Assignment 7: Bluetooth

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**1(a) What are the maximum speeds that can be achieved by Bluetooth?**

The maximum speed of Bluetooth depends on the version. Classic Bluetooth (Bluetooth 3.0 + HS) can achieve speeds of up to 24 Mbps by using an additional Wi-Fi channel. Bluetooth Low Energy (BLE) 5.0, on the other hand, can achieve data rates of up to 2 Mbps, though it is optimized for low power consumption rather than high throughput. (From GSM to LTE-Advanced Pro and 5G, 2021, p. 536)

**1(b) On what do they depend?**

The speeds depend on the version of Bluetooth, the modulation scheme used (e.g., GFSK for basic rates or 8DPSK for enhanced data rates), and whether the device is using Classic Bluetooth or BLE. The environment, such as interference and range, also impacts achievable speeds. (From GSM to LTE-Advanced Pro and 5G, 2021, p. 536)

**2. Describe the difference between the ‘classic’ Bluetooth and the Bluetooth low energy air interface?**

Classic Bluetooth is designed for continuous data transfer and is ideal for applications like audio streaming. BLE, on the other hand, is optimized for low-power, short-burst transmissions, making it suitable for devices like fitness trackers and smart sensors. BLE uses a different modulation technique and operates on smaller packet sizes, which enhances power efficiency. (From GSM to LTE-Advanced Pro and 5G, 2021, p. 557)

**3. How are data transferred over the BLE ATT protocol?**

Data is transferred in BLE using the Attribute Protocol (ATT), where each piece of data is stored as an attribute with a unique identifier (UUID). Devices exchange data by reading or writing to these attributes. ATT uses a client-server model where the client accesses data from the server’s attribute table. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 580-581)

**4. How can several data streams for different applications be transferred simultaneously by the L2CAP protocol?**

The Logical Link Control and Adaptation Protocol (L2CAP) allows for multiplexing multiple logical channels over a single Bluetooth connection. It provides channels with separate IDs for different services, allowing simultaneous data streams from multiple applications. Each channel is managed independently, making it possible to handle different types of traffic in parallel. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 542-543)

**5. How can several services use the RFCOMM layer simultaneously?**

RFCOMM (Radio Frequency Communication) is a serial port emulation protocol that allows multiple services to run simultaneously by creating multiple virtual serial ports. These virtual ports enable different services to use the same underlying Bluetooth connection while maintaining separate communication channels. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 552-554)

**6. What are the differences between the hands-free profile and the SIM-access-profile?**

The Hands-Free Profile (HFP) is used for audio communication between a phone and a hands-free device. It supports call handling, voice recognition, and audio routing. The SIM Access Profile (SAP), on the other hand, allows a remote device (e.g., a car's head unit) to access the SIM card of a phone for making calls, without needing to manage the network connection on the phone itself. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 572-573)

1. **What are the tasks of the link manager?**

The Link Manager Protocol (LMP) manages and controls the establishment of connections between Bluetooth devices. It handles tasks such as device authentication, encryption setup, power control, and link mode negotiation. It also manages the link states (e.g., active, hold, sniff, park) and handles paging and inquiry processes. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 543-543)

1. **What are the tasks of the service discovery database?**

The Service Discovery Protocol (SDP) enables Bluetooth devices to discover which services are available on another Bluetooth device. The service discovery database contains records of available services, including their UUIDs and associated attributes. Devices query the database to find and connect to specific services. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 554-555)

1. **What is FHSS and which enhanced functionalities are available with Bluetooth 1.2 in this regard?**

Frequency Hopping Spread Spectrum (FHSS) is a technique that spreads the signal over a wide range of frequencies, which helps to reduce interference from other devices operating in the same frequency band (2.4 GHz in the case of Bluetooth). FHSS divides the available spectrum into smaller frequency channels and hops between these channels in a predefined sequence, minimizing the chance of interference on any single frequency. The hopping occurs at a rapid rate, usually 1,600 times per second, making it harder for interference to degrade the signal quality. Bluetooth 1.2 introduced Adaptive Frequency Hopping (AFH), which improved on traditional FHSS by monitoring the environment for interference and dynamically avoiding frequency channels that are in use by other devices, such as Wi-Fi networks or microwave ovens. This makes Bluetooth communication more robust in environments where interference is common, ensuring a more stable connection and better performance, especially in busy wireless environments. (From GSM to LTE-Advanced Pro and 5G, 2021, p. 536)

1. **What is the difference between authentication and authorization?**

Authentication is the process of verifying the identity of a device or user. In Bluetooth, this is often done through methods such as password entry, pairing, or using encryption keys to ensure that the device attempting to connect is who it claims to be. For example, when two devices are paired for the first time, they exchange credentials to authenticate each other and establish trust. Authorization, on the other hand, occurs after authentication and determines the level of access that the authenticated device or user has. For instance, a device might be authenticated as a known entity, but it still needs to be authorized to access certain data or perform certain actions, such as reading messages, accessing files, or controlling another device. While authentication confirms identity, authorization controls permissions and access rights, ensuring that even trusted devices cannot perform unauthorized actions. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 563-565)

1. **What is the difference between inquiry and paging?**

Inquiry and paging are two essential processes in establishing Bluetooth connections.

* Inquiry: This is the process where a Bluetooth device searches for other devices in the vicinity. When a device enters inquiry mode, it sends out inquiry packets to discover nearby Bluetooth devices that are available for connection. The responding devices provide their Bluetooth addresses and device class information. This allows the inquiring device to identify potential connection targets, such as phones, speakers, or headsets.
* Paging: After a device has discovered another device via inquiry (or already knows its address), it enters the paging process to establish a connection. Paging involves the initiating device sending paging signals directly to the target device's Bluetooth address to synchronize and establish a physical link. Once a device responds to a paging request, they negotiate the connection parameters and establish a communication link. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 546-547)

1. **What is FHSS and which enhanced functionalities are available with Bluetooth 1.2 in this regard?**

Bluetooth devices, particularly Bluetooth Low Energy (BLE) devices, are designed with several power-saving mechanisms that allow them to operate efficiently, especially in applications that require long battery life.

* Sniff Mode: This mode allows a device to reduce its duty cycle by checking for data at defined intervals rather than continuously. It lowers power consumption by having the device “sniff” for signals periodically while remaining in a low-power state between these intervals. (From GSM to LTE-Advanced Pro and 5G, 2021, p. 577)
* Connection Interval: In BLE, the connection interval defines how often a device wakes up to communicate with a connected device. The longer the interval, the less frequently the device communicates, leading to significant power savings. Devices can be set to communicate only when needed, reducing active communication time and conserving battery life.
* Advertising Interval: In BLE, devices broadcast small data packets during an advertising phase when they are not connected to another device. The interval between these broadcasts can be adjusted to save power. Lower advertising frequency translates to less power consumption.
* Sleep States: BLE devices can enter deep sleep states between transmission events, which drastically reduces power consumption. These sleep states allow devices like fitness trackers or smart sensors to operate for extended periods (months or even years) on a small battery, since they are only active during necessary data exchanges.

These power-saving mechanisms, especially in BLE, are optimized to minimize energy consumption for applications that require minimal data transfer, such as wearables, health monitors, and IoT devices. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 577-589)

1. **What is FHSS and which enhanced functionalities are available with Bluetooth 1.2 in this regard?**

Several Bluetooth profiles facilitate the transfer of files and objects between devices:

* Object Push Profile (OPP): OPP is designed for simple data transfers such as business cards, images, or calendar events. It allows one device to push small objects to another device, commonly used for sharing contact information or pictures between phones.
* File Transfer Profile (FTP): FTP is used for more extensive file transfers and allows browsing of the file system of another device. With FTP, users can access, retrieve, and manage files on a remote Bluetooth-enabled device, similar to using traditional file transfer methods on computers. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 565-567)

1. **What is FHSS and which enhanced functionalities are available with Bluetooth 1.2 in this regard?**

Bluetooth profiles are necessary to ensure that devices can support a wide variety of use cases. Each profile defines the specific functions that a Bluetooth device can perform, ensuring compatibility between devices that may have different capabilities. The large number of profiles allows Bluetooth to be used across different industries and devices, each with distinct communication and functional requirements. For example:

* Audio profiles (such as A2DP) are designed for high-quality sound streaming.
* Data transfer profiles (such as OPP or FTP) focus on file sharing.
* Health Device Profile (HDP) enables the connection of medical devices to smartphones or computers.

Since each application requires a tailored set of capabilities and performance standards (e.g., low energy for wearables vs. high throughput for audio), Bluetooth profiles ensure that devices within a specific category can interoperate efficiently and deliver an optimized experience for their intended use. By having a variety of profiles, Bluetooth can adapt to different scenarios—ranging from low-power sensor networks to high-performance media streaming—making it highly versatile across industries and applications. (From GSM to LTE-Advanced Pro and 5G, 2021, pp. 565-567)

# References

From GSM to LTE-Advanced Pro and 5G. (2021). In M. Sauter, *And Introduction to Mobile Networks and Mobile Broadband* (pp. 15 - 100). Hoboken, New Jersey: John Wiley and Sons Ltd.