TÉCNICO LISBOA

Exam **A**

Mestrado em Engenharia Electrotécnica e de Computadores

Redes Móveis e Internet das Coisas

1st Exam

2nd May 2022

Duration 2h00

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

i. **The exam question paper spans 4 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. 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 station A and station B equally, with pattern 0, 0, -2, -1, 0, 0, +2, 0. Stations A and B are simultaneously transmitting to the base station: A is transmitting bit sequence 01, and B is transmitting bit sequence 10, and both are using SF4. Both signals arrive at the base station with a similar power level.

   a) What is the signal sequence measured at the base station? (1,0 val)

   i) 0,+2,-2,0,0,+2,-2,0 ☐

   ii) 0,+2,-4,-1,0,+2,0,0 ☐

   iii) 0,-2,+2,0,0,-2,+2,0 ☐

   iv) 0,-2,0,-1,0,-2,+4,0 ☐

   v) None of the above ☐

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b) Assuming that the received signal sequence is 0,+2,-3,-1,0,+1,+2,0, what are the data received by the base station? (1,0 val)

i) A: 0, 1; B: 1, 0 ☐

ii) A: 1, 1; B: 0, 0 ☐

iii) A: 1, 1; B: 1, 0 ☐

iv) A: 0, 1; B: 0, 0 ☐

v) None of the above ☐

c) In case a third station C joins the network, which would be the most suitable key? (1,0 val)

i) +1, -1, +1, -1, -1, -1, -1, -1 ☐

ii) -1, -1, +1, +1, +1, +1, -1, -1 ☐

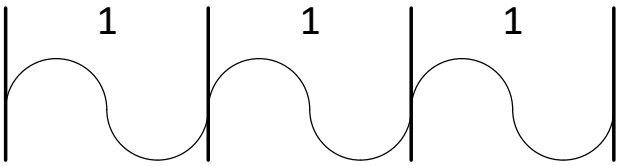
iii) -1, +1, -1, +1, +1, -1, +1, -1 ☐

iv) +1, +1, +1, +1, -1, -1, -1, -1 ☐

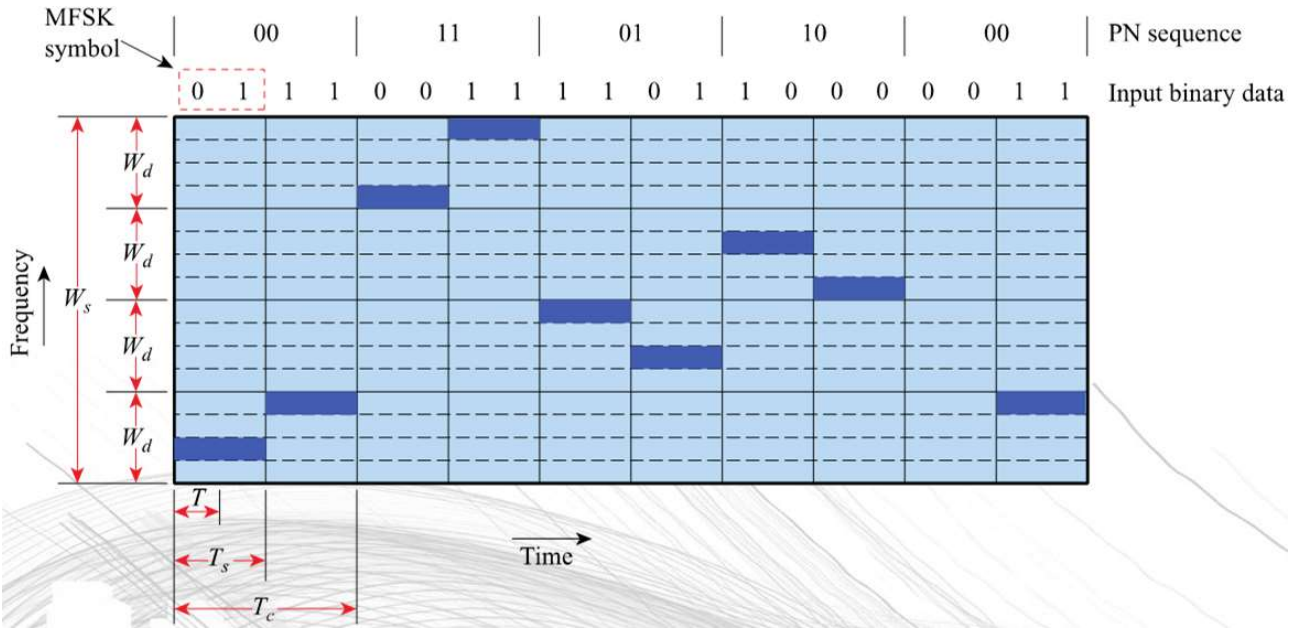
v) -1, +1, +1, +1, +1, -1, -1, +1 ☐

d) Consider that the chip rate is fixed at 3 Mchip/s? What is the bitrate transmitted by each station? Justify. (0,5 val)

e) In the considered system, chips are encoded using BPSK modulation. Draw the waveform produced by station A alone, indicating the values and time intervals of the bits (see example). (0,5 val)



2) Consider a wireless technology operating in the 2.4 GHz frequency band, using MFSK (roll-off factor is $\mathbf{r = 0}$) and FHSS (see the figure). The effective bandwidth is 40 MHz.



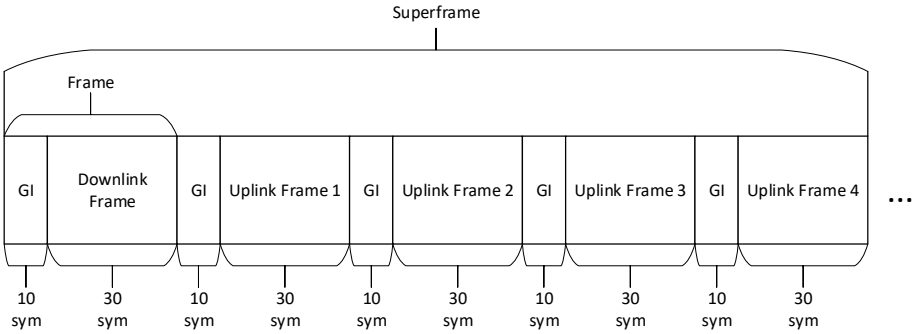
a) Calculate $\mathbf{T_c}$ and $\mathbf{T_s}$. (1,0 val)

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

c) Can FHSS be used to support multiple access, i.e. simultaneous transmissions by different devices with no interference? Justify. (1,0 val)

d) Consider that the system is attacked by a jamming signal whose interfering power at the receiver is $\mathbf{P_I}$. Compare the average SNIR with that attained by a narrowband (i.e., without spreading) MFSK system of bandwidth $\boldsymbol{W_d}$. (1,0 val)

3) Consider the control system of an automated factory facility. The propagation environment is quite harsh, with the path loss increasing with the 3rd power of distance. The decay measured at 1-meter distance from the transmitter is 15 dB. There are 4 robots and a common access point in the center of the installation, equidistant from the robots. The MAC is based on TDMA/TDD and each robot is allocated its own timeslot for uplink transmission. There is a single downlink timeslot, with the same size, in the beginning of the TDMA superframe. Each timeslot has a length of 40 modulation symbols, where only 30 symbols effectively constitute the data frame (the rest corresponds to a guard interval). The RF channel is 400 kHz wide and the center frequency is 868 MHz. The modulation is 16QAM and the roll-off factor is 1.0. The noise spectral density is -110 dBm/Hz. The antennas are isotropic. The transmit power is 20 mW and the receiver sensitivity is -70 dBm.



a) Calculate the maximum range between the access point and the robots. (1,0 val)

b) Calculate the FER when the access point is located at 30 m from the robots. (1,0 val)

c) Considering a FER of 0.1, calculate the effective throughput capacity in the uplink direction, for each robot. (1,5 val)

d) Which would the physical area of the antenna required to achieve a 3 dBi gain, considering an antenna efficiency of 60%? (0,5 val)

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) How many OFDM symbols are transmitted in each second? (1,0 val)

i) 12000000 ☐

ii) 250000 ☐

iii) 6000000 ☐

iv) 312500 ☐

v) None of the above ☐

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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 36 Mbit/s using 16-QAM. What in the code rate of the FEC (i.e., $\boldsymbol{CR} = \frac{\boldsymbol{k}}{\boldsymbol{n}}$) in this transmission mode? (1,0 val / -0,25)

i) 1/2 ☐

ii) 2/3 ☐

iii) 3/4 ☐

iv) 5/6 ☐

v) None of the above ☐

c) Explain the difference between OFDM and OFDMA. (1,0 val)

d) IEEE 802.11n and IEEE 802.11ac support carrier aggregation. Explain this concept, as well as its purpose. (1,0 val)

5) A mobile network operator wishes to provide NB-IoT coverage in a city, where it already has GSM and LTE-A coverage. In order to accomplish the objective, the some of the LTE-A cells will be upgraded to support NB-IoT. Since each upgraded eNodeB incurs on a cost, the objective is to upgrade the minimum number of LTE-A eNodeBs, just enough to support the required node density. For this purpose, the LTE-A cells will be grouped into clusters (as is done for frequency reuse), where in each cluster, only one of the eNodeBs will be upgraded. The radius of each LTE-A cell is approximately 0,877 km. There is only one PRB allocated for NB-IoT in each NB-IoT cell. For the purposes of network planning, each NB-IoT device is assumed to send 1 message per hour, and each message has a length of 6 subframes. Assume that, in each uplink NB-IoT frame, 3 subframes are used for control/signaling, with the remaining ones being used for data.

a) How many devices can be supported by each NB-IoT capable eNodeB? Justify. (1,5 val)

b) Assume that the correct answer to a) is 500000 devices. Consider that the actual device density is 30000 devices per km^2. What should be the size of the NB-IoT cluster in terms of the number of LTE-A cells? Justify. (1,5 val)

c) The mobile network operator has decided that the radio resources allocated to NB-IoT should not be taken from the radio resources dedicated to LTE-A. How can this be achieved in a standard way? (1,0 val)