TÉCNICO LISBOA

Exam **A**

Mestrado em Engenharia Electrotécnica e de Computadores

Redes Móveis e Internet das Coisas

2nd Exam

11th July 2023

Duration 2h00

Before starting to answer the questions, beware of the following:

i. **The exam question paper spans 5 pages.**
ii. **The duration of the exam is 2h00.**
iii. **The students are supposed to bring calculator, exam sheets and pen to the exam.**
iv. **The multiple choice questions are answered directly in the exam question paper. In the multiple choice questions, the wrong answers will be worth a penalty. In a question with N possible answers worth V points, the penalty is V/(N-1).**
v. **The exam has 4 versions: A, B, C e D.**
vi. **The students cannot consult any documents except the provided formulary.**
vii. **The students must place their identification document (student card) on the desk.**
viii. **All exam question paper sheets (see footer) and exam sheets must be identified with the following:**
   a) **Student Number;**
   b) **Name.**

1) In a radio network there are two mobile stations (A and B) and one base station (BS). Multiple access is done based on CDMA. Chip modulation is BPSK. Station A has the following spreading code: +1, +1, -1, -1, -1, -1, +1, +1. Station B has the following spreading code: -1, +1, -1, +1, -1, +1, -1, +1. The decoding thresholds are ≤-3 and ≥+3, respectively for logical "0" and logical "1". At the time instant in question, impulsive noise from a nearby radar affects the BS with pattern 0, +1, -1, 0, +1, 0, 0, 0. Station A and Station B are simultaneously transmitting to the BS with SF=4. The sequence effectively received at the BS is +2, +1, -1, -2, +1, +2, -2, 0. Power control ensures that the received power from the two stations at the BS is practically the same.

   a) Which data bits were received from A? (1,0 val)

   i) 0, ? ☐

   ii) 0, 1 ☐

   iii) 1, 0 ☐

   iv) ?, 1 ☐

   v) None of the above. ☐

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b) Which data bits were received from B? (1,0 val)

i) 0, ? ☐

ii) 0, 1 ☐

iii) 1, 0 ☐

iv) ?, 1 ☐

v) None of the above. ☐

c) Consider that the BS transmits bits "00" to A. What is the noise pattern that will affec reception at A? (1,0 val)

i) 0,+1,-1,0,+1,0,0,0 ☐

ii) +1,0,0,2,0,0,0,0 ☐

iii) +1,-1,+1,+2,0,0,+1,0 ☐

iv) Not enough data to know. ☐

v) None of the above. ☐

d) Which of the following SF=8 spreading codes could be used by a third station C so that A, B and C do not interfere if their transmissions are perfectly synchronized? (1,0 val)

i) 0, 0, 0, 0, -1, 0, 0, -1 ☐

ii) -1, -1, -1, -1, +1, +1, +1, -1 ☐

iii) -1, -1, +1, +1, +1, +1, -1, -1 ☐

iv) +1, -1, +1, -1, +1, -1, +1, -1 ☐

v) None of the above. ☐

2) Consider a point-to-point UHF radio link operating in a 10 MHz wide channel centered at 1 GHz, with QPSK modulation. Each communication endpoint is equipped with a parabolic antenna with physical area 11m^2, mounted on a mast 5m high. The terrain is flat between the antennas. The noise power spectral density is -170 dBm/Hz. The transmit power is 10 mW. The receiver sensitivity corresponds to the received power that leads to an FER of 1% for 20-byte frames. The roll-off factor of the employed output filters is 0.

a) Calculate the receiver sensitivity of the QPSK modulation. (1,0 val)

b) Knowing that the effective aperture ($\boldsymbol{A_e}$) of a parabolic antenna is related to its face area ($\boldsymbol{A}$) as $\boldsymbol{A_e = 0.56A}$, calculate the maximum range for a receiver sensitivity of -90 dBm (1,0 val)

c) Compare the bit error rate performance of BPSK and QPSK when the received signal power is the same. Justify. (1,0 val)

d) What is the theoretical bandwidth efficiency limit when the received signal power is -90 dBm? (1,0 val)

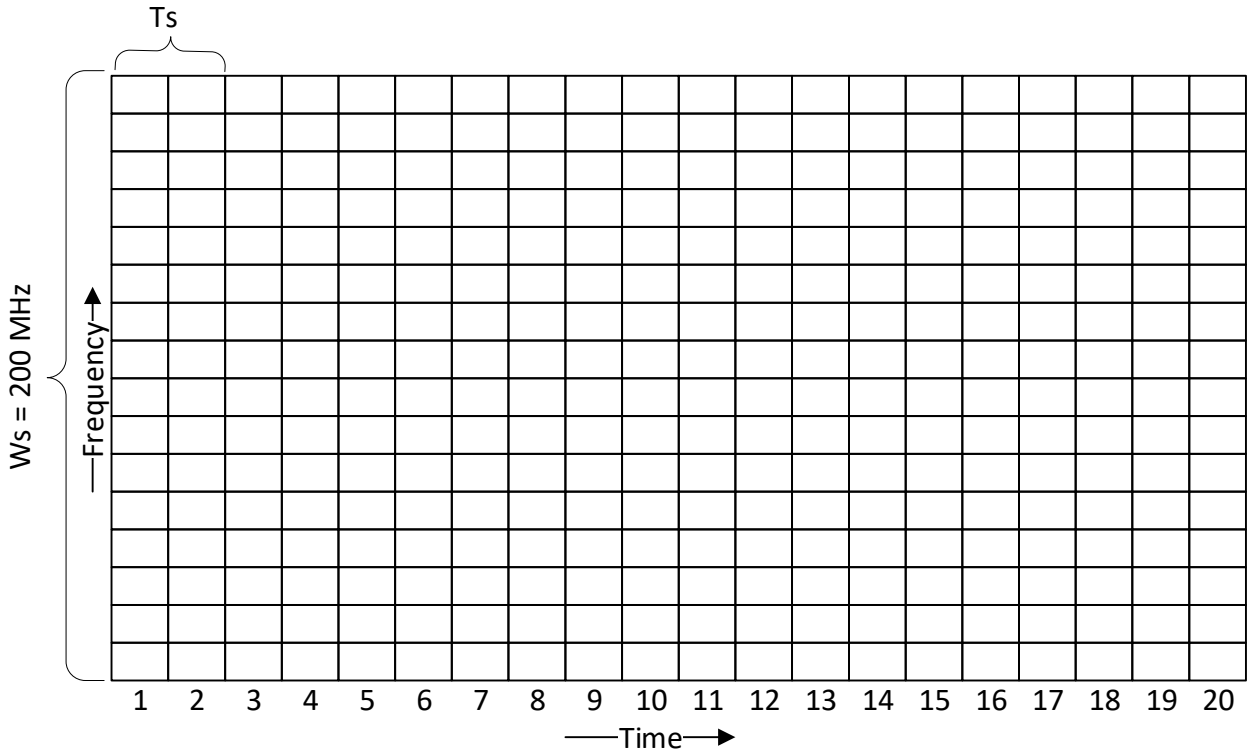
3) Consider a wireless technology operating in the 2.4 GHz frequency band, using 4-FSK (i.e., MFSK with $\boldsymbol{M = 4}$), and FHSS (see the figure). The roll-off factor is $\mathbf{r = 0}$. The effective bandwidth of the system is $\boldsymbol{W_s = 200\ MHz}$, which is divided into 4 FHSS subchannels of bandwidth $\boldsymbol{W_d}$. These subchannels are numbered in binary as 00, 01, 10, 11, from the lowest frequency to the highest frequency subchannel. Each 4-FSK symbol encodes a number of bits, which form a number. Higher binary number corresponds to a higher frequency within the 4-FSK subchannel. Assume that $\boldsymbol{T_s = 2 \cdot T_c}$.

a) What is the bitrate of the system? (1,0)

b) Does the system employ slow of fast FHSS? Justify. (1,0 val)

c) In the diagram below, mark the rectangles that correspond to the transmitted frequencies when the PN sequence and bit sequence are the following (2,0 val):

- PN sequence (repeated in time): 10, 11, 00, 01, 11, 00, 01, 10;
- Data bit sequence: 010010110001111110



4) Consider the OFDM implementation in the IEEE 802.11a standard. The channel bandwidth is 20 MHz and the subcarrier spacing is 312.5 kHz. A total of 48 subcarriers are used for data transmission, 4 subcarriers are used as pilot channels (i.e., for channel estimation) and 12 null subcarriers are used as guard band. The cyclic prefix is 0.8 μs.

a) What is the total duration of an OFDM symbol, including the cyclic prefix? (1,0 val)

i) 4.0us ☐

ii) 6.0us ☐

iii) 3.2us ☐

iv) 1.6us ☐

v) None of the above ☐

b) IEEE 802.11a employs FEC in order to be able to correct bits in error. One of the transmission modes achieves a net bitrate (i.e., useful data bitrate) of 18 Mbit/s using QPSK. In order to transmit 6 useful bits, how many FEC encoded bits (i.e., useful + redundant bits) must be transmitted in this transmission mode? (1,0 val / -0,25)

i) 4 ☐

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ii) 5 ☐

iii) 8 ☐

iv) 12 ☐

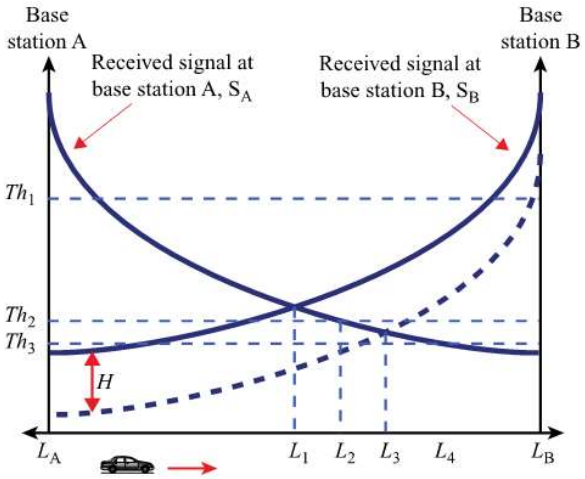
v) None of the above ☐

c) In IEEE 802.11ac, there are 52 data subcarriers. What is the approximate maximum useful PHY bitrate that can be achieved using 2x2 MIMO in IEEE 802.11ac, 0.8us cyclic prefix, 256-QAM and 3/4 FEC? (1,0 val)

d) Explain one of the advantages brought by IEEE 802.11ax in comparison with IEEE 802.11ac. (1,0 val)

5) Answer the following questions regarding the architecture and technologies of mobile cellular systems.

a) A mobile terminal is currently connected with Base Station A, and approaching Base Station B, as depicted in the following picture. Which handoff locations (L_A, L_1, L_2, L_3, L_4, L_B) result from the following strategy: Relative Signal Strength with Hysteresis and threshold Th2. (1,0 val)



Car is moving from base station A at location L_A to base station B at L_B

b) Consider that an LTE-A network operator is covering an area with cells of radius R=0.5 km. Each channel has a bandwidth of 3 MHz (15 RBs), and the total bandwidth is 36 MHz. Frequency assignment within a cell is uniform, there being no sectors or distinction between center and edge. The distance between the centers of cells using the same frequency channels is approximately 1.5 km.

i) How many Resource Blocks (RBs) are available in each cell? Justify. (1.0 val)

ii) One of the cells of a cluster comes out to be saturated, while the others have surplus capacity. A study reveals that its user density corresponds to twice the density in the other cells. What could be done to mitigate this problem without increasing the total bandwidth or adding more antennas? Justify with calculations. **Note: assume that each user contributes equally to the traffic load and that in the end, all cells should have the same amount of resources per user.** (1.0 val)

c) Consider an LTE system. A UDP/IP application has generated a data message of 1500 bytes. The UDP header has 8 bytes, and the IP header has 20 bytes. Considering the CQI table below, how many Resource Blocks will the scheduler reserve to transmit this message when the channel conditions are classified as CQI 2 and Extended CP is being used? (1.0)

Note 1: Consider that the scheduled Resource Blocks only carry data traffic and that all overheads below the IP layer can be ignored.

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Exam

A

CQI Index	Modulation	Code Rate × 1024	Efficiency
0	Out of Range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

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