Bluetooth 5.2 Technology and Application

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***Abstract*—Bluetooth, a wireless short-distance communication technology, realizes data exchange between fixed devices and mobile device. It widely used in wireless devices, including wireless mice, wireless headsets, notebook computers and other devices. With the development of the times, the traditional Bluetooth technology can no longer meet people's needs, and a new generation of low-power Bluetooth audio technology standards came into being. Bluetooth 5.2 uses LE Audio technology, which uses low-complexity communication coding and decoding technology to realize low-power transmission of high-quality audio. This paper mainly introduces the new features of Bluetooth 5.2 technology, including enhanced ATT protocol, LE Power Control and LE Isochronous Channels.**

Keywords-Bluetooth 5.2; LE Audio; Low-power Transmission; High-quality Audio

I. INTRODUCTION

Bluetooth is a short-distance wireless data communication technology, which can connect multiple devices at the same time. It has the characteristics of low cost, fast speed, convenient use and low power consumption [1]. Data transmission by frequency hopping spread spectrum technology has high security and anti-interference ability, and establishes data transmission channels for fixed and mobile devices. Therefore, it widely used in mobile phones, wireless headsets, notebook computers, automobiles and other related external devices [2].

Using Bluetooth technology, a connection channel can be established between fixed devices or mobile devices within an effective range, which is essentially to establish a universal Radio Air Interface for the communication environment between various devices, further combining communication technology with computer technology, and carrying out data intercommunication transmission without cables.

With the development of Bluetooth technology, the traditional Bluetooth technology can no longer meet the needs of some specific scenes [3-4]. For example, the traditional Bluetooth technology only supports point-to-point audio transmission, but cannot realize point-to-many transmission. In the process of data transmission, there will be delay between the transmitting end and the receiving end, which cannot guarantee the security of data. When the master device transmits data, the residual power consumption problem cannot be solved [5].

As a consequence, a new generation of low-power Bluetooth audio technology standard LE Audio came into being. This paper mainly introduces the new features of Bluetooth 5.2, mainly introduces the Enhanced Attribute Protocol (EATT), LE Power Control and LE Isochronous Channels technology.

II. COMMUNICATION PRINCIPLE OF BLUETOOTH

Bluetooth was invented by Ericsson with the original aim of making wireless headphones possible through wireless audio transmission. With the development of The Times, Bluetooth can also carry out wireless data transmission between devices. Data can be transmitted without optical cable in the effective range.

Bluetooth pairing is a very complicated process. Compared with WIFI, it has many options. When the Bluetooth Link Management Process (LMP) starts, it will initialize the clock calibration, version, characteristics, name and some

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connection states. The following is the main process of Bluetooth pairing:

Step1: The master device initiates a connection request (LMP_host_connection_req) by frequency hopping.

Step2: When the slave device receives the message, it will inform the upper layer to receive the connection information, and the slave will return a connection acceptance frame (LMP_accepted) or a link rejection frame (LMP_not_accepted).

Step3: If the slave device needs a roles witch, it will send a clock deflection information (LMP_slot_offset) and a switch request frame (LMP_switch_req).

Step4(a): If the slave accepts the connection request of the master device, the Bluetooth encryption process may wake up, and if there is no encryption request, the master device will send a connection completion message.

Step4(b): If the slave device rejects the connection request, it will send a disconnection frame (LMP_detach).

Step5: The two devices are connected successfully.

The main pairing process is shown in the following figure:

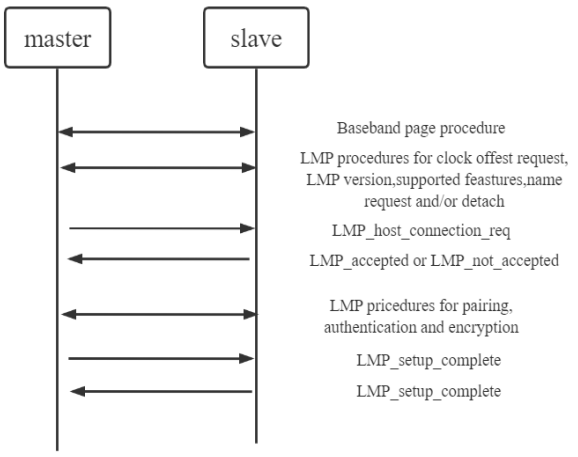

Figure 1. Bluetooth pairing process diagram

After the two parties complete the connection and exchange the features, the host starts to set up Adaptive Frequency Hopping (AFH). If there is a setting authorization, the host will request Link Key from the upper layer. When the connection requires authorization but the Link Key does not exist, it needs to be paired to generate the Link Key. After successful authorization and pairing, link encryption will be started. The connection establishment is complete.

The following figure is a detailed flow chart of Bluetooth pairing:

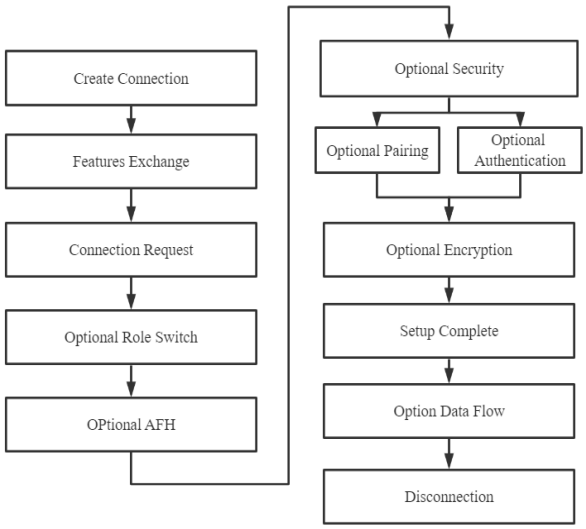

Figure 2. Bluetooth Pairing Flow Chart

III. BLUETOOTH 5.2 NEW FEATURE

A. Enhanced Attribute Protocol

In order to understanding of Enhanced Attribute Protocol (EATT), Bluetooth protocol stack is mainly divided into three layers. The Apps layer is the application layer, and the middle layer is the Host layer, including Generic Access Profiles (GAT), Security Manager Protocol (SMP), Generic Attribute Profile (GATT), Attribute Protocol (ATT) and Logical Link Control and Adaption (L2CAP). The third layer is the control layer, including Host Control Interface (HCL), Link Layer (LL) and Physical Layer (PHY). The lower layer provides services to the upper layer by packaging from bottom to top. The following picture shows Bluetooth protocol stack.

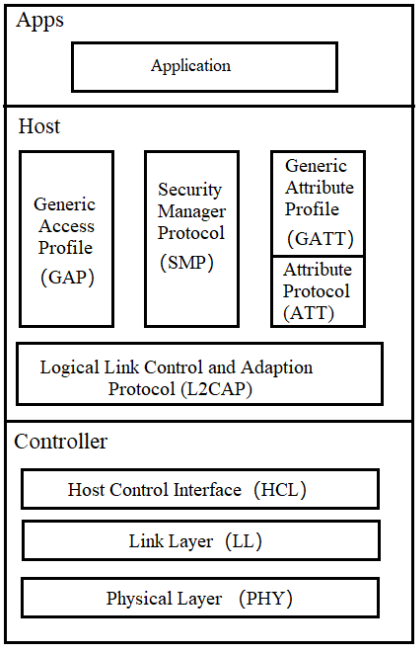

Figure 3. Bluetooth protocol stack

ATT mainly defines attribute parameters of different services, which are used for information exchange and negotiation between master and slave devices. L2CAP splits and assembles the upper data to match the ability of the Controller. EATT in Bluetooth 5.2 is an enhancement to ATT, which can handle concurrent transactions and adds flow control to improve the stability of EATT. In other words, EATT protocol allows different applications to execute concurrently on different L2CAP channels. And the size of the Maximum Transmission Unit (MTU) of ATT is allowed to be modified during connection. The ATT_MTU and LMPCAP_MTU in EATT protocol are independently configured. As shown in the following figure 4 (b).

In Bluetooth 5.1 and earlier versions, things are processed sequentially, and concurrency is not supported. Transactions can only be executed after a complete PDU (Protocol Data Unit). The size of MTU between ATT and L2CAP is fixed. That is to say, once a connection is established, the MTU of a certain service cannot be changed, and there is a one-to-one correspondence between them. As shown in figure 4 (a).

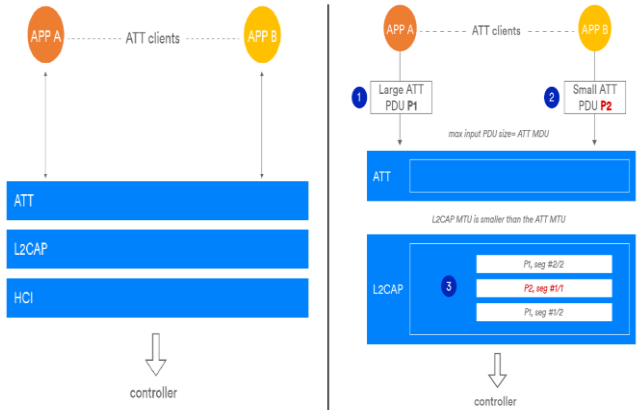

Figure 4. The relationship between ATT and L2CAP is about MTU

In a word, The ATT protocol is executed sequentially, in that only one transaction can be executed. While EATT can execute multiple events simultaneously between Bluetooth client and server with low power consumption. Therefore, the main advantages of EATT in application include convenience, flexibility and faster processing speed, which greatly improves the process and delay of stack multiple access and responds well to the expectation of eliminating security vulnerabilities.

B. LE Power Control

The purpose of adding LE Power Control function in Bluetooth 5.2 is to balance signal quality and power as well as reduce power consumption.

Bluetooth 5.2 integrates the bi-directional power control function of Bluetooth Low Energy (BLE). The low-power Bluetooth receiver can monitor the signal strength of the master device and request to change the transmission power, with the main purpose of balancing the signal quality and power. When the master device always transmits high-intensity signals, the link of the receiving device will fail and the power of the transmitting terminal will be wasted. On the contrary, when the signal strength is too low, the error rate of the receiving equipment is too high, resulting in transmission failure.

The LE Power Control function allows the Bluetooth controller to use the concept of "area" to monitor the change of path loss and report it to the Bluetooth host. Finally, this feature can also

improve the coexistence of other wireless devices in the 2.4GHz frequency range in the environment.

Bluetooth 5.2 can realize dynamic management of signal transmission power. The master device be notified to modify the power by detecting the signal strength of the other party. Compared with the equipment whose distance often changes, it saves power consumption, and can modify the power appropriately to hide the application requirements. The user can also change the transmission power autonomously and send the change instruction to the slave device. The advantage of LE Power Control is the efficient utilization of battery power. In the field of battery-powered sensors, like many applications existing in the Internet of Things and smart homes, the new low-power Bluetooth 5.2 performance allows dynamic optimization of battery life while minimizing the need for power maintenance, thus greatly reducing costs.

C. LE Isochronous Channels

Bluetooth 5.2 integrates the LE Isochronous channel for realizing the next generation of Bluetooth Low Power Audio (LE Audio). It defines a time-dependent data transmission channel and transmission strategy. Thereby ensuring that the data received by the receiver meets the timeliness requirements. It allows time-limited data to be transmitted to one or more devices for time synchronization.

LE Audio adopt a new Low Complexity Communication Code (LC3) with low complexity. Compared with the old Bluetooth audio coding SBC, it has the characteristics of good sound quality and low power consumption.

In the past, only connection-oriented asynchronous communication links and broadcast links in disconnected mode were supported. Bluetooth 5.2 supports synchronous audio stream transmission channel in connected mode and synchronous audio stream transmission channel in disconnected mode.

The Isochronous channel supports both connected mode and unconnected mode. In the one-to-one connection mode, Le-CIS (LE Connected Social Stream) is used to connect data streams synchronously, and the clearing mechanism flush the delayed data. Different LE-CIS form a CIG (Connected Isochronous Groups) synchronous connection group, and the CIS in the same CIG has the same time stamp to ensure that the data in the same group is synchronous. The most obvious application is headphones, and the left ear and the right ear are a CIS respectively. If they form a CIG, the time between them is synchronous.

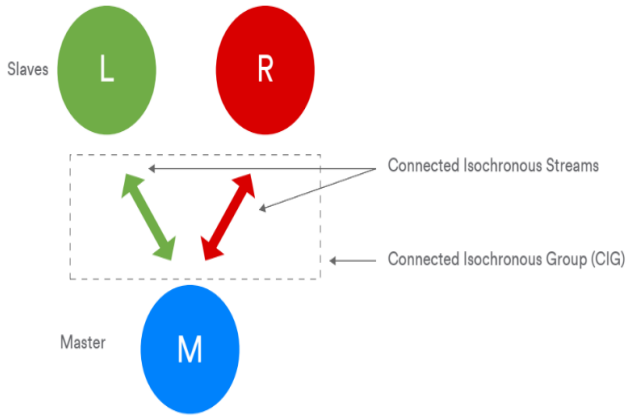

Figure 5. Isochronous channel diagram in connection mode

For the broadcast mode, it is called Broadcast Isochronous Stream (BIS), and multiple BIS can form a BIG synchronous broadcast group. Synchronization of broadcast mode is realized by a PDU broadcast in one cycle, which contains a time stamp for each BIS. Once synchronized, receiving convenience can be called synchronous receiver. In the same example, if a mobile phone plays, the left and right ears of each person in a group must also receive synchronous data streams, then the data of the left and right ears must belong to the same BIG.

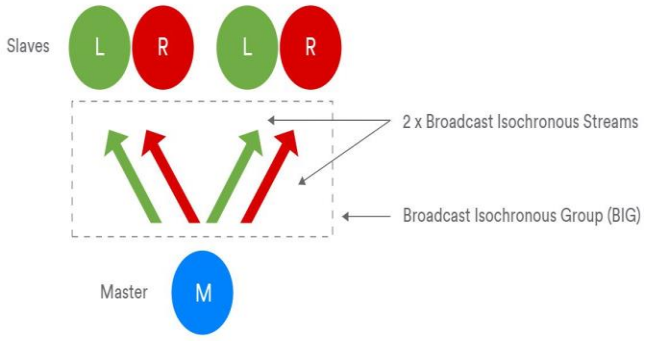

Figure 6. Isochronous channel diagram in broadcast mode

IV. APPLICATION SCENARIOS

Bluetooth 5.2 has a wide range of applications in daily life. While ensuring low power consumption, it can also provide high quality service. For example, smart wearables, public television, auxiliary reception, multilingual real-time translation, etc.

1) smart wearables

Because of the low-power Bluetooth, many smart devices rely on Bluetooth technology for no connection and data exchange, which reduces the power consumption of devices.

2) Public television

For example, in the gym, different fitness programs will be played on different screens, and there must be interference between the voices. At this time, different audio is divided into different groups, and the corresponding audio can be received by accessing the corresponding groups, thus reducing noise interference.

3) Auxiliary reception

The flight train information in the waiting hall of the waiting hall is played in a big speaker mode, which is difficult to hear clearly for some people with hearing impairment or when the environment is noisy. If the flight train information is broadcast through LE Audio equipment and the passengers receive it through Bluetooth headset or corresponding mobile APP, it can greatly save time and energy.

4) Multilingual real-time translation

Passengers on the plane can connect headphones to the flight information system, specify their favorite language, and hear flight information in this language.

V. CONCLUSIONS

On the basis of traditional Bluetooth, Bluetooth 5.2 adds and improves the enhanced ATT protocol, LE Power Control and LE Isochronous Channels to ensure the synchronous transmission of audio data with low power consumption. In addition Bluetooth technology has been widely used in our daily life, such as smart wearables, public television, auxiliary reception, multilingual real-time translation, etc.

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