1.

$$K_A = (+1, -1, +1, -1, +1, +1, +1, +1)$$

$$D_A = ("1", "1") = (+1, +1, +1, +1, +1, +1, +1, +1)$$

$$K_B = (-1, -1, +1, +1, +1, +1, -1, -1)$$

$$D_B = ("0", "1") = (-1, -1, -1, -1, +1, +1, +1, +1)$$

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

a)

$$R = K_A * D_A + K_B * D_B + N = (+2, +2, -1, -2, +1, +2, +1, +1)$$

b)

$$R = (+2, +2, -3, -2, +1, +1, +2, +1)$$

$$R_A^1 = K_A^1 \cdot R^1 = (+1, -1, +1, -1) \cdot (+2, +2, -3, -2) = -1 \in [-3, +3] \rightarrow ?$$

$$R_A^2 = K_A^2 \cdot R^2 = (+1, +1, +1, +1) \cdot (+1, +1, +2, +1) = +5 > +3 \rightarrow "1"$$

$$R_B^1 = K_B^1 \cdot R^1 = (-1, -1, +1, +1) \cdot (+2, +2, -3, -2) = -9 < -3 \rightarrow "0"$$

$$R_B^2 = K_B^2 \cdot R^2 = (+1, +1, -1, -1) \cdot (+1, +1, +2, +1) = -1 \in [-3, +3] \rightarrow ?$$

c)

The correct answer is (+1, +1, +1, +1, -1, +1, -1, +1). This is the only key that is completely orthogonal half-by-half (SF=4) with the keys of A and B. This can be easily checked by calculating the internal products.

d)

$$R_c = R_b \cdot SF = 2000000 \cdot 4 = 8\ Mchip/s$$

e)

By spreading the signal over a significantly wider bandwidth and keeping the power constant, the power spectral density can be reduced, sometimes towards levels that approach the noise spectral density, making the signal difficult to detect. On the other hand, in order to decode the signal, the interceptor must know the spreading key, which may be a secret key known only to the sender and to the receiver.

2.

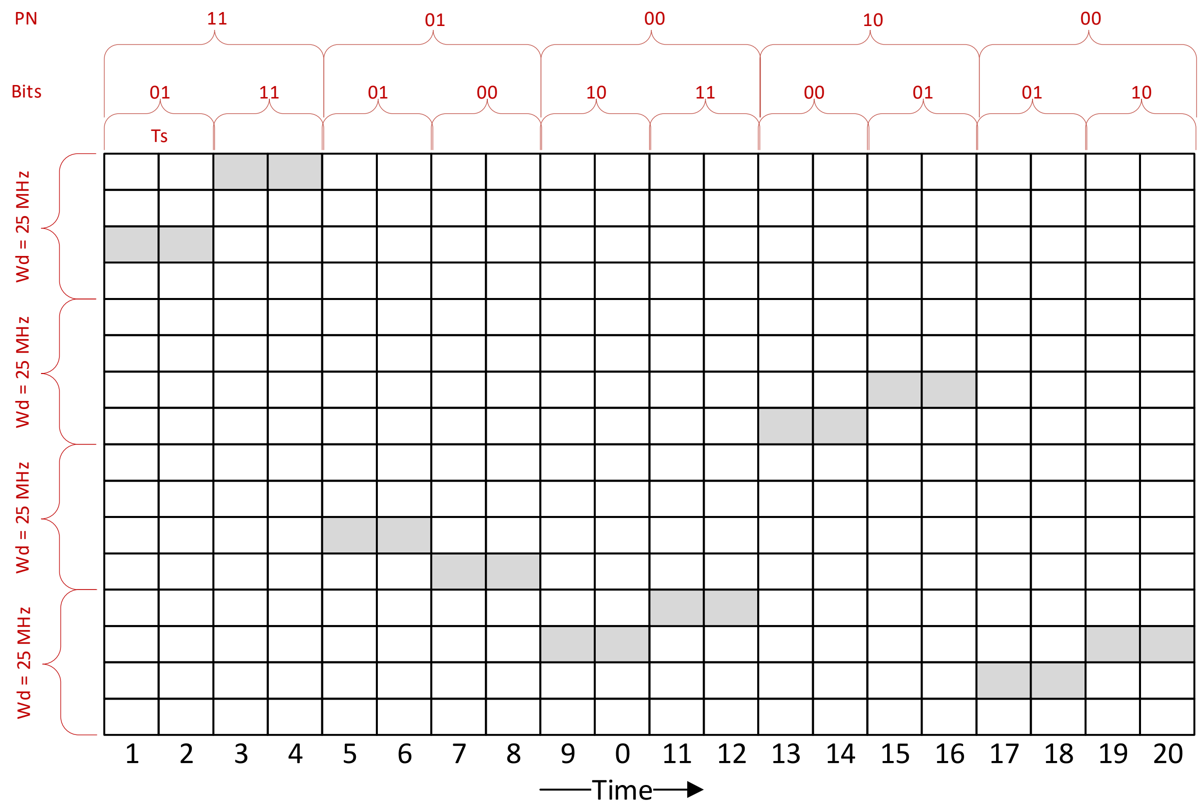
a)

4-FSK means FSK encoding with $M = 4$ symbols. The number of bits per symbol is $L = log_2(M) = 2$.

b)

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

c)



3.

a)

Network Server

b)

8 ms

c)

SF7

d)

SF11

4.

a)

Each image is 65536 bytes and each fragment is 2048 bytes, thus:

$$N_{frag} = \frac{65536}{2048} = 32$$

b)

Since, the image size is 65536 byte, which is a multiple of 2048, we have that:

$$Application\ packet\ size\ (l) =\ 2048\ byte = 16384\ bit$$

Since the fragmentation is done at the application layer, we don't need to worry with it at the MAC layer, i.e., each fragment is sent in a separate IP packet, i.e., in a separate MAC MSDU. The duration of a packet transmission is thus:

$$T_{packet}\ =\ DIFS\ +\ Backoff\ +\ PHo + \frac{(MACh\ +\ RTP/UDP/IP\ +\ l)}{R}\ +\ SIFS\ +\ PHo + \frac{ACK}{R} =$$

$$= 0.034\ +\ 0.067\ +\ \left(0.096\ + \frac{34\times 8\ +\ 40\times 8\ +\ 16384}{11000000}\right) +\ 0.016\ +\ 0.096 + \frac{14\times 8}{11000000} \approx 1.862\ ms$$

$$Throughput\ =\ \frac{16384}{1.862}\ kbps \approx 8.797\ Mbit/s$$

c)

$N = \lfloor 11/8.797 \rfloor = 8\ cameras$

d)

$FER_{MAC} = (FER_{PHY})^{1+7} = 0.05^8 = 3.91 \times 10^{-1}$

5.

a)

i) L3

ii) L2

b)

i)

In order to calculate the area, we will need to calculate the transmission range. The problem data includes the parameters of the log-distance path loss model, which we can apply directly.

$$P_r\ [dBm] = P_t\ [dBm] - PL_0 + G_t\ [dBi] + G_r\ [dBi] - 10 \cdot \alpha \cdot log_{10}\left(\frac{d}{d_0}\right) \Leftrightarrow \text{d}$$
$$= d_0 \cdot 10^{\frac{-P_r\ [dBm] + P_t\ [dBm] - PL_0 + G_t\ [dBi] + G_r\ [dBi]}{10 \cdot \alpha}} = 1 \cdot 10^{\frac{80+30-30+5+}{10 \cdot 3}} \Leftrightarrow d$$
$$= 1000\ m$$

Now, we just have to calculate the area of the hexagon:

$$A_{cell} = 1.5 \cdot \sqrt{3} \cdot d^2 \approx 2.6 \times 10^6\ m^2$$

ii)

Each Resource Block (RB) spans 12 subcarriers, and the maximum data rate is achieved with Normal CP, allowing 7 OFDM symbols per RB. In each subcarrier, each OFDM symbol corresponds to a QPSK modulation symbol, i.e., 2 bits. 2x2 MIMO allows two parallel streams. The duration of an RB corresponds to the duration of a slot, i.e., 0.5 ms. The maximum achieved data rate per RB can thus be calculated as follows:

$$R_{RB} = \frac{2 \cdot 7 \cdot CR \cdot MIMO}{T_{slot}} = \frac{12 \cdot 2 \cdot 7 \cdot 0.1885\ \cdot 2}{0.5} \approx 127\ kbit/s$$