OLLSCOIL NA hÉIREANN, CORCAIGH

THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH

UNIVERSITY COLLEGE, CORK

AUTUMN EXAMINATIONS, 2009

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.

1. (a) For a data communication system consisting of a transmitter, a receiver and a dedicated link between them, describe and give formulas for the following link quantities:

(i) The latency.

[*3 marks*]

(ii) The utilization.

[*2 marks*]

(b) For the system described in (a) illustrate the data and acknowledgement flow w.r.t. time if the link uses a "go back N" acknowledgement scheme. From the diagram derive a formula for the utilization of a "go back N" scheme assuming the link is error free.

[*10 marks*]

(c) A link such as (a) has a length of 30km and a data rate of 150Mbps. It uses a packet size of 2000 bits and an acknowledgement size of 100 bits. Assuming that the propagation delay along the link is 5μs/km and that the link is error free, calculate:

(i) The utilization if a frame window size of 1 is used (N=1)

[*2 marks*]

(ii) The minimum frame window size (N) needed to ensure a utilization of 100%

[*3 marks*]

2. (a) Illustrate the architecture of a GSM/3G cellular network and briefly describe the functions of the main blocks.

[8 *marks*]

(b) For modern cellular telephone systems briefly describe the following:

(i) Cell organization and frequency re-use.

[4 *marks*]

(ii) The main power control algorithms.

[4 *marks*]

(iii) The hand-off procedure when a user moves between adjacent cells.

[4 *marks*]

3. (a) Describe the three main signal degradation mechanisms in Digital Subscriber Line (DSL) technologies for broadband communications.

[5 *marks*]

(b) Describe the four commonly used transmission duplexing methods in DSL technologies.

[6 marks]

(c) Describe the allocation of frequencies in the Asymmetric DSL system and compare the operation of the DMT and CAP approaches to DSL.

[9 *marks*]

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

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

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) $H[Y|X] = -((1-p)Log_2[1-p] + pLog_2[\alpha])$.

[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*]

5. A baseband digital communications system uses rectangular wave signaling with A_1 volts representing logic 1 and A_2 volts representing logic 0 (where $A_2 < A_1$). The receiver takes a single sample of the received signal during the bit signaling time and compares this sample with a decision threshold T. The communications are affected by zero-mean additive Gaussian noise whose probability density function f_n is given by: -

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

P_0 and P_1 respectively denote the probability of sending logic 0 and logic 1 and, to minimize the resulting overall probability of error P_e, the threshold T is given by: -

$$T = \frac{A_1 + A_2}{2} + \frac{\sigma^2}{A_1 - A_2}\ln\left[\frac{P_0}{P_1}\right].$$

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

$$P_e = \frac{1}{2}\left(1 - \left(P_0 erf\left[\frac{T - A_2}{\sqrt{2\sigma^2}}\right] + (1 - P_0) erf\left[\frac{A_1 - T}{\sqrt{2\sigma^2}}\right]\right)\right)$$

where: -

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

[10 *marks*]

(b) Consider a system for which $A_1 = 2.5V$, $A_2 = -2.5V$ and $\sigma^2 = 0.45W$. Using the table of values of $erf[x]$ provided: -

(i) Prove that, if the threshold remains fixed at $T = 0V$, then P_e is independent of P_0 and calculate its value in this case.

[4 *marks*]

(ii) When the optimum threshold is employed in each case, calculate the value of P_e when $P_0 = 0.65$ and when $P_0 = 0.75$.

[6 *marks*]

6. A binary modulation scheme is described by: -

$$s_i(t) = \begin{cases} s_1(t) = A_1 \cos(\omega_c t) & 0 \le t \le T \\ s_2(t) = A_2 \cos(\omega_c t) & 0 \le t \le T \end{cases}$$

where T is an integer times $1/f_c$. For this modulation scheme, given that (under the usual assumptions) $P_e = Q\left[\sqrt{\frac{E_d}{2\eta}}\right]$, show that: -

(a) $P_e = Q\left[\sqrt{\frac{(A_1 - A_2)^2 T}{4\eta}}\right]$.

[8 *marks*]

(b) If the average signal energy per bit (denoted E_b) is a fixed constant, prove that P_e in part (a) above is minimized if $A_2 = -A_1$. Hint: - the minimum value of $Q\left[\sqrt{x}\right]$ occurs when x takes on its maximum possible value.

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

(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: -

$$v(x) = x^{29} + x^{14} + x^{13} + x^{11} + x^{10} + x^6 + x^4 + x^2 + 1,$$

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*]

Table of values of $erf(x)$

x	$erf(x)$		x	$erf(x)$
2.5	0.999593		2.63	0.9998
2.505	0.999604		2.635	0.999806
2.51	0.999614		2.64	0.999811
2.515	0.999625		2.645	0.999816
2.52	0.999635		2.65	0.999822
2.525	0.999644		2.655	0.999826
2.53	0.999654		2.66	0.999831
2.535	0.999663		2.665	0.999836
2.54	0.999672		2.67	0.999841
2.545	0.999681		2.675	0.999845
2.55	0.999689		2.68	0.999849
2.555	0.999698		2.685	0.999854
2.56	0.999706		2.69	0.999858
2.565	0.999714		2.695	0.999862
2.57	0.999722		2.7	0.999866
2.575	0.999729		2.705	0.999869
2.58	0.999736		2.71	0.999873
2.585	0.999744		2.715	0.999877
2.59	0.999751		2.72	0.99988
2.595	0.999757		2.725	0.999884
2.6	0.999764		2.73	0.999887
2.605	0.99977		2.735	0.99989
2.61	0.999777		2.74	0.999893
2.615	0.999783		2.745	0.999896
2.62	0.999789		2.75	0.999899
2.625	0.999795			