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THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

AUTUMN EXAMINATIONS, 2004

B.E. DEGREE (ELECTRICAL)

TELECOMMUNICATIONS
EE4004

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Time allowed: *3 hours*

Answer *six* questions.

The use of mathematical log tables and a Casio fx570w or fx570ms calculator is permitted.

1. (a) Compare the capacities of BPSK, QPSK, and QAM systems and discuss the factors that influence the choice of a particular modulation scheme?

[*7 marks*]

The capacity of a digital microwave link is to be increased by changing the modulation scheme from 64 QAM to 256 QAM. If the existing capacity of the link is six 5 MHz video channels with a signal to quantisation noise level better than 44 dB, how many video channels may be carried in the new system if the S/N is to be better than 50 dB?

[*6 marks*]

(b) Indicate briefly what is meant by each of the following terms; *noise figure, antenna noise temperature* and *system noise temperature*.

[*7 marks*]

2. (a) Contrast the operation of time division multiple access (TDMA) techniques in satellite and mobile communications systems.

[*10 marks*]

(b) For Local Area Networks based on the Ethernet protocol describe the following: -

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(i) The CSMA/CD algorithm.

[*5 marks*]

(ii) The truncated binary exponential back-off algorithm.

[*5 marks*]

3. (a) For a data communication system consisting of a transmitter, a receiver and a dedicated link between them, discuss 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 versus 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*]

4. For the communications channel model illustrated in Figure 1 below: -

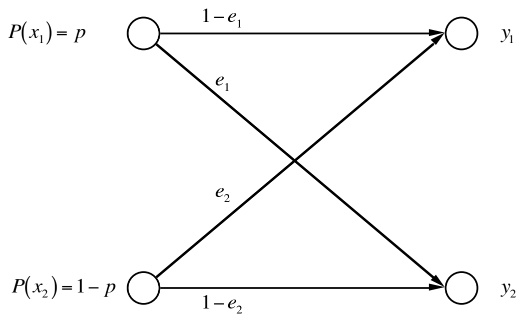

Figure 1 : Communications channel model.

show that if: -

$$\beta_1 = p(1 - e_1 - e_2) + e_2 \quad \text{and} \quad \beta_2 = p(e_1 + e_2 - 1) + 1 - e_2,$$

then: -

(a) $H(Y) = -Log_2\left[\beta_1^{\beta_1}\beta_2^{\beta_2}\right].$

[6 *marks*]

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(b)

$$I(X;Y) = Log_2\left[\frac{\left((1-e_1)^{1-e_1} e_1^{e_1}\right)^p \left((1-e_2)^{1-e_2} e_2^{e_2}\right)^{1-p}}{\beta_1^{\beta_1}\beta_2^{\beta_2}}\right].$$

[8 *marks*]

(c) Hence, or otherwise, for the particular case of a binary symmetric channel with equiprobable input symbols, deduce the appropriate expression for $I(X;Y)$.

[6 *marks*]

5. (a) For a parity-check linear block code, show that the syndrome $\underline{s}$ is the sum (modulo 2) of those rows of the matrix $\underline{H}^T$ corresponding to the error locations in the error pattern.

[8 *marks*]

(b) A parity-check linear block code has the parity-check matrix: -

$$\underline{H} = \begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}.$$

`If the received word is 110110, decode this received word.`

[4 *marks*]

(c) Prove using the Hamming bound, or otherwise, that this parity-check code can reliably correct no more than 1 error.

[4 *marks*]

(d) By choosing a suitable code word and introducing 2 errors, show that the parity-check linear block code fails to recover the original code word.

[4 *marks*]

6. (a) Given that the output signal to noise ratio (SNR) of a matched filter receiver subject to additive white Gaussian noise (AWGN) with power spectral density $\eta/2\ W/Hz$ is given by $2E_d/\eta$ where E_d denotes the energy in the difference signal, show 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, that the optimum output SNR is given by: -

$$\left(\frac{S}{N}\right)_{Optimum} = \frac{8E}{\eta}$$

where we stipulate that the signaling waveforms $s_1(t)$ and $s_2(t)$ <u>must</u> have the same signal energy E.

[8 *marks*]

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(b) A frequency shift keying modulation scheme is defined by: -

$$s_i(t) = \begin{cases} A\cos(\omega_1 t) & 0 \le t \le T_f \\ A\cos(\omega_2 t) & 0 \le t \le T_f . \end{cases}$$

Show that if $\omega_1 T_f >> 1$, $\omega_2 T_f >> 1$ and $(\omega_1 - \omega_2)T_f >> 1$ then the probability of error P_e when subject to AWGN with power spectral density $\eta/2\ W/Hz$ and optimum matched filtering detection is used is approximated by: -

$$P_e \approx Q\left[\sqrt{\frac{A^2 T_f}{2\eta}}\right].$$

[7 *marks*]

(c) A phase shift keying modulation scheme is defined by: -

$$s_i(t) = \begin{cases} A\cos(\omega_1 t) & 0 \le t \le T_\phi \\ -A\cos(\omega_1 t) & 0 \le t \le T_\phi . \end{cases}$$

where T_ϕ is an integer times $1/f_1$ (where $\omega_1 = 2\pi f_1$). If, under the same conditions as (b) above, this scheme must possess the same probability of error P_e as that of (b) above, deduce the value of T_f/T_ϕ and comment upon your result.

[5 *marks*]

7. (a) Derive a suitable expression for the probability of error (denoted P_e where $P_e = Q\left[\sqrt{\frac{E_d}{2\eta}}\right]$) for direct sequence spread spectrum (DSSS) signals in additive white Gaussian noise channels if the original information sequence is represented by a simple bipolar baseband signal.

[5 marks]

(b) Describe the relevant properties of m-sequence spreading codes as employed in DSSS communication systems.

[5 marks]

(c) Summarise the principle characteristics of DSSS communications.

[10 marks]

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