

Bluetooth® Low Energy Protocol Stack

Virtual UART Application

Introduction

This manual describes the software configuration, functions, operation check procedure, and implementation details of the Virtual UART Application that uses Bluetooth LE wireless technology.

The Virtual UART Application runs with Renesas Bluetooth® Low Energy Protocol Stack on a Renesas RL78/G1D device as embedded configuration and provides the following functions.

- Simple AT command function to control and configure Bluetooth LE connection
- Virtual UART function to send / receive characters or binary data to / from a remote device over Bluetooth LE communication
- A function to select communication with response or without response in Bluetooth LE communication

Target Device

RL78/G1D

Related Documents

Document Name	Document No.
Bluetooth® Low Energy Protocol Stack	
User's Manual	R01UW0095E
API Reference Manual: Basics	R01UW0088E
Quick Start Guide	R01AN2767E
GUI Tool	R01AN2469E
Bluetooth® Specification	
Vol 6. Low Energy Controller volume	Core_v4.2

Contents

1. Overview.....	5
1.1 Application Behavior.....	5
2. Architecture	6
2.1 Software Architecture	6
2.2 File Composition.....	7
3. Application Mode	9
3.1 mode.....	9
3.2 Selection of data communication with response or without response	9
3.3 Selection of data to communicate	10
3.3.1 Character data transmission and reception	10
3.3.2 Binary data transmission and reception	10
4. Simple AT Command Mode	11
4.1 Details of Simple AT Command	12
4.1.1 AT-C	12
4.1.2 AT-C=<addr>.....	12
4.1.3 AT-R	12
4.1.4 AT-AS=<addr>	13
4.1.5 AT-AS?	13
4.1.6 AT-AP=<addr>	13
4.1.7 AT-AP?	14
4.1.8 AT-DS.....	14
4.1.9 AT-S?	14
4.1.10 AT-CI=<con_intv>	15
4.1.11 AT-CI?	15
4.1.12 ATE0.....	16
4.1.13 ATE1.....	16
5. Virtual UART Mode.....	17
5.1 Virtual UART Profile	17
5.1.1 Data communication with response	17
5.1.2 Data communication without response	18
5.2 Buffering of the Send Characters	19
5.2.1 Data communication with response	19
5.2.2 Data communication without response	20
5.3 Encryption of BLE Connection	20
6. Power Saving Function.....	21
6.1 CPU STOP Mode	21
6.2 Changes of Advertising Interval	21

7.	Build and Operational Check.....	22
7.1	Environment.....	22
7.2	Build Procedure.....	23
7.2.1	e ² studio (32-bit version/64-bit version).....	23
7.2.2	CS+.....	23
7.2.3	BLE Protocol Stack / EEPROM emulation library.....	24
7.3	Preparation for Execution Environment.....	25
7.4	Usage Example.....	26
7.4.1	Character data transmission and reception.....	26
7.4.2	Binary data transmission and reception.....	30
8.	Implementation Details.....	35
8.1	Virtual UART Profile.....	35
8.2	Advertising.....	37
8.3	Connection.....	37
8.4	Pairing.....	38
8.5	Virtual UART Function API.....	39
8.5.1	Virtual UART Definitions.....	39
8.5.2	Function.....	41
8.5.2.1	RBLE_VUART_Server_Enable.....	41
8.5.2.2	RBLE_VUART_Server_Disable.....	41
8.5.2.3	RBLE_VUART_Server_Send_Indication.....	41
8.5.2.4	RBLE_VUART_Server_Send_Notification.....	42
8.5.2.5	RBLE_VUART_Client_Enable.....	42
8.5.2.6	RBLE_VUART_Client_Disable.....	42
8.5.2.7	RBLE_VUART_Client_Send_Chars.....	43
8.5.2.8	RBLE_VUART_Client_Send_Chars_Noresp.....	43
8.5.3	Event.....	44
8.5.3.1	RBLE_VUART_EVENT_SERVER_ENABLE_CMP.....	44
8.5.3.2	RBLE_VUART_EVENT_SERVER_WRITE_REQ.....	44
8.5.3.3	RBLE_VUART_EVENT_SERVER_WRITE_NORESP_REQ.....	44
8.5.3.4	RBLE_VUART_EVENT_SERVER_INDICATION_CFM.....	44
8.5.3.5	RBLE_VUART_EVENT_SERVER_NOTIFICATION_CMP.....	45
8.5.3.6	RBLE_VUART_EVENT_CLIENT_ENABLE_CMP.....	45
8.5.3.7	RBLE_VUART_EVENT_CLIENT_INDICATION.....	45
8.5.3.8	RBLE_VUART_EVENT_CLIENT_NOTIFICATION.....	45
8.5.3.9	RBLE_VUART_EVENT_CLIENT_WRITE_RSP.....	46
8.5.3.10	RBLE_VUART_EVENT_CLIENT_WRITE_NORSP_CMP.....	46
8.6	Application State Change.....	47
8.7	Application Detailed Sequence.....	48
8.7.1	Boot Sequence.....	48

8.7.2	Connection Sequence	49
8.7.3	Data Transfer Sequence (Write Request/Indication)	50
8.7.4	Data Transfer Sequence (Write Command/Notification).....	50
8.7.5	Disconnection Sequence.....	51
8.8	Macro Settings.....	52
8.8.1	Character data/Binary data transmission and reception setting	52
8.8.2	Local echo setting	52
8.9	Others.....	52
8.9.1	Caution when implementing the program to connect to the application	52
8.9.2	Read processing of DIP switch that select mode in binary data transmission / reception.....	53
8.9.3	Read processing of DIP switch that select whether to respond in data transmission / reception.....	53
8.9.4	CFG_CON macro.....	53
8.9.5	Data transmission from the terminal or host microcomputer	54
8.9.5.1	Example of data transmission during communication with response	54
8.9.5.2	Example of data transmission during communication without response	55
9.	Appendix.....	56
9.1	ROM size, RAM size	56
9.2	Operational Check by Using the GUI-Tool.....	57
9.2.1	Preparation.....	57
9.2.2	Operation.....	58
	Revision History	69

The *Bluetooth*® word mark and logos are registered trademarks owned by Bluetooth SIG, Inc. and any use of such marks by Renesas Electronics Corporation is under license. Other trademarks and registered trademarks are the property of their respective owners.

1. Overview

This manual describes the software configuration, functions, operation check procedure, and implementation details of the Virtual UART Application (hereinafter referred to as "application") that uses Bluetooth LE wireless technology.

The application runs with Renesas Bluetooth® Low Energy Protocol Stack (hereinafter referred to as "BLE Protocol Stack") on a Renesas RL78/G1D device as embedded configuration and provides the following functions.

- Simple AT command function to control and configure Bluetooth LE connection
- Virtual UART function to send / receive characters or binary data to / from a remote device over Bluetooth LE communication
 - Character data transmission and reception operation
 - Binary data transmission and reception operation
- A function to select communication with response or without response in Bluetooth LE communication
 - With response: Write Request, Indication
 - Without response: Write Command, Notification

1.1 Application Behavior

Figure 1-1 shows the application execution environment setup.

Prepare two RL78/G1D evaluation boards and write the application onto them. Then connect them respectively to PC via USB cable. A user operates the application through a terminal software.

Simple AT command can be used to establish, disconnect and configure Bluetooth LE connection. After establishing a Bluetooth LE connection, data typed on the local terminal are sent to a remote device and are displayed on the remote terminal. In the contrary, data typed on the remote terminal are sent to the local device and are displayed on the local terminal.

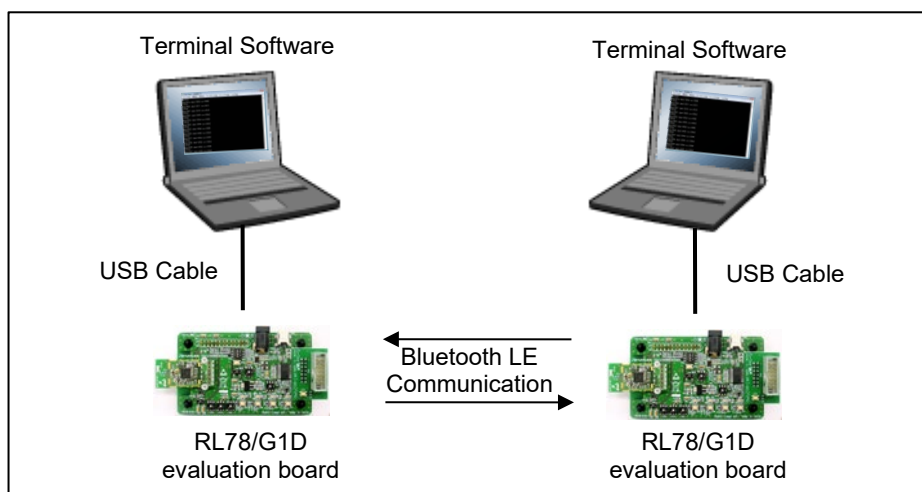


Figure 1-1: Application execution environment

2. Architecture

2.1 Software Architecture

Figure 2-1 shows software architecture of this application.

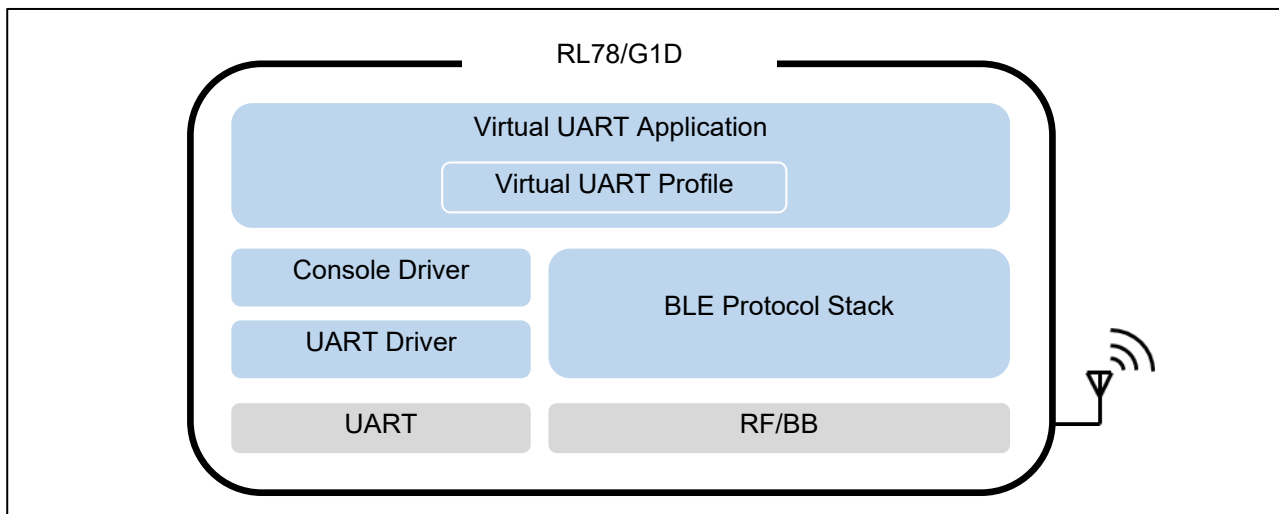


Figure 2-1: Software architecture

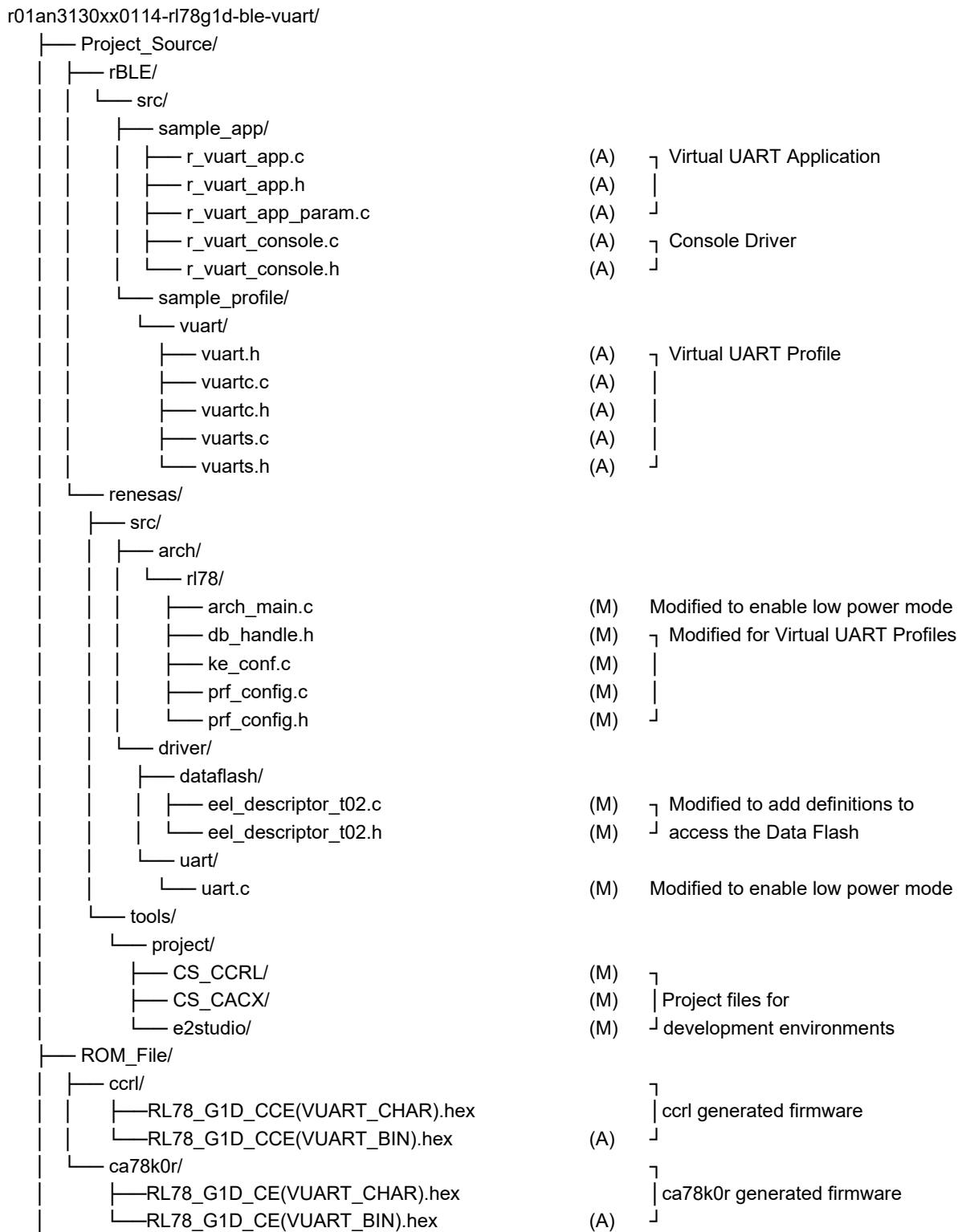
The software components are listed below.

Table 2-1: Software components

Component	Description
Virtual UART Application	The application is used for execution of simple AT command and transmission of characters or binary data. Virtual UART profile is defined to transfer characters.
Console Driver	The driver is used to relay data between a terminal software and Virtual UART application by using UART Driver functionality.
UART Driver	The device driver to control UART IP of RL78/G1D.
BLE Protocol Stack	Renesas Bluetooth® Low Energy Protocol Stack. Refer to "Bluetooth® Low Energy Protocol Stack User's manual" (R1UW0095E).

2.2 File Composition

The application is implemented based on BLE software which include BLE Protocol Stack. In this section, only files that have modified or added to the BLE software are listed. The modified files are marked with (M) and the added files are marked with (A).





3. Application Mode

3.1 mode

The application has two modes as shown in Table 3-1.

Table 3-1: Application mode

Application Mode	Description
Simple AT Command Mode	This mode is used for execution of the simple AT command to control and configure a Bluetooth LE connection. In this mode, characters are never sent to the remote device. Refer to "4. Simple AT Command Mode" for the detail.
Virtual UART Mode	This mode is used for transmission of character data or binary data over Bluetooth LE communication. In this mode, data typed during the application in disconnect state are not sent to the remote device. Refer to "5. Virtual UART Mode" for the detail.

3.2 Selection of data communication with response or without response

When data communication in virtual UART mode, you can select the communication method with or without response with the DIP switch on the RL78/G1D evaluation board.

Table 3-2: Setting of with response or without response

Number	Setting	Description
SW6-4	OFF (left side)	Data communication with response. from a client to a server : Write Request from a server to a client : Indication
	ON (right side)	Data communication without response. from a client to a server : Write Command from a server to a client : Notification

3.3 Selection of data to communicate

In the application, you can select "3.3.1 Character data transmission and reception" or "3.3.2 Binary data transmission and reception" in the macro settings. For macro settings, refer to "8.8.1 Character data/Binary data transmission and reception setting".

3.3.1 Character data transmission and reception

In the character data transmission and reception, ASCII printable characters and new-line character can be transmitted.

The application mode shown in Table 3-1 can be switched by entering the escape key (ASCII code: 0x1B) in the terminal software.

For an example of using character data transmission and reception, refer to "7. Build and Operational Check"->"7.4.1 Character data transmission and reception".

3.3.2 Binary data transmission and reception

In the binary data transmission and reception, all data including character data can be transmitted.

The application mode shown in Table 3-1 can be switched by the DIP switch on the RL78/G1D evaluation board.

For an example of using binary data transmission and reception, refer to "7. Build and Operational Check"->"7.4.2 Binary data transmission and reception".

Table 3-3: Operation settings for sending and receiving binary data

Number	Setting	Description
SW6-1	OFF (left side)	Simple AT Command Mode.
	ON (right side)	Virtual UART Mode. Note: In the virtual UART mode for sending and receiving binary data, local echo of the data input to the terminal software is prohibited.

4. Simple AT Command Mode

In Simple AT Command Mode, a user can control and configure Bluetooth LE connection by simple AT command.

Table 4-1 shows the simple AT commands that the application supports.

Table 4-1: List of simple AT commands

Simple AT command	Description
AT-C	Create a connection to the address specified by AT-AP=<addr>.
AT-C=<addr>	Create a connection to the address specified by <addr>.
AT-R	When the device is in connect state, disconnect the connection and start advertising. When the device is in disconnect state, start advertising.
AT-AS=<addr>	Set <addr> as the public device address of the local device.
AT-AS?	Display the public device address of the local device.
AT-AP=<addr>	Set the address used by AT-C.
AT-AP?	Display the address used by AT-C.
AT-DS	Display the address of devices which support virtual UART profile.
AT-S?	Display the application state. Connect state or Disconnect state.
AT-CI=<con_intv>	Change Connection Interval.
AT-CI?	Display Connection interval setting value.
ATE0	Disable local echo.
ATE1	Enable local echo.

4.1 Details of Simple AT Command

4.1.1 AT-C

Description	Create a connection to the address specified by AT-AP=<addr>	
Response	OK	Success
	ERROR	Failed due to the application is connect state
	CONNECT	Connection established
Command Example	AT-C OK CONNECT	

4.1.2 AT-C=<addr>

Description	Create a connection to the address specified by <addr>	
Response	OK	Success
	ERROR	Failed due to the application is connect state
	CONNECT	Connection established
Command Example	AT-C=CBA987654321 (Set CB:A9:87:65:43:21) OK CONNECT	

4.1.3 AT-R

Description	When the application is in connect state, disconnect the connection and start advertising. When the application is in disconnect state, start advertising.	
Response	OK	Success
	DISCONNECT	Disconnected
Command Example	[Connect state] AT-R OK DISCONNECT [Disconnect state] AT-R OK	

4.1.4 AT-AS=<addr>

Description	Set <addr> as the local device public device address. The address set by this command is preserved over power cycles. The address set by this command is reflected after reset. Please reset the system for example by pushing the reset button on the board.	
Response	OK	Success
	ERROR	Failed due to the application is connect state
Command Example	AT-AS=CCCCBBBBAAAA (Set CC:CC:BB:BB:AA:AA) OK	

4.1.5 AT-AS?

Description	Display the local device public address.	
Response	OK	Success
Command Example	AT-AS? -AS: CCCCBBBBAAAA (The address is CC:CC:BB:BB:AA:AA) OK	

4.1.6 AT-AP=<addr>

Description	Set <addr> as the public device address used by AT-C. The address set by this command is preserved over power cycles.	
Response	OK	Success
	ERROR	Failed due to the application is connect state
Command Example	AT-AP=CCCCBBBBAAAA (Set CC:CC:BB:BB:AA:AA) OK	

4.1.7 AT-AP?

Description	Display the public device address used by AT-C.	
Response	OK	Success
Command Example	AT-AP? -AP: CCCCBBBBAAAA (The address is CC:CC:BB:BB:AA:AA) OK	

4.1.8 AT-DS

Description	Display the address of the device which support virtual UART profile. Whether a device is supporting virtual UART profile is confirmed by checking the advertising data includes virtual UART service UUID.	
Response	OK	Success
	ERROR	Failed due to the application is connect state
Command Example	AT-DS -DS: CBA987654321 (The address is CB:A9:87:65:43:21) -DS: CCCCBBBBAAAA (The address is CC:CC:BB:BB:AA:AA) OK	

4.1.9 AT-S?

Description	Display the local device address connect state. The state is CONNECT or DISCONNECT.	
Response	OK	Success
Command Example	[Connect state] AT-S? CONNECT OK [Disconnect state] AT-S? DISCONNECT OK	

4.1.10 AT-CI=<con_intv>

Description	<p>Change Connection Interval.</p> <p>Execute this command in Disconnect state, the application retains the con_intv value internally, and the value will be used for following connection. This command cannot change Connection Interval in Connect state.</p> <p>Connection Interval is calculated by following calculation.</p> $\text{Connection Interval} = \text{con_intv} * 1.25[\text{ms}]$ <p>Ex) When you want to set 20[ms], execute AT-CI=16</p> <p>The default value of Connection Interval is 30[ms].</p> <p>Refer Figure 8-3 for Connection Interval Change sequence. After establishing the connection, Peripheral device requests Connection Interval parameter update to the Central device. Central device can decline the request depending on the restriction that Central device have. You can check whether requested Connection Interval is accepted by executing "AT-CI?" command.</p>	
Response	OK	Success
	ERROR	Failed due to the application is connect state
		The setting value is out of range (Range: 6~3200)
Command Example	<p>[Disconnect state]</p> <p>AT-CI=20</p> <p>OK</p> <p>AT-CI=3201</p> <p>[Connect state]</p> <p>AT-CI=20</p> <p>ERROR</p>	

4.1.11 AT-CI?

Description	<p>When execute this command in Connect state, display Connection Interval of the connection. When execute this command in Disconnect state, display the retained Connection Interval.</p> <p>To compute the actual Connection Interval, multiply the response value by 1.25[ms].</p> <p>Ex) If the response is "-CI: 20", Connection Interval is 20 * 1.25[ms] = 25[ms].</p>	
Response	OK	Success
Command Example	<p>AT-CI?</p> <p>-CI: 20</p> <p>OK</p>	

4.1.12 ATE0

Description	Disable local echo.	
Response	OK	Success
Command Example	ATE0 OK	

4.1.13 ATE1

Description	Enable local echo.	
Response	OK	Success
Command Example	ATE1 OK	

5. Virtual UART Mode

After establishing Bluetooth LE connection between two devices, a user can exchange data with the remote device.

In the character data transmission and reception, ASCII printable characters and new-line character can be transmitted. In the binary data transmission and reception, all data including character data can be transmitted.

5.1 Virtual UART Profile

Data transfer is enabled by GATT based virtual UART profile. Refer to 8.1.

The connection initiating device, which is executes AT-C command, works as GATT client and the remote device works as GATT server. Below is data transfer details.

5.1.1 Data communication with response

- To send data from the client to the server, send "Write Request" to the server. The server receives the data, and replies "Response" to the client.
- To send data from the server to the client, send "Indication" to the client. The client receives the data, and replies "Confirmation" to the server.

The data reception by the remote device can be confirmed by waiting for the "Response" or "Confirmation" reply from the remote device.

Figure 5-1 shows the data transfer sequence.

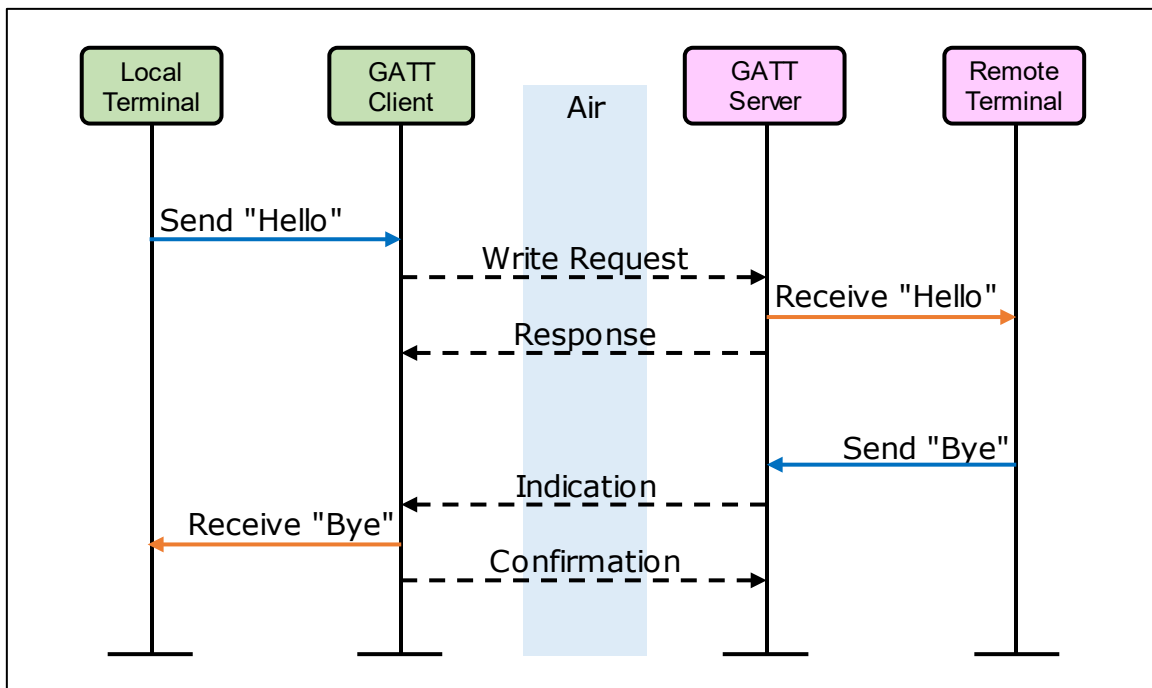


Figure 5-1: Data transfer sequence (with response)

5.1.2 Data communication without response

- To send data from the client to the server, send "Write Command" to the server.
- To send data from the server to the client, send "Notification" to the client.

Figure 5-2 shows the data transfer sequence.

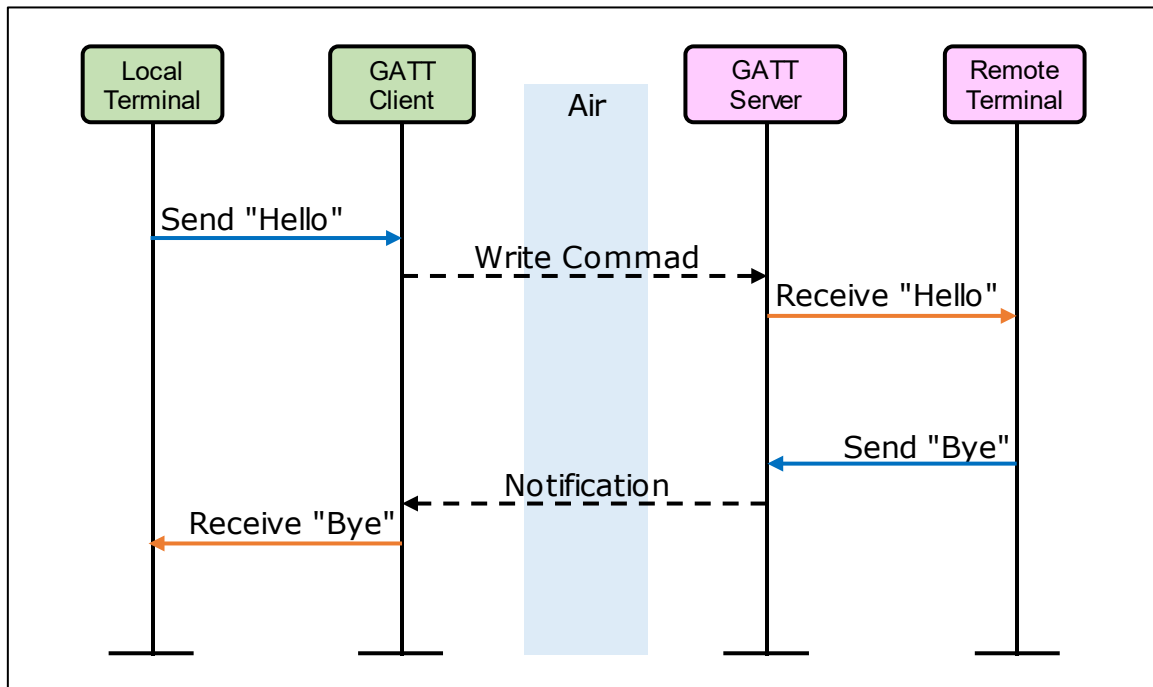


Figure 5-2: Data transfer sequence (without response)

5.2 Buffering of the Send Characters

In order to avoid the loss of send data, the application have a send data buffer.

5.2.1 Data communication with response

To send data within the period between “Write Request” and “Response” or “Indication” and “Confirmation” is not possible. So data typed within this period can be lost.

Virtual UART profile has a buffer and stores data typed within this period. If there are data in the buffer when receiving “Response” or “Confirmation” from the remote device, the profile sends it soon.

Figure 5-3 shows a send data buffering sequence.

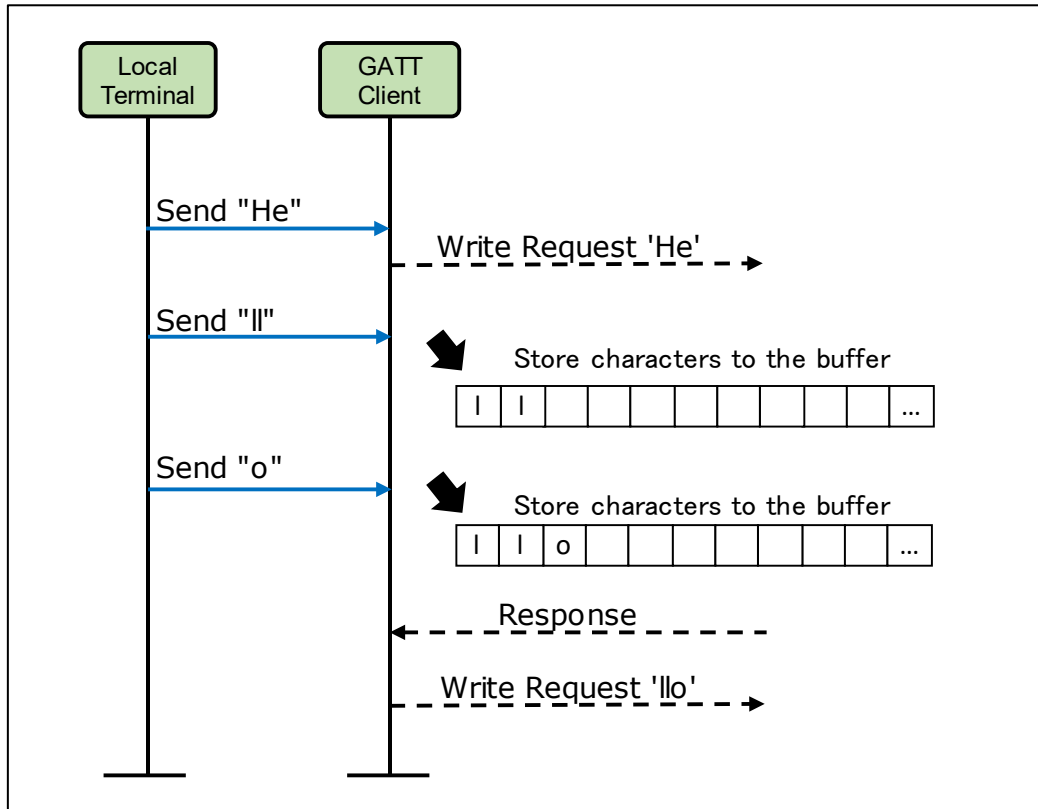


Figure 5-3: Send data buffering sequence (with response)

5.2.2 Data communication without response

After sending data with Write Command or Notification, use the timer function (ke_timer_set) of RWKE to wait for a certain period of time and buffer the data from the terminal software to some extent. Then send it after the timer has expired. This prevents the communication efficiency from dropping because it is sent in small units (1 byte or 2 bytes) if it is sent every time data is received from the terminal software. It also prevents the data entered by the user from being lost.

Figure 5-4 shows a send data buffering sequence.

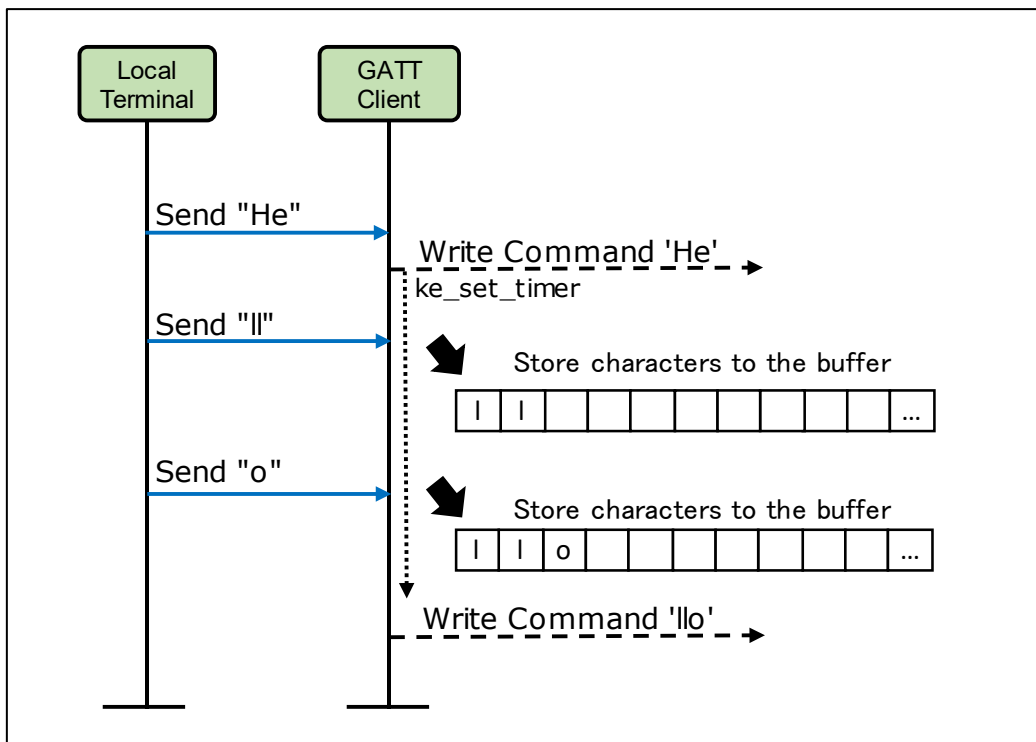


Figure 5-4: Send data buffering sequence (without response)

5.3 Encryption of BLE Connection

To protect the Bluetooth LE connection from such as eavesdropping, the encryption of the Bluetooth LE connection is enabled.

The application does not hold the pairing information, it performs pairing on each connection.

6. Power Saving Function

6.1 CPU STOP Mode

When 3 seconds have elapsed after the last data transfer, CPU enters STOP mode in order to reduce the power consumption. During STOP mode, the blinking of the LED1/LED2 becomes slower or stops. If data transfer is occurred when CPU is in STOP mode, CPU returns from STOP mode soon.

6.2 Changes of Advertising Interval

When 30 seconds has elapsed after advertising started, the application sets a longer advertising interval in order to reduce the power consumption. The longer advertising interval is reset by re-enabling advertising with connection and disconnection or AT-R.

The default advertising interval is 30 milliseconds and the longer advertising interval is 3 seconds.

If you do not want to change the advertising interval, comment out the code below.

r_vuart_app.c, line 60, line1009

```
60:      #define APP_ADV_LOW_POWER_DURATION (3000)
1009:    ke_timer_set(RBLE_APP_ADV_EVT, TASK_CON_APPL, APP_ADV_LOW_POWER_DURATION);
```

7. Build and Operational Check

7.1 Environment

Below is the environment to use for application build and operation check.

- Hardware
 - Host PC
 - PC/AT™ compatible machine
 - Processor Speed : 1.6GHz or higher
 - Main Memory : 1GB or more
 - Interface : USB2.0 (Used for E1 and RL78/G1D evaluation board)
 - Device
 - RL78/G1D evaluation board [RTK0EN0001010001BZ]
- Tool
 - Supports the following on-chip debuggers.
 - E1 emulator
 - E2 emulator
 - E2 emulator Lite

Note: The E1 emulator is used in this application note. We have already discontinued production of the E1 emulator due to components of the product having reached their EOL (end of life, i.e. end of production). Please click on the following link to confirm the details and our successor products.

[>> Tool News: \[Notification\] Advance Notice of E1 Emulator Product End of Life \(EOL\)](#)

- Software
 - Windows® 7 or later
 - Supports the following integrated environments.
 - e² studio 2020-07 (64-bit version) / RL78 Family C Compiler Package V1 (without IDE) V1.09.00
 - e² studio V7.8.0 (32-bit version) / RL78 Family C Compiler Package V1 (without IDE) V1.09.00
 - Renesas CS+ for CC V8.04.00 / RL78 Family C Compiler Package V1 (without IDE) V1.09.00
 - Renesas CS+ for CA, CX V4.04.00 / Renesas CA78K0R V1.72
 - Renesas Flash Programmer v3.06.02
 - Tera Term Version 4.105
 - UART-USB conversion device driver

Note: It may be that device driver of UART-USB conversion IC “FT232RL” is requested is in the first connection with host. In this case, you can get the device driver from below link.

FTDI (Future Technology Device International) – Drivers

<https://ftdichip.com/drivers/d2xx-drivers/>

7.2 Build Procedure

The application can be built using the following environment.

Since all the files required for build are included in this application note, there is no need to download the BLE protocol stack or EEPROM emulation library.

- e² studio 2020-07 (64-bit version) / RL78 Family C Compiler Package V1 (without IDE) V1.09.00
- e² studio V7.8.0 (32-bit version) / RL78 Family C Compiler Package V1 (without IDE) V1.09.00
- Renesas CS+ for CC V8.04.00 / RL78 Family C Compiler Package V1 (without IDE) V1.09.00
- Renesas CS+ for CA, CX V4.04.00 / Renesas CA78K0R V1.72

Note: Please refer to "8.8 Macro Settings" and set the application before building.

7.2.1 e² studio (32-bit version/64-bit version)

1. Launch e² studio.
2. Right click on "Project Explorer" and select "Import..." from the dropdown menu.
3. "Import" window is popped up and select "Existing Projects into Workspace" and click "Next >".
4. Fill "Select root directory:" form with the project folder shown in Table 7-1 and make sure that the project you selected is displayed in "Projects:" and click "Finish". Then the window is closed.
5. Right click on the project just imported on "Project Explorer" and Select "Build Project" from the dropdown menu.
6. Refer Table 7-1 for the Hex file firmware path.

Table 7-1: Project file and Hex file Location (e² studio)

e ² studio with CC-RL	
Project Folder	\\Project_Source\renesas\tools\project\e2studio\BLE_Embedded\BLE_Emb
Firmware	\\Project_Source\renesas\tools\project\e2studio\BLE_Embedded\BLE_Emb\DefaultBuild\rBLE_Emb_CCRL.hex

7.2.2 CS+

1. Double click the project file shown in Table 7-2.
2. Right click on "BLE_Emb" in "Project Tree" and select "Build BLE_Emb" from the dropdown menu.
3. Refer Table 7-2 for the Hex file firmware path.

Table 7-2: Project file and Hex file Location (CS+)

CS+ for CC	
Project File	\\Project_Source\renesas\tools\project\CS_CCRL\BLE_Embedded\BLE_Embedded.mtpj
Firmware	\\Project_Source\renesas\tools\project\CS_CCRL\BLE_Embedded\BLE_Emb\DefaultBuild\rBLE_Emb_CCRL.hex
CS+ for CA, CX	
Project File	\\Project_Source\renesas\tools\project\CS_CACX\BLE_Embedded\BLE_Embedded.mtpj
Firmware	\\Project_Source\renesas\tools\project\CS_CACX\BLE_Embedded\BLE_Emb\DefaultBuild\BLE_Emb.hex

7.2.3 BLE Protocol Stack / EEPROM emulation library

The BLE protocol stack and EEPROM emulation library used in this application can be download from the Renesas Web page.

- BLE protocol stack
 - <https://www.renesas.com/software-tool/bluetooth-low-energy-protocol-stack-rl78-family>
- EEPROM emulation library
 - EEPROM Emulation Library Pack02 Package Ver.2.00(for CA78K0R/CC-RL Compiler) for RL78 Family
 - <https://www.renesas.com/software-tool/data-flash-libraries>

NOTE: The link address can be changed without notice.

7.3 Preparation for Execution Environment

1. Write the firmware onto two RL78/G1D evaluation boards. Refer to "Bluetooth® Low Energy Protocol Stack Quick Guide" (R01AN2767E) Section 5.

You can use the pre-built HEX file included in this application note. This application note uses the CC-RL HEX file.

Table 7-3: Pre-built HEX file

Function	File
Character data transmission and reception	\\ROM_File\ccr\RL78_G1D_CCE(VUART_CHAR).hex
Binary data transmission and reception	\\ROM_File\ccr\RL78_G1D_CCE(VUART_BIN).hex

2. As shown in Figure 1-1, connect both RL78/G1D evaluation boards to PCs respectively.
3. Launch a terminal software on both PCs and configure them as Table 7-4. This application note uses Tera Term as the terminal software.

Table 7-4: Terminal software configuration

Setting	Value
New-line Receive	LF
New-line Send	CR
Baud rate	4800 [bps]
Data length	8 [bit]
Parity bit	none
Stop bit	1 [bit]
Flow control	none

4. Set the DIP switches on the two RL78/G1D evaluation boards according to Table 7-5.

Table 7-5: DIP switch setting

DIP switch	Setting
SW6-1	OFF (left side: Simple at command mode) Note: Used in "7.4.2 Binary data transmission and reception"
SW6-4	OFF (left side: Data communication with response)

7.4 Usage Example

7.4.1 Character data transmission and reception

In this example, set device addresses, establish a Bluetooth LE connection, transfer characters and disconnect the connection.

Figure 7-1 shows execution results of the terminal. Figure 7-2 and Figure 7-3 shows the sequence diagram of this example usage. The red numbers in figures are corresponding to the numbers in the following procedures.

1. Set local and remote device address. To set the device address use “AT-AS=<addr>” command. For example, to set 12:34:56:78:9A:BC, execute “AT-AS=123456789ABC”. To display current device address settings, use “AT-AS?”.
If a device address is 00:00:00:00:00:00 or the local device and the remote device have the same addresses, you need to change the device address. In the following example, we assume that you set 12:34:56:78:9A:BC to the local device address, CB:A9:87:65:43:21 to the remote device address.
2. When you change a device address by “AT-AS=<addr>” command, you need to reset the device to reflect the change by pushing RESET button (SW5) on the board.
3. Execute “AT-AP=CBA987654321” to set the target device address for a connection.
4. Execute “AT-C” on the local terminal. This command start the connection to the device which have the address CB:A9:87:65:43:21. After the connection established, “CONNECT” response is displayed on both of the local and remote terminal.
5. Type ESC key on the local terminal to switch the application mode to Virtual UART mode.
6. Set the DIP switch (SW6-4) of the local device to OFF (left side: communication with response).
7. Type “Hello” to the local terminal. Then “Hello” is displayed on the remote terminal.
8. Type ESC key on the remote terminal to switch the application mode to Virtual UART mode.
9. Set the DIP switch (SW6-4) of the remote device to OFF (left side: communication with response).
10. Type “Bye” on the remote terminal. Then “Bye” is displayed on the local terminal.
11. Set the DIP switch (SW6-4) of the local device to ON (right side: communication without response).
12. Type “Hello” to the local terminal. Then “Hello” is displayed on the remote terminal.
13. Set the DIP switch (SW6-4) of the remote device to ON (right side: communication without response).
14. Type “Bye” on the remote terminal. Then “Bye” is displayed on the local terminal.
15. Type ESC key on the local terminal to switch the application mode to AT command mode.
16. Execute “AT-R” on the local terminal to disconnect the connection. After completing the disconnection, “DISCONNECT” response is displayed on both of the local and remote terminal.

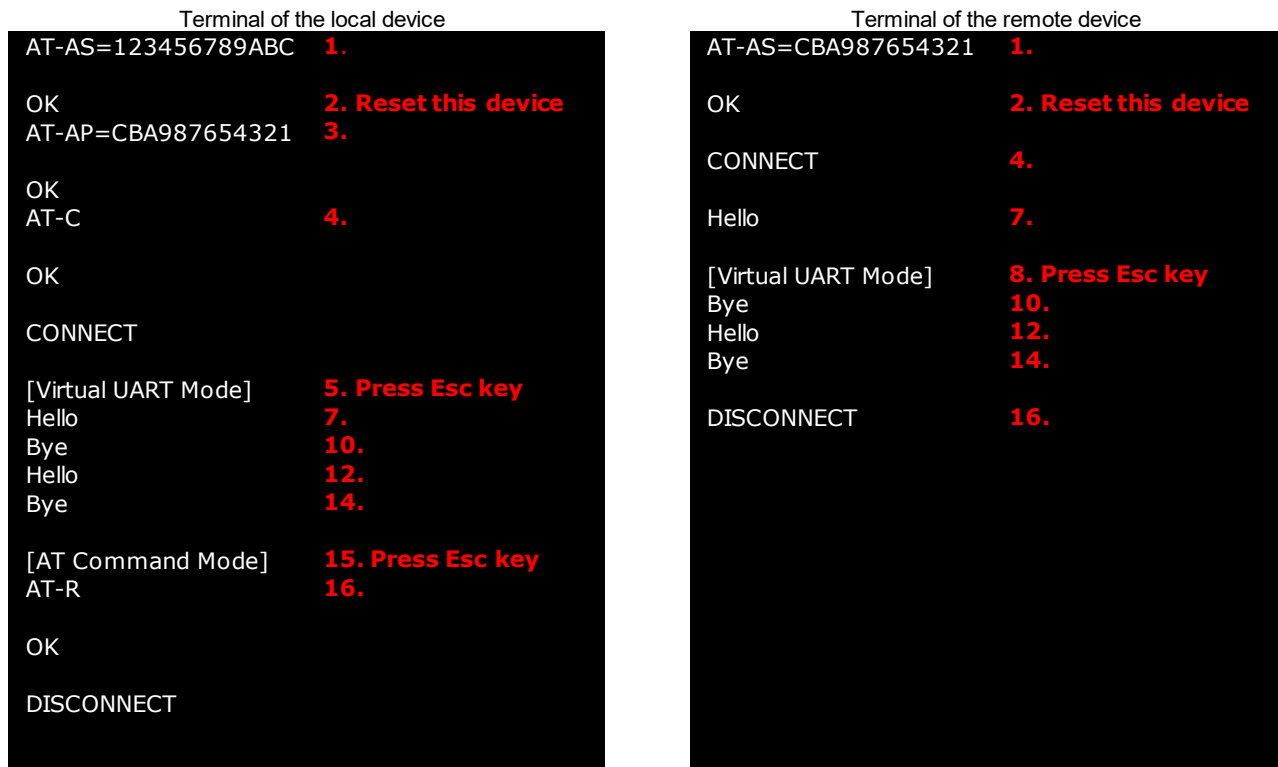


Figure 7-1: Terminal result

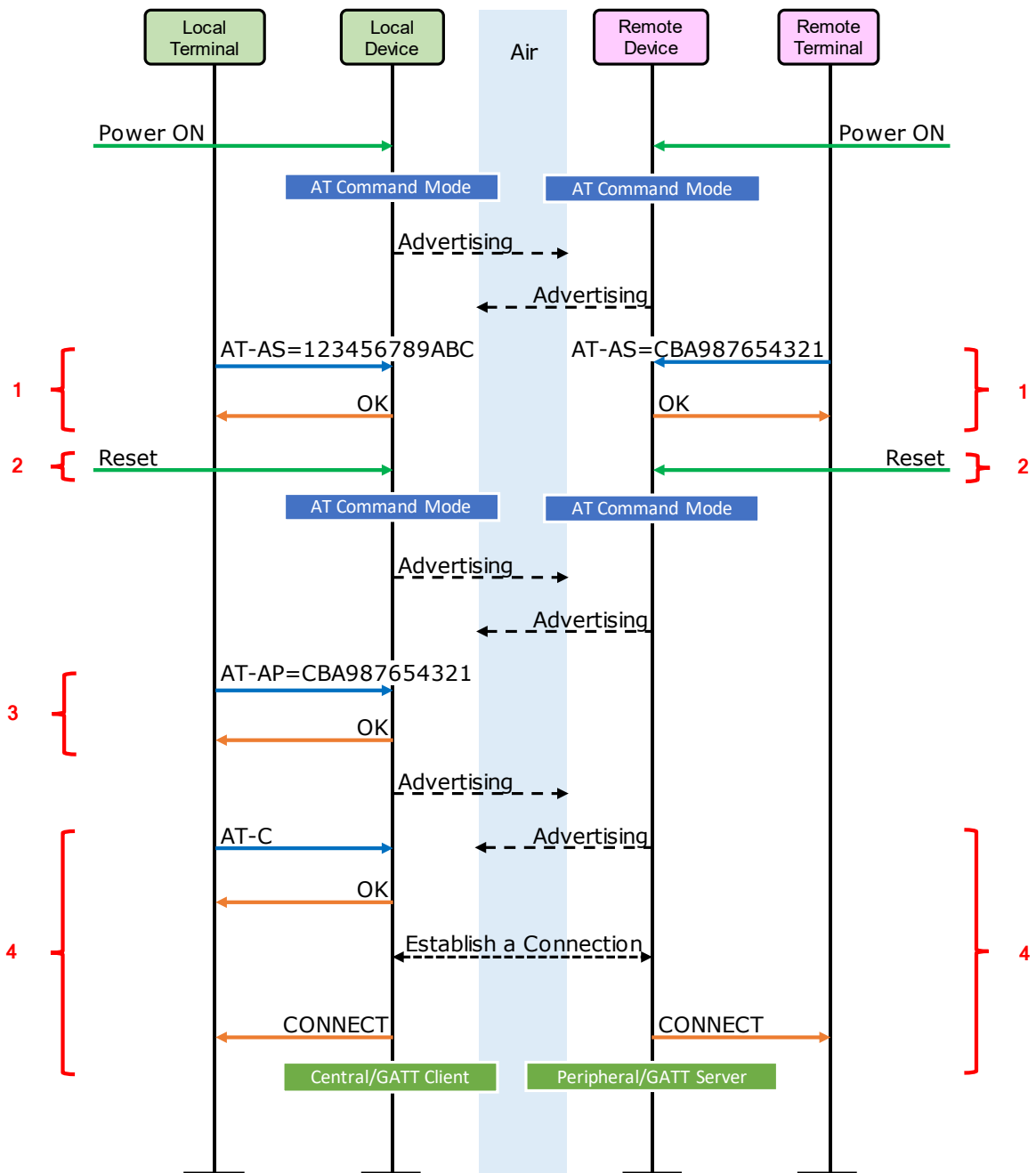


Figure 7-2: Example usage sequence of character data transmission and reception (1/2)

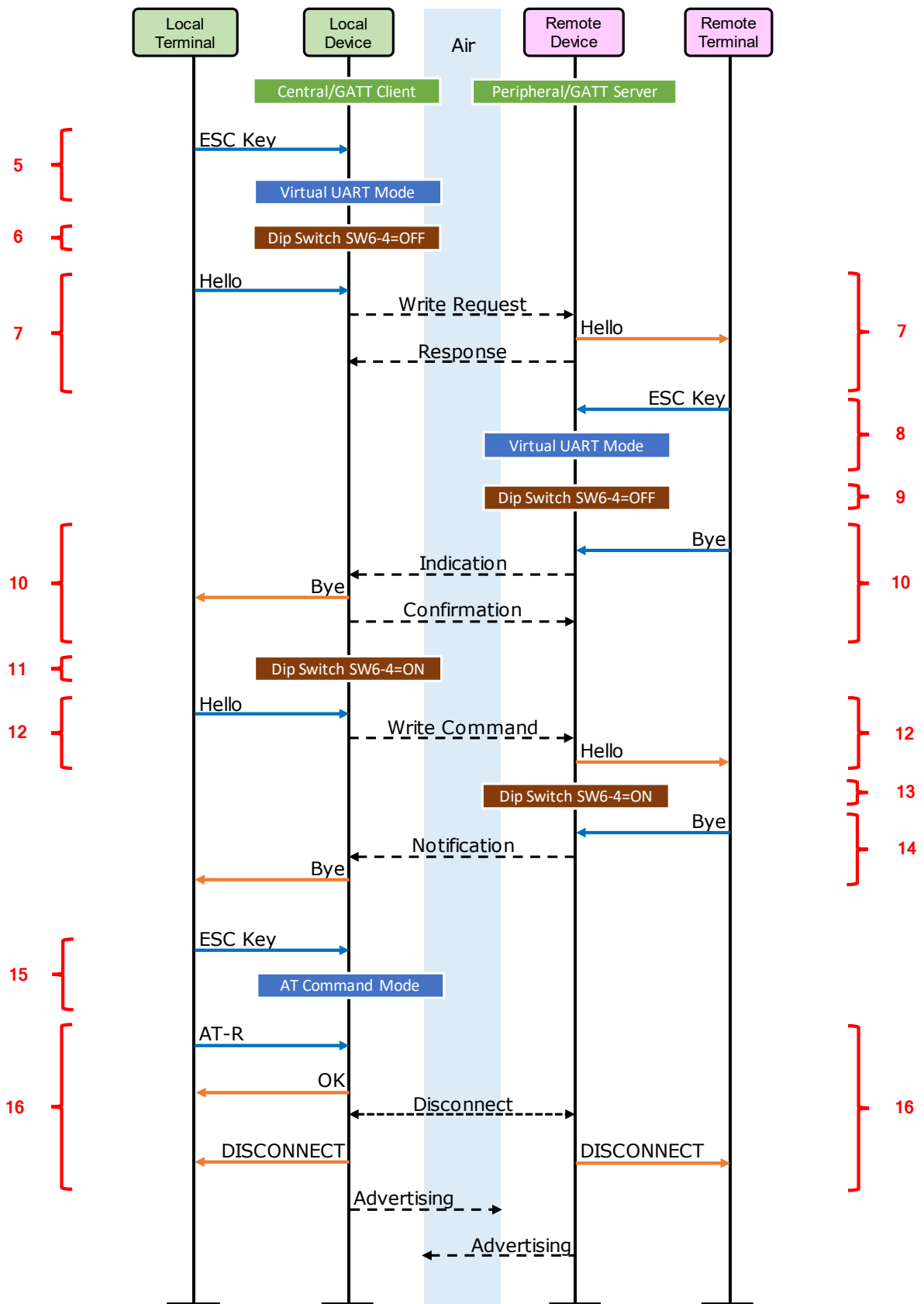


Figure 7-3: Example usage sequence of character data transmission and reception (2/2)

7.4.2 Binary data transmission and reception

In this example, set device addresses, establish a Bluetooth LE connection, transfer binary data and disconnect the connection.

Also, use the macro function of the terminal when binary data transmission and reception. The macro files to be used is shown below.

Table 7-6: Macro file (r01an3130xx0114-r178g1d-ble-vuart\Macro\)

File name	Description
tt_debug_mode_on.ttl	Turn on the debug mode of Tera Term. The terminal display will be in hexadecimal.
tt_debug_mode_off.ttl	Turn off the debug mode of Tera Term. The terminal display will be in the initial state.
tt_send_bin_1.ttl	Sends binary data (0x00 0x01 0x02 0x03 0x04).
tt_send_bin_2.ttl	Sends binary data (0xF0 0xF1 0xF2 0xF3 0xF4).

Figure 7-4 shows execution results of the terminal. Figure 7-5 and Figure 7-6 shows the sequence diagram of this example usage. The red numbers in figures are corresponding to the numbers in the following procedures.

1. Set the DIP switch (SW6-1) of local and remote device to OFF (left side: Simple AT command mode).
2. Set local and remote device address. To set the device address use "AT-AS=<addr>" command. For example, to set 12:34:56:78:9A:BC, execute "AT-AS=123456789ABC". To display current device address settings, use "AT-AS?".
If a device address is 00:00:00:00:00:00 or the local device and the remote device have the same addresses, you need to change the device address. In the following example, we assume that you set 12:34:56:78:9A:BC to the local device address, CB:A9:87:65:43:21 to the remote device address.
3. When you change a device address by "AT-AS=<addr>" command, you need to reset the device to reflect the change by pushing RESET button (SW5) on the board.
4. Execute "AT-AP=CBA987654321" to set the target device address for a connection.
5. Execute "AT-C" on the local terminal. This command start the connection to the device which have the address CB:A9:87:65:43:21. After the connection established, "CONNECT" response is displayed on both of the local and remote terminal.
6. Set the DIP switch (SW6-1) of local and remote device to ON (right side: Virtual UART mode).
7. Set the DIP switch (SW6-4) of the local device to OFF (left side: communication with response).
8. Run the macro on the local and remote device terminals to put the terminal in debug mode.
Select "Control" from the terminal menu and select "Macro" from the dropdown menu. "MACRO" window is popped up and select the macro file "tt_debug_mode_on.ttl" in Table 7-6. click "Open".
9. Send binary data from the local device.
Select "Control" from the terminal menu and select "Macro" from the dropdown menu. "MACRO" window is popped up and select the macro file "tt_send_bin_1.ttl" in Table 7-6. click "Open".
Then "00 01 02 03 04" is displayed on the remote terminal.
10. Send binary data from the remote device.
Select "Control" from the terminal menu and select "Macro" from the dropdown menu. "MACRO" window is popped up and select the macro file "tt_send_bin_2.ttl" in Table 7-6. click "Open".
Then "F0 F1 F2 F3 F4" is displayed on the remote terminal.
11. Set the DIP switch (SW6-4) of the local and remote device to ON (right side: communication without response).
12. Send binary data from the local device.
Select "Control" from the terminal menu and select "Macro" from the dropdown menu. "MACRO"

window is popped up and select the macro file "tt_send_bin_2.ttl" in Table 7-6. click "Open".
Then "F0 F1 F2 F3 F4" is displayed on the remote terminal.

13. Send binary data from the remote device.
Select "Control" from the terminal menu and select "Macro" from the dropdown menu. "MACRO" window is popped up and select the macro file "tt_send_bin_1.ttl" in Table 7-6. click "Open".
Then "00 01 02 03 04" is displayed on the local terminal.
14. Run the macro on the local and remote device terminals to put the terminal in initial mode.
Select "Control" from the terminal menu and select "Macro" from the dropdown menu. "MACRO" window is popped up and select the macro file "tt_debug_mode_off.ttl" in Table 7-6. click "Open".
15. Set the DIP switch (SW6-1) of local and remote device to OFF (left side: Simple AT command mode).
16. Execute "AT-R" on the local terminal to disconnect the connection. After completing the disconnection, "DISCONNECT" response is displayed on both of the local and remote terminal.

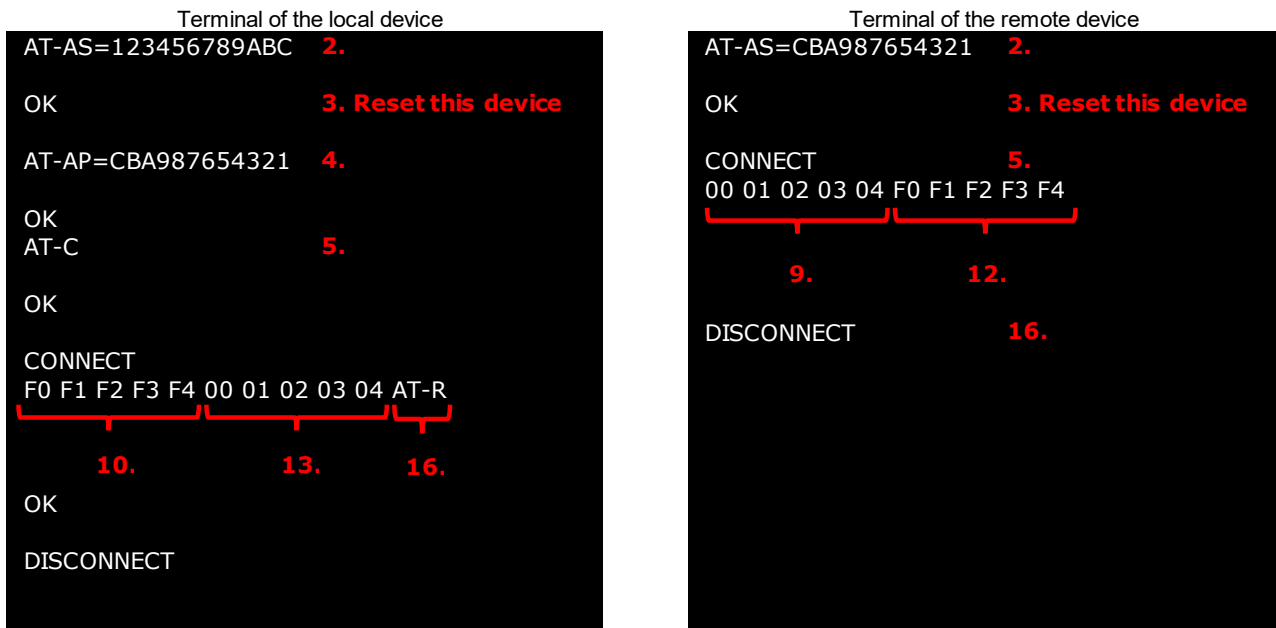


Figure 7-4: Terminal result

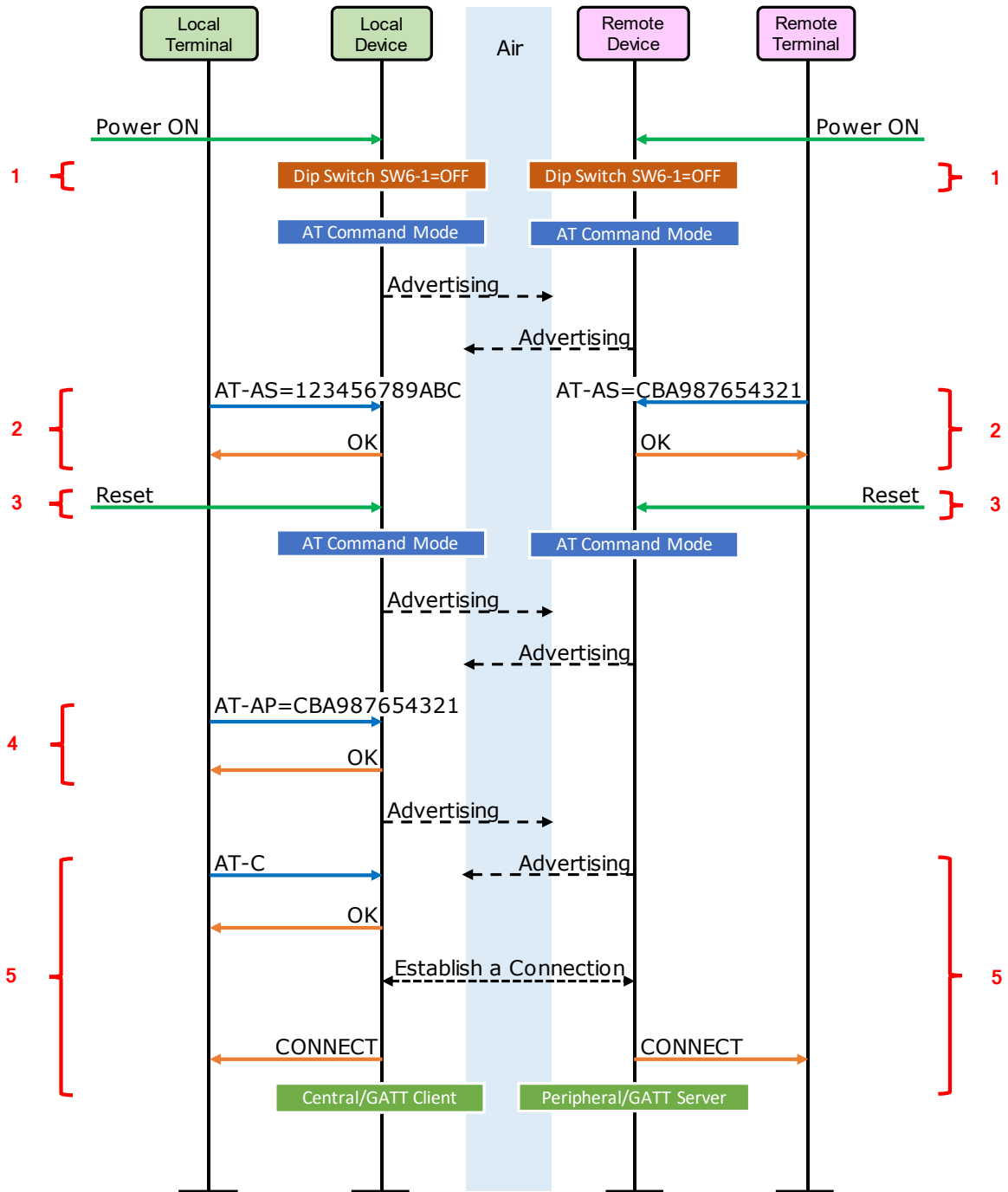


Figure 7-5: Example usage sequence of binary data transmission and reception (1/2)

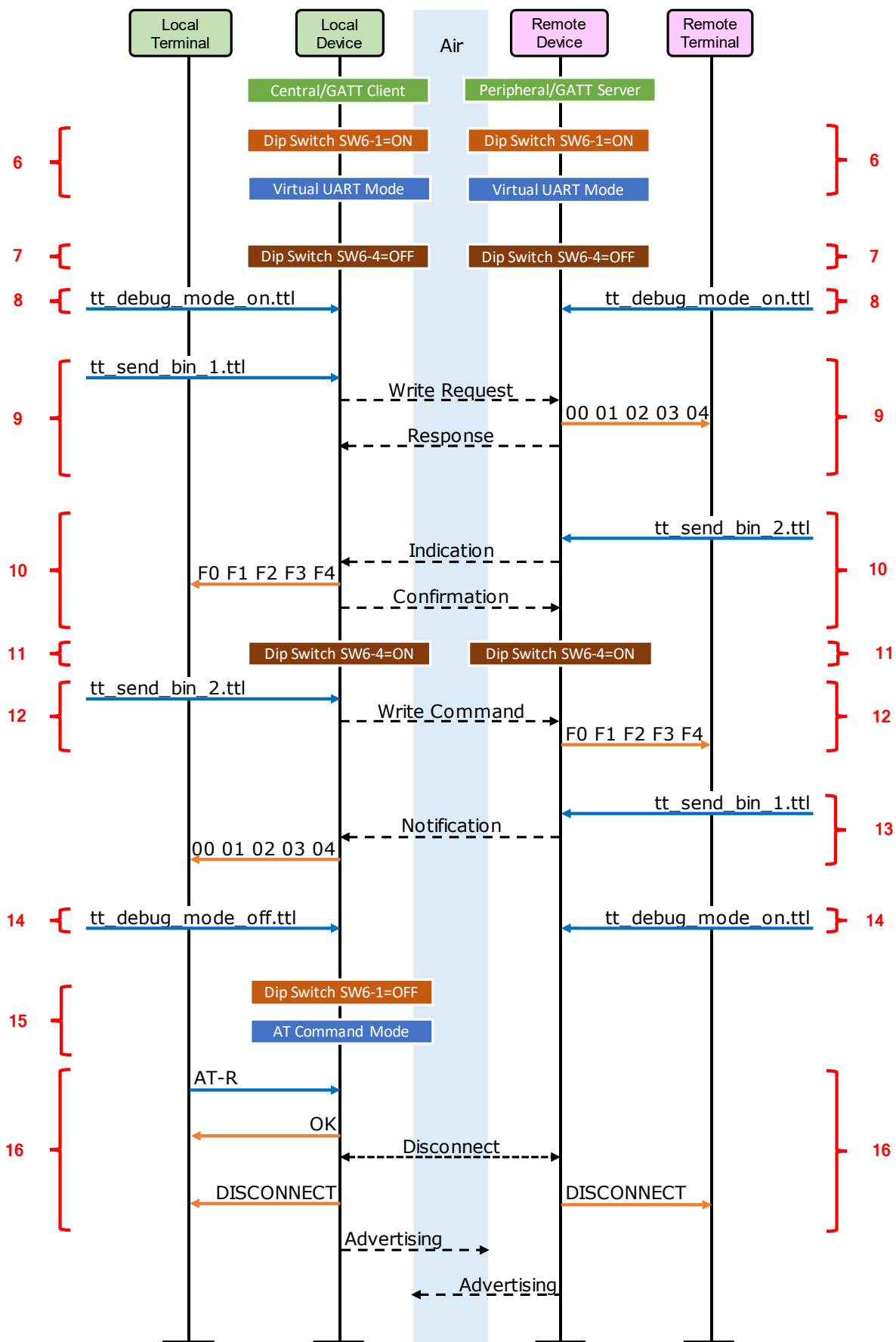


Figure 7-6: Example usage sequence of binary data transmission and reception (2/2)

8. Implementation Details

8.1 Virtual UART Profile

Table 8-1 and Table 8-2 shows the specification of Virtual UART Profile.

Table 8-1: Virtual UART Profile specification (1/2)

Attribute Handle	Attribute type and the value
VUART_HDL_SVC 0x000C	Type: Primary Service Declaration UUID: D68C0001-A21B-11E5-8CB8-0002A5D5C51B UUID for virtual UART service
VUART_HDL_INDICATION_CHAR 0x000D	Type: Characteristic Declaration UUID: D68C0002-A21B-11E5-8CB8-0002A5D5C51B Property: Indicate Used for data transfer from the server to the client
VUART_HDL_INDICATION_VAL 0x000E	Type: Indication Value By setting data to this characteristic and send Indication, the data are sent from the server to the client. Max 20 bytes.
VUART_HDL_INDICATION_CFG 0x000F	Type: Client Characteristic Configuration Descriptor Used for Indication enable / disable of the server from the client
VUART_HDL_WRITE_CHAR 0x0010	Type: Characteristic Declaration UUID: D68C0003-A21B-11E5-8CB8-0002A5D5C51B Property: Write Used for data transfer from the client to the server.
VUART_HDL_WRITE_VAL 0x0011	Type: Write Value By writing data to this characteristic with "Write Request", the data are sent from the client to the server. Max 20 bytes.

Note: The hex value of attribute handle can be changed depends on profiles included in the firmware.

Table 8-2: Virtual UART Profile specification (2/2)

Attribute Handle	Attribute type and the value
VUART_HDL_NOTIFICATION_CHAR 0x0012	Type: Characteristic Declaration UUID: D68C0004-A21B-11E5-8CB8-0002A5D5C51B Property: Notify Used for data transfer from the server to the client
VUART_HDL_NOTIFICATION_VAL 0x0013	Type: Notification Value By setting data to this characteristic and send Notification, the data are sent from the server to the client. Max 20 bytes.
VUART_HDL_NOTIFICATION_CFG 0x0014	Type: Client Characteristic Configuration Descriptor Used for Notification enable / disable of the server from the client
VUART_HDL_WRITE_NORESP_CHAR 0x0015	Type: Characteristic Declaration UUID: D68C0005-A21B-11E5-8CB8-0002A5D5C51B Property: Write Used for data transfer from the client to the server.
VUART_HDL_WRITE_NORESP_VAL 0x0016	Type: Write Value By writing data to this characteristic with "Write Command", the data are sent from the client to the server. Max 20 bytes.

Note: The hex value of attribute handle can be changed depends on profiles included in the firmware.

8.2 Advertising

Table 8-3 shows the default settings of advertising.

Table 8-3: Advertising specification

Advertising Type	Connectable undirected advertising (ADV_IND)
Advertising Interval Min	Default: 20 [ms], Low Power: 1.5 [s]
Advertising Interval Max	Default: 30 [ms], Low Power: 3 [s]
Advertising Channel Map	All Channels (37, 38, 39 ch)
Advertising Data	-
Length of this Data	2 [bytes]
Data Type	<<Flags>> (0x01)
Flags	LE General Discoverable Mode BR/EDR Not Supported
Length of this Data	8 [bytes]
Data Type	<<Complete Local Name>> (0x09)
Local Name	REL-BLE
Length of this Data	17 [bytes]
Data Type	<<Complete List of 128-bit Service Class UUIDs>> (0x07)
UUID	D68C0001-A21B-11E5-8CB8-0002A5D5C51B
Scan Response Data	none

8.3 Connection

Table 8-4 shows the default settings of connection.

Table 8-4: Connection specification

Scan Interval	30 [ms]
Scan Window Size	30 [ms]
Initiator Filter Policy	Ignore Accept List
Peer Address Type	Public Address
Peer BD Address	Specified by AT-C or AT-AP
Own Address Type	Public Address
Minimum of Connection Interval	30 [ms]
Maximum of Connection Interval	30 [ms]
Connection Latency	0 [ms]
Link Supervision Timeout	5 [s]
Minimum CE Length	0 [ms]
Maximum CE Length	50 [ms]

8.4 Pairing

Table 8-5 shows the pairing default settings.

Table 8-5: Pairing specification

Bonding	Bondable Mode
Security Mode	Unauthenticated pairing with encryption
Pairing Method	Just Works
IO capability	No Input No Output
OOB flag	OOB Data not present
Authentication Requirements	No MITM Bonding
Encryption key size	128 [bit]
Initiator key distribution	None
Responder key distribution	Encryption key

8.5 Virtual UART Function API

This section describes virtual UART function definitions and APIs.

8.5.1 Virtual UART Definitions

- Event type enumeration declaration

```
typedef enum {
    // Server Role
    RBLE_VUART_EVENT_SERVER_ENABLE_CMP = 0x01,
    RBLE_VUART_EVENT_SERVER_WRITE_REQ,
    RBLE_VUART_EVENT_SERVER_WRITE_NORESP_REQ,
    RBLE_VUART_EVENT_SERVER_INDICATION_CFM,
    RBLE_VUART_EVENT_SERVER_NOTIFICATION_CMP,
    // Client Role
    RBLE_VUART_EVENT_CLIENT_ENABLE_CMP = 0x81,
    RBLE_VUART_EVENT_CLIENT_INDICATION,
    RBLE_VUART_EVENT_CLIENT_NOTIFICATION,
    RBLE_VUART_EVENT_CLIENT_WRITE_RSP,
    RBLE_VUART_EVENT_CLIENT_WRITE_NORSP_CMP,
} RBLE_VUART_EVENT_TYPE;
```

- Event callback function declaration

```
typedef void (*RBLE_VUART_EVENT_HANDLER) (RBLE_VUART_EVENT *event);
```

- Event parameter structure

```
typedef struct RBLE_VUART_EVENT_t {
    RBLE_VUART_EVENT_TYPE type;    Virtual UART event type
    union Event_Vuart_Paramter_u {
```

Server role enable completion event

```
struct {
    RBLE_STATUS status;    Status
} server_enable_cmp;
```

Server role data receive event (Write Request)

```
struct {
    RBLE_STATUS status;    Status
    char value[20];        Received data
    uint16_t len;          Received data length
} server_write_req;
```

Server role data receive event (Write Command)

```
struct {
    RBLE_STATUS status;    Status
    char value[20];        Received data
    uint16_t len;          Received data length
} server_write_noresp_req;
```

Server role data send completion event (Indication)

```
struct {
    RBLE_STATUS status;      Status
} server_indicate_cnf;
```

Server role data send completion event (Notification)

```
struct {
    RBLE_STATUS status;      Status
} server_notify_cmp;
```

Client role enable completion event

```
struct {
    RBLE_STATUS status;      Status
} client_enable_cmp;
```

Client role data receive event (Indication)

```
struct {
    RBLE_STATUS status;      Status
    char value[20];          Received data
    uint16_t len;           Received data length
} client_indication;
```

Client role data receive event (Notification)

```
struct {
    RBLE_STATUS status;      Status
    char value[20];          Received data
    uint16_t len;           Received data length
} client_notification;
```

Client role data send completion event (Write Request)

```
struct {
    RBLE_STATUS status;      Status
} client_write_rsp;
```

Client role data send completion event (Write Command)

```
struct {
    RBLE_STATUS status;      Status
} client_write_norsp;
} param;
} RBLE_VUART_EVENT;
```


8.5.2 Function

8.5.2.1 RBLE_VUART_Server_Enable

RBLE_STATUS RBLE_VUART_Server_Enable(uint16_t conhdl, RBLE_VUART_EVENT_HANDLER callback)	
This function enables server role of virtual UART function. The result is informed by RBLE_VUART_EVENT_SERVER_ENABLE_CMP event.	
Parameters:	
<i>conhdl</i>	Connection handle
<i>callback</i>	Callback for virtual UART event
Return:	
<i>RBLE_OK</i>	Success
<i>RBLE_STATUS_ERROR</i>	Failed due to rBLE mode is in RBLE_MODE_ACTIVE

8.5.2.2 RBLE_VUART_Server_Disable

RBLE_STATUS RBLE_VUART_Server_Disable(void)	
This function disables server role of virtual UART function.	
Parameters:	
-	-
Return:	
<i>RBLE_OK</i>	Success

8.5.2.3 RBLE_VUART_Server_Send_Indication

RBLE_STATUS RBLE_VUART_Server_Send_Indication(const char *chars, uint16_t len)	
This function sends data from the server to the client. The data sent by the server are received by the client. After the reception, the client responses with Confirmation. The confirmation is informed to the server by RBLE_VUART_EVENT_SERVER_INDICATION_CFM event.	
Parameters:	
<i>chars</i>	Received data
<i>len</i>	Received data length
Return:	
<i>RBLE_OK</i>	Success
<i>RBLE_STATUS_ERROR</i>	Failed due to rBLE mode is in RBLE_MODE_ACTIVE

8.5.2.4 RBLE_VUART_Server_Send_Notification

RBLE_STATUS RBLE_VUART_Server_Send_Notification(const char *chars, uint16_t len)		
This function sends data from the server to the client. Executing this function will notify the server of RBLE_VUART_EVENT_SERVER_NOTIFICATION_CMP. Notes: This event does not guarantee the sending.		
Parameters:		
	<i>chars</i>	Received data
	<i>len</i>	Received data length
Return:		
	<i>RBLE_OK</i>	Success
	<i>RBLE_STATUS_ERROR</i>	Failed due to rBLE mode is in RBLE_MODE_ACTIVE

8.5.2.5 RBLE_VUART_Client_Enable

RBLE_STATUS RBLE_VUART_Client_Enable(uint16_t conhdl, RBLE_VUART_EVENT_HANDLER callback)		
This function enables client role of virtual UART function. The result is informed by RBLE_VUART_EVENT_CLIENT_ENABLE_CMP event.		
Parameters:		
	<i>conhdl</i>	Connection handle
	<i>callback</i>	Callback for virtual UART event
Return:		
	<i>RBLE_OK</i>	Success
	<i>RBLE_STATUS_ERROR</i>	Failed due to rBLE mode is in RBLE_MODE_ACTIVE

8.5.2.6 RBLE_VUART_Client_Disable

RBLE_STATUS RBLE_VUART_Client_Disable(void)		
This function disables client role of virtual UART function.		
Parameters:		
	-	-
Return:		
	<i>RBLE_OK</i>	Success

8.5.2.7 RBLE_VUART_Client_Send_Chars

RBLE_STATUS RBLE_VUART_Client_Send_Chars(const char *chars, uint16_t len)	
This function sends data from the client to the server. The data sent by the client are received by server. After the reception, the server responses with "Response" to the client. The response is informed to the client by RBLE_VUART_EVENT_CLIENT_WRITE_RSP event.	
Parameters:	
<i>chars</i>	Received data
<i>len</i>	Received data length
Return:	
<i>RBLE_OK</i>	Success
<i>RBLE_STATUS_ERROR</i>	Failed due to rBLE mode is in RBLE_MODE_ACTIVE

8.5.2.8 RBLE_VUART_Client_Send_Chars_Noresp

RBLE_STATUS RBLE_VUART_Client_Send_Chars_Noresp(const char *chars, uint16_t len)	
This function send data from the client to the server. Executing this function will notify the server of RBLE_VUART_EVENT_CLIENT_WRITE_NORSP_CMP. Notes: This event does not guarantee the sending.	
Parameters:	
<i>chars</i>	Received data
<i>len</i>	Received data length
Return:	
<i>RBLE_OK</i>	Success
<i>RBLE_STATUS_ERROR</i>	Failed due to rBLE mode is in RBLE_MODE_ACTIVE

8.5.3 Event

This section describes the events defined by virtual UART function.

8.5.3.1 RBLE_VUART_EVENT_SERVER_ENABLE_CMP

RBLE_VUART_EVENT_SERVER_ENABLE_CMP		
This event informs completion of server role enable.		
Parameters:		
	<i>status</i>	server role enable status

8.5.3.2 RBLE_VUART_EVENT_SERVER_WRITE_REQ

RBLE_VUART_EVENT_SERVER_WRITE_REQ		
This event informs that the server has received the data that the client sent using the RBLE_VUART_Client_Send_Chars function.		
Parameters:		
	<i>status</i>	The result of receiving data
	<i>value</i>	Received data
	<i>len</i>	Received data length

8.5.3.3 RBLE_VUART_EVENT_SERVER_WRITE_NOESP_REQ

RBLE_VUART_EVENT_SERVER_WRITE_NOESP_REQ		
This event informs that the server has received the data that the client sent using the RBLE_VUART_Client_Send_Chars_NoResp function.		
Parameters:		
	<i>status</i>	The result of receiving data
	<i>value</i>	Received data
	<i>len</i>	Received data length

8.5.3.4 RBLE_VUART_EVENT_SERVER_INDICATION_CFM

RBLE_VUART_EVENT_SERVER_INDICATION_CFM		
This event informs the completion of sending the data sent by the server using the RBLE_VUART_Server_Send_Indication function.		
Parameters:		
	<i>status</i>	The result of data send

8.5.3.5 RBLE_VUART_EVENT_SERVER_NOTIFICATION_CMP

RBLE_VUART_EVENT_SERVER_NOTIFICATION_CMP	
This event informs that the server has sent data using the <code>RBLE_VUART_Server_Send_Notification</code> function.	
Notes: This event does not guarantee the sending.	
Parameters:	
<i>status</i>	The result of data send

8.5.3.6 RBLE_VUART_EVENT_CLIENT_ENABLE_CMP

RBLE_VUART_EVENT_CLIENT_ENABLE_CMP	
This event informs client role enable completion.	
Parameters:	
<i>status</i>	

8.5.3.7 RBLE_VUART_EVENT_CLIENT_INDICATION

RBLE_VUART_EVENT_CLIENT_INDICATION	
This event informs that the client has received the data that the server sent using the <code>RBLE_VUART_Server_Send_Indication</code> function.	
Parameters:	
<i>status</i>	The result of data receive
<i>value</i>	Received data
<i>len</i>	Received data length

8.5.3.8 RBLE_VUART_EVENT_CLIENT_NOTIFICATION

RBLE_VUART_EVENT_CLIENT_NOTIFICATION	
This event informs that the client has received the data that the server sent using the <code>RBLE_VUART_Server_Send_Notification</code> function.	
Parameters:	
<i>status</i>	The result of data receive
<i>value</i>	Received data
<i>len</i>	Received data length

8.5.3.9 RBLE_VUART_EVENT_CLIENT_WRITE_RSP

RBLE_VUART_EVENT_CLIENT_WRITE_RSP		
This event informs the completion of sending the data that the client sent using the RBLE_VUART_Client_Send_Chars function.		
Parameters:		
	<i>status</i>	The result of data sending

8.5.3.10 RBLE_VUART_EVENT_CLIENT_WRITE_NORSP_CMP

RBLE_VUART_EVENT_CLIENT_WRITE_NORSP_CMP		
This event signals that the client has sent data using the RBLE_VUART_Client_Send_Chars_Noresp function.		
Notes: This event does not guarantee the sending.		
Parameters:		
	<i>status</i>	The result of data sending

8.6 Application State Change

Figure 8-1 shows the application state transition diagram. The application changes the state depends on connection and disconnection event and simple AT command execution.

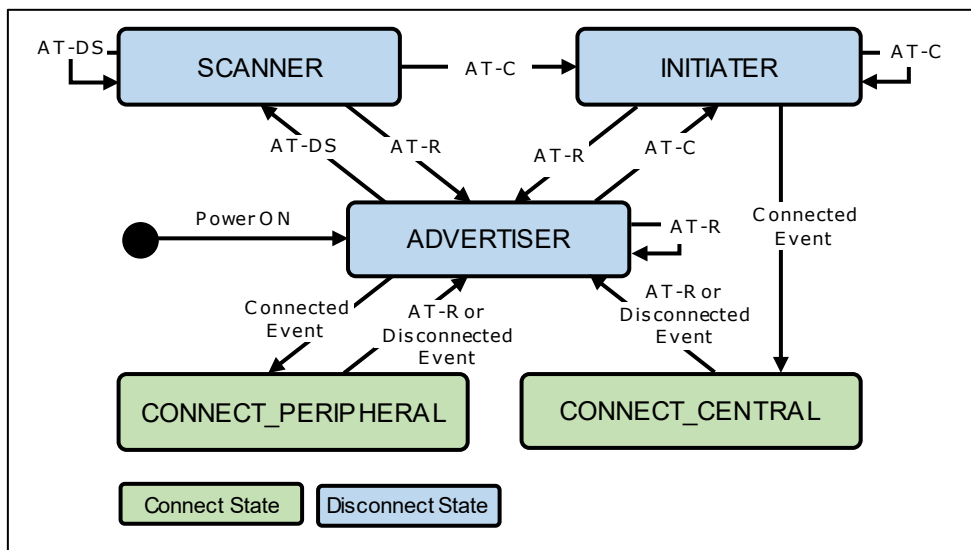


Figure 8-1: Application state diagram

Table 8-6 shows the application state list.

Table 8-6: Application state list

Application State	Description
ADVERTISER	The application is advertising.
SCANNER	The application is scanning neighbor devices by executing AT-DS command. After AT-DS has finished, the application remains in this state.
INITIATER	The application creates a connection to a remote device by executing AT-C.
CONNECT_CENTRAL	Bluetooth LE connection is established as master role. CONNECT_CENTRAL is GATT client.
CONNECT_PERIPHERAL	Bluetooth LE connection is established as slave role. CONNECT_PERIPHERAL is GATT sever.

8.7 Application Detailed Sequence

This section shows the sequence of boot, connection, character transfer and disconnection. Refer to "Bluetooth® Low Energy Protocol Stack API Reference: Basics" (R01UW0088E).

8.7.1 Boot Sequence

Figure 8-2 shows the boot sequence.

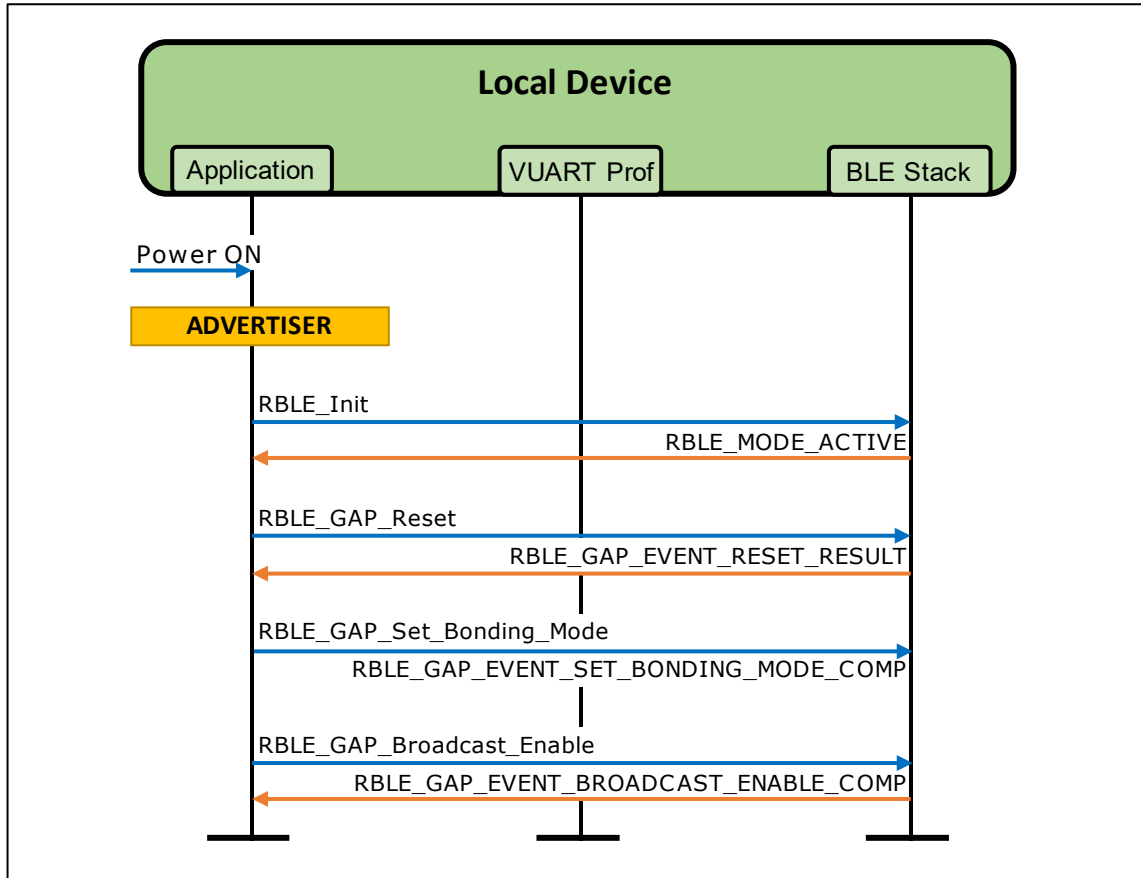


Figure 8-2: Boot Sequence

8.7.2 Connection Sequence

Figure 8-3 shows the connection sequence.

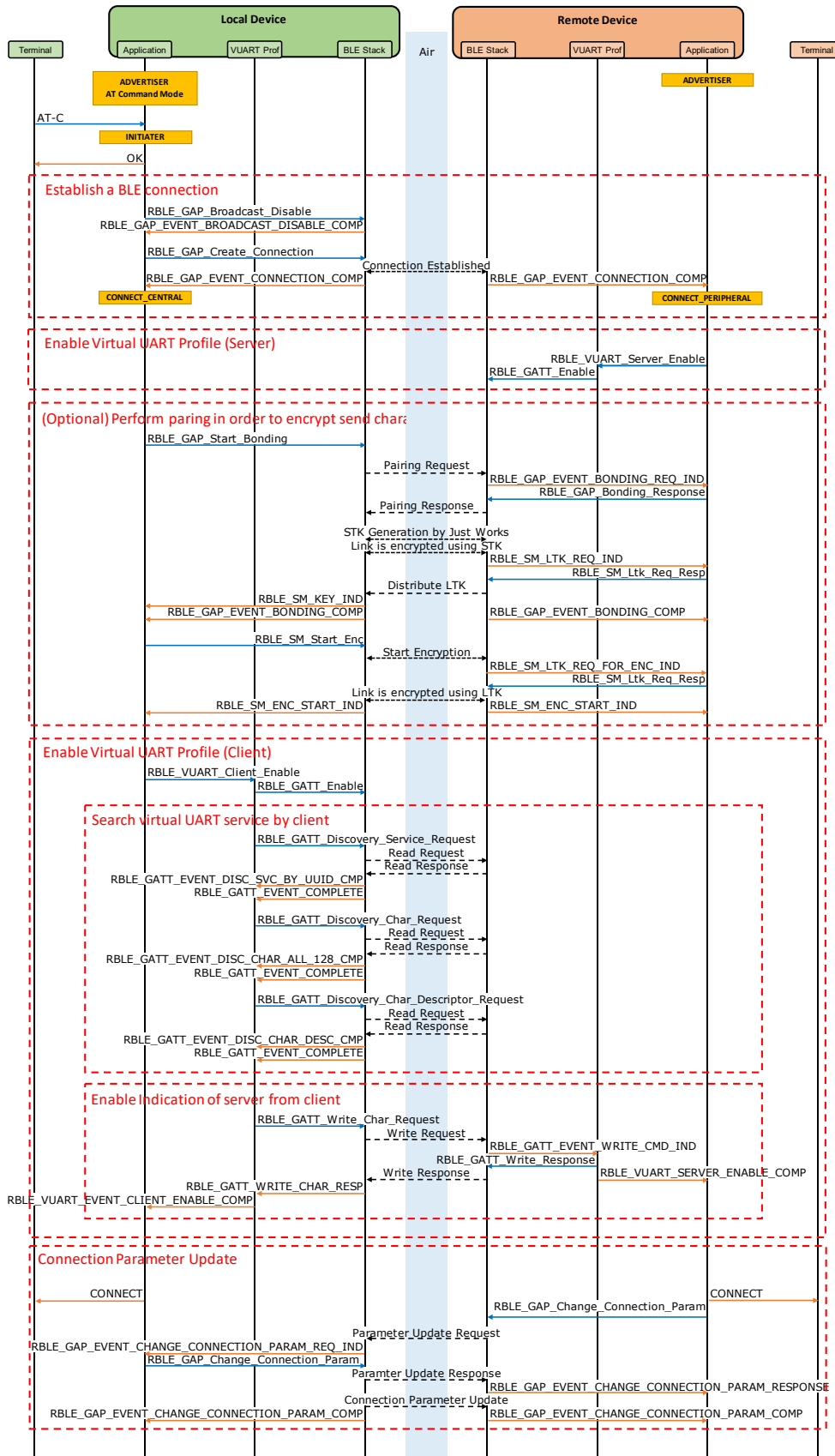


Figure 8-3: Connection sequence

8.7.3 Data Transfer Sequence (Write Request/Indication)

Figure 8-4 shows the data transfer sequence.

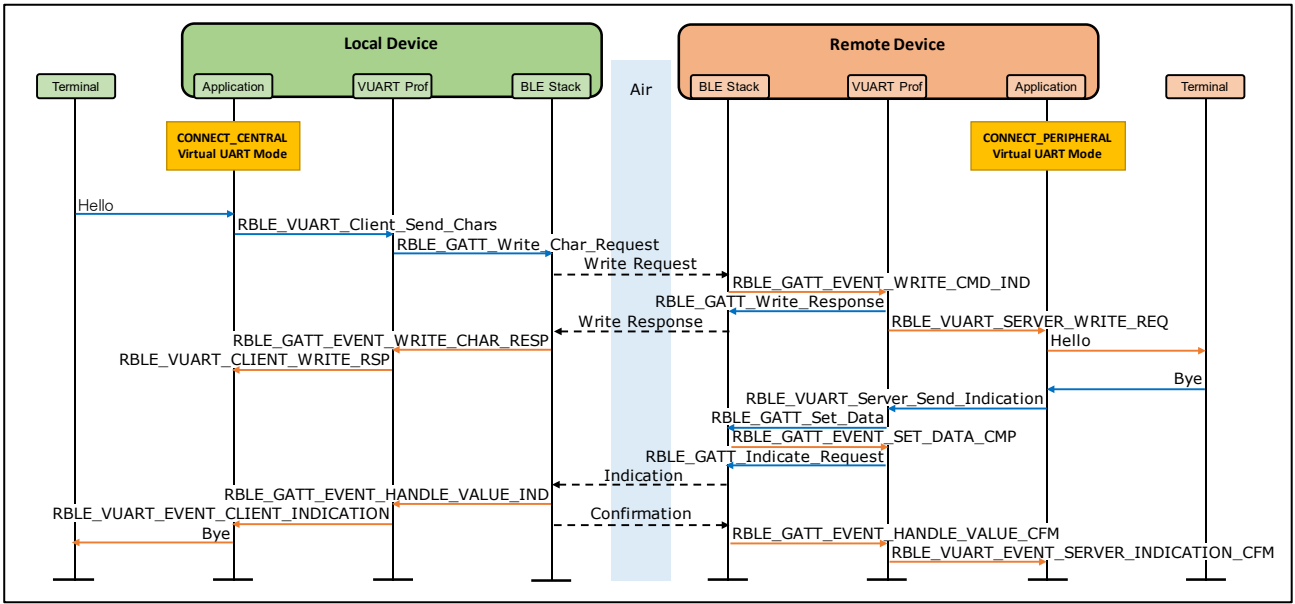


Figure 8-4: Data transfer sequence (Write Request/Indication)

8.7.4 Data Transfer Sequence (Write Command/Notification)

Figure 8-5 shows the data transfer sequence.

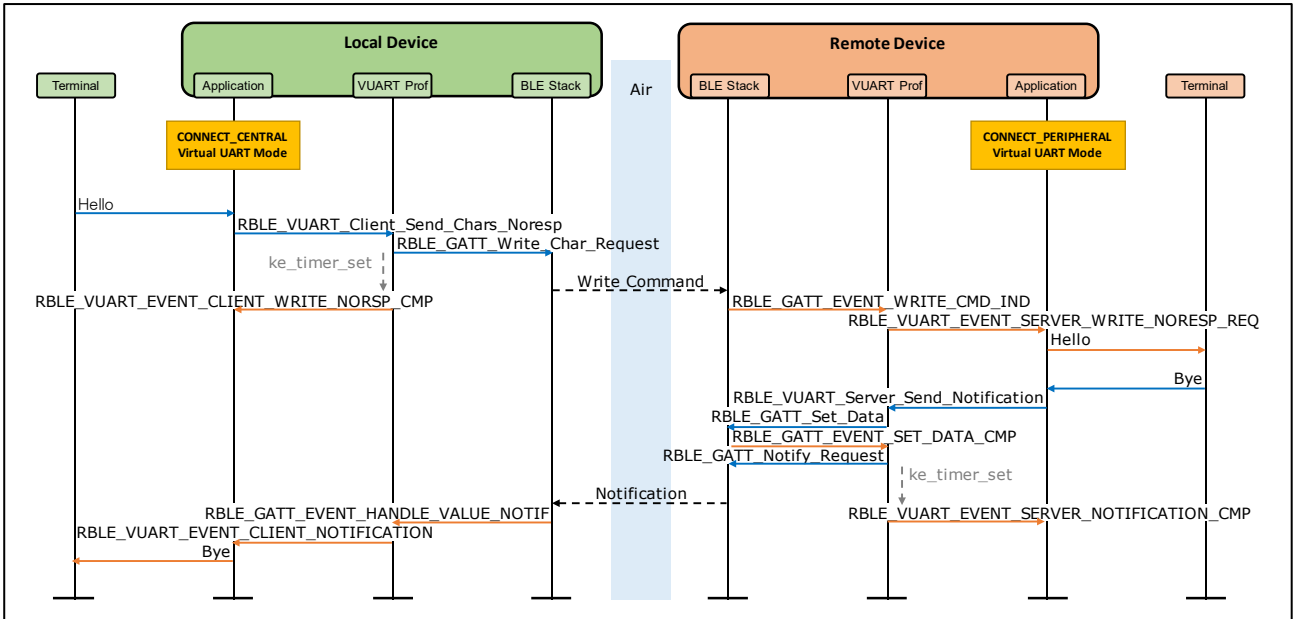


Figure 8-5: Data transfer sequence (Write Command/Notification)

8.7.5 Disconnection Sequence

Figure 8-6 shows the disconnection sequence.

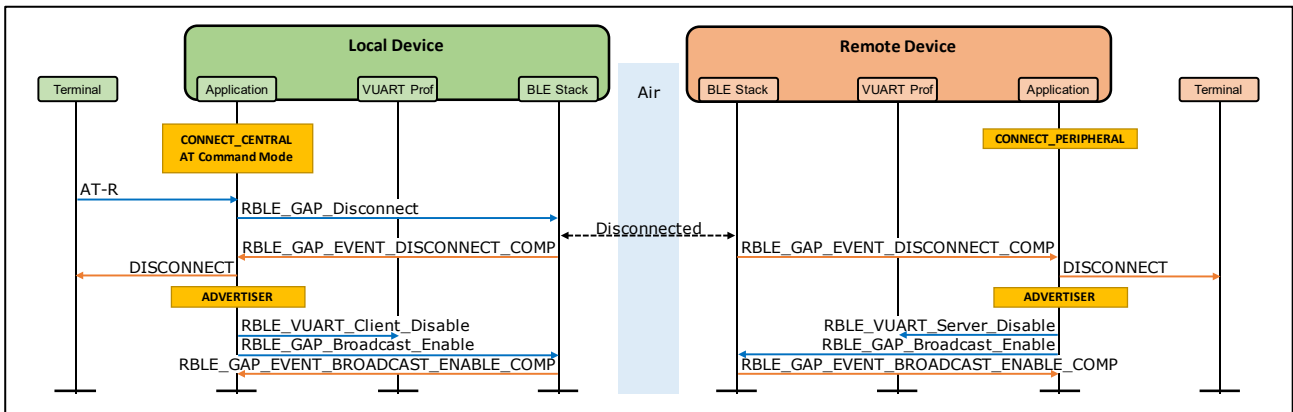


Figure 8-6: Disconnection sequence

8.8 Macro Settings

This section describes macros that set the behavior of this application.

8.8.1 Character data/Binary data transmission and reception setting

Set the type of data (character data / binary data) to transmit / received in virtual UART mode. The default setting is 1 (character data).

Note: In the case of binary data transmission / reception setting, local echo in virtual UART mode is disabled.

r_vuart_app.h, line 47-49

```
47:     #define CFG_VUART_CHAR          (1)          /* Switch between AT mode and VUART mode. */
48:                                         /* (0): Binary mode                        */
49:                                         /* (1): Character mode (default)          */
```

8.8.2 Local echo setting

Set the default setting for local echo to "disable local echo". The default setting is 0 (local echo enabled).

Note: In the case of binary data transmission / reception setting, local echo in virtual UART mode is disabled.

r_vuart_app.h, line 51-53

```
51:     #define CFG_DISABLE_LOCAL_ECHO_BY_DEFAULT  (0) /* Disable local echo                        */
52:                                         /* (0): Enable local echo (default)        */
53:                                         /* (1): Disable local echo                */
```

8.9 Others

8.9.1 Caution when implementing the program to connect to the application

As described in 8.7.2, when AT-C command is executed, the following processing are executed in order. After these steps have finished successfully the application responses with "CONNECT" message on both of the devices. If you implement the program connect to the application also follows these steps. The pairing is optional.

- Establish a BLE connection
- Perform pairing in order to encrypt send characters
- Search virtual UART service by client
- Enable Indication of server from client

8.9.2 Read processing of DIP switch that select mode in binary data transmission / reception

The DIP switch state read processing used by the application to select the mode for binary data transmission / reception is shown below.

r_vuart_app.c, line 1916-1921

```
1916:  BOOL read_dipsw1(void)
1917:  {
1918:      /* TRUE (1) : AT command mode */
1919:      /* FALSE(0) : VUART mode      */
1920:      return ((BOOL)readl_sfr(P1, 0));
1921:  }
```

8.9.3 Read processing of DIP switch that select whether to respond in data transmission / reception

The DIP switch state read processing used by the application to select whether to respond to data transmission / reception is shown below.

r_vuart_app.c, line 1931-1936

```
1931:  BOOL read_dipsw4(void)
1932:  {
1933:      /* TRUE (1) : with response.   Indication, Write          */
1934:      /* FALSE(0) : without response. Notification, Write without response */
1935:      return ((BOOL)readl_sfr(P0, 2));
1936:  }
```

8.9.4 CFG_CON macro

The CFG_CON macro sets the heap memory of the RF section of the RL78/G1D at the same time as setting the maximum number of connections. Setting CFG_CON 4 (default) is recommended.

8.9.5 Data transmission from the terminal or host microcomputer

The maximum size of data transmitted by UART from a PC terminal or host microcomputer should be 20 bytes.

Examples of RL78/G1D receiving the data transmitted from the terminal via UART and transmitting it via Bluetooth LE communication are shown in 8.9.5.1 and 8.9.5.2.

The settings of this application are baud rate 4800bps, data length 20 bytes, and connection interval 30ms.

8.9.5.1 Example of data transmission during communication with response

Figure 8-7 shows an example of Indication transmission as communication with response.

Indication communication is a communication that combines data transmission by Indication and response reception by Confirmation. Data cannot be sent with the next Indication until a Confirmation is received.

Indication sends the amount of data (2 bytes) received from the terminal in the first Bluetooth LE communication. The next Indication cannot be sent until the Confirmation is received, so the remaining data (18 bytes) received from the terminal is suspended. When Confirmation is received, the remaining data (18 bytes) will be sent by Indication at the next Bluetooth LE communication timing. When Confirmation is received, the remaining data (18 bytes) will be sent by Indication at the next Bluetooth LE communication timing.

At this time, if data of 21 bytes or more is sent, the packet size (20 bytes) of RL78 / G1D may be exceeded and invalid data may be transmitted. When sending data from the terminal, send it in 20 bytes units at intervals larger than the time of the connection interval x3 (100ms in this example).

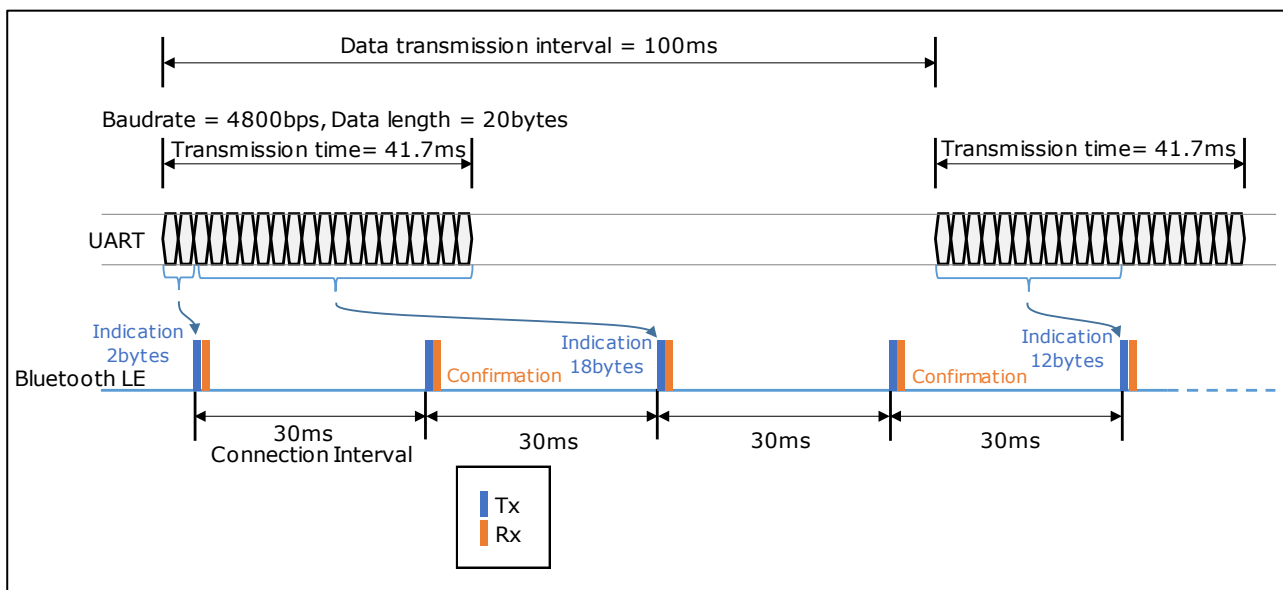


Figure 8-7: Data reception from terminal and Indication communication example

8.9.5.2 Example of data transmission during communication without response

Figure 8-8 shows an example of Notification transmission as communication without response.

Notification communication can be sent data at each timing of Bluetooth LE communication.

Notification will send the amount of data (2 bytes) received from the terminal in the first Bluetooth LE communication. If there is data (15 bytes) received from the terminal before the next Bluetooth LE communication timing, it will be sent by Notification. In this way, Notification allows you to send data at Bluetooth LE communication timing if there is data to send.

When sending data from the terminal via UART, send it in 20 bytes units as in response communication. Also, if data is sent continuously without any gaps, an error may occur in the UART. The data should be sent at an interval larger than the connection interval (50ms in this example).

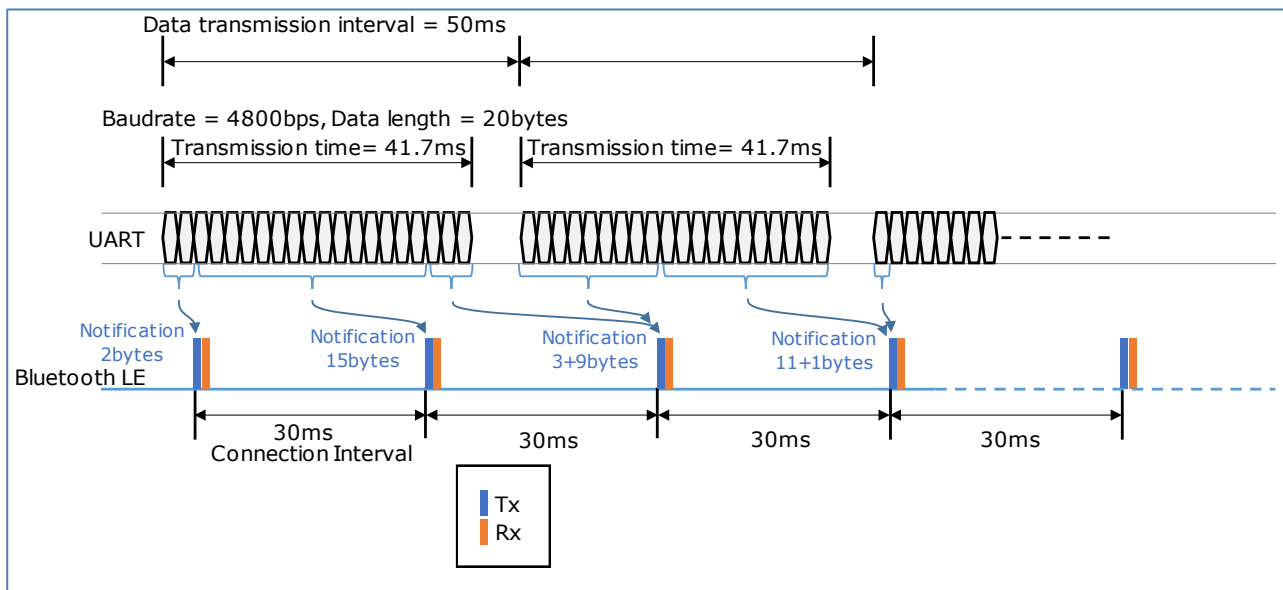


Figure 8-8: Data reception from terminal and Notification communication example

9. Appendix

9.1 ROM size, RAM size

Table 9-1 and Table 9-2 show the ROM size and RAM size when the virtual UART application is used with the BLE protocol stack V1.21.

Table 9-1: ROM size, RAM size (Character data transmission / reception)

Compiler	ROM size	RAM size
RL78 Family C Compiler Package V1 V1.09.00	127,002	11,535
Renesas CA78K0R V1.72	155,849	11,609

Table 9-2: ROM size, RAM size (Binary data transmission / reception)

Compiler	ROM size	RAM size
RL78 Family C Compiler Package V1 V1.09.00	126,684	11,535
Renesas CA78K0R V1.72	155,676	11,609

9.2 Operational Check by Using the GUI-Tool

This section describes the operation check procedure of Virtual UART by using the GUI-Tool (R01AN2469).

Figure 9-1 shows overview diagram of operational check by using the GUI-Tool. This application operates as a Virtual UART server, and the GUI-Tool operates as a Virtual UART client. It is possible to transfer characters to each other.

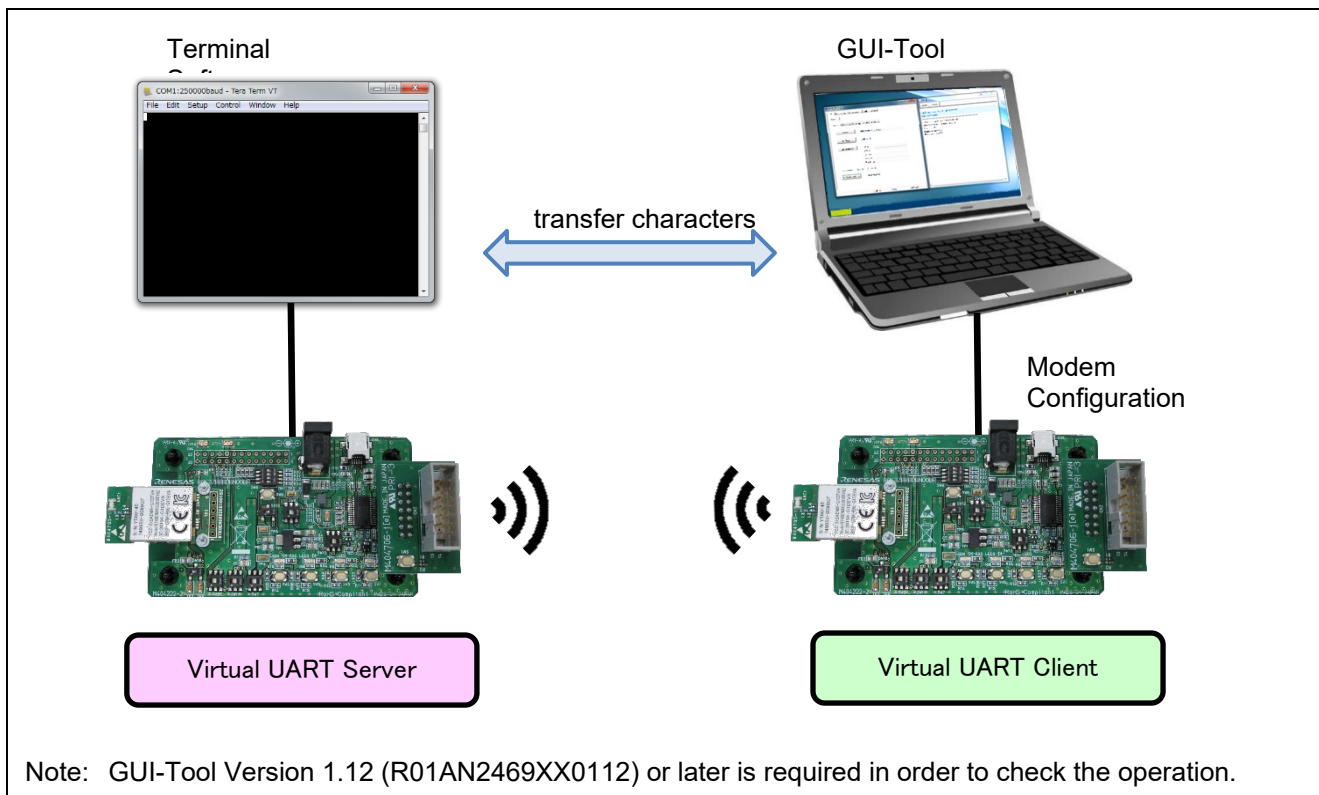


Figure 9-1: Operation check by using the GUI-Tool

Hereafter, the combination of evaluation board (Virtual UART application was written) and terminal software is mentioned as “Virtual UART Server”. And the combination of evaluation board (Modem Configuration Hex file was written) and the GUI-Tool is mentioned as “Virtual UART Client”.

9.2.1 Preparation

- Virtual UART Server

In accordance with the procedures described in the following section, write the firmware onto RL78/G1D evaluation board and then launch a terminal software on PC.

7.2 Build Procedure

7.3 Preparation for Execution Environment

This section uses character data transmission / reception (RL78_G1D_CCE(VUART_CHAR).hex).

- Virtual UART Client

Write a Modem configuration Hex file (any of the build environment) that is included in the package of BLE protocol stack onto RL78/G1D evaluation board, then launch the GUI-Tool.

Notes: 1. In order to access the service on the Virtual UART Server by using the GATT APIs, it does not matter the profile type of Hex file to be written.

2. Refer to "Bluetooth Low Energy Protocol Stack GUI Tool" (R01AN2469) "6. Utilization" about how to launch the GUI-Tool.

9.2.2 Operation

It is possible to transfer characters by operating Virtual UART Server and Virtual UART Client in the following procedure.

1. Discoverable Mode (Virtual UART Server)

Push the RESET button (SW5) on RL78/G1D evaluation board that operates as Virtual UART Server. After the reset, the virtual UART application transitions to discoverable mode automatically, and then start the Advertising.
2. Device Discovery (Virtual UART Client)

Search discoverable mode devices by operating the GUI-Tool.

 - (1) Activate [Scanning] tab of [GAP] tab.
 - (2) Select "General Discovery" in the Discovery group.
 - (3) Press [Discover] button.

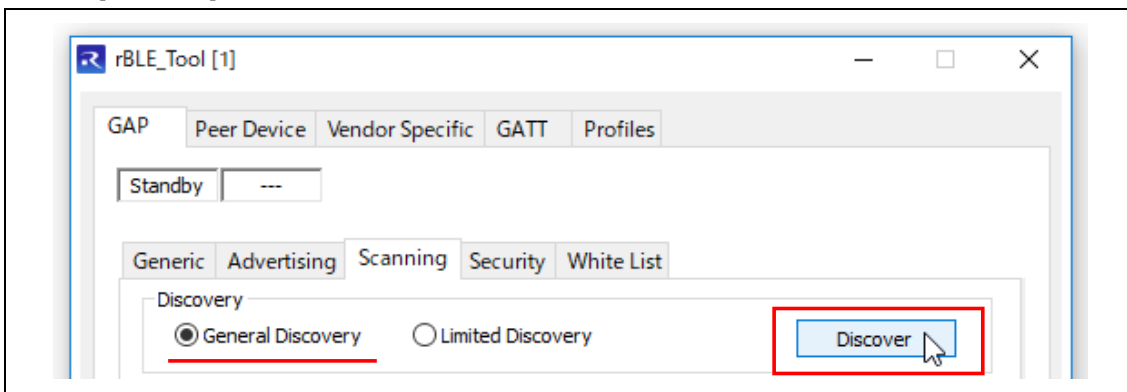


Figure 9-2: Device Discovery

- (4) Discoverable mode devices will display in the list of Received Advertising data.

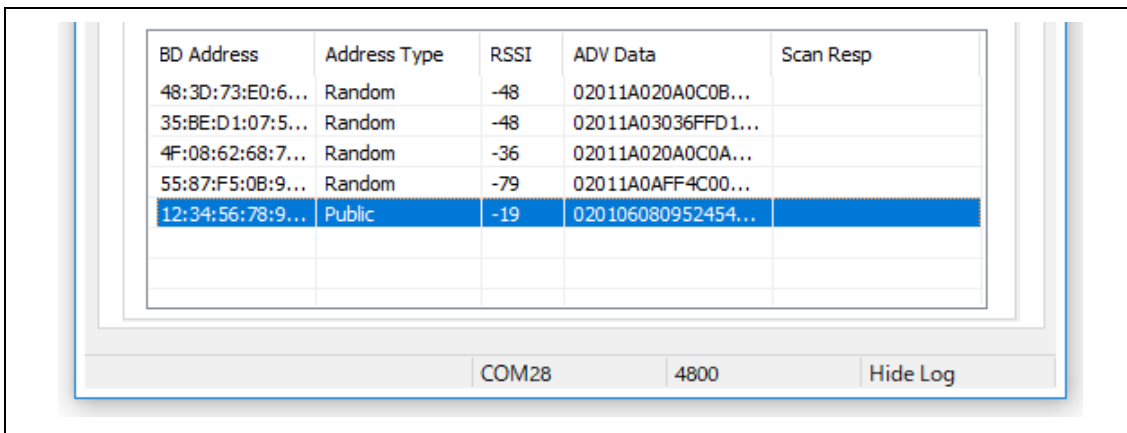


Figure 9-3: Result of Device Discovery

3. Connection (Virtual UART Client)

Initiate connection to Virtual UART Server by operating the GUI-Tool.

- (1) Confirm that the `RBLE_GAP_EVENT_DEVICE_SEARCH_COMP` event has occurred in the log dialog.

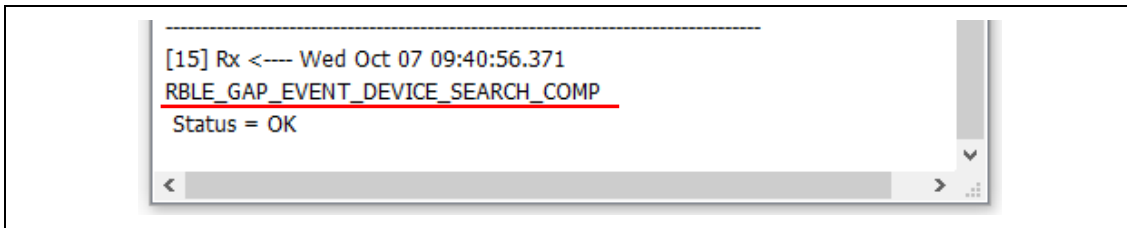


Figure 9-4: Confirmation of `RBLE_GAP_EVENT_DEVICE_SEARCH_COMP` event

- (2) In [Scanning] tab, Double-click onto the target device in the list of Received Advertising data.

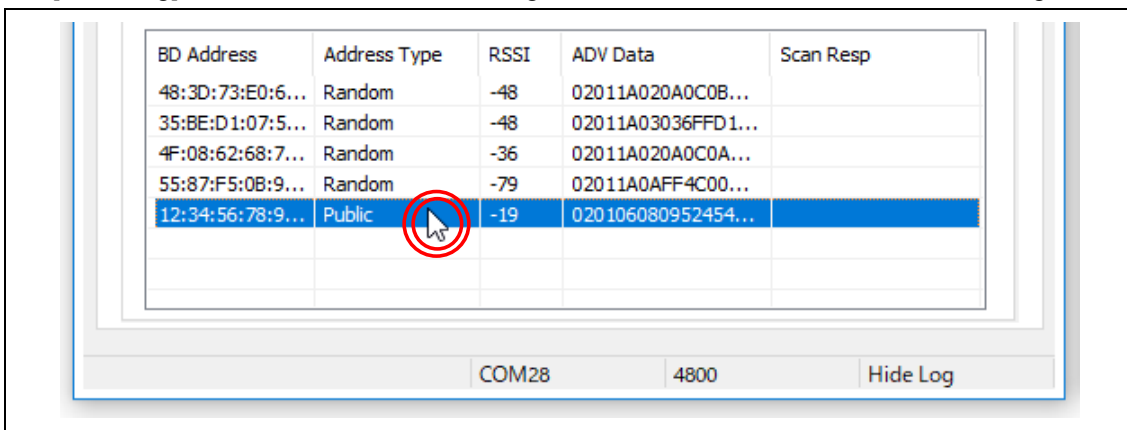


Figure 9-5: Select Device

Tips: It will be displayed the Advertising data analysis dialog by [Ctrl] key + double-clicking arbitrary row in the list of Received Advertising data.

The device which operates as Virtual UART Server contains “Renesas Virtual UART Service” to the <<Complete List of 128-bit Service UUIDs>>

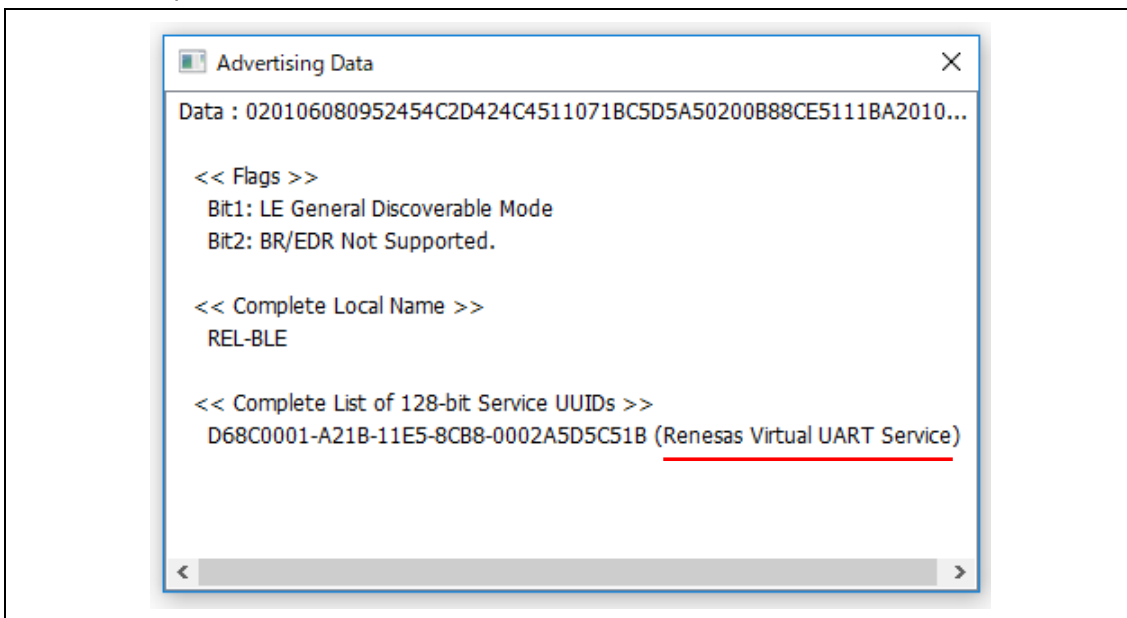


Figure 9-6: Advertising Data Analysis Dialog

- (3) Activate [Connection] tab of [Peer Device] tab.
At this time, make sure that the target device address will reflect to “Peer Addr” field in top of [Peer Device] tab.
- (4) Initiate a connection to Virtual UART Server by pressing [Connect] button.

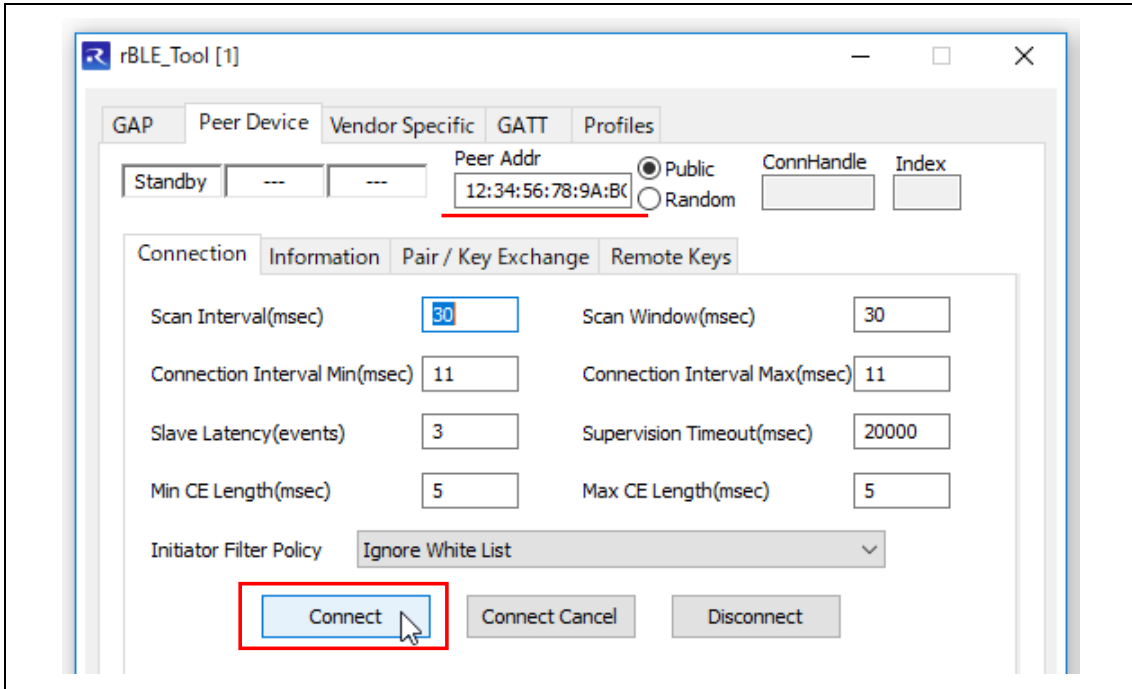


Figure 9-7: Initiate Connection

- (5) When a connection is established, the State display in top of [Peer Device] tab is changed to “Connected”.

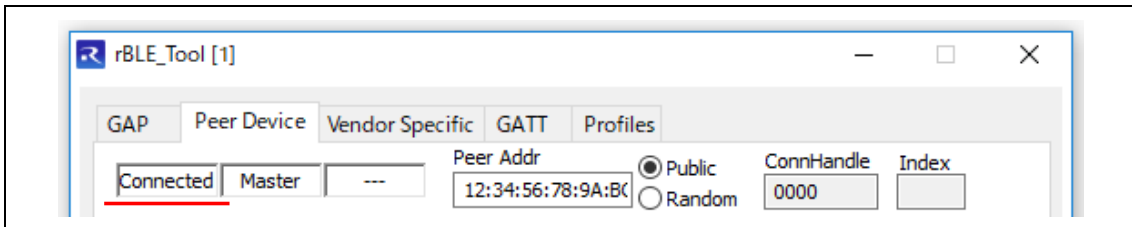


Figure 9-8: Established Connection

4. Service Discovery (Virtual UART Client)

Discover services and characteristics on Virtual UART Server by operating the GUI-Tool.

- Service Discovery

Discover all services on Virtual UART Server.

(1) Activate [Service Discovery] tab of [GATT]→[Client] tab.

(2) Select “Discover All Primary Services” in the Discovery Type drop-down list, and press [Discover] button.

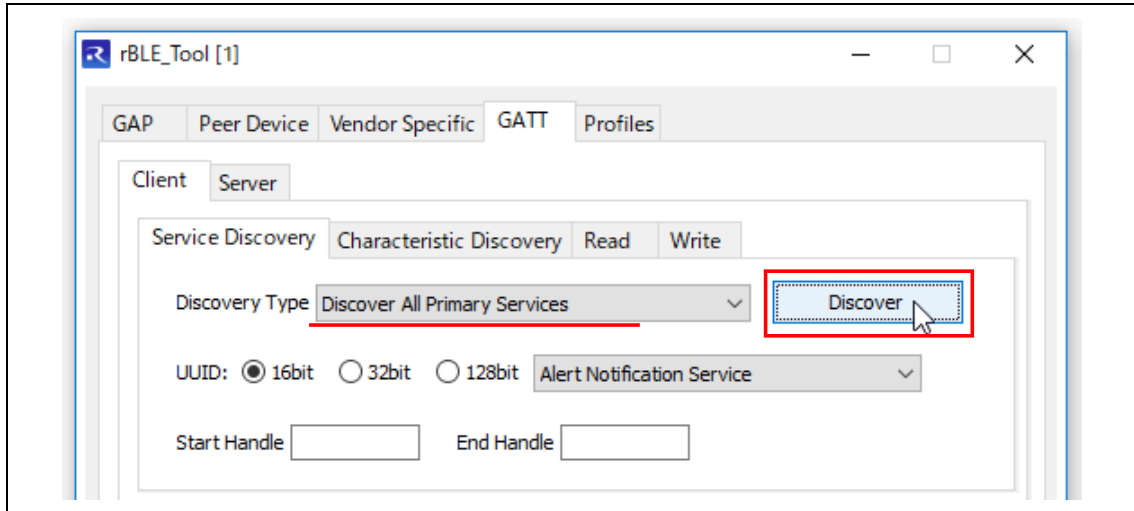


Figure 9-9: Service Discovery

(3) Acquired service information is displayed in the list of “Remote GATT Database”.

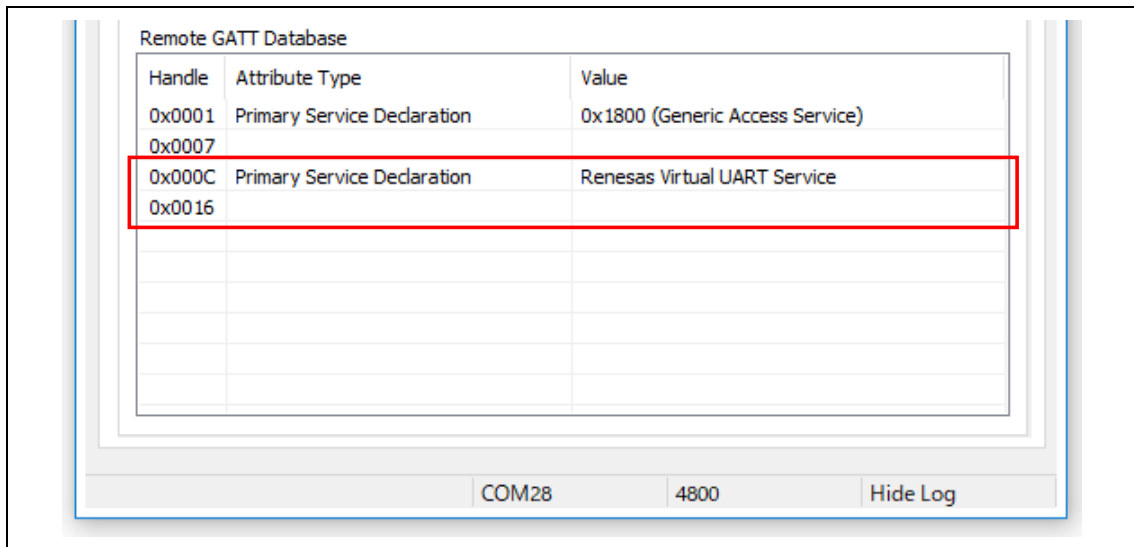


Figure 9-10: Result of Service Discovery

- Characteristic Discovery

Discover all service characteristics on Virtual UART Server.

- (1) Activate [Characteristic Discovery] tab of [GATT]→[Client] tab.
- (2) Select “Discover Characteristics of a Service” in the Discovery Type drop-down list, and press [Discover] button.

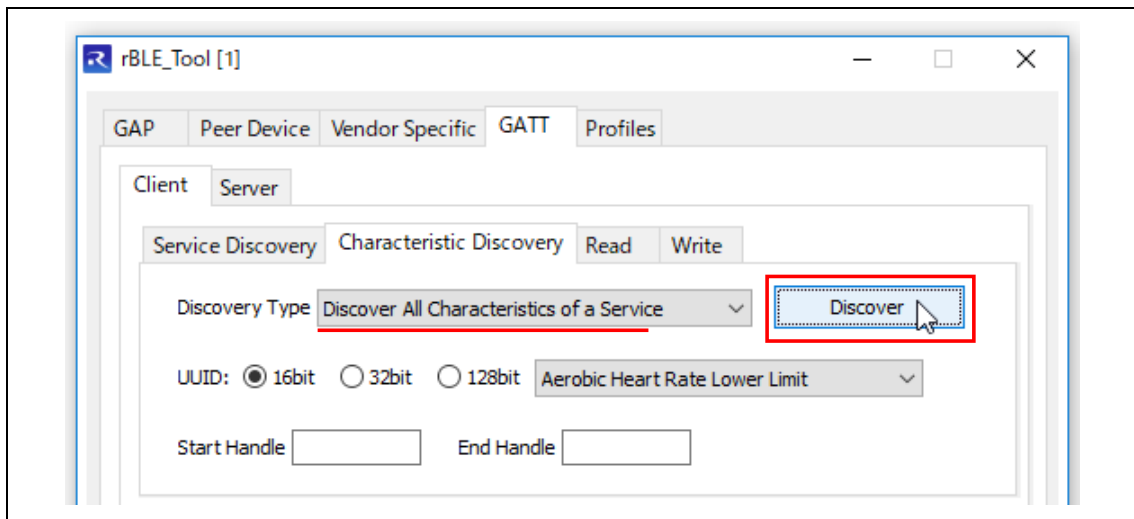


Figure 9-11: Characteristic Discovery

- (3) Acquired characteristic information is displayed in the list of “Remote GATT Database”.

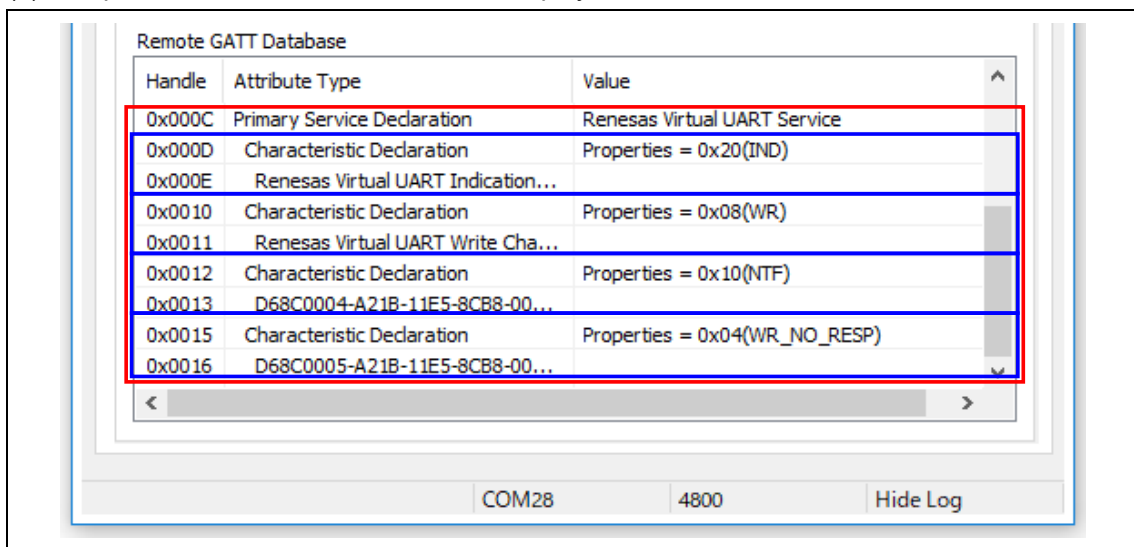


Figure 9-12: Result of Characteristic Discovery

- Characteristic Descriptor Discovery

Discover characteristic descriptors of a characteristic on Virtual UART Server.

- (1) Activate [Characteristic Discovery] tab of [GATT]→[Client] tab.
- (2) Select “Discover All Characteristic Descriptors” in the Discovery Type drop-down list, and press [Discover] button.

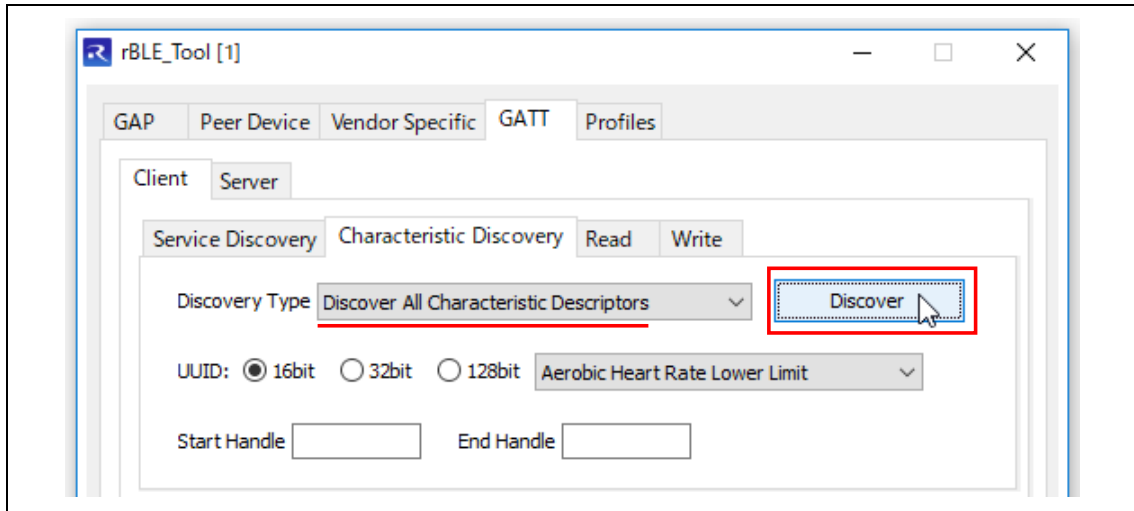


Figure 9-13: Characteristic Descriptor Discovery

- (3) Acquired characteristic descriptor information is displayed in the list of “Remote GATT Database”.

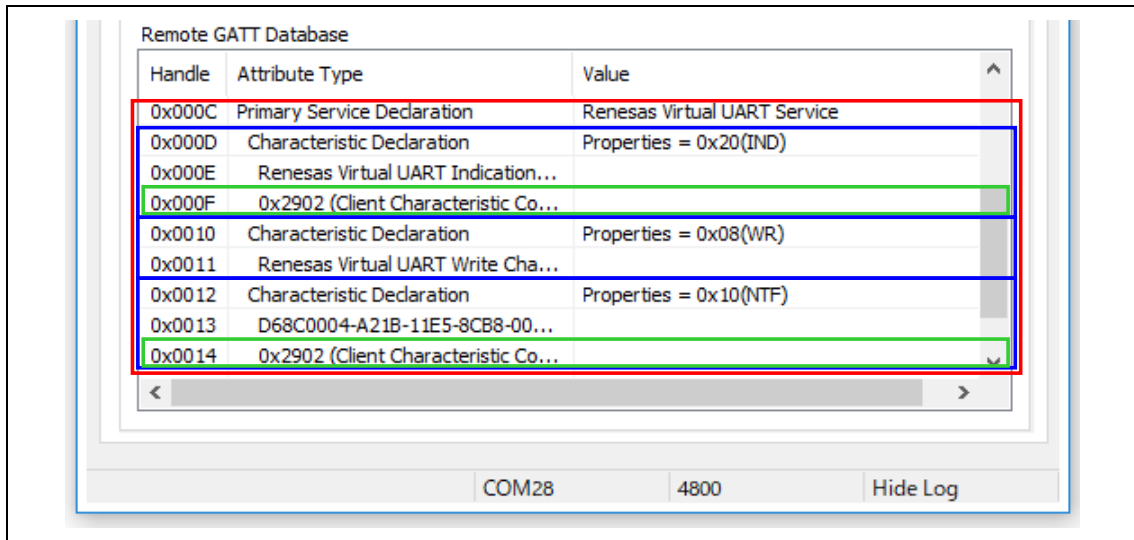


Figure 9-14: Result of Characteristic Descriptor Discovery

5. Enable Indication (Virtual UART Client)

Enable character transfer from Virtual UART Server to Virtual UART Client (Indication, Notification) by operating the GUI-Tool.

- (1) Activate [Write] tab of [GATT]→[Client] tab.
- (2) Select "Write Characteristic Descriptors" in the Write Type drop-down list.
- (3) In the list of "Remote GATT Database", double-click the Client Characteristic Configuration Descriptor within "Renesas Virtual UART Indication Characteristic".
By double-clicking, the handle value of Client Characteristic Configuration Descriptor will reflect to "Handle" field in [Write] tab.
- (4) Enter the value of "0002" (it means that "Indications enabled") in "Write Data" field.
- (5) By pressing [Write] button, write the characteristic descriptor value to Virtual UART Server.

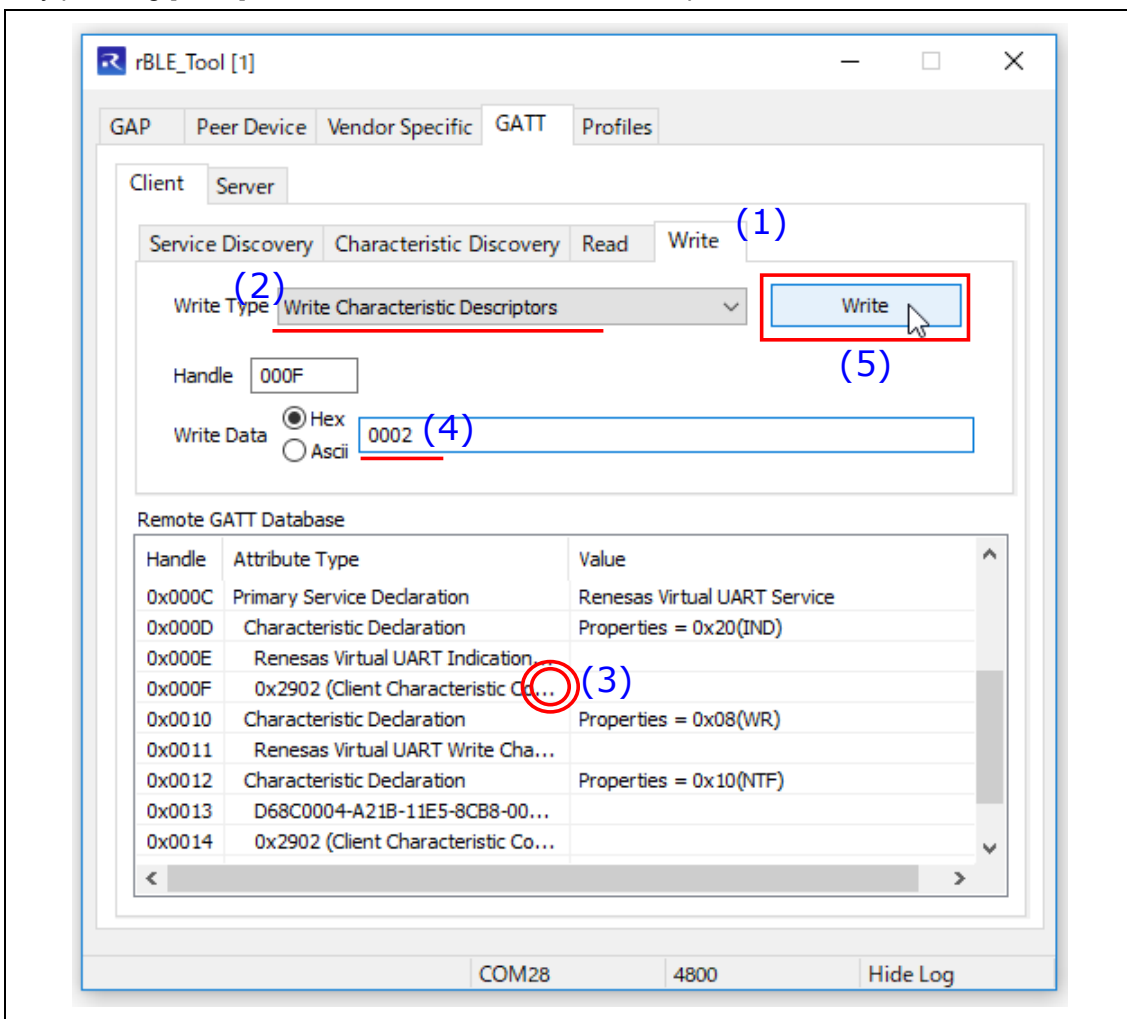


Figure 9-15: Enable Indication

- (6) In the list of "Remote GATT Database", double-click the Client Characteristic Configuration Descriptor within "D68C0004-A21B-11E5-8CB8-0002A5D5C51B" (Renesas Virtual UART Notification Characteristic).
By double-clicking, the handle value of Client Characteristic Configuration Descriptor will reflect to "Handle" field in [Write] tab.
- (7) Enter the value of "0001" (it means that "Notification enabled") in "Write Data" field.
- (8) By pressing [Write] button, write the characteristic descriptor value to Virtual UART Server.

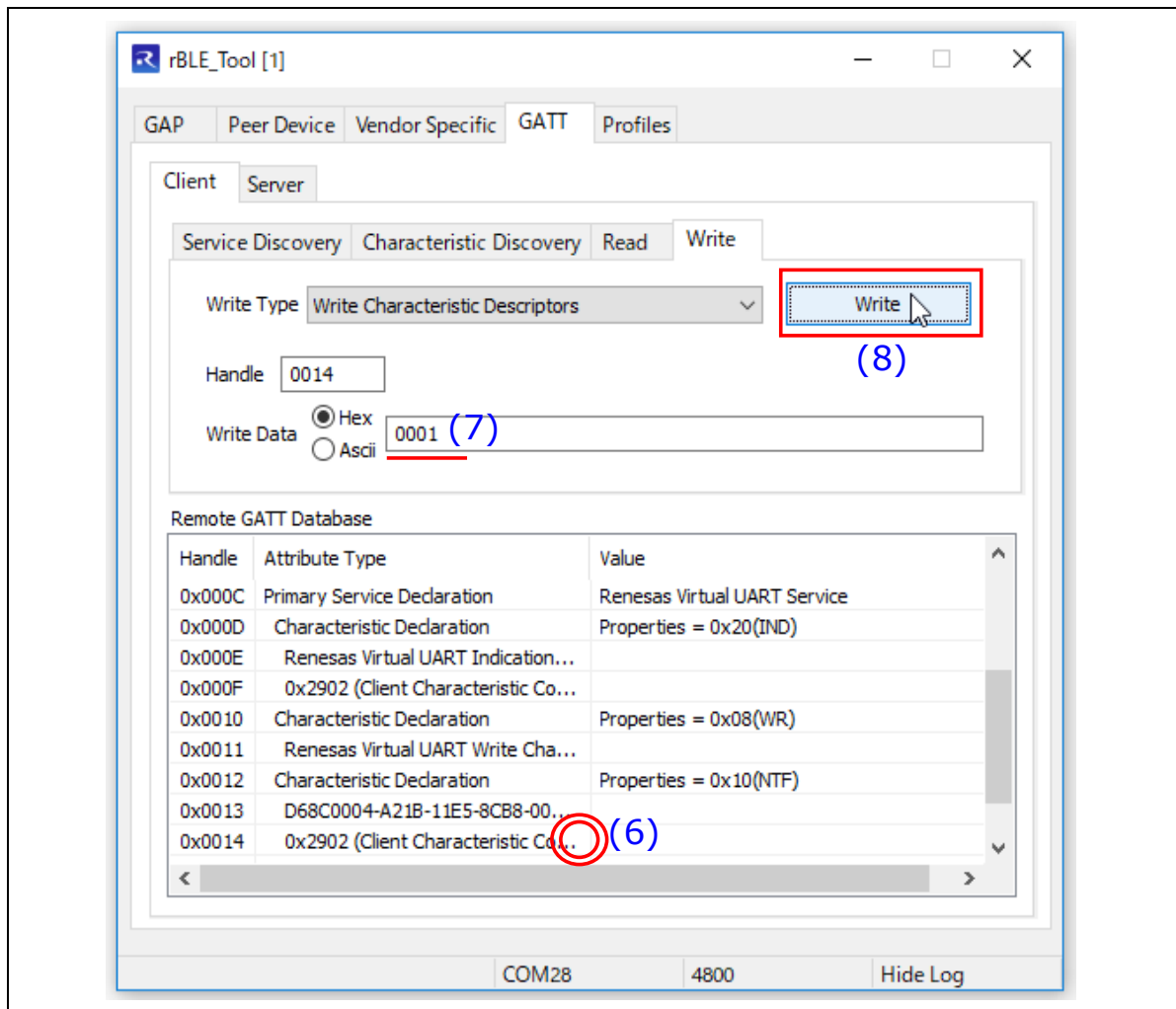


Figure 9-16: Enable Notification

- (9) The Parameter Update Request dialog is displayed. Press "Accept".

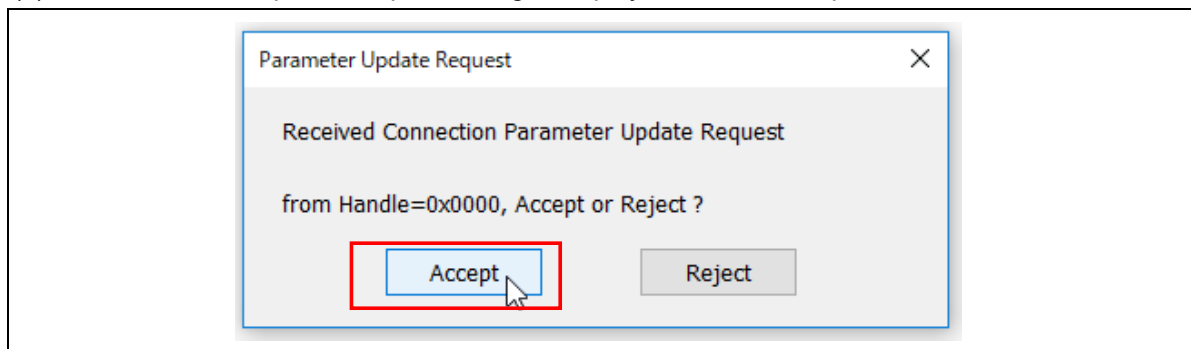


Figure 9-17: Accept Parameter Update Request

(10) Console window is displayed when the response is received from Virtual UART Server.

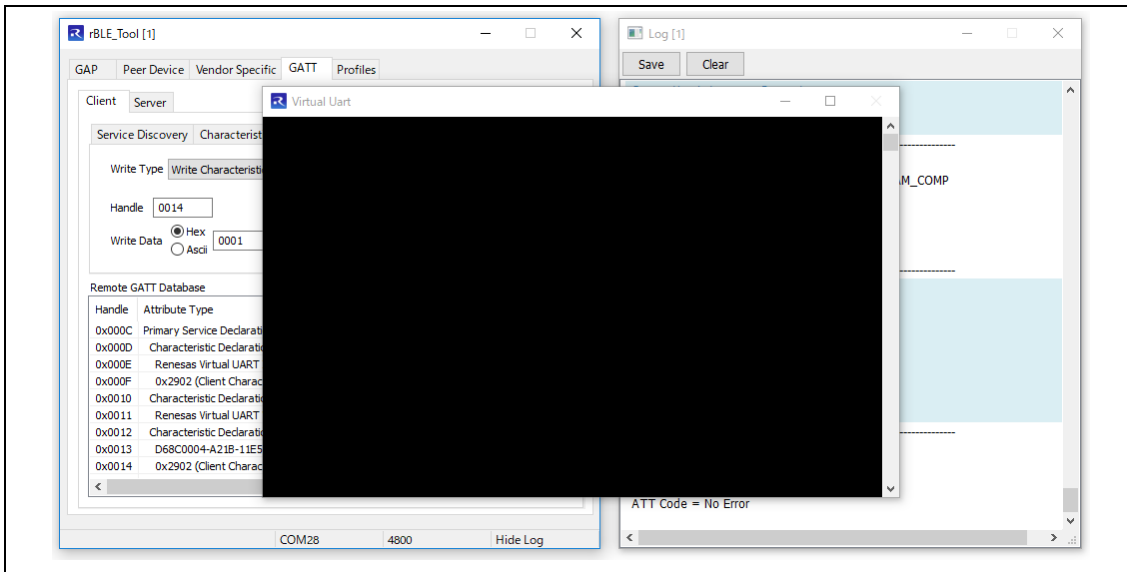


Figure 9-18: Console Window

6. Character Transfer (Virtual UART Server / Virtual UART Client)

- Character transfer from Virtual UART Server
 - (1) Input ESC key on the terminal software in order to switch the application mode to Virtual UART mode.
 - (2) Type arbitrary characters (e.g. "Hello!") on the terminal software.
 - (3) Input characters are displayed by yellow characters in the console window of Virtual UART Client.

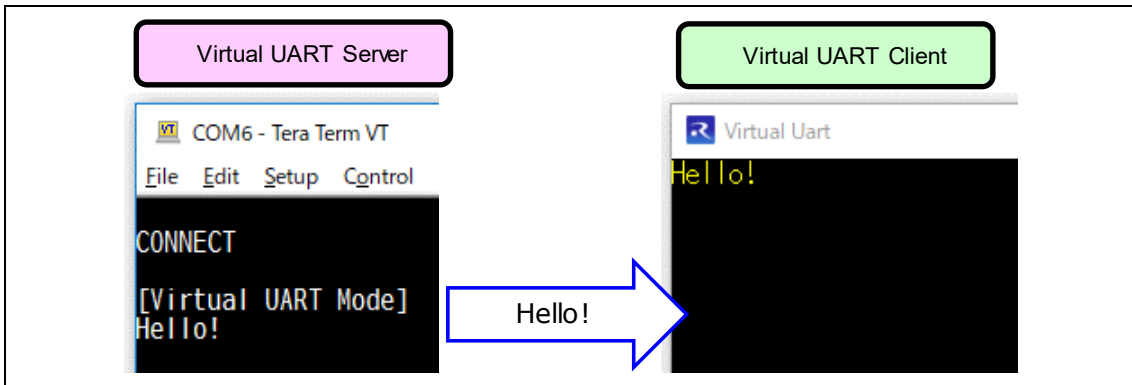


Figure 9-19: Character Transfer (Server→Client)

- Character transfer from Virtual UART Client
 - (1) Type arbitrary characters (e.g. "Bye") on the console window.
 - (2) Input characters are displayed in the terminal software of Virtual UART Server.

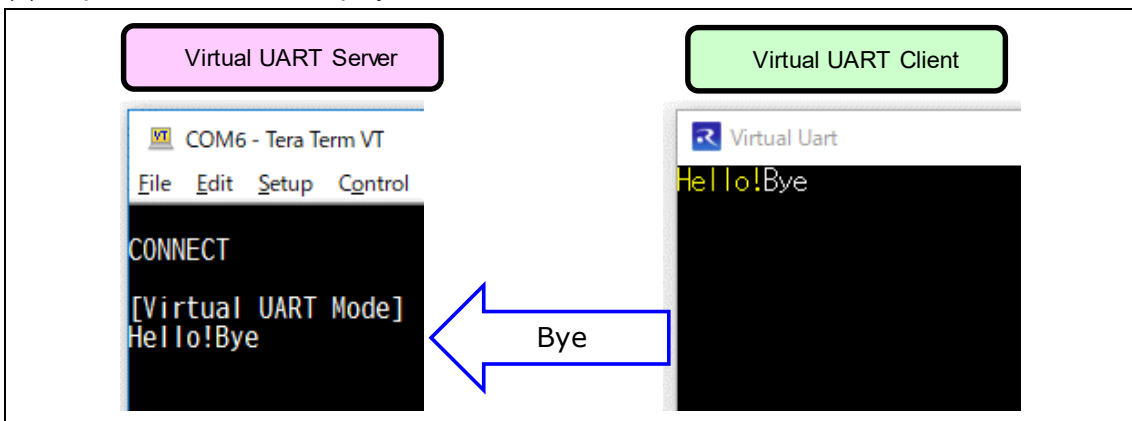


Figure 9-20: Character Transfer (Client→Server)

7. Disconnection (Virtual UART Server / Virtual UART Client)

- Disconnect from Virtual UART Server
 - (1) Input ESC key on the terminal software in order to switch the application mode to Simple AT command mode.
 - (2) Execute “AT-R” on the terminal software (Disconnect the established connection).
 - (3) When the connection is terminated, it will be displayed “DISCONNECT” on the terminal software.

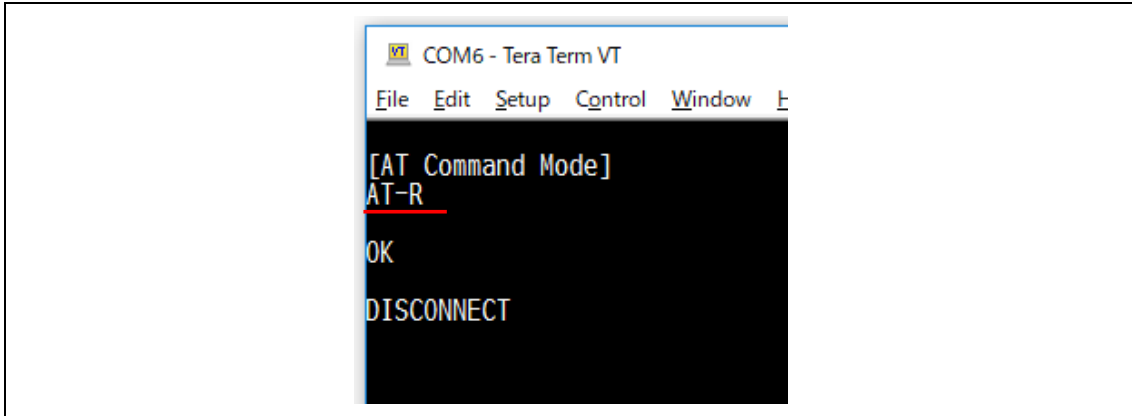


Figure 9-21: Disconnect from Virtual UART Server

- Disconnect from Virtual UART Client
 - (1) Activate [Connection] tab of [Peer Device] tab.
 - (2) Disconnect the established connection by pressing [Disconnect] button.
 - (3) When the connection is terminated, the State display in top of [Peer Device] tab is changed to “Standby”.

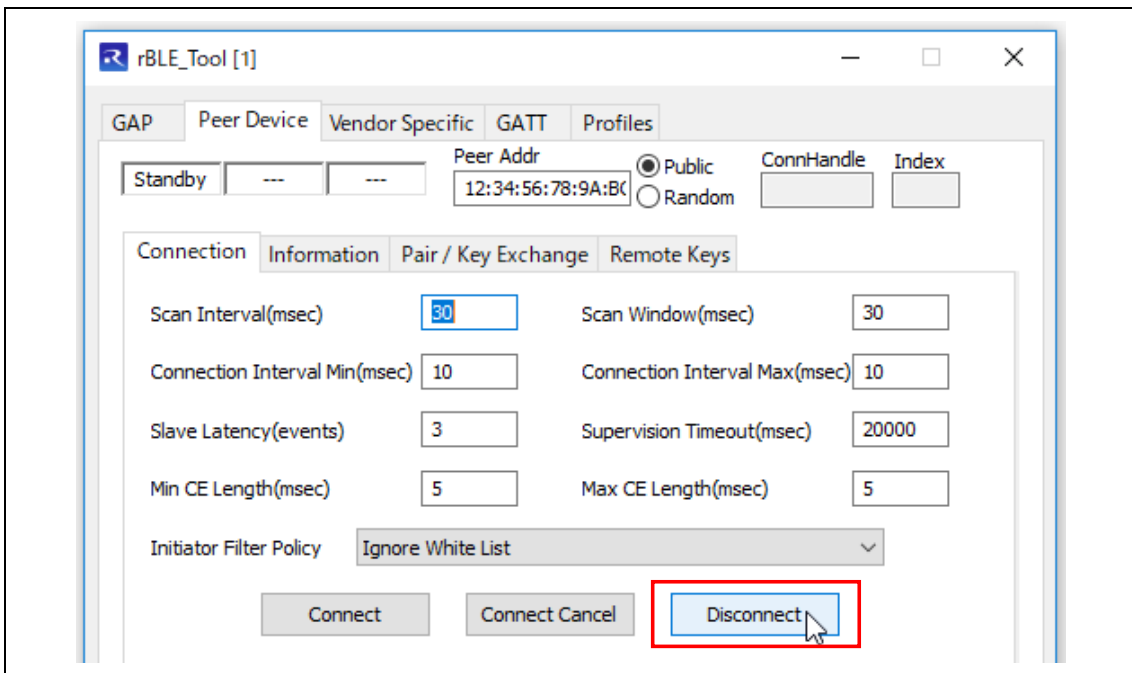


Figure 9-22: Disconnect from Virtual UART Client

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Feb 24, 2016	—	Initial issue
1.10	Oct 7, 2016	7	2.2 File Composition : Add the file composition for development environments and firmware.
		11	4 Simple AT Command Mode : Add commands AT-CI=<con_intv>, AT-CI?, ATE0, ATE1.
		22	7 Build and Operational Check : Add Environment setup and build procedure descriptions for development environments.
		26	7.4 Usage Example: Add the procedure to set a device address.
		37	8.3 Connection : Change Connection Interval Default setting value.
		49	8.7.2 Connection Sequence : Add the procedure for Connection Interval change.
		57	9.2 Operational Check by Using the GUI-Tool : Newly added.
1.11	Nov 22, 2016	-	Revision change (No document update).
1.12	Oct 20, 2017	24	7.2.3 BLE Protocol Stack / EEPROM : Update EEPROM emulation library download path.
1.13	Jul 12, 2019	-	Fix the AT-AS command. (No document update)
1.20	Oct 23, 2020	-	This is a revised version that supports sending and receiving binary data and non-response communication (write command, notification).
		5	1. Overview : Added an overview of sending and receiving binary data and non-response communication.
		7	2.2 File Composition : Added HEX file for sending and receiving binary data. Added macro file of Tera Term.
		9	3. Application Mode : Added function explanations for sending and receiving binary data and non-response communication.
		17	5. Virtual UART Mode : Added explanation of sending and receiving binary data and communication without response.
		21	6.2 Changes of Advertising Interval : Posted the code to change the advertising interval.
		22	7. Build and Operational Check : Updated build environment. Added build procedure and usage example for sending and receiving binary data and non-response communication.
35	8. Implementation Details : Added profiles, functions, and events for sending and receiving binary data and non-response communication.		
56	9. Appendix : Updated ROM size and RAM size. Updated GUI tool operation method by supporting non-response communication.		
1.20	Jan 31, 2022	-	Fixed due to the end of IAR support in Bluetooth Low Energy Protocol Stack.

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity.

Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).

7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
 2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
 3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
 4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
 5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
 - "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
 - "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
- Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
 7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
 8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
 9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
 10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
 11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
 12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/.