GigaDevice Semiconductor Inc.

GD32VW553 BLE Development Guide

Application Note
AN152

Revision 1.3

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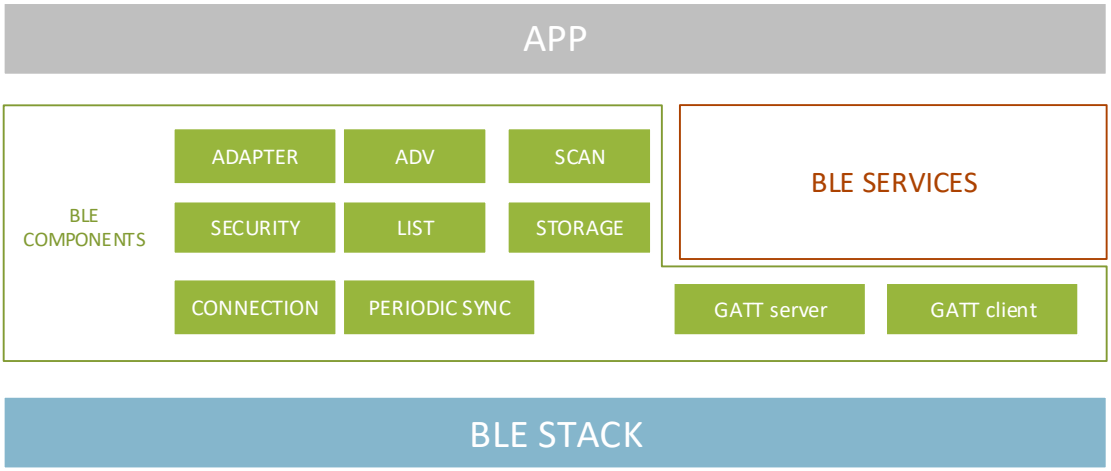
1. Overview of BLE SDK

The GD32VW553 series chip is a 32-bit microcontroller (MCU) with RISC-V as the core, which contains Wi-Fi4/Wi-Fi6 and BLE5.3 connection technologies. GD32VW553 Wi-Fi+BLE SDK integrates the Wi-Fi driver, BLE driver, LwIP TCP/IP protocol stack, MbedTLS, and other components, allowing developers to quickly develop IoT applications based on GD32VW553. This document describes the BLE software framework and related API interfaces aiming to help developers become familiar with BLE APIs and use them to develop their own applications. For related Wi-Fi information, please refer to the "AN158 GD32VW553 Wi-Fi Development Guide".

1.1. BLE software framework

Figure 1-1. BLE software framework



As shown in ***Figure 1-1. BLE software framework***, the GD32VW553 BLE software part consists of four modules: BLE STACK, BLE COMPONENTS, BLE services, and BLE APP.

BLE STACK is the implementation of the BLE protocol stack, which includes GAP, GATT, SMP, L2CAP, HCI, LL, and other modules. BLE STACK runs in a separate task and interacts with BLE COMPONENTS through TASK messages. APP needs to operate STACK through BLE COMPONENTS.

BLE COMPONENTS consists of multiple components, and runs in the same task as BLE service and BLE APP to provide APP with interfaces for STACK control and status notification, etc. Note that most operations of BLE are executed asynchronously. APP needs to register a callback handler in each module, and BLE COMPONENTS will notify APP of the API call execution result or report the operation request initiated by the peer device in the callback function. Each component is independent of each other. APP can select different components to initialize them and register the corresponding callback functions as required.

The BLE ADAPTER module mainly provides interfaces for configuring and obtaining local BLE related attributes. ***BLE adapter API*** introduces how to use API of the ADAPTER module.

The BLE ADV module mainly provides interfaces for creating/deleting advertising sets, starting/stopping sending advertising packets, etc. ***BLE advertising API*** introduces how to use API of the ADV module, and ***BLE advertising data API*** provides some interfaces for searching for specific AD type data in advertising data.

The BLE SCAN module mainly provides interfaces for searching for advertising sets and reports the search results to the APP. ***BLE scan API*** introduces how to use API of the SCAN module.

The BLE CONNECTION module mainly provides interfaces for creating connections, obtaining peer device information, and obtaining or setting connection parameters, etc. ***BLE connection API*** introduces how to use API of the CONNECTION module.

The BLE SECURITY module mainly provides interfaces required for interaction during pairing, authentication, encryption, and other processes. ***BLE security API*** introduces how to use API of the SECURITY module.

The BLE LIST module mainly provides interfaces for operating FAL, RAL, and PAL, including operations such as adding devices to the list, deleting devices from the list, and clearing the list. ***BLE list API*** introduces how to use API of the LIST module.

The BLE PERIODIC SYNC module mainly provides interfaces for synchronizing periodic advertising, reporting received periodic advertising data, etc. ***BLE periodic sync API*** introduces how to use API of the PERIODIC SYNC module.

The BLE STORAGE module uses flash to store and manage the bond information of the peer device. The bond information includes peer_irk, peer_ltk, peer_csrk, local_irk, local_ltk, local_csrk, etc. ***BLE storage API*** introduces how to use API of the STORAGE module.

The BLE GATT server module mainly provides interfaces for registering/deleting GATT service, sending notification/indication to GATT client, etc. ***BLE gatts API*** introduces how to use API of the GATT server module.

The BLE GATT client module mainly provides the following functions: initiate GATT discovery, read and write attribute in the peer GATT server. ***BLE gattc API*** introduces API usage of GATT client module.

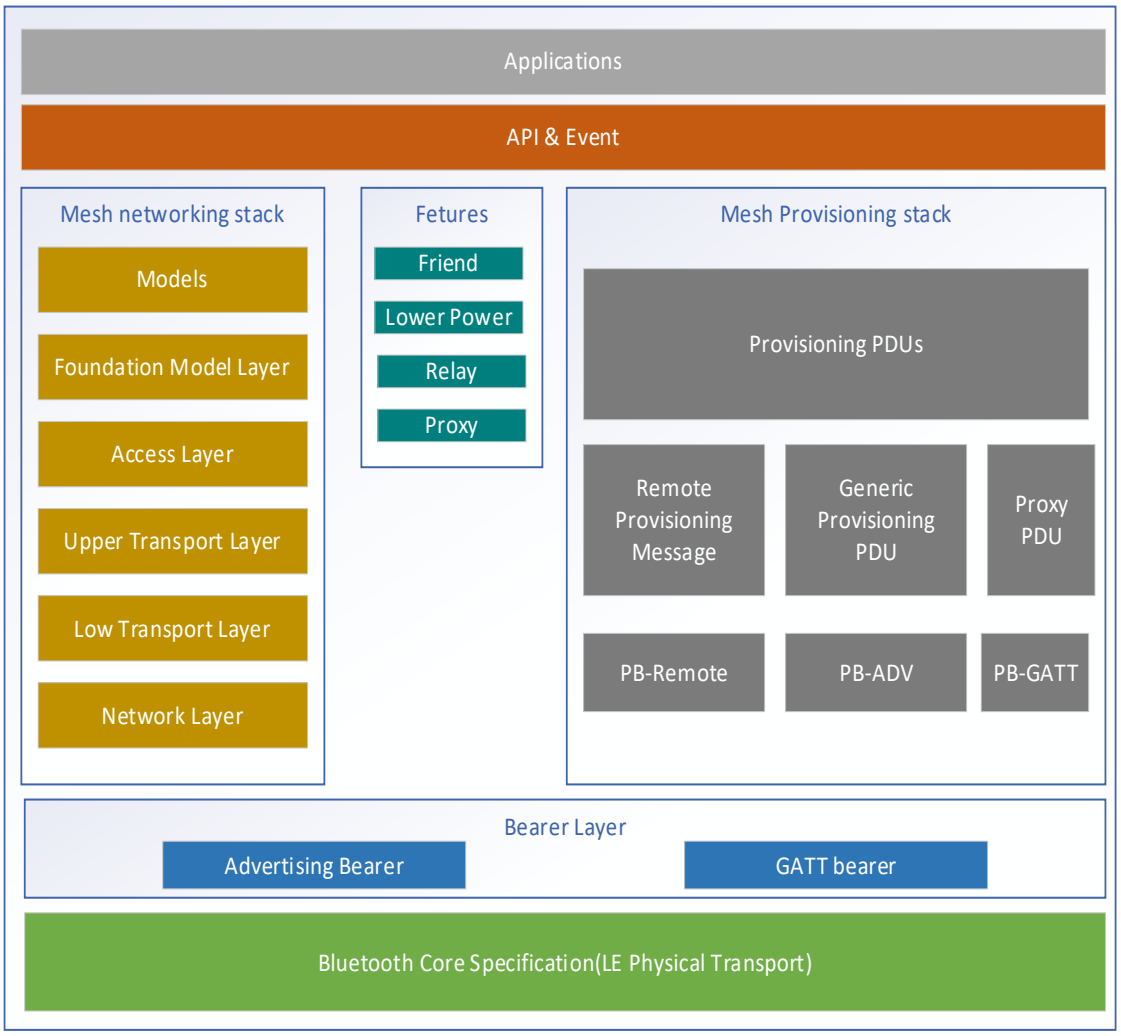
BLE services are different services and profiles realized based on GATT server and GATT client modules, including BAS and DIS, etc. Users can also realize private services by using GATT server and GATT client interfaces required.

The BLE APP layer is a collection of multiple applications, such as blue courier (Bluetooth distribution network) and user-defined applications. APP can register callback functions with different modules to process corresponding messages according to different requirements.

1.2. Overview of BLE Mesh

Based on the Zephyr open-source Bluetooth Mesh protocol stack, we have implemented a comprehensive Bluetooth Mesh 1.1 network solution. This solution supports device networking, multi-node communication, dynamic data interaction, and remote control functionalities, making it suitable for scenarios such as smart homes, industrial IoT, and asset tracking. It offers high reliability, low latency, and low power consumption, with the capability to support large-scale node deployment.

Figure 1-2. BLE Mesh Framework Diagram



As shown in ***Figure 1-2. BLE Mesh Framework Diagram***, the GD32VW553 BLE Mesh is an application-level protocol implemented based on the BLE protocol stack. It consists of modules such as the Mesh networking stack, Mesh provisioning stack, and Applications.

The Mesh networking stack enables layers including the Bearer Layer, Network Layer, Transport Layer, Access Layer, Foundation Model Layer, and Model Layer. The Networking Layer supports functionalities like Key Refresh, IV Update, IV Index Recovery, Node Removal, and Node Provisioning Protocol Interface. The provisioning stack supports network setup

through advertising (PB-ADV), connections (PB-GATT), or existing mesh networks (PB-Remote). It also features Friend Nodes, Low Power Nodes, Relay Nodes, and Proxy Nodes.

The Foundation Models include Configuration Models, Health Models, Remote Provisioning Models, Bridge Models, Mesh Private Beacon Models, On-Demand Private Proxy Models, SAU Configuration Models, Solicitation PDU RPL Models, Opcodes Aggregator Models, and Large Composition Data Models.

Additionally, models support Device Firmware Update (DFU), enabling wireless firmware upgrades for devices over a Mesh network. This functionality eliminates the need for physical contact and allows secure upgrades for tens or hundreds of nodes simultaneously.

For related Zephyr Mesh modules, refer to the BLE Mesh Profile, and for programmatic references, check the Mesh API.

2. BLE API

2.1. BLE adapter API

The header file is ble_adapter.h.

The BLE adapter module mainly provides interfaces for configuring and obtaining local BLE related settings.

2.1.1. Adapter message type

APP can register a callback function in the BLE adapter module, and the BLE adapter module will send the following event message to APP through the callback function.

- BLE_ADP_EVT_ENABLE_CMPL_INFO

This message will be sent after the BLE adapter is initialized. The message data type is ble_adp_info_t, including whether the initialization is successful; if yes, local attributes such as local version and local IRK will also be reported.

APP can only perform BLE related operations after it receives this message and the status indicates that the initialization is successful.

- BLE_ADP_EVT_RESET_CMPL_INFO

This message will be sent after the BLE adapter is reset. The message data type is uint16_t, indicating whether the reset is successful.

- BLE_ADP_EVT_DISABLE_CMPL_INFO

This message returns the result of APP calling ble_adp_disable API to disable the BLE module. The message data type is uint16_t, indicating whether the disable is successful.

- BLE_ADP_EVT_CHANN_MAP_SET_RSP

This message returns the result of APP calling ble_adp_chann_map_set API to set the channel map. The message data type is uint16_t, indicating whether the channel map is set successfully.

- BLE_ADP_EVT_LOC_IRK_SET_RSP

This message returns the result of APP calling ble_adp_loc_irk_set API to set the local IRK. The message data type is uint16_t, indicating whether the local IRK is set successfully.

- BLE_ADP_EVT_LOC_ADDR_INFO

This message is used to notify APP of new address information after the local address changes, for example, after RPA timeout. The message data type is ble_gap_local_addr_info_t.

- BLE_ADP_EVT_NAME_SET_RSP

This message returns the result of APP calling ble_adp_name_set API to set the local name. The message data type is uint16_t, and the status indicates whether the local name is set successfully.

- BLE_ADP_EVT_ADDR_RESLV_RSP

This message returns the result of APP calling ble_adp_addr_resolve API to reslove the passed in RPA. The message data type is ble_gap_addr_resolve_rsp_t, including whether the RPA is resolved successful; if yes, it also contains the address after the resloving and the corresponding IRK information.

- BLE_ADP_EVT_RAND_ADDR_GEN_RSP

This message returns the result of APP calling ble_adp_none_resolvable_private_addr_gen API, ble_adp_static_random_addr_gen API, or ble_adp_resolvable_private_addr_gen API to generate a random address. The message data type is ble_gap_rand_addr_gen_rsp_t. If the random address is successfully generated, the corresponding address information is also provided.

- BLE_ADP_EVT_TEST_TX_RSP

This message returns the result of APP calling ble_adp_test_tx API. The message data type is uint16_t, indicating whether the tx test starts to be executed successfully.

- BLE_ADP_EVT_TEST_RX_RSP

This message returns the result of APP calling ble_adp_test_rx API. The message data type is uint16_t, indicating whether the rx test starts to be executed successfully.

- BLE_ADP_EVT_TEST_END_RSP

This message returns the result of APP calling ble_adp_test_end API. The message data type is ble_gap_test_end_rsp_t, including whether the test is ended successfully.

- BLE_ADP_EVT_TEST_RX_PKT_INFO

This message is used to notify APP about the successfully received packet number after test rx mode is ended. The message data type is ble_gap_test_rx_pkt_info_t.

2.1.2. ble_adp_callback_register

Prototype: ble_status_t ble_adp_callback_register(ble_adp_evt_handler_t callback)

Function: Register the callback function that processes BLE adapter messages. For the description of adapter messages, see ***Adapter message type***.

Input parameter: callback, callback function pointer

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.3. ble_adp_callback_unregister

Prototype: ble_status_t ble_adp_callback_unregister(ble_adp_evt_handler_t callback)

Function: Unregister the callback function from BLE adapter module

Input parameter: callback, callback function to be unregistered

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.4. ble_adp_reset

Prototype: ble_status_t ble_adp_reset(void)

Function: Reset BLE protocol stack and each module

Input parameter: None

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After the resetting, a BLE_ADP_EVT_RESET_CMPL_INFO message is sent to the callback function

2.1.5. ble_adp_chann_map_set

Prototype: ble_status_t ble_adp_chann_map_set(uint8_t *p_chann_map)

Function: Set the channel map available for BLE

Input parameter: p_chann_map, channel map array, whose length is 5 bytes and effective bits are the lower 37 bits. Bit 0 of byte 0 is set to use channel index 0, bit 1 of byte 0 is set to use channel index 1, and so on

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After the setting, a BLE_ADP_EVT_CHANN_MAP_SET_RSP message is sent to the callback function

2.1.6. ble_adp_loc_irk_set

Prototype: ble_status_t ble_adp_loc_irk_set(uint8_t *p_irk)

Function: Set local IRK

Input parameter: p_irk, the IRK pointer to be set, whose length is 16 bytes

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After the setting, a BLE_ADP_EVT_LOC_IRK_SET_RSP message is sent to the callback function

2.1.7. ble_adp_loc_irk_get

Prototype: ble_status_t ble_adp_loc_irk_get (uint8_t *p_irk)

Function: Get local IRK used by BLE adapter

Input parameter: None

Output parameter: p_irk, local IRK pointer, whose length is 16 bytes, is used to save the obtained local IRK information

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.8. ble_adp_identity_addr_get

Prototype: ble_status_t ble_adp_identity_addr_get (ble_gap_addr_t *p_id_addr)

Function: Get identity address used by BLE adapter

Input parameter: None

Output parameter: p_id_addr, identity address pointer, including address type and

address value

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.9. ble_adp_public_addr_get

Prototype: ble_status_t ble_adp_public_addr_get(uint8_t *p_addr)

Function: Get public address used by BLE adapter

Input parameter: None

Output parameter: p_addr, public address pointer

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.10. ble_adp_identity_addr_set

Prototype: ble_status_t ble_adp_public_addr_set(uint8_t *p_addr)

Function: Set public address used by BLE adapter, the address will be used after nex reboot

Input parameter: None

Output parameter: p_addr, public address pointer

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.11. ble_adp_name_set

Prototype: ble_status_t ble_adp_name_set (uint8_t *p_name, uint8_t name_len)

Function: Set device name used by BLE adapter

Input parameter: p_name, device name pointer

name_len, device name length

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After the setting, a BLE_ADP_EVT_NAME_SET_RSP message is sent to the callback function

2.1.12. ble_adp_local_ver_get

Prototype: ble_status_t ble_adp_local_ver_get (ble_gap_local_ver_t *p_val)

Function: Get BLE adapter version information

Input parameter: None

Output parameter: p_val, local version structure pointer, including hci version, lmp version, etc.

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.13. ble_adp_sugg_dft_data_len_get

Prototype: ble_status_t ble_adp_sugg_dft_data_len_get(ble_gap_sugg_dft_data_t *p_data)

Function: Get default transmit data parameters of BLE adapter

Input parameter: None

Output parameter: p_data, suggest data structure pointer, including max tx time and max tx octets

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.14. ble_adp_tx_pwr_range_get

Prototype: ble_status_t ble_adp_tx_pwr_range_get(ble_gap_tx_pwr_range_t *p_val)

Function: Get the BLE adapter transmit power range

Input parameter: None

Output parameter: p_val, tx power range structure pointer, including min tx power and max tx power

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.15. ble_adp_max_data_len_get

Prototype: ble_status_t ble_adp_max_data_len_get(ble_gap_max_data_len_t *p_len)

Function: Get BLE adapter max data length information

Input parameter: None

Output parameter: p_len, max data length structure pointer, including max tx octets, max tx time, max rx octets, and max rx time

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.16. ble_adp_adv_sets_num_get

Prototype: ble_status_t ble_adp_adv_sets_num_get (uint8_t *p_val)

Function: Get the maximum number of advertising sets supported by BLE adapter

Input parameter: None

Output parameter: p_val, advertising set number pointer

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.1.17. ble_adp_addr_resolve

Prototype: ble_status_t ble_adp_addr_resolve(uint8_t *p_addr, uint8_t *p_irk, uint8_t irk_num)

Function: Use the keys in the provided IRK list in turn to resolve the input RPA

Input parameter: p_addr, resolvable private address to be resolved

p_irk, IRK list pointer

irk_num, the number of keys in the IRK list

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure After execution, a BLE_ADP_EVT_ADDR_RESLV_RSP message is sent to the callback function. If the provided address can be resolved, the message data includes the resolved identity address and the used IRK.

2.1.18. ble_adp_static_random_addr_gen

Prototype: ble_status_t ble_adp_static_random_addr_gen(void)

Function: Generate static random address

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure After execution, a BLE_ADP_EVT_RAND_ADDR_GEN_RSP message is sent to the callback function

2.1.19. ble_adp_resolvable_private_addr_gen

Prototype: ble_status_t ble_adp_resolvable_private_addr_gen(void)

Function: Generate static resolvable private address

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure After execution, a BLE_ADP_EVT_RAND_ADDR_GEN_RSP message is sent to the callback function

2.1.20. ble_adp_none_resolvable_private_addr_gen

Prototype: ble_status_t ble_adp_none_resolvable_private_addr_gen(void)

Function: Generate static non-resolvable private address

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.After execution, a BLE_ADP_EVT_RAND_ADDR_GEN_RSP message is sent to the callback function

2.1.21. ble_adp_test_tx

Prototype: ble_status_t ble_adp_test_tx(uint8_t chann, uint8_t tx_data_len, uint8_t tx_pkt_payload, uint8_t phy, int8_t tx_pwr_lvl)

Function: Configure BLE controller to enter the test mode and send test packet

Input parameter: chann, tx rf channel index, whose range is 0x00-0x27

tx_data_len, length of tx packet, whose range is 0x00-0xFF

tx_pkt_payload, type of tx packet, whose range is 0x00-0x07

phy, PHY used by tx, 1: 1M, 2: 2M, 3: coded S=8, 4: coded S=2

tx_pwr_lvl: tx power

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure After execution, a BLE_ADP_EVT_TEST_TX_RSP message is sent to the callback function

2.1.22. ble_adp_test_rx

Prototype: ble_status_t ble_adp_test_rx(uint8_t chann, uint8_t phy, uint8_t modulation_idx)

Function: Configure BLE controller to enter the test mode and receive test packet

Input parameter: chann, rf channel index used by rx, whose range is 0x00-0x27

phy, PHY used by rx, 1: 1M, 2: 2M, 3: coded

modulation_idx: Whether BLE controller has stable modulation index

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure After execution, a BLE_ADP_EVT_TEST_RX_RSP message is sent to the callback function

2.1.23. ble_adp_test_end

Prototype: ble_status_t ble_adp_test_end(void)

Function: Configure BLE controller to exit the test mode

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure After execution, a BLE_ADP_EVT_TEST_END_RSP message is sent to the callback function. If test rx mode is ended, a BLE_ADP_EVT_TEST_RX_PKT_INFO message is also sent.

2.2. BLE advertising API

The header file is ble_adv.h.

The BLE advertising module mainly provides interfaces for creating/deleting advertising sets, starting/stopping sending advertising packets, etc.

2.2.1. Advertising message type

- BLE_ADV_EVT_OP_RSP

This message is a response to APP calling advertising APIs. The message data type is ble_adv_op_rsp_t, which includes the type of operation code and the status indicating

whether the execution was successful.

- BLE_ADV_EVT_STATE_CHG

This message is used to notify APP after the state of advertising sets changes. The state of advertising sets is defined as ble_adv_state_t, including the new state, the reason for state change, and the changed adv index.

- BLE_ADV_EVT_DATA_UPDATE_INFO

This message is usd to notify APP about the result of updating the data of the advertising set being used after calling ble_adv_data_update API. The message data type is ble_adv_data_update_info_t, including the updated advertising data type and the update success or failure state.

- BLE_ADV_EVT_SCAN_REQ_RCV

If scan request notification is enabled upon the creation of advertising set, and a scan request packet is received after advertising is enabled, APP will receive this message. The message data type is ble_adv_scan_req_rcv_t, including the set address for sending the scan request.

2.2.2. ble_adv_create

Prototype: ble_status_t ble_adv_create(ble_adv_param_t *p_param,
ble_adv_evt_handler_t hdlr, void *p_context)

Function: Create BLE advertising set

Input parameter: p_param, advertising parameter structure pointer, which can be used to configure adv type, interval, phy, and other parameters
hdlr, a handler that registers messages related to the adv.
For the description of adv messages, see ***Advertising message type***.
p_context, a parameter that can be additionally returned to the message handler

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After calling this API, a BLE_ADV_EVT_OP_RSP message will be sent to the registered message handler to notify if the operation is started successfully. If so, after the advertising set is successfully created, a BLE_ADV_EVT_STATE_CHG message is also sent, and the state is BLE_ADV_STATE_CREATE. In addition, adv index can be obtained from the message and used in subsequent APIs.

2.2.3. ble_adv_start

Prototype: ble_status_t ble_adv_start(uint8_t adv_idx, ble_adv_data_set_t *p_adv_data, ble_adv_data_set_t *p_scan_rsp_data, ble_adv_data_set_t *p_per_adv_data)

Function: Set advertising set data and start sending advertising packet

Input parameter: adv_idx, advertising index

p_adv_data, advertising data structure pointer, data can be generated by the ble adv module through configuration or directly set by the caller

p_scan_rsp_data, scan response which needs to be set when the created advertising set is scannable advertising

p_per_adv_data, periodic advertising data structure pointer, which needs to be set when the created advertising set is periodic advertising

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_ADV_EVT_OP_RSP message will be sent to the registered message handler to notify if the operation is started successfully. If so, a BLE_ADV_EVT_STATE_CHG message is also sent. According to the advertising data need to set, there may be messages whose state is BLE_ADV_STATE_ADV_DATA_SET, BLE_ADV_STATE_SCAN_RSP_DATA_SET, or BLE_ADV_STATE_PER_ADV_DATA_SET. Finally, there is a message whose state is BLE_ADV_STATE_START

2.2.4. ble_adv_restart

Prototype: ble_status_t ble_adv_restart(uint8_t adv_idx)

Function: Resend advertising packet after the advertising set is stopped

Input parameter: adv_idx, advertising index

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_ADV_EVT_OP_RSP message will be sent to the registered message handler to notify if the operation is started successfully. If so, a BLE_ADV_EVT_STATE_CHG message is also sent with state

BLE_ADV_STATE_START

2.2.5. ble_adv_stop

Prototype: ble_status_t ble_adv_stop(uint8_t adv_idx)

Function: Stop sending advertising packets

Input parameter: adv_idx, advertising index

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_ADV_EVT_OP_RSP message will be sent to the registered message handler to notify if the operation is started successfully. If so, after the advertising set is stopped, a BLE_ADV_EVT_STATE_CHG message is also sent with state BLE_ADV_STATE_CREATE

2.2.6. ble_adv_remove

Prototype: ble_status_t ble_adv_remove(uint8_t adv_idx)

Function: Delete the advertising set that no longer sends advertising packets.

If the advertising set is sending advertising packets, that is,

the state is BLE_ADV_STATE_START, first call ble_adv_stop to stop it,

and then call this function to remove it.

Input parameter: adv_idx, advertising index

Output parameter: None

Return value: Return 0 on success, and return the error code definedin ble_status_t on failure.

After calling this API, a BLE_ADV_EVT_OP_RSP message will be sent to the registered message handler to notify if the operation is started successfully.

2.2.7. ble_adv_data_update

Prototype: ble_status_t ble_adv_data_update(uint8_t adv_idx, ble_adv_data_set_t *p_adv_data, ble_adv_data_set_t *p_scan_rsp_data, ble_adv_data_set_t *p_per_adv_data)

Function: Update the adv data, scan response data, and periodic adv data of

the advertising set which is sending advertising packets and

whose state is BLE_ADV_STATE_START

Input parameters: adv_idx, advertising index

p_adv_data, advertising data structure pointer

p_scan_rsp_data, scan response data structure pointer

p_per_adv_data, periodic advertising data structure pointer

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_ADV_EVT_OP_RSP message will be sent to the registered message handler to notify if the operation is started successfully. After execution, one or more BLE_ADV_EVT_DATA_UPDATE_INFO messages will be sent to the callback function

2.3. BLE advertising data API

The header file is ble_adv_data.h.

The BLE advertising data module mainly provides interfaces for searching for the specified ad type in advertising data.

2.3.1. ble_adv_find

Prototype: uint8_t *ble_adv_find(uint8_t *p_data, uint16_t data_len, uint8_t ad_type, uint8_t *p_len)

Function: Search for data of the specified ad type in advertising data

Input parameter: p_data, the address of advertising data for searching

data_len, the length of advertising data for searching

ad_type, the ad type to be searched

Output parameter: p_len, the length of the searched data value of the corresponding type

Return value: The address of the searched data value of the corresponding type.

If not found, return NULL

2.3.2. ble_adv_cmpl_name_find

Prototype: bool ble_adv_cmpl_name_find(uint8_t *p_data, uint16_t data_len, uint8_t *p_name, uint16_t name_len)

Function: Search for the specified complete name in advertising data

Input parameter: p_data, the address of advertising data for searching

data_len, the length of advertising data for searching

p_name, the address of the complete name to be searched

name_len, the length of the complete name to be searched

Output parameter: None

Return value: Return true if the specified complete name can be found in advertising data; otherwise, return false

2.3.3. ble_adv_short_name_find

Prototype: bool ble_adv_short_name_find (uint8_t *p_data, uint16_t data_len, uint8_t *p_name, uint16_t name_len_min)

Function: Search for the specified short name in advertising data

Input parameter: p_data, the address of advertising data for searching

data_len, the length of advertising data for searching

p_name, the address of the short name to be searched

name_len_min, the minimum length that the short name needs to match

Output parameter: None

Return value: Return true if the specified short name can be found in advertising data; otherwise, return false

2.3.4. ble_adv_srv_uuid_find

Prototype: bool ble_adv_srv_uuid_find(uint8_t *p_data, uint16_t data_len, ble_uuid_t *p_uuid)

Function: Search for the specified service uuid in advertising data

Input parameter: p_data, the address of advertising data for searching

data_len, the length of advertising data for searching

p_uuid, the uuid structure pointer to be searched, including uuid length and uuid content

Output parameter: None

Return value: Return true if the specified service uuid can be found in advertising data; otherwise, return false

2.3.5. ble_adv_appearance_find

Prototype: bool ble_adv_appearance_find(uint8_t *p_data, uint16_t data_len,
uint16_t appearance)

Function: Search for the specified appearance in advertising data

Input parameter: p_data, the address of advertising data for searching
data_len, the length of advertising data for searching
appearance, the appearance value to be searched

Output parameter: None

Return value: Return true if the specified appearance can be found
in advertising data; otherwise, return false

2.4. BLE scan API

The header file is ble_scan.h.

The BLE scan module mainly provides interfaces for searching for advertising data and reports the search results.

2.4.1. Scan message type

APP can register a callback function in the BLE scan module, and the BLE scan module will send the following event message to APP through the callback function.

- BLE_SCAN_EVT_ENABLE_RSP

This message is a response to notify APP if the scan enable procedure is successfully started after APP calling ble_scan_enable API. The message data type is ble_scan_enable_rsp_t, including the operation status.

- BLE_SCAN_EVT_DISABLE_RSP

This message is a response to notify APP if the scan disable procedure is successfully started after APP calling ble_scan_disable API. The message data type is ble_scan_disable_rsp_t, including the operation status.

- BLE_SCAN_EVT_STATE_CHG

This message is sent to the callback function when the scan state changes. The message data type is ble_scan_state_chg_t, including the current scan state and the reason for change.

- BLE_SCAN_EVT_ADV_RPT

This message is used to notify APP of the data received after the advertising packet is scanned. The message data type is ble_gap_adv_report_info_t. The structure contains the received advertising packet type, advertiser address, advertising sid, data, etc.

2.4.2. ble_scan_callback_register

Prototype: ble_status_t ble_scan_callback_register(ble_scan_evt_handler_t callback)

Function: Register the callback function for processing BLE scan messages

Input parameter: callback, a function that processes BLE scan messages.

For the description of scan messages, see ***Scan message type***.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.4.3. ble_scan_callback_unregister

Prototype: ble_status_t ble_scan_callback_unregister(ble_scan_evt_handler_t callback)

Function: Unregister the callback function from BLE scan module

Input parameter: callback, callback function to be unregistered

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.4.4. ble_scan_enable

Prototype: ble_status_t ble_scan_enable(void)

Function: Enable BLE scan, and a BLE_SCAN_EVT_ADV_RPT message is sent to the callback function to notify it of the scanned device.

Input parameter: None

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_SCAN_EVT_ENABLE_RSP message will be sent to the registered message handler to notify if the operation is started successfully. If so, after scan is enabled, a BLE_SCAN_EVT_STATE_CHG message is also sent with state BLE_SCAN_STATE_ENABLED

2.4.5. ble_scan_disable

Prototype: ble_status_t ble_scan_disable(void)

Function: Disable BLE scan

Input parameter: None

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_SCAN_EVT_DISABLE_RSP message will be sent to the registered message handler to notify if the operation is started successfully. If so, after scan is disabled, a BLE_SCAN_EVT_STATE_CHG message is also sent with state BLE_SCAN_STATE_DISABLED

2.4.6. ble_scan_param_set

Prototype: ble_status_t ble_scan_param_set (ble_gap_local_addr_type_t own_addr_type,
ble_gap_scan_param_t *p_param)

Function: Set BLE local address type and scan parameters used for scan

Input parameter: own_addr_type, local address type used for scan
p_param, scan parameter structure pointer, including scan type,
interval, window, etc.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.4.7. ble_scan_param_get

Prototype: ble_status_t ble_scan_param_get (ble_gap_local_addr_type_t
*p_own_addr_type, ble_gap_scan_param_t *p_param)

Function: Get BLE local address type and scan parameters used for scan

Input parameter: p_own_addr_type, pointer to local address type used for scan
p_param, scan parameter structure pointer, including scan type,
interval, window, etc.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5. BLE connection API

The header file is ble_conn.h.

The BLE connection module mainly provides interfaces for creating connections, obtaining peer device information, and obtaining or setting connection parameters.

2.5.1. Connection message type

APP can register a callback function in the BLE connection module, and the BLE connection module will send the following event messages to APP through the callback function.

- BLE_CONN_EVT_CONN_RSP

This message is a response to notify APP the result of calling ble_conn_connect API. The message data type is ble_conn_conn_rsp_t, including status which indicates if the connect procedure is started successfully.

- BLE_CONN_EVT_DISCONN_RSP

This message is a response to notify APP the result of calling ble_conn_disconnect API. The message data type is ble_conn_disconn_rsp_t, including status which indicates if the disconnect procedure is started successfully.

- BLE_CONN_EVT_CONN_CANCEL_RSP

This message is a response to notify APP the result of calling ble_conn_connect_cancel API. The message data type is ble_conn_conn_cancel_rsp_t, including status which indicates if the cancel procedure is started successfully.

- BLE_CONN_EVT_SEC_INFO_SET_RSP

This message is a response to notify APP the result of calling ble_conn_sec_info_set API. The message data type is ble_conn_sec_info_set_rsp_t, including status which indicates if the keys stored by APP are sent to BLE stack successfully.

- BLE_CONN_EVT_INIT_STATE_CHG

This message is sent to the callback function when the state changes during active creation of connections. The data type is ble_init_state_chg_t, including the current state, the reason for state change, and whether the filter accept list is used.

- BLE_CONN_EVT_STATE_CHG

This message is sent to the callback function after the connection state changes. The data type is ble_conn_state_chg_t, which contains the new state. When the state is BLE_CONN_STATE_CONNECTED, it also contains information of connections whose structure is ble_gap_conn_info_t. When the state is BLE_CONN_STATE_DISCONNECTD, it also contains the information of disconnections whose structure is ble_gap_disconn_info_t.

- BLE_CONN_EVT_PEER_NAME_GET_RSP

This message returns the result of APP calling ble_conn_peer_name_get to get the name information in the peer GATT database. The message data type is ble_gap_peer_name_get_rsp_t, including the status of the obtained attribute. If the status is BLE_ERR_NO_ERROR, it also contains the attribute handle, name length, name content, etc.

- BLE_CONN_EVT_PEER_VERSION_GET_RSP

This message returns the result of APP calling ble_conn_peer_version_get to get the peer version information. The message data type is ble_gap_peer_ver_get_rsp_t, including the status of the obtained version. If the status is BLE_ERR_NO_ERROR, it also contains the company id, lmp version, lmp subversion, etc.

- BLE_CONN_EVT_PEER_FEATS_GET_RSP

This message returns the result of APP calling ble_conn_peer_feats_get to get the information of features supported by the peer device. The message data type is ble_gap_peer_feats_get_rsp_t, including the obtained status. If the status is BLE_ERR_NO_ERROR, it also contains the feature array supported by the peer, etc.

- BLE_CONN_EVT_PEER_APPEARANCE_GET_RSP

This message returns the result of APP calling ble_conn_peer_appearance_get to get the appearance information in the peer GATT database. The message data type is ble_gap_peer_appearance_get_rsp_t, including the status of the obtained attribute. If the status is BLE_ERR_NO_ERROR, it also contains the attribute handle, appearance, etc.

- BLE_CONN_EVT_PEER_SLV_PRF_PARAM_GET_RSP

This message returns the result of APP calling ble_conn_peer_slave_prefer_param_get to get the information of the attribute slave preferred parameter in the peer GATT database. The message data type is ble_gap_slave_prefer_param_get_rsp_t, including the status of the obtained attribute. If the status is BLE_ERR_NO_ERROR, it also contains the attribute handle, slave preferred connection interval, latency, etc.

- BLE_CONN_EVT_PEER_ADDR_RESLV_GET_RSP

This message returns the result of APP calling ble_conn_peer_addr_resolution_support_get to get the information of the attribute central address resolution support in the peer GATT database. The message data type is ble_gap_peer_addr_resol_get_rsp_t, including the status of the obtained attribute. If the status is BLE_ERR_NO_ERROR, it also contains the attribute handle, central address resolution support, etc.

- BLE_CONN_EVT_PEER_RPA_ONLY_GET_RSP

This message returns the result of APP calling ble_conn_peer_rpa_only_get to get the information of the attribute resolvable private address only in the peer GATT database. The message data type is ble_gap_peer_rpa_only_get_rsp_t, including the status of the obtained

attribute. If the status is BLE_ERR_NO_ERROR, it also contains the attribute handle, resolvable private address only, etc.

- BLE_CONN_EVT_PEER_DB_HASH_GET_RSP

This message returns the result of APP calling ble_conn_peer_db_hash_get to get the information of the attribute database hash in the peer GATT database. The message data type is ble_gap_peer_db_hash_get_rsp_t, including the obtained status. If the status is BLE_ERR_NO_ERROR, it also contains the attribute handle, database hash etc.

- BLE_CONN_EVT_PING_TO_VAL_GET_RSP

This message returns the result of APP calling ble_conn_ping_to_get to get the BLE link ping timeout value. The message data type is ble_gap_ping_tout_get_rsp_t, including the obtained status. If the status is BLE_ERR_NO_ERROR, it also contains the ping timeout value.

- BLE_CONN_EVT_PING_TO_INFO

This message is used to actively notify APP after ping timeout. The message data type is ble_gap_ping_tout_info_t , including the connection index where the ping timeout occurs.

- BLE_CONN_EVT_PING_TO_SET_RSP

This message returns the result of APP calling ble_conn_ping_to_set to set the ping timeout value. The message data type is ble_gap_ping_tout_set_rsp_t, including the set status, etc.

- BLE_CONN_EVT_RSSI_GET_RSP

This message returns the result of APP calling ble_conn_rssi_get to get the RSSI of the last packet successfully received through the corresponding connection. The message data type is ble_gap_peer_feats_get_rsp_t, including the obtained status. If the status is BLE_ERR_NO_ERROR, it also contains the RSSI, etc.

- BLE_CONN_EVT_CHANN_MAP_GET_RSP

This message returns the result of APP calling ble_conn_chann_map_get to get the channel map used by the corresponding connection. The message data type is ble_gap_chann_map_get_rsp_t, including the obtained status. If the status is BLE_ERR_NO_ERROR, it also contains the channel map array information.

- BLE_CONN_EVT_NAME_GET_IND

This message is used to notify APP when the peer device tries to get the local name. The message data type is ble_gap_name_get_ind_t, including the start offset and the maximum name length of the name to return. APP can call ble_conn_name_get_cfm to reply.

- BLE_CONN_EVT_APPEARANCE_GET_IND

This message is used to notify APP when the peer device tries to get the local appearance. The message data type is ble_gap_appearance_get_ind_t. APP can call ble_conn_appearance_get_cfm to reply.

- BLE_CONN_EVT_SLAVE_PREFER_PARAM_GET_IND

This message is used to notify APP when the peer device tries to get the local slave preferred parameter attribute. The message data type is ble_gap_slave_prefer_param_get_ind_t. APP can call ble_conn_slave_prefer_param_get_cfm to reply.

- BLE_CONN_EVT_NAME_SET_IND

This message is used to notify APP when the peer device tries to set the local name. The message data type is ble_gap_name_set_ind_t, including the name length and name content to be set. APP can call ble_conn_name_set_cfm to reply.

- BLE_CONN_EVT_APPEARANCE_SET_IND

This message is used to notify APP when the peer device tries to set the local appearance. The message data type is ble_gap_appearance_set_ind_t, including the appearance value to be set. APP can call ble_conn_appearance_set_cfm to reply.

- BLE_CONN_EVT_PARAM_UPDATE_IND

This message is used to notify APP when the peer initiates the connection parameter update. The message data type is ble_gap_conn_param_update_ind_t, including parameters such as connection interval, latency, and supervision timeout that the peer wants to update. APP can call ble_conn_param_update_cfm to reply.

- BLE_CONN_EVT_PARAM_UPDATE_RSP

This message returns the result of APP calling ble_conn_param_update_req to initiate the connection parameter update. The message type is ble_gap_conn_param_update_rsp_t, including the update status.

- BLE_CONN_EVT_PARAM_UPDATE_INFO

This message is used to notify APP after the connection parameter update initiated by the peer or local device is completed. The message data type is ble_gap_conn_param_info_t, including the connection interval, latency, supervision timeout, etc. used after the update.

- BLE_CONN_EVT_PKT_SIZE_SET_RSP

This message returns the result of APP calling ble_conn_pkt_size_set to set the size of packets sent by the local device. The message data type is ble_gap_pkt_size_set_rsp_t, including the set status.

- BLE_CONN_EVT_PKT_SIZE_INFO

This message is used to notify APP after the packet size update initiated by the peer or local device is completed. The message data type is ble_gap_pkt_size_info_t, including the max tx octets, max tx time, max rx octets, and max rx time.

- BLE_CONN_EVT_PHY_GET_RSP

This message returns the result of APP calling ble_conn_phy_get to get the PHY information

used by the connection. The message data type is ble_gap_phy_get_rsp_t, including the obtained status.

- BLE_CONN_EVT_PHY_SET_RSP

This message returns the result of APP calling ble_conn_phy_set to set the PHY used by the connection. The message data type is ble_gap_phy_set_rsp_t, including the set status.

- BLE_CONN_EVT_PHY_INFO

This message is used to notify APP of the currently used PHY information after APP gets the connection PHY information and APP or the peer completes the setting of connection PHY. The message data type is ble_gap_phy_info_t, including the tx PHY and rx PHY information of the current connection.

- BLE_CONN_EVT_LOC_TX_PWR_GET_RSP

This message returns the result of APP calling ble_conn_local_tx_pwr_get to get the local transmit power. The message data type is ble_gap_local_tx_pwr_get_rsp_t, including the obtained status. If the status is BLE_ERR_NO_ERROR, it also contains the obtained PHY, the currently used transmit power on the corresponding PHY, and the maximum transmit power.

- BLE_CONN_EVT_PEER_TX_PWR_GET_RSP

This message returns the result of APP calling ble_conn_peer_tx_pwr_get to get the peer transmit power. The message data type is ble_gap_peer_tx_pwr_get_rsp_t, including the obtained status. If the status is BLE_ERR_NO_ERROR, it also contains the obtained PHY, the transmit power on the corresponding PHY used by the peer, and power flags.

- BLE_CONN_EVT_TX_PWR_RPT_CTRL_RSP

This message returns the result of APP calling ble_conn_tx_pwr_report_ctrl to set the transmit power report. The message data type is ble_gap_tx_pwr_report_ctrl_rsp_t, including the set status.

- BLE_CONN_EVT_LOC_TX_PWR_RPT_INFO

This message is used to notify APP after APP calls ble_conn_tx_pwr_report_ctrl to enable the report when the local transmit power changes. The message data type is ble_gap_tx_pwr_report_info_t, including the PHY reported by the local device, the transmit power on the corresponding PHY, power flags, and changed transmit power delta.

- BLE_CONN_EVT_PEER_TX_PWR_RPT_INFO

This message is used to notify APP after APP calls ble_conn_tx_pwr_report_ctrl to enable the report when the peer transmit power changes. The message data type is ble_gap_tx_pwr_report_info_t, including the PHY reported by the peer device, the transmit power on the corresponding PHY, power flags, and changed transmit power delta.

- BLE_CONN_EVT_PATH_LOSS_CTRL_RSP

This message returns the result of APP calling ble_conn_path_loss_ctrl to set the path loss. The message data type is ble_gap_path_loss_ctrl_rsp_t, including the set status.

- BLE_CONN_EVT_PATH_LOSS_THRESHOLD_INFO

This message is used to notify APP after APP calls ble_conn_path_loss_ctrl to set the path loss and the path loss zone changes. The message data type is ble_gap_path_loss_threshold_info_t, including the current path loss value and the corresponding zone information.

- BLE_CONN_EVT_PER_SYNC_TRANS_RSP

This message returns the result of APP calling ble_conn_per_adv_sync_trans to sync transfer periodic advertising to the peer device. The message type is ble_gap_per_adv_sync_trans_rsp_t, including the transfer success or failure status.

2.5.2. ble_conn_callback_register

Prototype: ble_status_t ble_conn_callback_register(ble_conn_evt_handler_t callback)

Function: Register the callback function for processing BLE connection messages

Input parameter: callback, a function that processes BLE connection messages. For the description of connection messages, see ***Connection message type***.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.3. ble_conn_callback_unregister

Prototype: ble_status_t ble_conn_callback_unregister(ble_conn_evt_handler_t callback)

Function: Unregister the callback function from the BLE connection module

Input parameter: callback, a function that processes BLE connection messages

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.4. ble_conn_connect

Prototype: ble_status_t ble_conn_connect(ble_gap_init_param_t *p_param,
ble_gap_local_addr_type_t own_addr_type,
ble_gap_addr_t *p_peer_addr_info, bool use_wl)

Function: Initiate BLE connection

Input parameters: p_param, the parameter structure pointer used when initiating connections, including the connection interval, window, etc.

own_addr_type, the local address type used when creating connections

p_peer_addr_info, the peer device address information pointer

use_wl, indicating whether FAL is used; if yes, it will connect to the device in FAL instead of the address specified by p_peer_addr_info.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_CONN_EVT_CONN_RSP message is sent to the callback function to notify if create connection procedure is started successfully. If so, a BLE_CONN_EVT_STATE_CHG message is also sent with state as BLE_CONN_STATE_CONNECTED. The connection index included in the connection info can be used for subsequent operations.

2.5.5. ble_conn_disconnect

Prototype: ble_status_t ble_conn_disconnect(uint8_t conidx, uint16_t reason)

Function: Disconnect BLE connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection

reason, the reason for disconnection; use BLE_ERROR_HL_TO_HCI (BLE_LL_ERR_xxx), and BLE_LL_ERR_xxx is the error code of the LL group in ble_err_t

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_CONN_EVT_DISCONN_RSP message will be sent to the callback function to notify if disconnect procedure is started successfully. If so, after successful disconnection, a BLE_CONN_EVT_STATE_CHG message is also sent with state BLE_CONN_STATE_DISCONNECTED

2.5.6. ble_conn_connect_cancel

Prototype: ble_status_t ble_conn_connect_cancel(void)

Function: Cancel the BLE connection being initiated

Input parameter: None

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_CONN_EVT_CONN_CANCEL_RSP message will be sent to the callback function to notify if cancel procedure is started successfully

2.5.7. ble_conn_sec_info_set

Prototype: ble_status_t ble_conn_sec_info_set(uint8_t conidx, uint8_t *p_local_csrk, uint8_t *p_peer_csrk, uint8_t pairing_lvl, uint8_t enc_key_present)

Function: If APP manages security keys, after receiving the BLE_CONN_EVT_STATE_CHG message showing the connection state is BLE_CONN_STATE_CONNECTED, it should call this API to transfer key information to BLE stack.

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

p_local_csrk, local CSRK

p_peer_csrk, peer CSRK

pairing_lvl, pairing level

enc_key_present, which indicates whether encryption key is present

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_CONN_EVT_SEC_INFO_SET_RSP message will be sent to the callback function to notify if cancel procedure is started successfully.

2.5.8. ble_conn_peer_name_get

Prototype: ble_status_t ble_conn_peer_name_get(uint8_t conidx)

Function: Get the name of the peer device that has established a connection in the GATT database

Input parameter: conidx, BLE connection index, which can be obtained in

the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_NAME_GET_RSP message is sent to the callback function

2.5.9. ble_conn_peer_feats_get

Prototype: ble_status_t ble_conn_peer_feats_get(uint8_t conidx)

Function: Get the features supported by the peer device that has established a connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_FEATS_GET_RSP message is sent to the callback function

2.5.10. ble_conn_peer_appearance_get

Prototype: ble_status_t ble_conn_peer_appearance_get(uint8_t conidx)

Function: Get the appearance of the peer device that has established a connection in the GATT database

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_APPEARANCE_GET_RSP message is sent to the callback function

2.5.11. ble_conn_peer_version_get

Prototype: ble_status_t ble_conn_peer_version_get(uint8_t conidx)

Function: Get the version information of the peer device that has established a connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_VERSION_GET_RSP message is sent to the callback function

2.5.12. ble_conn_peer_slave_prefer_param_get

Prototype: ble_status_t ble_conn_peer_slave_prefer_param_get(uint8_t conidx)

Function: Get the slave prefer parameters attribute of the peer device that has established a connection in the GATT database

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_SLV_PRF_PARAM_GET_RSP message is sent to the callback function

2.5.13. ble_conn_peer_addr_resolution_support_get

Prototype: ble_status_t ble_conn_peer_addr_resolution_support_get(uint8_t conidx)

Function: Get the address resolution support attribute of the peer device that has established a connection in the GATT database

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_ADDR_RESLV_GET_RSP message is sent to the callback function

2.5.14. ble_conn_peer_rpa_only_get

Prototype: ble_status_t ble_conn_peer_rpa_only_get(uint8_t conidx)

Function: Get the RPA only attribute of the peer device that has established a connection in the GATT database

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_RPA_ONLY_GET_RSP message is sent to the callback function

2.5.15. ble_conn_peer_db_hash_get

Prototype: ble_status_t ble_conn_peer_db_hash_get(uint8_t conidx)

Function: Get the database hash attribute of the peer device that has established a connection in the GATT database

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_DB_HASH_GET_RSP message is sent to the callback function

2.5.16. ble_conn_phy_get

Prototype: ble_status_t ble_conn_phy_get(uint8_t conidx)

Function: Get the PHY being used by the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PHY_GET_RSP message is sent to the callback function. If the PHY is successfully obtained, a BLE_CONN_EVT_PHY_INFO message is also sent to the callback function

2.5.17. ble_conn_phy_set

Prototype: ble_status_t ble_conn_phy_set(uint8_t conidx, uint8_t tx_phy, uint8_t rx_phy, uint8_t phy_opt)

Function: Set the PHY used by the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

tx_phy, the PHY bitfield used by tx, which is composed of ble_gap_le_phy_bf_t

rx_phy, the PHY bitfield used by rx, which is composed of ble_gap_le_phy_bf_t

phy_opt, in the case of coded PHY, set the preference of S=2 or S=8

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PHY_SET_RSP message is sent to the callback function. After the PHY is successfully set, a BLE_CONN_EVT_PHY_INFO message is also sent to the callback function

2.5.18. ble_conn_pkt_size_set

Prototype: ble_status_t ble_conn_pkt_size_set(uint8_t conidx, uint16_t tx_octets, uint16_t tx_time)

Function: Set the maximum packet size that an established connection can use when transmitting

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

tx_octets, the maximum number of octets in the tx packet

tx_time, the maximum time for sending tx packets

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PKT_SIZE_SET_RSP message is sent to the callback function. After packet size is successfully set, a BLE_CONN_EVT_PKT_SIZE_INFO message is sent to the callback function.

2.5.19. ble_conn_chann_map_get

Prototype: ble_status_t ble_conn_chann_map_get(uint8_t conidx)

Function: Get the channel map used by the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_CHANN_MAP_GET_RSP message is sent to the callback function

2.5.20. ble_conn_ping_to_get

Prototype: ble_status_t ble_conn_ping_to_get(uint8_t conidx)

Function: Get the ping timeout value of the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PING_TO_VAL_GET_RSP message is sent to the callback function

2.5.21. ble_conn_ping_to_set

Prototype: ble_status_t ble_conn_ping_to_set(uint8_t conidx, uint16_t tout)

Function: Set the ping timeout value of the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

tout, ping timeout value, in 10 ms

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PING_TO_SET_RSP message is sent to the callback function

2.5.22. ble_conn_rssi_get

Prototype: ble_status_t ble_conn_rssi_get(uint8_t conidx)

Function: Get the rssi of the packet recently received on the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_RSSI_GET_RSP

message is sent to the callback function.

2.5.23. ble_conn_param_update_req

Prototype: ble_status_t ble_conn_param_update_req (uint8_t conidx, uint16_t interval, uint16_t latency, uint16_t supv_to, uint16_t ce_len)

Function: Set connection parameters of the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

interval, the connection event period to be set, in 1.25 ms

latency, the maximum number of connection events for the master packet that the slave does not need to listen to

supv_to, disconnection timeout, in 10 ms

ce_len, the length of connection events, in 0.625 ms

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PARAM_UPDATE_RSP message is sent to the callback function. After the connection parameters are successfully updated, a BLE_CONN_EVT_PARAM_UPDATE_INFO message is also sent to the callback function

2.5.24. ble_conn_per_adv_sync_trans

Prototype: ble_status_t ble_conn_per_adv_sync_trans(uint8_t conidx, uint8_t trans_idx, uint16_t srv_data)

Function: Forward periodic advertising information to the peer device that has established a connection, so that it can directly initiate sync

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

trans_idx, the index to be forwarded, which can be the index of periodic advertising created by the local device or the sync index after the

local sync is successful

srv_data, the service data that APP can set

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PER_SYNC_TRANS_RSP message is sent to the callback function

2.5.25. ble_conn_name_get_cfm

Prototype: ble_status_t ble_conn_name_get_cfm(uint8_t conidx, uint16_t status, uint16_t token, uint16_t cmpl_len, uint8_t *p_name, uint16_t name_len)

Function: This function is used to reply the request initiated by the peer device to get the local name after receiving the BLE_CONN_EVT_NAME_GET_IND message in the callback function

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

status, the confirm status; if there is an error or exception, fill in the error code; otherwise, fill in 0

token, message token, which is obtained in the BLE_CONN_EVT_NAME_GET_IND message

cmpl_len, the total length of the local name

p_name, a pointer to the complete or partial content of the replied name

name_len, the length of the name in this reply. If the complete name is replied, the length is equal to cmpl_len

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.26. ble_conn_appearance_get_cfm

Prototype: ble_status_t ble_conn_appearance_get_cfm(uint8_t conidx, uint16_t status, uint16_t token, uint16_t appearance)

Function: This function is used to reply the request initiated by the peer device to get the local appearance after receiving the BLE_CONN_EVT_APPEARANCE_GET_IND message in the callback function

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

status, the confirm status; if there is an error or exception, fill in the error code; otherwise, fill in 0

token, which is obtained in the BLE_CONN_EVT_APPEARANCE_GET_IND message

appearance, the local appearance replied

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.27. ble_conn_slave_prefer_param_get_cfm

Prototype: ble_status_t ble_conn_slave_prefer_param_get_cfm (uint8_t conidx, uint16_t status, uint16_t token, ble_gap_prefer_periph_param_t *p_param)

Function: This function is used to reply the request initiated by the peer device to get the slave prefer parameter after receiving the BLE_CONN_EVT_SLAVE_PREFER_PARAM_GET_IND message in the callback function

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

status, the confirm status; if there is an error or exception, fill in the error code; otherwise, fill in 0

token, which is obtained in the BLE_CONN_EVT_SLAVE_PREFER_PARAM_GET_IND message

p_param, slave prefer parameter structure pointer, including the interval, latency, etc.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.28. ble_conn_name_set_cfm

Prototype: ble_status_t ble_conn_name_set_cfm (uint8_t conidx, uint16_t status, uint16_t token)

Function: This function is used to reply the request initiated by the peer device to set the local name after receiving the BLE_CONN_EVT_NAME_SET_IND message in the callback function

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

status, the confirm status; if there is an error or exception, fill in the error code; otherwise, fill in 0

token, which is obtained in the BLE_CONN_EVT_NAME_SET_IND message

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.29. ble_conn_appearance_set_cfm

Prototype: ble_status_t ble_conn_appearance_set_cfm(uint8_t conidx, uint16_t status, uint16_t token)

Function: This function is used to reply the request initiated by the peer device to set the local appearance after receiving the BLE_CONN_EVT_APPEARANCE_SET_IND message in the callback function

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

status, the confirm status; if there is an error or exception, fill in the error code; otherwise, fill in 0

token, which is obtained in the BLE_CONN_EVT_APPEARANCE_SET_IND message

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.30. ble_conn_param_update_cfm

Prototype: ble_status_t ble_conn_param_update_cfm(uint8_t conidx, bool accept,
uint16_t ce_len_min, uint16_t ce_len_max)

Function: This function is used to reply the connection parameter update request
initiated by the peer device after receiving
the BLE_CONN_EVT_PARAM_UPDATE_IND message in the callback function

Input parameter: conidx, BLE connection index, which can be obtained in
the connection success message
accept, true means to accept the connection parameter update request;
otherwise, return false
ce_len_min, the minimum time of connection events, in 0.625 ms
ce_len_max, the maximum time of connection events, in 0.625 ms

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.5.31. ble_conn_local_tx_pwr_get

Prototype: ble_status_t ble_conn_local_tx_pwr_get(uint8_t conidx,
ble_gap_phy_pwr_value_t phy)

Function: Get the local transmit power on the corresponding PHY of
the established connection

Input parameter: conidx, BLE connection index, which can be obtained in
the connection success message
phy, the PHY corresponding to the obtained power

Output parameter: None

Return value: Return 0 on successful execution, and return the error code
defined in ble_status_t on failure. After execution,
a BLE_CONN_EVT_LOC_TX_PWR_GET_RSP
message is sent to the callback function

2.5.32. ble_conn_peer_tx_pwr_get

Prototype: ble_status_t ble_conn_peer_tx_pwr_get (uint8_t conidx,
ble_gap_phy_pwr_value_t phy)

Function: Get the peer transmit power used on the corresponding PHY of the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message
phy, the PHY corresponding to the obtained power

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_PEER_TX_PWR_GET_RSP message is sent to the callback function

2.5.33. ble_conn_tx_pwr_report_ctrl

Prototype: ble_status_t ble_conn_tx_pwr_report_ctrl(uint8_t conidx, uint8_t local_en,
uint8_t remote_en)

Function: Set whether to send a notification to APP when the local or peer transmit power changes on the established connection

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message
local_en, whether to notify APP when the local transmit power changes
remote_en, whether to notify APP when the peer transmit power changes

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_CONN_EVT_TX_PWR_RPT_CTRL_RSP message is sent to the callback function. If local enable is successfully set, when the local transmit power changes,

a BLE_CONN_EVT_LOC_TX_PWR_RPT_INFO

message is sent to the callback function. If remote enable is successfully set,

when the peer tx power changes,

a BLE_CONN_EVT_PEER_TX_PWR_RPT_INFO

message is sent to the callback function

2.5.34. ble_conn_path_loss_ctrl

Prototype: ble_status_t ble_conn_path_loss_ctrl (uint8_t conidx, uint8_t enable,
uint8_t high_threshold, uint8_t high_hysteresis, int8_t low_threshold,
uint8_t low_hysteresis, uint16_t min_time)

Function: Set the path loss notification on the established connection

Input parameter: conidx, BLE connection index, which can be obtained in
the connection success message
enable, whether to notify of path
loss high_threshold, the threshold of path loss in the high zone
high_hysteresis, the hysteresis value of the high threshold
low_threshold, the threshold of path loss in the low zone
low_hysteresis, the hysteresis value of the low threshold
min_time, the minimum number of connection events to stay after
the path changes

Output parameter: None

Return value: Return 0 on successful execution, and return the error code
defined in ble_status_t on failure. After execution,
a BLE_CONN_EVT_PATH_LOSS_CTRL_RSP
message is sent to the callback function. If it is successfully set to enable,
when the path zone changes,
a BLE_CONN_EVT_PATH_LOSS_THRESHOLD_INFO
message is sent to the callback function

2.5.35. ble_conn_enable_central_feat

Prototype: ble_status_t ble_conn_enable_central_feat(uint8_t conidx)

Function: When the device serves as peripheral, it actively obtains and configures the central gap service information.

Input parameter: conidx, BLE connection index, which can be obtained in the connection success message

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6. BLE security API

The header file is ble_sec.h.

The BLE security module mainly provides interfaces required for interaction during pairing, authentication, encryption, and other processes.

2.6.1. Security message type

APP can register a callback function with the BLE security module, and the BLE security module will send the following event messages to APP through the callback function.

- BLE_SEC_EVT_PAIRING_REQ_IND

This message is used to notify APP after the pairing request initiated by the peer device is received. The message data type is ble_gap_pairing_req_ind_t, including the peer authentication request level, etc. APP can call ble_sec_pairing_req_cfm to reply.

- BLE_SEC_EVT_LTK_REQ_IND

This message is used to get the long term key of the paired device from APP during authentication. The message data type is ble_gap_ltk_req_ind_t, including the LTK size information. APP can call ble_sec_ltk_req_cfm to reply.

- BLE_SEC_EVT_KEY_DISPLAY_REQ_IND

This message is used to get the PIN CODE from APP during pairing. The message data type is ble_gap_tk_req_ind_t, including the connection index information. APP can call ble_sec_key_display_enter_cfm to reply.

- BLE_SEC_EVT_KEY_ENTER_REQ_IND

This message is used to notify APP when the user is required to enter the passkey during

pairing. The message data type is ble_gap_tk_req_ind_t, including the connection index information. APP can call ble_sec_key_display_enter_cfm to reply.

- BLE_SEC_EVT_KEY_OOB_REQ_IND

This message is used to notify APP when APP is required to use OOB data as the temp key. The message data type is ble_gap_tk_req_ind_t, including the connection index information. APP can call ble_sec_oob_req_cfm to reply.

- BLE_SEC_EVT_NUMERIC_COMPARISON_IND

This message is used to notify APP when the user is required to compare the generated number on both sides during pairing. The message data type is ble_gap_nc_ind_t, including the number to be compared. APP can call ble_sec_nc_cfm to reply.

- BLE_SEC_EVT_IRK_REQ_IND

This message is used to notify APP when the local IRK needs to be obtained and distributed during pairing. The message data type is ble_gap_irk_req_ind_t, including the connection index information. APP can call the ble_sec_irk_req_cfm function to reply.

- BLE_SEC_EVT_CSRK_REQ_IND

This message is used to notify APP when the local CSRK needs to be obtained and distributed during pairing. The message data type is ble_gap_csrk_req_ind_t, including the connection index information. APP can call the ble_sec_csrk_req_cfm function to reply.

- BLE_SEC_EVT_OOB_DATA_REQ_IND

This message is used to get OOB data from APP when using the OOB mode during pairing. The message data type is ble_gap_oob_data_req_ind_t, including the connection index information. APP can call the ble_sec_oob_data_req_cfm function to reply.

- BLE_SEC_EVT_PAIRING_SUCCESS_INFO

This message is used to notify APP after the pairing is successful. The message data type is ble_sec_pairing_success_t, including whether it is a secure connection, the pairing level, etc.

- BLE_SEC_EVT_PAIRING_FAIL_INFO

This message is used to notify APP when the pairing fails. The message data type is ble_sec_pairing_fail_t, including the reason for pairing failure, etc.

- BLE_SEC_EVT_SECURITY_REQ_INFO

This message is used to notify APP when the master receives the security request initiated by the peer slave. The message data type is ble_sec_security_req_info_t, including the authentication request level and other information of the peer device. APP can decide to initiate encryption or pairing based on whether there is a LTK from the peer device after receiving the message.

- BLE_SEC_EVT_ENCRYPT_REQ_IND

This message is used to notify APP after the encryption request initiated by the peer device is received. The message data type is ble_gap_encrypt_req_ind_t, including the ediv, random number, etc. APP can call ble_sec_encrypt_req_cfm to reply.

- BLE_SEC_EVT_ENCRYPT_INFO

This message is used to notify APP after encryption is completed. The message data type is ble_sec_encrypt_info_t, including the encryption success or failure status. If successful, it also contains the pairing level and other information.

- BLE_SEC_EVT_OOB_DATA_GEN_INFO

This message is used to notify APP after APP calls ble_sec_oob_data_gen to generate a set of OOB data. The message data type is ble_sec_oob_data_info_t, including the generated OOB data.

- BLE_SEC_EVT_KEY_PRESS_NOTIFY_RSP

This message returns the result of APP calling ble_sec_key_press_notify. The message data type is ble_gap_key_press_ntf_rsp_t, including the status of sending key press notification.

- BLE_SEC_EVT_KEY_PRESS_INFO

This message is used to notify APP after the key press notification of the peer device is received. The message data type is ble_gap_key_pressed_info_t, including the key press type and other information of the peer device.

2.6.2. ble_sec_callback_register

Prototype: ble_status_t ble_sec_callback_register(ble_sec_evt_handler_t callback)

Function: The interface is used to register the event message handler with the BLE security module.

Input parameter: callback, callback handler. For the description of security messages, See ***Security message type***.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

2.6.3. ble_sec_callback_unregister

Prototype: ble_status_t ble_sec_callback_unregister(ble_sec_evt_handler_t callback)

Function: Unregister the callback function from BLE security module

Input parameter: callback, callback function to be unregistered

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

2.6.4. ble_sec_security_req

Prototype: ble_status_t ble_sec_security_req(uint8_t conidx, uint8_t auth)

Function: Send a security request message for active pairing as a slave.

Input parameter: conidx, connection index

auth, indicating the pairing security type. Refer to the enum ble_gap_auth_mask_t.

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.5. ble_sec_bond_req

Prototype:ble_status_t ble_sec_bond_req(uint8_t conidx, ble_gap_pairing_param_t *p_param, uint8_t sec_req_level)

Function: Send a pairing request message for active pairing as a master, or respond to the security request from the peer slave to initiate pairing after receiving the BLE_SEC_EVT_SECURITY_REQ_INFO message

Input parameter: conidx, connection index

p_param, the parameter of the pairing request message. Refer to the structure ble_gap_pairing_param_t

sec_req_level, security request level. Refer to the enum ble_gap_sec_req_t

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.6. ble_sec_encrypt_req

Prototype: ble_status_t ble_sec_encrypt_req(uint8_t conidx, ble_gap_ltk_t *p_peer_ltk)

Function: Send an encryption request when there is a LTK from the peer device

Input parameter: conidx, connection index

p_peer_ltk, the peer ltk

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.7. ble_sec_key_press_notify

Prototype: ble_status_t ble_sec_key_press_notify(uint8_t conidx, uint8_t type)

Function: Send a keypress notify message

Input parameter: conidx, connection index

type， 0： Passkey entry started

1： Passkey digit entered

2： Passkey digit erased

3： Passkey cleared

4： Passkey entry completed

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_SEC_EVT_KEY_PRESS_NOTIFY_RSP message is sent to the callback function

2.6.8. ble_sec_key_display_enter_cfm

Prototype: ble_status_t ble_sec_key_display_enter_cfm(uint8_t conidx, bool accept, uint32_t passkey)

Function: This function is used to reply PIN CODE or passkey during pairing after receiving BLE_SEC_EVT_KEY_DISPLAY_REQ_IND or BLE_SEC_EVT_KEY_ENTER_REQ_IND in the callback function.

Input parameter: conidx, connection index

accept, whether to accept the request

passkey, the value range is 000000-999999

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.9. ble_sec_oob_req_cfm

Prototype: ble_status_t ble_sec_oob_req_cfm(uint8_t conidx, bool accept, uint8_t *p_key)

Function: This function is used to reply OOB TK during pairing after receiving the BLE_SEC_EVT_KEY_OOB_REQ_IND message in the callback function

Input parameter: conidx, connection index

accept, whether to accept the request

p_key, 128-bit key value

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.10. ble_sec_nc_cfm

Prototype: ble_status_t ble_sec_nc_cfm(uint8_t conidx, bool accept)

Function: This function is used to reply the results of numeric comparison during pairing after receiving the BLE_SEC_EVT_NUMERIC_COMPARISON_IND message in the callback function

Input parameter: conidx, connection index

accept, whether the results of numeric comparison are consistent

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.11. ble_sec_ltk_req_cfm

Prototype: ble_status_t ble_sec_ltk_req_cfm(uint8_t conidx, uint8_t accept, ble_gap_ltk_t *p_ltk)

Function: This function is used to reply the local LTK information or reject the request after receiving the BLE_SEC_EVT_LTK_REQ_IND message in the callback function

Input parameter: conidx, connection index

accept, whether to accept the request

p_ltk, a pointer to the ltk value

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.12. ble_sec_irk_req_cfm

Prototype: ble_status_t ble_sec_irk_req_cfm(uint8_t conidx, uint8_t accept, ble_gap_irk_t *p_irk)

Function: The function is used to reply the local IRK information or reject the request after receiving the BLE_SEC_EVT_IRK_REQ_IND message in the callback function

Input parameter: conidx, connection index

accept, whether to accept the request

p_irk, a pointer to the irk value

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.13. ble_sec_csrk_req_cfm

Prototype: ble_status_t ble_sec_csrk_req_cfm(uint8_t conidx, uint8_t accept, ble_gap_csrk_t *p_csrk)

Function: This function is used to reply the local CSRK information or reject the request after receiving the BLE_SEC_EVT_CSRK_REQ_IND message in the callback function

Input parameter: conidx, connection index

accept, whether to accept the request

p_csrk, a pointer to the csrk value

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.14. ble_sec_encrypt_req_cfm

Prototype: ble_status_t ble_sec_encrypt_req_cfm(uint8_t conidx, bool found, uint8_t *p_ltk, uint8_t key_size)

Function: This function is used to reply the local LTK information or reject the request during encryption after receiving the BLE_SEC_EVT_ENCRYPT_REQ_IND message in the callback function

Input parameter: conidx, connection index

found, whether the key exists

p_ltk, a pointer to the local ltk value

key_size, key size

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.15. ble_sec_pairing_req_cfm

Prototype: ble_status_t ble_sec_pairing_req_cfm(uint8_t conidx, uint8_t accept, ble_gap_pairing_param_t *p_param, uint8_t sec_req_lvl)

Function: This function is used to reply the pairing response to the peer device for setting or reject the request after receiving the BLE_SEC_EVT_PAIRING_REQ_IND message in the callback function

Input parameter: conidx, connection index

accept, whether to accept the request

p_param, the parameter of the pairing response message.

Refer to the structure ble_gap_pairing_param_t

sec_req_level, security request level. Refer to the enum ble_gap_sec_req_t

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.16. ble_sec_oob_data_req_cfm

Prototype: ble_status_t ble_sec_oob_data_req_cfm(uint8_t conidx, uint8_t accept, uint8_t *p_conf, uint8_t *p_rand)

Function: This function is used to reply the local OOB information or reject the request during pairing after receiving the BLE_SEC_EVT_OOB_DATA_REQ_IND message in the callback function.

Input parameter: conidx, connection index

accept, whether to accept the request

p_conf, the peer confirm value

p_rand, the peer random value

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.6.17. ble_sec_oob_data_gen

Prototype: ble_status_t ble_sec_oob_data_gen(void)

Function: This function is used to generate a set of OOB data.

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After OOB data is successfully generated, a BLE_SEC_EVT_OOB_DATA_GEN_INFO message is sent to the callback function

2.7. BLE list API

The header file is ble_list.h.

The BLE list module mainly provides interfaces for operating FAL, RAL, and PAL, including operations such as adding devices to the list, deleting devices from the list, and clearing the list.

2.7.1. List message type

- BLE_LIST_EVT_OP_RSP

This message returns the result of APP calling the function ble_fal_op, ble_fal_list_set, ble_fal_list_clear, ble_ral_op, ble_ral_list_set, ble_ral_list_clear, ble_pal_op, ble_pal_list_set, or ble_pal_list_clear to operate the list. The message data type is ble_list_data_t, including the list type, op type, etc. Determine which list operation the reply is for according to the type in the data.

- BLE_LIST_EVT_LOC_RPA_GET_RSP

This message returns the result of APP calling ble_loc_rpa_get to get the local resolvable address. The message data type is ble_list_data_t; the list type is BLE_RAL_TYPE, and the op type is GET_LOC_RPA.

- BLE_LIST_EVT_PEER_RPA_GET_RSP

This message returns the result of APP calling ble_peer_rpa_get to get the peer resolvable address. The message data type is ble_list_data_t; the list type is BLE_RAL_TYPE, and the op type is GET_PEER_RPA.

2.7.2. ble_list_callback_register

Prototype: ble_status_t ble_list_callback_register(ble_list_evt_handler_t callback)

Function: Register the callback function for processing BLE list messages

Input parameter: callback, a function that processes BLE list messages.

For the description of list messages, see ***List message type***.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.7.3. ble_list_callback_unregister

Prototype: ble_status_t ble_list_callback_unregister(ble_list_evt_handler_t callback)

Function: Unregister the callback function from BLE list module

Input parameter: callback, callback function to be unregistered

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.7.4. ble_fal_op

Prototype: ble_status_t ble_fal_op(ble_gap_addr_t *p_addr_info, bool add)

Function: Add the specified device to or remove it from the filter accept list

Input parameter: p_addr_info, device address pointer

add, true means to add to FAL, false means to remove from FAL

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_LIST_EVT_OP_RSP message is sent to the callback function; list type is BLE_FAL_TYPE, and op type is RMV_DEVICE_FROM_LIST or ADD_DEVICE_TO_LIST

2.7.5. ble_fal_list_set

Prototype: ble_status_t ble_fal_list_set(uint8_t num, ble_gap_addr_t *p_addr_info)

Function: Set the filter accept list. This operation will update the whole FAL to the specified content

Input parameter: num, the number of devices that need to be set to FAL

p_addr_info, device array, which contains the information of num addresses

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_LIST_EVT_OP_RSP message is sent to the callback function; list type is BLE_FAL_TYPE, and op type is SET_DEVICES_TO_LIST

2.7.6. ble_fal_clear

Prototype: ble_status_t ble_fal_clear(void)

Function: Clear the filter accept list

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_LIST_EVT_OP_RSP message is sent to the callback function, list type is BLE_FAL_TYPE, and op type is CLEAR_DEVICE_LIST

2.7.7. ble_fal_size_get

Prototype: uint8_t ble_fal_size_get(void)

Function: Get the maximum number of elements in the filter accept list

Input parameter: None

Output parameter: None

Return value: The maximum number of elements in the filter accept list

2.7.8. ble_ral_op

Prototype: ble_status_t ble_ral_op(ble_gap_ral_info_t *p_ral_info, bool add)

Function: Add the specified device to or remove it from the resolving list

Input parameter: p_ral_info, RAL structure pointer, including the identity address, IRK, etc.
add, true means to add to RAL, false means to remove from RAL

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_LIST_EVT_OP_RSP message is sent to the callback function; list type is BLE_RAL_TYPE, and op type is RMV_DEVICE_FROM_LIST or ADD_DEVICE_TO_LIST

2.7.9. ble_ral_list_set

Prototype: ble_status_t ble_ral_list_set(uint8_t num, ble_gap_ral_info_t *p_ral_info)

Function: Set the resolving list. This operation will update the whole RAL to the specified content

Input parameter: num, the number of devices that need to be set to RAL
p_ral_info, RAL structure array, which contains num RAL structures

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_LIST_EVT_OP_RSP message is sent to the callback function; list type is BLE_RAL_TYPE, and op type is SET_DEVICES_TO_LIST

2.7.10. ble_ral_clear

Prototype: ble_status_t ble_ral_clear(void)

Function: Clear the resolving list

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution, a BLE_LIST_EVT_OP_RSP message is sent to the callback function; list type is BLE_RAL_TYPE, and op type is CLEAR_DEVICE_LIST

2.7.11. ble_ral_size_get

Prototype: uint8_t ble_ral_size_get(void)

Function: Get the maximum number of elements in the resolving list

Input parameter: None

Output parameter: None

Return value: The maximum number of elements in the resolving list

2.7.12. ble_loc_rpa_get

Prototype: ble_status_t ble_loc_rpa_get(uint8_t *p_peer_id, uint8_t peer_id_type)

Function: Get the local resolvable private address currently used for the specified device

Input parameter: p_peer_id, the identity address of the specified device
peer_id_type, the identity address type of the specified device

Output parameter: None

Return value: Return 0 on successful execution, and return the error code

defined in ble_status_t on failure. After execution,
a BLE_LIST_EVT_LOC_RPA_GET_RSP message is sent to
the callback function.

2.7.13. ble_peer_rpa_get

Prototype: ble_status_t ble_peer_rpa_get(uint8_t *p_peer_id, uint8_t peer_id_type)

Function: Get the resolvable private address currently used for the specified device

Input parameter: p_peer_id, the identity address of the specified device
peer_id_type, the identity address type of the specified device

Output parameter: None

Return value: Return 0 on successful execution, and return the error code
defined in ble_status_t on failure. After execution,
a BLE_LIST_EVT_PEER_RPA_GET_RSP message is sent to
the callback function

2.7.14. ble_pal_op

Prototype: ble_status_t ble_pal_op(ble_gap_pal_info_t *p_pal_info, bool add)

Function: Add the specified device to or remove it from the periodic advertising list

Input parameter: p_pal_info, PAL structure pointer, including the address, SID, etc.
add, true means to add to PAL, false means to remove from PAL

Output parameter: None

Return value: Return 0 on successful execution, and return the error code
defined in ble_status_t on failure. After execution, a BLE_LIST_EVT_OP_RSP
message is sent to the callback function; list type is BLE_PAL_TYPE,
and op type is RMV_DEVICE_FROM_LIST or ADD_DEVICE_TO_LIST

2.7.15. ble_pal_list_set

Prototype: ble_status_t ble_pal_list_set(uint8_t num, ble_gap_pal_info_t *p_pal_info)

Function: Set the periodic advertising list. This operation will update the whole PAL to
the specified content

Input parameter: num, the number of devices that need to be set to PAL

p_ral_info, PAL structure array, which contains num PAL structures

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution,

a BLE_LIST_EVT_OP_RSP message is sent to the callback function;

list type is BLE_PAL_TYPE, and op type is SET_DEVICES_TO_LIST

2.7.16. ble_pal_clear

Prototype: ble_status_t ble_pal_clear(void)

Function: Clear the periodic advertising list

Input parameter: None

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure. After execution,

a BLE_LIST_EVT_OP_RSP message is sent to the callback function;

list type is BLE_PAL_TYPE, and op type is CLEAR_DEVICE_LIST

2.7.17. ble_pal_size_get

Prototype: uint8_t ble_pal_size_get(void)

Function: Get the maximum number of elements in the periodic advertising list

Input parameter: None

Output parameter: None

Return value: The maximum number of elements in the periodic advertising list

2.8. BLE periodic sync API

The header file is ble_per_sync.h.

The BLE periodic sync module mainly provides interfaces for synchronizing periodic advertising, reporting received periodic advertising data, etc.

2.8.1. Periodic sync message type

APP can register a callback function with the BLE periodic sync module, and the BLE protocol stack will send the following event message to APP through the callback function.

- BLE_PER_SYNC_EVT_START_RSP

This message is a response to APP calling ble_per_sync_start to start periodic sync. The message data type is ble_per_sync_start_rsp_t, including the status of starting periodic sync.

- BLE_PER_SYNC_EVT_CANCEL_RSP

This message is a response to APP calling ble_per_sync_cancel to cancel periodic sync. The message data type is ble_per_sync_cancel_rsp_t, including the status of cancelling periodic sync.

- BLE_PER_SYNC_EVT_TERMINATE_RSP

This message is a response to APP calling ble_per_sync_terminate to terminate a periodic sync train. The message data type is ble_per_sync_terminate_rsp_t, including the status of terminating periodic sync train.

- BLE_PER_SYNC_EVT_STATE_CHG

This message is sent to the callback function when the periodic sync state changes. The message data type is ble_per_sync_state_chg_t, including the new state and the reason for change.

- BLE_PER_SYNC_EVT_REPORT

This message is sent to the callback function after the periodic advertising report is received. The message data type is ble_gap_adv_report_info_t, including the device address for sending periodic advertising, the sent PHY, advertising data, etc.

- BLE_PER_SYNC_EVT_ESTABLISHED

This message is sent to the callback function after the periodic advertising is synchronized. The message data type is ble_per_sync_established_t, including the the PHY of synchronized periodic advertising, interval, SID, etc.

- BLE_PER_SYNC_EVT_RPT_CTRL_RSP

This message returns the result of APP calling ble_per_sync_report_ctrl to set the report content. The message data type is ble_per_sync_rpt_ctrl_rsp_t, including the set status.

2.8.2. ble_per_sync_callback_register

Prototype: ble_status_t ble_per_sync_callback_register(

ble_per_sync_evt_handler_t callback)

Function: Register the callback function that processes periodic sync messages.

For the description of per sync messages, see ***Periodic sync message type***.

Input parameter: callback, callback function that processes periodic sync messages

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.8.3. ble_per_sync_callback_unregister

Prototype: ble_status_t ble_per_sync_callback_unregister(

ble_per_sync_evt_handler_t callback)

Function: Unregister the callback function from BLE periodic sync module

Input parameter: callback, callback function to be unregistered

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.8.4. ble_per_sync_start

Prototype: ble_status_t ble_per_sync_start (ble_gap_local_addr_type_t own_addr_type,

ble_gap_per_sync_param_t *p_param)

Function: Start periodic sync

Input parameter: own_addr_type, the local address type used in the sync process

p_param, periodic sync parameter structure pointer

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_PER_SYNC_EVT_START_RSP will be sent to the callback function to notify if execution is successful. If so, a BLE_PER_SYNC_EVT_STATE_CHG message is also sent. If successfully synchronized, a BLE_PER_SYNC_EVT_ESTABLISHED message is also sent and a BLE_PER_SYNC_EVT_REPORT message is sent to report the received data

2.8.5. ble_per_sync_cancel

Prototype: ble_status_t ble_per_sync_cancel (void)

Function: Cancel the ongoing periodic sync process

Input parameter: None

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_PER_SYNC_EVT_CANCEL_RSP will be sent to the callback function to notify if execution is successful. If so, a BLE_PER_SYNC_EVT_STATE_CHG message is also sent

2.8.6. ble_per_sync_terminate

Prototype: ble_status_t ble_per_sync_terminate (uint8_t sync_idx)

Function: Abort the periodic sync train that has been successfully synchronized

Input parameter: sync_idx, sync index

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

After calling this API, a BLE_PER_SYNC_EVT_TERMINATE_RSP will be sent to the callback function to notify if execution is successful. If so, a BLE_PER_SYNC_EVT_STATE_CHG message is also sent

2.8.7. ble_per_sync_report_ctrl

Prototype: ble_status_t ble_per_sync_report_ctrl(uint8_t sync_idx, uint8_t ctrl)

Function: Modify the content of notification reported after successful synchronization

Input parameter: sync_idx, sync index

ctrl, periodic sync report control bit, which is composed of bits in

ble_per_sync_rpt_ctrl_bit_t

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After the setting, a BLE_PER_SYNC_EVT_RPT_CTRL_RSP

message is sent to the callback function

2.9. BLE storage API

The header file is ble_storage.h. The module uses flash to store and manage the bond information of the peer device, including peer_irk, peer_ltk, peer_csrk, local_irk, local_ltk, local_csrk, etc.

The macro definition BLE_PEER_NUM_MAXin the header file is used to define the maximum number of peer devices. When the number of peer devices stored has reached the upper limit while new peer information needs to be stored, use the LRU algorithm to delete the oldest peer information that has not been used.

2.9.1. ble_peer_data_bond_store

Prototype: ble_status_t ble_peer_data_bond_store(ble_gap_addr_t *addr,
ble_gap_sec_bond_data_t *bond_data)

Function: The function is used to store the bond information of the peer device, which will also be saved in flash. If the bond information with the same index already exists, it will be updated and saved. If keys_user_mgr is false during BLE adapter config, the BLE security will automatically store the bond information, and APP does not need to perform related operations.

Input parameter: addr, the address of the connected device. If bond_data does not contain identity addr, the address will be stored as an index. If bond_data contains identity addr, identity addr will be stored as an index, and this address will not work; however, it cannot be empty
bond_data: the bond information needs to store

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.9.2. ble_peer_data_bond_load

Prototype: ble_status_t ble_peer_data_bond_load(ble_gap_addr_t *addr,
ble_gap_sec_bond_data_t *bond_data)

Function: The function is used to get bond information

Input parameter: addr, which can be identity addr or RPA, with the address as an index to get information

Output parameter: bond_data, the obtained bond information

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.9.3. ble_peer_data_delete

Prototype: ble_status_t ble_peer_data_delete(ble_gap_addr_t *addr)

Function: The function is used to delete the peer information corresponding to the specified addr, and the content in flash will also be deleted.

Input parameter: addr, which can be identity addr or RPA, with the address as an index to delete the peer information

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.9.4. ble_peer_all_addr_get

Prototype: ble_status_t ble_peer_all_addr_get(uint8_t *num, ble_gap_addr_t *id_addrs)

Function: The function is used to get the identity addr of all peer devices under the storage module

Input parameter: num, the num pointer value indicates the maximum number of peer devices that need to be obtained, which cannot exceed BLE_PEER_NUM_MAX and determines the memory size of the id_addrs pointer to be num*sizeof(ble_gap_addr_t)

Output parameter: num, whose value is the actual number obtained id_addrs, the id_addrs pointer stores the actually obtained peer identity addr

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.9.5. ble_svc_data_save

Prototype: ble_status_t ble_svc_data_save(uint8_t conn_idx, uint16_t data_id , uint32_t len, uint8_t *p_data)

Function: The function is provided to the upper-layer BLE service to store data related to the service of the connected device to the flash.

Input parameter: conn_idx, BLE connection index, which can be obtained in the connection success message

data_id, identifies service information and is defined by the upper-layer APP

len, length of p_data

p_data, store service information pointer

Output parameter: None

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.9.6. ble_svc_data_load

Prototype: ble_status_t ble_svc_data_load(uint8_t conn_idx, uint16_t data_id, void **pp_data, uint32_t *p_len)

Function: The function is provided to the upper-layer BLE service to obtain data about the service stored in the flash on the connected device.

Input parameter: conn_idx, BLE connection index, which can be obtained in the connection success message

data_id, identifies service information and is defined by the upper-layer APP

Output parameter: pp_data, the obtained service information pointer

p_len, length of pp_data

Return value: Return 0 on successful execution, and return the error code defined in ble_status_t on failure.

2.10. BLE gatts API

The header file is ble_gatts.h.

The BLE GATT server module mainly provides interfaces for registering/deleting GATT service, sending notification/indication to the client, etc.

2.10.1. gatts message type

BLE services can register a callback function with the BLE GATT server module, and the BLE GATT server module will send the following event messages to BLE services through the callback function.

- BLE_SRV_EVT_SVC_ADD_RSP

This message returns the result of calling the ble_gatts_svc_add function to add a service to the GATT server module. The message data type is ble_gatts_svc_add_rsp_t, including the status of the added service. If the status is 0, it also contains the assigned service ID and the start handle value of the service in the database.

- BLE_SRV_EVT_SVC_RMV_RSP

This message returns the result of calling the ble_gatts_svc_rmvfunction to remove a service from the GATT server module. The message data type is ble_gatts_svc_rmv_rsp_t, including the status of the removed service and the service ID.

- BLE_SRV_EVT_CONN_STATE_CHANGE_IND

This message is sent to the callback function when the device connection state changes. The message data type is ble_gatts_conn_state_change_ind_t, including the connection status. If the connection state is connected, the connection index and address information of the peer device will be included; If the connection state is disconnected, the reason for disconnection will also be included.

- BLE_SRV_EVT_GATT_OPERATION

This message is sent to the callback function when interacting with the peer GATT client. The message data type is ble_gatts_op_info_t, including the subevent, connection index of interacted connection, and message data of different subevents . The message includes the following subevents:

  - BLE_SRV_EVT_READ_REQ

    When the peer client initiates the attribute read request, this subevent will be notified to the callback function. The corresponding data type is ble_gatts_read_req_t, including the attribute index to be read, and the offset and the maximum length of the attribute value. At the same time, the message also contains pending_cfm flag, through which the upper layer can determine whether to directly reply to the peer client with the read result through the GATT server module after the message is process by the callback function. If required, copy the data to the pre-allocated location (the maximum length) of the server module; otherwise, set pending_cfm to true, and call ble_gatts_svc_attr_read_cfm to reply as required.

  - BLE_SRV_EVT_WRITE_REQ

    When the peer client initiates the attribute write request, this subevent will notify the callback function by using the data type of ble_gatts_write_req_t, including the attribute index to be written, and the offset, length, and content of the written data. There is a local_req parameter in the messag data which indicates whether the write reqest is triggered by local (by calling ble_gatts_set_attr_val) or remote device, if triggered by local, there is no need to confirm. The message also contains pending_cfm flag, through which the upper layer can determine whether to directly

reply with the write result through the GATT server module after the message is process by the callback function. If not required, set pending_cfm to true, and call ble_gatts_svc_attr_write_cfm to reply as required.

- BLE_SRV_EVT_NTF_IND_SEND_RSP

  This subevent returns the result of calling ble_gatts_ntf_ind_send or ble_gatts_ntf_ind_send_by_handle to send a GATT notification or indication. The subevent data type is ble_gatts_ntf_ind_send_rsp_t, including the status of the sent data, service id, and attribute index.

- BLE_SRV_EVT_NTF_IND_MTP_SEND_RSP

  This subevent returns the result of calling ble_gatts_ntf_ind_mtp_send to send notifications or indications to multiple remote devices. The message data type is ble_gatts_ntf_ind_mtp_send_rsp_t, including the status of the sent data, service id, and attribute index.

- BLE_SRV_EVT_MTU_INFO

  When GATT MTU changes, this subevent will notify the callback function by using the data type of ble_gatts_mtu_info_t, including the new MTU to be used.

2.10.2. ble_gatts_svc_add

Prototype: ble_status_t ble_gatts_svc_add(uint8_t *p_svc_id, const uint8_t *uuid,
uint16_t start_hdl, uint8_t info, const void *p_table, uint16_t table_length,
p_fun_srv_cb srv_cb)

Function: Add a service to the GATT server module.

Input parameter: uuid, service UUID address
start_hdl, service start attribute handle value; 0 means that the handle is not specified and is automatically assigned by the module
info, service information. For details, see ble_gatt_svc_info_bf
p_table, all attribute arrays of the service; each attribute structure is ble_gatt_attr_desc_t
table_length, the length of service attribute array
srv_cb, the message handler function of GATT server. For the message type, see ***gatts message type***

Output parameter: p_svc_id, the ID assigned by the BLE GATT server module to the service

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After execution, a BLE_PRF_MGR_EVT_SVC_ADD_RSP message is sent to the callback function

2.10.3. ble_gatts_svc_rmv

Prototype: ble_status_t ble_gatts_svc_rmv(uint8_t svc_id)

Function: remove a service

Input parameter: svc_id, the ID assigned to the service when ble_gatts_svc_add is called

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After execution, a BLE_SRV_EVT_SVC_RMV_RSP message is sent to the callback function

2.10.4. ble_gatts_ntf_ind_send

Prototype: ble_status_t ble_gatts_ntf_ind_send (uint8_t conn_idx, uint8_t svc_id, uint16_t att_idx, uint8_t *p_val, uint16_t len, ble_gatt_evt_type_t evt_type)

Function: Send a notification/indication

Input parameter: conn_idx, connection index

svc_id, the ID assigned to the service when ble_gatts_svc_add is called

att_idx, the index value of the attribute in the array when ble_gatts_svc_add is called

p_val, the address of data to be sent

len, the length of data to be sent

evt_type, whether the type of data sent this time is notification or indication

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After execution, a BLE_SRV_EVT_GATT_OPERATION message with a subevent of BLE_SRV_EVT_NTF_IND_SEND_RSP is sent to the callback function

2.10.5. ble_gatts_ntf_ind_send_by_handle

Prototype: ble_status_t ble_gatts_ntf_ind_send_by_handle(uint8_t conn_idx,
uint16_t handle, uint8_t *p_val, uint16_t len, ble_gatt_evt_type_t evt_type)

Function: Send a notification/indication through the attribute handle

Input parameter: conn_idx, connection index
handle, the handle value of the attribute, which can be obtained through the index of the attribute in the array and the start handle of the service when ble_gatts_svc_add is called
p_val, the address of data to be sent
len, the length of data to be sent
evt_type, whether the type of data sent this time is notification or indication

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure
After execution, a BLE_SRV_EVT_GATT_OPERATION message with the subevent of BLE_SRV_EVT_NTF_IND_SEND_RSP is sent to the callback function

2.10.6. ble_gatts_ntf_ind_mtp_send

Prototype: ble_status_t ble_gatts_ntf_ind_mtp_send (uint32_t conidx_bf, uint8_t svc_id,
uint16_t att_idx, uint8_t *p_val, uint16_t len, ble_gatt_evt_type_t evt_type)

Function: Send a notification/indication to multiple connections

Input parameter: conidx_bf, connection index bit combination, bit 0 represents connection index 0x00, bit 1 represents connection index 0x01, and so on
svc_id, the ID assigned to the service when ble_gatts_svc_add is called
att_idx, the index value of the attribute in the array when ble_gatts_svc_add is called
p_val, the address of data to be sent
len, the length of data to be sent
evt_type, whether the type of data sent this time is notification or indication

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After execution, a BLE_SRV_EVT_GATT_OPERATION message with the subevent of BLE_SRV_EVT_NTF_IND_MTP_SEND_RSP is sent to the callback function

2.10.7. ble_gatts_mtu_get

Prototype: ble_status_t ble_gatts_mtu_get(uint8_t conidx, uint16_t *p_mtu)

Function: Obtain GATT MTU of the connection.

Input parameter: conn_idx, connection index

Output parameter: p_mtu, obtained GATT MTU of the connection

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.10.8. ble_gatts_svc_attr_write_cfm

Prototype: ble_status_t ble_gatts_svc_attr_write_cfm(uint8_t conn_idx, uint16_t token, uint16_t status)

Function: When receiving BLE_SRV_EVT_GATT_OPERATION and the subevent is BLE_SRV_EVT_WRITE_REQ and local_req parameter is false in the message data, if automatic reply by GATT server module isnot needed, pending_cfm in the message data should be sent to true, then ble_gatts_svc_attr_write_cfm should be called by user to confirm the write request according to user requirement.

Input parameter: conn_idx, connection index

token, GATT token, which is obtained in the BLE_SRV_EVT_WRITE_REQ message

status, a status of replying to the write request

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.10.9. ble_gatts_svc_attr_read_cfm

Prototype: ble_status_t ble_gatts_svc_attr_read_cfm(uint8_t conn_idx, uint16_t token,

uint16_t status, uint16_t total_len, uint16_t value_len, uint8_t *p_value)

Function: When receiving BLE_SRV_EVT_GATT_OPERATION and the subevent is BLE_SRV_EVT_READ_REQ, if automatic reply by GATT server module is not needed, pending_cfm in the message data should be sent to true, then ble_gatts_svc_attr_read_cfm should be called by user to confirm the read request according to user requirement.

Input parameter: conn_idx, connection index

token, GATT token, which is obtained in the BLE_SRV_EVT_READ_REQ message

status, a status of replying to the read request

total_len, the total length of attribute to be read

value_len, the attribute data length replied with to the read request

p_value, the attribute data content replied with to the read request

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.10.10. ble_gatts_get_start_hdl

Prototype: ble_status_t ble_gatts_get_start_hdl(uint8_t svc_id, uint16_t *p_handle)

Function: Obtain the start handle value allocated by the GATT server module to the service.

Input parameter: svc_id, service id, which is obtained in ble_gatts_svc_add

Output parameter: p_handle, obtained start handle value

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.10.11. ble_gatts_set_attr_val

Prototype: ble_status_t ble_gatts_set_attr_val(uint8_t conn_idx, uint8_t svc_id, uint8_t char_idx, uint16_t len, uint8_t *p_value)

Function: Set attribute value in GATT server database.

Input parameter: conn_idx, connection index

svc_id, service id, which is obtained in ble_gatts_svc_add

char_idx, characteristic index in the service attribute table

len, attribute value length

p_value, pointer to attribute value data to be set

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After calling this API, a BLE_SRV_EVT_GATT_OPERATION message with subevent BLE_SRV_EVT_WRITE_REQ will be used to notify the corresponding service, and local_req parameter in the message data is true.

2.10.12. ble_gatts_list_svc

Prototype: ble_status_t ble_gatts_list_svc(p_fun_svc_list_cb cb)

Function: Get all the service information registered in the GATT server module.

Input parameter: cb, callback function to handle service information

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.10.13. ble_gatts_list_char

Prototype: ble_status_t ble_gatts_list_char(uint8_t svc_id, p_fun_char_list_cb cb)

Function: Get all the characteristic information in the specified service.

Input parameter: svc_id, service id, which is obtained in ble_gatts_svc_add

cb, callback function to handle characteristic information

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.10.14. ble_gatts_list_desc

Prototype: ble_status_t ble_gatts_list_desc(uint8_t svc_id, uint16_t char_val_idx, p_fun_desc_list_cb cb)

Function: Get specified characteristic descriptor information.

Input parameter: svc_id, service id, which is obtained in ble_gatts_svc_add

char_val_idx, characteristic value index in the service table

cb, callback function to handle characteristic descriptor information

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.11. BLE gattc API

The header file is ble_gattc.h.

The BLE GATT client module mainly provides the following functions: GATT discovery; read and write attribute value from the peer GATT server, etc.

2.11.1. gattc message type

BLE services can register a callback function to the BLE GATT client module, which will send the following event messages to BLE services through the callback function.

- BLE_CLI_EVT_CONN_STATE_CHANGE_IND

This message is sent to the callback function when the device connection state changes. The message data type is ble_gattc_conn_state_change_ind_t, including the connection state conn_state. If the connection state is connected, the connection index and address information of the peer device will be included; however, if the connection state is disconnected, the reason for disconnection will also be included.

- BLE_CLI_EVT_GATT_OPERATION

This message is sent to the callback function when interacting with the peer GATT server. The message data type is ble_gattc_op_info_t, including the subevent gattc_op_sub_evt of GATT client operation, connection index conn_idx, and message data of different subevents. The message includes the following subevents:

- BLE_CLI_EVT_SVC_DISC_DONE_RSP

  After ble_gattc_start_discovery is called to discover services of the peer GATT server, this subevent returns whether the registered service is found. The subevent data type is ble_gattc_svc_dis_done_t, including whether the service is found and the number of instances.

- BLE_CLI_EVT_READ_RSP

  This subevent returns the result of reading the data of peer GATT server attribute by calling ble_gattc_read. The subevent data type is ble_gattc_read_rsp_t, including service uuid and characteristic uuid.

- BLE_CLI_EVT_WRITE_RSP

  This subevent returns the result of writing data to the peer GATT server by calling ble_gattc_write_req, ble_gattc_write_cmd, or ble_gattc_write_signed. The subevent data type is ble_gattc_write_rsp_t, including service uuid and

characteristic uuid.

- BLE_CLI_EVT_NTF_IND_RCV

  When the peer GATT server sends notification or indication, this subevent is sent to the registered callback function. The subevent data type is ble_gattc_ntf_ind_t, including service uuid, characteristic uuid, and attribute handle.

- BLE_CLI_EVT_MTU_UPDATE_RSP

  This subevent returns the result of updating GATT MTU by calling ble_gattc_mtu_update. The subevent data type is ble_gattc_mtu_update_rsp_t, including the status of updating MTU.

- BLE_CLI_EVT_MTU_INFO

  When GATT MTU changes, this subevent will notify the callback function by using subevent data type ble_gattc_mtu_info_t which includes the new MTU to be used.

2.11.2. ble_gattc_start_discovery

Prototype: ble_status_t ble_gattc_start_discovery(uint8_t conn_idx,
p_discovery_done_cb callback)

Function: Start to discover services in the peer GATT server.

Input parameter: conn_idx, connection index
callback, discovery complete callback function

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.11.3. ble_gattc_svc_reg

Prototype: ble_status_t ble_gattc_svc_reg(ble_uuid_t *p_svc_uuid, p_fun_cli_cb p_cb)

Function: Register the callback function and service UUID to the BLE GATT client module.

Input parameter: p_svc_uuid, service uuid client pays attention to
p_cb, the message handler function of GATT client. For the message type,
see ***gattc message type***.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.11.4. ble_gattc_svc_unreg

Prototype: ble_status_t ble_gattc_svc_unreg(ble_uuid_t *p_svc_uuid)

Function: Unregister the callback function and service UUID from BLE GATT client module

Input parameter: p_svc_uuid, service uuid to be unregistered

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.11.5. ble_gattc_read

Prototype: ble_status_t ble_gattc_read(uint8_t conidx, uint16_t hdl, uint16_t offset,
uint16_t length)

Function: Read the attribute data of the peer GATT server.

Input parameter: conidx, connection index

hdl, attribute handle

offset, data offset to be read

length, data length to be read

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure After execution, the BLE_CLI_EVT_GATT_OPERATION message with a subevent of BLE_CLI_EVT_READ_RSP will be sent to the registered callback function.

2.11.6. ble_gattc_write_req

Prototype: ble_status_t ble_gattc_write_req(uint8_t conidx, uint16_t hdl, uint16_t length,
uint8_t *p_value)

Function: Write data to peer server (write request)

Input parameter: conidx, connection index

hdl, attribute handle

length, data length to be written

p_value, data to be written

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure After execution, the BLE_CLI_EVT_GATT_OPERATION message with a subevent of BLE_CLI_EVT_ WRITE_RSP will be sent to the callback function.

2.11.7. ble_gattc_write_cmd

Prototype: ble_status_t ble_gattc_write_cmd(uint8_t conidx, uint16_t hdl, uint16_t length, uint8_t *p_value)

Function: Write data to peer server (write command)

Input parameter: conidx, connection index

hdl, attribute handle

length, data length to be written

p_value, data to be written

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure After execution, the BLE_CLI_EVT_GATT_OPERATION message with a subevent of BLE_CLI_EVT_ WRITE_RSP will be sent to the registered callback function.

2.11.8. ble_gattc_write_signed

Prototype: ble_status_t ble_gattc_write_signed(uint8_t conidx, uint16_t hdl, uint16_t length, uint8_t *p_value)

Function: Write data to peer server (write signed)

Input parameter: conidx, connection index

hdl, attribute handle

length, data length to be written

p_value, data to be written

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on

failure After execution, the BLE_CLI_EVT_GATT_OPERATION message with a subevent of BLE_CLI_EVT_ WRITE_RSP will be sent to the registered callback function.

2.11.9. ble_gattc_mtu_update

Prototype: ble_status_t ble_gattc_mtu_update(uint8_t conidx, uint16_t mtu_size)

Function: Update GATT mtu.

Input parameter: conidx, connection index

mtu_size, preferred mtu to update, 0 means let stack choose

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

After calling the API, a BLE_CLI_EVT_GATT_OPERATION message with subevent BLE_CLI_EVT_MTU_UPDATE_RSP will notify the callback function whether the updating executes successful. If so, a BLE_CLI_EVT_MTU_INFO message will also notify callback function after update procedure complete.

2.11.10. ble_gattc_mtu_get

Prototype: ble_status_t ble_status_t ble_gattc_mtu_get(uint8_t conidx, uint16_t *p_mtu)

Function: Obtain the GATT mtu value of the connection.

Input parameter: conidx, connection index

Output parameter: p_mtu, mtu size

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.11.11. ble_gattc_find_char_handle

Prototype: ble_status_t ble_gattc_find_char_handle(uint8_t conn_idx, ble_gattc_uuid_info_t *svc_uuid, ble_gattc_uuid_info_t *char_uuid, uint16_t *handle)

Function: Find the value handle value of the characteristic.

Input parameter: conidx, connection index

svc_uuid, service uuid

char_uuid, characteristic uuid

Output parameter: handle, attribute handle value

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.11.12. ble_gattc_find_desc_handle

Prototype: ble_status_t ble_gattc_find_desc_handle(uint8_t conn_idx, ble_gattc_uuid_info_t *svc_uuid, ble_gattc_uuid_info_t *char_uuid, ble_gattc_uuid_info_t *desc_uuid, uint16_t *handle)

Function: Find the handle value of description.

Input parameter: conidx, connection index

svc_uuid, service uuid

char_uuid, characteristic uuid

desc_uuid, description uuid

Output parameter: handle, attribute handle value

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.12. BLE export API

The header file is ble_export.h.

The file contains the initialization and free of the BLE stack, functions to send messages to BLE APP task and register message callback function etc.

2.12.1. ble_sw_init

Prototype: ble_status_t ble_sw_init(ble_init_param_t *p_param)

Function: Initialize the BLE stack.

Input parameter: p_param , pointer to init parameters, including role, BLE task priority and stack size, BLE APP task priority and stack size etc.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure

2.12.2. ble_sw_deinit

Prototype: ble_status_t ble_sw_deinit(void)

Function: Deinit the BLE stack and release related resources.

Input parameter: None.

Output parameter: None

Return value: Return 0 on success, and return the error code defined in ble_status_t on failure.

2.12.3. ble_stack_task_resume

Prototype: void ble_stack_task_resume(bool isr)

Function: Resume the BLE stack task. If BLE task is in the sleep mode, this function can be called by an external interrupt to wake up the BLE task.

Input parameter: isr, which indicates whether it is called by an interrupt

Output parameter: None

Return value: None

2.12.4. ble_local_app_msg_send

Prototype: bool ble_local_app_msg_send (void *p_msg, uint16_t msg_len)

Function: If the upper layer determines to handle the message asynchronously, it can send a message to the BLE APP task, specifying that the message should be handled in the callback function. In this case, ble_app_msg_hdl_reg should be called to register the callback function in advance.

Input parameter: p_msg, message content

msg_len, the length of message content

Output parameter: None

Return value: Return "true" upon success and "false" upon failure.

2.12.5. ble_app_msg_hdl_reg

Prototype: void ble_app_msg_hdl_reg(ble_app_msg_hdl_t p_hdl)

Function: Work together with ble_local_app_msg_send to register the callback function for APP message.

Input parameter: p_hdl, callback function

Output parameter: None

Return value: None

2.12.6. ble_sleep_mode_set

Prototype: void ble_sleep_mode_set(uint8_t mode)

Function: Set the BLE sleep mode.

Input parameter: mode: 0 means normal mode, while 1 means sleep mode. (If there are no task to deal with, the task and BLE core are in the sleep mode)

Output parameter: None

Return value: None

2.12.7. ble_sleep_mode_get

Prototype: uint8_t ble_sleep_mode_get(void)

Function: Get the BLE sleep mode.

Input parameter: None

Output parameter: None

Return value: mode: 0 means normal mode, while 1 means sleep mode. (If there are no tasks, the task and BLE core are in the sleep mode)

2.12.8. ble_core_is_deep_sleep

Prototype: bool ble_core_is_deep_sleep(void)

Function: Query whether BLE core is in the deep sleep mode.

Input parameter: None

Output parameter: None

Return value: true for the deep sleep mode and false for other modes

2.12.9. ble_modem_config

Prototype: void ble_modem_config(void)

Function: Configure the modem parameter under BLE core every time it is woken up from the sleep mode.

Input parameter: None

Output parameter: None

Return value: None

2.12.10. ble_ work_status_get

Prototype: ble_work_status_t ble_ work_status_get(void)

Function: Get the BLE working status.

Input parameter: None

Output parameter: None

Return value: mode: 0 means enable, while 1 means disable.

2.12.11. ble_internal_encode

Prototype: void ble_internal_encode(uint8_t *data, uint16_t len, uint8_t rand)

Function: Encode the data by using the internal algorithm.

Input parameter: data, input data

len, the length of input data

rand, random number, through which different values can be output from the same input

Output parameter: data, encoded data

Return value: None

2.12.12. ble_internal_decode

Prototype: void ble_internal_decode(uint8_t *data, uint16_t len, uint8_t rand)

Function: Decode the data by using the internal algorithm.

Input parameter: data, input data

len, the length of input data

rand, random number, through which different values can be output from the same input

Output parameter: data, decoded data

Return value: None

3. Application examples

3.1. Scan

The BLE scan function is used to find Bluetooth low energy devices in the surrounding environment. Enabling the scan function will report the scanned devices to the application layer.

Quickly use the function in the following steps:

1. Register an event handler to handle changes in scan status and report advertising data.

Table 3-1. Example code of scan event handler

```
static void ble_app_scan_mgr_evt_handler(ble_scan_evt_t  event, ble_scan_data_u  *p_data)
{
    switch (event) {
    case BLE_SCAN_EVT_STATE_CHG:
        if (p_data->scan_state.scan_state == BLE_SCAN_STATE_ENABLED) {
            dbg_print(NOTICE, "Ble Scan enabled status 0x%x\r\n", p_data->scan_state.reason);
        } else if (p_data->scan_state.scan_state == BLE_SCAN_STATE_ENABLING) {
            scan_mgr_clear_dev_list();
        } else if (p_data->scan_state.scan_state == BLE_SCAN_STATE_DISABLED) {
            dbg_print(NOTICE, "Ble Scan disabled status 0x%x\r\n",
p_data->scan_state.reason);
        }
        break;

    case BLE_SCAN_EVT_ADV_RPT:
        scan_mgr_report_hdlr(p_data->p_adv_rpt);
        break;
    }
}
```

2. Configure scan parameters through ble_scan_param_set. The structure parameters are as follows:

type---scan type, which can be set to *general discovery (general scan)*, *limit discovery (limit scan)*, etc.

prop---scan attribute, which can be set to *active scan* or *passive scan* of *1M and CODED PHY, filter strategy*, etc.

dup_filt_pol---duplicate filtering. When it is enabled, the received advertising signal will not be repeatedly reported to the application.

scan_intv---scan interval, how often the controller scans.

scan_win---scan window, the duration of each scan.

duration---scan duration, which indicates continuous scan when configured to 0.

period---whether to scan periodically, with the duration as the period.

Table 3-2. Example code of configure scan parameters

```
/**@brief Function for set scan parameters.
 *
 * @param[in] param                    scan parameters (see enum #ble_gap_scan_param_t)
 * @retval BLE_ERR_NO_ERROR            If ble scan module disable successfully.
 */
ble_status_t ble_scan_param_set(ble_gap_scan_param_t *p_param);

/** The default scan parameters are as follows*/
p_ble_scan_env->param.type = BLE_GAP_SCAN_TYPE_GEN_DISC;
p_ble_scan_env->param.prop = BLE_GAP_SCAN_PROP_PHY_1M_BIT |
                             BLE_GAP_SCAN_PROP_ACTIVE_1M_BIT |
                             BLE_GAP_SCAN_PROP_PHY_CODED_BIT |
                             BLE_GAP_SCAN_PROP_ACTIVE_CODED_BIT;
p_ble_scan_env->param.dup_filt_pol = BLE_GAP_DUP_FILT_EN;
p_ble_scan_env->param.scan_intv_1m = 160; // 100ms
p_ble_scan_env->param.scan_intv_coded = 160; // 100ms
p_ble_scan_env->param.scan_win_1m = 48;  // 30ms
p_ble_scan_env->param.scan_win_coded = 48;  // 30ms
p_ble_scan_env->param.duration = 0;
p_ble_scan_env->param.period = 0;
```

3. To enable the scan function, call ble_scan_enable API.

Table 3-3. Example code of enable scan

```
void app_scan_enable(bool update_rssi)
{
    if (ble_scan_enable() != BLE_ERR_NO_ERROR) {
        dbg_print(NOTICE, "app_scan_enable fail!\r\n");
        return;
    }
}
```

3.2. Advertising

The BLE advertising function is used to send advertising messages, allowing surrounding BLE devices to discover and connect it or send periodic data, etc. It can be configured as legacy advertising (traditional advertising), extended advertising, and periodic advertising.

Quickly use the function in the following steps:

1. Register an event handler to handle changes in advertising status and report received scan requests.

Table 3-4. Example code of advertising event handler

```
static void app_adv_mgr_evt_hdlr(ble_adv_evt_t adv_evt, void *p_data, void *p_context)
{
    app_adv_actv_t *p_adv = (app_adv_actv_t *)p_context;

    switch (adv_evt) {
    case BLE_ADV_EVT_STATE_CHG: {
        ble_adv_state_chg_t *p_chg = (ble_adv_state_chg_t *)p_data;
        ble_adv_state_t old_state = p_adv->state;

        dbg_print(NOTICE, "adv state change 0x%x ==> 0x%x, reason 0x%x\r\n", old_state,
p_chg->state, p_chg->reason);

        p_adv->state = p_chg->state;

        if ((p_chg->state == BLE_ADV_STATE_CREATE) && (old_state ==
BLE_ADV_STATE_CREATING)) {
            p_adv->idx = p_chg->adv_idx;
            app_print("adv index %d\r\n", p_adv->idx);

            app_adv_start(p_adv);
        } else if ((p_chg->state == BLE_ADV_STATE_CREATE) && (old_state ==
BLE_ADV_STATE_START)) {
            dbg_print(NOTICE, "adv stopped, remove %d\r\n", p_adv->remove_after_stop);

            if (p_adv->remove_after_stop) {
                ble_adv_remove(p_adv->idx);
                p_adv->remove_after_stop = false;
            }
        } else if (p_chg->state == BLE_ADV_STATE_IDLE) {
            free_adv_actv(p_adv);
        }
    } break;

    case BLE_ADV_EVT_DATA_UPDATE_RSP: {
        ble_adv_data_update_rsp_t *p_rsp = (ble_adv_data_update_rsp_t *)p_data;
        dbg_print(NOTICE, "adv data update rsp, type %d, status 0x%x\r\n", p_rsp->type,
p_rsp->status);
    } break;

    case BLE_ADV_EVT_SCAN_REQ_RCV: {
```

```
            ble_adv_scan_req_rcv_t *p_req = (ble_adv_scan_req_rcv_t *)p_data;
            dbg_print(NOTICE, "scan req rcv, device addr %02X:%02X:%02X:%02X:%02X:%02X\r\n",
                    p_req->peer_addr.addr[5], p_req->peer_addr.addr[4], p_req->peer_addr.addr[3],
                    p_req->peer_addr.addr[2], p_req->peer_addr.addr[1], p_req->peer_addr.addr[0]);
        } break;

        default:
            break;
        }
}
```

2. The device sends a advertising message mainly in two steps: create a advertising and enable it. The advertising can be enabled only in successfully created status. For example, the following application layer creates advertising code and configures different advertising parameters based on different advertising types.

Table 3-5. Example code of create advertising

```
ble_status_t app_adv_create(app_adv_param_t *p_param)
{
    app_adv_actv_t *p_adv;
    ble_adv_param_t adv_param = {0};

    p_adv = get_free_adv_actv();
    if (p_adv == NULL) {
        return BLE_ERR_NO_RESOURCES;
    }

    p_adv->max_data_len = p_param->max_data_len;

    adv_param.param.own_addr_type = p_param->own_addr_type;

    if (p_param->type == BLE_ADV_TYPE_LEGACY) {
        adv_param.param.type = BLE_GAP_ADV_TYPE_LEGACY;
        adv_param.param.prop = p_param->prop;

        if (p_param->wl_enable) {
            adv_param.param.filter_pol = BLE_GAP_ADV_ALLOW_SCAN_FAL_CON_FAL;
            adv_param.param.disc_mode = BLE_GAP_ADV_MODE_NON_DISC;
        } else {
            adv_param.param.filter_pol = BLE_GAP_ADV_ALLOW_SCAN_ANY_CON_ANY;
            adv_param.param.disc_mode = p_param->disc_mode;
        }

        adv_param.param.ch_map = APP_ADV_CHMAP;
        adv_param.param.primary_phy = p_param->pri_phy;
```

```
} else if (p_param->type == BLE_ADV_TYPE_EXTENDED) {
    adv_param.param.type = BLE_GAP_ADV_TYPE_EXTENDED;
    adv_param.param.prop = p_param->prop;

    if (p_param->wl_enable) {
        adv_param.param.filter_pol = BLE_GAP_ADV_ALLOW_SCAN_FAL_CON_FAL;
        adv_param.param.disc_mode = BLE_GAP_ADV_MODE_NON_DISC;
    } else {
        adv_param.param.filter_pol = BLE_GAP_ADV_ALLOW_SCAN_ANY_CON_ANY;
        adv_param.param.disc_mode = p_param->disc_mode;
    }

    adv_param.param.ch_map = APP_ADV_CHMAP;
    adv_param.param.primary_phy = p_param->pri_phy;
    adv_param.param.adv_sid = get_adv_sid();
    adv_param.param.max_skip = 0x00;
    adv_param.param.secondary_phy = p_param->sec_phy;
} else {
    return BLE_GAP_ERR_INVALID_PARAM;
}

if (adv_param.param.prop & BLE_GAP_ADV_PROP_DIRECTED_BIT) {
    adv_param.param.peer_addr = p_param->peer_addr;
    adv_param.param.disc_mode = BLE_GAP_ADV_MODE_NON_DISC;
    p_adv->peer_addr = p_param->peer_addr;
}

if (adv_param.param.prop & BLE_GAP_ADV_PROP_ANONYMOUS_BIT) {
    adv_param.param.disc_mode = BLE_GAP_ADV_MODE_NON_DISC;
}

p_adv->disc_mode = adv_param.param.disc_mode;

adv_param.param.adv_intv_min = APP_ADV_INT_MIN;
adv_param.param.adv_intv_max = APP_ADV_INT_MAX;

if (p_adv->disc_mode == BLE_GAP_ADV_MODE_LIM_DISC) {
    adv_param.param.duration = 1000;          // 10s
}

if (p_param->type != BLE_ADV_TYPE_LEGACY) {
    adv_param.include_tx_pwr = true;
    adv_param.scan_req_ntf = true;
```

```
    }

    return ble_adv_create(&adv_param, app_adv_mgr_evt_hdlr, p_adv);
}
```

3. Enable the advertising. After receiving the message that the advertising is successfully created in the registered event handler, call the ble_adv_start interface to enable the advertising. Afterwards, receiving the reported advertising status BLE_ADV_STATE_START in the event handler means that the advertising is enabled successfully.

The last three parameters in the ble_adv_start API are used to set advertising data, scan response data, and periodic advertising data respectively. The content can be set directly by the application layer or packaged by the BLE ADV module through configuration parameters. For example, all data are set directly by the application layer in the following code.

Table 3-6. Example code of enable advertising

```
static uint8_t adv_data_1[7] = {0x06, 0x16, 0x52, 0x18, 0x18, 0x36, 0x9A};
static uint8_t per_data_1[52] = {0x33, 0x16, 0x51, 0x18, 0x40, 0x9c, 0x00, 0x01, 0x02, 0x06,
                                 0x00, 0x00, 0x00, 0x00, 0x0d, 0x02, 0x01, 0x08, 0x02, 0x02,
                                 0x01, 0x03, 0x04, 0x78, 0x00, 0x02, 0x05, 0x01, 0x07, 0x03,
                                 0x02, 0x04, 0x00, 0x02, 0x04, 0x80, 0x01, 0x06, 0x05, 0x03,
                                 0x00, 0x04, 0x00, 0x00, 0x02, 0x06, 0x05, 0x03, 0x00, 0x08,
                                 0x00, 0x00
                                };

static void app_adv_start(app_adv_actv_t *p_adv)
{
    ble_adv_data_set_t adv;
    ble_adv_data_set_t scan_rsp;
    ble_adv_data_set_t per_adv;
    ble_data_t adv_data;
    ble_data_t per_adv_data;

    adv.data_force = true;
    scan_rsp.data_force = true;
    per_adv.data_force = true;

    adv_data.len = 7;
    adv_data.p_data = adv_data_1;

    per_adv_data.len = 52;
    per_adv_data.p_data = per_data_1;

    adv.data.p_data_force = &adv_data;
```

```
    scan_rsp.data.p_data_force = &adv_data;
    per_adv.data.p_data_force = &per_adv_data;

    ble_adv_start(p_adv->idx, &adv, &scan_rsp, &per_adv);
}
```

3.3. GATT server application

GD32VW553 SDK provides functions such as adding/deleting services and sending notification/indication as BLE GATT server role. Users can implement specific services according to their requirements. For specific APIs, see ***BLE gatts API*** *错误!未找到引用源。*. Here is an example of DIS to illustrate how to use these APIs to implement a service server. The file is MSDK\ble\profile\dis\ble_diss.c.

3.3.1. Adding a service

Add a service to the BLE GATT server module through the ble_gatts_svc_add function, whose input parameters include service UUID, service attribute database, callback handler for GATT server message, etc. Service UUID can be 16-bit, 32-bit, or 128-bit. They need to be described in the *info and table type* parameters. For example, in the code of ble diss, UUID 16 is used for service UUID. When calling the ble_gatts_svc_add function, use SVC_UUID(16) to describe it.

Table 3-7. Example code of add a service

```
ret = ble_gatts_svc_add(&ble_diss_svc_id, ble_dis_uuid, 0, SVC_UUID(16), ble_diss_attr_db,
                        BLE_DIS_HDL_NB, ble_diss_srv_cb);
```

3.3.2. Service attribute database

Service attribute database is an array composed of a series of ble_gatt_attr_desc_t elements. Each element in the array is an attribute, which can be primary service, characteristic declaration, characteristic value declaration, etc. Users can freely combine them according to the requirements of different services.

Each attribute consists of a UUID and its attribute description. All attributes in DIS are read-only, so just specify the RD property. For the characteristic value declaration, the maximum size of the value can also be specified.

Table 3-8. Example code of service database

```
const ble_gatt_attr_desc_t ble_diss_attr_db[BLE_DIS_HDL_NB] =
{
    [BLE_DIS_HDL_SVC] = {UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_PRIMARY_SERVICE),
PROP(RD), 0},
```

```
    [BLE_DIS_HDL_MANUFACT_NAME_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_MANUFACT_NAME_VAL] =
{UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_MANUF_NAME), PROP(RD),
BLE_DIS_VAL_MAX_LEN},

    [BLE_DIS_HDL_MODEL_NB_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_MODEL_NB_VAL] =
{UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_MODEL_NB), PROP(RD),
BLE_DIS_VAL_MAX_LEN},

    [BLE_DIS_HDL_SERIAL_NB_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_SERIAL_NB_VAL] =
{UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_SERIAL_NB), PROP(RD),
BLE_DIS_VAL_MAX_LEN},

    [BLE_DIS_HDL_HARD_REV_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_HARD_REV_VAL] = {UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_HW_REV),
PROP(RD), BLE_DIS_VAL_MAX_LEN},

    [BLE_DIS_HDL_FIRM_REV_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_FIRM_REV_VAL] = {UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_FW_REV),
PROP(RD), BLE_DIS_VAL_MAX_LEN},

    [BLE_DIS_HDL_SW_REV_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_SW_REV_VAL] = {UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_SW_REV),
PROP(RD), BLE_DIS_VAL_MAX_LEN},

    [BLE_DIS_HDL_SYSTEM_ID_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_SYSTEM_ID_VAL] = {UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_SYS_ID),
PROP(RD), BLE_DIS_SYS_ID_LEN},

    [BLE_DIS_HDL_IEEE_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_IEEE_VAL] = {UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_IEEE_CERTIF),
PROP(RD), BLE_DIS_VAL_MAX_LEN},
```

```
    [BLE_DIS_HDL_PNP_ID_CHAR] =
{UUID_16BIT_TO_ARRAY(BLE_GATT_DECL_CHARACTERISTIC), PROP(RD), 0},
    [BLE_DIS_HDL_PNP_ID_VAL] = {UUID_16BIT_TO_ARRAY(BLE_DIS_CHAR_PNP_ID),
PROP(RD), BLE_DIS_PNP_ID_LEN},
};
```

3.3.3. Service attribute read and write

The last parameter of ble_gatts_svc_add is to register a GATT server event handler callback function, which is executed when the peer client performs read or write operation on the service, GATT server event type is BLE_SRV_EVT_GATT_OPERATION, subevent type is BLE_SRV_EVT_READ_REQ or BLE_SRV_EVT_WRITE_REQ, subevent data structure is ble_gatts_read_req_t or ble_gatts_write_req_t, in which there is an att_idx parameter indicates the corresponding attribute index in database table when registered.

Table 3-9. Example code of attribute read and write function

```
ble_status_t ble_diss_srv_cb(ble_gatts_msg_info_t *p_srv_msg_info)
{
    uint8_t attr_idx = 0;
    uint16_t len = 0;
    uint8_t attr_len = 0;
    uint8_t *p_attr = NULL;

    if (p_srv_msg_info->srv_msg_type == BLE_SRV_EVT_GATT_OPERATION) {
        if (p_srv_msg_info->msg_data.gatts_op_info.gatts_op_sub_evt ==
BLE_SRV_EVT_READ_REQ) {
            ble_gatts_read_req_t * p_read_req =
&p_srv_msg_info->msg_data.gatts_op_info.gatts_op_data.read_req;

            attr_idx = p_read_req->att_idx;
            switch (attr_idx) {
            case BLE_DIS_HDL_MANUFACT_NAME_VAL: {
                p_attr = ble_diss_val.manufact_name;
                attr_len = ble_diss_val.manufact_name_len;
            } break;

            case BLE_DIS_HDL_MODEL_NB_VAL: {
                p_attr = ble_diss_val.model_num;
                attr_len = ble_diss_val.model_num_len;
            } break;

            case BLE_DIS_HDL_SERIAL_NB_VAL: {
                p_attr = ble_diss_val.serial_num;
                attr_len = ble_diss_val.serial_num_len;
```

```
} break;

case BLE_DIS_HDL_HARD_REV_VAL:  {
    p_attr     = ble_diss_val.hw_rev;
    attr_len  = ble_diss_val.hw_rev_len;
} break;

case BLE_DIS_HDL_FIRM_REV_VAL:  {
    p_attr     = ble_diss_val.fw_rev;
    attr_len  = ble_diss_val.fw_rev_len;
} break;

case BLE_DIS_HDL_SW_REV_VAL:  {
    p_attr     = ble_diss_val.sw_rev;
    attr_len  = ble_diss_val.sw_rev_len;
} break;

case BLE_DIS_HDL_SYSTEM_ID_VAL:  {
    p_attr     = ble_diss_val.sys_id;
    attr_len  = BLE_DIS_SYS_ID_LEN;
} break;

case BLE_DIS_HDL_IEEE_VAL:  {
    p_attr     = ble_diss_val.ieee_data;
    attr_len  = ble_diss_val.ieee_data_len;
} break;

case BLE_DIS_HDL_PNP_ID_VAL:  {
    p_attr     = ble_diss_val.pnp_id;
    attr_len  = BLE_DIS_PNP_ID_LEN;
} break;

default:
    return BLE_ATT_ERR_INVALID_HANDLE;
}

if (p_read_req->offset > attr_len) {
    return BLE_ATT_ERR_INVALID_OFFSET;
}

len = ble_min(p_read_req->max_len,  attr_len - p_read_req->offset);
p_read_req->val_len  = len;
memcpy(p_read_req->p_val,  p_attr, len);
```

```
        }
    }

    return BLE_ERR_NO_ERROR;
```

If there is an attribute in the service that supports Client Characteristic Configuration declaration (CCCD) and if peer client enables it, then ble_srv_ntf_ind_send interface can be used to send a notification/indication.

Table 3-10. Example code of send notification

```
static void bcwl_ntf_event_send(uint8_t *p_val, uint16_t len)
{
    if (bcwl_env.ntf_cfg == 0) {
        dbg_print(ERR, "%s fail\r\n", __func__);
        return;
    }

    ble_gatts_ntf_ind_send(bcwl_env.conn_id, bcwl_env.prf_id, BCW_IDX_NTF, p_val, len,
BLE_GATT_NOTIFY);
```

3.4. BLE distribution network

Blue courier is a BLE-based WIFI network configuration function. The SSID, password, channel, and encryption type of WiFi are transferred through the protocol to the GD device, which can be connected to AP through such information or establish SoftAP. The link supports data fragmentation and CRC16 integrity verification. Security relies on the encryption of the BLE link, and the encoding method is taken for the transfer of the message containing SSID and password to avoid transferring the plaintext over the air. Execute the ble_courier_wifi command in the "AN153 GD32VW553 Basic Commands User Guide".

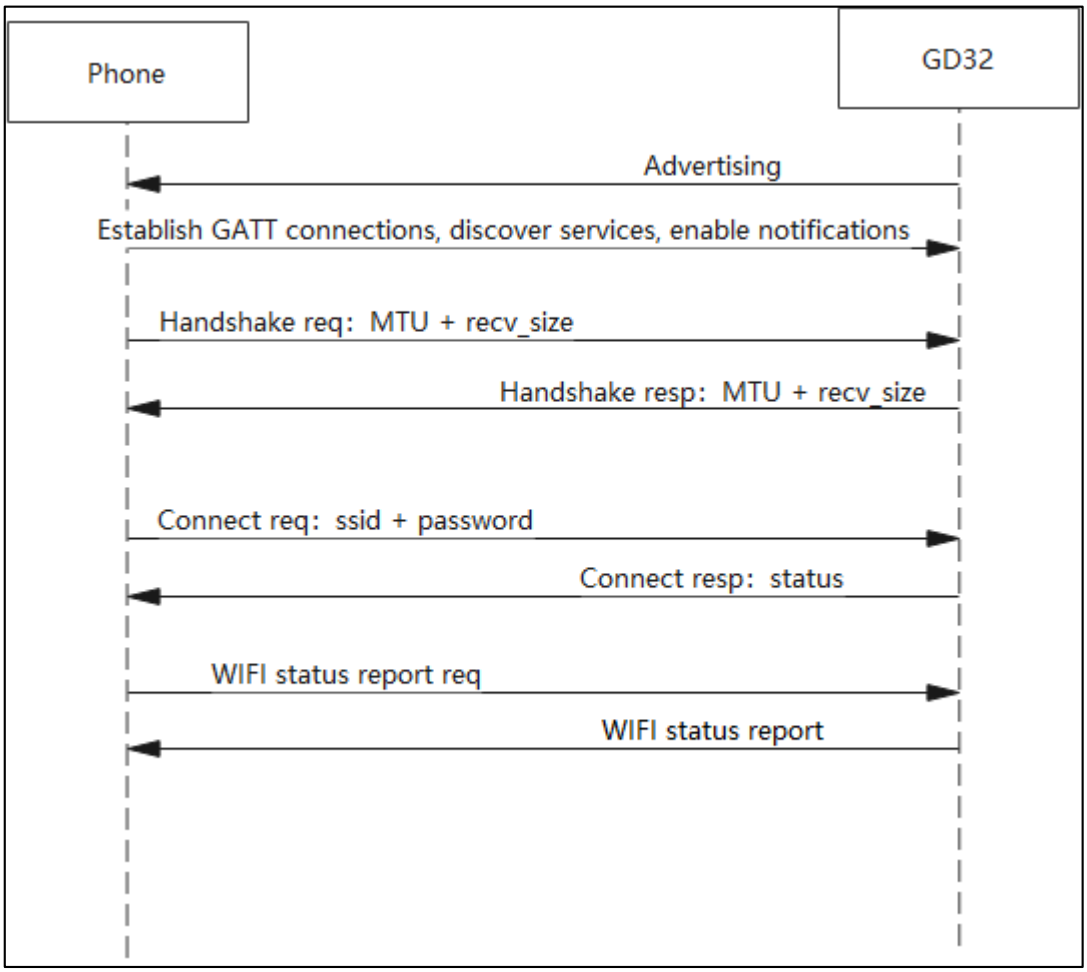
3.4.1. Process of Blue courier

By taking the example of configuring WiFi as the station to connect to AP, the following introduces key steps of advertising, connection, service discovery, enable notification, handshake, data transfer, and reportconnection sate.

1. After Blue courier wifi is enabled, the GD device will register the service with the GATT server module and send the advertisingwith special advertising data. The advertising can be defined by the user as required.
2. After the advertising is searched for through a WeChat Mini Program, the phone as GATT Client will connect to the GD device.
3. After establishing the GATT connection, the phone will send the handshake request message to the GD device, which will return the handshake response message upon receiving the message.

4. The phone can send the following messages to the GD device: Connect to WiFi; create SoftAp; get the WiFi status.

Figure 3-1. Process of Blue courier



3.4.2. GATT description

To add a distribution network service, refer to the description in ***Adding a service***.

For the description of UUID used by the distribution network service, see ***Table 3-11. Distribution network service UUID*** *错误!未找到引用源。*.

Table 3-11. Distribution network service UUID

Attribute	Description
Blue courier WIFI Service	UUID = 0000FFF0-0000-1000-8000-00805F9B34FB
C1 Characteristic (Client TX Buffer)	UUID = 0000FFF1-0000-1000-8000-00805F9B34FB Characteristic Properties = Write max length = 256 bytes Security level=unauth (the link must be encrypted, and pairing is required for the first time of connection)
C2 Characteristic	UUID = 0000FFF2-0000-1000-8000-00805F9B34FB

(Client RX Buffer)	Characteristic Properties = Notify max length = 256 bytes

3.4.3. Advertising data

The Blue courier WiFi Service UUID must be included in the advertising data so that other devices can discover that the local device supports the BLE distribution network function. The peer device can filter by Service UUID when searching for BLE devices. For details, see the following table.

Table 3-12. Service UUID in advertising data

Byte	Value	Description
0	0x03	AD[0] Length == 3 bytes
1	0x03	AD[0] Type == 1 (Flags) Complete list of 16 bit service UUIDs.
2-3	0xFFF0	16-bit Blue courier WIFI Service UUID

3.4.4. Frame format

The frame format for communication between the mobile app of Blue courier and the GD device is as follows:

Table 3-13. Frame format of blue courier

Field	Size (byte)
flag	1
sequence	1
opcode	1
data_len	1
data	${data_len}
crc	2

flag

The frame control field occupies a byte, where each bit has a different meaning, as listed in the following table:

Table 3-14. Frame control field

Bit	Meaning
0x01	Begin: It means whether the frame is the first fragment. • 0: It means the frame is the remaining fragment. • 1: It means the frame is the first fragment. • The fragment is used to transfer long data. Only the first two bytes in the data field of the first packet of the fragmented packet show the total length of the data content and are used to indicate the memory size allocated for peer receiving, namely, data = total_len + data.
0x02	End: It means whether the frame is the last fragment.

	• 0: It means the frame is not the last fragment. • 1: It means the frame is the last fragment. If both the Begin and End bits are set to 1, the packet is not fragmented.
0x04	ACK: It means whether the receiver should reply with ACK. • 0: It means the receiver unnecessarily replies with ACK. • 1: It means the receiver should reply with ACK.
0x08~0x80	Reserved

sequence

Sequence control field. When a frame is sent, regardless of its type, its sequence will automatically increase by 1 to prevent replay attack. The sequence will be cleared after each re-connection.

opcode

The opcode field occupies a byte, divided into two parts: Type and Subtype. The Type occupies two higher bits, which indicate the frame is the management or data frame. The Subtype occupies six lower bits, which indicate the meaning of the management or data frame.

1. Management frame (binary system: 0x0 b'00).

Table 3-15. Content of management frame

Management frame	Meaning	Description	Content
0x0 (b'000000)	Handshake	Handshake is used to exchange the mtus at both ends and the maximum receiving length, determining the size of the fragmented packet and the total length of the largest report. The mtu, whichever is smaller, should be taken as the fragment size at both ends. recv_size is the maximum peer receiving length, which should be taken as the maximum sending length by the receiver.	The data field totally occupies four bytes, including two bytes for mtu and two bytes for recv_size. Phone -> GD device: mtu + recv_size GD device -> phone: mtu + recv_size
0x1 (b'000001)	ACK	The data field of the ACK frame uses the sequential value of the response frame.	The data field occupies a byte, using the same sequential value as that of the response frame.

0x2 (b'000100)	Error reporting	The data field is used to report an error to the peer device. The error code can be defined by the user.	status: 1byte

2. Data frame (binary system: 0x1 b’01).

Table 3-16. Content of data frame

Data frame	Meaning	Description	Remarks
0x0 (b'000000)	Send the user-defined data.	The data field is used to transfer the user-defined data to the peer device for test.	
0x1 (b'000001)	Get the information of the WiFi scan list.	The phone sends the message with a length of 0 to the GD device. Upon receiving the message, the GD device will trigger WiFi scan and send the scan information through the message to the phone.	GD device -> phone: Structure of each ssid: len+rssi+mode+ssid len = 2byte(rssi+mode) + ssid length
0x2 (b'000010)	Send the connection request of the STA device.	Upon receiving the information of AP to be connected by the STA device, the GD device will trigger WiFi connection and send the connection result to the phone. The sent data should be randomly encoded to avoid generating the same code data.	Phone -> GD device: ssid_len + ssid + password_len + password + random GD device -> phone: status ssid_len, password_len, random, status: 1byte
0x3 (b'000011)	Send the disconnection request of the STA device.	The phone sends the message with a length of 0 to the GD device. Upon receiving the message, the GD device will trigger WiFi disconnection and send the status to the phone.	GD device -> phone: status status: 1byte
0x4 (b'000100)	Send the request of creating the SoftAP mode.	Upon receiving the information of AP to be created by the device, the GD device will trigger softAp creation and send the creation result to the	Phone -> GD device: ssid_len + ssid + password_len + password + channel + akm + hide + random GD device -> phone:

		phone. The sent data should be randomly encoded to avoid generating the same code data.	status ssid_len, passw ord_len, channel, akm, hide, random, status: 1byte
0x5 (b'000101)	Send the request of stopping the SoftAP mode.	The phone sends the message w ith a length of 0 to the GD device. Upon receiving the message, the GD device w ill trigger softAp stopping and send the status to the phone.	GD device -> phone: status status: 1byte
0x6 (b'000110)	Get WiFi status.	The phone sends the message w ith a length of 0 to the GD device. After receiving the message, the GD device w ill report WiFi status to the phone.	It w ill notify the phone of the current device mode, connection status, SSID, and channel by reporting the WiFi connection status to the phone. For the message content structure, refer to the app implementation end.

crc

crc16 is used for integrity verification for communication through Blue courier by making a calculation based on four parts, namely sequence, opcode, data_len, and data.

4. Revision history

Table 4-1. Revision history

Revision No.	Description	Date
1.0	Initial release	Nov.24.2023
1.1	Add API such as ble_conn_enable_central_feat, ble_svc_data_save, ble_svc_data_load and ble_register_hci_uart. Modify API such as ble_stack_init and ble_stack_task_init.	Feb.29.2024
1.2	Add APIs such as ble_adp_callback_unregister, ble_adp_disable, ble_scan_callback_unregister, ble_sec_callback_unregister, ble_list_callback_unregister, ble_per_sync_callback_unregister, ble_gattc_svc_unreg, ble_stack_task_deinit, ble_app_task_deinit. Modify APIs such as ble_stack_init and ble_stack_task_init. Delete API such as ble_stack_task_suspend.	Jul.10.2024
1.3	Add APIs such as ble_adp_public_addr_get, ble_adp_public_addr_set, ble_scan_param_get, ble_gatts_set_attr_val, ble_gatts_list_svc, ble_gatts_list_char, ble_gatts_list_desc Modify APIs such as ble_scan_param_set, ble_sw_init, ble_sw_deinit Delete APIs such as ble_adp_init, ble_adp_disable, ble_adp_cfg, ble_adv_init, ble_adv_deint, ble_scan_init, ble_scan_reinit, ble_conn_init,	Mar.4.2025

	ble_sec_init, ble_list_init, ble_per_sync_init, ble_storage_init, ble_gatts_init, ble_gattc_init, ble_stack_task_init, ble_stack_deinit, ble_app_task_init, ble_app_task_deinit, ble_w ork_status_set, ble_register_hci_uart. Add overview of BLE Mesh.	

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