1.

a)
Not enough data to know.

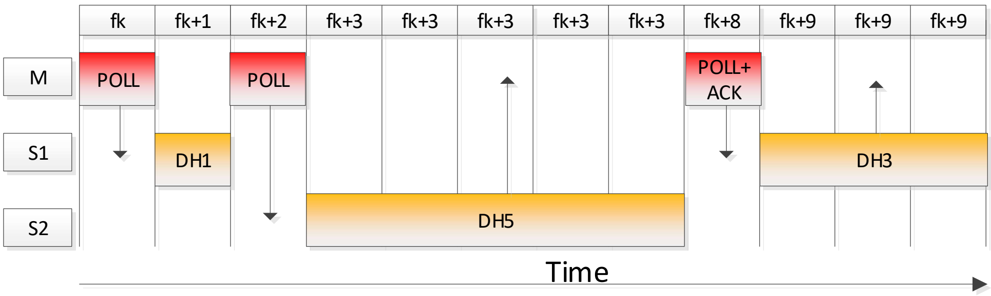
b)

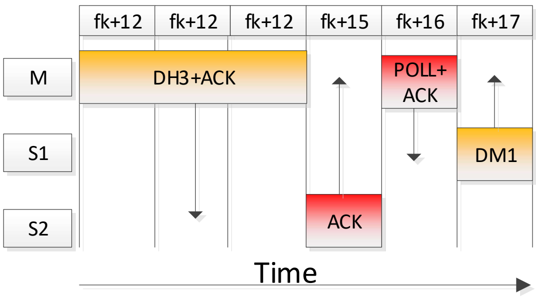
$$D_{A,0} = (+1,+1,-1,-1) \cdot (0,-3,+1,+2) = -6 \Rightarrow 0$$
$$D_{A,1} = (+1,+1,-1,-1) \cdot (0,-2,+1,+2) = -5 \Rightarrow 0$$

c)
In this exercise, it is assumed that the received bits correspond to the ones that were in fact transmitted. So, we already know the bits that were transmitted by the BS to A and B.

$$S_A = -1 \cdot (+1,+1,-1,-1) \,||\, -1 \cdot (+1,+1,-1,-1) = (-1,-1,+1,+1,-1,-1,+1,+1)$$
$$S_B = +1 \cdot (+1,-1,-1,+1) \,||\, -1 \cdot (-1,+1,+1,-1) = (+1,-1,-1,+1,+1,-1,-1,+1)$$
$$S_A + S_B = (0,-2,0,+2,0,-2,0,+2)$$
$$N_A = (0,-3,+1,+2,0,-2,+1,+2) - (S_A + S_B) = (0,-1,+1,0,0,0,+1,0)$$

d)
Not enough data to know.

2.
a)




b)
Each HV2 packet carries 20 bytes. Since a SCO voice session has a rate of 64000 bit/s in each direction, we have the following equality:

$$64000 = \frac{20 \times 8}{P} \Leftrightarrow P = 2{,}5\ ms,$$

Where P is the HV2 packet period. This value of P corresponds to 4 slots of 625 us. Since SCO sessions are bi-directional, in each sequence of 4 slots, two slots will be occupied by HV2 packets. Two slots are left free, each being assigned to each direction. The maximum ACL bitrate in the downlink direction occurs when DH1 packets are used and their payload is full. The resulting maximum bitrate is:

$$R = \frac{27 \times 8}{2{,}5} = 86{,}4\ kbit/s$$

c)

Slot	Time window start time [us]	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]	Tokens inside Bucket (end of time window) [Byte]
1	625	300	0	18.75	0	0	318.75
2	1250	318.75	0	18.75	17	17	320,50
3	1875			18.75	0	0	339,50
4	2500			18.75	0	0	358,00
5	3125			18.75	0	0	376,75
6	3750			18.75	0	0	395,5

3.
a)
The spectral efficiency is the bitrate that can be achieved per Hz. It can be obtained dividing the bitrate by the bandwidth of the channel. Since the system employs FDD, we must consider only one direction, which has a bandwidth of 2 MHz:

Transmission Mode	Spectral Efficiency
1 Mbit/s	0.5 bit/s/Hz
2 Mbit/s	1 bit/s/Hz
3 Mbit/s	1.5 bit/s/Hz
4 Mbit/s	2.0 bit/s/Hz

Hence, the system can achieve a maximum spectral efficiency of 2.0 bit/s/Hz.

b)
We must first calculate the received power, using the log-distance path loss model. The power decay at $\boldsymbol{d_0} = 100\ m$, PL_0, is calculated with the Friis model, for an isotropic antenna:

$$PL_0 = P_t\ [dBm] - P_r\ [dBm] = 10 \cdot log10\left(\frac{(4 \cdot \pi \cdot d_0)^2}{\lambda^2}\right) \approx 86.42\ dB$$

Pode então aplicar-se o modelo log-distance:

$$P_r\ [dBm] = P_t\ [dBm] - PL_0 + G_t\ [dBi] + G_r\ [dBi] - 10 \cdot \alpha \cdot log_{10}\left(\frac{d}{d_0}\right) \Leftrightarrow$$

$$P_r\ [dBm] = 10 \cdot log_{10}(300) - 86.42 + 20 + 20 - 10 \cdot 4 \cdot log_{10}\left(\frac{6000}{100}\right) \approx -92.78$$

This received power is greater than the receiver sensitivity of mode 2 Mbit/s, but lower than the receiver sensitivity of 3 Mbit/s. The maximum possible bitrate is thus 2 Mbit/s.

c)
The question is: which fraction of the transmitted bits corresponds to useful bits? This requires calculating how many raw bits (useful+FEC) are being transmitted. We know the modulation (QPSK), the roll-factor and bandwidth, so we can calculate the raw bitrate:

$$B = \left(\frac{1+r}{log_2(M)}\right) \cdot R_b \Leftrightarrow R_b = 2000000 \cdot log_2(4) = 400000\ bit/s$$

It is now easy to calculate the code rate, dividing the number of useful bits by the number of total (or raw) bits:

$$\frac{k}{n} = \frac{3000000}{4000000} = 3/4$$

4.
a)
The answer is 9 bits/symbol, given by the SF.

b)
Minimum packet period w/ 100% duty-cycle: 0.7071s
Minimum packet period w/ 1% duty-cycle: 70.71s

So, the packet rate is $\frac{1}{70.71} \approx 0.014\, packets/s$

c)
Application Server

d)
SF=7, since packets are shorter, and thus reduces the probability of collision.

5.

a)
i) L3
ii)L2

b)
If the objective is to maximize the total throughput, the resource manager must assign each slice to the UE whose SINR is higher:
S1:UE1, S2:UE3, S3:UE4, S4:UE1

c)

i)
Knowing that subcarrier spacing is 15kHz, the total number of subcarriers can be calculated as follows:

$$N_f = \frac{4500000}{15000} = 300$$

The total area of the cell can be calculated based on the radius:

$$A_t = 1.5 \cdot R^2 \cdot \sqrt{3} \approx 415692.19\, m^2$$

The number of frequencies used in the center of the cell, N_{center} is simply calculated as follows:

$$N_{center} = N_f - 200 = 100$$

The average number of frequencies used in the periphery of each cell can be calculated as follows:

$$M = \frac{200}{7} \approx 28.57$$

The average total number of frequencies used in the cell is then calculated as follows:

$$N_f^{cell} = N_{center} + M = 100 + \frac{200}{7} \approx 128,57$$

Then, we can calculate A_p:

$$A_p = \frac{M}{N_f^{cell}} \cdot 415692.19 = 92376.04\, m^2$$

ii)

$$D = R \cdot \sqrt[2]{3G} \approx 1833\, m$$