AN14163

Bluetooth Direct Test Mode (DTM)

Rev. 2.0 — 4 July 2024 Application note

Document information

Information	Content
Keywords	Bluetooth Low-Energy (BLE), Direct Test Mode (DTM), Device Under Test (DUT)
Abstract	Explains how to perform DTM tests using HCI commands.

1 About this document

Direct Test Mode (DTM) is used to control the Device Under Test (DUT) and provide a report back to the Tester. With this mode, the operation of the radio at the physical level, such as Transmission power and receiver sensitivity, Frequency offset and drift, Modulation characteristics, Packet error rate can be tested. More details on DTM are described in the Bluetooth Core Specification, Volume 6, Part F [1].

This document explains how to perform DTM tests using HCI commands.

1.1 Supported devices

This feature is supported by the following devices:

- AW611 [2]
- AW690 [3]
- IW416 [4]
- IW611 [5]
- IW612 [6]
- IW620 [7]
- 88Q9098/88Q9098S [8]
- 88W8887 [9]
- 88W8897P [10]
- 88W8977 [11]
- 88W8987 [12]
- 88W8997 [13]
- 88W9098[14]

Note: *In the following sections, the supported devices may be referred to as "Wireless SoC".*

1.2 Notation conventions

This document employs the following notation conventions:

- Commands and examples of command outputs are shown in paragraphs with grey background color

```
This is an example of command
```

- Terms related to commands use a `monospace` font:
  - `parameter`
  - `option`
  - `command name`
- File names, directory names and paths are shown in *italics:*
  - *<file name>.<extension>*
  - *<directory>*
  - *path/to/directory/and/file*

2 Setup

The following hardware is required to perform DTM tests:

- Laptop
- Bluetooth RF Tester
- NXP DUT
- RS232 cable/RF cable

Figure 1 shows the general setup structure for DTM testing.

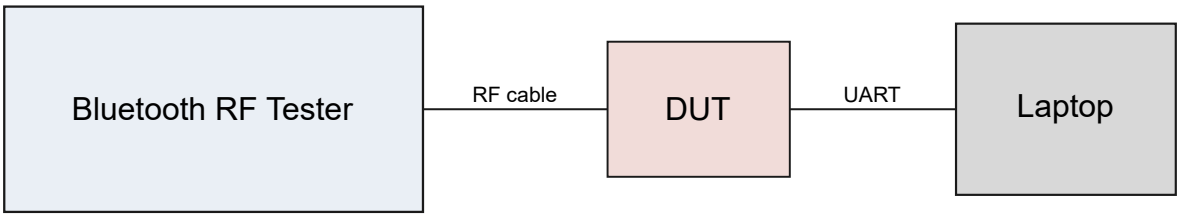

Figure 1. DTM setup

3 Commands

In order to perform DTM, HCI commands are used. The commands are:

- HCI_LE_Transmitter_Test
- HCI_LE_Receiver_Test
- HCI_LE_Test_End

3.1 HCI_LE_Transmitter_Test

This command is used to start a test where the DUT generates test reference packets at a fixed interval.

Syntax:

```
hcitool -i hci0 cmd 08 <OCF> <TX_Channel> <Test_Data_Length> <Packet_Payload>
 <PHY>
```

Table 1 and Table 2 provide information about the command and return parameters.

Table 1. HCI_LE_Transmitter_Test command

Parameter	Description
OGF	0x08
OCF	0x001E = v1 [v4.2 and above] 0x0034 = v2 [v5.0 and above]
TX_Channel	TX channel 1 octet N = (F-2402) / 2 Range (N) = 0x00 to 0x27 Frequency Range (F) = 2402 MHz to 2480 MHz
Test_Data_Length	Length in bytes of payload data in each packet 1 octet Range = 0x00 to 0xFF
Packet_Payload	contents of the Payload of the test reference packets 1 octet 0x00 = PRBS9 sequence '11111111100000111101…' (in transmission order)
PHY (Applicable if OCF = 0x0034)	PHY requested 1 octet 0x01 = Transmitter set to use the LE 1M PHY 0x02 = Transmitter set to use the LE 2M PHY 0x03 = Transmitter set to use the LE Coded PHY with S=8 data coding 0x04 = Transmitter set to use the LE Coded PHY with S=2 data coding

Table 2. Return Parameters

Parameter	Description
Status	Status 1 octet 0x00 = success, 0x1 to 0xFF = error
Events	Command complete event returned.

3.2 HCI_LE_Receiver_Test

This command is used to start a test where the DUT receives test reference packets at a fixed interval. The tester generates the test reference packets. There are two versions of this command with differing parameters.

Syntax:

```
hcitool -i hci0 cmd 08 <OCF> <RX_Channel> <PHY> <Modulation_Index>
```

Table 3 and Table 4 provide information about the command and return parameters.

Table 3. HCI_LE_Receiver_Test command

Parameter	Description
OGF	0x08
OCF	0x001D = v1 [v4.2 and above] 0x0033 = v2 [v5.0 and above]
RX_Channel	RX channel 1 octet N = (F-2402) / 2 Range (N) = 0x00 to 0x27 Frequency Range (F) = 2402 MHz to 2480 MHz
PHY (Applicable if OCF = 0x0033)	PHY requested 1 octet 0x01 = Transmitter set to use the LE 1M PHY 0x02 = Transmitter set to use the LE 2M PHY 0x03 = Receiver set to use the LE Coded PHY
Modulation_Index (Applicable if OCF = 0x0033)	Specifies whether the Controller should assume the receiver has a stable modulation index 1 octet 0x00 = Assume transmitter will have a standard modulation index 0x01 = Assume transmitter will have a stable modulation index

Table 4. Return Parameters

Parameter	Description
Status	Status 1 octet 0x00 = success 0x1 – 0xFF = error
Events	Command complete event returned.

3.3 HCI_LE_Test_End

This command is used to stop a DTM test.

Syntax:

```
hcitool -i hci0 cmd 08 1F
```

Table 5 and Table 6 provide information about the command and return parameters.

Table 5. HCI_LE_Test_End command

Parameter	Description
OGF	0x08
OCF	0x001F

Table 6. Return Parameters

Parameter	Description
Status	Status 1 octet 0x00 = success 0x001 to 0xFF = error
Num_Packets	0xXXXX – Number of packets received 2 octets
Events	Command complete event returned.

4 Examples

This section provides DTM tests examples.

4.1 LE transmitter test

This example shows how to test LE TX.

Step 1 – Set up the test environment.

Step 2 – Load the drivers and firmware onto the DUT.

Step 3 – Check if the Bluetooth interface is UP RUNNING on DUT.

```
hciconfig -a
```

Example output:

```
hci0: Type: Primary Bus: UART
        BD Address: 88:88:88:88:88:88 ACL MTU: 1021:7 SCO MTU: 120:6
        UP RUNNING
        RX bytes:1513 acl:0 sco:0 events:92 errors:0
        TX bytes:1282 acl:0 sco:0 commands:92 errors:0
```

In the following steps, the Bluetooth interface, hci0 is used.

Step 4 – Connect DUT to spectrum analyzer

Step 5 – Configure spectrum analyzer

Step 6 – Start the LE transmit test with appropriate parameters.

Syntax:

```
hcitool -i hci0 cmd 08 <OCF> <TX_Channel> <Test_Data_Length> <Packet_Payload>
 <PHY>
```

Example command:

- OGF = 08
- OCF = 34
- TX_Channel = 00 // 2402 MHz
- Test_Data_Length = FF
- Packet_Payload = 00 // PRBS9 sequence
- PHY = 02 // LE 2M PHY

```
hcitool -i hci0 cmd 08 34 00 ff 00 02
```

Example output:

```
< HCI Command: ogf 0x08, ocf 0x0034, plen 4
  00 FF 00 02
> HCI Event: 0x0e plen 4
  01 34 20 00
```

Step 7 – Stop the test.

```
hcitool -i hci0 cmd 08 1F
```

Example output:

```
< HCI Command: ogf 0x08, ocf 0x001f, plen 0
> HCI Event: 0x0e plen 6
  01 1F 20 00 00 00
```

4.2 LE Receiver test

This example shows how to test LE RX.

Step 1 – Set up the test environment.

Step 2 – Load the drivers and firmware onto the DUT.

Step 3 – Check if the Bluetooth interface is UP RUNNING on DUT.

```
hciconfig -a
```

Example output:

```
hci0: Type: Primary Bus: UART
        BD Address: 88:88:88:88:88:88 ACL MTU: 1021:7 SCO MTU: 120:6
        UP RUNNING
        RX bytes:1513 acl:0 sco:0 events:92 errors:0
        TX bytes:1282 acl:0 sco:0 commands:92 errors:0
```

In the following steps, the Bluetooth interface, hci0 is used.

Step 4 – Connect DUT to spectrum analyzer

Step 5 – Configure spectrum analyzer

Step 6 – Start LE receive the appropriate HCI_LE_Reciever_test command.

Syntax:

```
hcitool -i hci0 cmd 08 <OCF> <RX_Channel> <PHY> <Modulation_Index>
```

Example command:

- OGF = 08
- OCF = 33
- RX_Channel = 00 // 2402 MHz
- PHY = 02 // LE 2M PHY
- Modulation_Index = 00 // Standard modulation

```
hcitool -i hci0 cmd 08 33 00 02 00
```

Example output:

```
< HCI Command: ogf 0x08, ocf 0x0033, plen 3
  00 02 00
> HCI Event: 0x0e plen 4
  01 33 20 00
```

Step 7 – Stop LE test.

```
 hcitool -i hci0 cmd 08 1F
```

Example output:

```
< HCI Command: ogf 0x08, ocf 0x001f, plen 0
> HCI Event: 0x0e plen 6
  01 1F 20 00 00 00
```

5 Acronyms and abbreviations

Table 7. Acronyms

Acronym	Description
DTM	Direct test mode
DUT	Device under test
LE	Low Energy
BT	Bluetooth
TX	Transmit
RX	Receive
HCI	Host Controller Interface

6 References

[1] Specification - Bluetooth Core 5.3 specification (link)
[2] Webpage - AW611: 2.4/5 GHz Dual-Band 1x1 Wi-Fi® 6 (802.11ax) + Bluetooth® 5.2 Automotive Solution (link)
[3] Webpage - AW690: Wi-Fi® 6 1x1 Concurrent Dual Wi-Fi (CDW) and Bluetooth® 5.3 Combo SoC (link)
[4] Webpage - IW416: 2.4/5 GHz Dual-Band 1x1 Wi-Fi® 4 (802.11n) + Bluetooth® 5.2 Solution (link)
[5] Webpage - IW611: 2.4/5 GHz Dual-Band 1x1 Wi-Fi® 6 (802.11ax) + Bluetooth® 5.2 Solution (link)
[6] Webpage - IW612: 2.4/5 GHz Dual-Band 1x1 Wi-Fi® 6 (802.11ax) + Bluetooth® 5.2 + 802.15.4 Tri-radio Solution (link)
[7] Webpage - IW620: 2.4/5 GHz Dual-Band 2x2 Wi-Fi® 6 (802.11ax) + Bluetooth® 5.1 Solution (link)
[8] Webpage - 88Q9098/88Q9098S: 2.4/5 GHz Dual-Band 2x2 Wi-Fi® 6 (802.11ax) + Bluetooth® 5.3 Automotive Solution (link)
[9] Webpage - 88W8887: 1x1 Dual-band Wi-Fi® 5 (802.11ac) and Bluetooth®5.2 Combo Solution (link)
[10] Webpage - 88W8897P: (Automotive): 2.4/5 GHz Dual-Band 2x2 Wi-Fi® 5 (802.11ac) + Bluetooth® 5 Solution (link)
[11] Webpage - 88W8977: 2.4/5 GHz Dual-Band 1x1 Wi-Fi® 4 (802.11n) + Bluetooth® 5.2 Solution (link)
[12] Webpage - 88W8987: 2.4/5 GHz Dual-Band 1x1 Wi-Fi® 5 (802.11ac) + Bluetooth® 5.2 Solution (link)
[13] Webpage - 88W8997: 2.4/5 GHz Dual-Band 2x2 Wi-Fi® 5 (802.11ac) + Bluetooth® 5.3 Solution (link)
[14] Webpage - 88W9098: 2.4/5 GHz Dual-Band 2x2 Wi-Fi® 6 (802.11ax) + Bluetooth® 5.3 (link)

7 Note about the source code in the document

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8 Revision history

Table 8. Revision history

Document ID	Release date	Description
AN14163 v.2	04 July 2024	Security status changed to public. • Section 1.1 "Supported devices": updated.
AN14163 v.1	19 April 2024	• Initial version

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