TÉCNICO LISBOA

Mestrado em

Engenharia Electrotécnica e de Computadores

Redes Móveis e Sem Fios

2º Teste

19 de Junho de 2019

Duração 1h30

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

1) Consider a Bluetooth piconet, comprising one master and two slave devices (S1 and S2). S1 has the following ACL packets in its transmission queue, which are ordered as follows (format is <higher level destination, packet>): <S2, DH5>, <M, DM1>, <M, DM1>. S2 has one packets in the queue: <S1, DM3>.

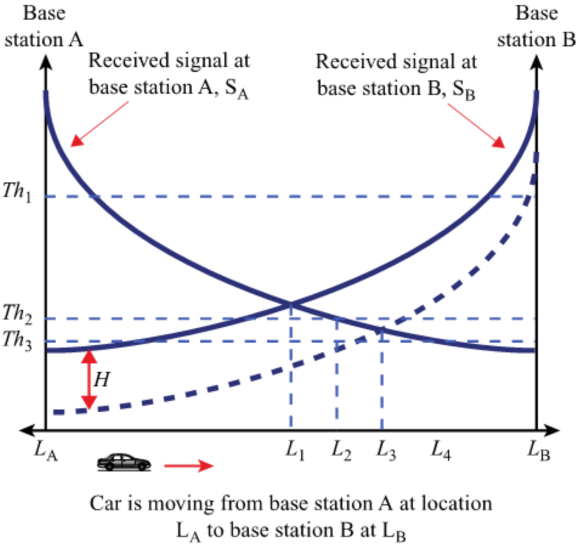
   a) Draw the timeline diagram of packet transmissions, clearly indicating the timeslot assignment (for each packet, indicate the type, the occupied slots, the sender and the receiver), as well as the frequency in use in each slot. Also indicate the acknowledgements (both standalone and piggybacked): e.g., ACK1 for an ACK directed to S1. The diagram ends when the last ACL packet is transmitted. (2,0 val)

   b) Consider that a SCO session in in place between a Master a Slave using HV2 packets, and no ACL traffic in the downlink direction. Calculate the maximum data rate that would be supported in the uplink direction. Justify. (2,0 val)

   c) Consider one direction of an L2CAP session whose traffic is being shaped by a Token Bucket mechanism. All the transmitted packets are DH1 with maximum payload size. The negotiated flow spec for the connection is <Token Rate, Token Bucket Size> = <1350 Byte/s, 54 Byte>. The data arrival pattern as a function of time is given in the table. Calculate the number of transmitted packets and remaining queue length at the end of each time window of 20 ms. Copy the table to your exam sheet and complete it by filling the empty cells**. Note: Consider that the number of bytes allowed to be transmitted during each time window of 20 ms (including data generated during the window) is a function of the bucket occupancy at the beginning of the window.** (1.0 val)

Time window start time [ms]	Tokens inside Bucket (beginning of time window) [Byte]	Queue Length (beginning of time window) [Byte]	Tokens arriving during the time window [Byte]	Data generated during time window [Byte]	Data transmitted during time window [Byte]
0	0	0	27	27	0
20	27			54	
40				0	
60				0	
80				0	
100				0	
120				108	
140				0	

2) Consider a mobile cellular system. A mobile terminal is currently connected with Base Station A, and approaching Base Station B, as depicted in the following picture.

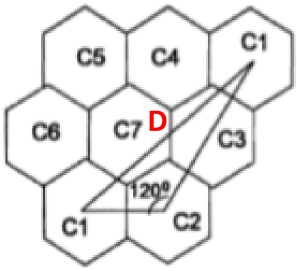


a) Which handoff locations (L_A, L_1, L_2, L_3, L_4, L_B) result from the following handover strategies:

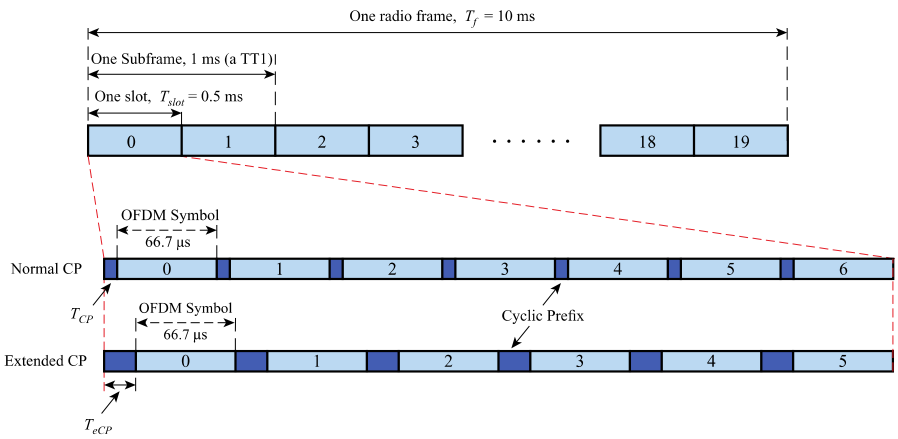
i) Relative Signal Strength with threshold *Th3*. (1,0 val)

ii) Relative Signal Strength with Hysteresis and Threshold *Th3*. (1,0 val)

b) In a cellular network, any feasible cell clustering pattern of size $\boldsymbol{G}$, we have that $\boldsymbol{G} = \boldsymbol{I}^2 + \boldsymbol{J}^2 + (\boldsymbol{I} \times \boldsymbol{J})\ \boldsymbol{st}\ \boldsymbol{I}, \boldsymbol{J} = \boldsymbol{0}, \boldsymbol{1}, \boldsymbol{2}, \boldsymbol{etc.}$ Demonstrate this result, knowing that $\boldsymbol{D} = \sqrt{\boldsymbol{3G}} \cdot \boldsymbol{R}$, where $\boldsymbol{D}$ is the distance between co-channel cells (i.e., cells using the same channels) and $\boldsymbol{R}$ is the radius of a cell. Note: the following example depicts a cell cluster of size 7, where we can see the distance $\boldsymbol{D}$ between two cells reusing the same channels. (2.0 val)



c) LTE frames are divided into 20 slots of 0,5 ms each. Inside each slot, OFDM symbols are transmitted, which are separated by either Normal Cyclic Prefix (Normal CP) or Extended Cyclic Prefix (Extended CP). Compare the advantages and disadvantages of each type of Cyclic Prefix. (1.0)



3) A new IoT company, whose founders are former RMSF students, is going to deploy a pet tracking service in a neighborhood in the center of Porto, where it expects to have a significant number of subscribers. They are going to deploy their own network, based on a proprietary technology. Although this technology uses unlicensed spectrum, the cost of the base station increases with the number of channels that it has to support. In the beginning, they planned to deploy a single base station equipped with an omnidirectional antenna. In order to send a data burst, the IoT devices use a special control channel to request access to an uplink data channel during some time interval. The base station assigns the uplink data channels, indicating the respective ownership through the control channel, or declining, if no channel is available at that moment. When a device sees its request being declined, it waits a random time interval and tries again. The average duration of a data burst is 10 ms. The average arrival rate of a data burst requests is 100 $\boldsymbol{s^{-1}}$. Assume an Erlang B model (see table below).

a) How many channels will be needed when each of the following criteria is adopted? For each situation, also indicate the resulting grade of service.

   a. The main objective is to minimize the number of channels, but subject to the constraint that the grade of service offered to the customers must be at least $\boldsymbol{P = 0.02}$.. (1,0 val)

   b. The main objective is to minimize the number of channels, but subject to the constraint that the grade of service offered to the customers must be at least $\boldsymbol{P = 0.01}$. (1,0 val)

b) Calculate the average channel utilization when 7 channels are used. (1,0 val)

c) Calculate the maximum supported carried traffic when there are 7 channels and the grade of service is $\boldsymbol{P = 0,005}$. (1,0 val)

d) Assuming a target $\boldsymbol{P = 0,002}$, from the point of view of supported traffic intensity, is it better to cover the same area with 4 channels in a single sector cell, or divide it into six sectors with 2 channels each? (1,0 val)

Capacity (Erlangs) for Grade of Service of					
Number of Data Channels (N)	***P=0.02 (1/50)***	***P=0.01 (1/100)***	***P=0.005 (1/200)***	***P=0.002 (1/500)***	***P=0.001 (1/1000)***
2	***0,20***	***0,15***	***0,1***	***0,05***	***0,00***
3	***0,60***	***0,45***	***0,3***	***0,20***	***0,15***
4	***1,05***	***0,85***	***0,7***	***0,50***	***0,40***
5	***1,65***	***1,35***	***1,10***	***0,85***	***0,75***
6	***2,25***	***1,90***	***1,60***	***1,30***	***1,10***
7	***2,90***	***2,50***	***2,15***	***1,75***	***1,55***

8	***3,60***	***3.10***	***2,70***	***2,30***	***2,05***

4) Consider an experimental LEO satellite system operating in the 1,5 GHz frequency, with transmit power of 40 dBm. One of the functions of the satellite is to perform the echo of received signals. A ground station is located in the line that forms the projection of satellite's orbit. Each time the satellite passes right over it, the ground station transmits one sounding signal and receives its echo. The measured time interval between the transmission of the signal and the reception of the echo is 20 ms, which includes 10 ms of processing delay. The satellite and ground station antennas have similar characteristics, featuring a beamwidth of 22º. The atmosphere introduces an additional attenuation of 10 dB.

   a) Calculate the period of transmissions from the ground station, knowing that the satellite has an equatorial orbit and follows the rotational movement of the Earth. (2,0 val)

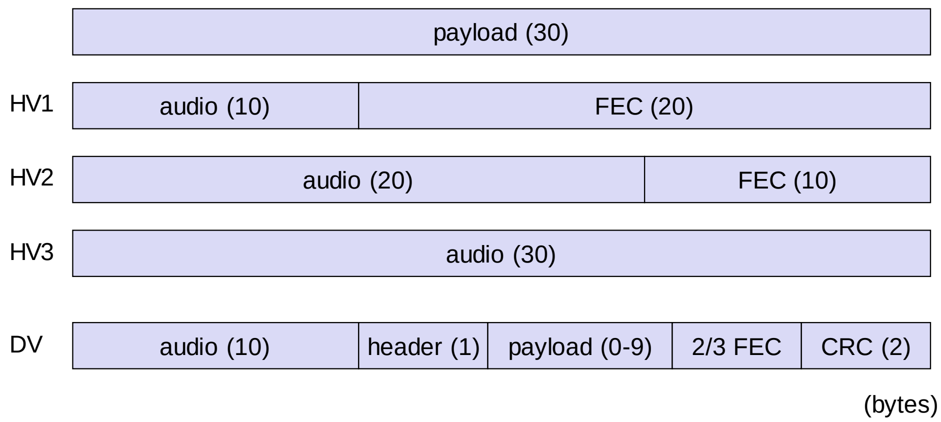
   b) Calculate the footprint area. (1,0 val)

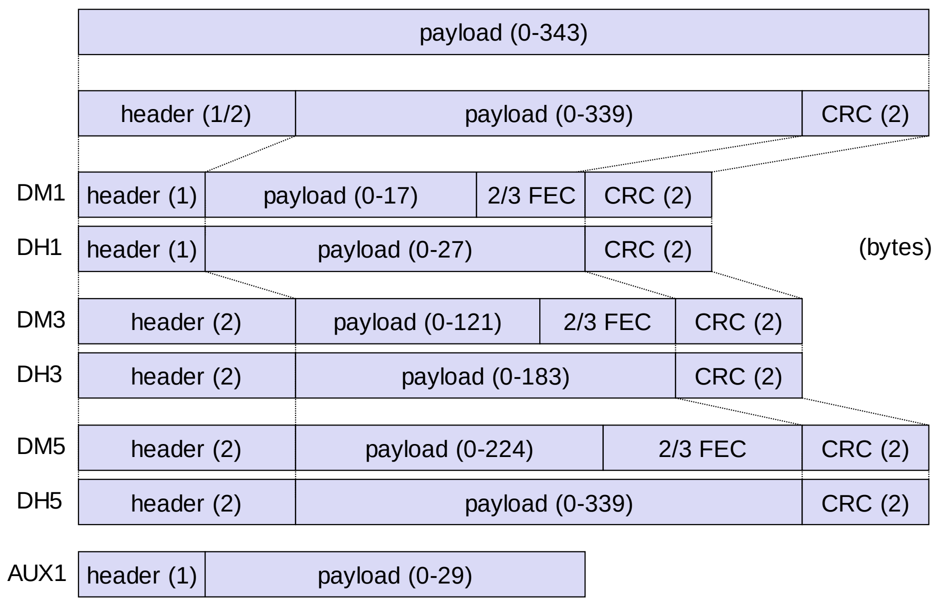
   c) Knowing that the receiver sensitivity is approximately -84,93 dBm and that a 6 dB safety margin should be left above that sensitivity, calculate the minimum transmit power. (2,0 val)

Bluetooth

1 slot = 625us

SCO stream throughput = 64 kbit/s

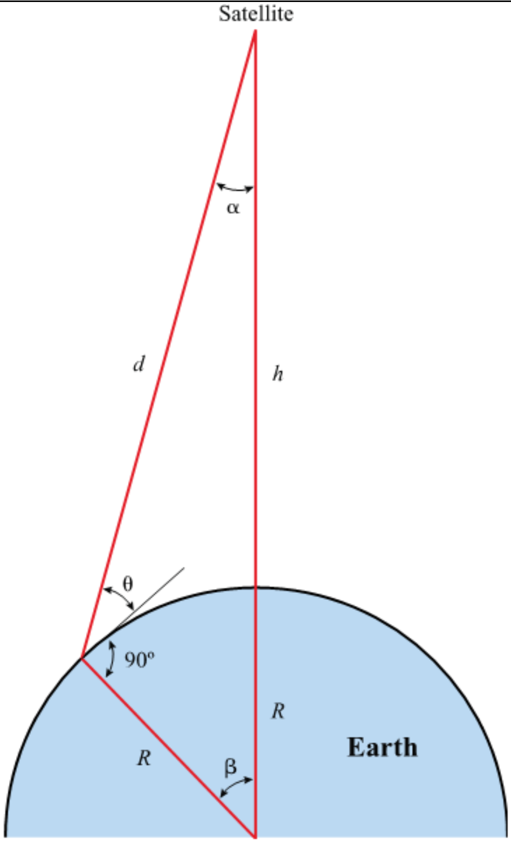




Satellite Systems	
$F_g = m \cdot g \cdot (R/r)^2$ $g = 9.81 m/s^2$ *(gravitational acceleration)* $R = 6370\ km$ *(radius of the Earth)*	$F_c = m \cdot r \cdot \omega^2$
$L = \left(\frac{4 \cdot \pi \cdot d \cdot f}{c}\right)^2$	$Footprint\ Diameter = 2 \times \alpha \times d$
$G_{(1plane)} = 2\pi/(2 \times \alpha)$	$A_{eff} = \eta \cdot A_{phy} = \frac{\lambda^2}{4\pi} G$

$$P_r(dBm) = P_t(dBm) + 10 \cdot log_{10}\left(\frac{G_t \cdot G_r \cdot \lambda^2}{(4 \cdot \pi \cdot d)^2}\right) - At$$

$$P_r(dBm) = P_t(dBm) - 10 \cdot log_{10}\left(\frac{4 \cdot Footprint}{\pi^2 \cdot A_{eff}}\right) - At$$



$$\frac{R}{R+h} = \frac{sin(\alpha)}{sin\left(\theta + \frac{\pi}{2}\right)} =$$

$$\frac{sin\left(\frac{\pi}{2} - \beta - \theta\right)}{sin\left(\theta + \frac{\pi}{2}\right)} = \frac{cos(\beta + \theta)}{cos(\theta)}$$

$$\frac{d}{R+h} = \frac{sin(\beta)}{sin\left(\theta + \frac{\pi}{2}\right)} =$$

$$= \frac{sin(\beta)}{cos(\theta)}$$

$$d = \frac{(R+h) \cdot sin(\beta)}{cos(\theta)} = \frac{R \cdot sin(\beta)}{sin(\alpha)}$$

Cellular Networks and Traffic Engineering	
Hexagonal cell area: $A_{cell} = 1.5 \times R^2 \times \sqrt{3}$	*Distance between hexagonal cell centers:* $d = \sqrt{3} \times R$
Frequency reuse factor: $RF = \frac{1}{G}$	*Cell cluster sizes:* $G = I^2 + J^2 + (I \times J)\ st\ I, J = 0, 1, 2, etc.$
Traffic intensity: $A = \lambda \cdot h$	*Traffic intensity:* $A = \rho \cdot N$
Grade of service for ∞ sources LCC: $P = \frac{\frac{A^N}{N!}}{\sum_{x=0}^{N} \frac{A^x}{x!}}$	*Capacity of blocking system:* $C = A(1 - P)$
Law of cosines: **for any triangle of sides** a, b **and** c **with opposite angles** A, B **and** C, $c^2 = a^2 + b^2 - 2ab \cdot cos(C)$	