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

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER EXAMINATIONS, 2008

B.E. DEGREE (ELECTRICAL)
B.E. DEGREE (MICROELECTRONIC)

TELECOMMUNICATIONS
EE4004

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Time allowed: *3 hours*

Answer *five* questions.

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

1. (a) Illustrate the operation of a store and forward packet data network considering source and destination nodes and two intermediate nodes (nodes 1 and 2). From this, determine formulas for the network delay (ND) and total message transmission time (TT). You may ignore the propagation delay.

[*12 marks*]

(b) A message of 2000 bits is to be sent over a data network from source to destination via two intermediate nodes. Each link along the route has a data-rate of 2Mbps and is totally dedicated to this transmission. When the message is broken into packets, a header size of 200 bits is used in all cases. Calculate the network delay and the total transmission time if the message is subdivided into the following numbers of packets:

(i) 1

[*2 marks*]

(ii) 5

[*2 marks*]

(iii) 10

[*2 marks*]

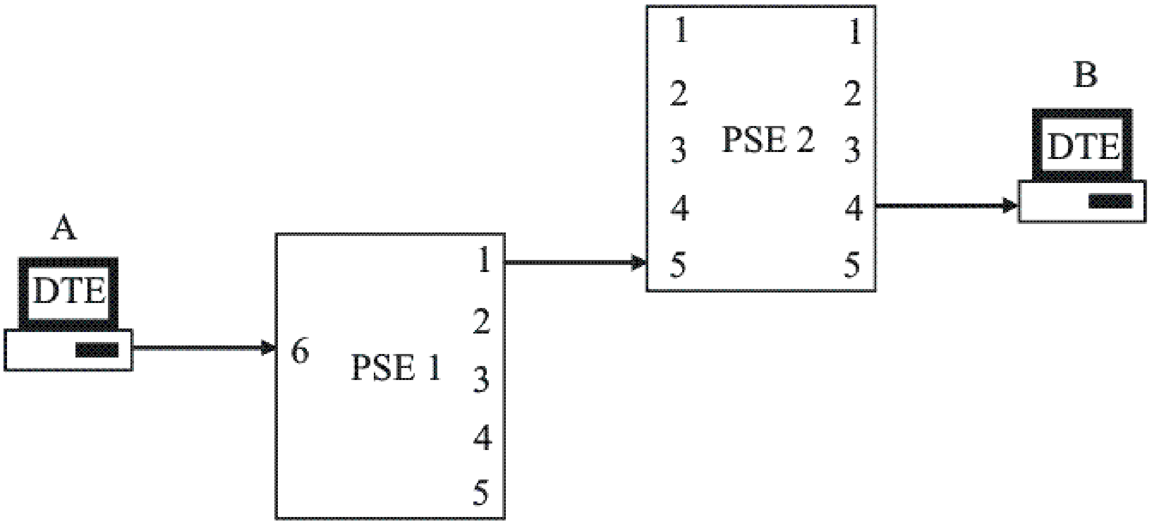
Comment on the trend arising from the 3 calculations above.

[*2 marks*]

2. (a) Describe the routing of packets in an X.25 data network including the role of multiplexing, packet switching exchanges and logical channel identifiers.

[7 *marks*]

(b)



The diagram above shows two end-users communicating on an X.25 packet network via two intermediate packet switching exchanges, with the ports on the exchanges being numbered. Show suitable routing tables for PSE1 and PSE2 to route the data successfully from user A to user B.

[4 *marks*]

(c) (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*]

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) For a cellular telephone system (2G and 3G) briefly discuss the following:

(i) Cell organization and frequency re-use.

[4 *marks*]

(ii) The main power control algorithms.

[4 *marks*]

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

[4 *marks*]

Q.4. The channel matrix for the binary symmetric erasure channel (BSEC) is shown below:

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

(a) Show that $H\left(Y|X\right)=-\left(\delta\log_2[\delta]+\varepsilon\log_2[\varepsilon]+(1-\delta-\varepsilon)\log_2[1-\delta-\varepsilon]\right)$.

[8 *marks*]

(b) If the input symbols $x_i,\ 1\le i\le 2$ are equiprobable, show that the channel capacity, C_{BSEC}, in this case is given by: -

$$C_{BSEC}=(\delta-1)\log_2\left[\frac{1-\delta}{2}\right]+\varepsilon\log_2[\varepsilon]+(1-\delta-\varepsilon)\log_2[1-\delta-\varepsilon].$$

[8 *marks*]

(c) By considering the case $\delta\to 0$, or otherwise, deduce the channel capacity of the binary symmetric channel (BSC).

[2 *marks*]

(d) By considering the case $\varepsilon\to 0$, or otherwise, deduce the channel capacity of the binary erasure channel (BEC).

[2 *marks*]

Q.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 on page 6: -

(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*]

Q.6 (a) An analogue signal having an 10-kHz bandwidth is sampled at 1.5 times the Nyquist rate and each sample is quantised into one of 256 equally likely levels. Assuming that successive samples are statistically independent, the signal power at the receiver is 0.4 mW and the communication is affected by additive white Gaussian noise with power spectral density $\eta/2 = 10^{-11}\ W/Hz$, estimate via the use of a suitable graph, or otherwise, the minimum channel bandwidth required for error-free transmission of the information produced by this source.

[10 *marks*]

(b) A binary modulation scheme is described by: -

$$s_i(t) = \begin{cases} s_1(t) = A_1 \cos(\omega_1 t) & 0 \le t \le T \\ s_2(t) = A_2 \cos(\omega_2 t) & 0 \le t \le T \end{cases}$$

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

$$P_e = Q\left[\sqrt{\frac{E_b}{\eta}}\right]$$

where E_b denotes the average signal energy per bit.

[10 *marks*]

Q.7. (a) Using the primitive polynomial $p(x) = x^5 + x^2 + 1$, generate the field $GF(2^5)$.

[9 *marks*]

(b) Show that for the $(31,21)$ double error correcting code primitive BCH code based upon $GF(2^5)$: -

(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*]

(iii) The corresponding generator polynomial, $g(x)$, satisfies: -

$$g(\alpha) = g(\alpha^3) = 0.$$

[3 *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			