TÉCNICO LISBOA

Mestrado em

Engenharia Electrotécnica e de Computadores

Redes Móveis e Sem Fios

2º Teste

17 de Junho de 2021

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>): <M, DH3>, <S2, DM1>, <M, DM5>. S2 has one packets in the queue: <M, DH1>. The master's polling policy is round-robin, starting by S1.

   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 which packets are POLL packets and 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 HV3 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. The negotiated flow spec for the connection is <Token Rate, Token Bucket Size> = <59000 Byte/s, 847 Byte>. The amount of tokens in the token bucket at $\boldsymbol{t = 0}$ is 400. What will be the amount of tokens in the token bucket after a full DM3 packet is transmitted at the end of the next 6 slots? (1,0 val)

2) The Internet of Things enables the accessibility of smart objects through the Internet, allowing the development of applications that make decisions based on the measurements performed by smart objects, while also allowing dynamic smart object management and control.

   a) Explain the three QoS levels supported by the MQTT protocol. (1.5 val)

   b) Compare TCP and UDP regarding the support of IoT applications featuring sporadic transmission of short messages by battery powered devices. It is enough to present two relevant advantages of each one over the other. (1.5 val)

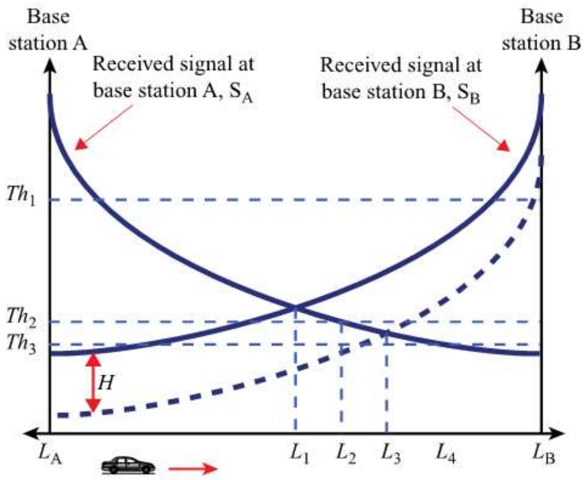
   c) Draw the message diagram of a COAP GET request between a client and a server, indicating, for each message, the Type, Message ID, Token and contents. Assume that the first Message ID is 0x4567, and the first Token is 0x34, the resource being read is /temperature and the respective value measured by the server node is "50". Assume a piggy-backed confirmed response message model. (2.0 val)

3) 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 handover strategies:

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

      ii) Relative Signal Strength with Hysteresis and Threshold *Th1*. (1,0 val)



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

b) Consider that a GSM network operator is covering an area with cells of radius *R=1 km*. Each GSM frequency channel is 200 KHz wide, and each cell uses 20 frequency channels. The distance between the centers of cells using the same frequency channels is approximately *4,58 km*.

i) What is the total bandwidth needed to cover that area? Justify. (1.0 val)

ii) What is the best grade of service that can be guaranteed by the network when the **carried traffic** is 11,0445 Erlang? **Note:** the grades of service in the table are the only ones considered valid. (1.0 val.)

Offered Traffic (in Erlangs) for Grade of Service of					
Number of Servers (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)***
10	***5.08***	***4.46***	***3.96***	***3.43***	***3.09***
20	***13.19***	***12.03***	***11.10***	***10.07***	***9.41***
24	***16.64***	***15.27***	***14.21***	***13.01***	***12.24***
40	***31.0***	***29.0***	***27.3***	***25.7***	***24.5***
70	***59.13***	***56.1***	***53.7***	***51.0***	***49.2***
100	***87.97***	***84.1***	***80.9***	***77.4***	***75.2***

c) Consider an LTE system. A TCP/IP application has generated a data message of 3901 bytes. The TCP header has 20 bytes, as well as the IP header. Taking into account the CQI table below, how many Resource Blocks will the scheduler reserve to transmit this message when the channel conditions are classified as CQI 1 and Normal 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.

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

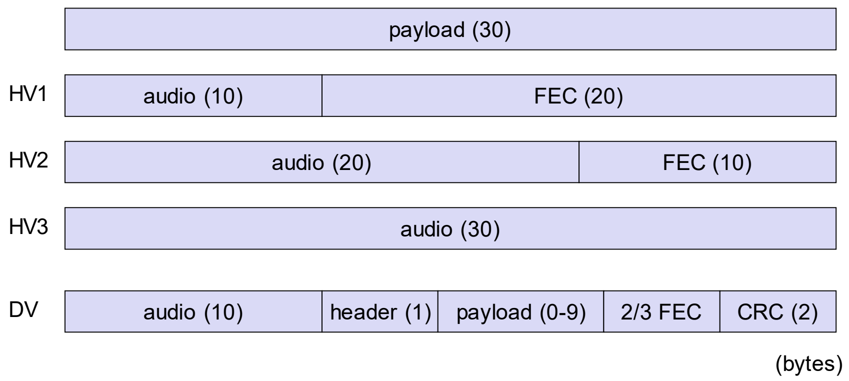
4) Consider an experimental LEO satellite system operating in the 1,5 GHz frequency, with transmit power of 40 dBm. One of the functions of the satellite is to perform the echo of received signals. A ground station is located in the line that forms the projection of satellite's orbit. Each time the satellite 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.

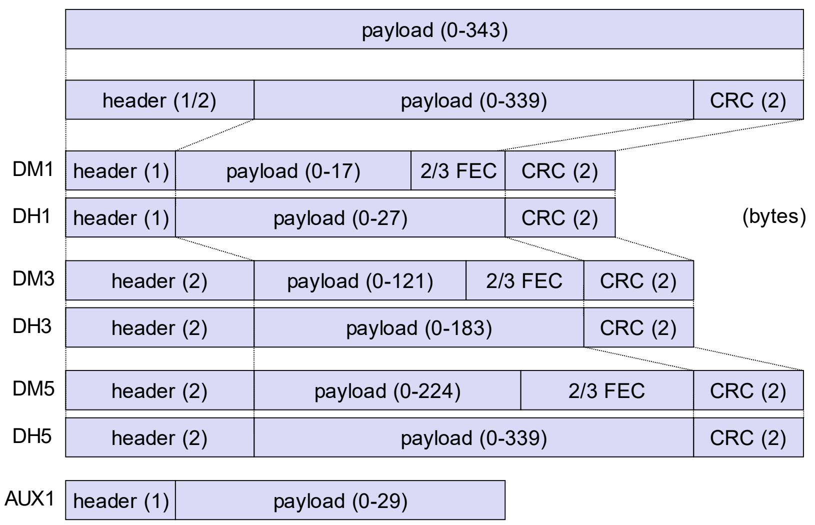
a) Calculate the period of transmissions from the ground station, knowing that the satellite has an equatorial orbit and follows the rotational movement of the Earth. (2,0 val)

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

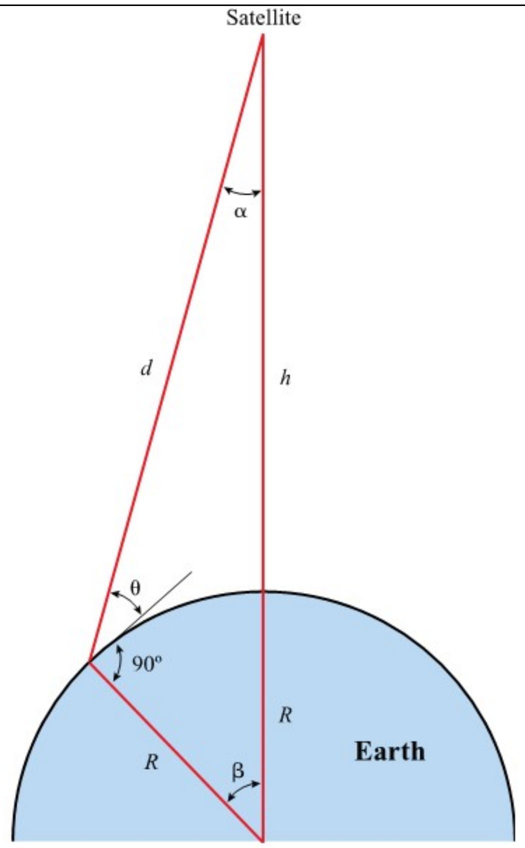
c) Knowing that the receiver sensitivity is approximately -84,93 dBm and that a 6 dB safety margin should be left above that sensitivity, calculate the minimum transmit power. (2,0 val)

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:*** $d = \sqrt{3} \times R$
Distance between hexagonal cell centers using the same frequencies: $\frac{D}{R} = \sqrt{3G}$	
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**,** $c^2 = a^2 + b^2 - 2ab \cdot cos(C)$	