LoRa®-based Solutions for RA Family

Introduction

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RENESAS ELECTRONICS CORPORATION

Introduction

This guide provides an overview of the protocol stacks, evaluation tools, software development environment for better understanding before starting the development of the LoRaWAN® and LoRa® based applications.
This document covers the following topics:

- **LoRa®/LoRaWAN® Overview**
- **LoRa®-based Solution for RA Family (Protocol Stacks, Evaluation Tools)**
- **Software Development Environment**

Note that blue and underlined text indicates a link to a web page or document.

(For your reference)
For RL78 family, "Introduction of LoRa®-based Solutions for RL78 Family (EP2P-AA-24-0398)" is also available in the following web page.

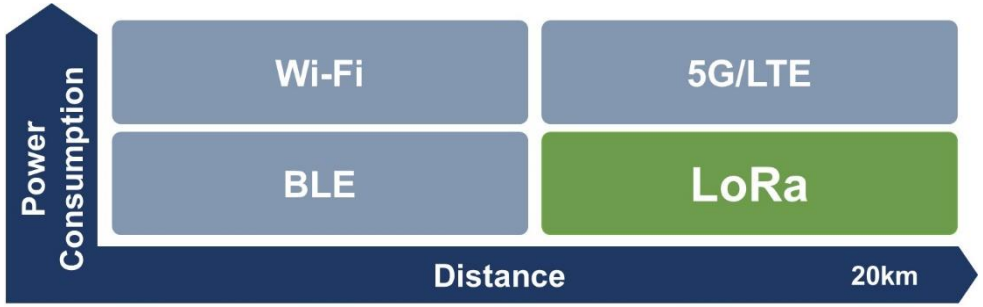
LoRa®-based Solutions for RL78 Family Web Page
https://www.renesas.com/us/en/application/communication-computing-infrastructure/wireless-network/lora-solutions/lora-solution-rl

LoRa® / LoRaWAN® Overview

About LoRa® and LoRaWAN®

LoRa® is a modulation technique, and LoRaWAN® is a standardized protocol that uses the LoRa®-based modulation technique.

- **LoRa® (Long Range)**
  - A spread spectrum modulation technique derived from chirp spread spectrum (CSS) technology developed by Semtech Corporation.
  - Suitable for long distance (Up to 20km in line of sight), low data rate (several hundreds of bps to several tens of kbps), low power consumption communication.
  - LoRaWAN® protocol on top of LoRa®-based modulation has been standardized.
  - Custom protocol on top of LoRa®-based modulation can be adopted.
- **LoRaWAN® (LoRa® Wide Area Network)**
  - Communication protocol for low power and long distance targeted for IoT devices, standardized by LoRa Alliance®.
  - Modulation schemes of LoRa® and GFSK (Gaussian Frequency Shift Keying) are utilized.



Application examples for LoRa® / LoRaWAN®

Wireless Data Communication with Low Quantity Data, Low Rate, Less Frequent and Periodic, Wide Range

- **Metering**
  - Data gathering for town/propane gas, water flowmeter etc.
  - Data gathering of POS system for vending machine e.g. beverage

- **Industry / Building**
  - Data management/forwarding of infrastructure for traffic network e.g. bus, taxi, rent-a-car, bicycle, traffic signal, street light, etc.
  - Data gathering for monitoring on large structure e.g. tunnel, bridge, buildings, signboard
  - Building management related: open/close-door, locking, operation management for air conditioning / lighting / curtain, operation & position management for elevator / escalator, inventory management at warehouse, alarm for alert region
  - Centralized data management for agriculture / stockbreeding e.g. watering, positioning system for livestock, monitoring for bird flu etc.

- **Consumer / Home**
  - Data management/forwarding for wearable gadget for healthcare
  - Tracking system for person e.g. children, elderly people.

Requirements for LPWA Wireless Network

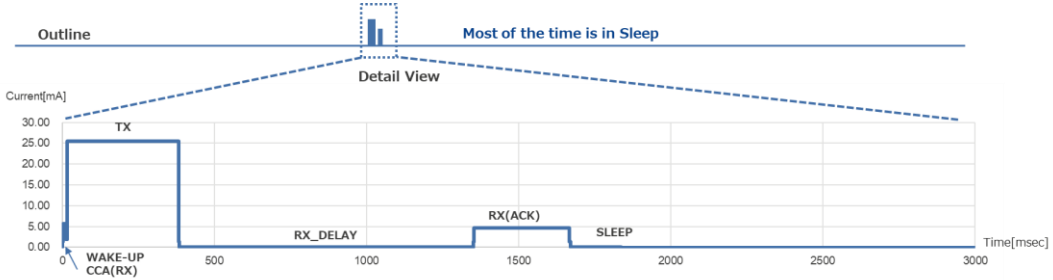
For low-power wide-area (LPWA) network, easy network construction and low-power communications are required.

- **Easy network construction**

  LoRaWAN® ecosystem provides LoRaWAN®-compatible end devices, gateways, network servers, and cloud services. This makes it easy to build a network by preparing them.

- **Low power communications**

  Many LPWA applications require smaller number of batteries and long-term operations.
  In this case, applications send notifications once every few hours and transit to sleep state in most of the time.
  This requires a microcontroller with lower current consumption in sleep state.



Battery Life	
Hour	190407.6333
Year	21.7360312
21 years, 8 months	
Average Current / Period [uA]	
6.78	

Current / State

		WAKE-UP	RX DELAY	TX	RX(ACK)	SLEEP
RA2E1	Current	1.0 mA	0.59 uA	0.59 uA	0.59 uA	0.59 uA
	State	RUN (8MHz)	SW Standby (32kHz)(*1)	SW Standby (32kHz)(*1)	SW Standby (32kHz)(*1)	SW Standby (32kHz)(*1)
RF	Current	0.6 mA	0.6 uA	25.5 mA	4.6 mA	0.16 uA
	State	STDBY_RC	Warm Sleep	TX	RX	Cold Sleep

*1) TML32:ON, LVD0:ON

Conditions

Voltage[V]	3.3
Clock[MHz]	8
TX Power [dBm]	14
Data payload [byte]	10
Data rate [bps] SF / BW [kHz]	976 SF10/125
Temp.[℃]	25
Battery[mAh]	1650
Self discharge[%/year]	1.0
Interval [sec]	1800

LoRa®-based Solutions for RA Family

LoRa®-based Solutions for RA Family

Features

Super low power solutions suitable for IoT end node required for long-term battery operations

Low Power

- Ultra-low power microcontroller (RA2E1/RA2L1/RA0E1/RA0E2) + Semtech LoRa® Transceiver (SX1261/SX1262)
- Communication software designed for low power consumption fully utilizing power saving features of RA2E1/RA2L1/RA0E1/RA0E2

Achieves less than 1 µA of the current consumption in sleep mode (0.75µA in case of RA0E1)
Enables system cost reduction by reducing capacity/number of batteries and lifetime extension

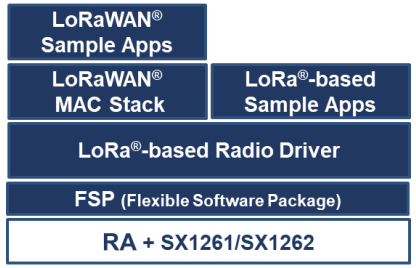
Current in Sleep Mode 0.75µA

Easy to Design

- Communication software for LoRaWAN® protocol
- Sample applications easily controlled by AT commands
- Sample applications working with cloud services (AWS, Azure) to visualize sensor data, etc.

Easy to design IoT applications with low power consumption utilizing LoRaWAN® communication software designed for low power consumption and optimized to meet timing constraints of LoRaWAN®

Communication Software

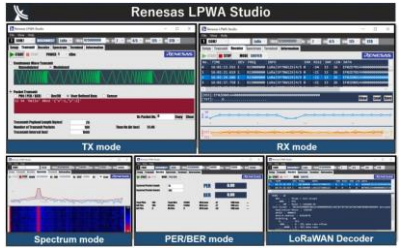


Easy to Evaluate

- Evaluation tools useful to estimate power consumption before development, evaluate the wireless performance after prototyping, and analyze the protocol in the event of issues.

Easy to evaluate developed wireless boards and applications.

Wireless Evaluation Tool



LoRa®-based Solutions for RA Family
Current Consumption and Wireless Performance

Chipset

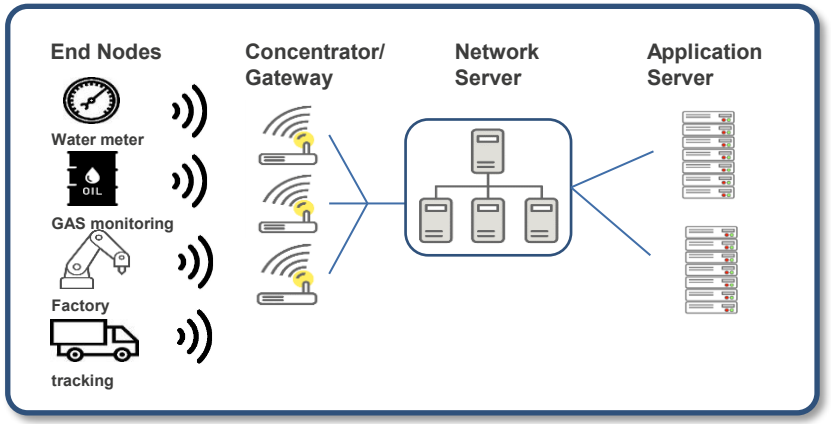
- **RA2E1/RA2L1/RA0E1/RA0E2** (Microcontroller)
  + Semtech **SX1261/SX1262** (LoRa® Transceiver)

Lower power consumption suitable for long-term battery operation

- **RA0E1**: Operating mode: 1.0mA@8MHz(*1)
  Software Standby mode: 590nA(*1)(*2)
- **SX1261/SX1262** : Tx: 32mA@+15Bm(*3), 118mA@:+22dBm(*4)
  Rx: 4.6mA(*3)(*4)

High performance LoRa® transceiver achieves longer range communication

- **Min Rx sensitivity**: -148dBm
- **Max Tx power**: +15dBm(*3), +22dBm(*4)
- **Long range**: Link budget 170dBm (Max)



Suitable for IoT end node required for long-term battery operation

Support low power Semtech SX1261/SX1262
In comparison with Semtech SX1276,
- Rx current: approx. 50% (max) reduced
- Tx current: approx. 20% (max) reduced

*1) RA0E1(R7FA0E107), *2) LVD0: ON, TML32: ON
*3) Semtech SX1261, *4) Semtech SX1262

LoRa®-based Solutions for RA Family

Current Consumption in Sleep, Frame Tx/Rx Modes

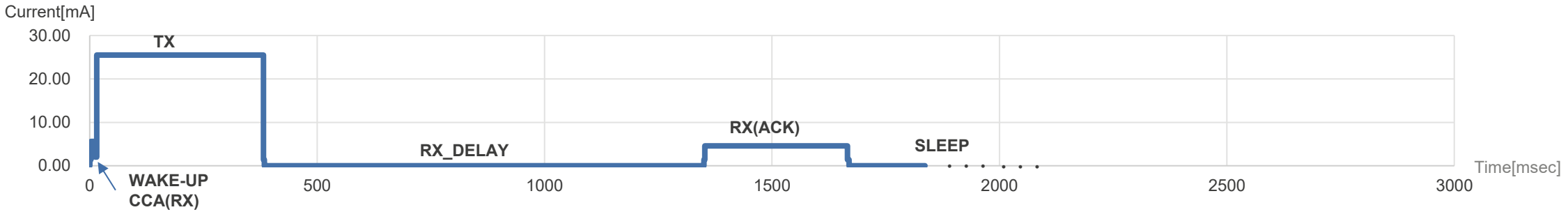
Ultra low power consumption

	RA2E1 SX1261	RA0E1 SX1261	
Sleep	0.89 µA	0.75 µA	Current in Sleep Mode (MCU + RF)
Rx / Tx	4.6 / 25.5 mA	4.6 / 25.5 mA	Current in Rx/Tx Modes (MCU + RF)

MCU: RA2E1(R7FA2E1A9), RA0E1(R7FA0E107), 3.3V
RF: SX1261, LoRa(SF7, BW125KHz)@915MHz, Tx 14dBm
Sleep(RF+RA2E1): Cold sleep(RF)+Software Standby+2ch AGT+LVD0(RA2E1)
Sleep(RF+RA0E1): Cold sleep(RF)+Software Standby+TML32+LVD0(RA0E1)

LoRaWAN® Average Current (Estimation)
LoRaWAN® Class A operation - Tx + Rx(ACK)

- **Low Power Consumption Functions of LoRaWAN® Stack**
  - LoRaWAN® stack shifts RF part to the most suitable low consumption mode automatically according to the inner operating state.
  - MCU part can be shifted to a low consumption mode during frame sending and receiving.
  - The timer function of the low consumption optimized in intermittent operations is supported. This can also be used from an application.



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	State	RUN (8MHz)	SW Standby (32kHz)(*2)	SW Standby (32kHz)(*2)	SW Standby (32kHz)(*2)	SW Standby (32kHz)(*2)
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*1) RA0E1(R7FA0E107), 2) TML32:ON, LVD0:ON

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TX Power [dBm]	14
Data payload [byte]	10
Data rate [bps] SF / BW [kHz]	976 SF10/125
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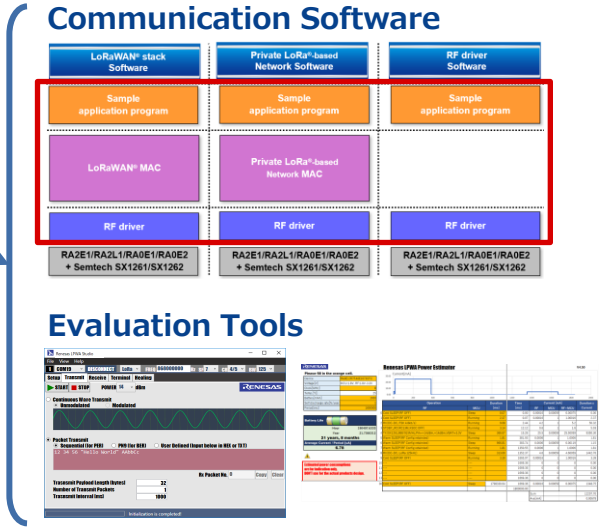
Interval [sec]	1800

LoRa®-based Wireless Software Package
Contents

■ **Communication software, evaluation tools and documents are bundled into one package (*1).**

➢ **LoRa®-based Wireless Software Package (Sample Code)**

First, please refer to the following application note.
LoRa®-based Wireless Software Package (Application Note)



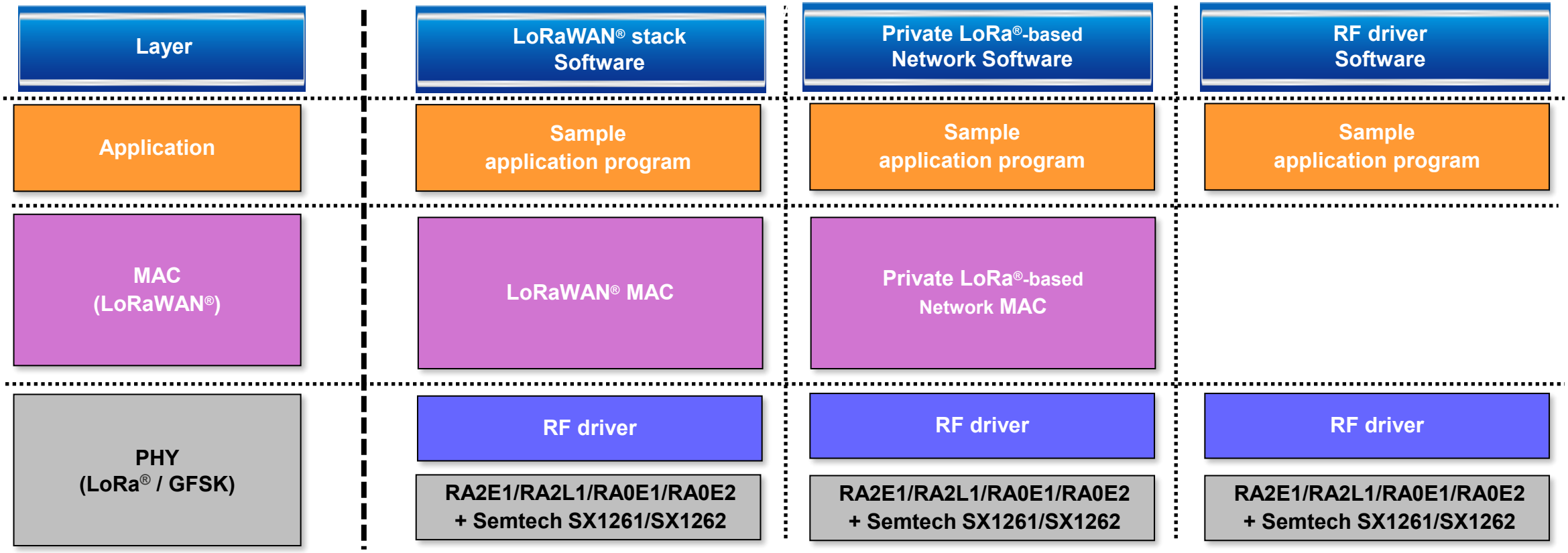
(Contents)

- **Sample Applications (Six Types)** Location: samples¥project
  - **RadioEvalApp**: RF characteristics evaluation program (AT command interface)
  - **Ping-pong**: Simple application using RF driver
  - **LoRaSample**: LoRaWAN® sample application (AT command interface)
  - **LoRaFuotaSample**: LoRaWAN® FUOTA sample application (AT command interface)
  - **PrivateLoRaSample**: Private LoRa®-based network sample application (AT command interface)
  - **LoraWanPrivateLoRaComboSample**: LoRaWAN®-Private LoRa® combination sample application (AT command interface)
- **Evaluation Tools (Two Types)** Location: samples¥tools
  - **Renesas LPWA Studio:** RF characteristics evaluation tool (GUI)
  - **Renesas Power Estimator:** Power estimation tool (Excel)
- **Documents** Location: samples¥documents

*1) Except for LoRaWAN® Sensor Demo.

LoRa®-based Communication Software

- Offers three types of software for LoRa®-based communication software.
  - **LoRaWAN® protocol stack :** Compliant to LoRaWAN® spec. For interoperability required applications.
  - **Private LoRa®-based Network:** Proprietary LoRa®-based communication spec. For interoperability not required applications.
  - **RF driver:** Applicable for user custom protocol. For interoperability not required applications.



Network Topology Example

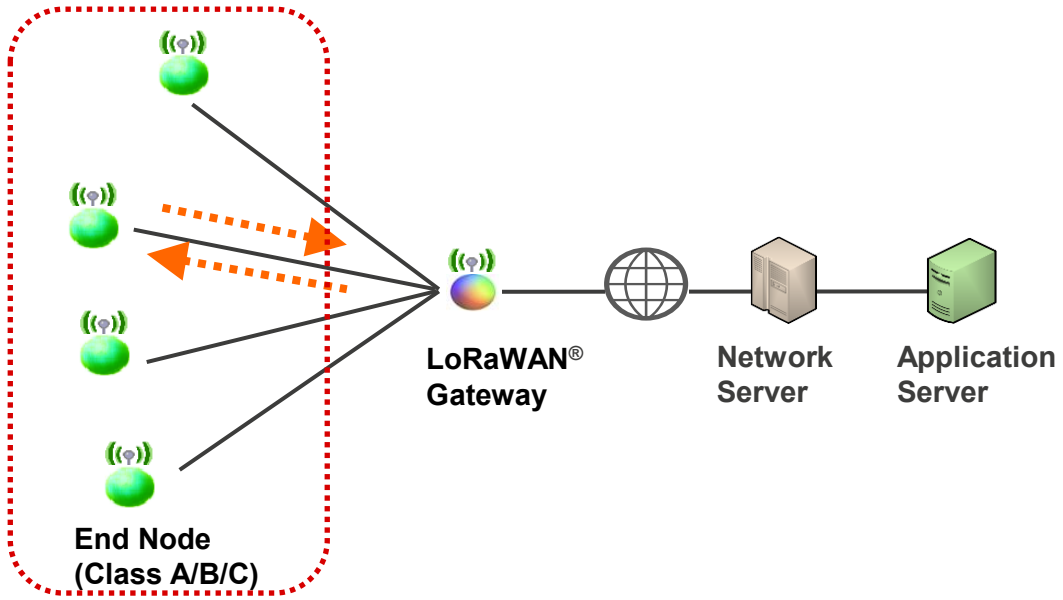
LoRaWAN® Stack

- Standardized protocol
- Interoperable with multi-vendor

Private LoRa-based® Network RF Driver

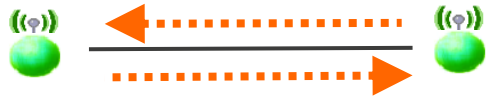
- Applicable for custom protocol
- Flexible for various application

■ LoRaWAN® Network

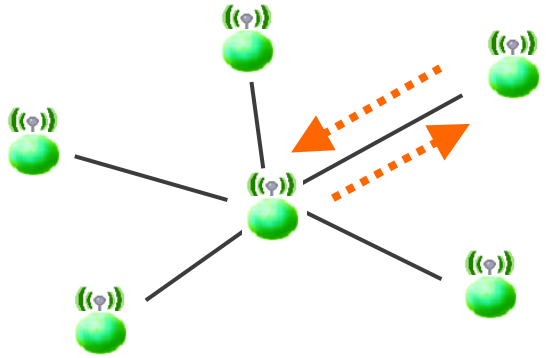


* LoRaWAN® stack supports End Node.

■ P2P Network (1 to 1)



■ Star Network (1 to N)



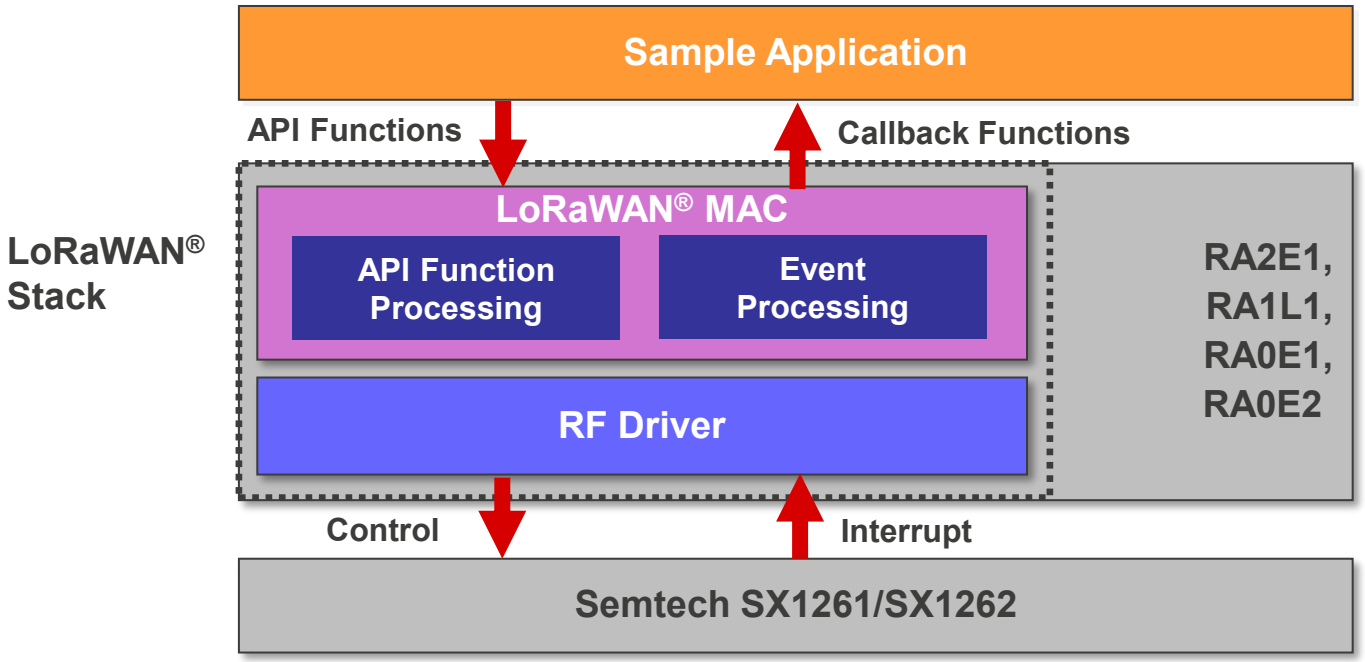
Comparison of LoRaWAN® and Private LoRa®-based Network

- LoRaWAN® uses a communication protocol standardized by LoRa Alliance®, has high interoperability, and is easily connected to the Internet using third parties, making it suitable for building large networks.
- Private LoRa®-based network uses proprietary LoRa®-based communication protocol, allowing control of communication speed and frequency to fit the environment, and are suitable for building small-scale networks.

	LoRaWAN®	Private LoRa®-based Network
Protocol	LoRa Alliance® Standard	Proprietary (custom)
Interoperability	✓	NG
Cloud Connectivity	✓	Optional
Network Capacity	Large	Small
Building an Ecosystem	✓	Optional
Gateway/Server	Required	Not required
Customizability	Optional	✓
Communication Cost	Optional	✓
Bidirectional Communication	Optional	✓
Low Power Consumption Features	✓	✓
Security Functions (Encryption, Tamper-proof)	✓	✓

LoRaWAN® Stack Software
Features

- Provides API functions to control LoRaWAN® protocol, power mode of MCU block and timer optimized for low power operation
- Application can request to LoRaWAN® stack via API functions (ex. Request to TX/RX)
- Application is notified of asynchronous event via callback functions (ex. Notification of TX/RX completion)
- LoRaWAN® stack controls power mode of RF block automatically
- OS independent. Easily to implement to various systems



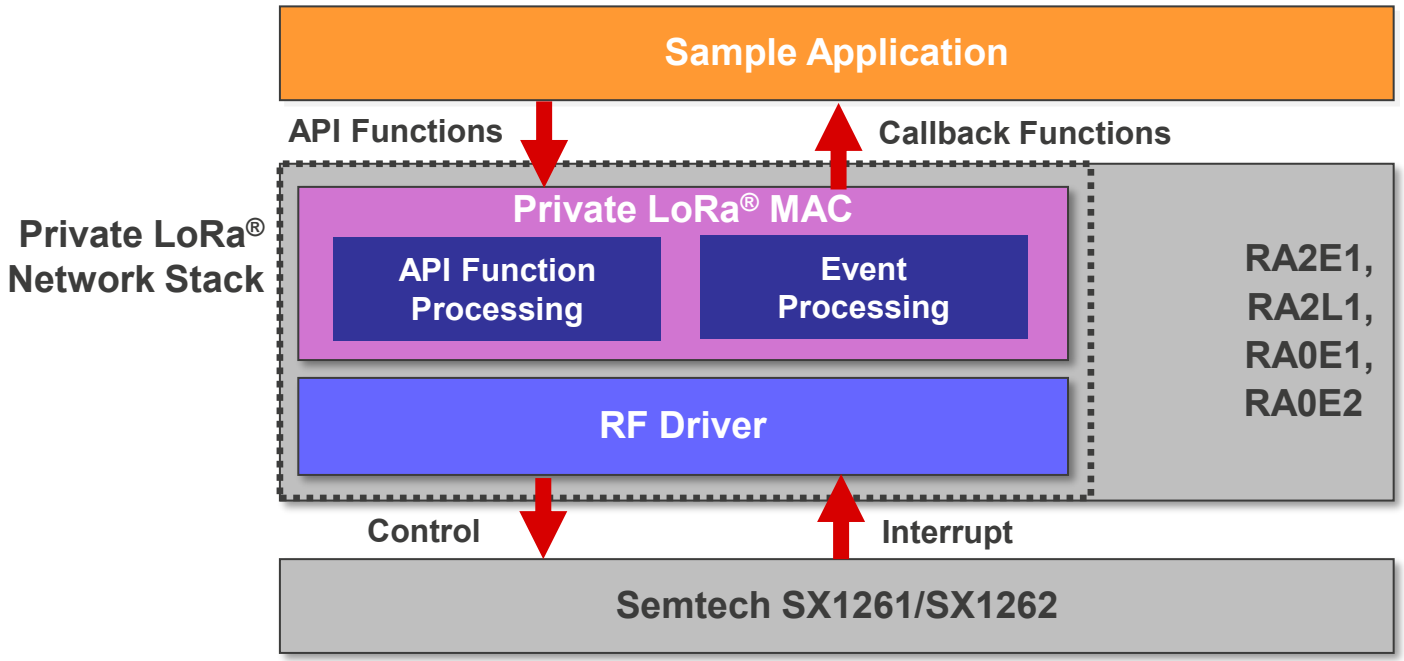
LoRaWAN® Stack Software
Specification Outline

Function	Specification
LoRaWAN® Version	V1.0.4/1.0.3/1.0.2
Device Type	End-device (Class A, Class B*1, Class C)
Frequency Band	868Mz(EU), 915MHz(US), 920MHz(ASEAN/Japan), 865MHz(India), 915MHz(Australia), 920MHz(Korea)
Modulation	LoRa® / GFSK
Data Rate	Data rate is region specific (e.g. LoRa®: 250 bps - 11 kbps, FSK: 50 kbps for AS923/EU868)
Data Size	Maximum payload size is region specific (e.g. Max: 250 bytes for AS923/EU868)
Tx Options	Listen before talk, ACK request
Frame Type	Join Request, Join Accept, Confirmed/Unconfirmed data message
Security	Authentication (OTAA), Encryption/Decryption(AES-CTR), Integrity check (AES-CMAC)
Radio Regulation Control Support	Check whether configured radio parameters conform to regional radio regulation before frame transmission/reception
Low Power Support	Provides API to control power mode of MCU block and timer optimized for low power operation LoRaWAN® stack controls power mode of RF block automatically

*1) Supported for RA2E1 and RA2L1

Private LoRa® Network Sample Software
Features

- Provides API functions to control private LoRa® network protocol, power mode of MCU block and timer optimized for low power operation
- Application can request to private LoRa® network stack via API functions (ex. Request to TX/RX)
- Application is notified of asynchronous event via callback functions (ex. Notification of TX/RX completion)
- Private LoRa® network stack controls power mode of RF block automatically
- OS independent. Easily to implement to various systems

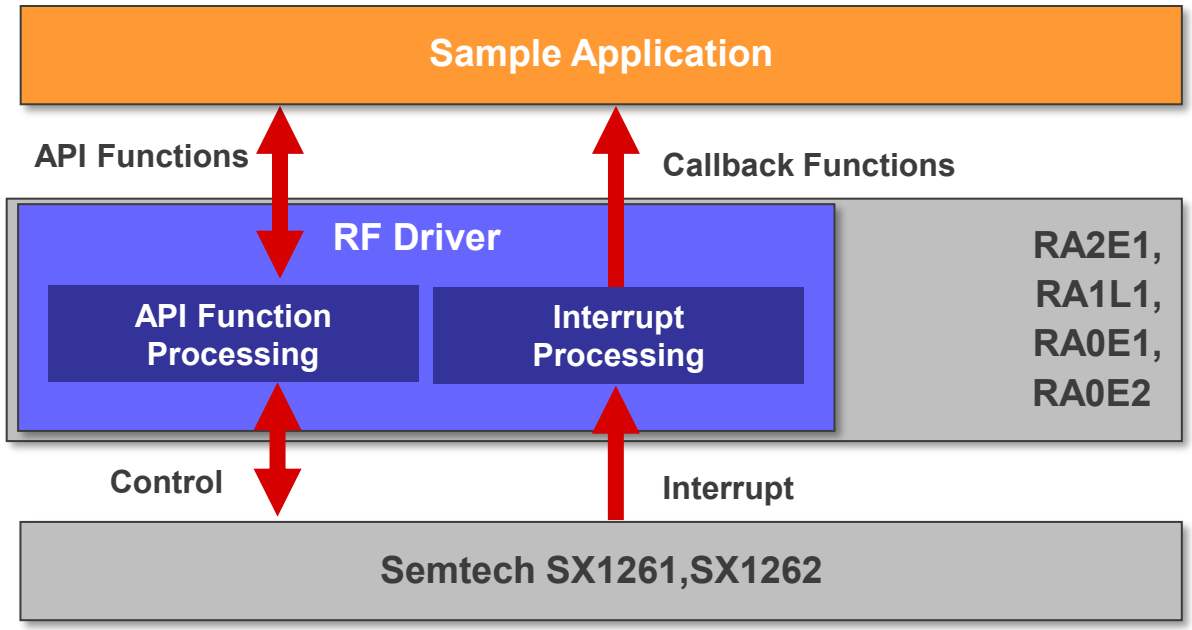


Private LoRa® Network Sample
Specification Outline

Function	Specification
Operation Mode	Intermittent Tx/Rx mode / Continuous Rx mode
Frequency Band	868Mz(EU), 915MHz(US), 920MHz(ASEAN/Japan), 865MHz(India), 915MHz(Australia), 920MHz(Korea)
Modulation	LoRa® / GFSK
Data Rate	Data rate is region specific (e.g. LoRa®: 250 bps - 11 kbps, FSK: 50 kbps for AS923/EU868)
Data Size	Maximum payload size is region specific (e.g. Max: 250 bytes for AS923/EU868)
Tx Options	Listen before talk, ACK request
Security	Encryption/Decryption(AES-CTR), Integrity check (AES-CMAC)
Radio Regulation Control Support	Check whether configured radio parameters conform to regional radio regulation before frame transmission/reception
Low Power Support	Provides API to control power mode of MCU block and timer optimized for low power operation private LoRa® network stack controls power mode of RF block automatically

RF Driver for LoRa®
Features

- Provides API functions to control LoRa® and GFSK PHY layer, power mode of RF block and MCU block and timer optimized for low power operation
- Application can request to RF driver via API functions (ex. Request to TX/RX)
- Application is notified of asynchronous event via callback functions (ex. Notification of TX/RX completion)
- OS independent. Easily to implement to various systems



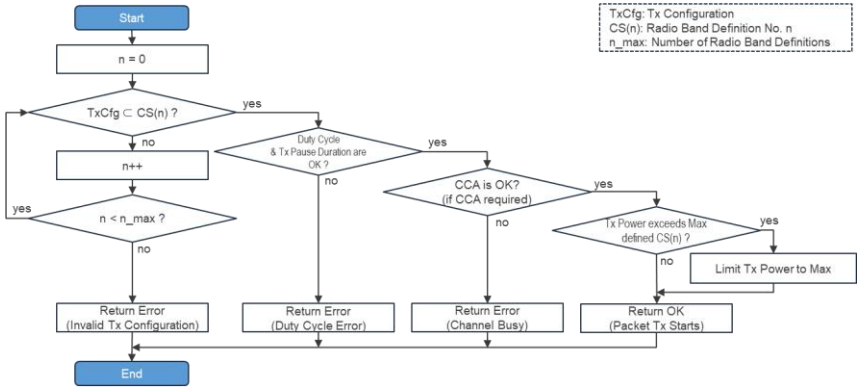
RF Driver Software
Functional Specification Outline

Items	LoRa®	GFSK
Radio frequency range	426MHz to 928MHz	
Max payload length	255 bytes	
Data rate	11.4bps to 62.5kbps	600bps to 300kbps
Bandwidth	7.8kHz to 500kHz	2.6kHz to 250kHz
Spread factor	SF5 to SF12	-
Coding rate	4/5, 4/6, 4/7, 4/8	-
Carrier sense	Yes	
Energy detection	Yes	
RF characteristics evaluation	Continuous unmodulated transmission	
Radio Regulation Control Support	Check whether configured radio parameters conform to regional radio regulation before frame transmission/reception	
Low power support	Provides API to control power mode of RF block, MCU block and timer optimized for low power operation	

RF Driver

Support Functions for Regional Radio Regulation

- RF driver supports the functions to make it easier for the protocols and applications on top of the RF driver to control to conform with the regional radio regulation.
  Supported country/region: 868MHz(EU), 915MHz(US), 920MHz(ASEAN/Japan), 865MHz(India), 915MHz(Australia), 920MHz(Korea)
- When this functions are enabled, RF driver checks the following radio parameter configurations and transmission intervals before starting the frame transmission/reception. If RF driver determines those are not compliant with the regulation, it will cancel the transmission/reception. In case the carrier sense is required for the regulation, RF driver automatically executes the carrier sense before sending the frame transmission and cancels it if the carrier is detected.
  - **Channel frequency / band width**
  - **Minimum pause duration**
  - **Maximum sending duration**
  - **Maximum sending duty cycle**



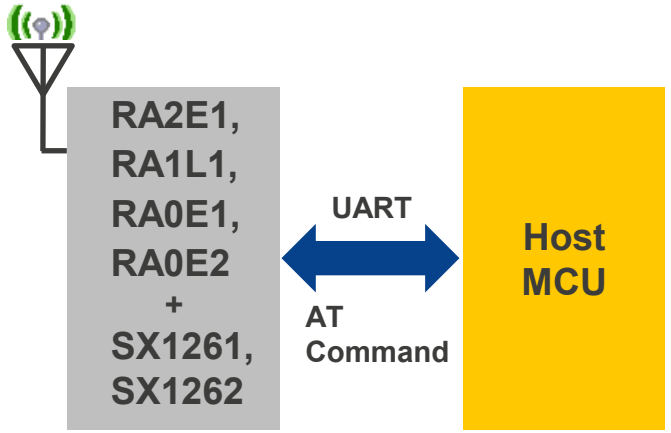
- **Caution**
  These functions are intended to make it easier for you to design for compliance with the radio laws and regulations, and does not warrant or guarantee the compliance with the radio laws and regulations. You shall be responsible for using the functions in compliance with the applicable laws and regulations.

Radio Driver Support Functions for Regional Radio Regulations
https://www.renesas.com/node/25467896

LoRaWAN® Stack Software
Sample Program Command List (Excerpt)

- LoRaWAN® stack sample program supports AT commands to request to join network and send/receive data messages to/from LoRaWAN® stack.
- It also supports the certification test mode that can be used for the LoRaWAN certification test.

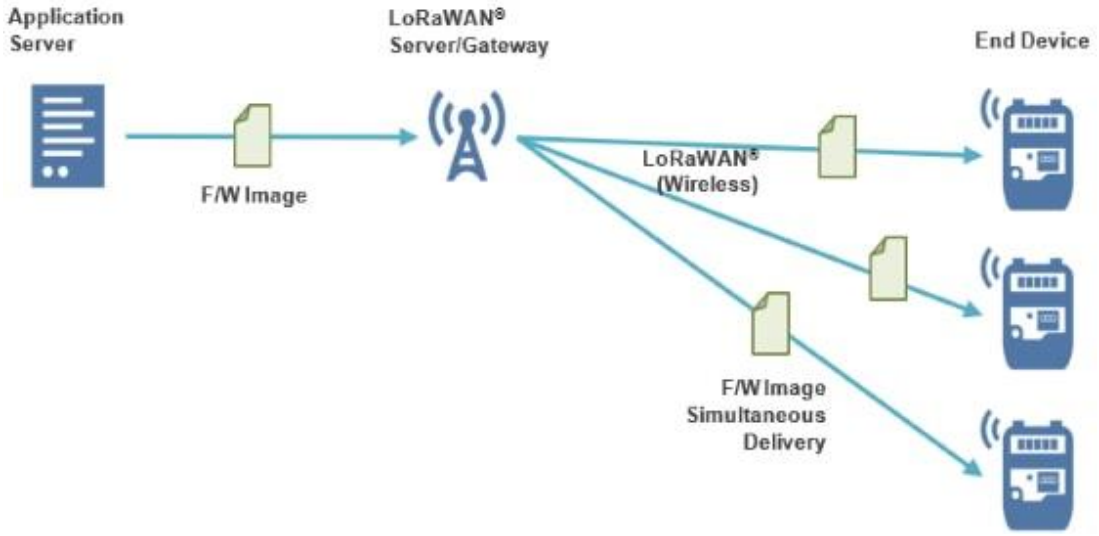
Command	Description
+SAVE	Save parameters to the data flash
+LOAD	Load parameters from the data flash
+REGION	Set/get region
+CLASS	Set/get device class
+ACTMODE	Set/get activation mode
+DEVEUI	Set/get device EUI (DevEUI)
+APPEUI	Set/get application identifier (AppEUI)
+APPKEY	Set application key (AppKey)
+JOIN	Activate the device according to the activation mode
+MTYPE	Set/get message type (confirmed / unconfirmed) of data messages to be sent
+FPORT	Set/get port number (FPort) of data messages to be sent
+RSSI	Enable/disable RSSI display
+SENDHEX	Send data message of hexadecimal
+RCVD	Notify reception of a data message
+ADR	Enable/disable ADR mode
+DR	Set/get default data rate in case ADR is disabled
+DCYCLE	Enable/disable duty cycle control
+COMPLIANCE	Set/get certification test mode setting or enable certification test mode

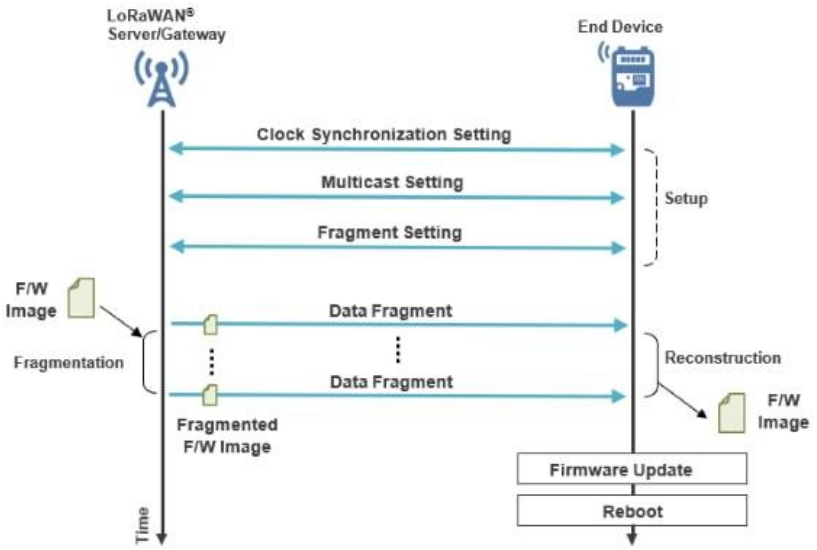


LoRaWAN® Stack Software

Firmware Update over LoRaWAN® *1

- FUOTA (Firmware Updates Over The Air) provides a function to remotely update a firmware over wireless communication. This function is a key feature for IoT applications deployed widely in the field and that require long term operation.
- The LoRa Alliance® standardized the FUOTA process utilizing the application layer protocols on top of the LoRaWAN® protocol, such as Clock Synchronization Message Package, Remote Multicast Setup Package and Fragmented Data Block Transport Package. These protocols can deliver a firmware image to multiple devices at the time specified by an application server.
- To update the firmware of the MCU, the application program including the communication part can be updated by switching to the firmware rewrite program using the startup area select function of the RA2 MCU.



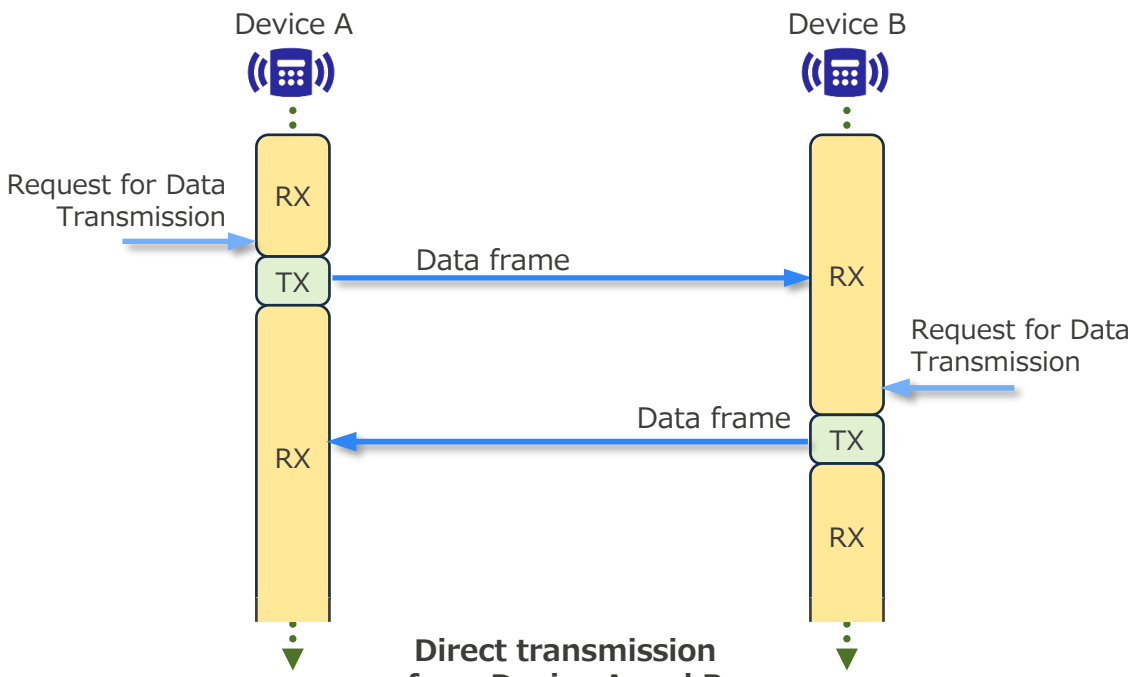


*1) Supported for RA2L1

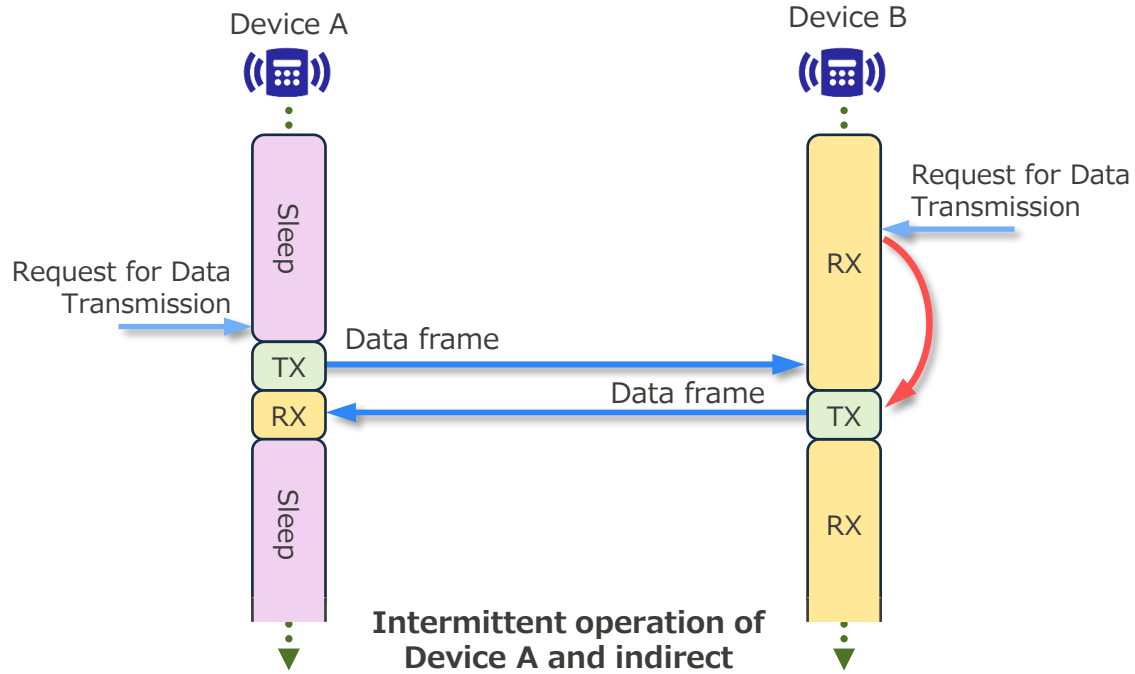
Private LoRa®-based Network Sample

Features

- Private LoRa®-based network sample provides a small network environment using LoRa®-based protocol.
- It allows direct and indirect transmissions between devices, as well as bidirectional communication.
- AT commands can be used to control intermittent operation and key exchange necessary for security, making it easy to construct a network environment.
- Communication interval can be flexibly changed, which is useful for balancing the amount of data communication and power consumption.



Direct transmission from Device A and B

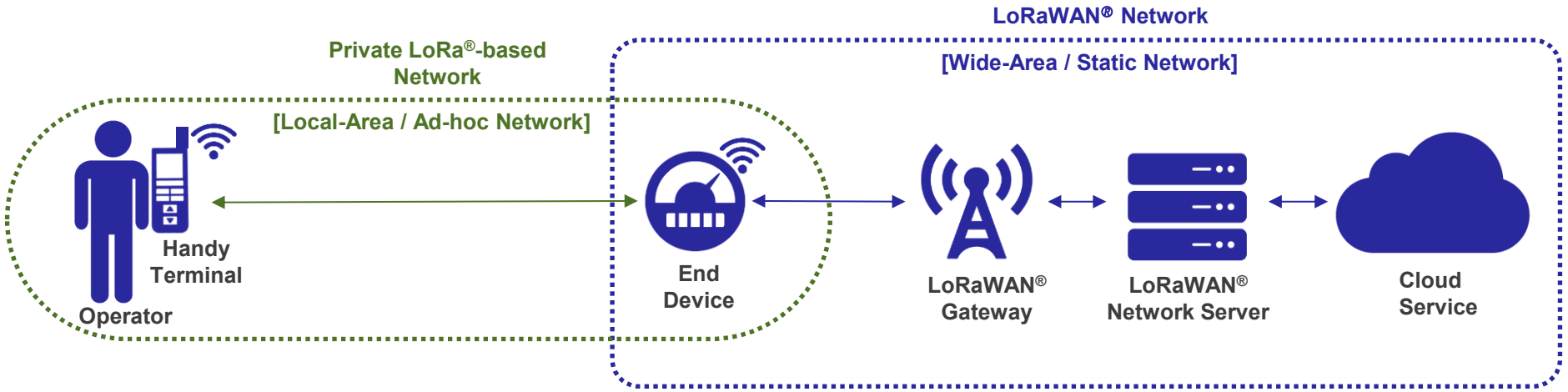


Intermittent operation of Device A and indirect transmission of Device B

Private LoRa®-based Network Sample

LoRaWAN® and Private LoRa®-based Network Combination Sample*1

- LoRaWAN® and private LoRa®-based network can be switched dynamically (time-division operation), which are suitable for wide-area / large-scale network communication and small / ad-hoc network communication, respectively.
- Resumes communication immediately after network switch by retaining parameters required for LoRaWAN® and private LoRa®-based network.
- Supports low power function utilizing intermittent operation, frame encryption and frame integrity check functions.
- Use case: automatic meter reading application
  LoRaWAN® is used as main network to collect metering data automatically. Private LoRa®-based network can be used as sub network for operator to get metering data directly from a meter in case of bad wireless environment



*1) Supported for RA2E1 and RA2L1

Evaluation Tool
Renesas LPWA Studio

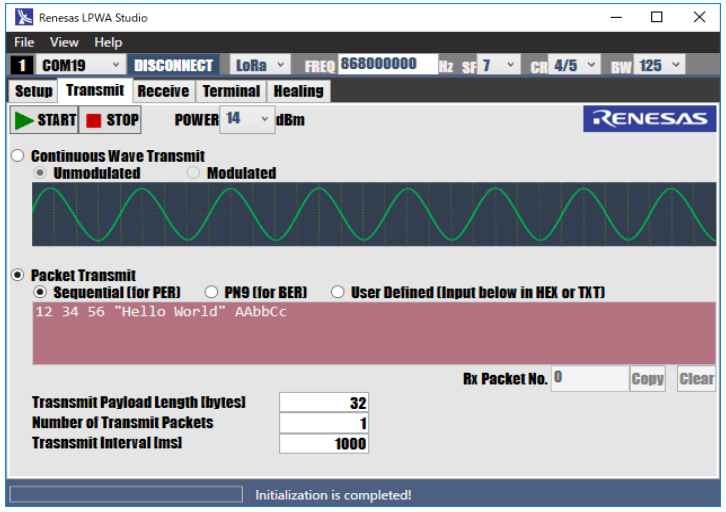
- **RF Characteristics Evaluation Function**

  RF characteristic evaluations such as packet transmission/reception, PER/BER(*1) measurement, RSSI measurement can be conducted via the GUI.

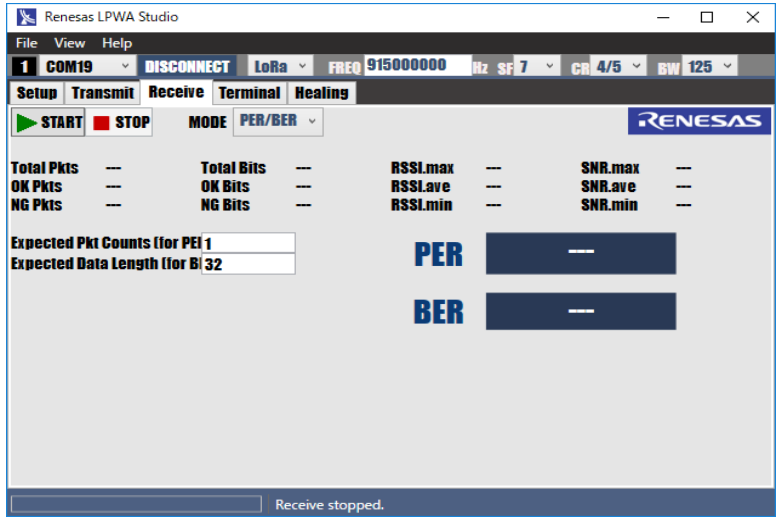
- **Sniffer Function**

  LoRa® / GFSK frames can be captured and analyzed fields of the frames can be shown on the GUI.
  Analysis of the LoRaWAN® protocol frames are also supported.

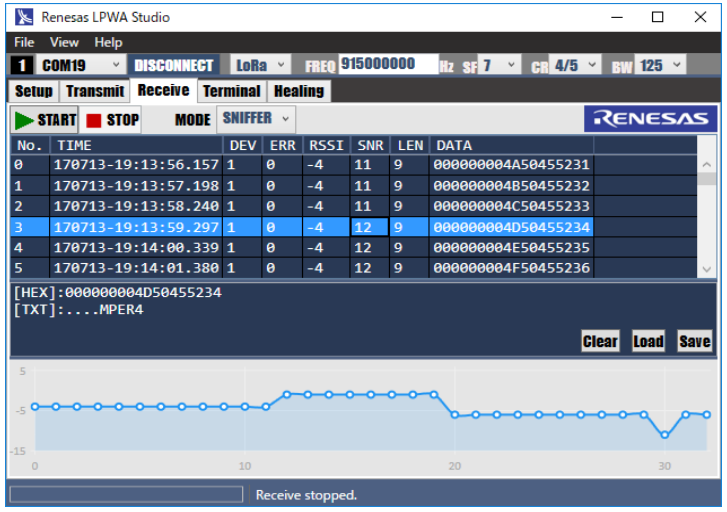
*1) PER: Packet Error Rate, BER: Bit Error Rate



Transmission mode



Reception mode (PER/BER)

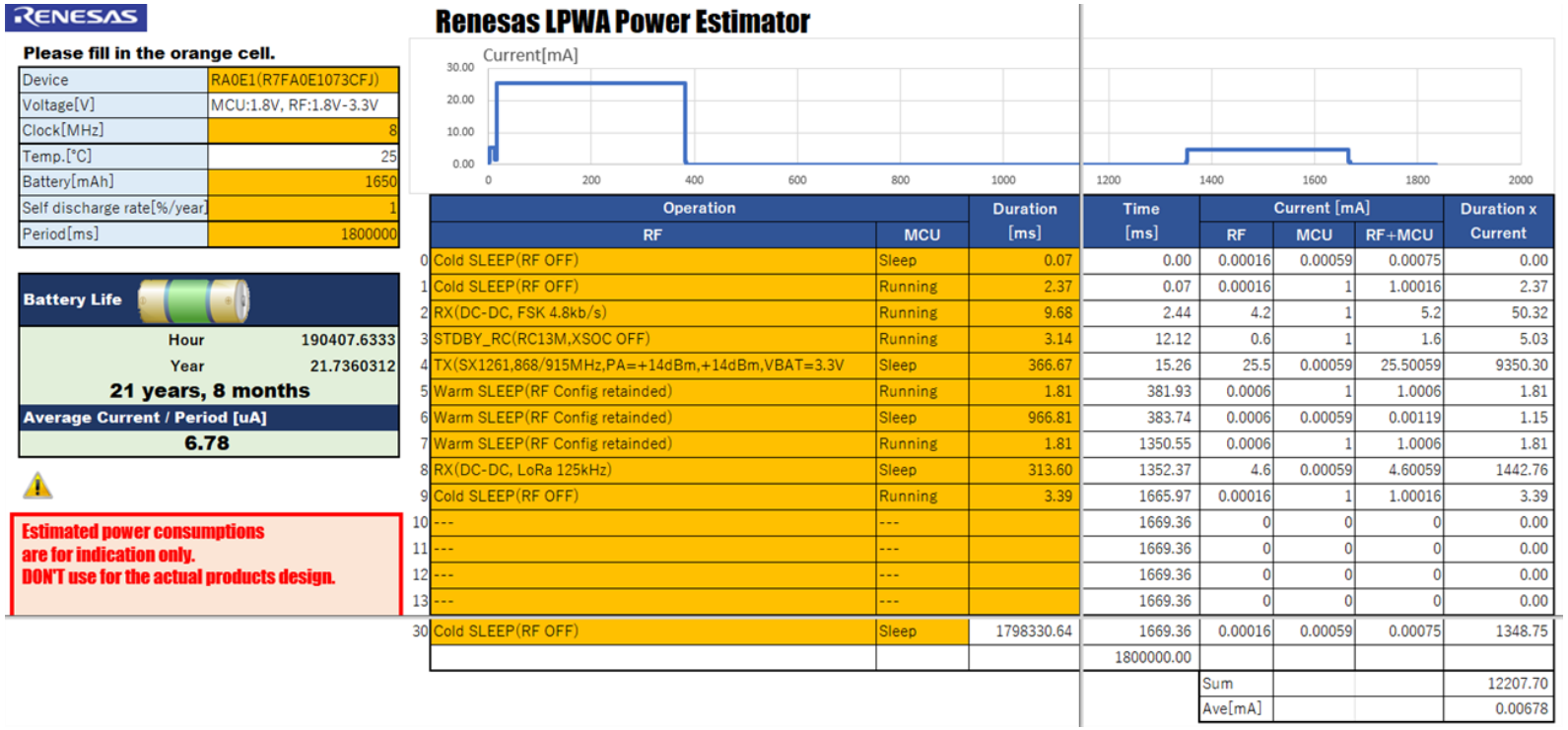


Reception mode (Sniffer)

Renesas LPWA Studio: https://www.renesas.com/node/1400056

Evaluation Tool
Renesas Power Estimator

- Evaluation tool to estimate the average current consumption and battery life in case of the intermittent operation (frame transmission/reception, low power mode, etc).
- Shows the current consumption and battery life after the interval of the intermittent operation, the periods for each state, the operation voltage, and the battery capacity are input to the tool.



RENESAS

Please fill in the orange cell.

Device	RA0E1(R7FA0E1073CFJ)
Voltage[V]	MCU:1.8V, RF:1.8V-3.3V
Clock[MHz]	8
Temp.[°C]	25
Battery[mAh]	1650
Self discharge rate[%/year]	1
Period[ms]	1800000

Battery Life

Hour	190407.6333
Year	21.7360312

21 years, 8 months

Average Current / Period [uA]

6.78

Estimated power consumptions are for indication only. DON'T use for the actual products design.

Renesas LPWA Power Estimator

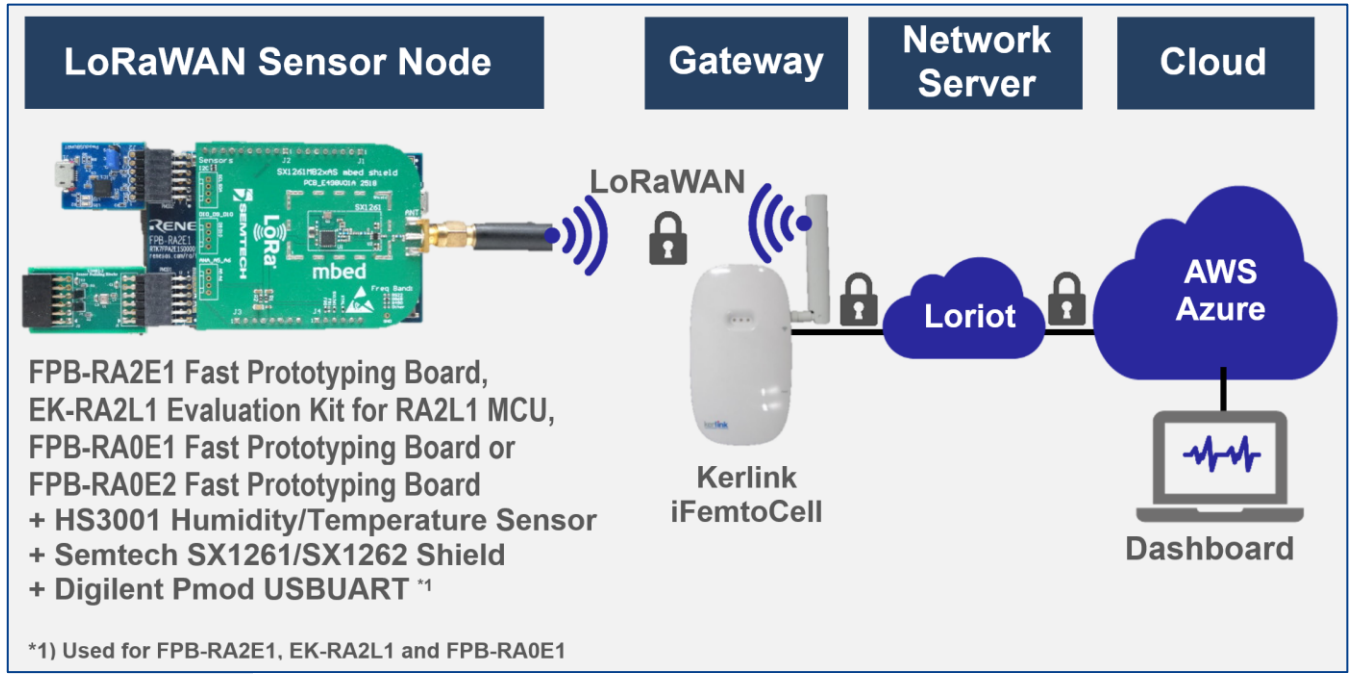
	Operation		Duration	Time	Current [mA]			Duration x
	RF	MCU	[ms]	[ms]	RF	MCU	RF+MCU	Current
0	Cold SLEEP(RF OFF)	Sleep	0.07	0.00	0.00016	0.00059	0.00075	0.00
1	Cold SLEEP(RF OFF)	Running	2.37	0.07	0.00016	1	1.00016	2.37
2	RX(DC-DC, FSK 4.8kb/s)	Running	9.68	2.44	4.2	1	5.2	50.32
3	STDBY_RC(RC13M,XSOC OFF)	Running	3.14	12.12	0.6	1	1.6	5.03
4	TX(SX1261,868/915MHz,PA=+14dBm,+14dBm,VBAT=3.3V	Sleep	366.67	15.26	25.5	0.00059	25.50059	9350.30
5	Warm SLEEP(RF Config retainded)	Running	1.81	381.93	0.0006	1	1.0006	1.81
6	Warm SLEEP(RF Config retainded)	Sleep	966.81	383.74	0.0006	0.00059	0.00119	1.15
7	Warm SLEEP(RF Config retainded)	Running	1.81	1350.55	0.0006	1	1.0006	1.81
8	RX(DC-DC, LoRa 125kHz)	Sleep	313.60	1352.37	4.6	0.00059	4.60059	1442.76
9	Cold SLEEP(RF OFF)	Running	3.39	1665.97	0.00016	1	1.00016	3.39
10	---	---		1669.36	0	0	0	0.00
11	---	---		1669.36	0	0	0	0.00
12	---	---		1669.36	0	0	0	0.00
13	---	---		1669.36	0	0	0	0.00
30	Cold SLEEP(RF OFF)	Sleep	1798330.64	1669.36	0.00016	0.00059	0.00075	1348.75
				1800000.00				
					Sum			12207.70
					Ave[mA]			0.00678

Renesas Power Estimator: https://www.renesas.com/node/704381

Example of Application
LoRaWAN® Sensor Demo

- Application note, LoRaWAN® Sensor Demo, introduces you how to visualize sensor data transmitted by the RA2E1/RA2L1/RA0E1/RA0E2 Sensor Node to the Cloud (AWS/Azure) via LoRaWAN® networks.

- **Contents**
  - How to setup the evaluation board and demo application
  - How to setup the LoRaWAN® gateway
  - How to setup the LoRaWAN® network server
  - How to setup of the cloud server (AWS/Azure)



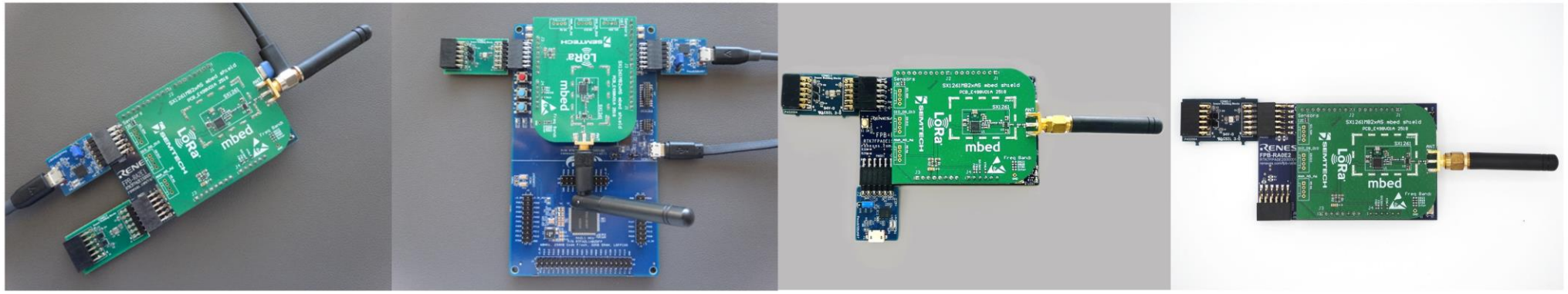
HS3001 has been obsolete. For details about the replacement devices, etc., please refer to PLC# : 250010 End-of- Life (EOL) process on select part numbers.

RA2E1, RA2L1, RA0E1, RA0E2 LoRaWAN® Sensor Demo
https://www.renesas.com/node/1685416 (Application Note)
https://www.renesas.com/node/1685421 (Sample Code)

Software Development Environment

Software Development Environment
Hardware

- RA2E1 Fast Prototyping Board (RTK7FPA2E1S00001BE), EK-RA2L1 (RTK7EKA2L1S00001BE), RA0E1 Fast Prototyping Board (RTK7FPA0E1S00001BJ) or RA0E2 Fast Prototyping Board (RTK7FPA0E2S00001BJ), and the Semtech SX1261/1262 Shield can be used for the software development environment.
- The development and evaluation of applications can be started immediately by using the providing software.



FPB-RA2E1
(RA2E1 Fast Prototyping Board)
+ SX1261/SX1262 Shield
+ HS3001 Humidity Sensor

EK-RA2L1
(Evaluation Kit for RA2L1 MCU Group)
+ SX1261/SX1262 Shield
+ HS3001 Humidity Sensor

FPB-RA0E1
(RA0E1 Fast Prototyping Board)
+ SX1261/SX1262 Shield
+ HS3001 Humidity Sensor

FPB-RA0E2
(RA0E2 Fast Prototyping Board)
+ SX1261/SX1262 Shield
+ HS3001 Humidity Sensor

FPB-RA2E1: https://www.renesas.com/en/products/microcontrollers-microprocessors/ra-cortex-m-mcus/fpb-ra2e1-fast-prototyping-board-ra2e1-mcu-group
EK-RA2L1: https://www.renesas.com/en/products/microcontrollers-microprocessors/ra-cortex-m-mcus/ek-ra2l1-evaluation-kit-ra2l1-mcu-group
FPB-RA0E1: https://www.renesas.com/us/en/products/microcontrollers-microprocessors/ra-cortex-m-mcus/fpb-ra0e1-ra0e1-fast-prototyping-board#design_development
FPB-RA0E2: https://www.renesas.com/en/products/microcontrollers-microprocessors/ra-cortex-m-mcus/fpb-ra0e2-fast-prototyping-board-ra0e2-mcu-group
HS3001 has been obsolete. For details about the replacement devices, etc., please refer to PLC# : 250010 End-of- Life (EOL) process on select part numbers.

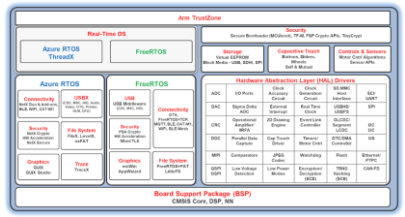
Software Development Environment
Development Tool

- **e² studio - information for RA Family (GNU Compiler)**

  https://www.renesas.com/en/software-tool/e2studio-information-ra-family

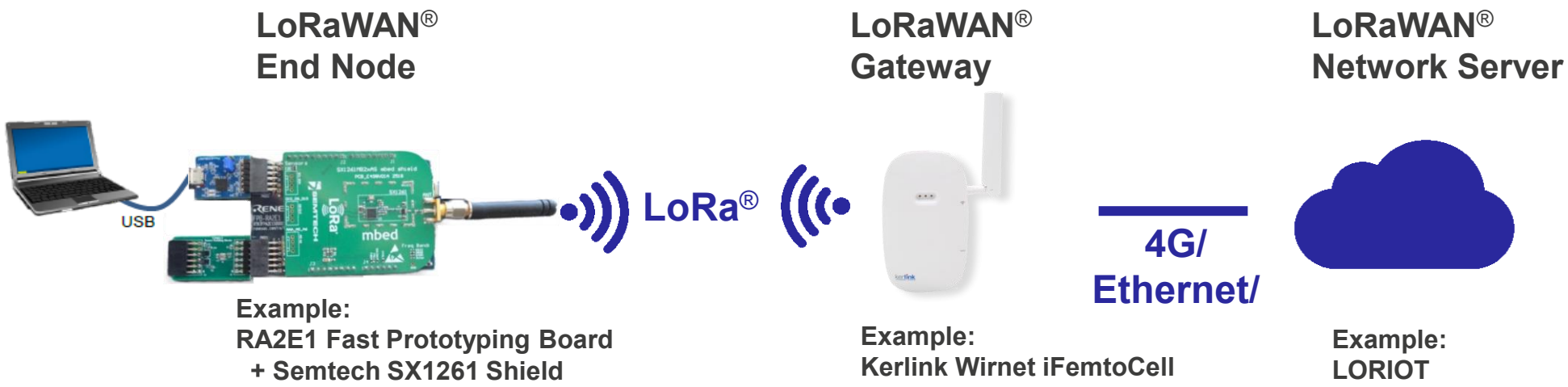
- **RA Flexible Software Package (FSP)**

  https://www.renesas.com/en/software-tool/flexible-software-package-fsp



LoRaWAN® Evaluation Environment

- **To try to evaluate LoRaWAN® communication, LoRaWAN® gateway and LoRaWAN® network server need to be prepared.**
  - For LoRaWAN® gateway, LoRaWAN®-compatible product is necessary.
  - For LoRaWAN® network server, some vendors offer services that are free to try for proof-of-concept purposes.
  - LoRaWAN® network server can be connected to cloud services.
  - Some of cloud services support LoRaWAN® network server.



LoRa®-based Solutions Web Pages

- LoRa®-based Solutions Web Page
  https://www.renesas.com/us/en/application/communication-computing-infrastructure/wireless-network/lora-solutions
- LoRa®-based Solutions for RA Family Web Page
  https://www.renesas.com/us/en/application/communication-computing-infrastructure/wireless-network/lora-solutions/lora-solution-ra
- Video: RA LoRa®-based Solutions
  https://www.renesas.com/us/en/show-video/nojs/13107416
- Video: RA LoRaWAN® Sensor Demo Tutorial
  https://www.renesas.com/us/en/show-video/nojs/13107421
- Blog: Would You Like to Use a LoRa®-Based Solution from Renesas to Develop IoT Applications with Low Power Consumption?
  https://www.renesas.com/us/en/blogs/would-you-use-lora-based-solution-renesas-develop-iot-applications-low-power-consumption

Appendix
Memory Size

Application	FPB-RA2E1[*1]		EK-RA2L1[*2]		FPB-RA0E1[*1]		FPB-RA0E2[*1]	
	ROM	RAM	ROM	RAM	ROM	RAM	ROM	RAM
LoRaSample[*3 *4 *5]	68.7	9.5	68.9	9.5	53.7	8.7	66.1	9.4
LoRaFuotaSample[*3 *4 *6]	N/A	N/A	104.4	19.6	N/A	N/A	N/A	N/A
LoRaSensorSample[*3 *4 *7]	73	9.8	72.6	9.7	57.1	9.7	69.6	9.6
LoRaWanPrivateLoRaComboSample[*3 *4 *8]	86.1	10.5	86.4	10.5	N/A	N/A	83.5	10.3
PrivateLoRaSample[*3 *4]	54.9	7.7	55.2	7.7	45.1	7.4	52.4	7.5
RadioEvalApp[*3 *9]	50.1	8.1	49.6	8.1	42	8	47.4	8.2
Radio Driver Only[*9]	19.5	1.8	19.7	1.8	12.7	1.1	18.5	1.9
LoRaWAN MAC Only[*4]	21.5	2.6	21.5	2.6	24	2.6	21.3	2.6

Tool: GCC Toolchain: 13.2.1.arm-13-7, Optimize options: -Os (RA2E1, RA2L1, RA0E2), -Os -fto (RA0E1), FSP: 5.9.0.

Note1: FPB stands for Fast Prototyping Board.
Note2: EK stands for Evaluation Kit.
Note3: Stack size (2.0KiB) and heap size (1.0KiB) are included in the RAM size.
Note4: LoRaWAN V1.0.4, Class A/C, multicast and region EU868 are enabled. An additional ROM(7.7KiB) / RAM(0.4KiB) are required when Class B is enabled. (RA2E1, RA2L1, RA0E2)
LoRaWAN V1.0.4, Class A/C and region EU868 are enabled. Class B and multicast are not supported. (RA0E1)
Note5: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaSample.
An additional ROM(9.0KiB) / RAM(0.4KiB) are required when Class B is enabled. (RA2E1, RA2L1, RA0E2)
Note6: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaFuotaSample. RAM size also includes the fragment data block buffer for FUOTA (4KiB).
An additional ROM(9.6KiB) / RAM(0.4KiB) are required when Class B is enabled (RA2L1).
Note7: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaSensorSample.
An additional ROM(9.0KiB) / RAM(0.4KiB) are required when Class B is enabled (RA2E1, RA2L1, RA0E2).
Note8: ROM/RAM sizes include LoRaWAN MAC, Radio Driver, and the lower layer's code required by LoRaWanPrivateLoRaComboSample.
An additional ROM(9.0KiB) / RAM(0.4KiB) are required when Class B is enabled (RA2E1, RA2L1, RA0E2).
Note9: ROM/RAM size includes the lower layer's code required by PrivateLoRaSample, RadioEvalApp, or Radio driver.
An additional ROM(3.4KiB(RA2E1, RA2L1), 2.9KiB(RA0E1), 3.5KiB(RA0E2)) / RAM(0.2 KiB) are required when regulatory function is enabled.

Appendix
Peripheral Resource Usage

Resources	Function	FPB-RA2E1[*1]	EK-RA2L1[*2]	FPB-RA0E1[*1]	FPB-RA0E2[*1]
Timer	Interval timer Capture&Comp	AGT0 AGT1	AGT0 AGT1	TML32 TAU02	ML32 TAU02
SX126x	CLK MISO MOSI ANTSW NSS DIO1 BUSY XTAL_SEL DEVICE_SEL FREQ_SEL NRESET	SCK0 (P102) MISO0 (P100) MOSI0 (P101) OUT (P403) OUT (P113) IRQ5 (P302) IN (P104) IN (P003) IN (P002) IN (P001) OUT (P000)	SCK0 (P102) MISO0 (P100) MOSI0 (P101) OUT (P109) OUT (P113) IRQ4 (P111) IN (P400) IN (P003) IN (P002) IN (P001) OUT (P000)	SCK11 (P407) SI11 (P212) SO11 (P213) OUT (P109) OUT (P103) IRQ3 (P208) IN (P201) IN (P009) IN (P012) IN (P013) OUT (P014)	SCK00 (P500) SI00 (P502) SO00 (P501) OUT (P106) OUT (P115) IRQ5 (P201) IN (P409) IN (P012) IN (P013) IN (P014) OUT (P015)
UART	Tx Rx	TxD9 (P109) PMOD2 RxD9 (P110) PMOD2	TxD9 (P203) PMOD2 RxD9 (P202) PMOD2	TxD0 (P101) PMOD1 RxD0 (P100) PMOD1	TxDA0 (P101) RxDA0 (P100)
I²C for sensor (Option)	SCL SDA	SCL0 (P400) PMOD1 SDA0 (P401) PMOD1	SCL2 (P301) PMOD1 SDA2 (P302) PMOD1	SCL20 (P112) PMOD2 SDA20 (P110) PMOD2	SCLA1 (P400) PMOD2 SDAA1 (P401) PMOD2

Note1: FPB stands for Fast Prototyping Board, Note2: EK stands for Evaluation Kit.

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