1.

a)

The IPv6 header is even longer than the IPv4 header (40 bytes), mainly due to the source and address fields (each of 128 bits). Since the maximum PHY payload size of IEEE 802.15.4 is 127 bytes, 40 bytes will take a significant fraction that could otherwise be used for useful data. On the other hand, even if the data is very short and 127 bytes are enough, the IPv6 header contributes to increase the frame error rate and energy expenditure, which can be significant in such low power wireless sensor networks.

b)

Since communication is taking place between two global addresses, the complete IPv6 source and destination addresses must be included without compression in the 6LoWPAN header: in our scenario, where the source belongs to the IEEE 802.15.4 LoWPAN under analysis, the complete source address must arrive at the destination and the complete destination address is needed outside the LoWPAN in order to route the packet.

If the Edge Router supports more advanced 6LoWPAN processing, the source address could be omitted from the 6LoWPAN header. In this case, the Edge Router could easily recover the IPv6 prefix of the source (because it’s the same as that of its LoWPAN interface) and it could recover the source’s interface identifier from the source MAC address.

c)

With context-based compression, the nodes can keep a context database of 16 entries, where each entry (indexed by only 4 bits) can be associated with an address (namely a global address), including the respective prefix and interface identifier. Since all the nodes in the LoWPAN share the same context, an address can be compressed to the 4 bits of the respective context index.

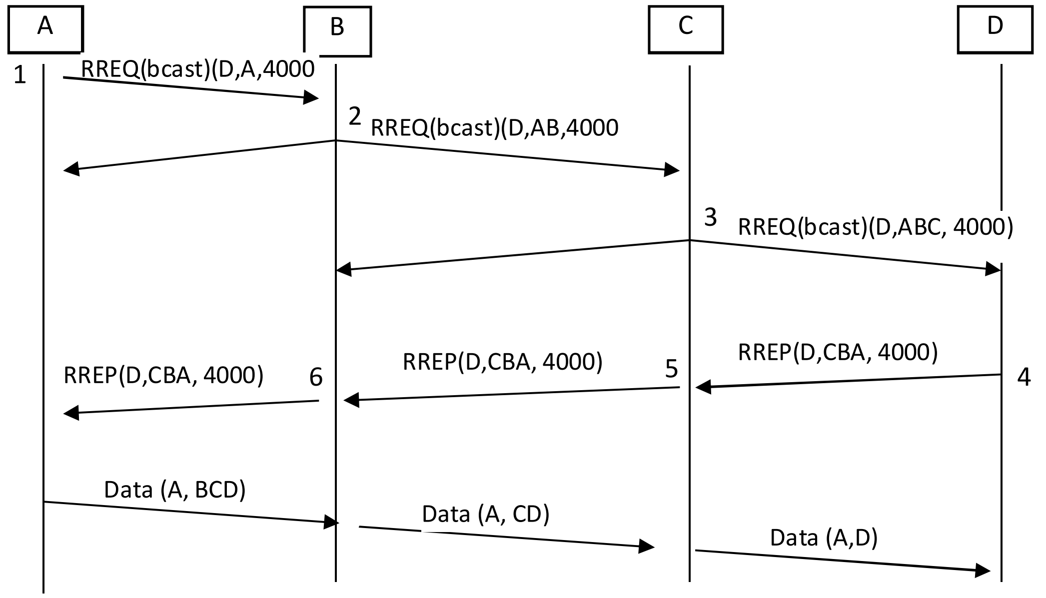
2.

a)

Reactive routing protocols only establish the routes when there is data traffic to use them, while proactive routing protocols establish the routes a priori, even when there is no data traffic being generated. The advantage of reactive protocols is that routing overhead is not incurred unnecessarily, but only if and when there is data to be transmitted. On the other hand, they incur on a delay penalty during the transmission of the first packets of a flow, since the route must be established on-the-fly. Proactive protocols do not incur on this delay penalty. However, their routing overhead may be very significant when data transmission is scarce.

b)

Parameters of the message RREQ (broadcast): Destination IP, Route, SeqNum



c)

The DSR implementations can make use of caching to keep known paths, allowing an intermediate node to respond with RREP even before the RREQ reaches the destination, when this intermediate node has a path towards the requested destination in its cache. However, the use of path caching demands some memory capacity to be reserved for that purpose.

3.

a)

In uplink transmission, the sender is the smartphone, which relies on a battery and thus has a limited transmit power in comparison with the base station. The lower frequencies are assigned to the uplink channels since they suffer less attenuation with distance, and thus require a lower transmit power to attain the same SNR at the receiver.

b) Considering the maximum possible cell size, its radius will correspond to the maximum transmission range of 35 km. The area of the cell can be easily calculated as follows:

$$\boldsymbol{A_{cell}} = \mathbf{1.5} \times \boldsymbol{R^2} \times \sqrt{\mathbf{3}} \approx 3182.64\, km^2$$

c)

We know that the available FDMA channels (16) will be divided among the cells in each cluster. We also know that each FDMA channel is able to support 8 concurrent calls, corresponding to the division of time into 8 independent TDMA slots. Consequently, we know how to calculate the maximum number of concurrent calls (*N*, equivalent to “number of servers”) supported in one cell, for each cluster size:

- $G = 3$: $N = \frac{16}{3} \times 8 \approx 42.67$
- $G = 4$: $N = \frac{16}{4} \times 8 = 32$
- $G = 7$: $N = \frac{16}{7} \times 8 \approx 18.29$

For P=0.01, we can see than $N = 20$ is enough to achieve $A = 12.3$, so we must select the option with the biggest possible cluster size (lowest interference) that still has $N \geq 20$. This corresponds to $\boldsymbol{G} = \mathbf{4}$.

4.

a)

The first step is to calculate the diameter of the footprint, based on the footprint's area, which is given:

$$FootprintArea = \pi \cdot \left(\frac{FootprintDiameter}{2}\right)^2 \Leftrightarrow FootprintDiameter \approx 785398\ m$$

Based on the diameter, we can apply the formula that relates it with the altitude of the satellite and the divergence angle:

$$\boldsymbol{FootprintDiameter = \theta_{div} \times d \Leftrightarrow \theta_{div} = \frac{785398}{1500000} \approx 30°}$$

b)

The gain is related with the divergence angle by:

$$G_{(1plane)} = 10 \cdot log_{10}\left(\frac{360°}{\theta_{div}}\right) \approx 10.8\ dBi$$

This is the gain taking into account only one plane, but we must take two planes into account:

$$\boldsymbol{G = 2 \times G_{(1plane)} \approx 21.6\ dBi}$$

c)

The key to solve the exercise is to calculate the angular speed of the satellite (ω):

$$r = \sqrt[3]{\frac{g \cdot R^2}{\omega^2}} \Leftrightarrow \omega = \sqrt{\frac{g \cdot R^2}{r^3}} \approx 0.0519\ °/s$$

The ground station will maintain connectivity with the satellite while it remains within its footprint. The footprint's diameter corresponds to an arc in the Earth's perimeter, whose fraction is calculated as follows:

$$\rho_{footprint} = \frac{FootprintDiameter}{2 \cdot \pi \cdot R} = \frac{785398}{40022710} \approx 0.0196$$

The corresponding angle is obtained as follows:

$$\theta = \rho_{footprint} \times 360° \approx 7.06°$$

Since the minimum elevation angle that allows communication is 10 degrees, we must also check that the arc considered above is contained within $180° - 2 \times 10° = 160°$, which is true.

The time that the satellite covers an arc of $7.06°$ is:

$$t_{connect} = \frac{7.06}{0.0519} \approx 136s$$