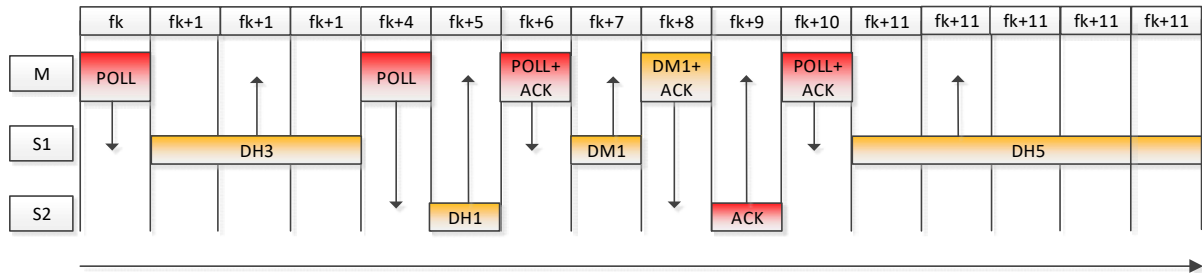


1.

a)



b)

Each HV3 packet carries 30 bytes. Since a SCO voice session has a rate of 64000 bit/s in each direction, we have the following equality:

$$64000 = \frac{30 \times 8}{P} \Leftrightarrow P = 3,75 \text{ ms},$$

Where P is the HV3 packet period. This value of P corresponds to 6 slots of 625 us. Since SCO sessions are bi-directional, in each sequence of 6 slots, two slots will be occupied by HV3 packets. Four slots are left free. The maximum ACL bitrate in the uplink direction occurs when DH3 packets are used in the uplink and their payload is full. The resulting maximum bitrate is:

$$R = \frac{183 \times 8}{3,75} = 390,4 \text{ kbit/s}$$

c)

A full DM3 packet has a payload of 121 bytes. After 6 slots, the token bucket will have the following amount of tokens, assuming that the tokens are discounted at the end of packet transmission:

$$tb(t) = tb(6 \cdot 625 \times 10^{-6}) = \min(847,400 + TR \cdot 6 \cdot 625 \times 10^{-6}) - 121 \approx 500,$$

where TR is the token rate.

2.

a)

QoS 0 (at most once): only one attempt is made to deliver the message, PUBLISH without confirmation.

QoS 1 (at least once): the message is retransmitted (PUBLISH) until an acknowledgement (PUBACK) is received. There can be duplicates that the application must filter.

QoS 2 (exactly once): a four-way exchange (PUBLISH-PUBACK-PUBREL-PUBCOMP) takes place in order to guarantee that the message is received only once by the subscriber.

b)

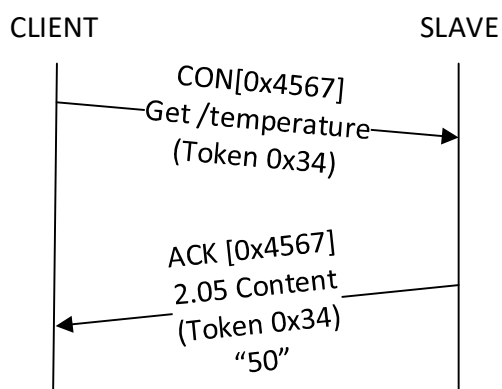
Advantages of TCP:

- Packet error recovery.
- Supports HTTP, MQTT and TLS.

Advantages of UDP:

- No need for connection establishment handshake for each message (less energy consumption).
- Header is smaller.

c)



3.

a)

i) L2

ii) L3

b)

i)

The distance between the centers of cells using the same frequencies is given, as well as the cell radius, so the cluster size  $G$  can be easily calculated:

$$\frac{D}{R} = \sqrt{3G} \Leftrightarrow G = \frac{\left(\frac{D}{R}\right)^2}{3} \approx 7$$

Knowing that the bandwidth of one channel is 200 kHz and the number of channels per cell, it is easy to calculate the bandwidth used by the system:

$$B = 200 \times 20 \times 7 = 28000 \text{ kHz}$$

ii)

We know that the number of servers (channels) is 20, so it is enough to look at the respective line in the table. We know the carried traffic  $C$ , so we can calculate the offered traffic  $A$  for each grade of service, to see which one is compatible with the offered traffic. Grade of service  $P = 0.002$  will not meet our traffic needs.  $P = 0.005$  looks promising:

$$A = \frac{C}{1 - P} = \frac{11,0445}{0.005} = 11.1$$

Indeed, we don't need to test  $P = 0.01$ , since  $P = 0.005$  is already able to carry the required offered traffic.

c)

For CQI 1, the efficiency is  $\varepsilon = 0,1523$ , which already includes the impacts of modulation and coding.

The total number of data bits to be transmitted is  $L = (20 + 20 + 3901) \times 8 = 31528$ , which includes the TCP/IP overhead.

With Normal CP, each Resource Block (RB) is a matrix with 12 subcarriers (in frequency) by 7 OFDM symbols (in time), which corresponds to a number of resource elements equal to  $N_{RE} = 12 \times 7 = 84$ .

The required number of RBs is thus:

$$N_{RB} = \left\lceil \frac{L}{\varepsilon \cdot N_{RE}} \right\rceil = 2465$$

4.

a)

$$h = 0,5 \cdot (20 - 10) \times 10^{-3} \times c \approx 1500000 \text{ m}$$

Note: This is in fact a LEO altitude.

$$r = R + h$$

$$F_g = F_c \Leftrightarrow m \cdot g \cdot \left(\frac{R}{r}\right)^2 = m \cdot r \cdot \omega^2 \Leftrightarrow \omega \approx 9,0 \times 10^{-4} \text{ rad/s}$$

$$\omega_{Earth} = \frac{2\pi}{24 \times 3600} \approx 7,28 \times 10^{-5} \text{ rad/s}$$

$$T = \frac{2\pi}{\omega - \omega_{Earth}} \approx 7561,4 \text{ s}$$

b)

Knowing the beamwidth ( $2 \times \alpha_{div}$ ), the footprint diameter corresponds to the projection of that width on the surface of the Earth. If the curvature of the Earth surface is not taken into account, the footprint diameter can be approximated as follows:

$$Footprint_D \approx h \times 2 \times \alpha_{div} = 575958,65 \text{ m}$$

The area is then calculated as:

$$Footprint_A \approx \pi \times \left(\frac{Footprint_D}{2}\right)^2 = 2,61 \times 10^{11} \text{ m}^2$$

c)

$$\lambda = \frac{300000000}{1500000000} = 0,2 \text{ m}$$

$$G_t = G_r \approx \left(\frac{360^\circ}{22^\circ}\right)^2 = 267,77$$

$$P_r(\text{dBm}) + 6 = P_t(\text{dBm}) + 10 \cdot \log_{10} \left( \frac{G_t \cdot G_r \cdot \lambda^2}{(4 \cdot \pi \cdot d)^2} \right) - A_t \Leftrightarrow -84,93 + 6$$

$$= P_t(\text{dBm}) + 10 \cdot \log_{10} \left( \frac{267,77 \cdot 267,77 \cdot 0,2^2}{(4 \cdot \pi \cdot 1500000)^2} \right) - 10 \Leftrightarrow P_t(\text{dBm}) \approx 42 \text{ dBm}$$