

BLUETOOTH TECHNOLOGY AND ITS CAPABILITIES

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Annotation: *Bluetooth technology is a wireless communication standard that enables devices to exchange data over short distances. It has evolved from a simple alternative to wired communication to a key enabler of the Internet of Things (IoT), providing efficient, low-power connectivity solutions for a variety of applications.*

Keywords: *Bluetooth, wireless communication, Internet of Things (IoT), Bluetooth Low Energy (BLE), Bluetooth Mesh, data transfer, device control, smart homes, industrial automation, healthcare, connectivity solutions, short-range communication.*

To understand Bluetooth architecture, it is essential to first understand what Bluetooth is. Bluetooth is a radio wave technology designed primarily for wireless communication over short distances. The frequency of these waves ranges from 2.400 to 2.485 gigahertz, and the range between two devices can extend up to a maximum of 164 feet. Each Bluetooth device has a transmitter and a receiver. The power of the device's transmitter controls the range at which the Bluetooth device can operate; in other words, the transmitter defines the communication range.

Today, Bluetooth is a widely used technology found in many products. It is utilized in various sectors such as healthcare, sports and fitness, electronics, home automation, and security [1].

Some applications of Bluetooth:

- Wireless control and communication between mobile phones and headsets.
- Wireless communication between smartphones and smart locks for door opening.
- For low bandwidth applications that do not require high USB bandwidth and require wireless connection. For example, smartwatches, smart lights.

Bluetooth architecture has two types of networks: The Bluetooth network is called a piconet. If it consists of one server and one client, it is called a single piconet. Similarly, if it includes one server and multiple clients, it is called multiple piconets.

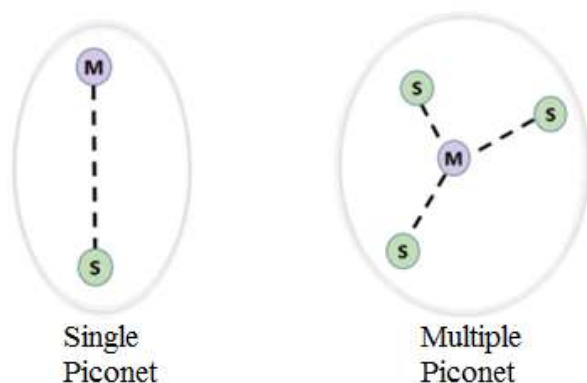


Fig.1. Single and multiple connected piconet networks

The master initiates communication with other devices and determines when a client device can transmit. Direct communication between client-to-client is not possible. In multiple piconets, a maximum of 7 active clients can be present. In other words, at any given time, only a maximum of 8 devices, including the server, can communicate in a piconet [2].

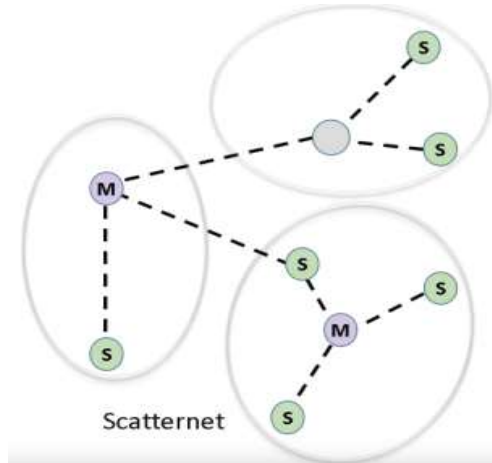


Fig.2. Scatternet network

Scatternet is a combination of multiple piconets, where the server of one piconet can be a client in another piconet. This node can receive messages from the server in one piconet and forward them to its client in another piconet. Therefore, such nodes are called bridge nodes. Importantly, a station cannot be a server in two piconets at the same time.

As the architecture of the Bluetooth IoT application, we need to refer to the Bluetooth "stack" to understand why the latest changes in Bluetooth standards are important for IoT applications. The evolution of Bluetooth, from replacing RS-232 data cables to mass IoT connectivity solutions, is a significant event, adding new layers to the stack. The latest Bluetooth specification for IoT is Bluetooth Mesh, which was developed in the BLE 4.xx or 5.xx stack, an extension of the Bluetooth Core ("classic") specification [3]. Therefore, the emerging Bluetooth network includes three stacked layers:

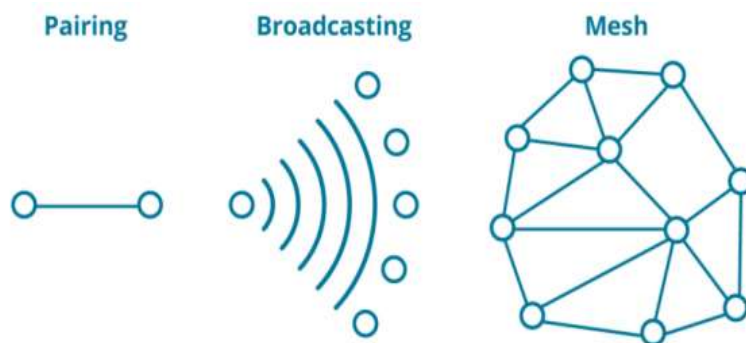


Fig.3. Bluetooth topologies: pairing, broadcasting, network

➤ **Pairing:** Bluetooth as a means to connect two devices. For example, a computer connected to a wireless mouse.

➤ **Broadcasting:** Bluetooth as a means to broadcast data from one device to multiple devices, or vice versa. For example: Listening to music on smart speakers and simultaneously projecting photos to a projector using a single iPhone.

➤ **Mesh:** Bluetooth as a method to connect many devices together, similar to a spiderweb. For example: Connecting 1278 high-intensity lights in a warehouse to automatically dim or brighten based on activity and personal preferences.

Types of Bluetooth Protocols: The main function of Bluetooth is the Bluetooth protocol stack within the Bluetooth architecture. In other words, it defines and provides various layers and functionalities. Bluetooth can run different applications through various protocol stacks, but each of these protocol stacks uses the same Bluetooth link and physical layers. The diagram below shows the complete Bluetooth protocol set. It illustrates the relationship between protocols that use services from other protocols when there is a payload transmitted over the air. However, protocols also have many other relationships between each other— for example, some protocols (L2CAP, TCS Binary) use LMP for link management control.

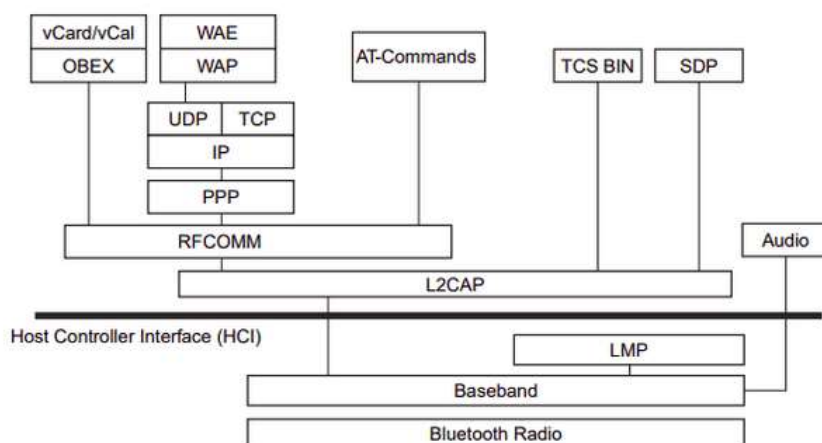


Fig.4. Bluetooth protocol architecture

The complete protocol set of Bluetooth architecture consists of Bluetooth-specific protocols such as the Object Exchange Protocol (OBEX) and the User Datagram Protocol (UDP). The main principle is to minimize the reuse of existing protocols for different purposes at higher layers, similar to inventing the wheel again.

Reusing protocols is beneficial for ensuring smooth operation and interoperability of applications when working with Bluetooth technology for older applications.

Therefore, many applications are being developed for immediate use of software and hardware tools.

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