Combination of Private LoRa® and LoRaWAN® Stack

Reference Guide

Introduction

This application note describes information to use the combination of Private LoRa® and LoRaWAN® stack.

Target Device

MCU: Renesas RL78/G23 (R7F100GSN, R7F100GLG), RL78/G14 (R5F104ML),
RA2E1 (R7FA2E1A9xxFM), RA2L1 (R7FA2L1AB2DFP) or RA0E2 (R7FA0E2094CFM)
Transceiver: Semtech SX1261 or SX1262

Contents

1. Overview

This application note contains information to use the combination of Private LoRa and LoRaWAN stack. This program communicates by switching between LoRaWAN and Private LoRa. For example, it usually communicates with the gateway using LoRaWAN, and communicates with the terminal device using Private LoRa only when necessary.

1.1 Feature of the Combination of Private LoRa and LoRaWAN Stack

- This program communicates by switching between LoRaWAN and Private LoRa. LoRaWAN and Private LoRa can be switched at any time.
- The parameters for LoRaWAN and Private LoRa are independent. So, they continue to work even after switching between LoRaWAN and Private LoRa.

1.2 Stack Block Diagram

Figure 1 shows a block diagram of the combination of Private LoRa and LoRaWAN stack.

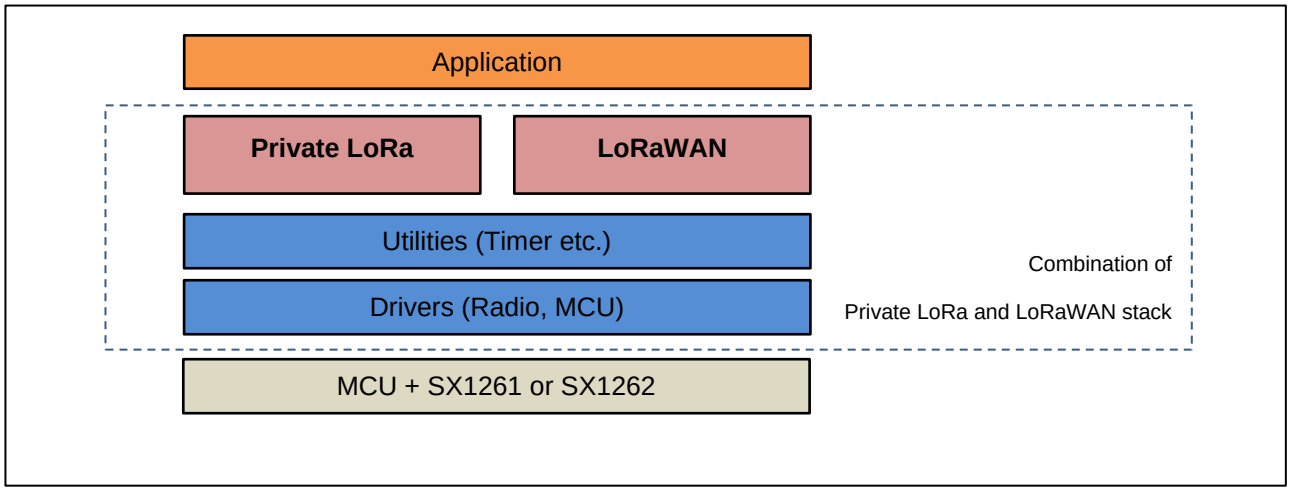

Figure 1. Stack Block Diagram

1.3 Directories (informative)

Table 1 shows a basic concept of what kind of codes each directory includes. This is just informative.

Table 1. Directories

Directories	Description
src/apps	Application code.
src/boards	Board specific codes.
src/boards/mcu	MCU drivers (except RL78/G23 and RL78/G22).
src/mac	LoRaWAN stack.
src/prvloramac	Private LoRa stack
src/radio	Radio driver for LoRa®.
src/peripherals	Security related codes.
src/system	Utility APIs, and so forth.
<ProjectDir>/src/smc_gen	MCU drivers for RL78/G23 and RL78/G22 generated by RL78 Smart Configurator. * <ProjectDir> is a folder for e2studio/CS+ project.

1.4 Resource Usage Example

Please refer to [3] or [4] in the following folder for the resource usage such as memory and peripherals.

Folder: `(package top)\documents\`

1.5 Acronyms and Abbreviations

Table 2. Acronyms and Abbreviations

Acronyms	Description
ABP	Activation By Personalization
EIRP	Equivalent Isotropic Radiated Power
MCPS	MAC Common Part Sublayer
MLME	MAC Layer Management Entity
OTAA	Over-The-Air-Activation
RFU	Reserved for Future Use
BW	Modulation bandwidth
DR	Data rate
US915	US902-928 MHz ISM Band
EU868	EU863-870 MHz Band
AS923	AS923 MHz Band
Group AS923-1	Composed of Asia countries having available frequencies in the 915-928 MHz range
Group AS923-2	Composed of Asia countries having available frequencies in the 920-923 MHz range
Group AS923-3	Composed of Asia countries having available frequencies in the 915-921 MHz range
Group AS923-4	Composed of Asia countries having available frequencies in the 917-920 MHz range
AS923-Japan	Perform ARIB STD-T108 regulation for using in Japan
IN865	IN865-867 MHz Band
AU915	AU915-928 MHz Band
KR920	KR920-923 MHz Band

1.6 Related Documentation

	Document No.	Title	Author	Language
[1]	R11AN0227	Radio Driver Reference Guide	Renesas Electronics	English
[2]	R11AN0834	Radio Driver Support Functions for Regional Radio Regulations	Renesas Electronics	English
[3]	R11AN0595	RL78/G23, RL78/G22, RL78/G14 LoRa®-based Wireless Software Package	Renesas Electronics	English
[4]	R11AN0596	RA2E1, RA2L1, RA0E1, RA0E2 LoRa®-based Wireless Software Package	Renesas Electronics	English
[5]	R11AN0228	LoRaWAN® Stack Reference Guide	Renesas Electronics	English
[6]	R11AN0231	LoRaWAN® Stack Sample Application	Renesas Electronics	English
[7]	R11AN0829	Private LoRa® Stack Reference Guide	Renesas Electronics	English
[8]	R11AN0830	Private LoRa® Stack Sample Application	Renesas Electronics	English
[9]	R11AN0937	Smart Configurator Usage for RL78 LoRa®-based Wireless Software Reference Guide	Renesas Electronics	English

2. Stack Interface

Please refer to [5] for LoRaWAN stack interface, and [7] for Private LoRa stack interface. This section describes stack interface specific to the combination of Private LoRa and LoRaWAN.

2.1 Macros

This section includes the following enumeration types.

2.1.1 Stack Settings

This subsection defines stack configurations macros. Macros in this subsection need to be defined in the project build option.

Table 3. Macros for Stack Setting

Macro	Description
LORACOMBO_ENABLED	Enable combination of Private LoRa and LoRaWAN. **This macro must be specified.** Note: Macro “PRVLORA_ENABLED” for Private LoRa is not necessary.
REGION_AS923	Enable AS923 feature. Note: Macro “RADIO_CFG_AS_ENABLED” for Private LoRa will be defined if REGION_AS923 macro is defined.
REGION_EU868	Enable EU868 feature. Note: Macro “RADIO_CFG_EU_ENABLED” for Private LoRa will be defined if REGION_EU868 macro is defined.
REGION_US915	Enable US915 feature. Note: Macro “RADIO_CFG_US_ENABLED” for Private LoRa will be defined if REGION_US915 macro is defined.
REGION_IN865	Enable IN865 feature. Note: Macro “RADIO_CFG_IN_ENABLED” for Private LoRa will be defined if REGION_IN865 macro is defined.
REGION_AU915	Enable AU915 feature. Note: Macro “RADIO_CFG_AU_ENABLED” for Private LoRa will be defined if REGION_AU915 macro is defined.
REGION_KR920	Enable KR920 feature. Note: Macro “RADIO_CFG_KR_ENABLED” for Private LoRa will be defined if REGION_KR920 macro is defined.
RP_USE_RADIO_CFG_CHECK	Enable the regulatory function for each region in Radio Driver. Refer to [2].

Note: Please refer to [5] for LoRaWAN stack setting macros, and [7] for Private LoRa stack setting macros.
Note: In case of RL78/G23 (R7F100GLG), only one region feature can be defined due to the memory size limitation.

2.2 Sample Code

Please refer to [5] for LoRaWAN stack sample code, and [7] for Private LoRa stack sample code. This section describes stack sample code specific to the combination of Private LoRa and LoRaWAN.

2.2.1 Initialize Private LoRa and LoRaWAN

The following code-snippet shows how to use the API to initialize both Private LoRa and LoRaWAN. Refer to [5] and [7] for detail on each stack's initialization.

```
#include “LoRaMac.h”
#include “PrvLoRa.h”

/* initialize LoRaWAN */          See [4] for detail.

static void McpsConfirm( McpsConfirm_t * );
static void McpsIndication( McpsIndication_t * );
static void MlmeConfirm( MlmeConfirm_t * );
static void MlmeIndication( MlmeIndication_t * );

static uint8_t AppLoraWanGetBatteryLevel( void );
static void AppNvmContextChange( uint32_t notifyMibFlags );
static void AppLoraWanMacErrorNotify( LoRaMacErrorNotificationStatus_t status );

LoRaMacPrimitives_t LoRaMacPrimitives;
LoRaMacCallback_t LoRaMacCallbacks;

LoRaMacPrimitives.MacMcpsConfirm     = McpsConfirm;
LoRaMacPrimitives.MacMcpsIndication  = McpsIndication;
LoRaMacPrimitives.MacMlmeConfirm     = MlmeConfirm;
LoRaMacPrimitives.MacMlmeIndication  = MlmeIndication;

LoRaMacCallbacks.GetBatteryLebel          = AppLoraWanGetBatteryLevel;
LoRaMacCallbacks.GetTemperatureLevel      = NULL;
LoRaMacCallbacks.NvmContextChange         = AppNvmContextChange;
LoRaMacCallbacks.MacProcessNotify         = NULL;
LoRaMacCallbacks.MacErrorNotify           = AppLoraWanMacErrorNotify;

LoRaMacInitialization( &LoRaMacPrimitives, &LoRaMacCallbacks, LORAMAC_REGION_EU868 );


/* Initialize Private LoRa */          See [6] for detail.

static void AppPrvLoRaCallbackMcpsConfirm( PrvLoRaMcpsCfm_t *p_mcpsCfm );
static void AppPrvLoRaCallbackMcpsIndication( PrvLoRaMcpsInd_t *p_mcpsInd );
static void AppPrvLoRaCallbackMlmeConfirm( PrvLoRaMlmeCfm_t *p_mlmeCfm );
static void AppPrvLoRaCallbackMlmeIndication( PrvLoRaMlmeInd_t *p_mlmeInd );
static void AppPrvLoRaCallbackMacNotification( PrvLoRaNotification_t *p_notify );

PrvLoRaPrimitives_t  appPrvLoRaPrimitives;

appPrvLoRaPrimitives.PrvLoRaMacMcpsConfirm      = AppPrvLoRaCallbackMcpsConfirm;
appPrvLoRaPrimitives.PrvLoRaMacMcpsIndication   = AppPrvLoRaCallbackMcpsIndication;
appPrvLoRaPrimitives.PrvLoRaMacMlmeConfirm      = AppPrvLoRaCallbackMlmeConfirm;
appPrvLoRaPrimitives.PrvLoRaMacMlmeIndication   = AppPrvLoRaCallbackMlmeIndication;
appPrvLoRaPrimitives.PrvLoRaMacNotification     = AppPrvLoRaCallbackMacNotification;

PrivateLoRaInitialization( &appPrvLoRaPrimitives, PRVLORA_REGION_EU868 );
```

2.2.2 Start either Private LoRa or LoRaWAN

The following code-snippet shows how to use the API to start either Private LoRa or LoRaWAN after initialization.

To start LoRaWAN first, call `LoRaMacStart()` API function. While LoRaWAN is running, Private LoRa API functions will result in an error.

```
/* Start LoRaWAN */
LoRaMacStart();
```

To start Private LoRa first, call `PrivateLoRaStart()` API function. While Private LoRa is running, LoRaWAN API functions will result in an error.

```
/* Start Private LoRa */
PrivateLoRaStart();
```

2.2.3 Switch Between Private LoRa and LoRaWAN

To switch from LoRaWAN to Private LoRa, call `LoRaMacStop()` API function to stop LoRaWAN first, and call `PrivateLoRaStart()` API function to start Private LoRa. After switching to Private LoRa, LoRaWAN API functions will result in an error.
Be sure to call `LoRaMacStop()` and `PrivateLoRaStart()` in order.

```
/* Stop LoRaWAN first */
LoRaMacStop();

/* Start Private LoRa */
PrivateLoRaStart();
```

To switch from Private LoRa to LoRaWAN, call `PrivateLoRaStop()` API function to stop Private LoRa first, and call `LoRaMacStart()` API function to start LoRaWAN. After switching to LoRaWAN, Private LoRa API functions will result in an error.
Be sure to call `PrivateLoRaStop()` and `LoRaMacStart()` in order.

```
/* Stop Private LoRa first */
PrivateLoRaStop();

/* Start LoRaWAN */
LoRaMacStart();
```

3. Sample Application

Please refer to [6] for LoRaWAN sample application, and [8] for Private LoRa sample application. This section describes sample application specific to the combination of Private LoRa and LoRaWAN.

3.1 Extended AT Command Reference

Please refer to [6] for LoRaWAN extended AT command sets, and [8] for Private LoRa extended AT command sets. Except for the following commands, AT commands for LoRaWAN cannot be used while Private LoRa is running, and AT commands for Private LoRa cannot be used while LoRaWAN is running. Since LoRaWAN and Private LoRa are independent, parameters must be set for each.

Commands	Description
AT+LORAMODE	Set/get LoRa mode.

3.1.1 AT+LORAMODE

Command	Result code	Description
+LORAMODE=<loramode> <loramode> LoRa mode. 0: LoRaWAN 1: Private LoRa	• OK • ERROR	• Switch LoRa mode to LoRaWAN or Private LoRa. • Normally, while using one LoRa mode, the commands of the other LoRa mode cannot be used. See Table 4 and Table 5 in below.
+LORAMODE?	<loramode> OK	• Read current LoRa mode.

Table 4. List of all extended AT commands

Commands	LoRa mode		supplement
	LoRaWAN	Private LoRa	
AT+LORAMODE	yes	yes	-
AT+VER	yes	yes	Firmware version of the currently selected LoRa mode can be read.
AT+RESET	yes	yes	If MCU is reset, LoRaWAN will start.
AT+SAVE	yes	yes	-
AT+LOAD	yes	yes	-
AT+REGION	yes	yes	-
AT+DEVEUI	yes	yes	-
AT+CLASS	yes	-	-
AT+DEVADDR	yes	-	-
AT+NETID	yes	-	-
AT+APPEUI	yes	-	-
AT+NWKSKEY	yes	-	-
AT+APPSKEY	yes	-	-
AT+APPKEY	yes	-	-
AT+ACTMODE	yes	-	-
AT+MTYPE	yes	-	-
AT+JOIN	yes	-	-
AT+SEND	yes	yes	In Private LoRa, parameter for specifying destination address is added.
AT+SENDHEX	yes	yes	In Private LoRa, parameter for specifying destination address is added.
AT+ADR	yes	-	-
AT+RSSI	yes	yes	-

AT+RX1DELAY	yes	-	-
AT+LINKCHK	yes	-	-
AT+FPORT	yes	-	-
AT+DCYCLE	yes	-	-
AT+DR	yes	yes	-
AT+DEVTIME	yes	-	-
AT+BCONACQ	yes	-	-
AT+PNGSLPERIOD	yes	-	-
AT+PNGSLINFO	yes	-	-
AT+GENAPPKEY	yes	-	-
AT+CHDEFMASK	yes	-	-
AT+DEVNONCE	yes	-	-
AT+APPNONCE	yes	-	-
AT+DOWNFCNT	yes	-	-
AT+UPFCNT	yes	-	-
AT+CHID	-	yes	-
AT+TXPOWER	-	yes	-
AT+RXON	-	yes	-
AT+RMTDEV	-	yes	-
AT+KEYREQ	-	yes	-
AT+KEYRES	-	yes	-
AT+TXOPT	-	yes	-
AT+DEVINFO	-	yes	-
AT+TXCYCLE	-	yes	-
AT+DEBUG	yes	yes	-

Table 5. List of all extended AT commands (notification)

Commands	**LoRa mode**		**supplement**
	LoRaWAN	**Private LoRa**	
+RCVD	yes	yes	The contents of the parameters are different between LoRaWAN and Private LoRa.
+RSSI	yes	yes	-
+BCONRCVD	yes	-	-
+BCONNORCVD	yes	-	-
+BCONLOST	yes	-	-
+KEYIND	-	yes	-
+TXCYCLEIND	-	yes	

3.2 Example operations of sample application

Please refer to [6] for example operation of LoRaWAN sample application, and [8] for example operation of Private LoRa.

3.2.1 Example Operation

The following command sequence is an example when current LoRa mode is LoRaWAN. When LoRaWAN mode is active, LoRaWAN commands are available and Private LoRa commands will be error.

AT+LORAMODE?
+LORAMODE: 0:LoRaWAN

Check current LoRa Mode -> current is LoRaWAN.

AT+CHID=0
ERROR

Private LoRa command will be error in LoRaWAN mode.

AT+REGION=6
OK

[LoRaWAN] Initialize setting for OTAA.

AT+DEVEUI=90F
OK

AT+APPEUI=10E
OK

AT+APPKEY=F0E
OK

AT+ACTMODE=1
OK

AT+JOIN
OK
+JOIN: JOIN_ACCEPTED

The following command sequence is an example to switch LoRa mode from LoRaWAN to Private LoRa. When Private LoRa mode is active, Private LoRa commands are available and LoRaWAN commands will be error.

AT+LORAMODE?
+LORAMODE: 0:LoRaWAN

Check current LoRa Mode -> current is LoRaWAN.

AT+LORAMODE=1
OK

Switch LoRa mode to Private LoRa.

AT+LORAMODE?
+LORAMODE: 1:PrivateLoRa

AT+DEVTIME
ERROR

LoRaWAN command will be error in Private LoRa mode.

AT+REGION=6
OK

[Private LoRa] Initial setting.

AT+DR=3
OK

AT+CHID=0
OK

AT+DEVEUI=AAAABBBBCCCCDDDD
OK

AT+RMTDEV=1111222233334444,5555555555555555AAAAAAAAAAAAAAAA
OK

AT+RXON=1
OK

[Private LoRa] Enable reception in idle state.

The following command sequence is an example to switch LoRa mode again. Previous status of each LoRa mode is kept.

AT+LORAMODE?
+LORAMODE: 1:PrivateLoRa

Check current LoRa Mode -> current is Private LoRa.

AT+LORAMODE=0
OK

Switch LoRa mode to LoRaWAN again.

AT+LORAMODE?
+LORAMODE: 0:LoRaWAN

AT+DEVTIME
OK
+DEVTIME: OK

[LoRaWAN] The state of LoRaWAN is kept; AT+DEVTIME and AT+LINKCHK can be executed successfully.

AT+LINKCHK
OK
+LINKCHK: 20,1

AT+LORAMODE=1
OK

Switch LoRa mode to Private LoRa again.

AT+LORAMODE?
+LORAMODE: 1:PrivateLoRa

[Private LoRa] The state of Private LoRa is kept; data can be sent and received with the destination device.

+RCVD: AAAABBBBCCCCDDDD,0,0,4,CC22DD33
+RSSI: -11, 11

AT+SENDHEX=1111222233334444,AA00BB11
OK
+SENDHEX: OK

Revision History

Rev.	Date	Description	
		Section	Summary
04.40	Dec.22.23	-	Initial Release
04.50	May 24.24	-	Change document revision.
04.60	Sep 27.24	1.3	Updated directories.
		1.6	Added related document [9].
04.70	Apr 18.25	-	Supported RA0E2 (R7FA0E2094CFM) as a target device.

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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.).

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

8. Differences between products

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

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