the error polynomial $e(x)$ and the original codeword $c(x)$, where $v(x) = c(x) + e(x)$.

[10 *marks*]