TÉCNICO LISBOA

Mestrado em

Engenharia Electrotécnica e de Computadores

Redes Móveis e Sem Fios

Exame de Recurso – 1ª parte

4 de Julho de 2017

Duração 1h30

In order to avoid grading mistakes, please answer each question <u>on a different page</u> and keeping the order as much as possible.

1) In a mobile network using CDMA with 4-symbol chip sequences, there are two mobile stations trying to transmit to a base station with keys S1= +1, +1, -1, +1, S2= +1, +1, +1, -1. The time of one bit corresponds to 4 chips and the keys of the stations are synchronized. Assume that the logical value “0” is represented by -1 and logic value “1” is represented by +1. The decoding thresholds are -1 and +1, respectively for logical “0” and logical “1”. The sequence that was received at the base station was the following: 0, 0, +3, -2, +2, 0, -2, +2.

   a) Assuming that the noise was too low to destroy the data, calculate which data bits were received from S1 and S2. (1,5 val)

   b) Quantify the noise. (1,0 val)

   c) Do the used keys present good characteristics regarding the mitigation of multipath fading? Suggestion: Calculate maximum delay spread (measured as chip intervals) that will be eliminated during reception, considering the transmission of a single station. (2,0 val)

2) Consider a Wireless Sensor Network (WSN) operating in a Log-distance path loss model environment, with $\boldsymbol{\alpha = 3}$ and measured path loss of 50 dB measured at 1 m. All antennas are isotropic.

   a) Consider three nodes $\boldsymbol{A}$, $\boldsymbol{B}$ and $\boldsymbol{C}$ in a WSN, forming a linear topology with $\boldsymbol{A}$ located on the left, $\boldsymbol{B}$ located *d* meters to the right of $\boldsymbol{A}$, and $\boldsymbol{C}$ located *d* meters to the right of $\boldsymbol{B}$. Node $\boldsymbol{A}$ wishes to transmit a message to node $\boldsymbol{C}$. Demonstrate mathematically that it is globally more power efficient to perform the multihop transmission $\boldsymbol{A} \underset{d}{\rightarrow} \boldsymbol{B} \underset{d}{\rightarrow} \boldsymbol{C}$, in comparison with the single-hop transmission $\boldsymbol{A} \underset{2d}{\rightarrow} \boldsymbol{C}$. Assume that energy is only consumed by transmission and that the received power corresponds to the receiver sensitivity in all cases. (1,5 val)

   b) Consider the linear topology $\boldsymbol{D} \underset{100m}{\longleftrightarrow} \boldsymbol{A} \underset{100m}{\longleftrightarrow} \boldsymbol{B} \underset{100m}{\longleftrightarrow} \boldsymbol{C}$. $\boldsymbol{B}$ transmits to $\boldsymbol{C}$, but $\boldsymbol{A}$ transmits to $\boldsymbol{D}$ at the same time. Both transmissions are performed at the minimum transmit power. The thermal noise spectral density is -201 dBm/Hz. The receiver sensitivity is -80 dBm. Calculate the SINR at $\boldsymbol{C}$, for a signal bandwidth of 2 MHz. (2,0 val)

   c) Under the conditions of b), calculate the FER for packets of 200 bytes, BPSK modulation and a roll-off factor of 0. In case you did not answer b), consider SINR=8.0 (linear units). (1,5 val)

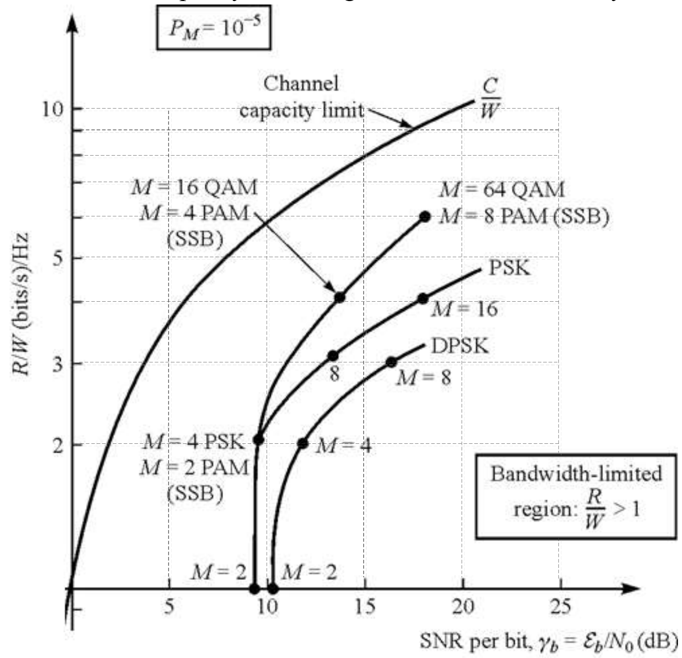
3) Consider an IEEE 802.11b network with WiFi telephones operating at 2.0 Mbps. The telephones are using a G.711 codec at 64kbps with an inter-packet interval of 40ms. The RTP+UDP+IP headers together have a length of 40 octets and RTS/CTS is not being used. Additional data are as follows: SIFS=16us, DIFS=34us, PHY overhead = 96us, MAC DATA header and trailer = 34 bytes, MAC ACK=14 bytes, avg. Backoff =67us. The maximum number of frame retransmissions is 4.

   a) Calculate the maximum throughput that can be offered to voice applications by this WLAN, assuming that there are no frame losses. (2,5 val)

   b) What is the maximum number of WiFi telephones supported in the network? (1,5 val)

   c) Calculate the effective DATA frame loss rate at the MAC layer, considering that the physical frame loss rate is 3% and assuming that ACK frame losses are negligible. (2,0 val)

4) Consider the chart below, which relates bandwidth efficiency and $\frac{E_b}{N_9}$ for different signal encoding techniques, for a symbol error rate $P_M = 10^{-5}$. In the chart, R represents the achieved bitrate, W represents the required bandwidth and C represents the maximum bitrate capacity according to the Shannon-Heartley theorem.



a) How much bandwidth is needed to achieve a bitrate of 12 Mbit/s with PSK at $\frac{E_b}{N_0} = \mathbf{18}$ dB? Note: round values to the closest integer. (1,5 val)

b) Which SNR is needed to achieve 400 kbit/s with $\frac{E_b}{N_0} = \mathbf{20\ dB}$ and the best possible signal encoding technique? (1,5 val)

c) What is the bit error rate achieved with 4-PSK (QPSK) when the symbol error rate is $P_M = 10^{-5}$? Assume that bit errors are independent, and the probabilities of changing 1 for 0 and 0 for 1 are the same (BSC channel). Suggestion: take into account the number of bits per symbol. (1,5 val)

Propagation Models	
Log-distance Model	$P_r\ [dBm] = P_t\ [dBm] - PL_0 + G_t\ [dBi] + G_r\ [dBi] - 10 \cdot \alpha \cdot log_{10}\ (d\ / d_0\ )$
Friis Free Space Model	$P_r = P_t \cdot \frac{G_t \cdot G_r \cdot \lambda^2}{(4 \cdot \pi \cdot d)^2}$
Two-Ray Model	$P_r = P_t \cdot \frac{G_t \cdot G_r \cdot (h_t \cdot h_r)^2}{d^4}$ $d_c = \frac{4 \cdot \pi \cdot h_t \cdot h_r}{\lambda}$
Fresnel Zone Radius	$r(F_n) = \sqrt{\frac{n \cdot \lambda \cdot d_1 \cdot d_2}{d_1 + d_2}}$

Maximum Channel Capacity	
Shannon-Heartley Theorem	$C = B \cdot log_2\left(1 + \frac{S}{N}\right)$
Nyquist Rate (applicable in baseband)	$C = 2 \cdot B \cdot log_2(M)$

Modulation Performance (B)	
ASK	$B = (1 + r) \cdot R_b$
M-PSK	$B = \left(\frac{1 + r}{log_2(M)}\right) \cdot R_b$
M-FSK	$B = \left(\frac{(1 + r) \cdot M}{log_2(M)}\right) \cdot R_b$

Modulation Performance (BER)	
BASK	$BER_{ASK} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$
BFSK	$BER_{BFSK} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$
DBPSK	$BER_{DBPSK} = 0.5 \cdot e^{-\frac{E_b}{N_0}}$
BPSK	$BER_{BPSK} = Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}}\right)$

QPSK	$BER_{QPSK} = Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}}\right)$
Q function	$Q(k) = P(X > \mu + k\sigma) = \frac{1}{\sqrt{2\pi}} \int_k^{+\infty} e^{-\lambda^2/2} d\lambda$

Probabilities
$\sum_{i=1}^{+\infty} i \cdot (1-p)^{i-1} \cdot p = \frac{1}{p}$
$\sum_{i=0}^{+\infty} i \cdot (1-p)^{i} \cdot p = \frac{p-1}{p}$

TABLE OF THE Q FUNCTION

0	5.000000e–01	2.4	8.197534e–03	4.8	7.933274e–07
0.1	4.601722e–01	2.5	6.209665e–03	4.9	4.791830e–07
0.2	4.207403e–01	2.6	4.661189e–03	5.0	2.866516e–07
0.3	3.820886e–01	2.7	3.466973e–03	5.1	1.698268e–07
0.4	3.445783e–01	2.8	2.555131e–03	5.2	9.964437e–06
0.5	3.085375e–01	2.9	1.865812e–03	5.3	5.790128e–08
0.6	2.742531e–01	3.0	1.349898e–03	5.4	3.332043e–08
0.7	2.419637e–01	3.1	9.676035e–04	5.5	1.898956e–08
0.8	2.118554e–01	3.2	6.871378e–04	5.6	1.071760e–08
0.9	1.840601e–01	3.3	4.834242e–04	5.7	5.990378e–09
1.0	1.586553e–01	3.4	3.369291e–04	5.8	3.315742e–09
1.1	1.356661e–01	3.5	2.326291e–04	5.9	1.817507e–09
1.2	1.150697e–01	3.6	1.591086e–04	6.0	9.865876e–10
1.3	9.680049e–02	3.7	1.077997e–04	6.1	5.303426e–10
1.4	8.075666e–02	3.8	7.234806e–05	6.2	2.823161e–10
1.5	6.680720e–02	3.9	4.809633e–05	6.3	1.488226e–10
1.6	5.479929e–02	4.0	3.167124e–05	6.4	7.768843e–11
1.7	4.456546e–02	4.1	2.065752e–05	6.5	4.016001e–11
1.8	3.593032e–02	4.2	1.334576e–05	6.6	2.055790e–11
1.9	2.871656e–02	4.3	8.539898e–06	6.7	1.042099e–11
2.0	2.275013e–02	4.4	5.412542e–06	6.8	5.230951e–12
2.1	1.786442e–02	4.5	3.397673e–06	6.9	2.600125e–12
2.2	1.390345e–02	4.6	2.112456e–06	7.0	1.279813e–12
2.3	1.072411e–02	4.7	1.300809e–06		