

## Redes Móveis e Sem Fios

Exame – 2ª parte

3 de Julho de 2019

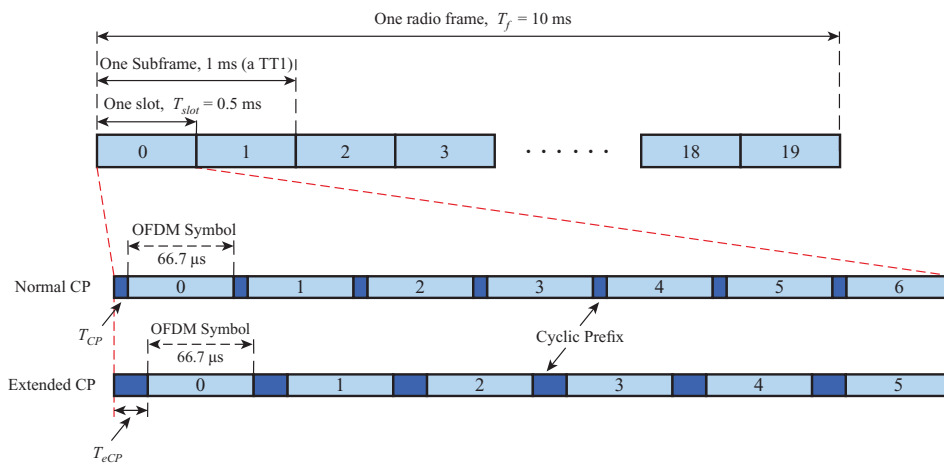
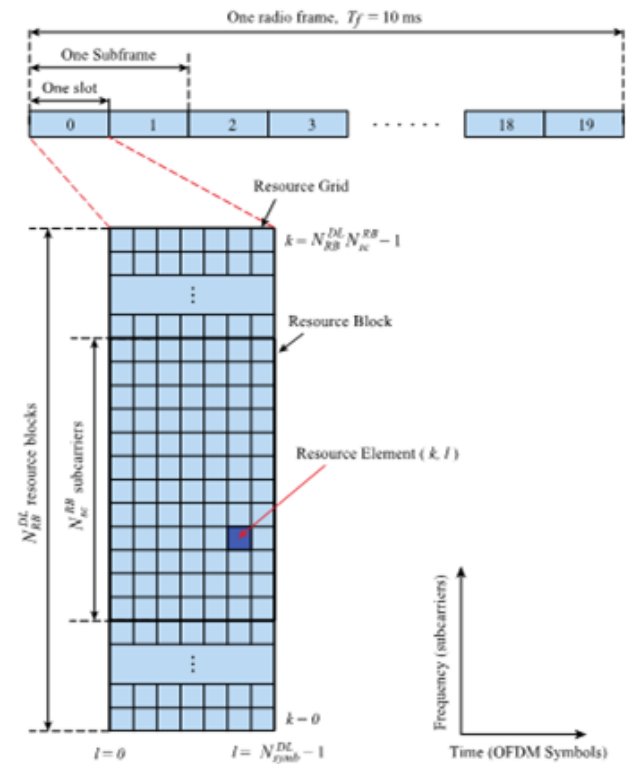
Duração 1h30

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

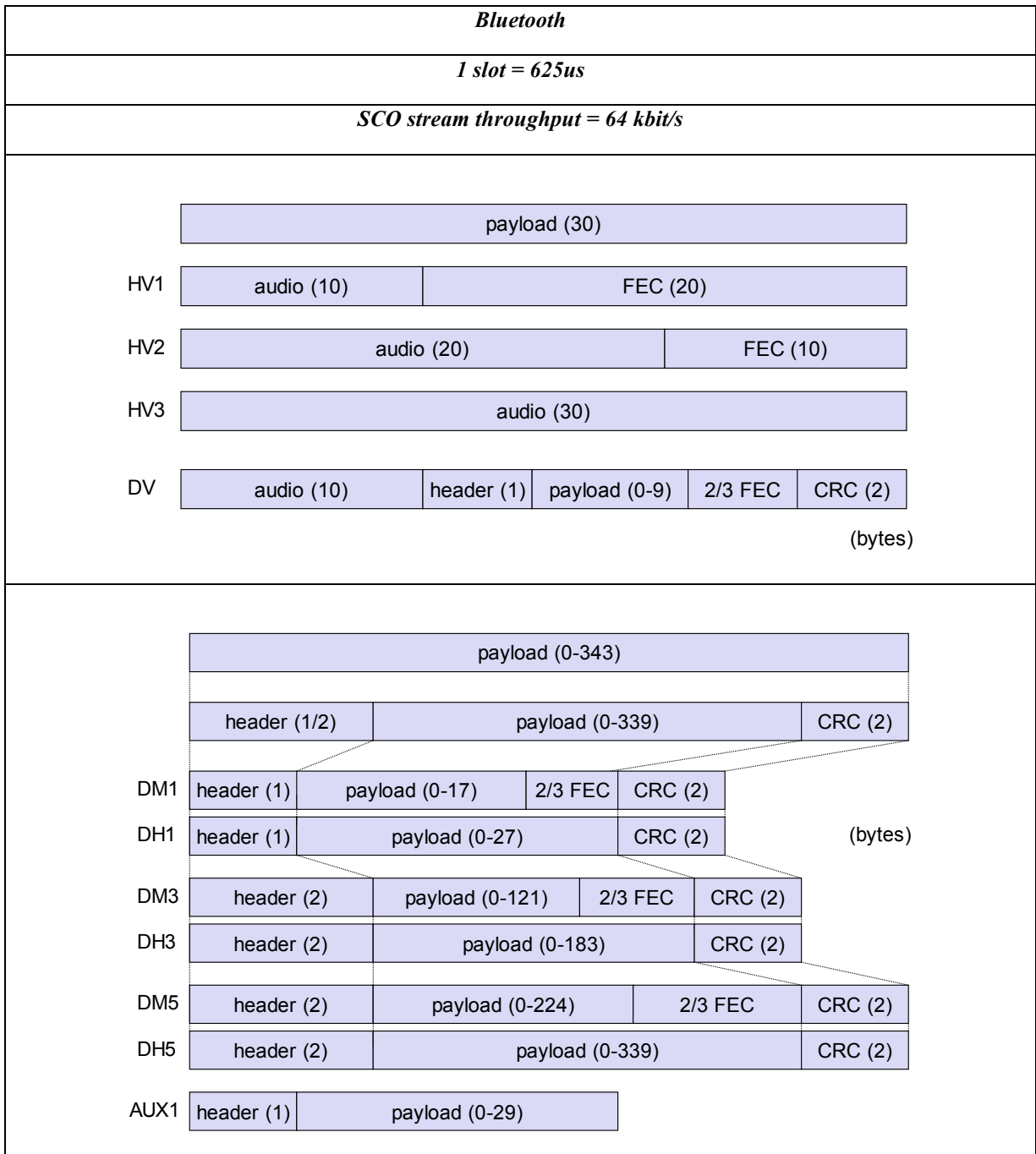
- 1) Consider a MIPv4 system with co-located CoA, routing optimization and reverse tunneling extensions, where the hop distances between the different entities are the following: CN→HA=40; HA→CN=33; HA→FA=70; FA→HA=70; HA→MN=50, MN→HA=55, FA→MN=7; MN→FA=7; MN→CN=50; CN→MN=45. The CN wishes to establish an HTTP session with the MN. Assume that the TTL field of the IP headers is always initialized with 100.
  - a) Explain the purpose of the routing optimization extension, indicating the extra requirements imposed on the relevant entities. (1,0 val)
  - b) Draw the message diagram of the signaling exchanged by the HA and CN after the latter receives a Binding Warning message from an FA. (1.0 val)
  - c) What are the TTL values of data packets arriving at the MN and at the CN? (1,0 val)
  - d) Consider that the relevant IPv4 addresses are the following: MN (193.154.3.10), CoA (195.137.10.20), HA (193.154.3.1), FA (195.137.10.2), CN (146.64.4.6). What are the source and destination IP addresses in IPv4 headers of data packets exchanged between those entities, considering both inner and outer headers (when applicable)? Justify. (2,0 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. COAP and MQTT are two protocols relevant in this context.
  - a) Compare CoAP and MQTT regarding the suitability to interwork with HTTP. Justify. (1,0 val)
  - b) Explain the difference between the Message ID and the Token in the context of CoAP. (1,0 val)
  - c) Compare MQTT and MQTT-SN regarding the required transport protocols. (1,0 val)
  - d) Draw the message diagram of an MQTT exchange between a publisher and subscriber with QoS Level 1 (deliver at least once), including the initial stages of session establishment with the Broker. (2,0 val)
  
- 3) Consider the LTE technology and VoLTE voice transmission. The table below presents the most suitable modulation and code rate to be used with each Channel Quality Indicator Index (CQI Index) value, as well as the respective spectral efficiency in bits/Hz. The pictures depict the resource structure of LTE. The bandwidth of each Resource Element (RE) is 15 kHz, and it corresponds to the transmission of one modulation symbol. Each Resource Block (RB) spans 12 carriers. VoLTE uses a AMR-WB 12.65 coder, which generates about 253 bits of coded speech every 20 ms, forming a payload of one voice packet. These voice bits are then encapsulated into RTP/UDP/IPv4, whose total overhead per packet is 60 bytes.
  - a) LTE employs OFDMA for downlink communication and SC-FDMA for uplink communication. Explain why. (1,0)
  - b) How many REs are comprised by an RB? (1,0)
  - c) Estimate the maximum bitrate that can be achieved with a 20 MHz channel at CQI Index 5 and a single MIMO stream. (1,0)

- d) How many RBs per frame are needed to support a single unidirectional VoLTE stream at CQI Index 10 and Normal CP? Note: consider that the RBs are fully dedicated to data plane traffic. (2,0 val)

CQI Index	Modulation	Code Rate $\times 1024$	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



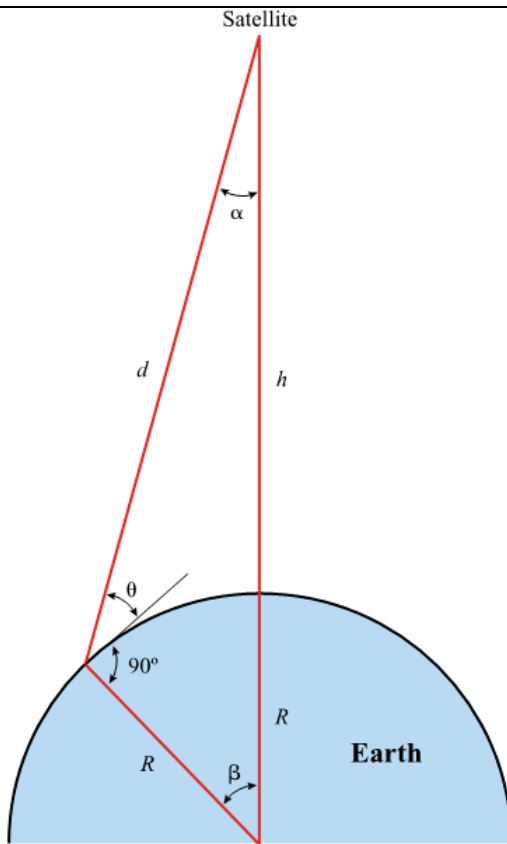
- 4) Consider a LEO satellite system with polar orbit operating in the S band, more specifically centered on 2,5 GHz, with transmit power of 40 dBm. The orbit of the satellite is polar. The altitude of the satellite is 1800 km. The satellite and ground station antennas have similar characteristics, featuring a beamwidth of 45°. The atmosphere introduces an additional attenuation of 10 dB.
- Calculate the period of the satellite's orbit. (1,5 val)
  - Calculate the effective aperture of the antenna. (1,5 val)
  - A ground station is located at latitude 83,46°N. When the satellite passes over the North Pole, the observed elevation angle is 61,96°. Calculate the received power at that moment. (2,0 val)



<b>Satellite Systems</b>	
$F_g = m \cdot g \cdot (R/r)^2$ <p><math>g = 9.81\text{m/s}^2</math> (gravitational acceleration)</p> <p><math>R = 6370\text{ km}</math> (radius of the Earth)</p>	$F_c = m \cdot r \cdot \omega^2$
$L = \left( \frac{4 \cdot \pi \cdot d \cdot f}{c} \right)^2$	<p style="text-align: center;"><b>Footprint Diameter = <math>2 \times \alpha \times d</math></b></p>
$G_{(1plane)} = 2\pi / (2 \times \alpha)$	$A_{eff} = \eta \cdot A_{phy} = \frac{\lambda^2}{4\pi} G$

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

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



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

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

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

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

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

### Cellular Networks and Traffic Engineering

**Hexagonal cell area:**

$$A_{\text{cell}} = 1.5 \times R^2 \times \sqrt{3}$$

**Distance between hexagonal cell centers:**

$$d = \sqrt{3} \times R$$

**Frequency reuse factor:**

$$RF = \frac{1}{G}$$

**Cell cluster sizes:**

$$G = I^2 + J^2 + (I \times J) \text{ st } I, J = 0, 1, 2, \text{ etc.}$$

**Traffic intensity:**

$$A = \lambda \cdot h$$

**Traffic intensity:**

$$A = \rho \cdot N$$

**Grade of service for  $\infty$  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  $C$ ,**

$$c^2 = a^2 + b^2 - 2ab \cdot \cos(C)$$

