1.

a)

$$R_c = R_b \times SF = Rb \times 4 = 8\ Mchip/s$$

b)

BPSK: M=2

r=0

With spreading, we must consider that chips, not bits, are the modulating signal elements, one chip in each modulation symbol. So, instead of calculating the bandwidth based on the bit rate ($\boldsymbol{R_b}$) directly, we use the chip rate ($\boldsymbol{R_c}$).

$$\boldsymbol{B_{BPSK}} = \left(\frac{\mathbf{1}+\boldsymbol{r}}{\boldsymbol{log_2(M)}}\right) \cdot \boldsymbol{R_c} \Leftrightarrow 8 \times 10^6 = \left(\frac{\mathbf{1}+\mathbf{0}}{\boldsymbol{log_2(2)}}\right) \cdot \boldsymbol{R_c}$$

$$R_c = 8\ Mchip/s$$

$$B = 8\ MHz$$

Without spreading, we calculate the bandwidth based on the bitrate ($\boldsymbol{R_b}$):

$$\boldsymbol{B_{BPSK}} = \left(\frac{\mathbf{1}+\boldsymbol{r}}{\boldsymbol{log_2(M)}}\right) \cdot \boldsymbol{R_b} \Leftrightarrow \left(\frac{\mathbf{1}+\mathbf{0}}{\boldsymbol{log_2(2)}}\right) \cdot \boldsymbol{R_b}$$

$$R_b = 2\ Mbit/s$$

$$B = 2\ MHz$$

c)

$$S + N = (-1, +1, -1, +1, +1, -1, +1, -1) + (0, 0, -2, -1, 0, 0, 0, 0) = (-1, +1, -3, 0, +1, -1, +1, -1)$$

$$RB_{0..3} = KB_{0..3} \cdot (S+N)_{0..3} = (+1, +1, +1, +1) \cdot (-1, +1, -3, 0) = -3 \rightarrow ?$$

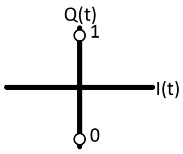
$$RB_{4..7} = KB_{4..7} \cdot (S+N)_{4..7} = (-1, -1, -1, -1) \cdot (+1, -1, +1, -1) = 0 \rightarrow ?$$

Station B is unable to interpret the bit values, since the decoding thresholds are not met in any of the transmitted bits

d)

$$SA + SB + N = SA + KB * DB + N$$
$$= (-1, +1, -1, +1, +1, -1, +1, -1) + (+1, +1, +1, +1, -1, -1, -1, -1)$$
$$* (+1, +1, +1, +1, +1, +1, +1, +1) + (0, 0, -2, -1, 0, 0, 0, 0)$$
$$= (0, +2, -2, +1, 0, -2, 0, -2)$$

e)



2.

a) At $\frac{E_b}{N_0} = \mathbf{15}$ dB, 4-DPSK is the most spectral efficient DPSK modulation possible that still respects the defined symbol error rate.

$$\frac{R}{W} = 2 \Leftrightarrow R = W \cdot 2 \Leftrightarrow R = 12000000 \cdot 2 = 24\ Mbit/2$$

b)

It is achieved with 16-QAM, which has 16 symbols, encoding 4 bits per symbol. The spectral efficiency is $\frac{R}{W} = 4$.

c)

1 symbol = 3 bits

$$1 - P_M = (1 - BER)^3 \Leftrightarrow P_M \approx 3 \times 10^{-5}$$

3.

a)

The theoretical maximum capacity is calculated with Shannon's formula, which needs the SNR and the bandwidth. In order to calculate the SNR, we need the received power. The problem description implies a log-distance path loss model, since it establishes the propagation model (free space) within a reference distance ($d0$), and indicates the path loss exponent beyond that distance ($\alpha = 3$). The first step is to calculate the wavelength, since then we can calculate the path loss at $d0$. The wavelength is $\lambda = \frac{300000000}{3500000000} \approx 0{,}086\ m$. The path loss at $d0$ is given: $PL0 = 103\ dB$.

We can now apply the log-distance model and calculate the received power:

$$\mathrm{Pr}[dBm] = Pt[dBm] + Gt + Gr - PL0 - 10 \cdot \alpha \cdot log10\left(\frac{d}{d0}\right)$$
$$\approx 26 + 2 \times 13 - 103 - 10 \cdot 3 \cdot log10\left(\frac{2000}{100}\right) \approx -90\ dBm$$

In order to calculate the noise power, we need the bandwidth:

$$B = \frac{6000 - 100}{2} = 2950\ kHz$$

The noise power is then calculated as follows:

$$N = N0 \cdot B = 10^{\frac{-170}{10}} \cdot 2950000 = 2{,}95 \times 10^{-11}\ mW$$

We can now apply Shannon's formula to calculate the capacity:

$$C = B \cdot log2\left(1 + \frac{Pr}{N}\right) \approx 2950000 \cdot log2\left(1 + \frac{10^{\frac{-90}{10}}}{2{,}95 \times 10^{-11}}\right) \approx 15{,}1\ Mbit/s$$

b)

Since we have calculated the received power in a), which is $Pr \approx -90\ dBm$, it is now a question of comparing this power with the receiver sensitivities of the different transmission modes. The maximum bitrate that can be used corresponds to 18 Mbit/s.

c)

$$Ae = G\frac{\lambda^2}{4\pi} \approx 0{,}012\ m^2$$

$$Aphy = \frac{Ae}{\mu} = \frac{Ae}{0{,}8} \approx 0{,}015\ m^2$$

d)

R=6 Mbit/s -> $\frac{R}{B} = \frac{6000000}{2950000} \approx 2{,}0\ bit/Hz$

R=12 Mbit/s -> $\frac{R}{B} = \frac{12000000}{2950000} \approx 4{,}1\ bit/Hz$

R=18 Mbit/s -> $\frac{R}{B} = \frac{18000000}{2950000} \approx 6{,}1\ bit/Hz$

R=24 Mbit/s -> $\frac{R}{B} = \frac{24000000}{2950000} \approx 8{,}1\ bit/Hz$

4.

a)

Since the HTTP session is bidirectional, the paths CN→MN and MN→CN must be analyzed separately and both must be feasible:

- CN->MN: An IP packet issued by CN is initialized with TTL=100 in the header. Remind that the tunnel between the HA and FA counts only 1 hop from the perspective of the inner IP packet (i.e., the original IP packet). The packet must follow the segments CN→HA (25 hops), HA→FA (1), FA→MN (7). This gives a total of 33 hops, which is less than 100. Consequently, this direction does not present any obstacles.
- MN→CN: The IP packet issued by the MN directly towards the CN, traversing MN→CN (90 hops). Consequently, the reverse direction is also feasible.

Conclusion Since both directions are feasible, the HTTP session can be established between the CN and the MN.

b)

Packet	**Outer Source Address**	**Outer Destination address**	**Inner Source Address**	**Inner Destination address**
CN→HA	146.64.4.6	193.154.3.10	N/A	N/A
HA→FA	193.154.3.1	195.137.10.2	146.64.4.6	193.154.3.10
FA→MN	146.64.4.6	193.154.3.10	N/A	N/A
MN→FA	193.154.3.10	146.64.4.6	N/A	N/A
FA→HA	195.137.10.2	193.154.3.1	193.154.3.10	146.64.4.6
HA→CN	193.154.3.10	146.64.4.6	N/A	N/A

c)

There is no Foreign Agent in MIPv6. The tunnels are established between the HA and MN.