Mestrado em

Engenharia Electrotécnica e de Computadores

Redes Móveis e Sem Fios

Exame – 1ª parte

3 de Julho de 2019

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, the chip rate is fixed at 3,85 Mchip/s. There are two mobile stations (A and B) trying to transmit to a common base station. Station A has the key +1 +1 +1 −1 −1 +1 −1 and is transmitting the logical sequence "11". Station B is simultaneously transmitting logical sequence "00", having as key +1, -1, -1, +1, -1, +1, +1. The decoding thresholds are -2 and +2, respectively for logical "0" and logical "1". Each station generates a bitrate of 0,55 Mbit/s.

    a) What is the spreading factor used by stations A and B, and what is the resulting DSSS signal for each station? Justify. (1,0 val)

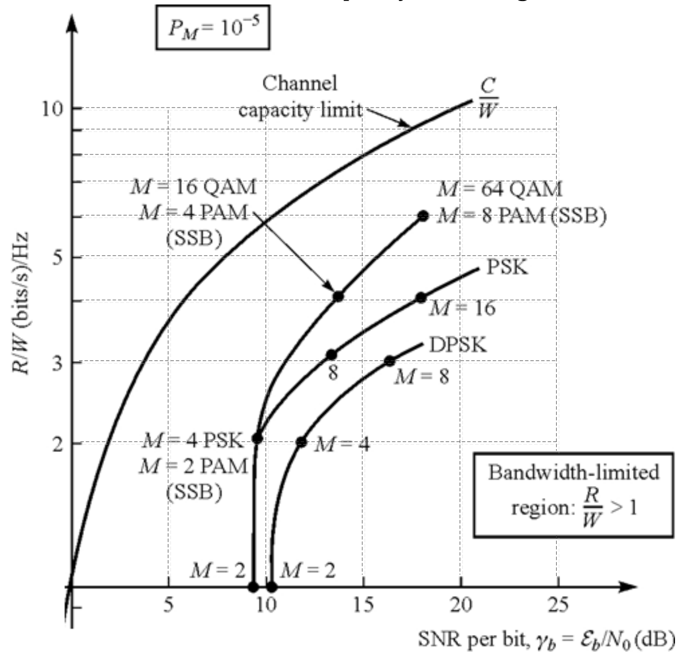
    b) Assuming that the signal from A arrives with ½ of the amplitude of the signal from B (i.e., assume chip amplitude of the main signal from B is multiplied by 1, while the amplitudes of A's signal is multiplied by 0,5) verify if the transmissions from A and B are correctly received. Present all calculations. (1,5 val)

    c) Are A and B using orthogonal codes, or most probably a pseudo-noise sequence? (0,5)

    d) Compare orthogonal codes with pseudo-noise sequences regarding their advantages and disadvantages. (1,0 val)

    e) Explain the purpose of the RAKE receiver. (1,0 val)

2) Consider the chart below, which relates bandwidth efficiency and $\frac{\mathbf{E_b}}{\mathbf{N_0}}$ for different signal encoding techniques, for a symbol error rate $\mathbf{P_M} = \mathbf{10^{-5}}$. 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) What is the maximum bitrate that can be achieved with a bandwidth of 6 MHz with DPSK at $\frac{E_b}{N_0} = \mathbf{15}$ dB? Note: round values to the closest integer. (1,5 val)

b) Would it be possible to achieve a bitrate more than 10% higher over the same bandwidth, for the same value of $\frac{E_b}{N_0}$? Justify. Note: consider all depicted modulations. (1,5 val)

c) The QAM modulation results from considering more than one amplitude level for the I and Q signal components.

i) Draw the 16-QAM constellation diagram. (1,0 val)

ii) How many amplitude levels are considered for this modulation? (1,0 val)

d) Considering FSK modulation, using two frequencies $\boldsymbol{f}$ and $\mathbf{2} \cdot \boldsymbol{f}$, draw a sketch of the transmission of the signal that corresponds to the following bit sequence: 100101. (1,0 val)

3) Consider a point-to-point radio link operating in a 5,1 MHz wide frequency range centered at 2.4 GHz. Within that frequency range, FDD is employed with bandwidth divided equally among the two directions, with a guard band of 100 kHz between directions. The link connects two buildings of the same company in a city, which are located 3 km apart. Propagation is free space up to 100 m from the receiver. Beyond that distance, a path loss exponent is 2,5 was estimated. The endpoint antennas stand 2 m high at the top of the buildings, featuring gains of 15 dBi in both cases. The employed radio technology has four modes of operation achieved with different combinations of channel coding and modulation, whose bitrates and respective sensitivities are the following: <1Mbit/s, -95 dBm>, <2Mbit/s, -93 dBm>, <3Mbit/s, -91 dBm>, <4Mbit/s, -89 dBm>. The transmit power is 300 mW. The noise power spectral density is -170 dBm/Hz.

a) What is the theoretical capacity limit of the channel in each direction? (1,5 val)

b) Assuming that the endpoints communicate at the maximum possible bitrate, what is that bitrate? (1,0 val)

c) Calculate the physical area of the antennas, knowing that the antenna efficiency is 80%. (1,5 val)

d) Calculate the spectral efficiency of each mode of operation when the error probability is negligible. (1,0 val)

4) Consider an IEEE 802.11b network with WiFi telephones operating at 11.0 Mbps. The telephones are using a G.728 codec at 8kbps 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 7.

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 4% and assuming that ACK frame losses are negligible. (2,0 val)

Propagation Models	
Antenna Apperture and Gain	$A_{eff} = \eta \cdot A_{phy} = \frac{\lambda^2}{4\pi} G$
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	$BER_{QPSK} = Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}}\right)$
M-PSK	$BER_{MPSK} = 2Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}} \cdot sin\left(\frac{\pi}{M}\right)\right)$
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		