TÉCNICO LISBOA

Exam **A**

Mestrado em Engenharia Electrotécnica e de Computadores

Redes Móveis e Internet das Coisas

Recovery Exam

19th July 2022

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. 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, +2, -1, 0, -1, 0, +1, +1. Stations A and B are simultaneously transmitting to the base station: A is transmitting bit sequence 11, and B is transmitting bit sequence 01, 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) -2,0,0,+1,-1,-1,0,+1 ☐

   ii) +1,+3,0,-1,+1,-1,0,-1 ☐

   iii) +2,0,0-1,+2,0,0-2 ☐

   iv) +2,+2,-1,-2,+1,+2,+1,+1 ☐

   v) None of the above ☐

Name:_____ **Number:**_____

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

i) A: 0, ?; B: 1, 0 ☐

ii) A: 1, ?; B: ?, 1 ☐

iii) A: ?, ?; B: 0, 1 ☐

iv) A: ?, 1; B: 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 ☐

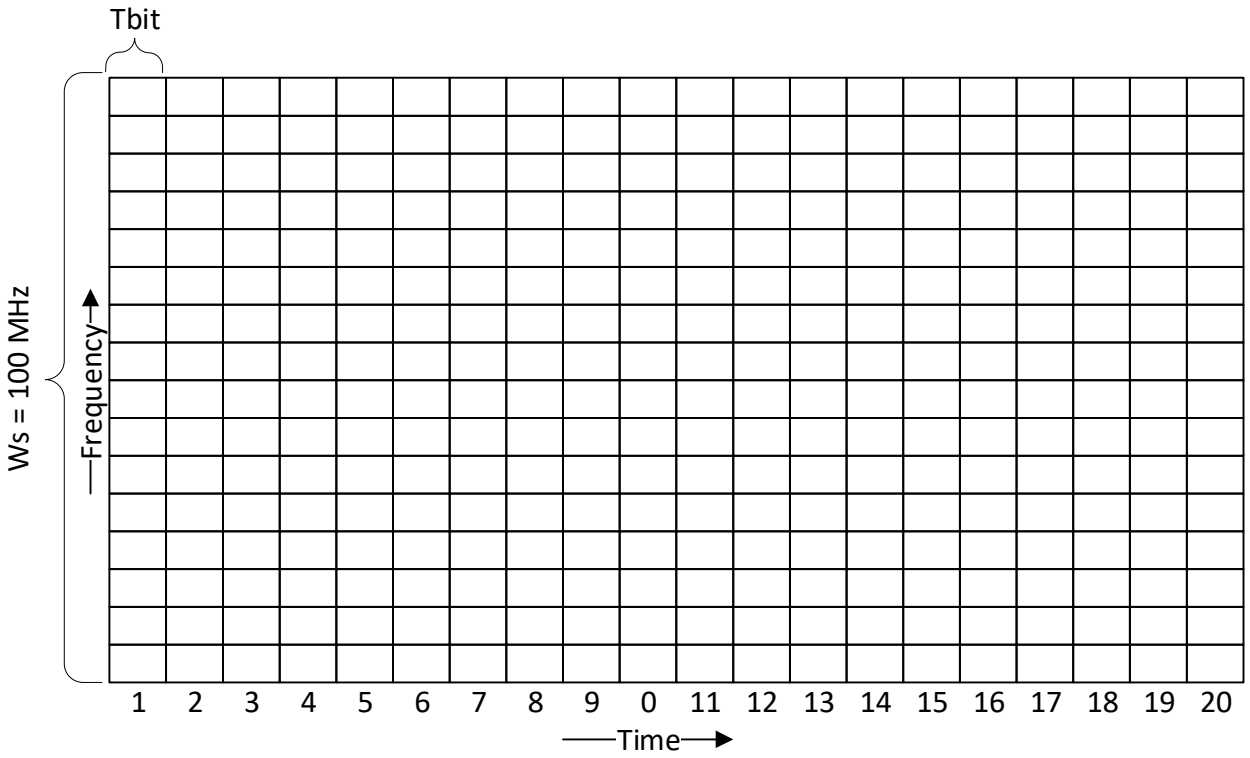
d) Consider that the bit rate of each station is currently 2 Mbit/s? What is the chip rate transmitted by each station? Justify. (0,5 val)

e) Explain two advantages of CDMA as regards avoiding signal interception by non-intended entities. (0,5 val)

2) 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 $\boldsymbol{W_s = 100\ MHz}$, 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 $\boldsymbol{T_c = 2 \cdot T_s}$.

TÉCNICO LISBOA

Exam A



a) What is the number of bits encoded in each symbol? (1,0)

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

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

- PN sequence: 11, 01, 00, 10, 00;
- Bit sequence: 01110100101100010110

3) LoRaWAN is a Low Power Wide Area Network (LPWAN) technology, which is currently considered very promising from the point of view of Internet of Things (IoT) implementation.

a) In LoRaWAN, which of the following entities participates in the Adaptive Data Rate (ADR) procedure? (1,0 val)

i) Gateway ☐

ii) Application Server ☐

iii) Join Server ☐

iv) Network Server ☐

v) None of the above ☐

Name:_____ **Number:**_____

b) What is the number that best approaches the duration of the transmission of 18 data bits using SF9, CR=4/8, and BW=250 kHz, in milliseconds? In the calculations, consider that the number of symbols required to transmit all the bits **rounds up** to the **closest integer**. (1,0 val)

i) 8 ☐

ii) 11 ☐

iii) 10 ☐

iv) 5 ☐

v) 12 ☐

c) Assume that the transmit power and code rate are kept constant, and there are no packet losses. Which spreading factor is the most energy-efficient? (1,0 val)

i) SF7 ☐

ii) SF9 ☐

iii) SF11 ☐

iv) SF 8 ☐

v) SF10 ☐

d) Assume that the transmit power and code rate are kept constant, and channel conditions are stable. Which spreading factor achieves the lowest bit error rate? (1,0 val)

i) SF7 ☐

ii) SF9 ☐

iii) SF11 ☐

iv) SF 8 ☐

v) SF10 ☐

4) Consider an IEEE 802.11b network operating at 11.0 Mbps, providing Internet connectivity to a number of micro cameras. Each micro camera generates a stream of video images, each of 65536 bytes in length, with an image rate of 2 images-per-second. Assume that each image is fragmented in individual chunks of 2048 bytes at the application layer. 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) How many MAC frames (DATA and ACK) are needed to transmit a single image? (0,5 val)

b) Calculate the maximum total throughput that can be offered when the WLAN is being used by the microcameras only, and assuming that there are no frame losses. (1,5 val)

c) What is the maximum number of WiFi micro cameras supported in the network? (1,0 val)

d) Calculate the effective DATA frame loss rate at the MAC layer, considering that the physical frame loss rate is 5% and assuming that ACK frame losses are negligible. (1,0 val)

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

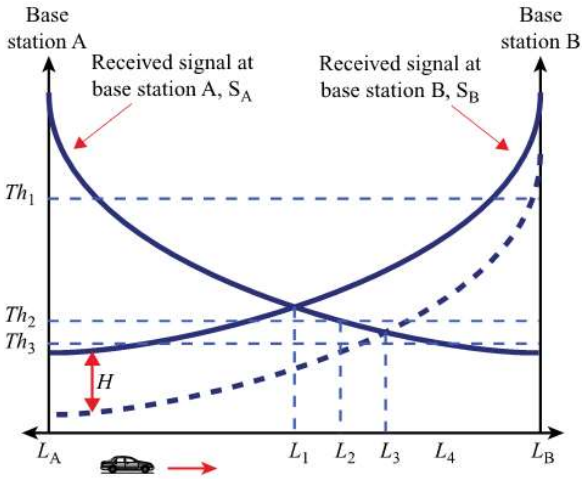
TÉCNICO LISBOA

Exam **A**

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 handover strategies:

i) Relative Signal Strength with threshold *Th2* and Hysteresis. (1,0 val)

ii) Relative Signal Strength with 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 network operator plans to cover an area using radio waves in the 1815 MHz frequency band, and bandwidth of 20 MHz. The area to be covered belongs to an urban setting, with attenuation factor $\boldsymbol{\alpha = 3}$. The decay measured at 1-meter distance from the transmitter is 30 dB. The target modulation is QPSK and the roll-off factor is 0. The noise spectral density is -110 dBm/Hz. The antennas have a gain of 5 dBi at both the base station and the mobile terminal. The transmit power is 30 dBm, and the receiver sensitivity is -80 dBm. The base station is located at the center of the cell.

i) Calculate the area of the cell. (1,0 val)

ii) What is the maximum data rate achieved per Resource Block when using a code rate of 0.1885 and 2x2 MIMO? (1.0 val)

Name:_____ **Number:**_____