Exc.	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5	**Sum**
max.	6	6	6	6	6	**30**
pts.						

Problem 1: *(General concepts within radio communication systems)*

(a) What does the acronyms IMT-2000 mean? Specify the name of the international organization who is behind its development, and define the main goals that were expected to be achieved. Why is important for a wireless technology to have the IMT-2000 label? How many radio interfaces were approved for IMT-2000? Enumerate them briefly, and mention the main characteristic(s) of each of them.

(b) Give examples of local/personal/metropolitan area communication systems. What are the acronyms that are used to identify them? What are the main characteristics (e.g., target data rate, coverage area, power consumption, etc.) that correspond to each category? Identify at least one representative example of a wireless communication technology that falls within each of these clasifications.

(c) Licensed and unlicensed spectrum: What is the difference between these two types of spectrum? Who is in charge of regulating the use of each of them? What kind of interference is expected to be observed in each case? Can quality of service be guaranteed in both cases? Why/why not? Enumerate 2 wireless technologies that use each kind of spectrum (if possible, specify the location of the corresponding frequency band in each case).

Problem 2: *(Channel modeling for mobile communication systems)*

(a) Physical channel modeling: In which situations can the physical channel modeling approach be used? Enumerate at least three propagation mechanisms that are used to model the wireless channel using the physical approach. Explain in a brief but clear way the physical principle that is used to predict the behavior of radio waves in presence of each propagation mechanism (try to use formulas and/or pictures whenever is possible).

(b) Explain briefly the Okumura-Hata (O-H) model. Why is the O-H model so popular after so many years of being developed? What kind of fading does it model? What are the radio system parameters that the O-H model takes into account? What are the limitations of this model? How are these limitations solved when dimensioning links in current wireless systems?

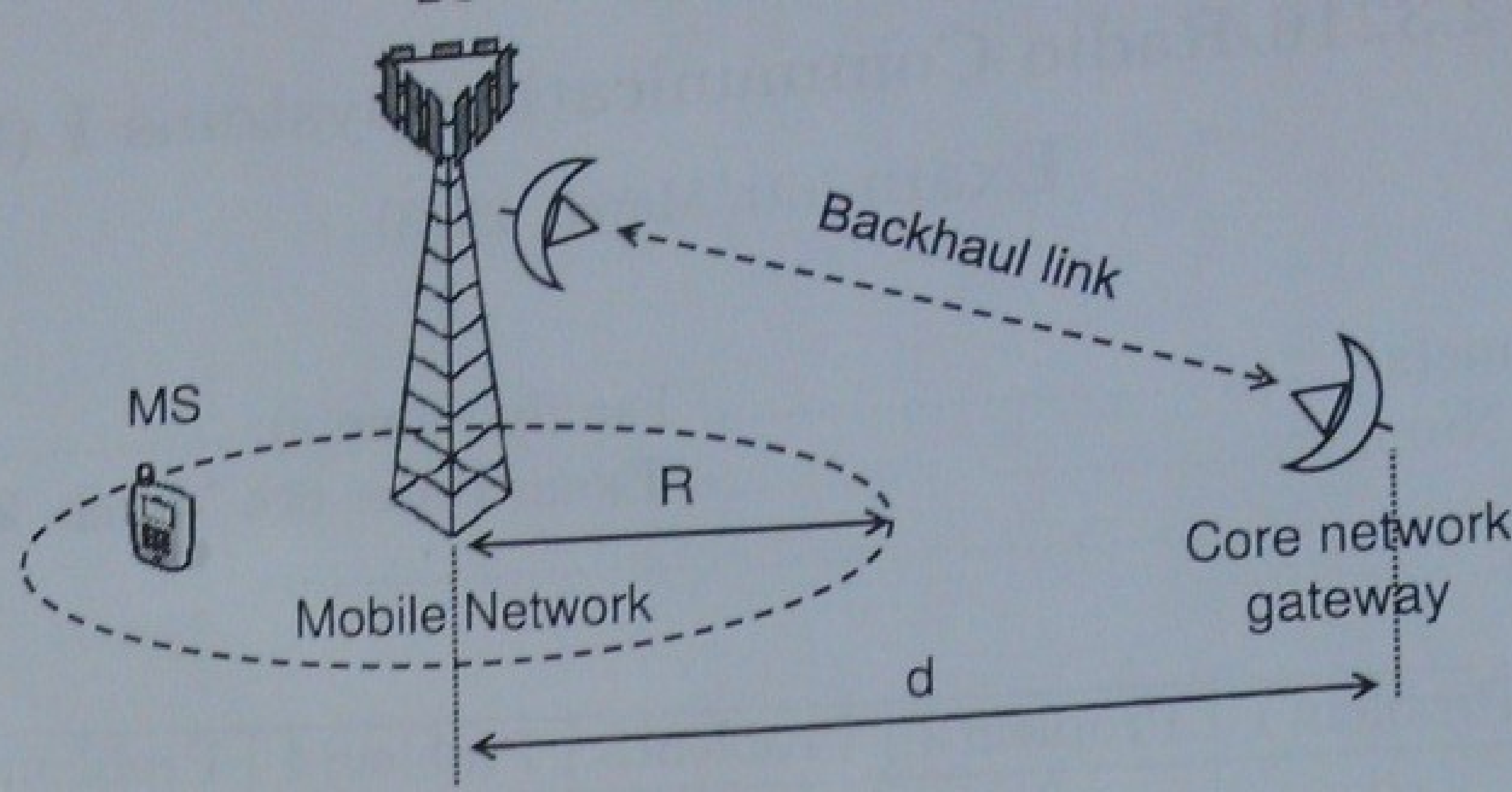

Figure 1: Wireless communication system operating in an isolated rural area with coverage area R. Backhaul link is implemented using a Line-of-Sight point-to-point link with directional antennas in the 38 GHz band, to cover a distance d between the core network gateway and the cell site.

(c) A single-cell wireless communication system operates at $f_c = 900$ MHz to serve an isolated village with environmental conditions similar to a rural area (see Fig.1 for more details). The wireless communications system has a single Base Station (BS) located in the center of the village. The height of the BS antenna and the height of the Mobile Station (MS) antenna are $h_b = 25\,\text{m}$ and $h_m = 1.5\,\text{m}$, respectively. The BS does not apply sectorization: it deploys an omnidirectional antenna with 3.5 dBi gain in all directions. The antenna gain at the MS is 0 dBi (perfect isotropic antenna).

The backhaul link to the core network is composed by Line-of-Sight (LoS) connection in the 38 GHz band, with powerful directional antennas at both extremes of the link (the gain of each antenna is 20 dBi).

1. What is the minimum transmit power that is required in the backhaul to cover a distance $d = 20$ km, if the threshold power that is required in reception for a proper quality of communication is -85 dBm. Express the result in dBm (do not consider any losses originated in cables, connectors, weather conditions, or due to any other phenomena).
2. Let us now focus on the mobile network coverage area. Assume that BS transmit power is 30 dBm. Calculate the cell range if shadow fading is not considered. Consider a receiver sensitivity of -104 dBm.
3. Calculate the new range that the cell should have when shadowing is taken into account for an outage probability of 1%, 10 % and 50 %. Use shadow fading standard deviation $\sigma_s = 7$ dB.

Problem 3: *(Functional blocks of a radio link and channel capacity concepts)*

(a) Explain the difference between the receiver noise (i.e., additive white Gaussian noise), co-channel interference, and adjacent channel interference (focus in the channel block part of a radio communication system). What are the sources of these three impairments?

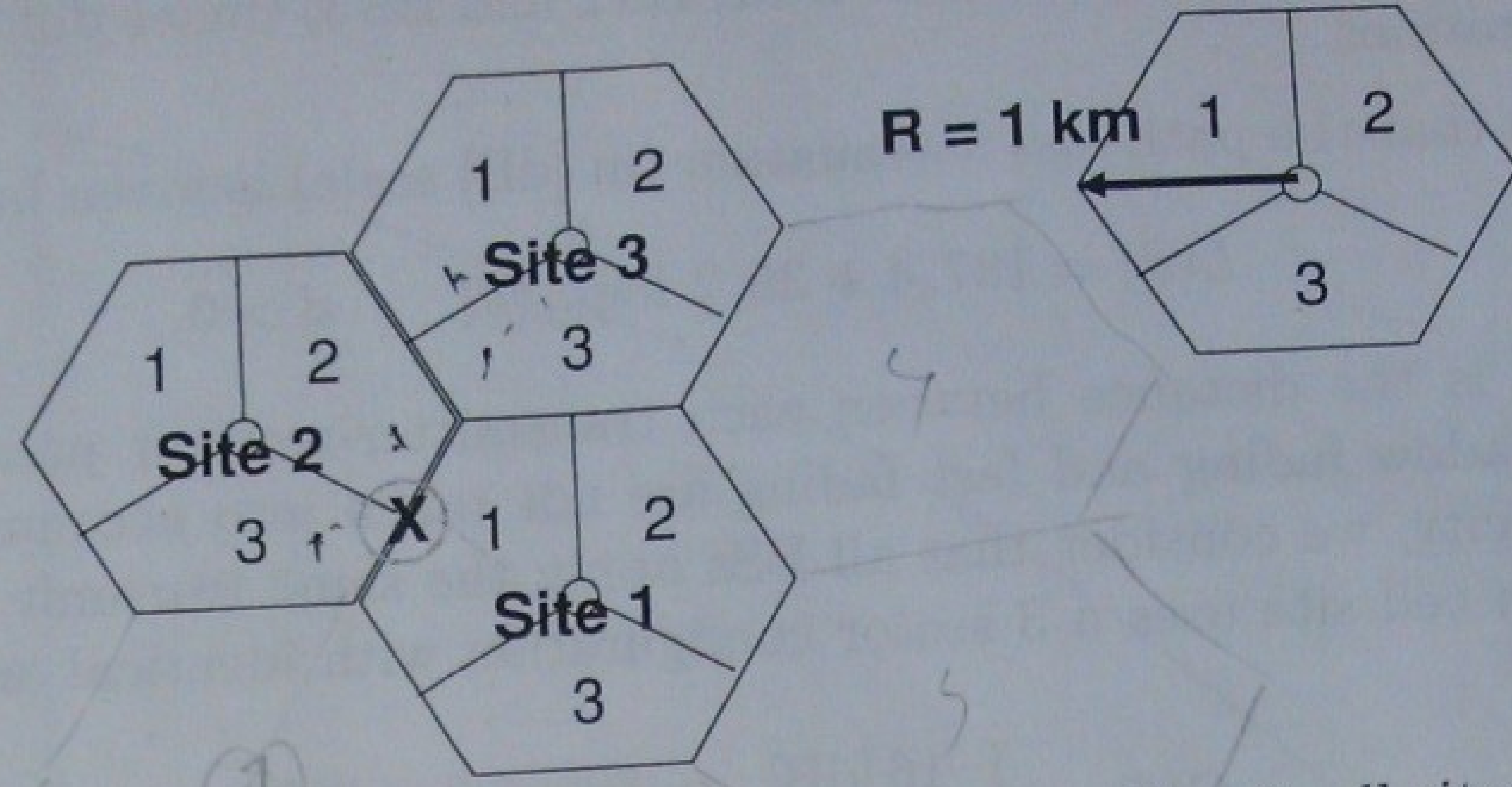

Figure 2: Wireless communication system composed by 3 cell sites with 120° sectors. The red cross ('X') shows the location for the mobile station.

(b) What is the purpose of combining an interleaving block with a channel encoder block? What would happen if the interleaving block is taken out from the transmitting chain? Justify your answer in a proper way.

(c) Explain the concept of Inter Symbol Interference (ISI). What is the physical phenomenon that generates this impairment in a wireless communication system? How is this impairment tackled in 3G systems (i.e., CDMA networks) and 4G systems (i.e., OFDMA networks)?

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Problem 4: *(Multiple access and duplexing)*

(a) Describe at least two advantages and two disadvantages of the following multiple access techniques: (1) CDMA and (2) OFDMA.

(b) Explain in a simple but clear way the following concepts related to TDMA networks: (1) Discontinuous Transmission and Reception (DTX/DRX) techniques and (2) Timing Advance (TA) control.

(c) What generates the so-called cross-slot interference problem in TDD wireless systems? Does it represent a serious challenge for network operators? How can this impairment be prevented?

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Problem 5: *(Co-channel interference in mobile systems)*

(a) Define intra-system interference and inter-system interference. In what kind of radio communication systems can be found? Give a brief explanation of their nature, and describe briefly the tools that hardware/network designers have to keep each of them under control.

(b) Define the concept of soft-capacity in CDMA-based wireless networks. Should this characteristic be interpreted as an advantage or a disadvantage? Justify you answer in a proper way.

(c) Consider the the wireless communication system presented in Fig. 2, composed by 3 cell site of radius $R = 1\,\text{km}$. We are interested in determining the signal strength that the MS (marked by a red 'X' in the figure) observes from each of the BSs (i.e., from BS 1, BS 2 and BS 3) under different system configurations.

Assume that the path loss attenuation (in [dB] scale) is given by

$$L(d) = 137,4 + 35,2\ \log_{10}(d) \qquad d > 0, \tag{1}$$

where d is the distance between each transmitter-receiver pair in kilometers. Shadow fading and fast fading are not taken into account. For sake of simplicity, we consider that all BSs apply the same transmit power, and that each cell site uses a 3 sector configuration with identical antenna gain patterns:

$$G(\theta) = \begin{cases} 16\,[\mathrm{dB}] & -60^\circ \leq \theta < 60^\circ \\ -8\,[\mathrm{dB}] & \text{otherwise} \end{cases} . \tag{2}$$

Assume that the MS is connected to BS number 1 (i.e., site 1).

(c.1) Determine the SIR that the MS perceives when the cluster size is 3 (i.e., each sector uses a different set of frequencies). Provide results in dB.

(c.2) Find the new SIR for the MS when the cluster size is reduced to 1 (i.e., all sectors use the same set of frequencies). Provide results in dB.

(c.3) Calculate the throughput that the terminal is able to support in the previous three cases using the following modified version of Shannon formula:

$$R = W\,A\,\log_2(1 + B\,\mathrm{SIR}), \tag{3}$$

where $A = 0.88$ is a parameter that accounts the bandwidth efficiency, $B = 0.8$ is a parameter that models the SIR efficiency, and bandwidth

1. $W = 10$ [MHz] when reuse 1/1 is applied, and
2. $W = \frac{10}{3}$ [MHz] when reuse 1/3 is used.

Appendix Information: *(Formulas and Curves that MAY be required)*

$$f(L_s) = \frac{1}{\sqrt{2\pi}\sigma_s} e^{-\frac{L_s^2}{2\sigma_s^2}} \tag{4}$$

$$\Pr\{L_s < L_0\} = \int^{L_0} f(t)\,dt = 1 - Q\left(\frac{L_0}{\ldots}\right) \tag{5}$$