

# Bluetooth® Low Energy Protocol Stack

## Fast Prototyping Board BLE & LoRaWAN® Application

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### Introduction

Sensor devices that support LoRaWAN® communication are required to be easily settable from smartphones using Bluetooth® Low Energy. For example, information such as encryption key and server ID required for LoRaWAN communication, management number and installation location required for sensor device application, etc.

The following are application examples of combining sensor devices that support LoRaWAN communication with Bluetooth Low Energy.

- Update the device firmware.
- Check current sensor data directly from the device.
- The device diagnostics.
- Manage the device position with a smartphone in cooperation with BLE.
- Manage the Application EUI/Key of device with a smartphone in cooperation with BLE.

This application note explains how to implement IoT wireless communication using the "RL78/G14 Fast Prototyping Board" as the main MCU, the "RL78/G1D BLE Module Expansion Board" for BLE communication, the "LoRaWAN stack sample application board" for LoRaWAN communication, and the sensor "TE Connectivity PMOD\_MS8607". Set the parameters necessary for LoRaWAN communication with BLE communication, and send sensor data to LoRaWAN Gateway with LoRaWAN communication.

### Target Device

RL78/G14 Fast Prototyping Board (Parts Number: RTK5RLG140C00000BJ)

RL78/G1D BLE Module Expansion Board (Parts Number: RTKYRLG1D0B00000BJ)

LoRaWAN stack sample application board

**Related Documents**

| Document Name                                      | Document No. |
|--|--------------|
| Bluetooth Low Energy Protocol Stack                |              |
| User's Manual                                      | R01UW0095E   |
| API Reference Manual: Basic                        | R01UW0088E   |
| Application Note: Sample Program                   | R01AN1375E   |
| Application Note: rBLE Command Specification       | R01AN1376E   |
| RL78/G1D   |              |
| User's Manual: Hardware                            | R01UH0515E   |
| RL78/G1D Module                                    |              |
| User's Manual: Hardware                            | R02UH0004E   |
| User's Manual: Firmware                            | R01UW0160E   |
| Application Note: Module Control Software          | R01AN3362E   |
| LoRaWAN  |              |
| LoRaWAN Stack Sample Application Command Reference | R11AN0231E   |
| LoRaWAN IoT Demo LPWA IoT Solution with Cloud      | R11AN0412E   |
| RL78/G14   |              |
| User's Manual: Hardware                            | R01UH0186E   |

**Contents**

|   |    |
|---|----|
| 1. Overview .....   | 5  |
| 2. Development Environment.....                                     | 6  |
| 2.1 Hardware Environment.....                                       | 6  |
| 2.2 Software Environment.....                                       | 6  |
| 3. Application Configuration.....                                   | 7  |
| 3.1 System Configuration .....                                      | 7  |
| 3.1.1 FPB Connection PIN .....                                      | 8  |
| 3.2 Software Configuration .....                                    | 10 |
| 3.2.1 BLE module Configuration .....                                | 10 |
| 3.2.2 LoRaWAN module Configuration .....                            | 12 |
| 3.3 Peripheral Configuration.....                                   | 13 |
| 3.4 File Configuration .....  | 14 |
| 4. How to Build .....   | 17 |
| 4.1 CS+ for CC .....  | 17 |
| 4.2 e2 studio .....   | 17 |
| 5. Execute Application .....  | 18 |
| 5.1 Install GATTBrowser .....                                       | 18 |
| 5.2 Prepare LORIoT LoRaWAN Network Server .....                     | 18 |
| 5.3 Execution Environment .....                                     | 18 |
| 5.4 Execution Process.....  | 19 |
| 5.4.1 LoRaWAN module parameters setting by Android device.....      | 23 |
| 5.4.2 LoRaWAN module parameters setting by iOS device .....         | 26 |
| 5.4.3 LoRaWAN Network Server.....                                   | 29 |
| 5.4.3.1 Check Sensor Data .....                                     | 29 |
| 5.4.3.2 LoRaWAN Gateway Communication End Command Transmitting..... | 29 |
| 6. Processing Flow .....  | 31 |
| 6.1 main loop .....   | 31 |
| 6.2 BLE module Communication Flow .....                             | 32 |
| 6.2.1 Connection with Smartphone .....                              | 32 |
| 6.2.2 Disconnection with Smartphone.....                            | 33 |
| 6.3 LoRaWAN module Communication Flow .....                         | 34 |
| 6.4 LoRaWAN module Commands .....                                   | 35 |
| 6.4.1 Parameter Setting AT Commands .....                           | 35 |
| 6.4.1.1 AT Command Format.....                                      | 35 |
| 6.4.1.2 AT Command Result Code Format.....                          | 36 |
| 6.4.1.3 AT Command Parameter Flag .....                             | 37 |
| 6.4.2 LoRaWAN Gateway End of Communication Command.....             | 37 |

|       |  |    |
|-------|--|----|
| 6.5   | BLE Modem Structure - UART 2-wire with branch connection ..... | 38 |
| 6.5.1 | Transmission Process .....                                     | 38 |
| 6.5.2 | Reception Process .....  | 39 |
| 7.    | BLE Sequence Chart .....                                       | 40 |
| 7.1   | Main sequence chart .....                                      | 40 |
| 7.2   | Step1. rBLE Initialize sequence .....                          | 41 |
| 7.3   | Step2. GAP Initialize sequence .....                           | 41 |
| 7.4   | Step3. Broadcast sequence .....                                | 42 |
| 7.5   | Step4. Connection sequence .....                               | 42 |
| 7.6   | Step5. Profile Enable sequence .....                           | 43 |
| 7.7   | Step6. Remote Device Check sequence .....                      | 43 |
| 7.8   | Step7. Pairing sequence .....                                  | 44 |
| 7.9   | Step8. Start Encryption sequence .....                         | 46 |
| 7.10  | Step9. Profile Communication sequence .....                    | 46 |
| 7.11  | Step10. Disconnection sequence .....                           | 47 |
| 8.    | LoRaWAN module AT Command Sequence Chart .....                 | 48 |
| 8.1   | Main Sequence .....  | 48 |
| 8.2   | Step1. Start program .....                                     | 48 |
| 8.3   | Step2. Set LoRaWAN parameters .....                            | 49 |
| 8.4   | Step3. Send sensor data .....                                  | 50 |
| 9.    | Appendix .....   | 51 |
| 9.1   | ROM size, RAM size .....                                       | 51 |
| 9.2   | References .....   | 51 |
|       | Revision History .....   | 52 |

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## 1. Overview

Sensor devices that support LoRaWAN® communication are required to be easily settable from smartphones using Bluetooth® Low Energy. For example, information such as encryption key and server ID required for LoRaWAN communication, management number and installation location required for sensor device application, etc.

The following are application examples of combining sensor devices that support LoRaWAN communication with Bluetooth Low Energy.

- Update the device firmware.
- Check current sensor data directly from the device.
- The device diagnostics.
- Manage the device position with a smartphone in cooperation with BLE.
- Manage the Application EUI/Key of device with a smartphone in cooperation with BLE.

This application note explains how to implement IoT wireless communication using the "RL78/G14 Fast Prototyping Board" as the main MCU, the "RL78/G1D BLE Module Expansion Board" for BLE communication, the "LoRaWAN stack sample application board" for LoRaWAN communication, and the sensor "TE Connectivity PMOD\_MS8607". Set the parameters necessary for LoRaWAN communication with BLE communication, and send sensor data to LoRaWAN Gateway with LoRaWAN communication.

RL78/G1D BLE Module Expansion Board and LoRaWAN stack sample application board are connected to the two Pmod interfaces of RL78/G14 Fast Prototyping Board, and TE Connectivity PMOD\_MS8607 is connected to the MCU header. Set the parameters required for LoRaWAN communication via BLE communication with a smartphone, and send sensor data to LoRaWAN Gateway via LoRaWAN communication. The sensor data sent to LoRaWAN Gateway is confirmed by LoRaWAN Network Server.

- The RL78/G14 Fast Prototyping Board is an evaluation board specializing in prototype development of applications incorporating the RL78/G14 microcomputer. Built-in emulator circuit equivalent to E2 Emulator Lite enables programming/debugging without additional tools. Hereinafter referred to as "FPB".
- The RL78/G1D BLE Module Expansion Board is a Pmod interface evaluation board equipped with the RL78/G1D module (RY7011). Firmware for checking operation is written and can be controlled from the Host MCU program with BLE protocol stack/modem configuration. Hereinafter referred to as "BLE module".
- LoRaWAN stack sample application board is a Pmod interface evaluation board in which LoRaWAN stack and Sample application are written. It can be controlled by AT command from Host MCU program. Hereinafter referred to as "LoRaWAN module".
- TE Connectivity PMOD\_MS8607 is a Pmod interface evaluation board that can measure temperature, pressure and relative humidity. Hereinafter referred to as "Sensor module".

## 2. Development Environment

Describes the build environment and the development environment used to operation confirmation.

### 2.1 Hardware Environment

#### — Host

- PC/AT™ compatible computer
- Processor: 1GHz or faster (with support for hyper threading and multicore CPUs)
- Main Memory: We recommend 2GB or more.
- Display: Graphics resolution should be at least 1024 x 768, and the mode should display at least 65,536 colors.
- Interface: USB2.0 (connection with Fast Prototyping Board)

#### — Development Board

- RL78/G14 Fast Prototyping Board (RTK5RLG140C00000BJ)
- RL78/G1D BLE Module Expansion Board (RTKYRLG1D0B00000BJ)
- LoRaWAN stack sample application board
- TE Connectivity PMOD\_MS8607 (DPP901Z000) (pressure, humidity, temperature)

#### — Smartphone

- Android device or iOS device

#### — LoRaWAN Communication Device

- Gateway: kerlink Wirnet™ iFemtoCell 923
- Network Server: LORIoT LoRaWAN Network Server  
(Browse from the host machine's web browser)

### 2.2 Software Environment

#### — OS

- Windows7 or later

#### — Web Browser

Use one of the following web browser.

- Microsoft Edge
- Google Chrome

#### — Integrated Development Environment/Compiler

Use one of the following integration environment and compiler combinations.

- CS+ for CC V8.02.00/CC-RL V1.08.00
- e<sup>2</sup> studio V7.60/CC-RL V1.08.00

### 3. Application Configuration

#### 3.1 System Configuration

The system configuration figure used in this application note is shown in "Figure 3-1 System Configuration". Connect the RL78/G1D BLE Module Expansion Board for BLE communication and the LoRaWAN stack sample application board for LoRaWAN communication to Pmod I/F of the FPB. Connect the TE Connectivity PMOD\_MS8607 to IICA0 pin of MCU header J1.

The FPB applications are mainly composed of programs with the following roles.

- The Host MCU program of the BLE protocol stack modem configuration <sup>Note</sup> that controls the BLE module.
- The program to control the LoRaWAN module with AT command.
- The program to read the data measured by controlling the Sensor module.

The FPB application controls the BLE module, communicates with the smartphone, and receives the LoRaWAN module configuration parameters. The FPB application sets the received parameters in the LoRaWAN module using AT commands, and sends the data measured by the Sensor module from the LoRaWAN module to the LoRaWAN Gateway. It can check the sensor data of the Sensor module from the LoRaWAN Gateway to the LoRaWAN Network Server using a PC web browser.

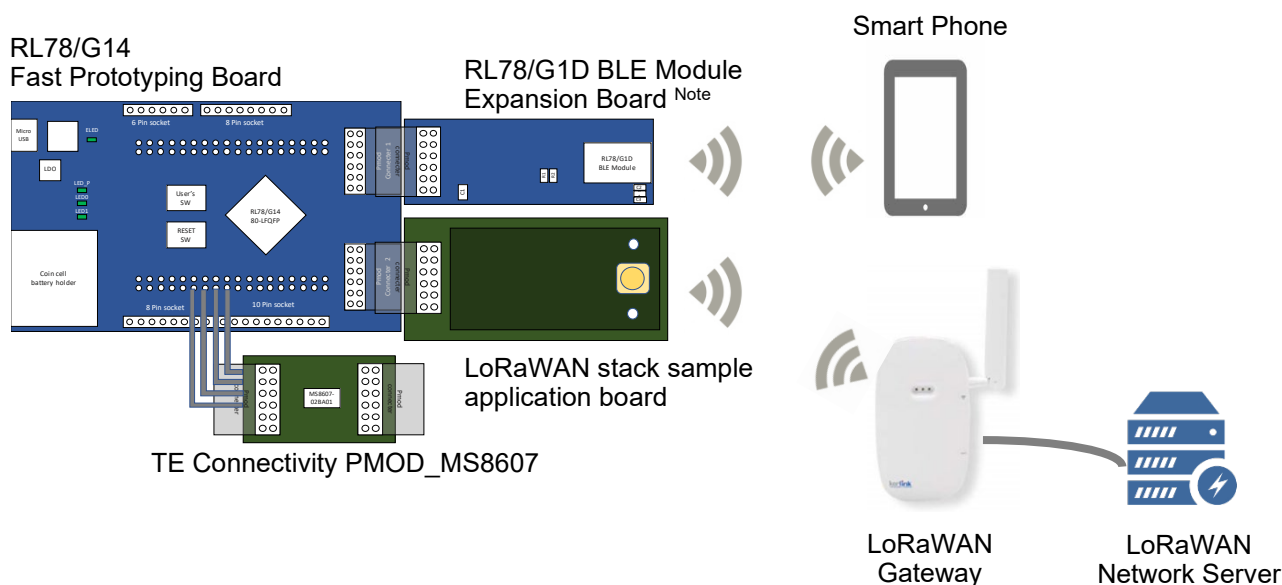


Figure 3-1 System Configuration

Note: The FPB and the BLE module use the BLE protocol stack modem configuration, and communication method is the UART 2-wire branch connection method. Refer to "3.2.1 BLE module Configuration" for Modem configuration and "6.5 BLE Modem Structure - UART 2-wire with branch connection" for UART 2-wire branch connection method.

### 3.1.1 FPB Connection PIN

The Pmod interface connector pin assignments and the MCU header J1 pin assignments shown in "Figure 3-1 System Configuration" are shown. The functions used for each pin are shown in blue.

#### (1) PMOD1

Table 3-1 Pin Assignment of PMOD1

| RL78/G14 Fast Prototyping Board                  |               | Pmod<br>Pin<br>Number | RL78/G1D BLE Module Expansion Board |   |
|--|---------------|-----------------------|-------------------------------------|---|
| Function Name                                    | Pin<br>Number |                       | Pin<br>Number                       | Function Name                             |
| P74 <sup>Note</sup> /KR4/INTP8                   | 33            | 1                     | 2                                   | P30/INTP3/RTC1HZ                          |
| P51/INTP2/SO00/TxD0/TOOLTxD/TRGIOB               | 42            | 2                     | 8                                   | P11/SI00/RxD0/TOOLRxD/SDA00/(TI06)/(TO06) |
| P50/INTP1/SI00/RxD0/TOOLRxD/SDA00/TRGIOA/(TRJO0) | 41            | 3                     | 7                                   | P12/SO00/TxD0/TOOLTxD/(TI05)/(TO05)       |
| P30/INTP3/RTC1HZ/SCK00/SCL00/TRJO0               | 40            | 4                     | 9                                   | P10/SCK00/SCL00/(TI07)/(TO07)             |
| GND  | -             | 5                     | -                                   | GND                                       |
| VCC  | -             | 6                     | -                                   | V <sub>DD</sub>                           |
| P140/PCLBUZ0/INTP6                               | 2             | 7                     | -                                   | N.C                                       |
| P130   | 72            | 8                     | 24                                  | RESET#                                    |
| P147/ANI18/VCOUT1                                | 58            | 9                     | -                                   | N.C                                       |
| P146   | 57            | 10                    | 23                                  | P40/TOOL0                                 |
| GND  | -             | 11                    | -                                   | GND                                       |
| VCC  | -             | 12                    | -                                   | V <sub>DD</sub>                           |

Note: The two boards are connected via the Pmod interface, the FPB TxD line required for the UART 2-wire branch connection method cannot be branched and input to INTP3 of the BLE module. In this application enables UART 2-wire branch connection communication by inputting a low level from P74 of FPB to INTP3 of BLE module.

#### (2) PMOD2

Table 3-2 Pin Assignment of PMOD2

| RL78/G14 Fast Prototyping Board                   |               | Pmod<br>Pin<br>Number | LoRaWAN stack sample application board |
|---|---------------|-----------------------|--|
| Function Name                                     | Pin<br>Number |                       | Function Name                          |
| P16/TI01/TO01/INTP5/TRDI0C0/IVREF0/(SI00)/(RxD0)  | 48            | 1                     | NC                                     |
| P13/TxD2/SO20/TRDIOA1/IVCMP1                      | 51            | 2                     | RxD                                    |
| P14/RxD2/SI20/SDA20/TRDIOD0/(SCLA0)               | 50            | 3                     | TxD                                    |
| P15/SCK20/SCL20/TRDIOB0/(SDAA0)                   | 49            | 4                     | NC                                     |
| GND   | -             | 5                     | GND                                    |
| VCC   | -             | 6                     | V <sub>DD</sub>                        |
| P141/PCLBUZ1/INTP7                                | 1             | 7                     | NC                                     |
| P110/(INTP11)                                     | 55            | 8                     | RESET#                                 |
| P17/TI02/TO02/TRDIOA0/TRDCLK/IVCMP0/(SO00)/(TxD0) | 47            | 9                     | NC                                     |
| P111  | 56            | 10                    | NC                                     |
| GND   | -             | 11                    | GND                                    |
| VCC   | -             | 12                    | V <sub>DD</sub>                        |



(3) MCU Header J1

Table 3-3 Pin Assignment of MCU Header J1

| RL78/G14 Fast Prototyping Board |               | TE Connectivity PMOD_MS8607 |               |
|---------------------------------|---------------|-----------------------------|---------------|
| Function Name                   | J1 Pin Number | Pmod Pin Number             | Function Name |
| -                               | -             | 1                           | NC            |
| -                               | -             | 2                           | NC            |
| P60/SCLA0                       | 21            | 3                           | SCL           |
| P61/SDAA0                       | 22            | 4                           | SDA           |
| EVSS0                           | 17            | 5                           | GND           |
| EVDD0                           | 19            | 6                           | VDD           |
| -                               | -             | 7                           | NC            |
| -                               | -             | 8                           | NC            |
| -                               | -             | 9                           | SCL           |
| -                               | -             | 10                          | SDA           |
| -                               | -             | 11                          | GND           |
| -                               | -             | 12                          | VDD           |

### 3.2 Software Configuration

#### 3.2.1 BLE module Configuration

The software configuration of RL78/G14 which is a Host MCU and RY7011 which is a BLE MCU is shown. Firmware for operation check is written in RY7011 at the time of shipment, and it supports some profiles. In this application, General Purpose Communication Profile (GPCP) is used. For other profiles, refer to "7. Profile" in the "RL78/G1D Module Firmware User's Manual" (R01UW0160).

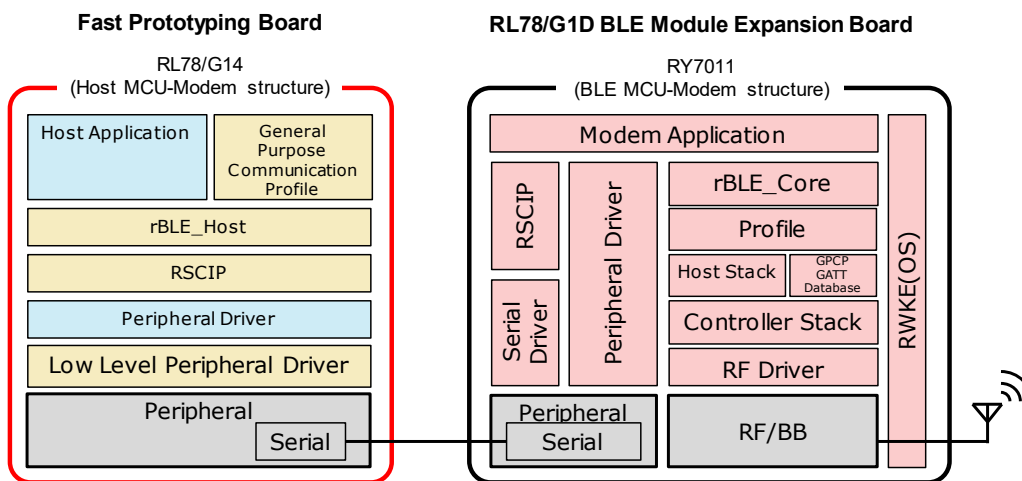


Figure 3-2 BLE module communication software configuration

The software of the Host MCU consists of low level peripheral drivers and the peripheral drivers which controls MCU peripheral hardware, the RSCIP (Renesas Serial Communication Interface Protocol), the rBLE\_Host which provides rBLE APIs, the host application which controls the system, and the General Purpose Communication Profile (GPCP) using the GATT API.

The low level peripheral driver code is generated by the Code Generator. The RSCIP and the rBLE\_Host are included in the BLE protocol stack package and provided code. When developing software, it is necessary to use the latest code which is provided by the BLE protocol stack package.

Table 3-4 Host MCU Software Configuration

| Software                                     | Functions  | When developing software                                   |
|--|--|--|
| Host Application                             | Initializing rBLE<br>Scheduling rBLE command execution<br>Registering rBLE event callbacks | <u>Need to be coded</u>                                    |
| General Purpose Communication Profile (GPCP) | Custom Profile using GATT APIs   | No need to be coded (provided by package) <sup>Note1</sup> |
| rBLE_Host                                    | Providing rBLE APIs<br>Executing rBLE event callbacks                                      | No need to be coded (provided by package) <sup>Note1</sup> |
| RSCIP (Renesas Serial Comm)                  | Controlling serial communication   | No need to be coded (provided by package) <sup>Note1</sup> |
| Peripheral Driver                            | Controlling Host MCU peripheral hardware   | <u>Need to be coded</u>                                    |
| Low Level Peripheral Driver                  | Controlling Host MCU peripheral hardware primitively                                       | No need to be coded (generated by tool) <sup>Note2</sup>   |

Notes: 1. Code files for software development are provided by BLE protocol stack package.  
2. Code files for software development are generated by the Code Generator.

The software of the BLE MCU consists of RF driver which controls RF/BB, Host/Controller stacks, Profiles, rBLE\_Core, Serial Driver and RSCIP for communicating with the Host MCU, RWKE (Renesas Wireless Kernel Extension) which manages the system and the Modem application. The build environment is provided by "RL78/G1D Module Control Software" (R01AN3362).

Table 3-5 BLE MCU Software Configuration

| Software                        | Functions   |
|---------------------------------|---|
| Modem Application               | Controlling RSCIP and rBLE                              |
| RWKE                            | Managing the whole system schedule and memory resource. |
| RSCIP                           | Controlling serial communication                        |
| Peripheral Driver/Serial Driver | Controlling BLE MCU peripheral hardware                 |
| rBLE_Core                       | Providing rBLE APIs                                     |
| Profile                         | Providing Profiles functions                            |
| Host Stack                      | Providing GAP, GATT, SM, L2CAP functions                |
| GSCP GATT Database              | GATT Database of General Purpose Communication Profile  |
| Controller Stack                | Providing LL functions                                  |

### 3.2.2 LoRaWAN module Configuration

The software configuration of the RL78/G14 of the FPB and the LoRaWAN module are shown below. The LoRaWAN module consists of LoRaWAN stack<sup>Note1</sup>, peripheral driver, sample application<sup>Note2</sup> that controls LoRaWAN stack with AT command. FPB consists of a LoRaWAN module application for controlling the LoRaWAN module by AT commands and a Sensor control application for controlling the Sensor module and reading the measured data.

- Notes: 1. Refer to "LoRaWAN stack reference guide" (R11AN0228)  
 2. Refer to "LoRaWAN Stack Sample Application Command Reference" (R11AN0231)

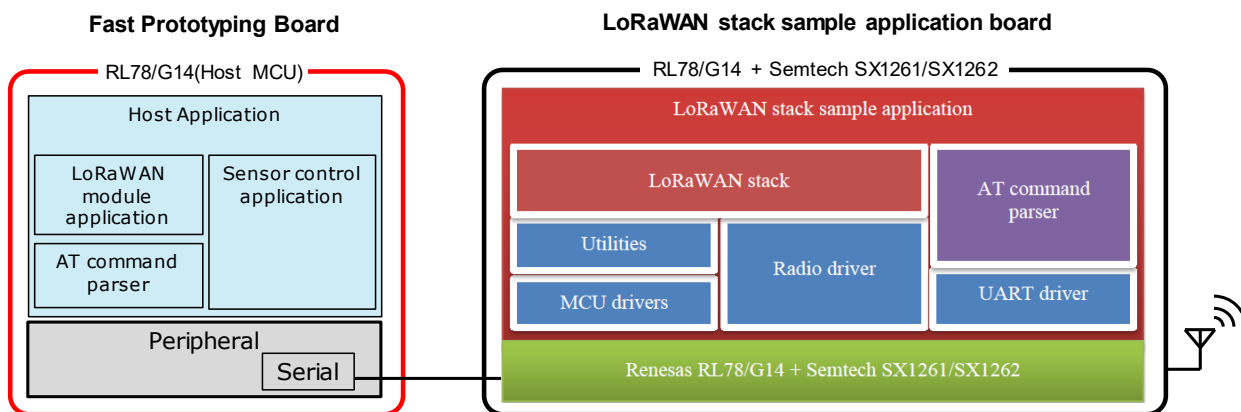


Figure 3-3 LoRaWAN module communication software configuration

### 3.3 Peripheral Configuration

The peripheral functions of The RL78/G14 used in the FPB applications are shown below.

The Peripheral functions that are necessary for applications to use the BLE module or the LoRaWAN module are defined as "Mandatory" and others as "Optional".

Table 3-6 Peripheral Functions

| Peripheral Function   | Purpose  |   | Necessity |
|-----------------------|--|---|-----------|
| Clock Generator       | Used for operating frequency of the RL78/G14.                                |   | Mandatory |
| Port                  | P74  | Used for a WAKEUP pin for UART 2-wire branch connection method in UART communication with the BLE module. | Mandatory |
|                       | P130   | Used for reset release pin of the BLE module.   | Mandatory |
|                       | P110   | Used for reset release pin of the LoRaWAN module.   | Mandatory |
|                       | P43  | Used for LED0 on the FPB.   | Optional  |
|                       | P44  | Used for LED1 on the FPB.   | Optional  |
|                       | P137   | Used for SW_USR on the FPB.   | Optional  |
| Serial-UART0          | Used for UART communication with the BLE module.                             |   | Mandatory |
| Serial-UART2          | Used for UART communication with the LoRaWAN module.                         |   | Mandatory |
| Serial-IICA0          | Used for IICA communication with the Sensor module.                          |   | Optional  |
| Timer-TAU0            | Used for A/D converter wait with the Sensor module.                          |   | Optional  |
| 12-Bit Interval Timer | Used for timer function used by rBLE_Host and RSCIP of BLE Host MCU program. |   | Mandatory |





|  |  |                                       |
|--|--|---------------------------------------|
|  | r_cg_timer.c   | timer array unit code file            |
|  | r_cg_timer.h   | timer array unit header file          |
|  | r_cg_timer_user.c  | timer array unit user code file       |
|  | r_cg_userdefine.h  | user defined macro header file        |
|  | r_main.c   | main loop code file                   |
|  | r_systeminit.c   | peripheral initialization code file   |
|  | └─e2studio   |                                       |
|  | .cproject  | e2studio project file                 |
|  | .project   | same as above                         |
|  | RL78G14_FPB_LoRaWAN_BLE_Application HardwareDebug.launch | same as above                         |
|  | r_option_cc.txt  | same as above                         |
|  | └─.settings  |                                       |
|  | com.renesas.tools.misrac.prefs                           | e2studio project file                 |
|  | CoverageSetting.xml                                      | same as above                         |
|  | Dependency_Scan_Preferences.prefs                        | same as above                         |
|  | e2studio_project.prefs                                   | same as above                         |
|  | renesasPGModel.xml                                       | same as above                         |
|  |  |                                       |
|  | └─CodeGenerator  |                                       |
|  | cgproject.cgp  | e2studio project file                 |
|  | cgprojectDatas.datas                                     | same as above                         |
|  |  |                                       |
|  | └─generate   |                                       |
|  | cstart.asm   | startup routine                       |
|  | iodefine.h   | I/O header file                       |
|  | stkinit.asm  | stack area initialize routine         |
|  |  |                                       |
|  | └─src  |                                       |
|  | r_cg_cgc.c   | clock generator driver code file      |
|  | r_cg_cgc.h   | clock generator driver header file    |
|  | r_cg_cgc_user.c  | clock generator driver user code file |
|  | r_cg_intc.c  | interrupt driver code file            |
|  | r_cg_intc.h  | interrupt driver header file          |
|  | r_cg_intc_user.c   | interrupt driver user code file       |
|  | r_cg_it.c  | interval timer driver code file       |
|  | r_cg_it.h  | interval timer driver header file     |
|  | r_cg_it_user.c   | interval timer driver user code file  |
|  | r_cg_macrodriver.h                                       | macro header file                     |
|  | r_cg_macrodriver_hostsample.h                            | macro header file (backup)            |
|  | r_cg_port.c  | port driver code file                 |
|  | r_cg_port.h  | port driver header file               |
|  | r_cg_port_user.c   | port driver user code file            |
|  | r_cg_serial.c  | serial driver code file               |
|  | r_cg_serial.h  | serial driver header file             |
|  | r_cg_serial_user.c                                       | serial driver user code file          |
|  | r_cg_timer.c   | timer array unit code file            |
|  | r_cg_timer.h   | timer array unit header file          |
|  | r_cg_timer_user.c  | timer array unit user code file       |
|  | r_cg_userdefine.h  | user defined macro header file        |
|  | r_main.c   | main loop code file                   |
|  | r_systeminit.c   | peripheral initialization code file   |



## 4. How to Build

The project and build procedure for building the FPB BLE · LoRaWAN Application are shown below.

Table 4-1 FPB BLE · LoRaWAN Application project

| CS+ for CC            |  |
|-----------------------|--|
| Project File          | RL78G14_FP_BLE_LoRaWAN_Application\project\cs_cc\<br>RL78G14_FP_BLE_LoRaWAN_Applicaiothn.mtpj                |
| HEX File              | RL78G14_FP_BLE_LoRaWAN_Application\project\cs_cc\DefaultBuild\<br>RL78G14_FP_BLE_LoRaWAN_Applicaiothn.hex    |
| e <sup>2</sup> studio |  |
| Project Folder        | RL78G14_FP_BLE_LoRaWAN_Application\project\e2studio  |
| HEX File              | RL78G14_FP_BLE_LoRaWAN_Application\project\e2studio\HardwareDebug\<br>RL78G14_FP_BLE_LoRaWAN_Application.hex |

### 4.1 CS+ for CC

1. Double click the project file shown in Project File of "Table 4-1 FPB BLE · LoRaWAN Application project".
2. Right click "RL78G14\_FP\_BLE\_LoRaWAN\_Application (Project)" in the "Project Tree" and select "Build RL78G14\_FP\_BLE\_LoRaWAN\_Application" from the dropdown menu to start the build.
3. The HEX file is generated in the path shown in the HEX File column of CS+ for CC in "Table 4-1 FPB BLE · LoRaWAN Application project".

### 4.2 e<sup>2</sup> studio

1. Launch e<sup>2</sup>studio.
2. Right click on the "Project Explorer" and select "Import" from the displayed menu.
3. The "Import" window will be displayed. Select "Existing project to workspace" and click "Next".
4. In the "Select root directory" form, select the project folder shown in the Project Folder of e<sup>2</sup> studio in "Table 4-1 FPB BLE · LoRaWAN Application project". After selection, confirm that the specified project is displayed in "Project" and click "Finish". Then the "Import" window is closed.
5. Right click on the project displayed on the "Project Explorer" and select "Build Project" to start the build.
6. The HEX file is generated in the path shown in the HEX File of e<sup>2</sup> studio in "Table 4-1 FPB BLE · LoRaWAN Application project".

## 5. Execute Application

Check the operation of BLE communication and LoRaWAN communication with the configuration shown in "Figure 5-1 Application Execution Environment".

### 5.1 Install GATTBrowser

Install GATTBrowser to a smartphone.

- GATTBrowser for Android

<https://play.google.com/store/apps/details?id=com.renesas.ble.gattbrowser>

- GATTBrowser for iOS

<https://itunes.apple.com/us/app/gattbrowser/id1163057977?mt=8>

### 5.2 Prepare LORIOT LoRaWAN Network Server

Refer to "3. LoRaWAN Network Server" in "LoRaWAN® IoT Demo LPWA IoT Solution with Cloud" (R11AN0412) for setup.

### 5.3 Execution Environment

Build the program referring to "4. How to Build". Then connect the FPB and PC with a USB cable and download the program.

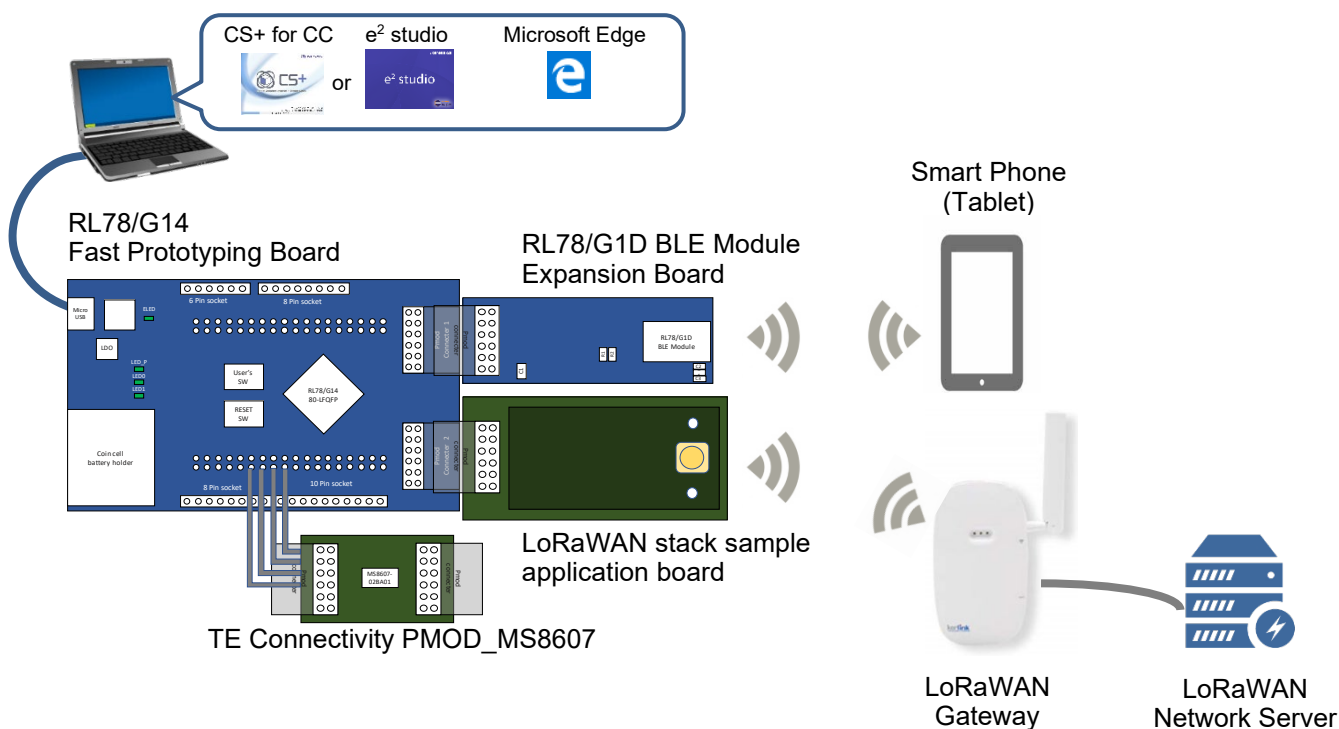


Figure 5-1 Application Execution Environment

### 5.4 Execution Process

The overall operation of the application is shown in "Figure 5-2 Application Flow".

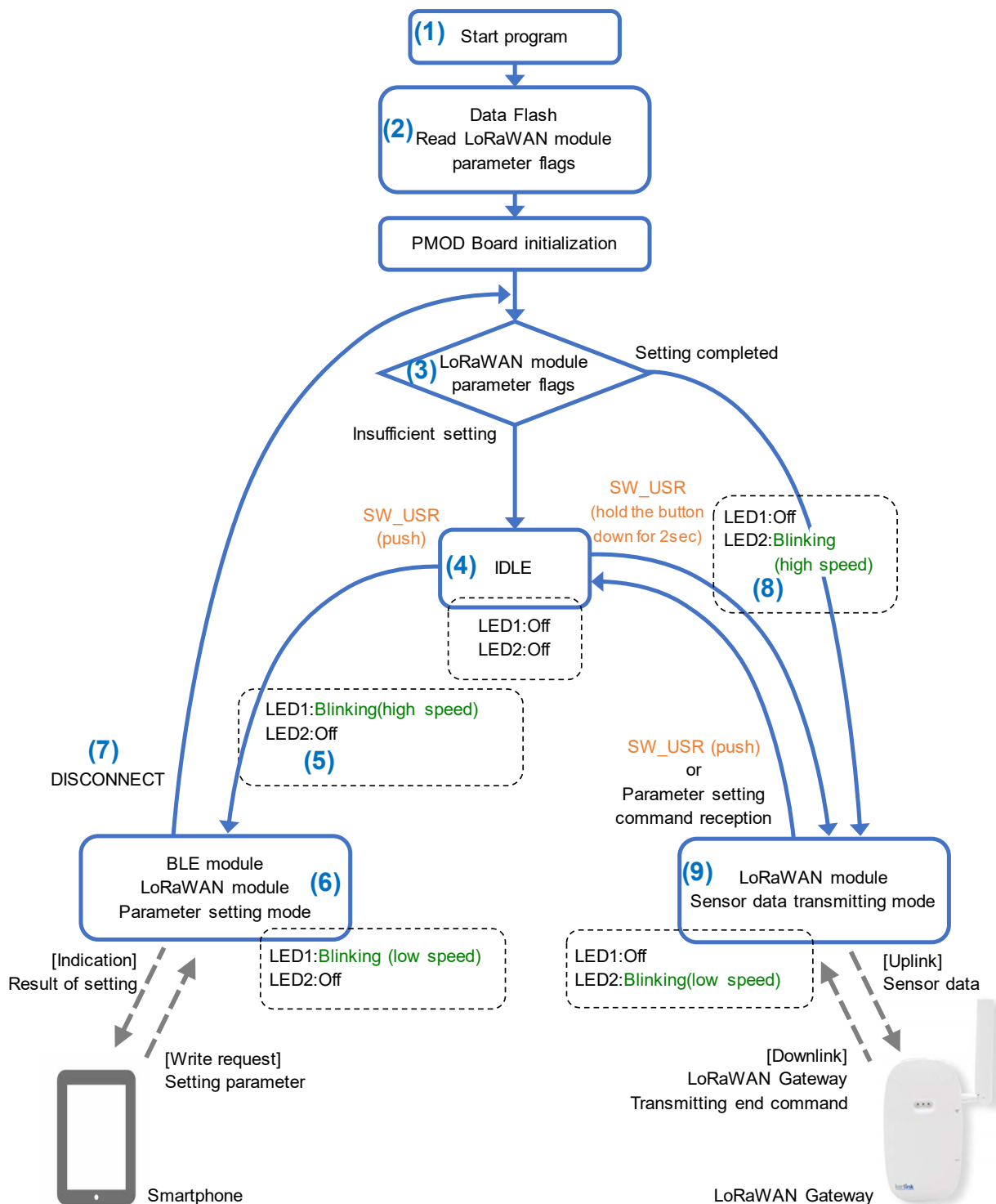


Figure 5-2 Application Flow

**[Start Program]**

- (1) Start Program.
- (2) Read the LoRaWAN module parameter flags from the FPB data flash.
- (3) Check whether LoRaWAN module parameter flags are set.
  - All parameters required for LoRaWAN module communication are set.
    - ➔ Go to [LoRaWAN module: Sensor data transmitting mode]
  - Parameters required for LoRaWAN module communication are not set.
    - ➔ Go to [IDLE]

**[IDLE]**

- (4) IDLE state. Wait for the push switch (SW\_USR) to be pushed.  
(LED1: Off, LED2: Off)
  - Push SW\_USR  
(Parameters required for LoRaWAN module communication are not set.)
    - ➔ Go to [BLE module: LoRaWAN parameter setting mode]
  - Push SW\_USR (hold the button down for 2sec)  
(All parameters required for LoRaWAN module communication are set.)
    - ➔ Go to [LoRaWAN module: Sensor data transmitting mode]

**[BLE module: LoRaWAN parameter setting mode]**

- (5) The BLE module starts advertising.  
(LED1: Blinking (high speed), LED2: Off)
- (6) Connect to the BLE module with a smartphone and set the LoRaWAN module parameters from the smartphone.  
(LED1: Blinking (low speed), LED2: Off)

For smartphone operations, refer to "5.4.1 LoRaWAN module parameters setting by Android device" for Android, and "0

LoRaWAN module parameters setting by iOS device" for iOS.

- (7) After setting all the LoRaWAN module parameters, disconnect BLE connection from the smartphone. When the BLE module detects a disconnection, it saves the parameter flag set to the LoRaWAN module to the FPB data flash. If you turn off the power or disconnect E2Lite without disconnecting from the smartphone, the parameter flag is not saved in the FPB data flash, so set it again.
- All parameters required for LoRaWAN module communication are set.
    - ➔ Go to [LoRaWAN module: Sensor data transmitting mode]
  - Parameters required for LoRaWAN module communication are not set.
    - ➔ Go to [IDLE]

**[LoRaWAN module: Sensor data transmitting mode]**

- (8) Start LoRaWAN module communication. First, activate to LoRaWAN Gateway.  
(LED1: Off, LED2: Blinking (high speed))
- (9) When the LoRaWAN Gateway is accepted, the measured data is read from the Sensor module at 1-minute intervals and sent to the LoRaWAN Gateway.  
(LED1: Off, LED2: Blinking (low speed))

Check the LORIoT Network Server site with a web browser and confirm that data is being sent from the LoRaWAN module to the LoRaWAN Network Server. Refer to "5.4.3.1 Check Sensor Data".

There are two ways to interrupt LoRaWAN module communication and return to IDLE.

- LoRaWAN module receives communication termination command sent from LoRaWAN Network Server. Refer to "5.4.3.2 LoRaWAN Gateway Communication End Command Transmitting".
  - ➔ Go to [IDLE]
  
- Push SW\_USR
  - ➔ Go to [IDLE]

**5.4.1 LoRaWAN module parameters setting by Android device**

1. Start GATTBrowser installed on the Android device.
2. Connect to the device displayed as RTK5RL140C from the scan results. (Arrow (1) in Figure A1)
3. When connected, a list of services is displayed. Scroll down to the bottom and select "Indication Characteristic" of "Renesas Virtual UART Service". (Arrow (2) in Figure A2)
4. Tap "Indication Off" to "Indication On". (Arrow (3) in Figure A3)
5. Return to the list of services. (Arrow (4) in Figure A3)

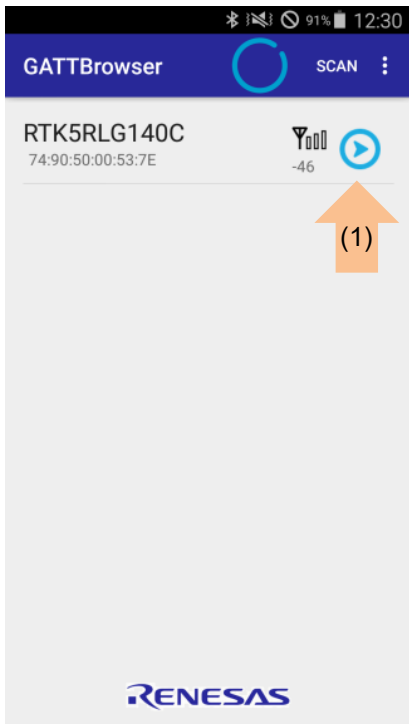


Figure A1

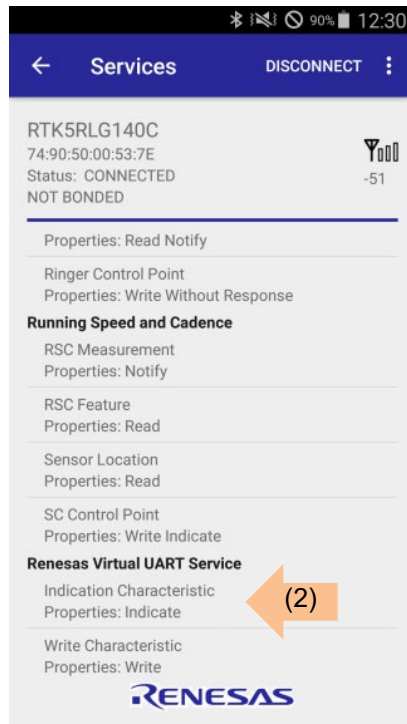


Figure A2

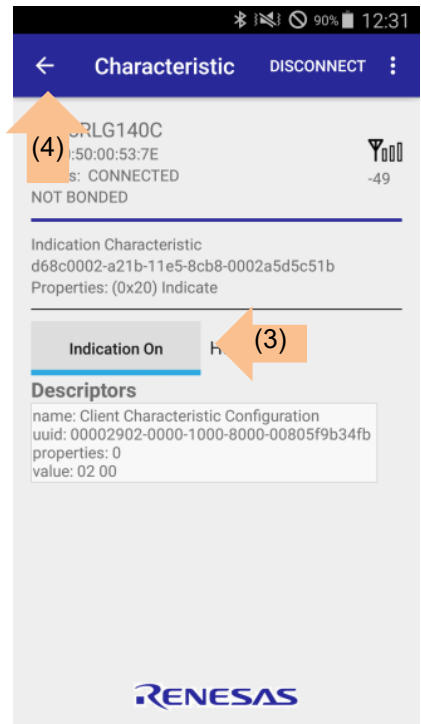


Figure A3

6. Select "Write Characteristic". (Arrow (5) in Figure A4)
7. Select "Hex". (Arrow (6) in Figure A5)
8. Input LoRaWAN setting parameter. (Arrow (7) in Figure A5)
9. Tap "Write" to send. (Arrow (8) in Figure A5)
10. Return to the list of services. (Arrow (9) in Figure A5)

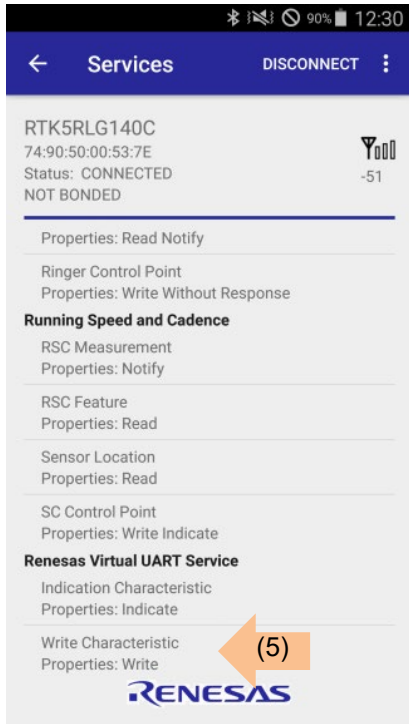


Figure A4

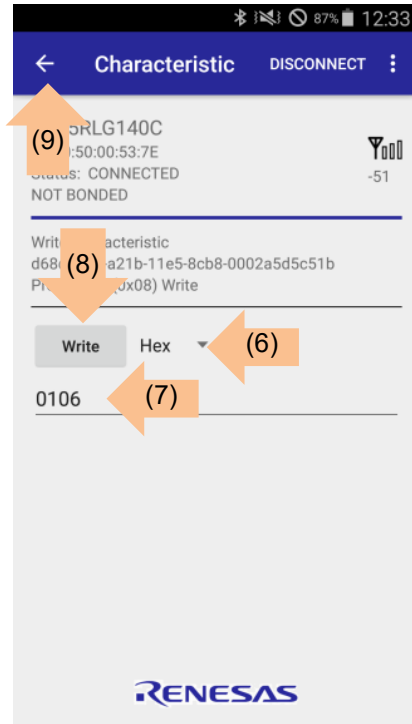


Figure A5



11. Select "Indication Characteristic". (Arrow (10) in Figure A6)
12. The LoRaWAN module parameter setting result is displayed. (Arrow (11) in Figure A7)  
Refer to "6.4.1.2 AT Command Result Code Format" for the result format.
13. After all parameters have been set, select "DISCONNECT". (Arrow (12) in Figure A7)  
To determine whether the setting is complete, check that 0x7F is displayed in the third byte (parameter flag) of the AT command result code format.

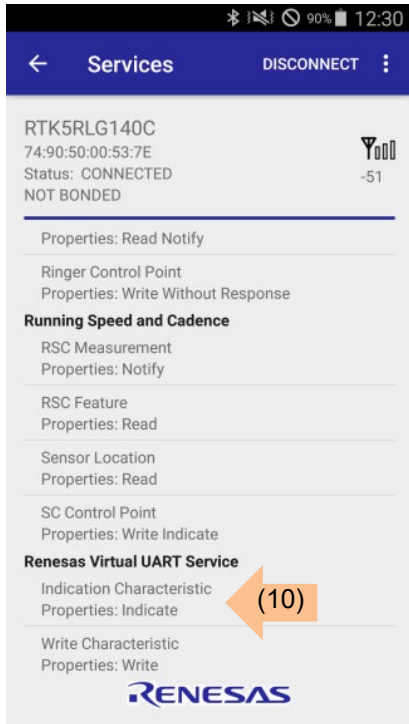


Figure A6

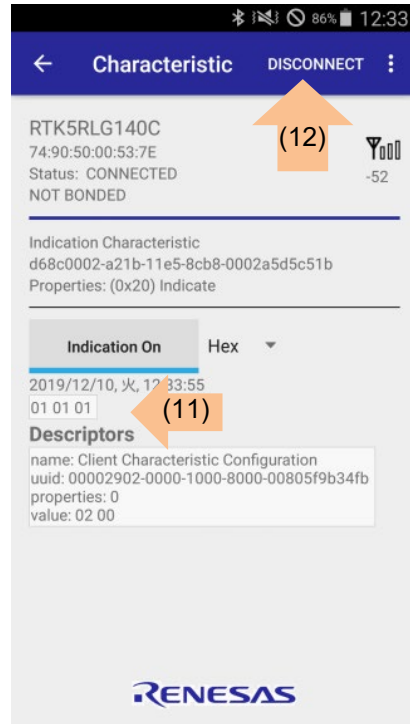


Figure A7

### 5.4.2 LoRaWAN module parameters setting by iOS device

1. Start GATTBrowser installed on the iOS device.
2. Connect to the device displayed as RTK5RL140C from the scan results. (Arrow (1) in Figure B1)
3. When connected, a list of services is displayed. Scroll down to the bottom and select "Indication Characteristic" of "Renesas Virtual UART Service". (Arrow (2) in Figure B2)
4. Tap "Enable Indication" to "Disable Indication". (Arrow (3) in Figure B3)
5. Return to the list of services. (Arrow (4) in Figure B3)

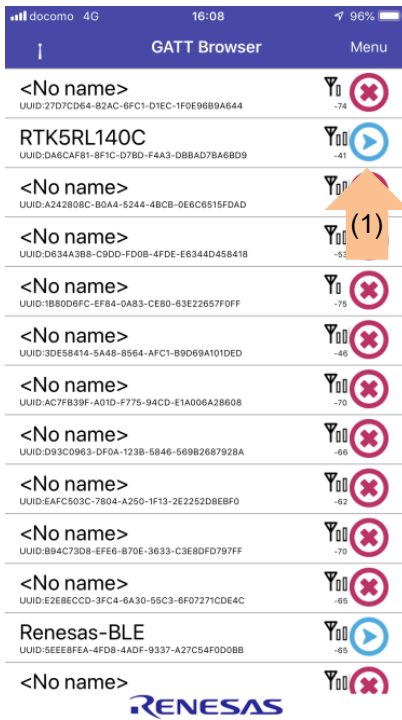


Figure B1

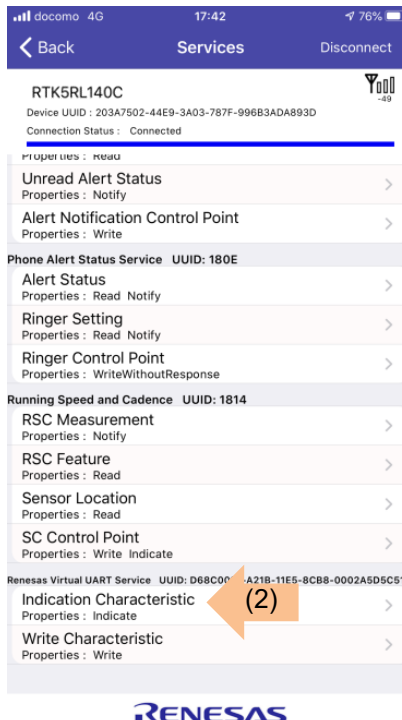


Figure B2

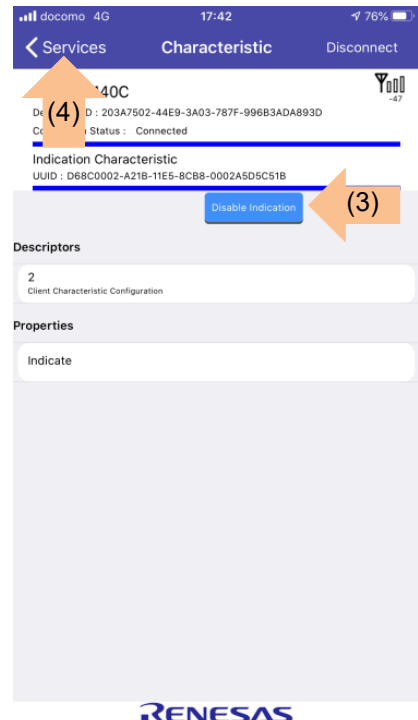


Figure B3

6. Select "Write Characteristic". (Arrow (5) in Figure B4)
7. Select "Hex". (Arrow (6) in Figure B5)
8. Input LoRaWAN setting parameter. (Arrow (7) in Figure B5)
9. Tap "Write" to send. (Arrow (8) in Figure B5)
10. Return to the list of services. (Arrow (9) in Figure B5)

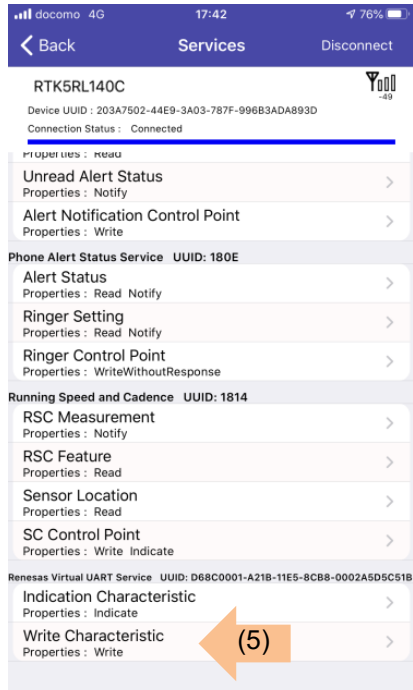


Figure B4

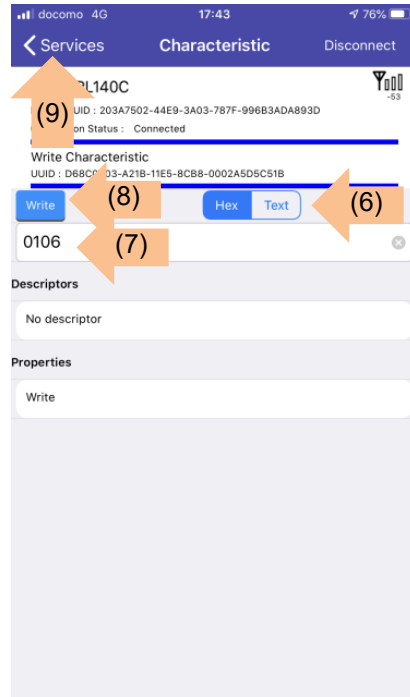


Figure B5

14. Select "Indication Characteristic". (Arrow (10) in Figure B6)
15. The LoRaWAN module parameter setting result is displayed. (Arrow (11) in Figure B7)  
Refer to "6.4.1.2 AT Command Result Code Format" for the result format.
16. After all parameters have been set, select "DISCONNECT". (Arrow (12) in Figure B7)  
To determine whether the setting is complete, check that 0x7F is displayed in the third byte (parameter flag) of the AT command result code format.

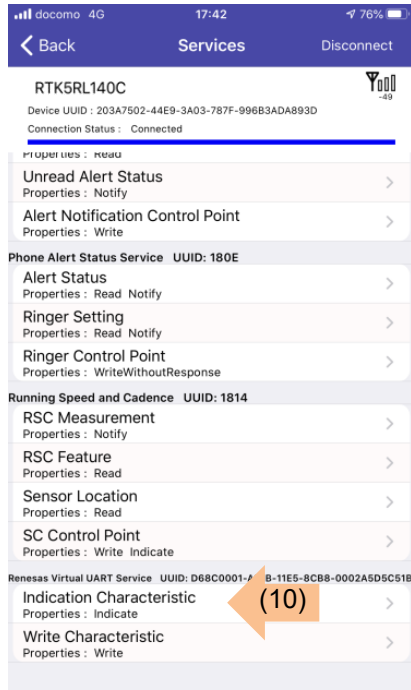


Figure B6

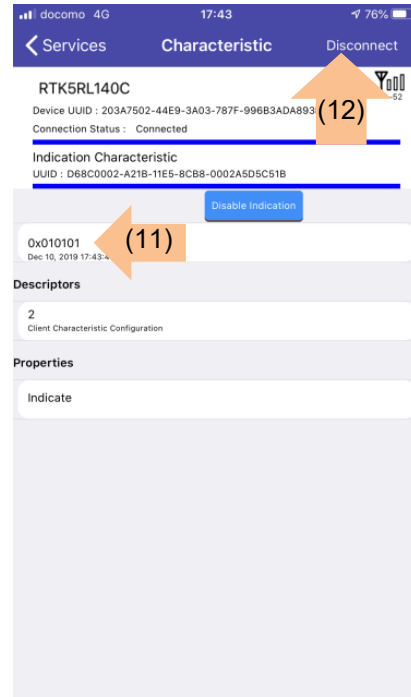


Figure B7

### 5.4.3 LoRaWAN Network Server

#### 5.4.3.1 Check Sensor Data

The sensor data sent from the LoRaWAN module is checked by the LoRaWAN Network Server operated by LORIOT.

You can confirm that sensor data (Payload) is received from LoRaWAN module with Device EUI of 0x749050FFFE000C2C.

| Device EUI       | Local time               | Freq [MHz] | Date rate      | RSSI (dBm) | SNR (dB) | FCntUp | Port | Payload                 |
|------------------|--------------------------|------------|----------------|------------|----------|--------|------|-------------------------|
| 749050FFFE000C2C | 2019-12-09 15:40:59 .181 | 924.000    | SF10 BW125 4/5 | -33        | 14       | 11     | 10   | 44 7d d3 d7 42 2c e6 40 |
| 749050FFFE000C2C | 2019-12-09 15:39:59 .320 | 924.000    | SF10 BW125 4/5 | -31        | 11.2     | 10     | 10   | 41 c2 3d 71             |
| 749050FFFE000C2C | 2019-12-09 15:38:59 .545 | 923.400    | SF10 BW125 4/5 | -46        | 12.5     | 9      | 10   | 44 7d d0 00 42 2d a1 c0 |
| 749050FFFE000C2C | 2019-12-09 15:37:59 .681 | 924.200    | SF10 BW125 4/5 | -47        | 11       | 8      | 10   | 41 c2 3d 71             |
| 749050FFFE000C2C | 2019-12-09 15:36:59 .890 | 923.600    | SF10 BW125 4/5 | -31        | 12       | 7      | 10   | 44 7d cf 5c 42 2d 63 40 |
| 749050FFFE000C2C | 2019-12-09 15:36:00 .22  | 924.000    | SF10 BW125 4/5 | -35        | 11.8     | 6      | 10   | 41 c2 a3 d7             |

Figure 5-3 Confirmation of sensor data with LoRaWAN Network Server

#### 5.4.3.2 LoRaWAN Gateway Communication End Command Transmitting

- (1) To check the sensor data, press the “Send Data To Device” button at the top of the page to display the "Send Data To Device" dialog.

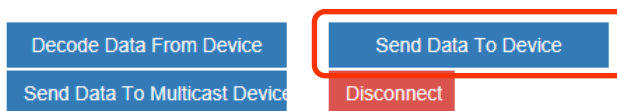


Figure 5-4 Send Data To Device Button

- (2) Enter the parameters set in the LoRaWAN module and the communication end command and press the “Send to device” button.

Send Data To Device

Device EUI (16 hex digits): 749050FFFE000C2C

Port (decimal number, 1 to 223): 10

Request confirmation

Payload (hex string): 11223344

Keep Sending Data

Figure 5-5 Send Data To Device Dialog

(3) The communication end command is held in the transmission queue.

SampleApp Websocket

Connected Last 123 entries

Decode Data From Device Send Data To Device

Send Data To Multicast Device Disconnect

| Device EUI       | Local time              | Freq [MHz] | Date rate      | RSSI (dBm) | SNR (dB) | FCntUp | Port | Payload                         |
|------------------|-------------------------|------------|----------------|------------|----------|--------|------|---------------------------------|
| 749050FFFE000C2C |                         |            |                |            |          |        |      | 11223344 (enqueued for sending) |
| 749050FFFE000C2C | 2019-12-09 17:22:02.102 | 923.800    | SF10 BW125 4/5 | -33        | 11.2     | 8      | 10   | 41 c1 33 33                     |
| 749050FFFE000C2C | 2019-12-09 17:21:02.322 | 923.200    | SF10 BW125 4/5 | -33        | 11       | 7      | 10   | 44 7d d1 ec 42 31 0c c0         |

Figure 5-6 Enqueued For Sending

(4) Sends a communication end command triggered by sensor data reception from LoRaWAN module.

SampleApp Websocket

Connected Last 126 entries

Decode Data From Device Send Data To Device

Send Data To Multicast Device Disconnect

| Device EUI       | Local time              | Freq [MHz] | Date rate      | RSSI (dBm) | SNR (dB) | FCntUp | Port | Payload                         |
|------------------|-------------------------|------------|----------------|------------|----------|--------|------|---------------------------------|
| 749050FFFE000C2C | 2019-12-09 17:23:02.197 |            |                |            |          |        |      | (enqueued data sent)            |
| 749050FFFE000C2C | 2019-12-09 17:23:01.988 | 923.400    | SF10 BW125 4/5 | -33        | 13       | 9      | 10   | 44 7d d5 1f 42 30 ce 40         |
| 749050FFFE000C2C |                         |            |                |            |          |        |      | 11223344 (enqueued for sending) |
| 749050FFFE000C2C | 2019-12-09 17:22:02.102 | 923.800    | SF10 BW125 4/5 | -33        | 11.2     | 8      | 10   | 41 c1 33 33                     |
| 749050FFFE000C2C | 2019-12-09 17:21:02.322 | 923.200    | SF10 BW125 4/5 | -33        | 11       | 7      | 10   | 44 7d d1 ec 42 31 0c c0         |

Figure 5-7 Enqueued For Sending

## 6. Processing Flow

This section describes the Host MCU application processing shown in "Figure 3-2 BLE module communication software configuration" and "Figure 3-3 LoRaWAN module communication software configuration".

### 6.1 main loop

The main loop of this application consists of two processing units, the BLE module communication unit and the LoRaWAN module communication unit, as shown in "Figure 6-1 Main Loop Processing".

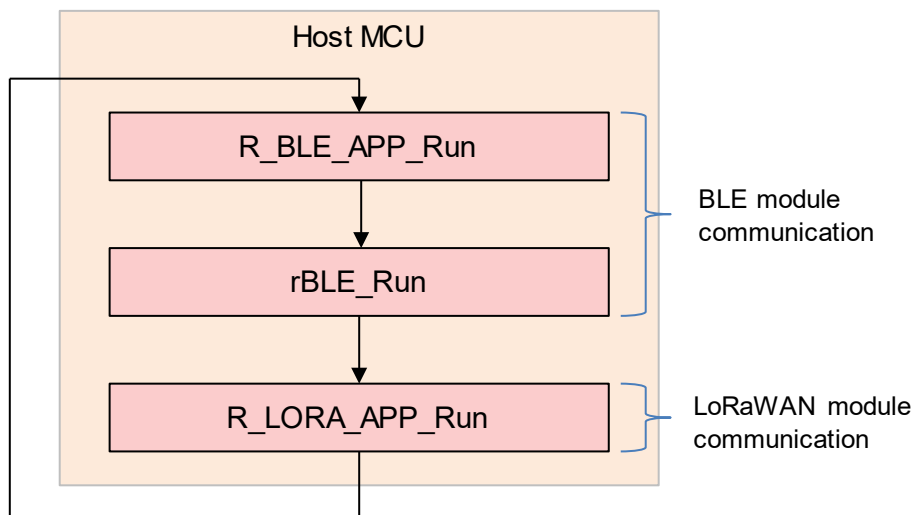


Figure 6-1 Main Loop Processing

The BLE module communication unit is executed by the R\_BLE\_APP\_Run function and the rBLE\_Run function. The R\_BLE\_APP\_Run function is an application part that connects to a smartphone to receive LoRaWAN module setting parameters, converts them to AT commands, and sets parameters in the LoRaWAN module. The rBLE\_Run function performs the process of sending the rBLE API called in the application part to the BLE module and the process of receiving the rBLE event from the BLE module and notifying the callback function of the application part.

The LoRaWAN module communication part is executed by R\_LORA\_APP\_Run function. The sensor data measured from the Sensor module is read out and sent to the LoRaWAN module using AT commands, and the communication termination command received from the LoRaWAN Gateway is processed.

## 6.2 BLE module Communication Flow

The flow for setting the parameters received from the smartphone to the LoRaWAN module is explained in "Figure 6-2 BLE module Communication Process".

### 6.2.1 Connection with Smartphone

The BLE module communication is executed by the R\_BLE\_APP\_Run function and rBLE\_Run function in the main loop.

The R\_BLE\_APP\_Run function is an application part that connects to a smartphone, receives LoRaWAN module setting parameters, and sets parameters to the LoRaWAN module with AT commands. The rBLE\_Run function performs the process of sending the rBLE API called in the application part to the rBLE module and the process of receiving the rBLE event from the BLE module and passing it to the callback function of the application part.

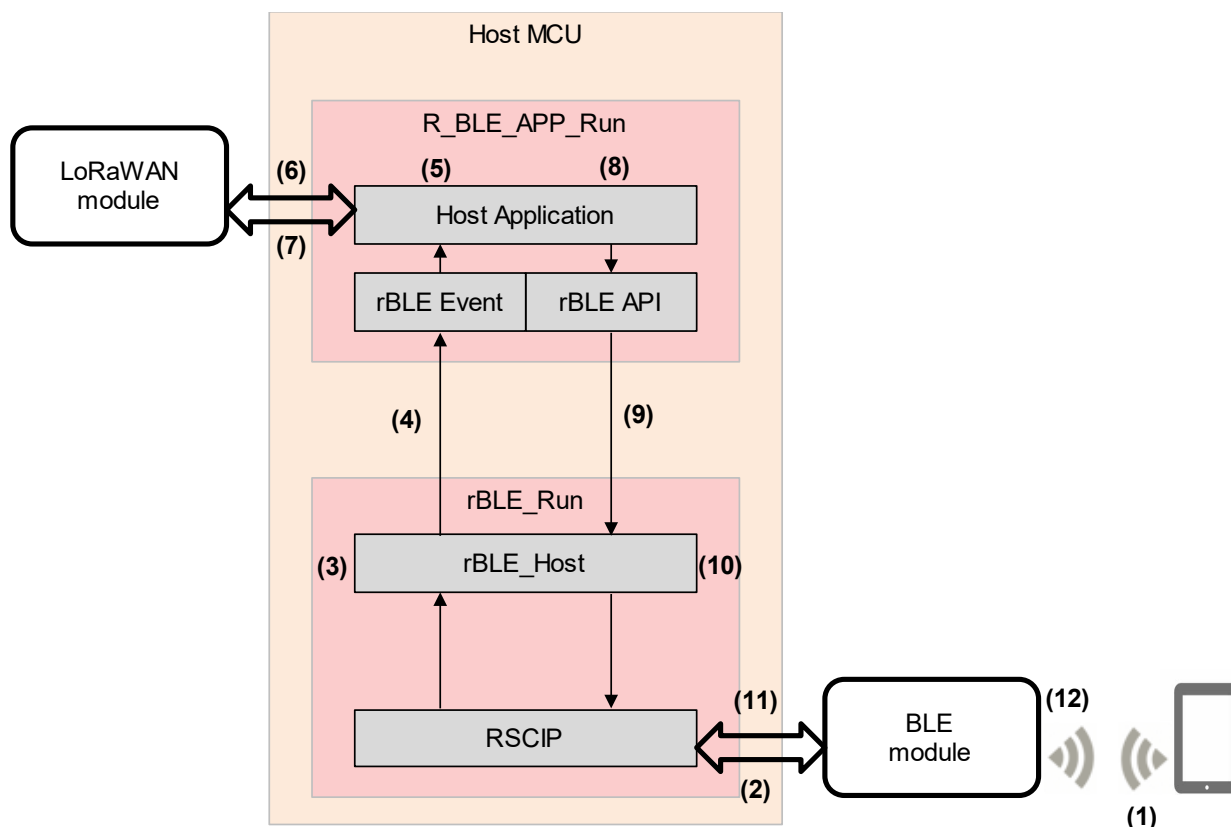


Figure 6-2 BLE module Communication Process

- (1) The smartphone sends LoRaWAN configuration parameters.
- (2) When the BLE module receives the LoRaWAN configuration parameters from the smartphone, it sends the rBLE event format via RSCIP and is passed from the Host MCU RSCIP to rBLE\_Host.
- (3) rBLE\_Host converts rBLE event format to rBLE event.
- (4) rBLE\_Host notifies the rBLE event by calling the callback function of Host Application.
- (5) Host Application extracts the hexadecimal LoRaWAN module configuration parameter from the rBLE event and converts it to an AT command string.
- (6) Host Application sends AT command to LoRaWAN module to set parameters.
- (7) Host Application receives the AT command execution result string from the LoRaWAN module.



- (8) Host Application converts the AT command execution result string to hexadecimal format.
- (9) Host Application calls rBLE API.
- (10) rBLE\_Host converts rBLE API and parameters specified by API into rBLE command format.
- (11) RSCIP sends the rBLE command format to the BLE module.
- (12) The AT command execution result is sent from the BLE module to the smartphone.

### **6.2.2 Disconnection with Smartphone**

When the BLE module detects that the smartphone has been disconnected, the flag indicating the parameter set in the LoRaWAN module is saved in the FPB data flash. If the FPB power is turned off or E2Lite is disconnected without executing the disconnection from the smartphone, the parameter flag is not saved in the FPB data flash. Connect to the smartphone and set the parameters again.

### 6.3 LoRaWAN module Communication Flow

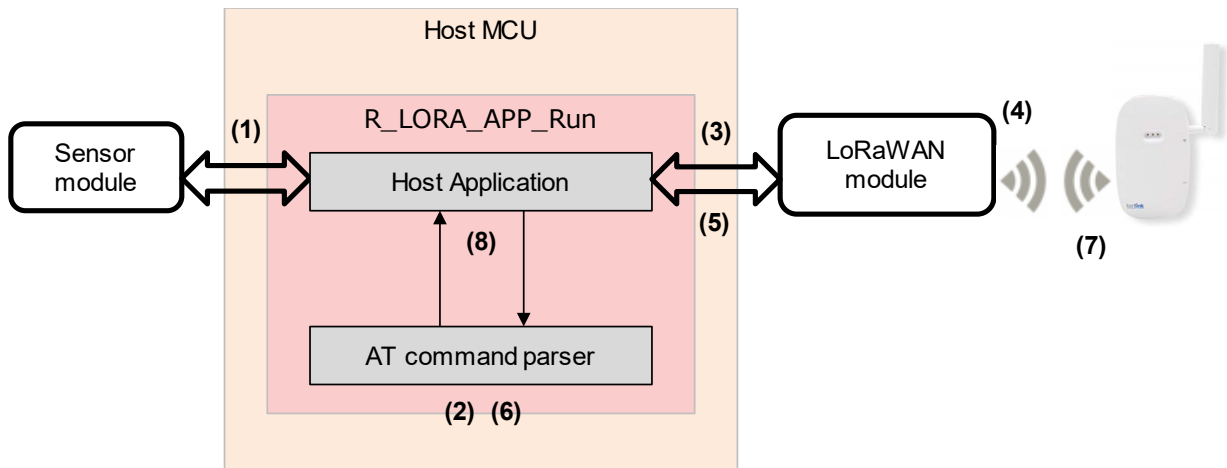


Figure 6-3 LoRaWAN module Communication Process

[Send a sensor data - Uplink]

- (1) Host Application reads the sensor data from the Sensor module and passes it to the AT command parser.
- (2) The AT command parser generates an AT command that includes sensor data read by the Host Application and passes it to the Host Application.
- (3) Host Application sends AT command to LoRaWAN module.
- (4) LoRaWAN module sends sensor data to LoRaWAN Gateway.
- (5) Host Application receives the sensor data transmission result and passes it to AT command parser.
- (6) The AT command parser analyzes the sensor data transmission result and notifies the Host Application.

[Receive the LoRaWAN Gateway communication end command - Downlink]

- (7) When LoRaWAN Gateway communication termination command is sent from LoRaWAN Network Server, LoRaWAN module is received through LoRaWAN Gateway and passed to Host Application.
- (8) Host Application analyzes using AT command parser and terminates communication with LoRaWAN Gateway.

## 6.4 LoRaWAN module Commands

This section describes the AT command communication format specification used to set parameters <sup>NOTE</sup> for the LoRaWAN module and the command specification for end communication with the LoRaWAN Gateway.

In this application, 7 AT commands are used to set parameters in LoRaWAN module. And, one unique command is used to end communication with the LoRaWAN Gateway.

Refer to “LoRaWAN Stack Sample Application Command Reference” (R11AN0231) for detailed explanation of AT commands.

Note: In this application note, parameters such as Device EUI are set because the LoRaWAN evaluation board (LoRaWAN stack sample application board) is used. Usually, two parameters that need to be set are Application Key and Application EUI. Other parameters are often written as device-specific parameters.

Table 6-1 LoRaWAN module Setting AT Commands

| AT Command | Description                |
|------------|----------------------------|
| AT+REGION  | Set Region                 |
| AT+DEVEUI  | Set Device EUI             |
| AT+CLASS   | Set Device class           |
| AT+APPEUI  | Set Application identifier |
| AT+APPKEY  | Set Application key        |
| AT+ACTMODE | Set Activation mode        |
| AT+FPORT   | Set Port number            |

### 6.4.1 Parameter Setting AT Commands

This section describes the format of the AT command sent from the smartphone, the format of the AT command execution result sent to the smartphone, and the parameter flag format for storing the set parameters in the FPB (RL78/G14) data flash.

#### 6.4.1.1 AT Command Format

The parameters set for the LoRaWAN module are sent from the smartphone.

The AT command and parameters sent to the LoRaWAN module are ASCII character strings, but the character strings may be longer depending on the parameters. Therefore, use a hexadecimal numeric string that contains the number and parameters assigned to each AT command, not an ASCII string.

Hexadecimal parameters received by the BLE module are converted to ASCII string AT commands by the FPB Host Application and sent to the LoRaWAN module.

The table below shows the correspondence between the hexadecimal AT command format sent from the smartphone and the character string to be converted after being received by the BLE module.

Hexadecimal AT command format: <AT command number> <Parameter>

AT command number: 1 byte

Parameter: Variable length

Table 6-2 AT Commands Number Correspondence Table

| AT Command Number | AT Command |
|-------------------|------------|
| 01                | AT+REGION  |
| 02                | AT+DEVEUI  |
| 03                | AT+CLASS   |
| 04                | AT+APPEUI  |
| 05                | AT+APPKEY  |
| 06                | AT+ACTMODE |
| 07                | AT+FPORT   |

Table 6-3 Correspondence Table between AT Command Numeric String and AT Command String

| AT Command numeric string <sup>Note1</sup> | AT Command string                          |
|--|--|
| 0106                                       | AT+REGION=06                               |
| 02749050FFFE000C2C                         | AT+DEVEUI=749050FFFE000C2C                 |
| 0300                                       | AT+CLASS=00                                |
| 040123456701234567                         | AT+APPEUI=0123456701234567                 |
| 0555555555555555AAAAAAAAAAAAAAAA           | AT+APPKEY=5555555555555555AAAAAAAAAAAAAAAA |
| 0601                                       | AT+ACTMODE=01                              |
| 0710                                       | AT+FPORT=10                                |

Notes: 1. The first byte is the AT command number, and the rest is the parameter. The parameters vary depending on the communication environment with LoRaWAN Gateway.

**6.4.1.2 AT Command Result Code Format**

When AT command is sent to LoRaWAN module, the execution result is returned as ASCII character string. The FPB Host Application converts the execution result from an ASCII character string to a hexadecimal numeric string and sends it from the BLE module to the smartphone.

The format of the AT command execution result sent from the smartphone is shown below.

Hexadecimal AT command result format:

<AT command number <sup>Note1</sup>> <AT command execution result <sup>Note2</sup>> <Parameter flag <sup>Note3</sup>>

- Notes: 1. Refer to "Table 6-2 AT Commands Number Correspondence Table".
- 2. Refer to "Table 6-4 AT Command Execution Result".
- 3. Refer to "Table 6-5 AT Command Parameter Flag".

Table 6-4 AT Command Execution Result

| AT Command execution result (ASCII) | AT Command execution result (Hexadecimal) |
|-------------------------------------|---|
| OK                                  | 01  |
| ERROR                               | 00  |

### 6.4.1.3 AT Command Parameter Flag

The AT command execution result set to the LoRaWAN module is saved in the FPB (RL78 / G14) data flash as a bit field parameter flag. The parameter flag is read at the start of the program to determine whether LoRaWAN module communication is possible. The AT command parameters set from the smartphone via BLE module communication are saved to the FPB data flash after the BLE module detects disconnection from the smartphone. If the FPB power is turned off or E2Lite is disconnected without disconnecting from the smartphone, the parameter flag is not saved in the FPB data flash, so set it again.

Table 6-5 AT Command Parameter Flag

| bit | bit name |
|-----|----------|
| 0   | region   |
| 1   | deveui   |
| 2   | class    |
| 3   | appeui   |
| 4   | appkey   |
| 5   | actmode  |
| 6   | fport    |
| 7   | -        |

### 6.4.2 LoRaWAN Gateway End of Communication Command

This command is sent from LoRaWAN Network Server to terminate sensor data communication with LoRaWAN Gateway. When LoRaWAN module receives the command, Host Application finishes sending sensor data and enters IDLE state.

Communication end command: 11223344

### 6.5 BLE Modem Structure - UART 2-wire with branch connection

This section describes the UART 2-wire branch connection method used for serial communication with the BLE module. Refer to "Table 3-1 Pin Assignment of PMOD1" for connection of FPB and BLE module using UART 2-wire branch connection method.

#### 6.5.1 Transmission Process

To perform transmission from the FPB (Host MCU) to the BLE module (BLE MCU), handshake is required. A handshake is performed by send REQ byte (0xC0) from the Host MCU and send ACK byte (0x88) or RSCIP packet from the BLE MCU. When handshaking is performed, monitoring is performed by a timer, and when a timeout occurs, handshaking is re-executed. The Host MCU of UART driver for performing a handshake, it has a 5 state by the transmission status.

Table 6-6 UART driver transmission state

| STATE              | Description   |
|--------------------|---|
| T_IDLE             | Initialize UART driver. RSCIP packet transmission completion.             |
| T_REQUESTING       | During REQ byte transmission.   |
| T_RCV_BF_REQUESTED | Receive RSCIP packet from the module instead of ACK bytes.                |
| T_REQUESTED        | REQ byte transmission completion. (Wait for the ACK byte from the module) |
| T_ACTIVE           | During RSCIP packet transmission.   |

Transmission from the Host MCU to the BLE MCU, always start with REQ byte. After sending the REQ byte, Host MCU branches to one of the following operations by the receiving state.

- (a) The Host MCU has not received RSCIP packet from the BLE MCU (Figure 6-4)
- (b) The Host MCU is receiving RSCIP packet from the BLE MCU (Figure 6-5)
- (c) ACK byte reception time-out (Figure 6-6)

#### (a) The Host MCU has not received RSCIP packet from the BLE MCU

This state is RSCIP packet has not been transmitted from the BLE MCU, after sending the REQ byte from the Host MCU, the Host MCU is waiting to receive an ACK byte. The BLE MCU receives REQ byte and sends ACK byte. The Host MCU which received ACK byte sends RSCIP packet to the BLE MCU.

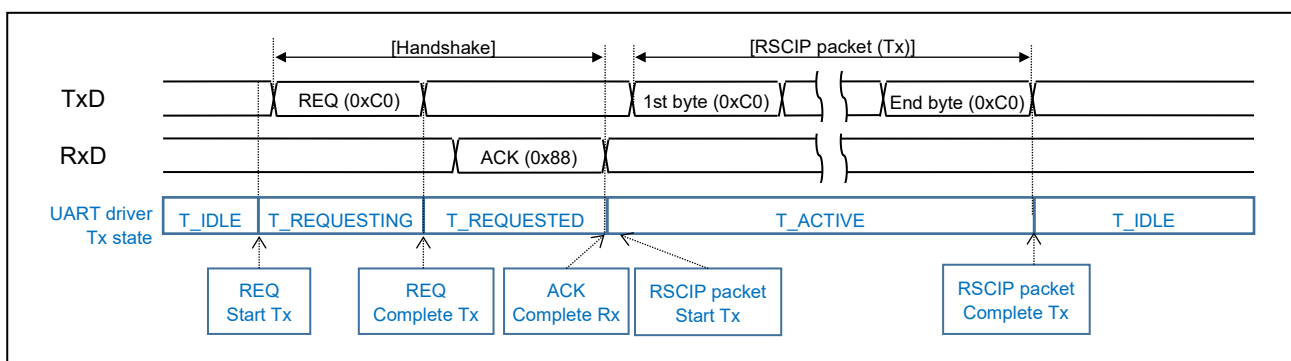


Figure 6-4 The Host MCU has not received RSCIP packet from the BLE MCU

**(b) The Host MCU is receiving RSCIP packet form the BLE MCU**

In this state, the BLE MCU is sending RSCIP packets, and the Host MCU is receiving RSCIP packets. **Even** if a module receives REQ, ACK byte isn't returned. RSCIP packet which is being sent is made a substitute of ACK byte. The Host MCU regards RSCIP packet from the BLE MCU as a substitute of ACK byte. And RSCIP packet is sent to the BLE MCU.

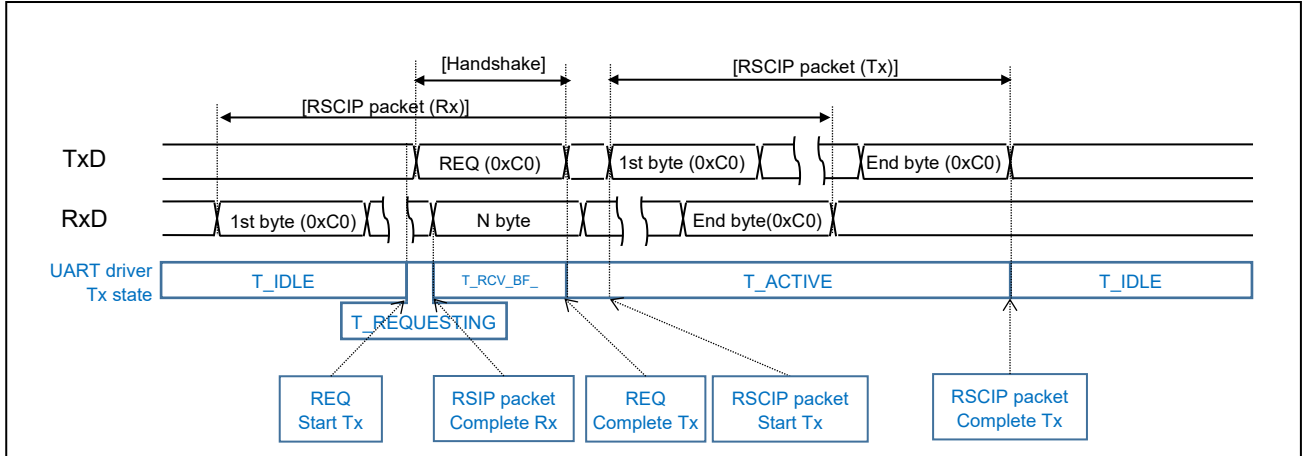


Figure 6-5 The Host MCU is receiving RSCIP packet from the module

**(c) ACK byte reception time-out**

After sending REQ byte, the Host MCU starts a timeout timer. If the ACK byte is not received for a certain time, and then the REQ byte is retransmitted.

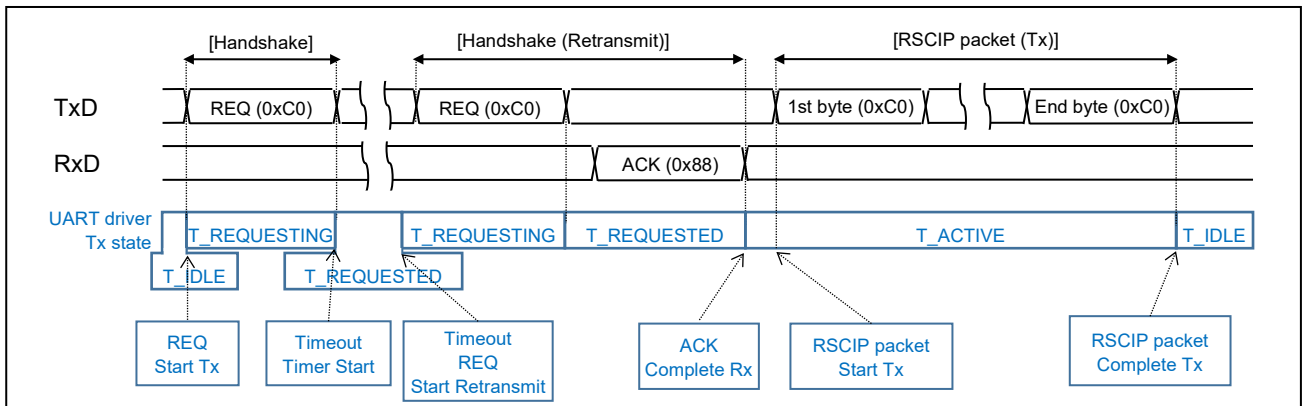


Figure 6-6 ACK byte reception time-out

**6.5.2 Reception Process**

There is no state transition of a UART driver at the reception. In order to receive the data from the BLE MCU, it listens for RSCIP packet from the BLE MCU in the specified number of bytes from the rBLE\_Host.

## 7. BLE Sequence Chart

The communication sequence of Local Device consisting of Host MCU and BLE MCU and Remote Device such as smartphone is shown.

### 7.1 Main sequence chart

In the Main Sequence Chart, the processing blocks of 10 steps are shown. The detail of each processing block is shown in following sections.

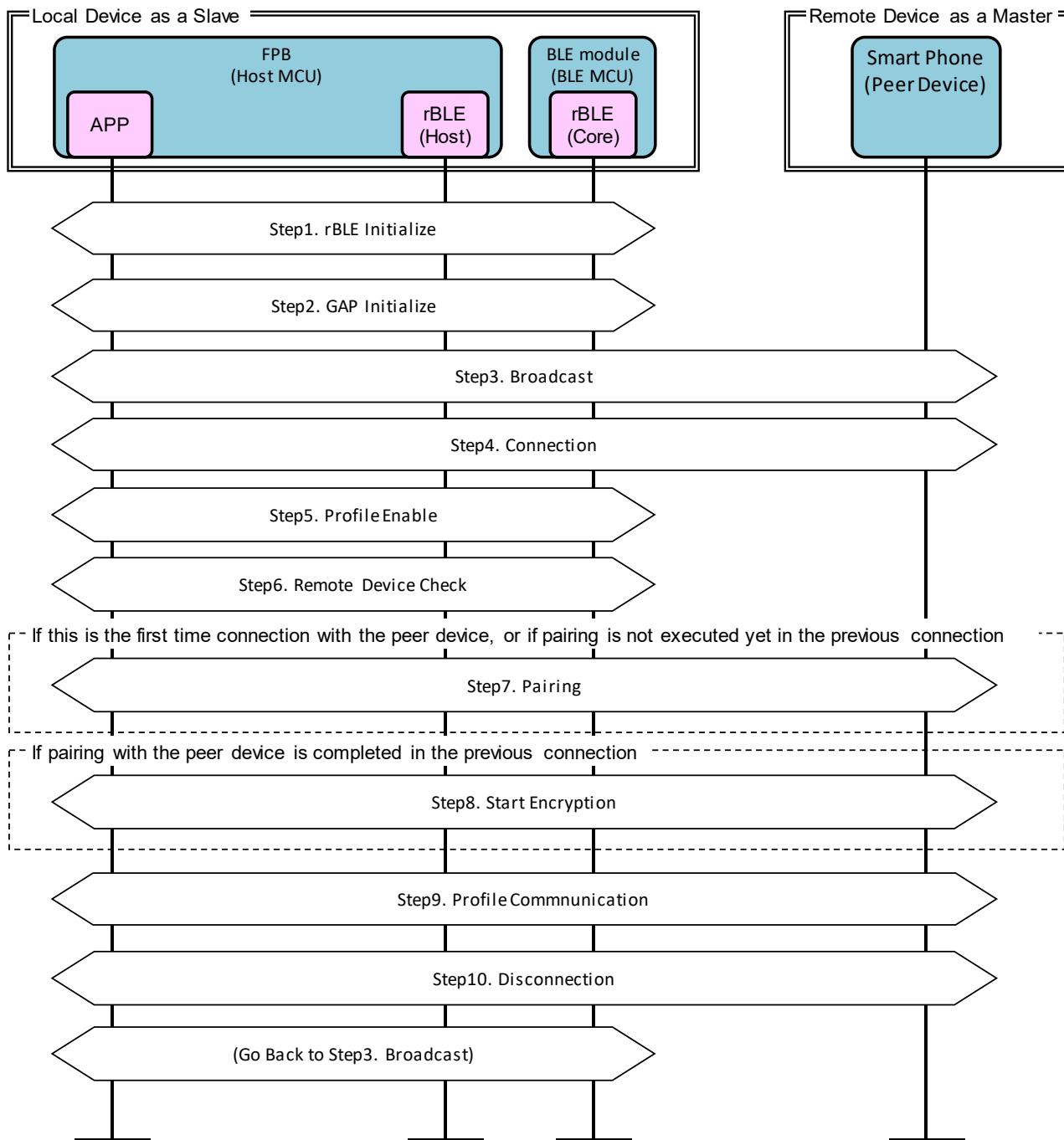


Figure 7-1 Main sequence chart



### 7.2 Step1. rBLE Initialize sequence

APP calls "RBLE\_Init" function to initialize rBLE (rBLE\_Host and rBLE\_Core). After initializing rBLE and establishing communication to BLE MCU, rBLE informs "RBLE\_MODE\_ACTIVE" event.

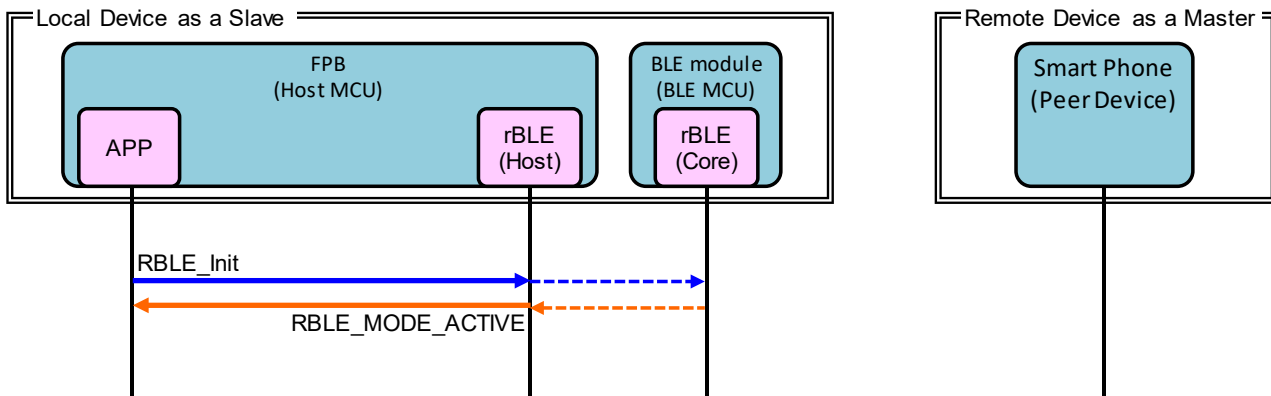


Figure 7-2 rBLE Initialize sequence chart

### 7.3 Step2. GAP Initialize sequence

APP calls "RBLE\_GAP\_Reset" function to reset GAP. After resetting rBLE, rBLE informs "RBLE\_GAP\_EVENT\_RESET\_RESULT" event.

APP calls "RBLE\_GAP\_Set\_Bonding\_Mode" function to permit the bonding with remote device. After setting the permission, rBLE informs "RBLE\_GAP\_EVENT\_SET\_BONDING\_MODE\_COMP" event.

APP calls "RBLE\_GAP\_Set\_Security\_Request" function to set security level. After setting security level, rBLE informs "RBLE\_GAP\_EVENT\_SET\_SECURITY\_REQUEST\_COMP" event.

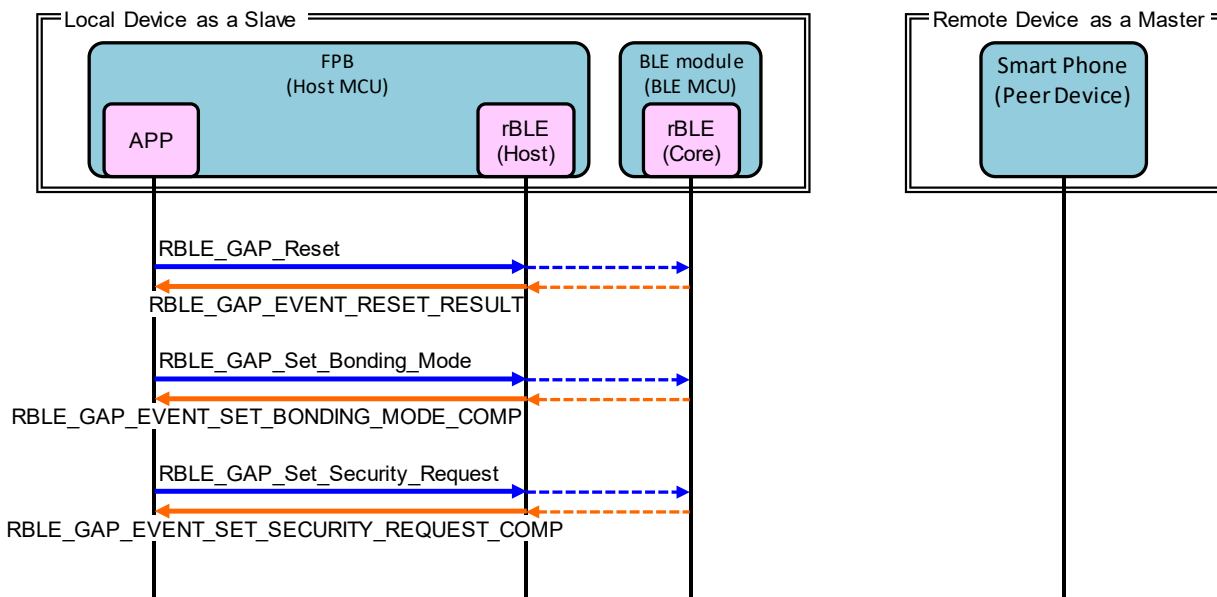


Figure 7-3 GAP Initialize sequence chart

### 7.4 Step3. Broadcast sequence

Local Device starts broadcasting to establish connection as a slave.

APP calls "RBLE\_GAP\_Broadcast\_Enable" function to start broadcasting. After starting the broadcast, rBLE informs "RBLE\_GAP\_EVENT\_BROADCAST\_ENABLE\_COMP" event.

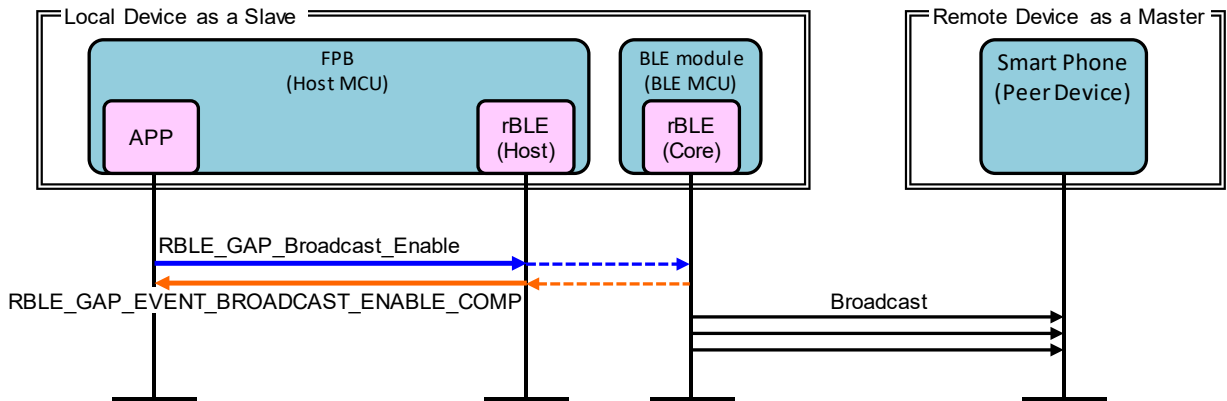


Figure 7-4 Broadcast sequence chart

### 7.5 Step4. Connection sequence

Remote Device receives the broadcast and requests to establish connection with Local Device.

If the connection between Remote Device and Local Device is established by receiving Connection Request from Remote Device, rBLE informs "RBLE\_GAP\_EVENT\_CONNECTION\_COMP" event.

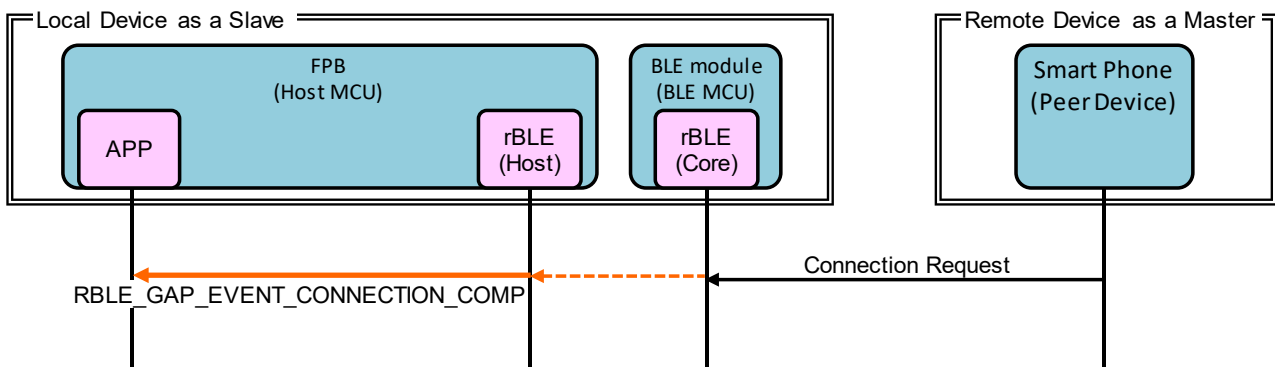


Figure 7-5 Connection sequence chart

### 7.6 Step5. Profile Enable sequence

Local Device enables GPCP (General Purpose Communication Profile) to send data.

APP calls "RBLE\_VUART\_Server\_Enable" function to enable GPCP. Enabling is complete when the Remote Device sends a Write Client Characteristic Configuration that allows Indication. Refer to "Figure 7-10 Profile Communication sequence chart".

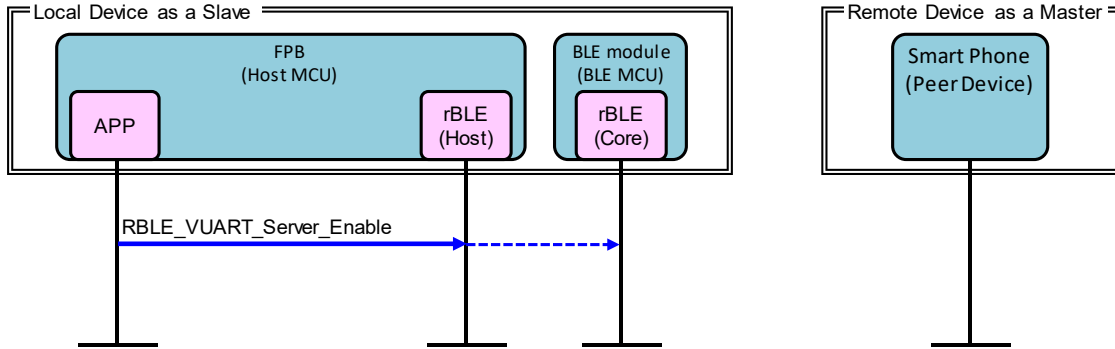


Figure 7-6 Profile Enable sequence chart

### 7.7 Step6. Remote Device Check sequence

Local Device confirms security information about Remote Device.

If the device address of Remote Device is public address or if it is random address except resolvable private address, rBLE informs "RBLE\_SM\_CHK\_BD\_ADDR\_REQ" event to acquire security information about Remote Device. APP calls "RBLE\_SM\_Chk\_Bd\_Addr\_Req\_Resp" function to inform security information.

If the device address of Remote Device is resolvable private address, rBLE informs "BLE\_SM\_IRK\_REQ\_IND" event to acquire IRK (Identify Resolving Key) which is used for resolving address. APP calls "RBLE\_SM\_Irk\_Req\_Resp" function to inform whether to have IRK or not and informs IRK. If resolving address is success, rBLE informs "RBLE\_GAP\_EVENT\_RPA\_RESOLVED" event. If resolving address is failed, rBLE informs "RBLE\_SM\_IRK\_REQ\_IND" event repeatedly until it is successful or until all of IRK which APP possess is checked.

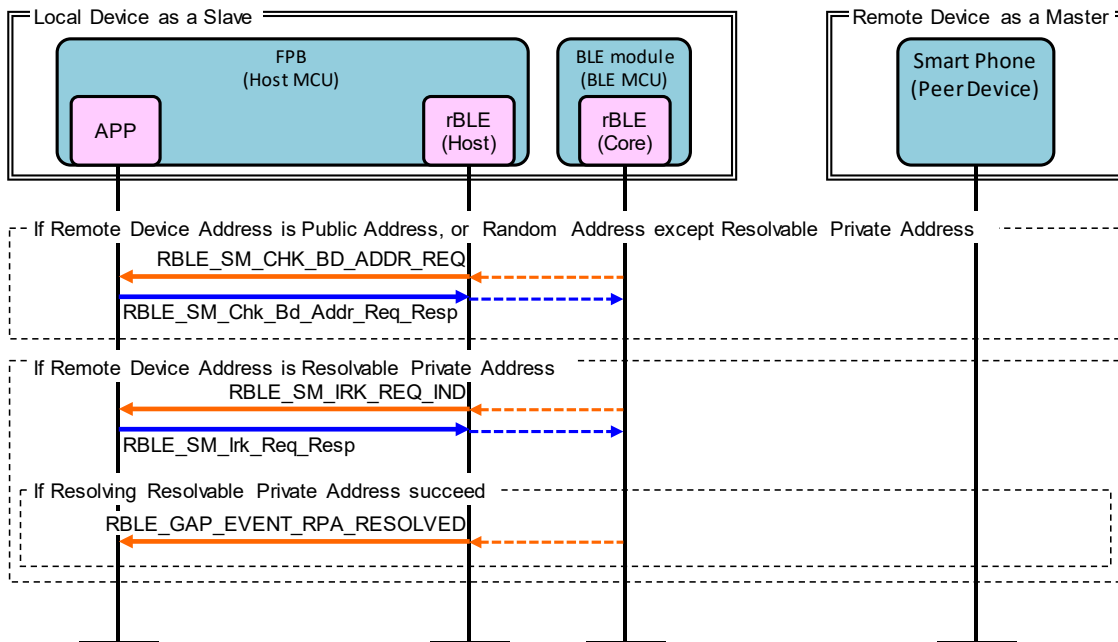


Figure 7-7 Remote Device Check sequence chart

## 7.8 Step7. Pairing sequence

If the connection with the Remote Device is first time or if pairing is not executed in previous connection, Local Device starts pairing sequence by request from Remote Device. Pairing sequence is consisted of PHASE1, PHASE2, starting encryption and PHASE3.

PHASE1 is for exchanging the pairing features between Local Device and Remote Device.

If Local Device receives Pairing Request from Remote Device, rBLE informs "RBLE\_GAP\_EVENT\_BONDING\_REQ\_IND" event. APP calls "RBLE\_GAP\_Bonding\_Response" function to send Pairing Response.

PHASE2 is for generating STK (Short Term Key).

rBLE informs "RBLE\_SM\_TK\_REQ\_IND" event to acquire TK (Temporary Key). APP calls "RBLE\_SM\_Tk\_Req\_Resp" function to inform TK. After generating STK by BLE\_MCU, Local Device and Remote Device start encrypting the contents of communication.

PHASE3 is for distributing encryption keys of Local Device and Remote Device.

rBLE informs "RBLE\_SM\_LTK\_REQ\_IND" event to acquire LTK (Long Term Key). APP calls "RBLE\_SM\_Ltk\_Req\_Resp" function to inform LTK and send Encryption Information (LTK).

By receiving Encryption Information (LTK) from Remote Device, rBLE informs "RBLE\_SM\_KEY\_IND" event.

By receiving Identity Information (IRK) from Remote Device, rBLE informs "RBLE\_SM\_KEY\_IND" event.

If pairing sequence is success, rBLE informs "RBLE\_GAP\_EVENT\_BONDING\_COMP" event.

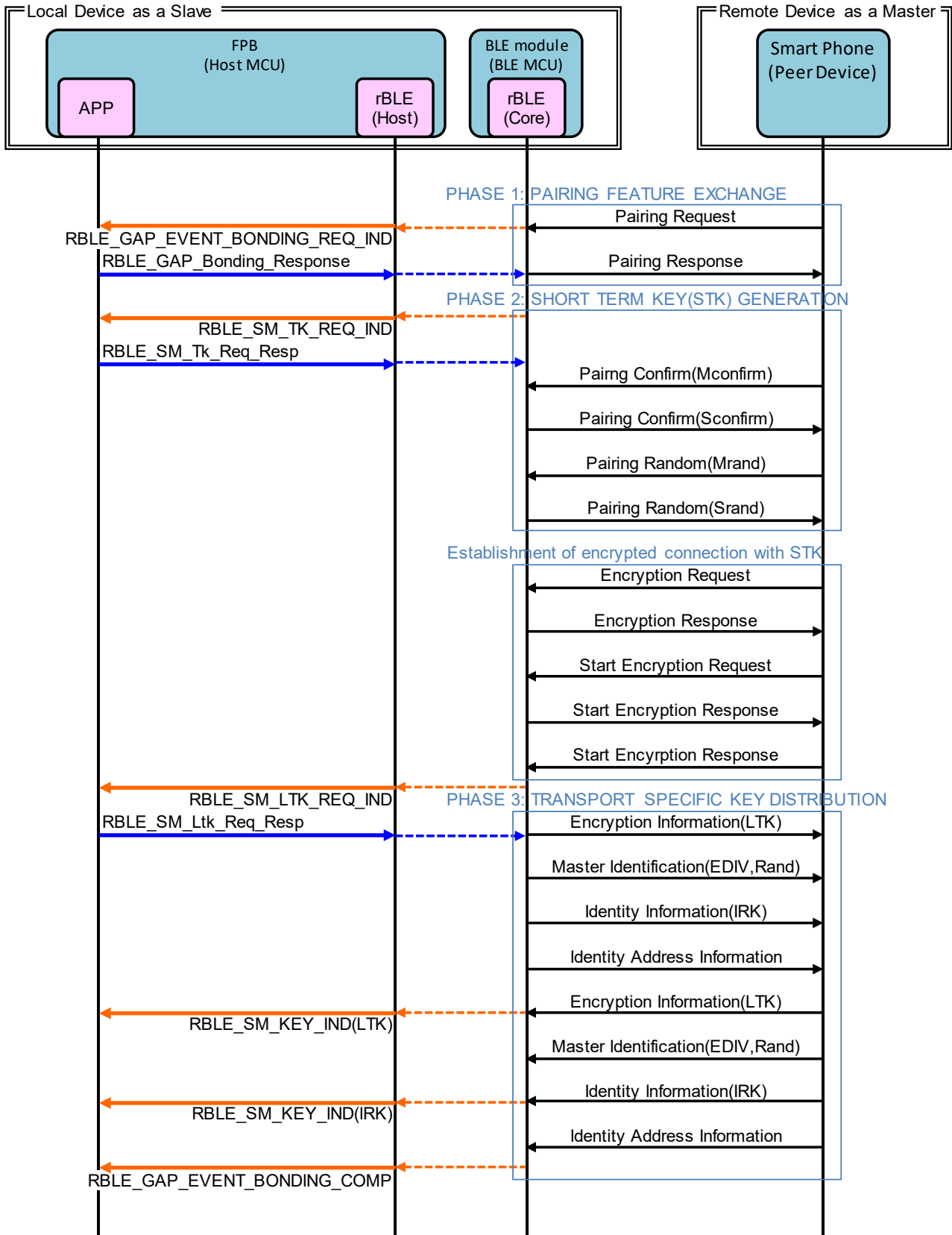


Figure 7-8 Pairing sequence chart



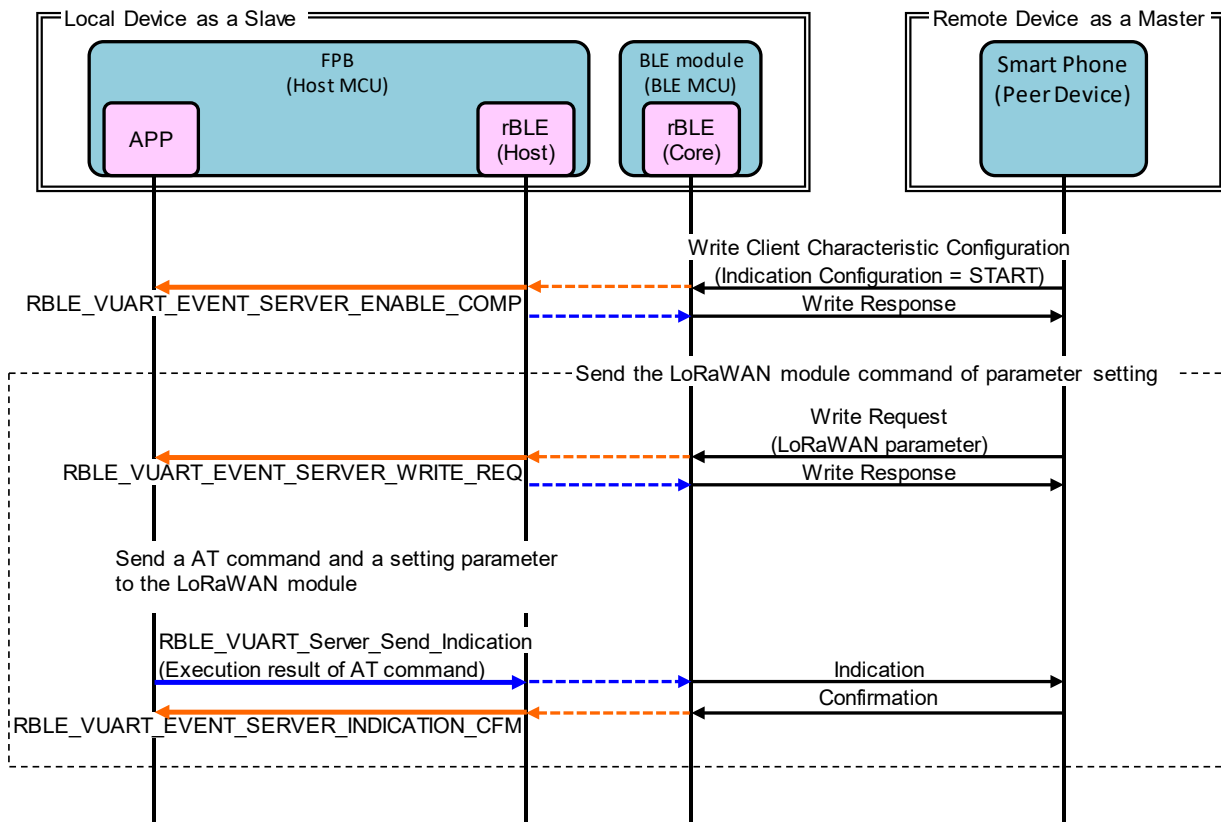


Figure 7-10 Profile Communication sequence chart

**7.11 Step10. Disconnection sequence**

By receiving Disconnect from Remote Device, rBLE disconnects connection and informs “RBLE\_GAP\_EVENT\_DISCONNECT\_COMP” event.

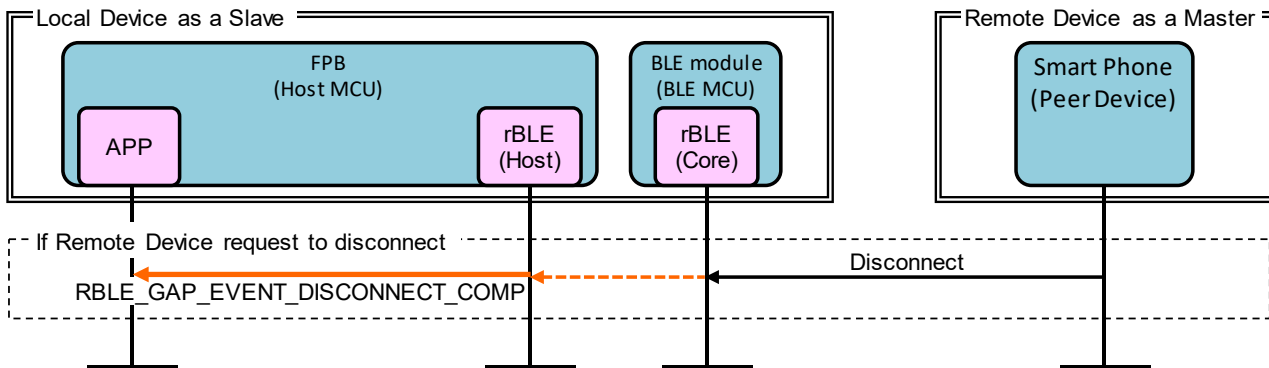


Figure 7-11 Disconnection sequence chart

### 8. LoRaWAN module AT Command Sequence Chart

This chapter describes the AT command sequence that communicates with FPB Host Application and LoRaWAN module.

#### 8.1 Main Sequence

The AT command sequence is divided into processing blocks Steps 1 to 3.

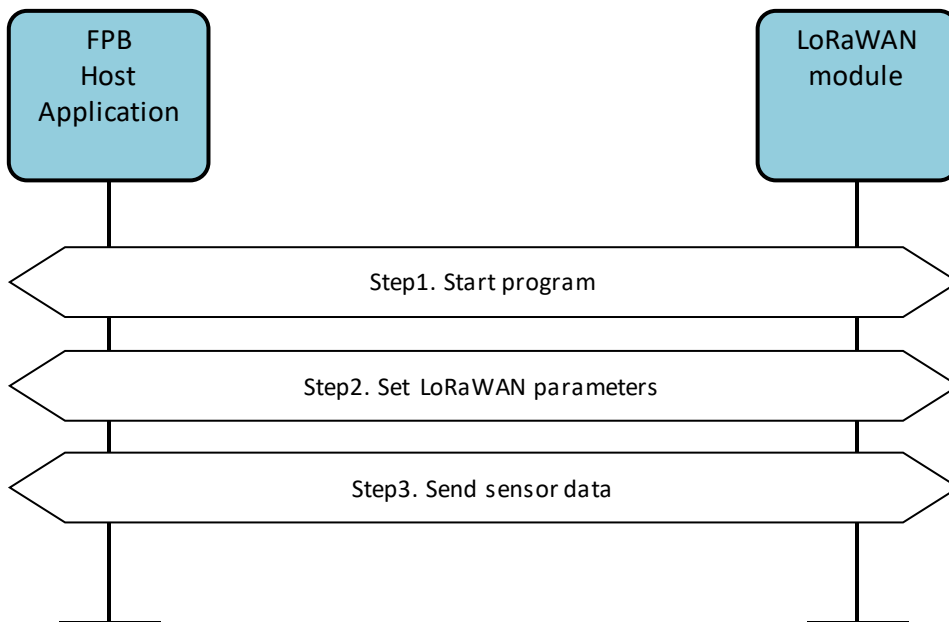


Figure 8-1 AT Command Main Sequence

#### 8.2 Step1. Start program

Echo back from the LoRaWAN module is prohibited immediately after starting the program.

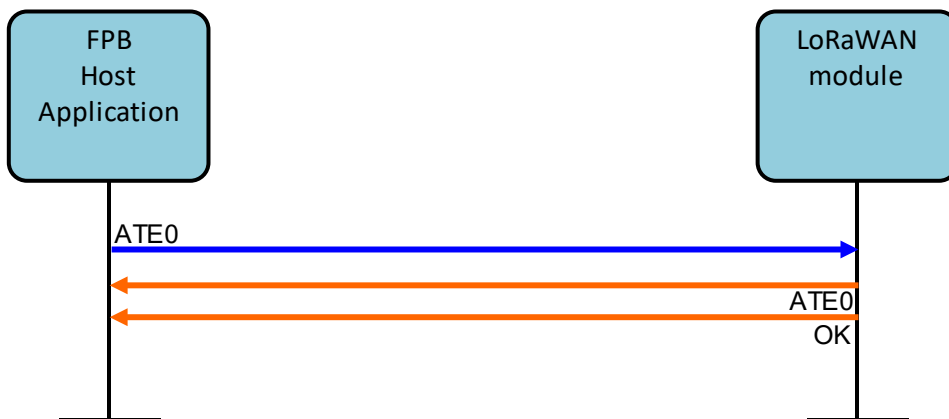


Figure 8-2 Start program



### 8.3 Step2. Set LoRaWAN parameters

Set parameters to LoRaWAN module with AT command.

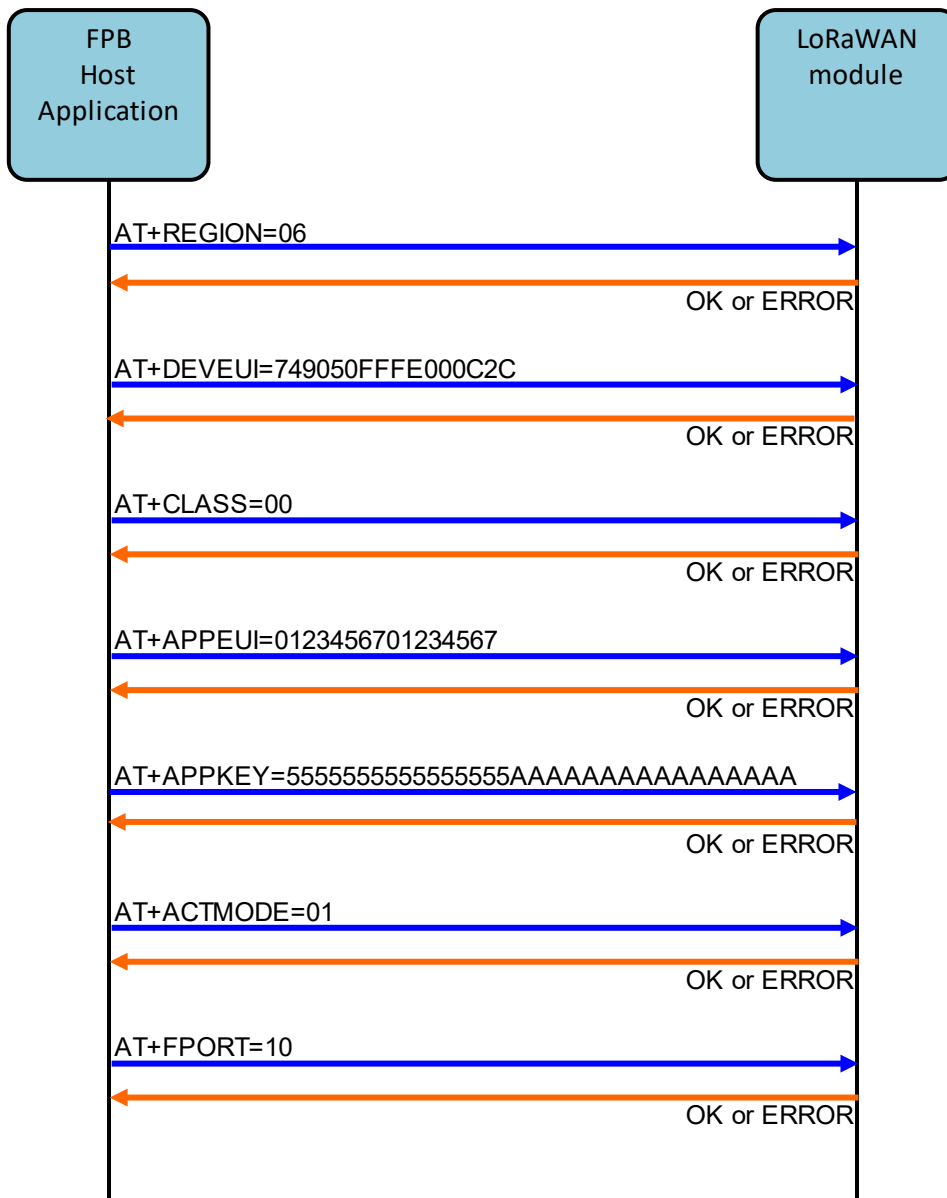


Figure 8-3 Set LoRaWAN parameters

### 8.4 Step3. Send sensor data

The AT command sequence for communicating with LoRaWAN Gateway is shown below. First, activate the LoRaWAN Gateway and start sending sensor data. To stop transmission, send a communication termination command from LoRaWAN Gateway.

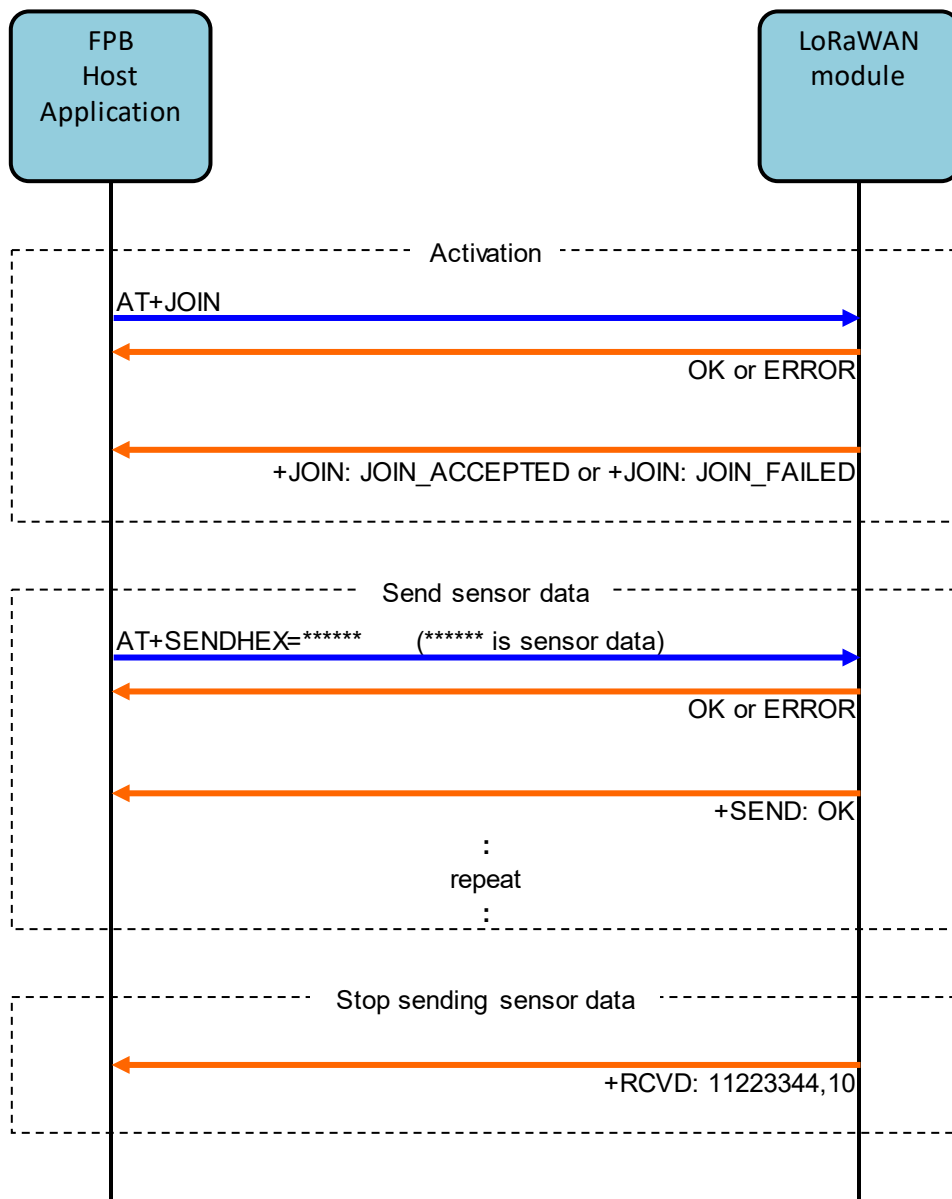


Figure 8-4 Send sensor data

## 9. Appendix

### 9.1 ROM size, RAM size

The ROM size and the RAM size which is used by this application is shown in "Table 9-1 ROM size, RAM size".

Table 9-1 ROM size, RAM size

| Compiler    | ROM (bytes) | RAM (bytes) |
|-------------|-------------|-------------|
| CC-RL V1.08 | 46,608      | 5,195       |

### 9.2 References

1. [Bluetooth Core Specification v4.2, Bluetooth SIG](#)
2. [Bluetooth SIG Assigned Numbers](#)
3. [Services UUID](#)
4. [Characteristics UUID](#)

**Revision History**

| Rev. | Date      | Description |                      |
|------|-----------|-------------|----------------------|
|      |           | Page        | Summary              |
| 1.0  | Dec.25.19 | -           | First edition issued |
|      |           |             |                      |

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

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## 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.

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