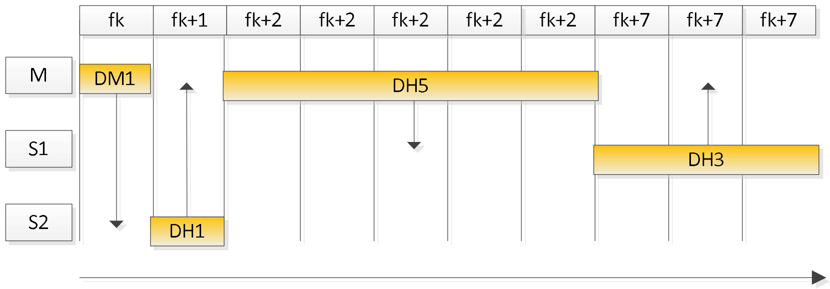
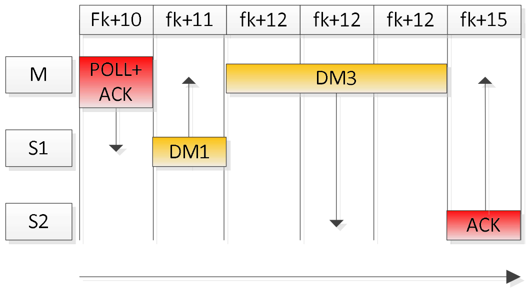
1.

a)





b)

A Bluetooth SCO voice stream occupies 64 kbit/s in each direction. The HV2 packet has a payload of 20 octets. Based on this, we can easily calculate the HV2 packet period *TP* in one direction:

$$TP = \frac{20 \times 8}{64000} = 2.5ms$$

This corresponds to $\frac{2500}{625} = 4$ slots.

This means that in each sequence of 4 slots, two of these slots will be occupied by HV2 of the SCO session, respectively for downlink (i.e. master to slave) and uplink, which leaves 2 slots free for use by ACL links. With 2 slots free, due to the polling nature of the Bluetooth MAC, the only possible combinations are those involving single slot ACL packets (downlink-uplink): DM1-DM1, DM1-DH1, DH1-DM1, or DH1-DH1. As such, it would be impossible to use the intervals between SCO packets to transmit the 3-slot and 5-slot ACL packets considered in a).

2.

a)

i) L3

ii) L1

iii) L3

b) The hystheresis is important to avoid the ping-pong effect of relative signal strength handoff strategies, when the signal strengths of the current and the candidate BSs are not very different. In this situation, variations due to fading effects may cause the best performing BS to switch from one BS to another, causing repeated handoff attempts to be made, which greatly decreases the performance of the system and may ultimately lead to handoff failure and call dropping.

3.

a)

First, we have to calculate the traffic intensity, *A*, expressed in Erlang.

$$A = \lambda \cdot h = 2 \cdot 38{,}7 = 77{,}4$$

Looking at the Erlang-B table, $A = 77{,}4$ with 100 channels corresponds to a blocking probability $P = 0.002$.

b)

Since the small cell has the same number of channels, it can support the same traffic intensity as the big cell from which it originated. The supported traffic intensity in the area of the big cell, which now encompasses the small cell, is now doubled: $A = 2 \cdot 77.4 = 154{,}8$.

c)

With the same number of channels and grade of service, and considering that user behavior pattern is constant across all the area, the small cell will be able to support as many client users as the remaining of the big cell. Since we are given the user density supported by the small cell, and since we have its radius, we can calculate its area and then the maximum number of users in the cell:

$$Area_{small} = 1.5 \times R_{small}^2 \times \sqrt{3} = 1.5 \times 500^2 \times \sqrt{3} \approx 649519\, m^2$$

$$N_{small} = \frac{1}{200} \cdot 649519 \approx 3248$$

We will now calculate the area of the remaining part of the big cell:

$$Area_{big} = 1.5 \times R_{big}^2 \times \sqrt{3} = 1.5 \times 4000^2 \times \sqrt{3} \approx 41569219\ m^2$$

$$Area_{remaining} = Area_{big} - Area_{small} \approx 40919700\ m^2$$

We now use the assumption of uniform user behavior pattern, which allow us to estimate the number of users in the remaining parts of the big cell as $N_{remaining} = N_{small}$. We can now estimate the maximum user density:

$$Density_{remaining} = \frac{N_{remaining}}{Area_{remaining}} \approx 8 \times 10^{-5}\ user/m^2$$

d)

For the same grade of service (0.002) a single cell system would need 200 RBs to support 154,8 Erlang.

4.

a)

The altitude of the orbit, *d*, is calculated as follows:

$$d = r - R = \sqrt[3]{\frac{g \cdot R^2}{\omega^2}} - R = \sqrt[3]{\frac{9.81 \cdot 6370000^2}{0.00082^2}} - 6370000 \approx 2027\ km,$$

which indeed corresponds to a LEO orbit.

b)

The gain is directly related to the divergence angle (45º=0,75 rad), which is the same in the vertical and horizontal planes. After obtaining the gain relative to one plane, we just need to square it:

$$\boldsymbol{G}_{(\mathbf{1plane})} = \frac{\mathbf{2\pi}}{\boldsymbol{\theta}_{div}} = \frac{\mathbf{2\pi}}{\mathbf{0,75}} \approx 8,38$$

$$G_t = G_r = \left(\boldsymbol{G}_{(\mathbf{1plane})}\right)^2 \approx 70,22 = 18,46 \text{ dBi}$$

c)

First, we calculate the footprint area:

$$Footprint\ Diameter = \theta_{div} \times d = 0{,}75 \times 2027 \approx 1521\ km$$

$$Footprint = \pi \times \left(\frac{Footprint\ Diameter}{2}\right)^2 \approx 1{,}818 \times 10^{12}\ m^2$$

We will also need the effective aperture of the receiver antenna:

$$\boldsymbol{A_{eff} = \frac{\lambda^2}{4\pi}\mathrm{G}_r = \frac{\frac{c^2}{f}}{4\pi}\mathrm{G}_r = \frac{\frac{300000000}{1000000000}^2}{4\pi}70{,}22 \approx 0{,}5\ m}$$

We can now apply the formula that calculates the receiver sensitivity, which is adapted to take into account the 6 dB margin relative to the received power:

$$\mathrm{RS}(dBm) = P_t(dBm) - 10 \cdot log_{10}\left(\frac{4 \cdot Footprint}{\pi^2 \cdot A_{eff}}\right) - At - 6 \approx -97{,}6\ dBm$$