

## Redes Móveis e Sem Fios

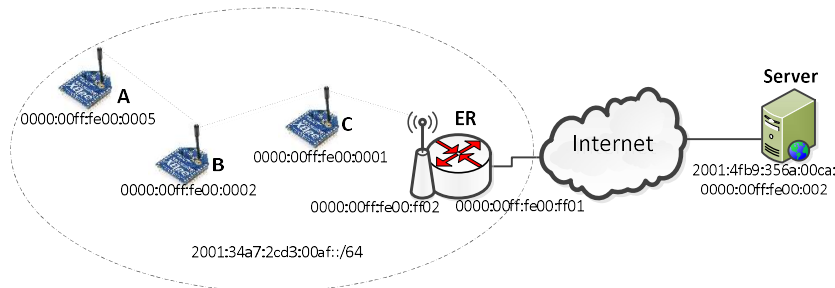
### Exame de Recuperação – 2ª parte

4 de Julho de 2017

Duração 1h30

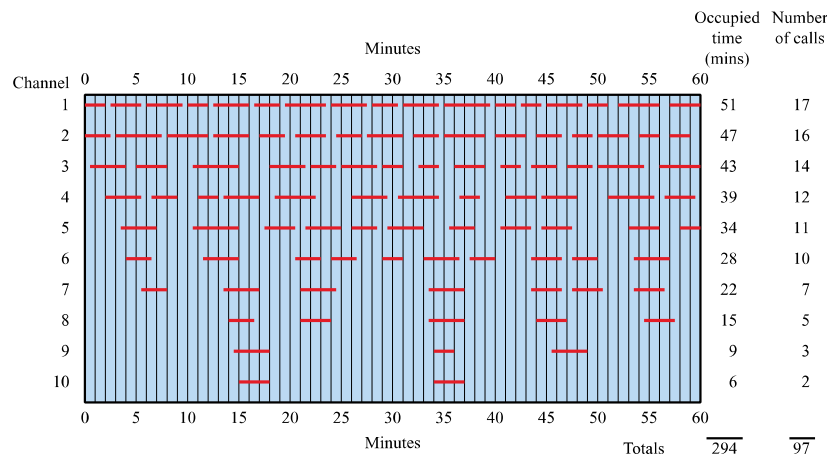
**In order to avoid grading mistakes, please answer each question on a different page, keeping the order as much as possible.**

- 1) Consider the 6LoWPAN wireless network represented in the figure below, which also shows the network prefixes and identifiers of the nodes. All interface identifiers in the LoWPAN are derived from the MAC address. Assume that in this 6LoWPAN implementation, interface identifiers from global IPv6 addresses are not compressed. Node A wishes to join, but it is out of direct range of the Edge Router (ER). In the meantime, nodes B and C are already members of the network.



- a) Draw the message diagram of the network bootstrapping phases of node A, namely the router discovery and address registration procedures, assuming that no router advertisements are sent without solicitation. (1,0 val)
  - b) Assuming stateless header compression, as defined in RFC4944, how many bits of the source and destination network prefixes and how many bits of the source and destination interface identifiers must be sent in the 6LoWPAN header when node A sends a packet to node fe80::0000:00ff:fe00:0002? Justify. (2,0 val)
  - c) Reconsider your response to b) in case improved IPv6 header compression (RFC6282) is used instead, in a scenario where there is only one context, which keeps the following global prefixes: 2001:34a7:2cd3:00af::/64 (source) and 2001:8bc2:349e:00bd (destination). (1,0 val)
- 2) OFDM is a mechanism currently used in the latest versions of IEEE 802.11: a, g, n, ac, etc. Consider an imaginary communication system originally operating in BPSK single carrier mode, using bandwidth  $B = 20 \text{ MHz}$  with roll-off factor of 0. The system was later upgraded to operate using OFDM, with  $N = 1024$  carriers, using BPSK, with cyclic prefix  $Cp = 8 \mu s$ .
- a) Explain the benefits of OFDM in comparison with a single carrier system using the same bandwidth. (1,5 val)
  - b) Calculate the duration of the OFDM symbol, and the number of BPSK symbols of the original single carrier system that fit in this duration? (1,5 val)
  - c) Explain the advantages and disadvantages of using a cyclic prefix. (1,0 val)
  - d) Explain the difference between OFDM and OFDMA. (1,0 val)

3) Consider the following call activity pattern, measured during one hour.

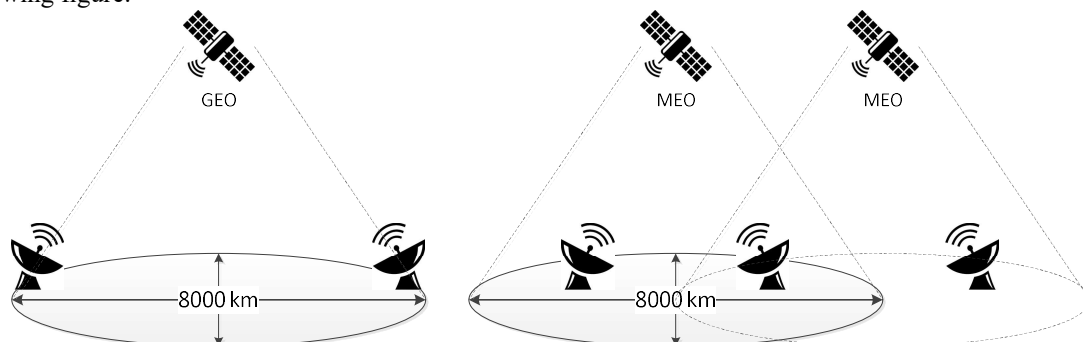


Note: horizontal lines indicate occupied periods to the nearest 1/2 minute

- Calculate the average call rate and call duration of the depicted carried traffic. (1,0 val)
- Calculate the traffic intensity assuming a non-blocking scenario. (1,0 val)
- Calculate the carried traffic intensity in Erlangs, assuming that the offered traffic is the same as in b), but the probability of blocking is now 0.01. (1,0 val)
- How many channels would be necessary to support the offered traffic in b) with a probability of blocking of 0.001, only taking into account values present in the table below? (1,0 val)
- Assuming that the target probability of blocking is to be the same, which configuration is more efficient to provide cellular coverage to a given area: one cell with  $N$  channels or two cells, each with  $\frac{N}{2}$  channels? (1,0 val)

Capacity (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	5.05	4.45	3.95	3.4	3.05
20	13.19	12.03	11.10	10.07	9.41
30	21.9	20.3	19.0	17.6	16.65
40	31.0	29.0	27.3	25.7	24.5

- 4) A new satellite operator is currently in the process of deciding whether to deploy a GEO or MEO satellite constellation. The MEO constellation is to be deployed at an altitude of 10000 km. In both cases, the orbits will be equatorial. MEO ground stations are located 4000 km apart, and each satellite will be able to simultaneously talk with two adjacent ground stations at each time instant. The alternative schemes are partially depicted in the following figure.



- Calculate the divergence angles of the satellite antennas, as well as the respective gains. (2, 0 val)

- b) For both cases, calculate the total delay of 100 byte messages exchanged between ground stations located 8000 km appart, considering the bitrate is 20 kbit/s in all links and that each intermediate node (satellite or ground station) receives the message completely before retransmitting it. Assume that that there are no inter-satellite links. Note: consider that the footprint diameter is negligible in comparison with the altitude of the satellites. (2,0 val)
- c) Repeat b) for MEO, now considering inter-satellite links. Note: the cord length ( $c$ ) of an arc  $\alpha$  of a circle of radius  $r$  is given by  $c = 2 \times r \times \sin\left(\frac{\alpha}{2}\right)$ . (2,0 val)

Modulation Performance (B)	
ASK	$B = (1 + r) \cdot R_b$
M-PSK	$B = \left(\frac{1 + r}{\log_2(M)}\right) \cdot R_b$
M-FSK	$B = \left(\frac{(1 + r) \cdot M}{\log_2(M)}\right) \cdot R_b$

Satellite Systems	
$F_g = m \cdot g \cdot (R/r)^2$ $g = 9.81 \text{ m/s}^2$ $R = 6370 \text{ km}$	$F_c = m \cdot r \cdot \omega^2$
$L = \left(\frac{4 \cdot \pi \cdot r \cdot f}{c}\right)^2$	$\text{Footprint Diameter} = \theta_{div} \times d$
$G_{(1plane)} = 2\pi/\theta_{div}$	$A_{eff} = \eta \cdot A_{phy} = \frac{\lambda^2}{4\pi} G$
$P_r(dB) = P_t(dB) - 10 \cdot \log_{10}\left(\frac{4 \cdot \text{Footprint}}{\pi^2 \cdot A_{eff}}\right) - At$	

Cellular Networks and Traffic Engineering	
<b>Hexagonal cell area:</b> $A_{cell} = 1.5 \times R^2 \times \sqrt{3}$	<b>Distance between hexagonal cell centers:</b> $d = \sqrt{3} \times R$
<b>Frequency reuse factor:</b> $RF = \frac{1}{G}$	<b>Cell cluster sizes:</b> $G = I^2 + J^2 + (I \times J) \text{ st } I, J = 0, 1, 2, \text{ etc.}$
<b>Traffic intensity:</b> $A = \lambda \cdot h$	<b>Traffic intensity:</b> $A = \rho \cdot N$
<b>Grade of service for <math>\infty</math> sources LCC:</b> $P = \frac{\frac{A^N}{N!}}{\sum_{x=0}^N \frac{A^x}{x!}}$	<b>Capacity of blocking system:</b> $C = A(1 - P)$

