1.

a)

“0” is negative and “1” is positive. Since the transmitted signal results from the product between the numerical value of the data bit (-1 for “0”, +1 for “1”) and the key, it is easy to conclude that:

$$K(A) = (+1, -1, +1, -1, -1, +1, -1, +1)$$

$$K(B) = (-1, +1, +1, -1)$$

Note: The spreading factors are different, since A transmits one bit as 8 chips, while B transmits 1 bits as 4 chips.

b)

$$R = (R1, R2) = (+1, -2, 0, 0, +2, 0, -2, +2)$$

$$D(A) = \sum R \cdot K(A) = +5 > +2 \rightarrow \text{"1"}$$

$$D1(B) = \sum R1 \cdot K(B) = (+1, -2, 0, 0) \cdot (-1, +1, +1, -1) = -3 < -2 \rightarrow \text{"0"}$$

$$D2(B) = \sum R2 \cdot K(B) = (+2, 0, -2, +2) \cdot (-1, +1, +1, -1) = -6 < -2 \rightarrow \text{"0"}$$

The data were received correctly.

c)

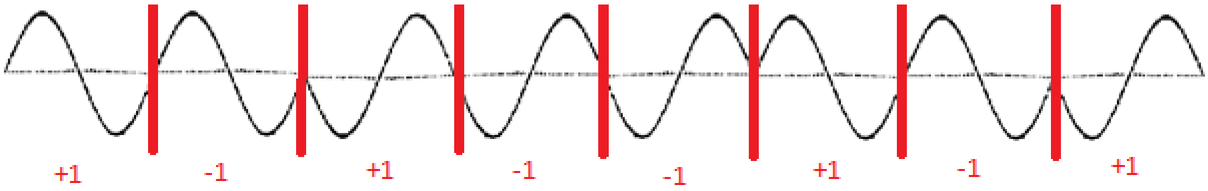
$$\begin{aligned} R_{theo} = S(A) + S(B) &= D(A) * K(A) + \big(D1(B), D2(B)\big) * \big(K(B), K(B)\big) \\ &= (+1,+1,+1,+1,+1,+1,+1,+1) * (+1,-1,+1,-1,-1,+1,-1,+1) \\ &+ (-1,-1,-1,-1,-1,-1,-1,-1) * (-1,+1,+1,-1,-1,+1,+1,-1) \\ &= (+2,-2,0,0,0,0,-2,+2) \end{aligned}$$

$$R = (+1, -2, 0, 0, +2, 0, -2, +2)$$

$$N = R - R_{theo} = (-1,0,0,0,2,0,0,0)$$

d)

Station A will transmit +1,-1,+1,-1,-1,+1,-1,+1. Assuming that logical “1” (+1) corresponds to phase change:



2.

a)

We will use the log-distance path loss model, since $\boldsymbol{d_0}$ and $\boldsymbol{PL_0}$ are given.

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

$$-60 = 10 \cdot log_{10}(20) - 15 + 0 + 0 - 10 \cdot 4 \cdot log_{10}\left(\frac{d}{1}\right) \Leftrightarrow$$

$$d \approx 28{,}2\ m$$

b)

Firstly, we have to calculate the bit error ratio (BER), based on E_b/N_0. In order to calculate E_b, we need the time of one bit. We know the modulation, which is QPSK, hence:

$$B = \left(\frac{1+r}{log_2(M)}\right) \cdot R_b \Leftrightarrow 200000 = \left(\frac{1+1}{log_2(4)}\right) \cdot R_b \Leftrightarrow R_b = 200000\frac{bit}{s}$$

$$T_b = \frac{1}{R} = 5 \times 10^{-6} s$$

We also need the received power:

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

$$= 10 \cdot log_{10}(20) - 15 + 0 + 0 - 10 \cdot 4 \cdot log_{10}\left(\frac{15}{1}\right) \approx -49\ dBm$$

$$\frac{E_b}{N_0} = \frac{T_b \times P_r}{N_0} = \frac{5 \times 10^{-6} \times 10^{\frac{-49}{10}}}{10^{\frac{-110}{10}}} \approx 6{,}25$$

Now, we can calculate the BER:

$$BER_{QPSK} = Q\left(\sqrt{\frac{2 \cdot E_b}{N_0}}\right) = Q(3{,}53) \approx 2{,}33 \times 10^{-4}$$

Now, we only need the packet length in order to calculate the FER. Since each data packet has only 70 data symbols and each QPSK symbol represents two bits, the packet length is 140 bits. The FER can now be calculated:

$$FER = 1 - (1 - BER)^{140} \approx 0{,}032$$

c)

The raw throughput of each robot is equal to the number of bits that it transmits per frame, divided by the period of one superframe, which corresponds to its duration. The first thing to do is to calculate the duration of the superframe, knowing that it carries 5 frames (1 downlink and 4 uplonk). The duration of the frame corresponds to the duration of 80 symbols.

$$B = \left(\frac{1+r}{log_2(M)}\right) \cdot R_b = (1+\mathrm{r}) \cdot R_s \Leftrightarrow R_s = \frac{B}{1+r} \Leftrightarrow T_s = \frac{1+r}{B} = \frac{2}{200000} = 1 \times 10^{-5}\ s$$

$$T_{frame} = 80 \times T_s = 80 \times 10^{-5}\ s$$

$$T_{superframe} = 5 \times T_{frame} = 4 \times 10^{-3}\ s$$

$$Th_{raw} = \frac{140}{4 \times 10^{-3}} = 35\frac{kbit}{s}$$

The effective throughput is equal to the raw throughput multiplied by the probability of successful frame reception:

$$Th_{eff} = Th_{raw} \times (1 - 0{,}1) = 31{,}5\ kbit/s$$

d)

This is calculated directly from the expression that relates the physical and effective area of the antenna with the gain:

$$\boldsymbol{\eta \times \mathrm{A}_{phy} = \frac{\lambda^2}{4\pi} G \Leftrightarrow 0,5 \times \mathrm{A}_{phy} \approx 9,5 \times 10^{-3} \times 10^{\frac{2}{10}} \Leftrightarrow \mathrm{A}_{phy} \approx 0,03\ m^2}$$

3.

a)

One must not forget that although the total effective bandwidth is 40 MHz, the system hops through a sequence of 4 independent frequency channels. From the point of view of the baseband MFSK modulation, only ¼ of the bandwidth is being used.

$$\boldsymbol{T_s = 2 \times T_b = 2 \times \frac{1}{R_b} = 2 \times \frac{1}{B/4}\left(\frac{(1+r)\cdot M}{log_2(M)}\right) = 2 \times \frac{1}{\frac{40 \times 10^6}{4}} \cdot \left(\frac{(1+1)\cdot 4}{2}\right) = 0.8\mu s}$$

$$\boldsymbol{T_c = 2 \cdot T_s = 1.6\mu s}$$

$$\boldsymbol{T_b = \frac{T_s}{2} = 0.4\mu s}$$

b)

The system employs slow frequency hopping, since $T_c > T_s$.

c)

Flat Fading, since $B_{coherence} > 10 \cdot B$.

Fast Fading, since $T_{coherence} < 10 \cdot T_b$.

d)

The average SNIR of the FHSS system is approximately four times that of the narrowband system. Assuming that the thermal noise power is negligible compared with the interference power:

$$\overline{SNIR_{FHSS-MFSK}} \approx \frac{P_r}{\frac{I}{4}} = 4\frac{P_r}{I}$$

$$\overline{SNIR_{NB-MFSK}} \approx \frac{P_r}{I}$$

4.

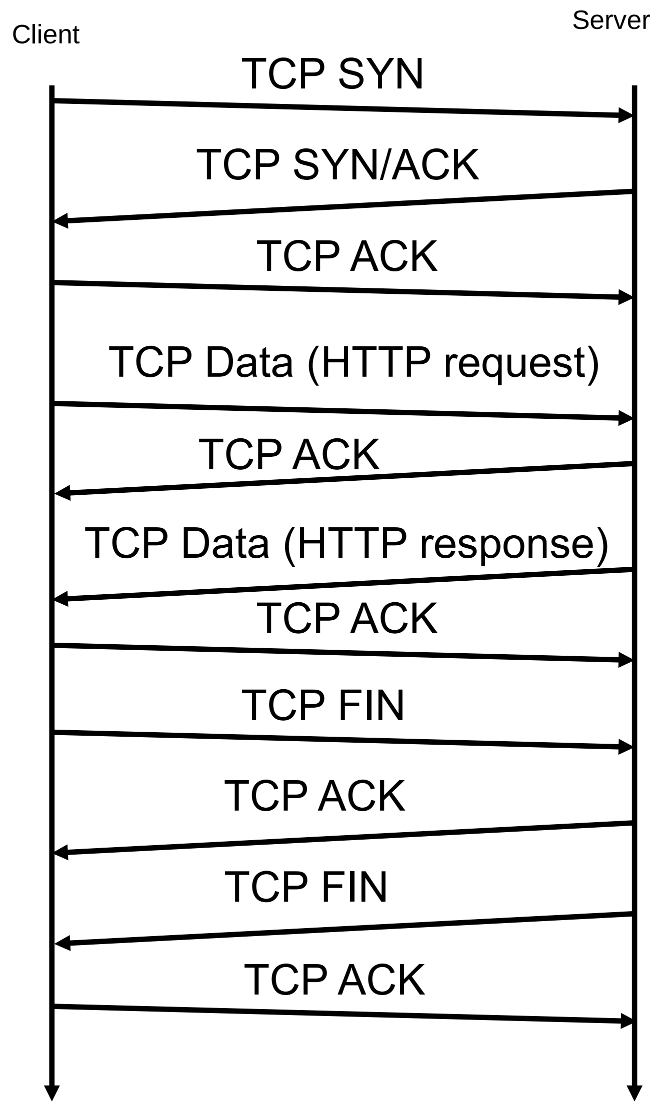
a)

Host H can use DHCP. A possible address at its current subnet is 10.1.0.1.

b)

Host H can send an address resolution request to a DNS server.

c)



d)

One must take into account that if more than one routing table entry matches the destination address, the longest match prevails. This rule must be considered when the packet is forwarded by R3. In this case, the packet goes to R1. At R1, there is an entry matching 24 bits of the destination address, pointing to R2. At R2, the packet is sent to the interface which has the same subnet address of the server S. The complete path is: H_R3_R1_R2_S.