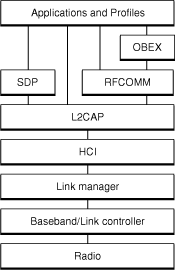
## Bluetooth Architecture:

### The Bluetooth Protocol Stack:

The heart of the Bluetooth specification is the Bluetooth protocol stack. By providing well-defined layers of functionality, the Bluetooth specification ensures interoperability of Bluetooth devices and encourages adoption of Bluetooth technology.



#### Lower Layers:

1. At the base of the Bluetooth protocol stack is the ***radio layer***. The radio module in a Bluetooth device is responsible for the modulation and demodulation of data into RF signals for transmission in the air.
2. The radio layer describes the physical characteristics a Bluetooth device’s receiver-transmitter component must have.These include modulation characteristics, radio frequency tolerance, and sensitivity level.
3. Above the radio layer is the *baseband* and ***link controller layer*.** The Bluetooth specification doesn’t establish a clear distinction between the responsibilities of the baseband and those of the link controller.
4. The best way to think about it is that the baseband portion of the layer is responsible for properly formatting data for transmission to and from the radio layer. In addition, it handles the synchronization of links.
5. The link controller portion of this layer is responsible for carrying out the link manager’s commands and establishing and maintaining the link stipulated by the link manager.
6. The *link manager* itself translates the host controller interface (HCI) commands it receives into baseband-level operations. It is responsible for establishing and configuring links and managing power-change requests, among other tasks

The Bluetooth specification defines two types of links between Bluetooth devices:

* ***Synchronous, Connection-Oriented (SCO)*,** for isochronous and voice communication using, for example, headsets.
* ***Asynchronous, Connectionless (ACL)*,** for data communication, such as the exchange of vCards.

Each link type is associated with a specific packet type.

* A SCO link provides reserved channel bandwidth for communication between a master and a slave, and supports regular, periodic exchange of data with no retransmission of SCO packets.
* An ACL link exists between a master and a slave the moment a connection is established.
* The***HCI (host controller interface)*** *layer* acts as a boundary between the lower layers of the Bluetooth protocol stack and the upper layers. The Bluetooth specification defines a standard HCI to support Bluetooth systems that are implemented across two separate processors. For example, a Bluetooth system on a computer might use a Bluetooth module‘s processor to implement the lower layers of the stack (radio, baseband, link controller, and link manager). It might then use its own processor to implement the upper layers (L2CAP, RFCOMM, OBEX, and selected profiles). In this scheme, the lower portion is known as the *Bluetooth module* and the upper portion as the *Bluetooth host*.

#### Upper Layers

Above the HCI layer are the upper layers of the protocol stack. The first of these is the***L2CAP (logical link control and adaptation protocol) layer***. The L2CAP is primarily responsible for:

1. Establishing connections across existing ACL links or requesting an ACL link if one does not already exist.
2. Multiplexing between different higher layer protocols, such as RFCOMM and SDP, to allow many different applications to use a single ACL link.
3. Repackaging the data packets it receives from the higher layers into the form expected by the lower layers

The L2CAP employs the concept of channels to keep track of where data packets come from and where they should go.

* The ***SDP (service discovery protocol)***defines actions for both servers and clients of Bluetooth services. The specification defines a service as any feature that is usable by another (remote) Bluetooth device.

1. A single Bluetooth device can be both a server and a client of services. An SDP client communicates with an SDP server using a reserved channel on an L2CAP link to find out what services are available.
2. When the client finds the desired service, it requests a separate connection to use the service. The reserved channel is dedicated to SDP communication so that a device always knows how to connect to the SDP service on any other device.
3. An SDP server maintains its own SDP database, which is a set of service records that describe the services the server offers. Along with information describing how a client can connect to the service, the service record contains the service’s ***UUID*, or *universally unique identifier*.**

* The **RFCOMM** protocol emulates the serial cable line settings and status of an RS-232 serial port. RFCOMM connects to the lower layers of the Bluetooth protocol stack through the L2CAP layer.By providing serial-port emulation, RFCOMM supports legacy serial-port applications. It also supports the OBEX protocol (discussed next) and several of the Bluetooth profiles.
* ***OBEX (object exchange)***is a transfer protocol that defines data objects and a communication protocol two devices can use to easily exchange those objects.

A Bluetooth device wanting to set up an OBEX communication session with another device is considered to be the client device.

1. The client first sends SDP requests to make sure the other device can act as a server of OBEX services.
2. If the server device can provide OBEX services, it responds with its OBEX service record. This record contains the RFCOMM channel number the client should use to establish an RFCOMM channel.
3. Further communication between the two devices is conveyed in packets, which contain requests and responses, and data. The format of the packet is defined by the OBEX session protocol.

**PICONET:**

A **piconet** is an [ad hoc network](https://en.wikipedia.org/wiki/Ad_hoc_network" \o "Ad hoc network) that links a [wireless user group](https://en.wikipedia.org/wiki/Wireless_user_group" \o "Wireless user group) of devices using [Bluetooth](https://en.wikipedia.org/wiki/Bluetooth" \o "Bluetooth) technology protocols. A piconet consists of two or more devices occupying the same physical channel (synchronized to a common clock and hopping sequence). It allows one *[master](https://en.wikipedia.org/wiki/Master_(device)" \o "Master (device))* device to interconnect with up to seven active *[slave](https://en.wikipedia.org/wiki/Slave_(device)" \o "Slave (device))* devices. Up to 255 further slave devices can be inactive, or *parked*, which the master device can bring into active status at any time, but an active station must go into parked first.

**MESH TECHNOLOGY:**

* Bluetooth Low Energy (LE) supports a mesh topology for establishing many-to-many (m:m) device communications.
* The mesh capability is optimized for creating large-scale device networks and is ideally suited for building automation, sensor network, and asset tracking solutions.
* Only Bluetooth mesh networking brings the proven, global interoperability and mature, trusted ecosystem associated with Bluetooth technology to the creation of industrial-grade device networks.​

**BLUETOOTH PROFILES:**

**A2DP(Advanced Audio Distribution Profile):**

* This profile defines how multimedia audio can be streamed from one device to another over a [Bluetooth](https://en.wikipedia.org/wiki/Bluetooth" \o "Bluetooth) connection (it is also called Bluetooth Audio Streaming).
* For example, music can be streamed from a [mobile phone](https://en.wikipedia.org/wiki/Mobile_phone" \o "Mobile phone), to a wireless [headset](https://en.wikipedia.org/wiki/Headphones" \o "Headphones), [hearing aid](https://en.wikipedia.org/wiki/Hearing_aid" \o "Hearing aid)/[cochlear implant](https://en.wikipedia.org/wiki/Cochlear_implant" \o "Cochlear implant) streamer, [car audio](https://en.wikipedia.org/wiki/Car_audio" \o "Car audio), or from a laptop/desktop to a wireless headset; also, voice can be streamed from a microphone device to a recorder on a PC.

**AVRCP(Audio/Video Remote Control Profile):**

This profile is designed to provide a standard interface to control TVs, Hi-fi equipment, etc. to allow a single [remote control](https://en.wikipedia.org/wiki/Remote_control" \o "Remote control) (or other device) to control all of the A/V equipment to which a user has access.

AVRCP has several versions with significantly increasing functionality:

* 1.0 — Basic remote control commands (play/pause/stop, etc.
* 1.3 — all of 1.0 plus metadata and media-player state support

The status of the music source (playing, stopped, etc.)

Metadata information on the track itself (artist, track name, etc.).

* 1.4 - all of 1.3 plus media browsing capabilities for multiple media players

Browsing and manipulation of multiple players

Browsing of media metadata per media player, including a "Now Playing" list

Basic search capabilities

Support for Absolute volume

* 1.5 — all of 1.4 plus specification corrections and clarifications to absolute volume control, browsing and other features
* 1.6 — all of 1.5 plus browsing data and track information

Number of items that are in a folder without downloading the list

**ATT(Attribute Profile):**

The ATT is a wire application protocol for the [Bluetooth Low Energy](https://en.wikipedia.org/wiki/Bluetooth_Low_Energy" \o "Bluetooth Low Energy) specification. It is closely related to Generic Attribute Profile (GATT).Every Low Energy profile must be based on GATT. So, ultimately, every LE service uses ATT as the application protocol.

The sole building block of ATT is the **attribute.** An attribute is composed by three elements:

* a 16-bit **handle; //Uniquely identifies an attribute**
* an **UUID** which defines the attribute **type; //Represents kind of data present**
* a **value** of a certaining **length. //Holds actual data content**

**DIP(Device ID Profile):**

* This profile allows a device to be identified above and beyond the limitations of the Device Class already available in Bluetooth.
* It enables identification of the manufacturer, product id, product version, and the version of the Device ID specification being met.
* It is useful in allowing a PC to identify a connecting device and download appropriate [drivers](https://en.wikipedia.org/wiki/Device_driver" \o "Device driver).

**Generic Audio Video Distribution Profile(GAVDP):**

GAVDP provides the basis for A2DP and VDP, the basis of the systems designed for distributing video and audio streams using Bluetooth technology.

The GAVDP defines two roles, that of an Initiator and an Acceptor:

* Initiator (INT) – This is the device that initiates a signaling procedure.
* Acceptor (ACP) – This is the device that shall respond to an incoming request from the INT

**Generic Attribute Profile(GATT):**

* It defines the way two BLE devices transfer data back and forth.Most important thing in GATT and connections is that BLE peripheral can only be connected to one centre device at a time.
* GATT comes into play once a dedicated connection is established between two devices.
* It defines how ATT attributes are grouped together.

**Health Device Profile(HDP):**

* Health Thermometer profile (HTP) and Heart Rate Profile (HRP) fall under this category as well.
* Profile designed to facilitate transmission and reception of Medical Device data.
* Also makes use of the Device ID Profile (DIP).

**Hands Free Profile(HFP):**

* A Bluetooth profile (mode) designed to enable a two-way wireless speaker-phone to be used with a Bluetooth phone.
* Although it can be used with a desktop speaker-phone accessory, its most common use is with car kits.
* A Bluetooth car kit will use HFP to connect to a Bluetooth phone, allowing phone calls to take place via the car's audio system (or an installed speaker) while the phone stays safely in a pocket or purse.

**Human Interface Device Profile(HID):**

* Provides support for devices such as [mice](https://en.wikipedia.org/wiki/Mouse_(computing)" \o "Mouse (computing)), [joysticks](https://en.wikipedia.org/wiki/Joystick" \o "Joystick), [keyboards](https://en.wikipedia.org/wiki/Computer_keyboard" \o "Computer keyboard), as well as sometimes providing support for simple buttons and indicators on other types of devices.
* It is designed to provide a low [latency](https://en.wikipedia.org/wiki/Latency_(engineering)" \o "Latency (engineering)) link, with low power requirements.
* [PlayStation 3](https://en.wikipedia.org/wiki/PlayStation_3" \o "PlayStation 3) controllers and [Wii](https://en.wikipedia.org/wiki/Wii" \o "Wii) remotes also use Bluetooth HID.

**Head Set Profile(HSP):**

* This is the most commonly used profile, providing support for the popular Bluetooth headsets to be used with mobile phones.
* It relies on SCO audio encoded in 64 kbit/s CVSD or PCM and a subset of [AT commands](https://en.wikipedia.org/wiki/Hayes_command_set" \o "Hayes command set) from GSM 07.07 for minimal controls including the ability to ring, answer a call, hang up and adjust the volume.

**Message Access Profile(MAP):**

* Message Access Profile (MAP) specification allows exchange of messages between devices.
* Mostly used for automotive handsfree use. The MAP profile can also be used for other uses that require the exchange of messages between two devices.

**Object Push Profile(OPP):**

* A basic profile for sending "objects" such as pictures, [virtual business cards](https://en.wikipedia.org/wiki/VCard" \o "VCard), or [appointment details](https://en.wikipedia.org/wiki/VCalendar" \o "VCalendar).
* It is called push because the transfers are always instigated by the sender (client), not the receiver (server).
* OPP uses the APIs of OBEX profile and the OBEX operations which are used in OPP are connect, disconnect, put, get and abort.

**Personal Area Networking Profile(PAN):**

This profile is intended to allow the use of [Bluetooth Network Encapsulation Protocol](https://en.wikipedia.org/wiki/Bluetooth_protocols" \l "Bluetooth_network_encapsulation_protocol_.28BNEP.29" \o "Bluetooth protocols) on [Layer 3](https://en.wikipedia.org/wiki/Network_layer" \o "Network layer) protocols for transport over a Bluetooth link.

**Phone Book Access Profile(PBAP,PBA):**

It allows exchange of Phone Book Objects between devices. It is likely to be used between a car kit and a mobile phone to:

* allow the car kit to display the name of the incoming caller;
* allow the car kit to download the phone book so the user can initiate a call from the car display.

The profile consists of two roles:

* PSE - Phone Book Server Equipment for the side delivering phonebook data, like a mobile phone
* PCE - Phone Book Client Equipment, for the device receiving this data, like a personal navigation device (PND).

**Serial Port Profile(SPP):**

* This profile is based on [ETSI](https://en.wikipedia.org/wiki/European_Telecommunications_Standards_Institute" \o "European Telecommunications Standards Institute) 07.10 and the [RFCOMM](https://en.wikipedia.org/wiki/RFCOMM" \o "RFCOMM) protocol.
* It emulates a serial cable to provide a simple substitute for existing [RS-232](https://en.wikipedia.org/wiki/RS-232" \o "RS-232), including the familiar control signals.
* It is the basis for [DUN](https://en.wikipedia.org/wiki/Dial-up_networking" \o "Dial-up networking), [FAX](https://en.wikipedia.org/wiki/FAX" \o "FAX), HSP and [AVRCP](https://en.wikipedia.org/wiki/AVRCP" \o "AVRCP).
* SPP maximum payload capacity is 128 bytes.
* Serial Port Profile defines how to set up virtual serial ports and connect two Bluetooth enabled devices.

**Service Discovery Application Profile(SDAP):**

* SDAP describes how an application should use SDP to discover services on a remote device.
* SDAP requires that any application be able to find out what services are available on any Bluetooth enabled device it connects to.

**SIM Access Profile(SAP,SIM,rSAP):**

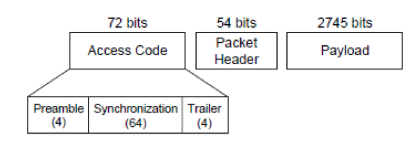
This profile allows devices such as car phones with built-in [GSM](https://en.wikipedia.org/wiki/Global_System_for_Mobile_Communications" \o "Global System for Mobile Communications) transceivers to connect to a [SIM card](https://en.wikipedia.org/wiki/Subscriber_Identity_Module" \o "Subscriber Identity Module) in a Bluetooth enabled phone, thus the car phone itself doesn't require a separate SIM card.

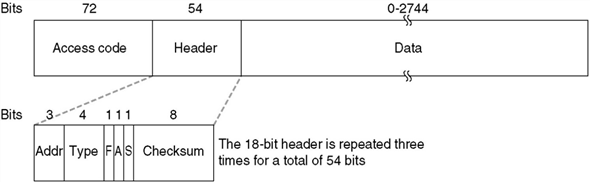
**Video Distribution Profile(VDP):**

This profile allows the transport of a video stream. It could be used for streaming a recorded video from a PC media center to a portable player, or a live video from a digital video camera to a TV.

**BLUETOOTH FRAME FORMAT:**

* The function of the access code is to identify the packets exchanged within a piconet, where each piconet has a unique access code.
* The access code is used to synchronize the slaves in a piconet to its master.
* The main function of the header of the Bluetooth packet is to determine an individual slave address in the piconet by the Logical Transport-Address (LT ADDR).
* The last part of the Bluetooth frame is the payload. Bluetooth has several types of packets. We focus in our study on a certain type called ACL packets which refers to Asynchronous Connectionless Communications. Packets of the ACL payload may be one of two types; DMx and DHx.
* M refers to medium data rate packets, while H refers to high data rate packets. The symbol x denotes the number of time slots between two hops in the frequency hopping system used.
* It takes the values of 1, 3, or 5 referring to 1, 3, or 5 time slots between consecutive frequency hops. Always DMx packets are coded packets and DHx packets are uncoded packets.





**Bluetooth Versions:**

### Bluetooth v1.2

Speed or data rate: 720 kbps   
Backward compatibility: v1.1

### Bluetooth v2.0

Speed: 2.1 Mbps  
Backward compatibility: Bluetooth v1.2

### Bluetooth v2.1

Speed: 2 Mbit/s   
Backward compatibility: Bluetooth v1.2

### Bluetooth version v3.0

Speed: 24 Mbps   
Backward compatibility: Bluetooth v2.1

### Bluetooth v4.0

Speed:24 Mbps   
Backward compatibility: Bluetooth v3.0

### Bluetooth v4.1

Designed to work seamlessly with LTE cellular technology.  
Backward compatible with previous versions.

**Bluetooth Low Energy(BLE):**

* BLE gives context to the environment around you. BLE allows smartphone users to have rich, interactive connections to their surroundings and move their mobile experience beyond the mobile handset.
* A BLE beacon is a small device – usually powered by battery or USB – that emits a Bluetooth Low Energy signal. A modern smartphone in the vicinity can pick up the signal being emitted by the beacon and gain some insight into its own positioning based on knowledge of the beacon’s placement.

**Bluetooth Classic vs. Bluetooth low energy:**

* Bluetooth consumes more power and transmits farther and with more data. It is suited for streaming media such as playing music on Bluetooth speakers or taking a call through a Bluetooth headset.
* BLE transmits less data over shorter distances using much less power than Bluetooth. BLE is designed for periodic transfers of very small amounts of data, such as beacons providing proximity in a store or a medical device providing glucose measurements to a doctor’s tablet or patient monitor.