1.

a)

OLSR is proactive, since link state information is disseminated among the nodes, even if no data is generated.

b)

- Hello messages: exchanged between neighbors, serve link sensing, permit each node to learn the knowledge of its neighbors up to two-hops (neighbor detection), Indicate selected multipoint relays.
- Link state messages: disseminated across the network by MPRs, carry sufficient link-state information to allow route calculation to all nodes in the network.

c)

MPRs optimize flooding of link state messages. MPRs are the nodes selected to broadcast these messages. Other nodes do not broadcast. In this way, the total number of broadcast transmissions is reduced, while still allowing link-state information to reach all the nodes.

d)

The MPRs of node E are nodes H and A. Node H must be an MPR because it is the only one-hop neighbor that allows to reach nodes J and K, which are two-hop neighbors of node E. Node A is selected by the algorithm after node H is selected because, among the remaining one-hop neighbors, it is the one that allows node E to reach all the remaining two-hop neighbors, in this case nodes B and C. Notice that one-hop neighbor F only allows access to two-hop neighbor B, and one-hop neighbor D only allows access to two-hop neighbor C.

2.

a)

DR4 employs SF8, which means that it will encode 8 bits in one LoRa symbol (chirp).

b)

The maximum uplink packet rate (in packets per second) when using DR3, maximum packet size, no acknowledgements, and with 100% duty cycle, is $\frac{1}{2{,}8} \approx 0{,}36$ packets/s. With 1% duty cycle, it is simply $0{,}36 \times 1\% = 0{,}0036$ packets/s.

c)

The Network Server.

d)

Class A devices do not have to wake up periodically to synchronize with gateways or receive downlink data; they sleep most of the time and only wake up when they have data to send. They only receive downlink packets as response to the uplink packets.

Class B devices, besides waking up to send data, also wake up periodically to receive downlink packets from the gateways, thus not having to wait for uplink traffic being generated. Nevertheless, waking up periodically causes additional energy consumption.

Class C devices are supposed to remain active all the time, which decreases the communication latency, while causing this class to be the less energy-efficient.

e)

SF7, the fastest one, since it reduces the Time-on-Air of transmitted packets. In this way, more packets can be transmitted during the same time interval, and, for the same number of transmitted packets, collisions are less probable.

3.

a)

i) L4

ii) L3

b)

i)

We need to calculate the area of the cell (A_t), M, and the number frequencies used in the cell (N_f^{cell}).

$A_t = 1.5 \times R^2 \times \sqrt{3} = 649519{,}1$ m^2

and

$M = RF_p \cdot 1200 = \frac{1}{3} \cdot 1200 = 400,$

where RF_p is the reuse factor for the 1200 frequencies reserved for use at the periphery of cells.

$N_f^{cell} = M + 2400 = 2800.$

Then:

$\frac{\boldsymbol{M}}{N_f^{cell}} \boldsymbol{A_t} = 92788{,}44$ m^2

ii)

In order to calculate the radius of the central hexagon (R_c), we firstly have to calculate the area of the central hexagon (A_c), which is simply:

$A_c = A_t - A_p = 556730{,}6$ m^2.

Now, just apply the formula that relates the area of a hexagon with its radius:

$A_c = 1.5 \times {R_c}^2 \times \sqrt{3} \Leftrightarrow R_c = 462{,}91$ m,

which makes sense, since it is less than 500 m.

iii)

The cluster size, taking into account the frequency use pattern at the peripheries of the cells is $G_p = \frac{1}{RF_p} = 3$.

Now, it is easy:

$\mathrm{D} = R\sqrt{3G} = 1500\ m.$

4.

a)

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

$F_g = F_c \Leftrightarrow m \cdot g \cdot \left(\frac{R}{r}\right)^2 = m \cdot r \cdot \omega^2 \Leftrightarrow d = r - R = \sqrt[3]{\frac{g \cdot R^2}{\omega^2}} - R = \sqrt[3]{\frac{9.81 \cdot 6370000^2}{0.000824^2}} - 6370000 \approx 2000\ km,$

which indeed corresponds to a LEO orbit.

b)

This is an easy one:

$$\omega T = 2\pi \Leftrightarrow T = 7626s$$

c)

$$P_r(dBm) = P_t(dBm) + 10 \cdot log_{10}\left(\frac{G_t \cdot G_r \cdot \lambda^2}{(4 \cdot \pi \cdot d)^2}\right) - At \Leftrightarrow -82{,}28$$

$$= 43 + 10 \cdot log_{10}\left(\frac{G_t \cdot G_r \cdot \left(\frac{300000000}{1000000000}\right)^2}{(4 \cdot \pi \cdot 2000)^2}\right) - 10 \Leftrightarrow G_t = G_r = 144 = 21{,}6\ dBi$$

d)

The gain is directly related to the beamwidth or divergence angle, which is assumed to be the same in the vertical and horizontal planes. We must first obtain the gain in one plane:

$G_t = G_r = \left(G_{(1plane)}\right)^2 \Leftrightarrow G_{(1plane)} = 12.$

We can now calculate the beamwidth:

$$G_{(1plane)} = \frac{2\pi}{\theta_{div}} \Leftrightarrow \theta_{div} = \frac{2\pi}{G_{(1plan\ )}} \approx 0{,}52\ rad \approx 29{,}8\text{º}$$