1.

a)

A Bluetooth SCO voice stream occupies 64 kbit/s in each direction. The HV2 packet has a payload of 20 octets. Based on this, we can easily calculate the HV2 packet period TP in one direction:

$$TP = \frac{20 \times 8}{64000} = 2.50ms$$

This corresponds to $\frac{2500}{625} = 4$ slots.

This means that in each sequence of 4 slots, two of these slots will be occupied by HV2 of the SCO session, respectively for downlink (i.e. master to slave) and uplink, which leaves 2 slots free for use by ACL links.

b)

The best case is to assume good channel conditions, allowing ACL data to be sent without FEC. Since there are only 2 slots available for ACL, only one of them can be used for transmissions from the PC, since the other is required for transmissions from the master device. No FEC means that the PC sends DH1 packets, whose maximum payload is 27 bytes. Since the period is 4 slots, the resulting bitrate is:

$$Th = \frac{27 \times 8}{4 \cdot 625 \times 10^{-6}} \approx 86{,}40 \text{ kbit/s}$$

c)

The Parked state allows a device to stay connected to the piconet, but in a power-saving mode, where it only passively keeps synchronization with the master, not being allowed to send any frames. While in the Parked state, the device is assigned an 8-bit Parked Member Address (PMA) and releases its 3-bit Active Member Address (AMA) for use by another device. A Parked device can later request to become Active again, being assigned the AMA.

The 8-bit PMA means that there can be a maximum of 256 Parked devices at any time in a piconet. The number of Active devices is restricted to 7 (the AMA has 3 bits, but the value 0 is reserved for broadcast transmissions from the master).

2.
a)

- Gateway: It performs the role of base station for the end devices, bridging between the LoRa air interface to the LoRaWAN network infrastructure. All traffic arriving from the end devices is sent to the Network Server. It also sends downlink traffic coming from the Network Server to the LoRa air interface.
- Network Server: It implements the LoRaWAN backend, including the MAC layer, being also responsible for LoRaWAN network management and control. At MAC layer, some of its important tasks are the following:
    - Elimination of duplicate uplink frames – since a frame can be received and forwarded to it by more than one Gateway.
    - Automatic Repeat Request (ARQ).
    - Adaptive Data Rate (ADR) and transmit power control.
    - Data traffic encapsulation (downlink) and decapsulation (uplink).

  At the network layer, the Network server performs routing and forwarding of uplink traffic to the Application Servers, as well as forwarding of downlink traffic from the Application Servers to the appropriate Gateways.
- Application Server: It constitutes the server side of the Application, storing and processing received uplink payloads, as well as storing and issuing downlink payloads.

b)
The receive windows allow the end device to receive acknowledgements of uplink frames, as well as downlink frames in an energy-efficient way. After transmitting an uplink frame, the end device starts a timer that makes it wake up just in time to open the first receive window (RX1). In case it successfully receives and decodes a downlink frame during RX1, it just goes to power save mode until the next uplink transmission. In case the reception during RX1 fails, the end device starts another timer, waking up just in time for the second receive window (RX2), where transmission is expected to be more robust, thus increasing the probability of successful downlink reception (at the expense of extra energy consumption). As to the Network Server, when it has downlink frames to send, it sends those frames twice, one in RX1 and another in RX2, hoping that the end device will receive the frame in one of them.

c)
The following data must be stored by the end device after activation:

- End--device address (DevAddr): identifies the end--device within the current network.
- Forwarding Network session integrity key (FNwkSIntKey): Uplink MIC key.
- Serving Network session integrity key (SNwkSIntKey): Downlink MIC key
- **Network session encryption key (NwkSEncKey): Encryption key between end device and Network Server (commands).**
- **Application session key (AppSKey): Encryption key between end device and Application Server (data).**

3.

a)

i) L1

ii) L3.

iii) L2.

iv) L4.

b) Transmit power control is a very important function in cellular networks, since it helps to mitigate interference and to save the battery power of the mobile terminal, while assuring the required link quality level. Open-loop power control is not as accurate as closed-loop power control, but can react quicker to fluctuations in signal strength (e.g., when the mobile unit is just coming out from behind a shadowing object, such as a building).

4.

a)

$h = 0{,}5 \cdot (50 - 10) \times 10^{-3} \times c \approx 6000000\ m$

Note: This is in fact a MEO altitude.

$$r = R + h$$

$$F_g = F_c \Leftrightarrow m \cdot g \cdot \left(\frac{R}{r}\right)^2 = m \cdot r \cdot \omega^2 \Leftrightarrow \omega \approx 4{,}6 \times 10^{-4}\ rad/s$$

$$\omega_{Earth} = \frac{2\pi}{24 \times 3600} \approx 7{,}28 \times 10^{-5}\ rad/s$$

$$T = \frac{2\pi}{\omega + \omega_{Earth}} \approx 11825{,}9\ s$$

b)

$$G_{(1pla\quad)} = \frac{360}{2 \times \alpha_{div}} = \frac{360}{21{,}55}$$

$$G = G_{(1pla\quad)}{}^2 \approx 279 \approx 24{,}46\ dBi$$

c)

$$\lambda = \frac{300000000}{2000000000} = 0{,}15\ m$$

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

$$= 40 + 10 \cdot log_{10}\left(\frac{279 \cdot 279 \cdot 0{,}15^2}{(4 \cdot \pi \cdot 6000000)^2}\right) \approx -95{,}1\ dBm$$

$$RS = -95{,}1 - 6 = -101{,}1\ dBm$$