

Bluetooth® Low Energy Protocol Stack Introduction

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R01QS0014EJ0101
Renesas Electronics Corporation

BIG IDEAS
FOR EVERY SPACE

Introduction

This document will help you to understand Bluetooth low energy (BLE) Protocol Stack, before you start an application which works on RL78/G1D. This document introduces following items.

- Overview of BLE Protocol Stack
- Development Environment for BLE Application
- Documents for Developing BLE Application
- Sample Programs and Tools for Developing BLE Application

Note that [under-lined and blue word](#) has a link to web page or document.

Overview of BLE Protocol Stack

Device for BLE Protocol Stack

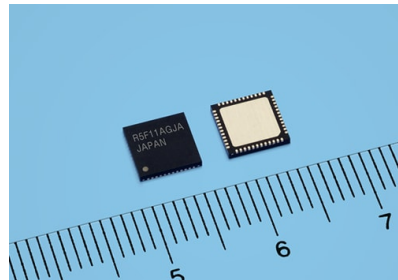
The BLE Protocol Stack works on RL78/G1D supporting Bluetooth low energy.

RL78/G1D ([Product Info](#))

A microcomputer incorporating the RL78 CPU core and RF transceiver supporting the Bluetooth low energy

RL78/G1D Module [RY7011] ([Product Info](#))

A module incorporating the RL78/G1D, a 32MHz crystal resonator for the RF transceiver, and an antenna



RL78/G1D

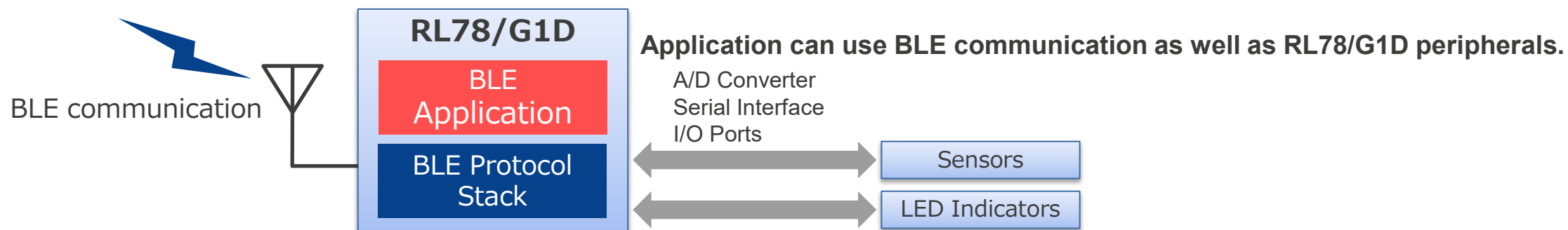


RL78/G1D Module
(including RL78/G1D)

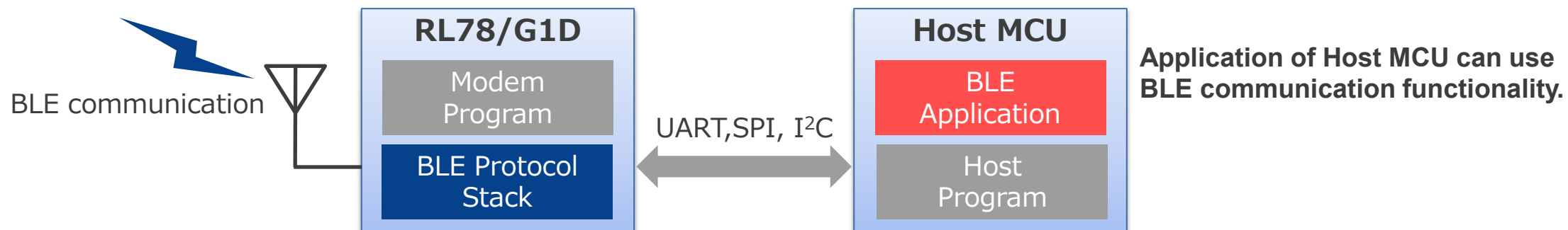
System Configuration of RL78/G1D

RL78/G1D can make either of the following **two system configurations** by using BLE Protocol Stack.

Embedded Configuration: RL78/G1D only



Modem Configuration: RL78/G1D and Host MCU which controls BLE communication

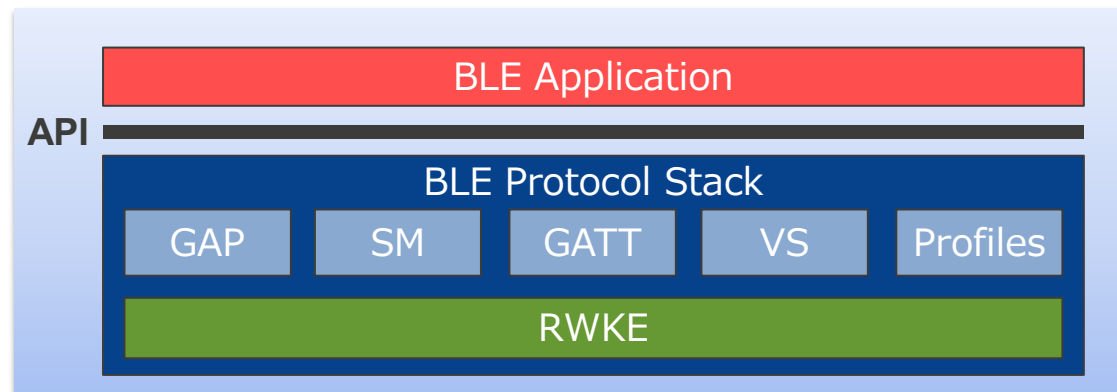


Functionalities of BLE Protocol Stack

The BLE Protocol Stack has the following functionalities.

BLE Application can use the functionalities of the BLE Protocol Stack by accessing API.

- **GAP (Generic Access Profile):** Device Discovery, Connection Management, and Security
- **SM (Security Manager):** Pairing, Authentication, and Encryption
- **GATT (Generic Attribute Profile):** Application Data Communication
- **Profiles:** GATT-based Data Communication specified by Bluetooth SIG
- **VS (Vendor Specific):** Extended Functionality specified by Renesas
- **RWKE:** simple OS Functionality



BLE Protocol Stack

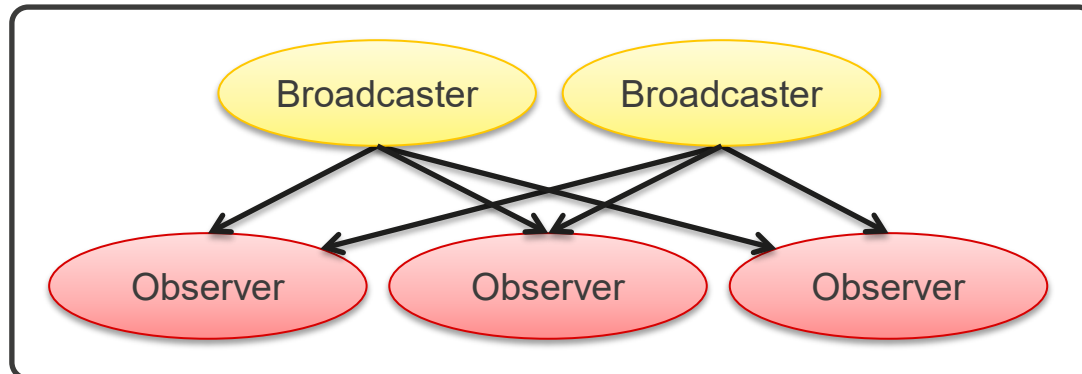
GAP(Generic Access Profile)

BLE Protocol Stack has the functionality of GAP (Generic Access Profile) to execute the follows:

- **Data Broadcast without establishing a connection**
- **Device Discovery in the surrounding area**
- **Establishment and Termination of a connection between peer device**

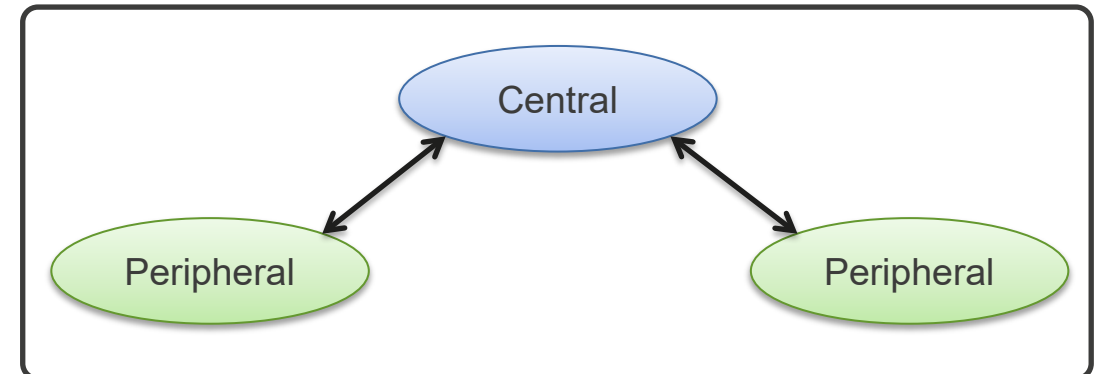
BLE Application can create the following networks.

Data Broadcast without establishing a connection



Broadcaster: transmits data to unspecified Observers
Observer: receives data from unspecified Broadcasters

Device Discovery and Connection



Peripheral: establishes connection to Central
Central: establishes connections to Peripherals (max.8)

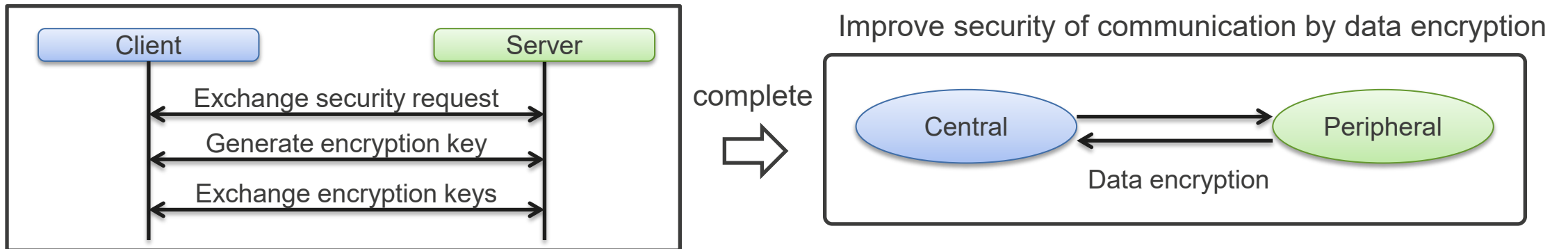
BLE Protocol Stack

SM(Security Manager)

BLE Protocol Stack has the functionality of SM (Security Manager) to execute the follows:

- Pairing for exchanging encryption keys
- Data Encryption, and Random Address Generation and Resolution

Pairing Sequence after connection



Pairing: Confirm security requirement and exchange the following encryption keys

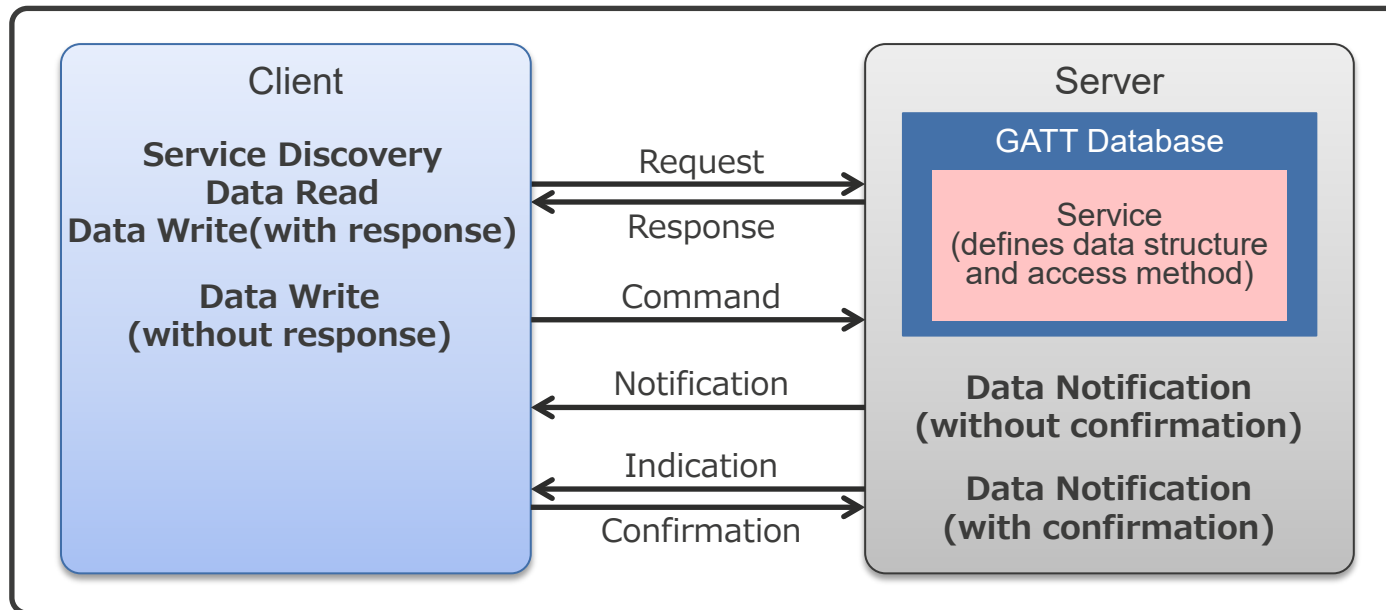
- Key to **encrypt data** (LTK)
- Key to **add a signature to data** (CSRK)
- Key to **change address dynamically** (IRK)

BLE Protocol Stack

GATT(Generic Attribute Profile)

BLE Protocol Stack has the functionality of GATT (Generic Attribute Profile) to **communicate application data** by the following Client / Server Architecture after establishing a connection.

Client / Server Architecture



BLE Application can communicate data in accordance with **the profile specified by user (custom profile)** by using the GATT functionality.

Note that which, of Central or Peripheral performs Client or Server, is different from each use-case.

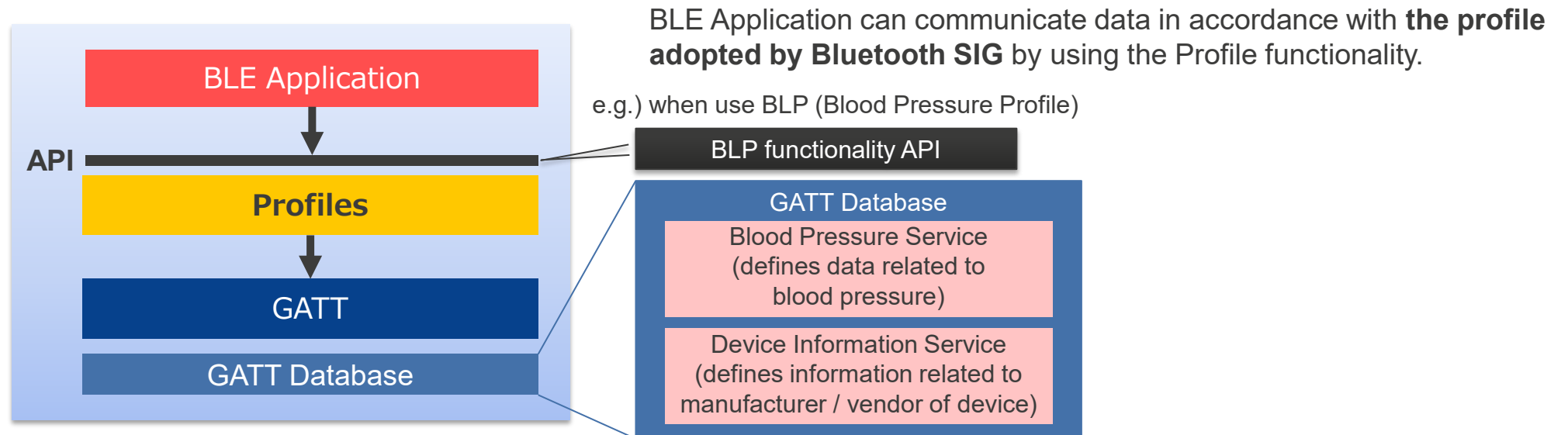
BLE Protocol Stack

Profiles

BLE Protocol Stack has the functionality to **communicate data in accordance with the GATT-based profile adopted by Bluetooth SIG such as the follows .**

BLE Protocol Stack corresponds to multiple profiles:

FMP(Find Me), PXP(Proximity), HTP(Health Thermometer), HRP(Heart Rate), BLP(Blood Pressure), GLP(Glucose), HOGP(HID Over GATT), CPP(Cycling Power), CSCP(Cycling Speed and Cadence), TIP (Time Profile), etc.



BLE Protocol Stack

VS (Vendor Specific)

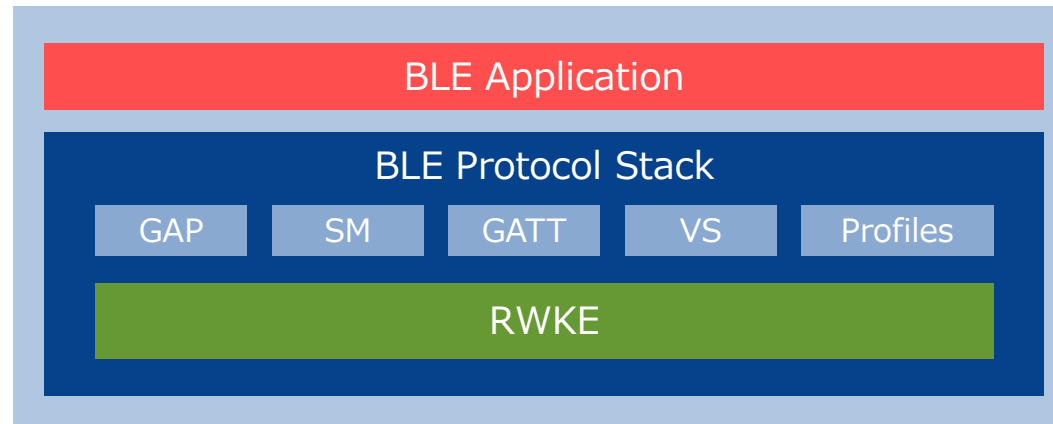
The BLE Protocol Stack has the following vendor specific functionalities to control and evaluate RL78/G1D.

- **Peak Current Notification** : notifies start and stop of transmission and reception operation of RF unit
- **Sleep** : switches MCU and RF state to low power consumption mode automatically
- **Bluetooth Device Address Write** : writes device address to data flash memory area
- **Direct Test Mode** : executes RF transmission and reception to evaluate RF characteristic
- **Transmission Power Selection** : changes RF transmission power
- **RF GPIO Port Control** : controls GPIO ports of RF unit
- **Adaptable Mode** : manages RF characteristic dynamically
- **RF Unit Power Control** : changes RF unit power states

BLE Protocol Stack

RWKE (Simple OS)

The BLE Protocol Stack has a **simple OS functionality to manage BLE application processing.**



RWKE Functionalities

- **Kernel Event Management:** manages execution order of processing associated with an event such as interrupt
- **Message Communication Management:** manages a message to communicate parameter among processing
- **Task State Management :** manages a state of task, and switch processing in accordance with the task state
- **Timer Management :** manages a timer to execute after expiration of time
- **Memory Management :** allocates memory dynamically from heap area

Development Environment for BLE Application

Development Environment (Hardware)

- **RL78/G1D Evaluation Board [RTK0EN0001D01001BZ]** ([Product Info](#))



- **RL78/G1D BLE Module Expansion Board [RTKYRLG1D0B00000BJ]** ([Product Info](#))



- **On-chip Debugging Emulator**
 - **E2 Emulator Lite [RTE0T0002LKCE00000R]** ([Product Info](#))



Development Environment (Software)

- **BLE Protocol Stack** ([Product Info](#), [Download](#))
- **Flash Libraries**
 - **Data Flash Library** ([Product Info](#), [Download](#))
 - **Code Flash Library** ([Product Info](#), [Download](#))
- **Either one of IDE and Compiler**
 - **CS+**: CC-RL Compiler (recommended) or CA78K0R Compiler ([Product Info](#))
 - **e²studio**: CC-RL Compiler only ([Product Info](#))
 - **IAR Embedded Workbench for Renesas RL78 V2.21.5**: IAR Compiler only ([Product Info](#))
- **Flash memory programming software**
 - **Renesas Flash Programmer** ([Product Info](#))

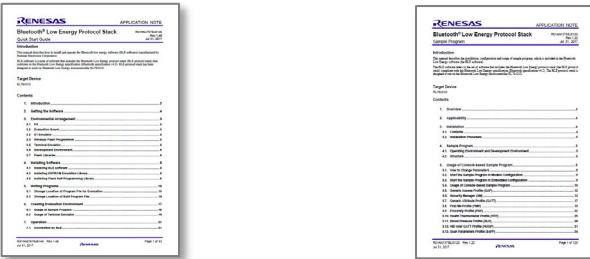
Sample Programs of BLE Protocol Stack

- **Programs for Evaluating Functionalities**
 - ✓ **Console-based Sample Program:** for evaluating BLE Functionalities by controlling through console
 - ✓ **Direct Test Mode Sample Program:** executes Direct Test Mode for evaluating RF characteristic of RL78/G1D
- **Programs for developing BLE Application**
 - ✓ **Modem Configuration Sample Program:** base program for developing Modem configuration BLE Application
 - ✓ **Simple Sample Program:** base program for developing Embedded configuration BLE Application
- **Practical Programs**
 - ✓ **Sample Custom Profile Sample Program:** executes a demonstration by using custom profile
 - ✓ **FW Update Program:** update BLE Application of RL78/G1D by BLE communication

Documents for Developing BLE Application

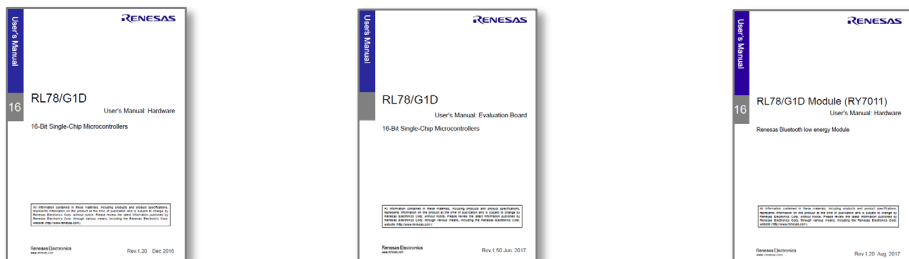
Documents for Developing BLE Application

For evaluating BLE Protocol Stack



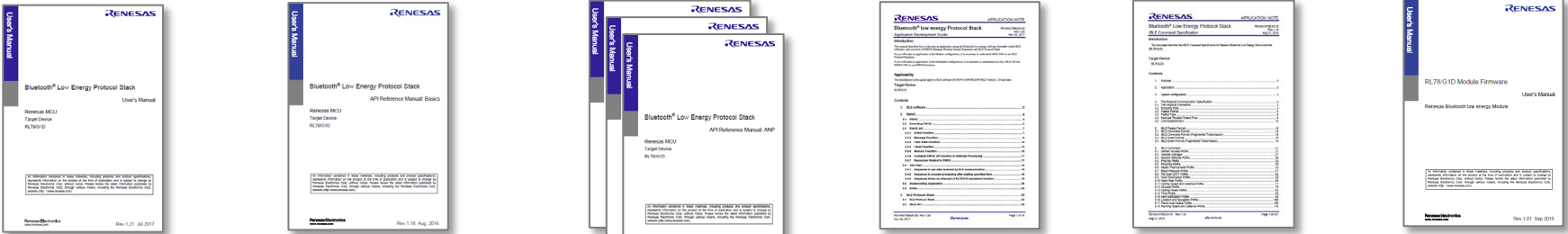
[Quick Start Guide](#) [Sample Program Application Note](#)

Hardware Specification



[RL78/G1D User's Manual](#) [RL78/G1D Evaluation Board User's Manual](#) [RL78/G1D Module User's Manual](#)

For developing BLE Application

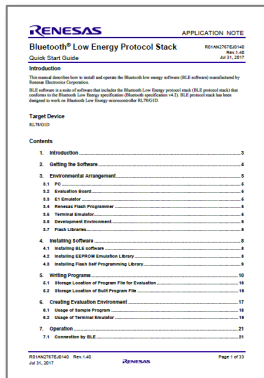


[User's Manual](#) [API Reference Manual Basics](#) [API Reference Manual Profiles](#) [Application Development Guide](#) [rBLE Command Specification](#) [RL78/G1D Module Firmware User's Manual](#)

Quick Start Guide

Environment Setup for Developing BLE Application

The Quick Start Guide describes **procedures to setup environment for developing BLE Application, and evaluate.**



Quick Start Guide

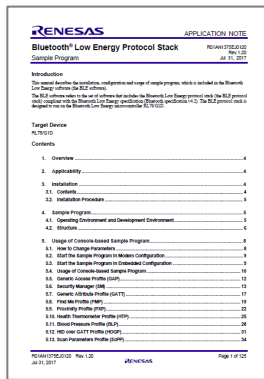
- **BLE Protocol Stack Quick Start Guide ([Download](#))**

- ✓ How to get environment (Chapter 1 - Chapter 3)
- ✓ How to setup environment (Chapter 4 - Chapter 6)
- ✓ How to evaluate BLE wireless communication (Chapter 7)
- ✓ How to customize and build BLE firmware (Chapter 8 and Chapter 9)

Sample Program Application Note

Evaluation Procedure of BLE Protocol Stack Sample Program

Sample Program Application Note describes **procedures to evaluate sample programs** included in BLE Protocol Stack. Evaluating sample program will help you to understand how BLE communication works.



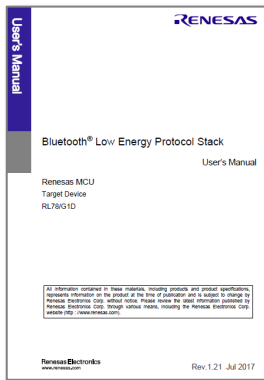
Sample Program Application Note

- BLE Protocol Stack Sample Program Application Note ([Download](#))
 - ✓ Console-based Sample Program (Chapter 5)
 - ✓ How to use Modem configuration (Section 5.2)
 - ✓ How to use Embedded configuration (Section 5.3)
 - ✓ How to evaluate GAP, SM, GATT, and Profiles (Section 5.5 – Section 5.19)
 - ✓ Simple Sample Program (Chapter 6)
 - ✓ Direct Test Mode Sample Program (Section 7.7)
 - ✓ FW Update Sample Program (Section 7.9)

User's Manual

Functional Specification of BLE Protocol Stack

User's Manual describes **software structure of BLE Protocol Stack and details of its functions**. This document will help you to understand functions provided by BLE Protocol Stack.



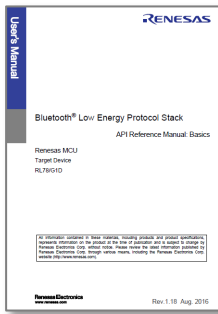
User's Manual

- **BLE Protocol Stack User's Manual ([Download](#))**
 - ✓ BLE Software Configuration (Chapter 5)
 - ✓ BLE Protocol Stack Features(Chapter 7, Chapter 11, and Chapter 12)
 - ✓ GAP (Section 7.2)
 - ✓ SM (Section 7.3)
 - ✓ GATT (Section 7.4)
 - ✓ Profiles (Section 7.5 – Section 7.19)
 - ✓ VS (Section 7.20)
 - ✓ FW Update (Chapter 11)
 - ✓ HCI Packet Monitor (Chapter 12)

API Reference Manual

API Specification of BLE Protocol Stack

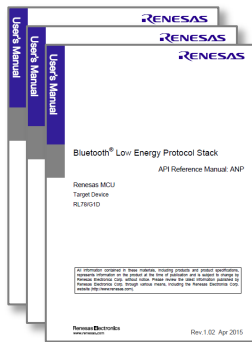
The API reference manual describes **API specification of BLE Protocol Stack**.



API Reference Manual: Basics

- **BLE Protocol Stack API Reference Manual: Basics** ([Download](#))

- ✓ GAP API (Chapter 5)
- ✓ SM API (Chapter 6)
- ✓ GATT API (Chapter 7)
- ✓ VS API (Chapter 8)
- ✓ RWKE API (Chapter 9)



API Reference Manual: Profiles

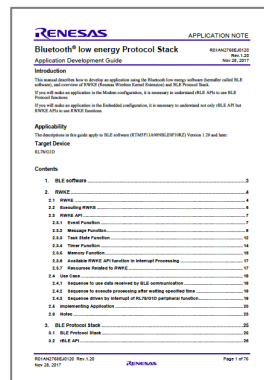
- **BLE Protocol Stack API Reference Manual: Profiles**

FMP, PXP, HTP, BLP, HOGP, ScPP, HRP, CSCP, CPP, GLP, TIP, RSCP, ANP, ...,etc

Application Development Guide

How to Implement BLE Application

Application Development Guide shows how to use API of BLE Protocol Stack.
This document will help you to understand how to implement BLE Application.



Application Development Guide

■ BLE Protocol Stack Application Development Guide ([Download](#))

- ✓ How to use RWKE API (Chapter 2)
- ✓ How to use rBLE API (Chapter 3)
- ✓ How to implement Custom Profile (Chapter 4)
- ✓ Overview of Application Operation (Chapter 5)
- ✓ Development Tips (Chapter 6)

rBLE Command Specification

Specification of RSCIP Communication in Modem Configuration

rBLE Command Specification describes **the specification of RSCIP which is serial communication protocol**. This document will help you to understand serial communication protocol in Modem configuration.

The image shows the cover page of the 'rBLE Command Specification' document. It features the Renesas logo at the top left and the title 'rBLE Command Specification' in the center. Below the title, there is a table of contents with the following items:

1. Region	3
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3. System configuration	3
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4.3 Physical Type	4
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rBLE Command Specification

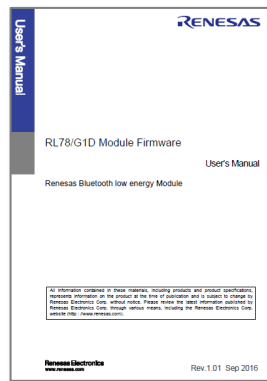
- BLE Protocol Stack rBLE Command Specification ([Download](#))

- ✓ RSCIP Communication Protocol Specification (Chapter 4)
- ✓ rBLE Packet Format Specification (Chapter 5)
- ✓ rBLE Command Format Details (Chapter 6)
- ✓ rBLE Event Format Details (Chapter 7)

RL78/G1D Module Firmware User's Manual

Specification of RL78/G1D Module Firmware

RL78/G1D Module Firmware User's Manual describes **specification, implemented profiles, and how to re-write the firmware of [RL78/G1D Module Firmware](#)**, which is optimized for RL78/G1D Module (RY7011).



RL78/G1D Module Firmware
User's Manual

- **RL78/G1D Module Firmware User's Manual** ([Download](#))
 - ✓ Firmware Specification (Chapter 5 and Chapter 6)
 - ✓ Profiles (Chapter 7)
 - ✓ How to Re-write Firmware (Chapter 8)

Other Useful Documents (1/2)

Following useful documents for developing BLE product are published.

Hardware Specification and Evaluation

- RL78/G1D User's Manual: Hardware ([Download](#))
- RL78/G1D User's Manual: Evaluation Board (RTK0EN0001D01001BZ) ([Download](#))
- RL78/G1D Module (RY7011) User's Manual: Hardware ([Download](#))
- RL78/G1D Measurement of Current Consumption Application Note ([Download](#))

Hardware Development

- RL78/G1D Guidelines for RF Board Design ([Download](#))
- Design data of the RL78/G1D Evaluation Module ([Download](#))
- RL78/G1D Design Guidelines for a Pattern Antenna ([Download](#))
- RL78/G1D Design of a Reference Antenna ([Download](#))

Other Useful Documents (2/2)

Following useful documents for developing BLE product are published.

Certification of the Radio Law

- RL78/G1D Testing for Certification of Compliance with the Radio Law (Japan) ([Download](#))

Certification of Bluetooth SIG

- BLE microcomputer / module Bluetooth qualification acquisition ([Download](#))

If You Want Help...

KNOWLEDGEBASE(FAQ): <https://en-support.renesas.com/knowledgeBase/category/31069>

The frequently asked questions are summarized in this web site.

Renesas Rulz: <https://renesasrulz.com/>

Renesas Rulz is a forum site to discuss technical topics with Renesas users.

Contact Us: <https://www.renesas.com/contact/>

This site guides to ask purchase and technical inquiry.

Sample Programs and Tools for Developing BLE Application

Sample Programs

Following sample programs using BLE Protocol Stack are released.

You can use these sample programs as a base program for developing BLE Application.

For Embedded Configuration

- [Embedded Configuration Sample Program](#)
- [Virtual UART Application](#)

For Modem Configuration (RL78/G1D Module)

- [RL78/G1D Module Control Software \(Including Module Firmware\)](#)

For Modem Configuration (Host MCU)

- [Host Sample \(RL78/G14 Renesas Starter Kit, RL78/G14 Fast Prototyping Board, RL78/I1E, or RX113\)](#)
- [Host Sample with Simple API \(RL78/G14 or RX113\)](#)

Other

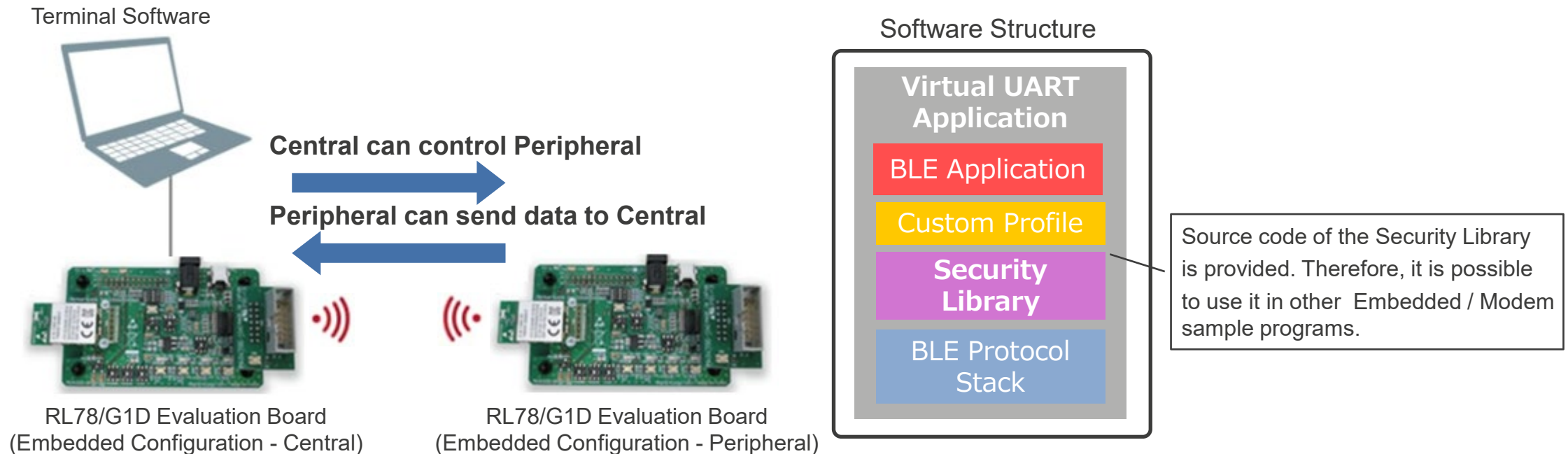
- [RL78/G1D Beacon Stack](#)

Embedded Configuration Sample Program

Base Program for BLE Application in Embedded Configuration

- **Embedded Configuration Sample Program** ([Download](#))

This sample program works as Central and Peripheral of Embedded Configuration, and it corresponds to simultaneous connections of Central. You can use it as a **base program for developing various applications**. Furthermore, it includes Security Library to use security function easily.



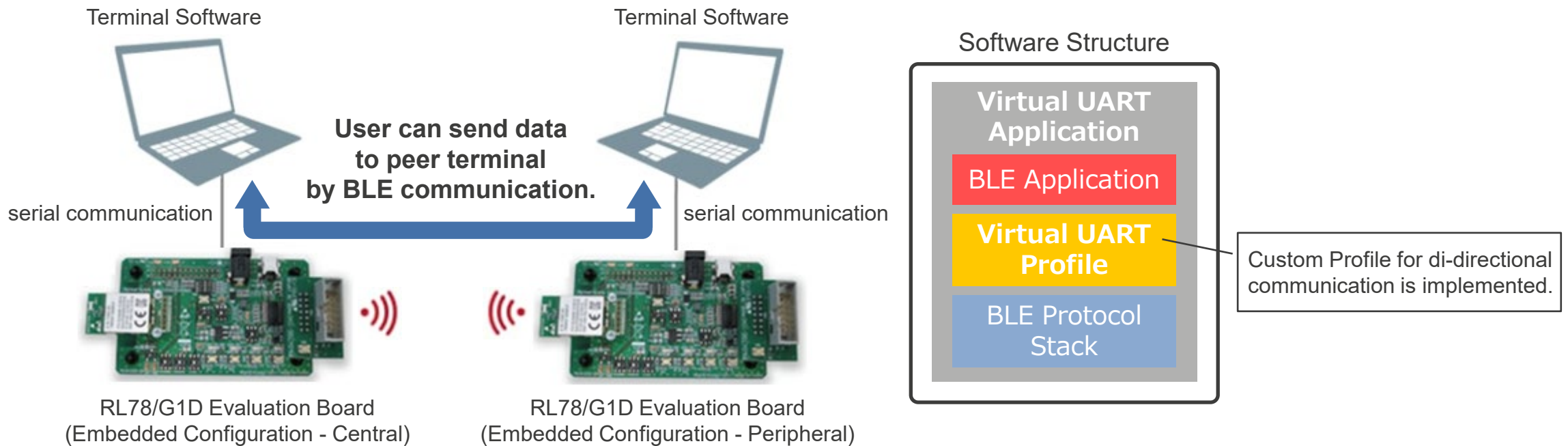
Embedded Configuration Virtual UART Application

Change from Serial Communication to Wireless Communication by RL78/G1D

- Virtual UART Application ([Download](#))

This sample program communicates characters di-directionally through terminal software.

You can use it for **changing wired communication such as UART to wireless communication** by using RL78/G1D.



Modem Configuration RL78/G1D Module Control Software

Sample Program optimized for RL78/G1D Module

- **RL78/G1D Module Control Software (Including Module Firmware)** ([Download](#))

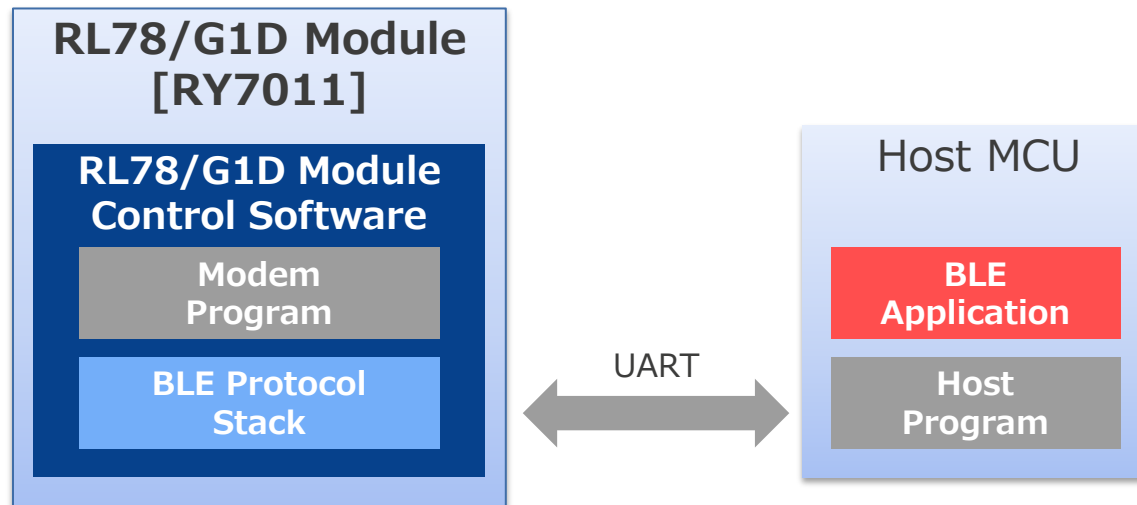
This sample program is Modem configuration software optimized for RL78/G1D Module RY7011 ([Product Info](#)).

The following custom profiles are implemented in this sample program.

- **General Purpose Communication Profile:** for di-directional communication among RL78/G1D and Host MCU
- **Firmware Update Profile:** for updating application of RL78/G1D

RL78/G1D Module Control Software

- Modem Configuration
- Optimized for RL78/G1D module
- Controlled by Host MCU



Modem Configuration Host Sample Program

Host Sample Program for RL78/G14 and RX113

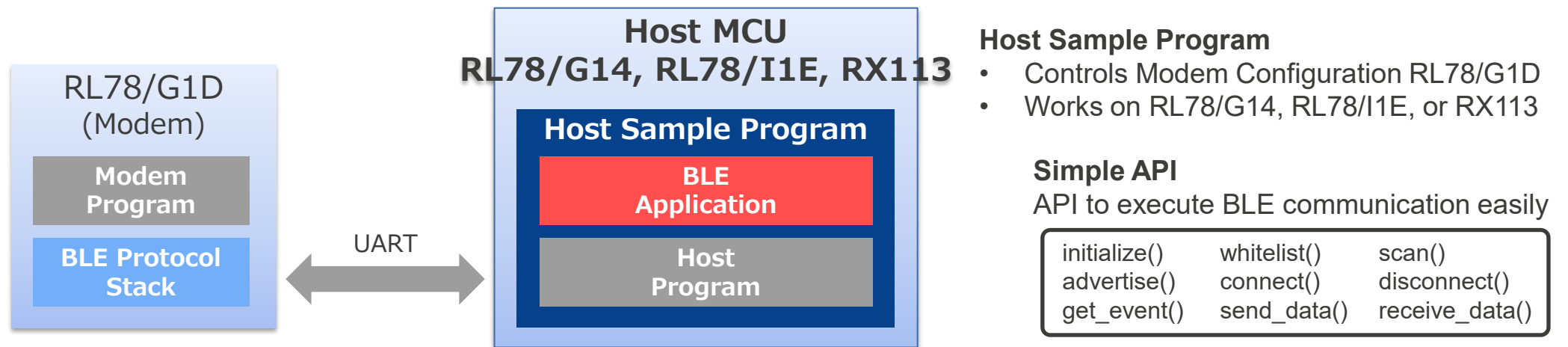
- **Host Sample** ([RL78/G14 Renesas Starter Kit](#), [RL78/G14 Fast Prototyping Board](#), [RL78/I1E](#), [RX113](#))

This sample program works on Host MCU to control Modem configuration RL78/G1D.

- **Host Sample with Simple API** ([RL78/G14](#), [RX113](#))

This is Host Sample that Simple API is added to above sample program.

General Purpose communication Profile and Firmware Update Profile are implemented in this sample.



RL78/G1D Beacon Stack

Software Stack optimized for BLE Beacon

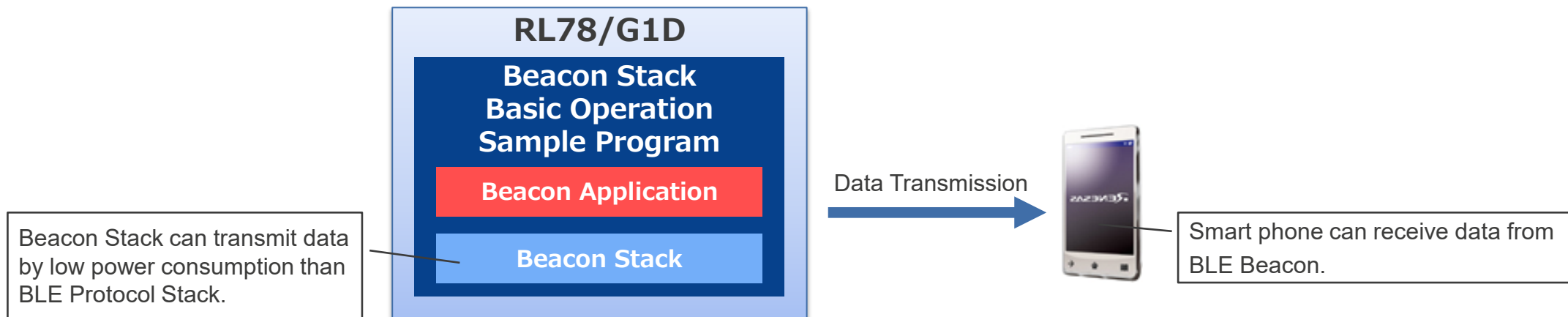
- **RL78/G1D Beacon Stack** ([Document](#))

RL78/G1D Beacon Stack is a software stack for RL78/G1D device as a BLE Beacon.

Library of the Beacon Stack is included in the following samples.

- **Basic Operation Sample Program** ([Download](#), [Document](#))

- **Connecting and Updating Beacon Data Sample Program** ([Download](#), [Document](#))



Tools

The following tools to generate source code or execute BLE wireless communication are released. You can use these tools for developing or evaluating BLE Application of RL78/G1D.

Tool for evaluating Modem Configuration

- [GUI Tool](#) : tool for controlling BLE communication of Modem configuration RL78/G1D by GUI
You can use for initial evaluation of BLE communication and confirmation of API sequence.

BLE Communication Tool for smart phone

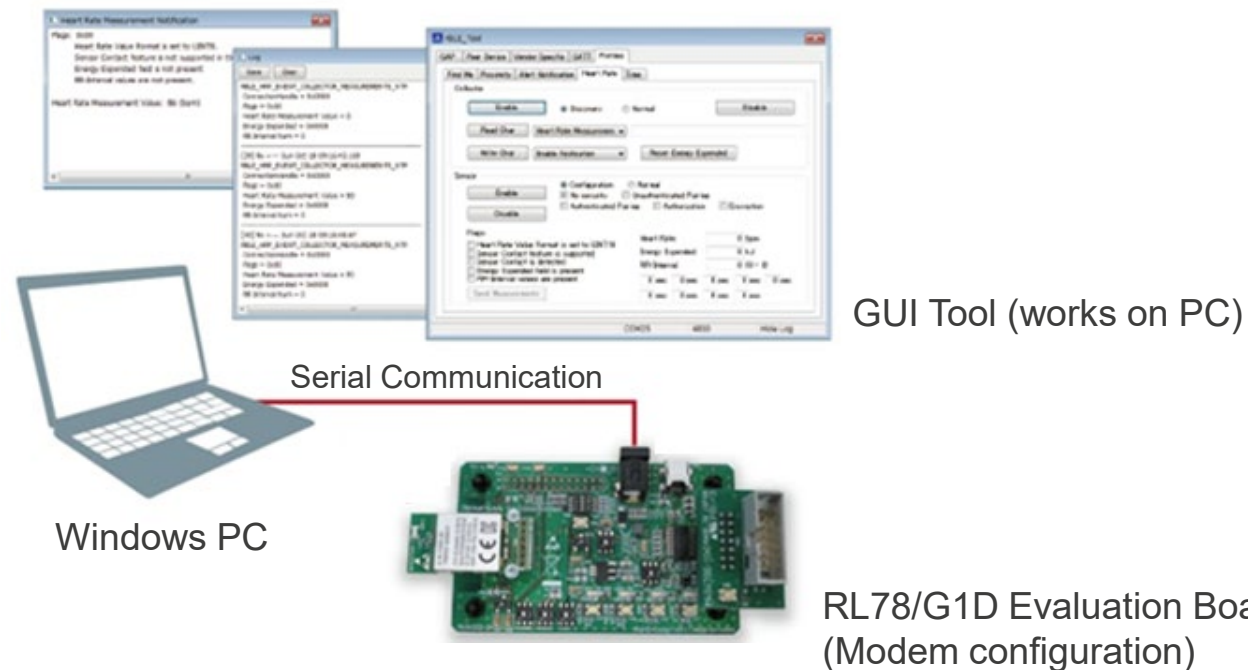
- [GATTBrowser \(iOS or Android\)](#) : smart phone application for executing GATT-based communication
You can use smart phone as a peer device in evaluating the sample program or debugging BLE application.

GUI Tool

Tool for Evaluating Modem Configuration

- GUI Tool ([Download](#))

This tool works on PC and controls BLE communication of Modem configuration RL78/G1D by GUI. You can use for initial evaluation of BLE communication and confirmation of API sequence.



GATTBrowser

Application to BLE-Communicate by Using Smart Phone

- **GATTBrowser** ([iOS](#), [Android](#))

This tool works on smart phone and communicates with BLE device by GATT-based.

When evaluate functionality of the sample programs or debug BLE Application in development, **you can use smart phone as a peer device of RL78/G1D.**



GATTBrowser (works on Android device or iOS device)



RL78/G1D Evaluation Board
(Embedded and Modem configuration)

BIG IDEAS FOR EVERY SPACE

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