Private LoRa® Stack

Sample Application

Introduction

This document describes a sample software to use Private LoRa® stack. This application operates the Private LoRa stack by user with some commands from a Host PC.

Target Devices

- MCU: Renesas RL78/G23 (R7F100GSN, R7F100GLG), RL78/G14 (R5F104ML), RL78/G22 (R7F102GGE), RA2E1 (R7FA2E1A9xxFM), RA2L1 (R7FA2L1AB2DFP), RA0E1 (R7FA0E1073CFJ) or RA0E2 (R7FA0E2094CFM)
- Transceiver: Semtech SX1261 or SX1262

Contents

1. Overview

This document describes the APIs for operating the Private LoRa stack sample application program. This application can be operated by the AT command sets.

1.1 Environment

Figure 1 indicates the environment to use this sample application. This sample application can be operated with the AT command sets from a Host PC via a serial interface.

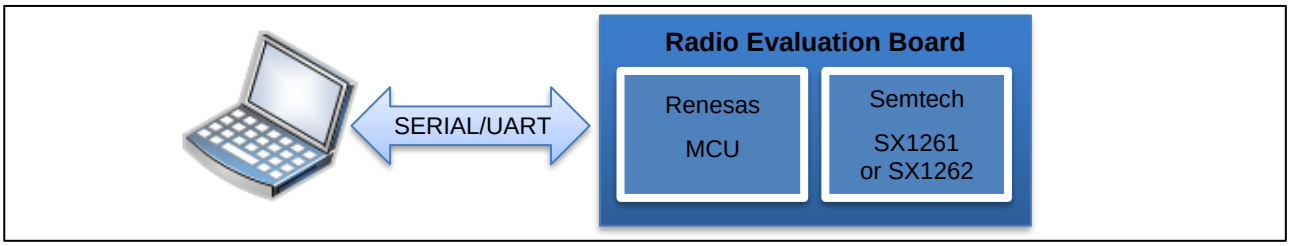


Figure 1. Sample Application Environment

The target MCU and the target RF for this sample application are Renesas MCU and Semtech SX1261 or SX1262.

1.2 Software Diagram

Figure 2 indicates a block diagram of this sample application.

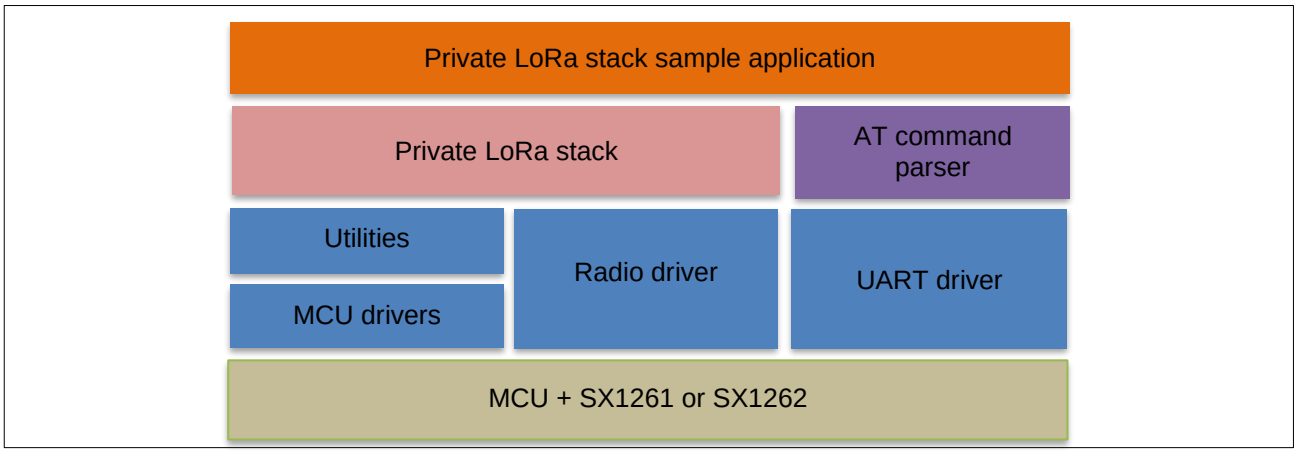


Figure 2. Sample Application Block Diagram

1.3 Directories (informative)

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

Table 1. Directories

Directories	Description
src/apps/PrivateLoRaSample	Private LoRa sample application codes.
src/boards	Board specific codes.
src/boards/mcu	MCU drivers (except RL78/G23 and RL78/G22).
src/prvloramac	Private LoRa MAC stack.
src/radio	Radio driver for LoRa®.
src/peripherals	Security related codes.
src/system	Utility codes.
src/system/flash/rfd/rfd	Renesas Flash Driver RL78 Type01 for RL78/G23. (*1)
<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.

CAUTION:

*1. This folder is for containing the flash driver to access the data and code flash memory. The driver for testing, 'Renesas Flash Driver RL78 Type 01 V1.00 for RL78/G23', is contained in advance. But when you start to develop a product, it is necessary to copy the newest library to this folder.

The flash driver is downloaded from Renesas website.

1.4 Resource Usage

Please refer to [4] for RL78 and [5] for RA in the following folder as for the resource usage such as memory and peripherals.

Folder: `(package top)\documents\`

1.5 Serial Terminal Software Configuration

The Serial Terminal Software configuration of this sample application is as shown in Table 2.

Table 2. Serial Terminal Software Configuration

Configuration Items	Value
Baud rate	115200 bps
Data bit	8 bits
Parity bit	None
Stop bit	1 bit
Flow control	None
Local echo back	Yes
Line terminator	Transmission: CR+LF Reception: CR+LF

1.6 Related Documentation

Table 3. Related Documentation

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

2. AT Command Syntax

2.1 Command Syntax

A command line is made up of three elements: the prefix, the body, and the termination character. The body is made up of individual commands as specified later in this document.

Note: This sample application program supports up to 512 characters for input of the command line. If the number of input characters exceeds the limit, the exceeded characters are ignored except for <BS>.

Table 4. General Command Syntax

Prefix	Body	Termination
“AT”	Individual commands as specified	<CR><LF>

2.1.1 Basic Command Syntax

The format of basic command syntax consists of <command>[<number>], where <command> is a single alphabetic character and where <number> may have a string of one or more characters from “0” to “9” decimal integer value.

Table 5. Basic Command Syntax

Prefix	Body	Termination	Description
“AT”	<command>[<number>]	<CR><LF>	Execute a command with number

2.1.2 Extended Command Syntax

There are two types of commands: action commands and parameter commands.

Action commands are used to “execute” a particular function of the equipment. Parameter commands are used to “set” value(s) to parameter(s) or to “read” current value(s) of parameter(s).

Table 6. Extended Command Syntax: Action Command

Prefix	Body (Subcommand)	Termination	Description
“AT”	+<name>	<CR><LF>	Execute an action command with no parameters
“AT”	+<name>=<value>|<compound values>	<CR><LF>	Execute an action command with one or more parameters

Table 7. Extended Command Syntax: Parameter Command

Prefix	Body (Subcommand)	Termination	Description
“AT”	+<name>=<value>|<compound values>	<CR><LF>	Store a <value> or <compound values>
“AT”	+<name>?	<CR><LF>	Read the current value

2.2 Response Syntax

Two types of response, the basic response and the extended response, are supported. The format used for these responses are shown in Table 8.

Table 8. General Response Syntax

Header	Information response	Trailer
<CR><LF>	Individual commands as specified	<CR><LF>

2.2.1 Basic Response

The basic response returns a result code in the information response as a result of basic and extended commands. Table 9 and Table 10 show the syntax of the basic response and the result codes respectively.

Table 9. Basic Response Syntax

Header	Result code	Trailer
<CR><LF>	<result code>	<CR><LF>

Table 10. Result Codes

Result code	Description
OK	Acknowledges execution of a command.
ERROR	Command not recognized, command line maximum length exceeded, parameter value invalid, or other problem with processing the command line.
BUSY	Other command is still running.

2.2.2 Extended Response Syntax

The extended response returns a subcommand information response in the information response as a result of extended commands. Table 11 shows the syntax of the extended response. The subcommand information response returns a value or compound values. The compound values use a comma as a delimiter. The response of the subcommand information response may be different except the common format.

Table 11. Extended Response Syntax

Header	Subcommand Information Response	Trailer	Description
<CR><LF>	+<name>:<value>|<compound values>	<CR><LF>	The body has the executed command name and the result value or compound values.

Some of the commands return what are referred to as an extended result code as extended response value. Table 12 shows the list of extended result codes a command can return.

Table 12. List of Extended Result Code

Extended Result Code	Description
OK	Success
BUSY	Private LoRa is busy
TX_NOACK	Did not receive an ACK to a data message
KEYREQ_SUCCESS	Received KeyRes in response to KeyReq
KEYREQ_FAILED	Did not receive KeyRes in response to KeyReq
SERVICE_UNKNOWN	Unknown MAC service
PARAMETER_INVALID	Invalid parameter is specified
CHANNEL_INVALID	Invalid channel (radio frequency) is specified
DATARATE_INVALID	Invalid data rate is specified
NOT_SUPPORTED	Specified region is not supported
RADIO_DUTYCYCLE_RESTRICTED	Transmission is under duty cycle restriction
RADIO_CHANNEL_BUSY	Transmission channels are busy
RADIO_ERROR	Radio driver error
RADIO_PARAMETER_INVALID	Radio parameter configuration invalid
MAC_ERROR	MAC error
UNKNOWN_STATUS	Unknown error

3. AT Command Sets

3.1 Basic AT Command Sets

3.1.1 Basic AT Command List

Commands	Description
AT	Tests whether to accept AT commands.
ATE	Enables / disables Echo-back. Echo-back is enabled in the initial state.
ATV	Changes the response format of the result code and response information.

3.2 Basic AT Command Reference

3.2.1 AT

Command	Result Code	Description
AT	• OK • ERROR	• Tests if the AT command interface is valid.

3.2.2 ATE

Command	Result code	Description
ATE<value> <value> 0: Echo-back is disabled (default) 1: Echo-back is enabled	• OK • ERROR	• Enables or disables the echo-back. • Echo-back is enabled by default.

Note: Unsupported for RA

3.2.3 ATV

Command	Result code	Description
ATV<value> <value> 0: Delimiter before result code and response information is omitted (default) 1: Delimiter before result code and response information is added	• OK • ERROR	• Set the response format of the result code and response information.

Category	ATV0	ATV1
Information response	<text><CR><LF>	<CR><LF> <text><CR><LF>
Result code	<text><CR><LF>	<CR><LF> <text><CR><LF>

3.3 Extended AT Command Sets

3.3.1 Extended AT Command List

Commands	Description
AT+VER	Show the version of this sample application.
AT+RESET	Reset Private LoRa stack or MCU.
AT+SAVE	Save parameters to the data flash.
AT+LOAD	Load parameters from the data flash.
AT+REGION	Set/get region.
AT+DEVEUI	Set/get device EUI (MAC address).

AT+CHID	Set/get channel ID.
AT+DR	Set/get data rate.
AT+TXPOWER	Set/get transmit power.
AT+RXON	Enable/disable reception in the idle state.
AT+RMTDEV	Register/unregister the pair of remote device and pre-shared key.
AT+KEYREQ	Request the session key exchange.
AT+KEYRES	Accept/reject the session key exchange request.
AT+TXOPT	Set/get transmit options.
AT+SEND	Send data message of character string.
AT+SENDHEX	Send data message of hexadecimal.
AT+DEVINFO	Send DevInfoReq command.
AT+TXCYCLE	Send TxCycleReq command.
AT+RSSI	Enable/disable RSSI display.
+RCVD	(Notification) Received a data message
+RSSI	(Notification) RSSI and SNR values on reception of messages.
+KEYIND	(Notification) Received and accepted KeyReq command.
+TXCYCLEIND	(Notification) Received TxCycleRes command.
AT+DEBUG	Set/get debug mode (debug purpose only).

3.4 Extended AT Command Reference

3.4.1 AT+VER

Command	Result code	Description
AT+VER?	<version string> OK	• Read firmware version.

3.4.2 AT+RESET

Command	Result code	Description
AT+RESET=<mode> <mode> 0: Re-initialize Private LoRa. 1: Reset MCU. 7: Initialize settings by formatting data flash and reset MCU.	• OK • ERROR	• Require the re-initialize Private LoRa (`<mode>=0`) or S/W reset (`<mode>=1`). • When <mode> is other than 0, 1 and 7, this command returns ERROR.

3.4.3 AT+SAVE

Command	Result code	Description
AT+SAVE	OK	• Save parameters to the data flash. • The parameters to save are `region, DevEUI (MAC address), channel, data rate, TxPower, RxOnWhenIdle, PermitKeyReq, txOptions, RSSI setting, TxCycle parameters (destination MAC address and TxCycleTime),` and `destination information (MAC address, AppKey, NwkSKey and frame counter).`

3.4.4 AT+LOAD

Command	Result code	Description
AT+LOAD AT+LOAD=<option> <option> 0: Load from the data flash (same as “AT+LOAD”). 1: Load default parameters.	OK	• Load parameters from the data flash when the option is not specified or set to 0. • Set default values to parameters when the option is set to 1.

3.4.5 AT+REGION

Command	Result code	Description
AT+REGION=<region> <region> Operation region. 0: EU 1: US 4: AU 6: AS1 7: KR 8: IN 22: AS2 23: AS3 24: AS4 30: JP 31: JP-LDC	• OK • ERROR	• Set operation region to the device. • When the `<region>` is other than the value for supported region, this command returns ERROR.
AT+REGION?	<region> OK	• Read the operation region set in the device.

3.4.6 AT+DEVEUI

Command	Result code	Description
AT+DEVEUI=<deveui> <deveui> Device EUI (MAC address) in 8 bytes hexadecimal value (16 characters).	• OK • ERROR	• Set DevEUI to the device. • When the length of `<deveui>` less than 8 bytes, pad with 0x00 from MSB. • When the length of `<deveui>` exceeds 8 bytes, this command returns ERROR.
AT+DEVEUI?	<deveui> OK	• Read the DevEUI set in the device.

3.4.7 AT+CHID

Command	Result code	Description
AT+CHID=<chid> <chid> Channel ID. Range: 0 – 63	• OK • ERROR • +CHID: BUSY	• Set channel ID to the device. • It is used to determine the frequency. • Actual frequencies are defined for each region and data rate. See 3.4.8. • When the reception mode in idle is enabled, this command returns BUSY error. See 3.4.10.
AT+CHID?	<chid> OK	• Read the channel ID set in the device.

3.4.8 AT+DR

Command	Result code	Description
AT+DR=<dr> <dr> Data rate ID. Range: 0 – 9	• OK • ERROR • +DR: BUSY	• Set the data rate of data messages to be sent. • It is used to determine the data rate. • Actual data rates are defined for each region. See below. • When the reception mode in idle is enabled, this command returns BUSY error. See 3.4.10.
AT+DR?	<dr> OK	• Read the data rate of data messages to be sent.

Available data rate IDs and channel IDs (3.4.7) are defined for each region.

Table 13. Available Data Rate ID and Channel ID (AS1)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 63	915.2 – 927.8	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 63	915.2 – 927.8	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 63	915.2 – 927.8	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 63	915.2 – 927.8	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 63	915.2 – 927.8	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 63	915.2 – 927.8	200
6	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 31	915.3 – 927.7	400
7	FSK	50 kbps	0 – 63	915.2 – 927.8	200

Table 14. Available Data Rate ID and Channel ID (AS2)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 13	920.2 – 922.8	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 13	920.2 – 922.8	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 13	920.2 – 922.8	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 13	920.2 – 922.8	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 13	920.2 – 922.8	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 13	920.2 – 922.8	200
6	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 5	920.5 – 922.5	400
7	FSK	50 kbps	0 – 13	920.2 – 922.8	200

Table 15. Available Data Rate ID and Channel ID (AS3)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 28	915.2 – 920.8	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 28	915.2 – 920.8	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 28	915.2 – 920.8	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 28	915.2 – 920.8	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 28	915.2 – 920.8	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 28	915.2 – 920.8	200
6	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 13	915.3 – 920.5	400
7	FSK	50 kbps	0 – 28	915.2 – 920.8	200

Table 16. Available Data Rate ID and Channel ID (AS4)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 14	917.1 – 919.9	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 14	917.1 – 919.9	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 14	917.1 – 919.9	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 14	917.1 – 919.9	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 14	917.1 – 919.9	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 14	917.1 – 919.9	200
6	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 6	917.3 – 919.7	400
7	FSK	50 kbps	0 – 14	917.1 – 919.9	200

Table 17. Available Data Rate ID and Channel ID (JP)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 14	920.6 – 923.4	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 14	920.6 – 923.4	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 14	920.6 – 923.4	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 14	920.6 – 923.4	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 37	920.6 – 928.0	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 37	920.6 – 928.0	200
6	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 3	920.7 – 921.9	400
7	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 13	922.7 – 927.9	400
8	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 18	920.9 – 928.1	400
9	FSK	50 kbps	0 – 37	920.6 – 928.0	200

Table 18. Available Data Rate ID and Channel ID (JP-LDC)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 14	920.6 – 923.4	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 14	920.6 – 923.4	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 14	920.6 – 923.4	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 14	920.6 – 923.4	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 14	920.6 – 923.4	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 14	920.6 – 923.4	200
6	FSK	50 kbps	0 – 14	920.6 – 923.4	200

Table 19. Available Data Rate ID and Channel ID (EU)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 27	863.1 – 868.5	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 27	863.1 – 868.5	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 27	863.1 – 868.5	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 27	863.1 – 868.5	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 27	863.1 – 868.5	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 27	863.1 – 868.5	200
6	LoRa®: SF7 – BW250 kHz	11000 bps	0 – 11	863.2 – 867.6	400
7	FSK	50 kbps	0 – 27	863.1 – 868.5	200

Table 20. Available Data Rate ID and Channel ID (US)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 41	920.9 – 927.5	600

Table 21. Available Data Rate ID and Channel ID (AU)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 21	915.5 – 928.1	600

Table 22. Available Data Rate ID and Channel ID (IN)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 14	865.1 – 867.9	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 14	865.1 – 867.9	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 14	865.1 – 867.9	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 14	865.1 – 867.9	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 14	865.1 – 867.9	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 14	865.1 – 867.9	200
6	FSK	50 kbps	0 – 14	865.1 – 867.9	200

Table 23. Available Data Rate ID and Channel ID (KR)

Data Rate ID	Configuration	Indicative physical bit rate	Channel ID	Frequency (MHz)	Steps (kHz)
0	LoRa®: SF12 – BW125 kHz	250 bps	0 – 14	865.1 – 867.9	200
1	LoRa®: SF11 – BW125 kHz	440 bps	0 – 14	865.1 – 867.9	200
2	LoRa®: SF10 – BW125 kHz	980 bps	0 – 14	865.1 – 867.9	200
3	LoRa®: SF9 – BW125 kHz	1760 bps	0 – 14	865.1 – 867.9	200
4	LoRa®: SF8 – BW125 kHz	3125 bps	0 – 14	865.1 – 867.9	200
5	LoRa®: SF7 – BW125 kHz	5470 bps	0 – 14	865.1 – 867.9	200
6	FSK	50 kbps	0 – 14	865.1 – 867.9	200

3.4.9 AT+TXPOWER

Command	Result code	Description
AT+TXPOWER=<txpower> <txpower> Transmission power. Range: -128 – 127 (dB)	• OK • ERROR	• Set the transmit power of data messages to be sent. • Actual transmit power depends on the regional specification and ability of SX126x.
AT+TXPOWER?	<txpower> OK	• Read the transmit power of data messages to be sent.

3.4.10 AT+RXON

Command	Result code	Description
AT+RXON=<rxon> <rxon> Enable/disable reception in idle state. 0: Disable (default) 1: Enable	• OK • ERROR • +RXON: DATARATE_INVALID • +RXON: CHANNEL_INVALID	• Set the reception mode in idle state. • If channel ID and/or data rate ID is invalid because of out of range and the regional specification, the reception mode cannot be set to enable.
AT+RXON?	<rxon> OK	• Read the reception mode in idle state.

3.4.11 AT+RMTDEV

Command	Result code	Description	
AT+RMTDEV=<addr>,<key> AT+RMTDEV=<addr> <addr> Device EUI (MAC address) of the remote device in 8 bytes hexadecimal value (16 characters). <key> PSK (Pre-Shared Key) in 16 bytes hexadecimal value (32 characters).	• OK • ERROR • +RMTDEV: MAC_ERROR	• Register the remote device and PSK. • When <key> is omitted, the remote device represented by <addr> is unregistered. Furthermore, if <addr> is all FF, all registered remote devices are unregistered. • Maximum entry of the remote device information is 1 for RL78/G22 and 3 for other case.	
		Extended result code	
		MAC_ERROR	No free entry to register.

3.4.12 AT+KEYREQ

Command	Result code	Description	
AT+KEYREQ=<addr> <addr> Device EUI (MAC address) of the remote device in 8 bytes hexadecimal value (16 characters).	• OK • ERROR • +KEYREQ: KEYREQ_SUCCESS • +KEYREQ: KEYREQ_FAILED • +KEYREQ: NO_REMOTE_DEVICE_ENTRY	• Request the remote device to exchange the new session key by sending `KeyReq` command frame. • Remote device must be registered by `AT+RMTDEV` command (See 3.4.11). • Transmit option can be specified. See also `AT+TXOPT` command (See 3.4.14).	
		Extended result code	
		KEYREQ_SUCCESS	Succeeded to exchange the new session key.
		KEYREQ_FAILED	Failed to exchange the new session key.
		NO_REMOTE_DEVICE_ENTRY	Specified remote device is not registered.

3.4.13 AT+KEYRES

Command	Result code	Description
AT+KEYRES=<keyres> <keyres> Accept or reject the request to exchange the session key. 0: Reject (default) 1: Accept	• OK • ERROR	• Accept or reject the request to exchange the session key from remote device.
AT+KEYRES?	<keyres> OK	• Read whether accept or reject to exchange the session key.

3.4.14 AT+TXOPT

Command	Result code	Description

AT+TXOPT=<txoptions>
 	
<txoptions>
Transmit options in 1byte hexadecimal value (2 characters).
Set the value obtained by Oring the following values.
01: Request ACK to the destination device.
02: Enable security. Encrypt transmit data.
04: Request indirect transmission.
	• OK
	• ERROR
		• Set the transmit options.
		• <txoptions> affects the following command.
		  • `AT+JOIN`
		  Only indirect transmission (04) is available.
		  • `AT+SEND`, `AT+SENDHEX`
		  All options are available.
		  • `AT+DEVINFO`, `AT+TXCYCLE`
		  Security (02) and indirect transmission (04) are available.

AT+TXOPT?	<txoptions> OK	• Read transmission options.

3.4.15 AT+SEND

Command	Result code	Description	
AT+SEND=<addr>,"<data>" <addr> Device EUI (MAC address) of the remote device in 8 bytes hexadecimal value (16 characters). <data> Data of character string.	• OK • ERROR • +SEND • +SEND: OK • +SEND: NO_REMOTE_DEVICE_ENTRY • +SEND: TX_NOACK	• Request to send a data message of character string. • Only visible characters, except space (0x20) and double quote (0x22) and comma (0x2c), are permitted for the character string. • Remote device must be registered by AT+RMTDEV command (See 3.4.11). • Transmit option can be specified. See also AT+TXOPT command (See 3.4.14).	
		Extended result codes	
		OK	Sent data message.
		NO_REMOTE_DEVICE_ENTRY	Specified remote device is not registered.
		TX_NOACK	Sent data message and failed to receive ACK.

3.4.16 AT+SENDHEX

Command	Result code	Description	
AT+SENDHEX=<addr>,<data> <addr> Device EUI (MAC address) of the remote device in 8 bytes hexadecimal value (16 characters). <data> Data of hexadecimal value	• OK • ERROR • +SENDHEX: OK • +SENDHEX: NO_REMOTE_DEVICE_ENTRY • +SENDHEX: TX_NOACK	• Request to send a data message of hexadecimal value. • Remote device must be registered by AT+RMTDEV command (See 3.4.11). • Transmit option can be specified. See also AT+TXOPT command (See 3.4.14).	
		Extended result codes	
		OK	Sent data message.
		NO_REMOTE_DEVICE_ENTRY	The device has not been activated.
		TX_NOACK	Sent data message and failed to receive ACK.

3.4.17 AT+DEVINFO

<table>
<tr><th>Command</th><th>Result code</th><th colspan="2">Description</th></tr>
<tr><td rowspan="5">AT+DEVINFO=<addr>

<addr>
Device EUI (MAC address) of the remote device in 8 bytes hexadecimal value (16 characters).</td><td rowspan="5">• OK
• ERROR
• +DEVINFO: <txpower>,<snr>,<txcycletime>
• +DEVINFO: ERROR
• +DEVINFO: NO_REMOTE_DEVICE_ENTRY</td><td colspan="2">• Query the information of remote device by sending DevInfoReq command frame.
• Remote device must be registered by AT+RMTDEV command (See 3.4.11).
• Transmit option can be specified. See also AT+TXOPT command (See 3.4.14).</td></tr>
<tr><td colspan="2">Extended result code</td></tr>
<tr><td><txpower>,<snr>,<txcycletime></td><td>Information of remote device.
<txpower>
Transmission power.
<snr>
Signal-to-noise ratio.
<txcycletime>
Periodicity of cyclic transmission.</td></tr>
<tr><td>ERROR</td><td>Response (DevInfoRes command) cannot be received.</td></tr>
<tr><td>NO_REMOTE_DEVICE_ENTRY</td><td>Specified remote device is not registered.</td></tr>
</table>

3.4.18 AT+TXCYCLE

<table>
<tr><th>Command</th><th>Result code</th><th colspan="2">Description</th></tr>
<tr><td rowspan="6">AT+TXCYCLE=<addr>,<txcycletime>

<addr>
Device EUI (MAC address) of the remote device in 8 bytes hexadecimal value (16 characters).
<txcycletime>
Periodicity of cyclic transmission in sec.
Range: 0, 10 – 131071 (sec)</td><td rowspan="6">• OK
• ERROR
• +TXCYCLE: OK
• +TXCYCLE: ERROR
• +TXCYCLE: NO_REMOTE_DEVICE_ENTRY</td><td colspan="2">• Request cyclic transmission to the remote device by sending TxCycleReq command frame.
• Remote device must be registered by AT+RMTDEV command (See 3.4.11).
• Transmit option can be specified. See also AT+TXOPT command (See 3.4.14).</td></tr>
<tr><td colspan="2">Extended result code</td></tr>
<tr><td>OK</td><td></td></tr>
<tr><td>ERROR</td><td>Response (TxCycleRes command) cannot be received.</td></tr>
<tr><td>NO_REMOTE_DEVICE_ENTRY</td><td>Specified remote device is not registered.</td></tr>
</table>

3.4.19 AT+RSSI

Command	Result code	Description
AT+RSSI=<rssi_on> <rssi_on> ON/OFF RSSI display. 0: OFF (default) 1: ON	• OK • ERROR	• Set RSSI display mode. • When RSSI display mode is ON, RSSI and SNR values of received data message are notified. See 3.4.21.
AT+RSSI?	<rssi_on> OK	• Read RSSI display mode.

3.4.20 +RCVD

Command	Description
+RCVD: <addr>,<sec>,<ack>,<length>,<data> <addr> Device EUI (MAC address) of the source device. <sec> 0:Received message was not encrypted. 1:Received message was encrypted. <ack> 0: ACK is not included in received message. 1: ACK is included in received message. <length> Received message length. <data> Hexadecimal data.	• Notify reception of a data message • This command is notified only when the data message is received without an error.

3.4.21 +RSSI

Command	Description
+RSSI: <rssi>,<snr> <rssi> RSSI value <snr> SNR value	• Notify RSSI and SNR values of received data message when RSSI display mode is ON. See 3.4.19.

3.4.22 +KEYIND

Command	Description
+KEYIND: <addr> <addr> Device EUI (MAC address) of the remote device which requests the session key exchange.	• Notify reception of session key exchange request from the remote device. • This command is notified if the setting is to accept the session key exchange request. See 3.4.13.

3.4.23 +TXCYCLEIND

Command	Description
+TXCYCLEIND: <addr>,<sec>,<txcycletime> <addr> Device EUI (MAC address) of the remote device which requests the cyclic transmission. <sec> 0:Received command was not encrypted. 1:Received command was encrypted. <txcycletime> Periodicity of cyclic transmission in sec.	• Notify reception of cyclic transmission request from the remote device.

3.4.24 AT+DEBUG

This command can be used for debug purpose only.

Command	Result code	Description
AT+DEBUG=<debugmode> <debugmode> Debug mode in 4 bytes hexadecimal value (8 characters). The default value is 00000100.	• OK • ERROR	• Set the debug mode. • One or more of the following debug mode bit(s) can be specified to `<debugmode>`. — 00000100 (bit 8): Enables Pseudo MCU low power operation (*Note1). It needs to be set if MCU cannot return from the low power mode before receiving UART data. — 00010000 (bit12): Enables debug log of received `TxCycleReq` command information. — 00020000 (bit13): Enables debug log of update remote device information. • This command can be used when `DEBUG_PRVLORA` macro is defined. (See 4.1.2) • Default debug mode can be set from the value of `DEBUG_PRVLORA_DEFAULT_MODE` macro if it is defined. (See 4.1.2)
AT+DEBUG?	<debugmode> OK	• Read the debug mode.

4. Example operations of sample application

This section describes the example operations of the Private LoRa stack sample application.

The section 4.1 describes the preparation required for the Private LoRa device. The section 4.2 describes the example operations using the AT commands.

4.1 Preparation for Private LoRa Device

The sample application needs to be built and programmed to the hardware you use.

4.1.1 Hardware Setup

As for how to setup the hardware required for the sample application, please refer to [4] and [5].

4.1.2 Configuration of Sample Application

Table 24 shows the major macros available for the configuration of the sample application. These macros can be specified in the project build option as needed.

Table 24. Macros Available for the Configuration of the Sample Application

Macro	Description	Default
PRVLORA_ENABLED	Enables Private LoRa features. Must be specified.	Defined
RADIO_CFG_AS_ENABLED	Enables AS1, AS2, AS3, AS4, JP and JP-LDC feature.	Defined
RADIO_CFG_EU_ENABLED	Enables EU feature	Defined
RADIO_CFG_US_ENABLED	Enables US feature	Defined
RADIO_CFG_IN_ENABLED	Enables IN feature	Not defined
RADIO_CFG_AU_ENABLED	Enables AU feature	Not defined
RADIO_CFG_KR_ENABLED	Enables KR feature	Not defined
RP_USE_RADIO_CFG_CHECK	Enable the regulatory function for each region in Radio Driver. Refer to [3].	Defined
DEBUG_PRVLORA	Enables the debug mode. The debug mode is necessary if MCU cannot wake up from low power mode by an interrupt before receiving UART data.	Defined
DEBUG_PRVLORA_DEFAULT_MODE=0xXXXXXXXX	Specifies the default debug mode with the Ored value of the following if necessary. See 3.4.24 for more detail. 0x0000100: Enables Pseudo MCU low power operation. 0x0001000: Enables debug log of received `TxCycleReq` command information. 0x0002000: Enables debug log of update remote device information. This macro can be specified when DEBUG_PRVLORA is defined.	Defined. Set to 0x00000100

4.1.3 Building of Sample Application

As for how to build the sample application, please refer to [4] and [5].

4.1.4 Programing of Object Files to Code Flash Memory

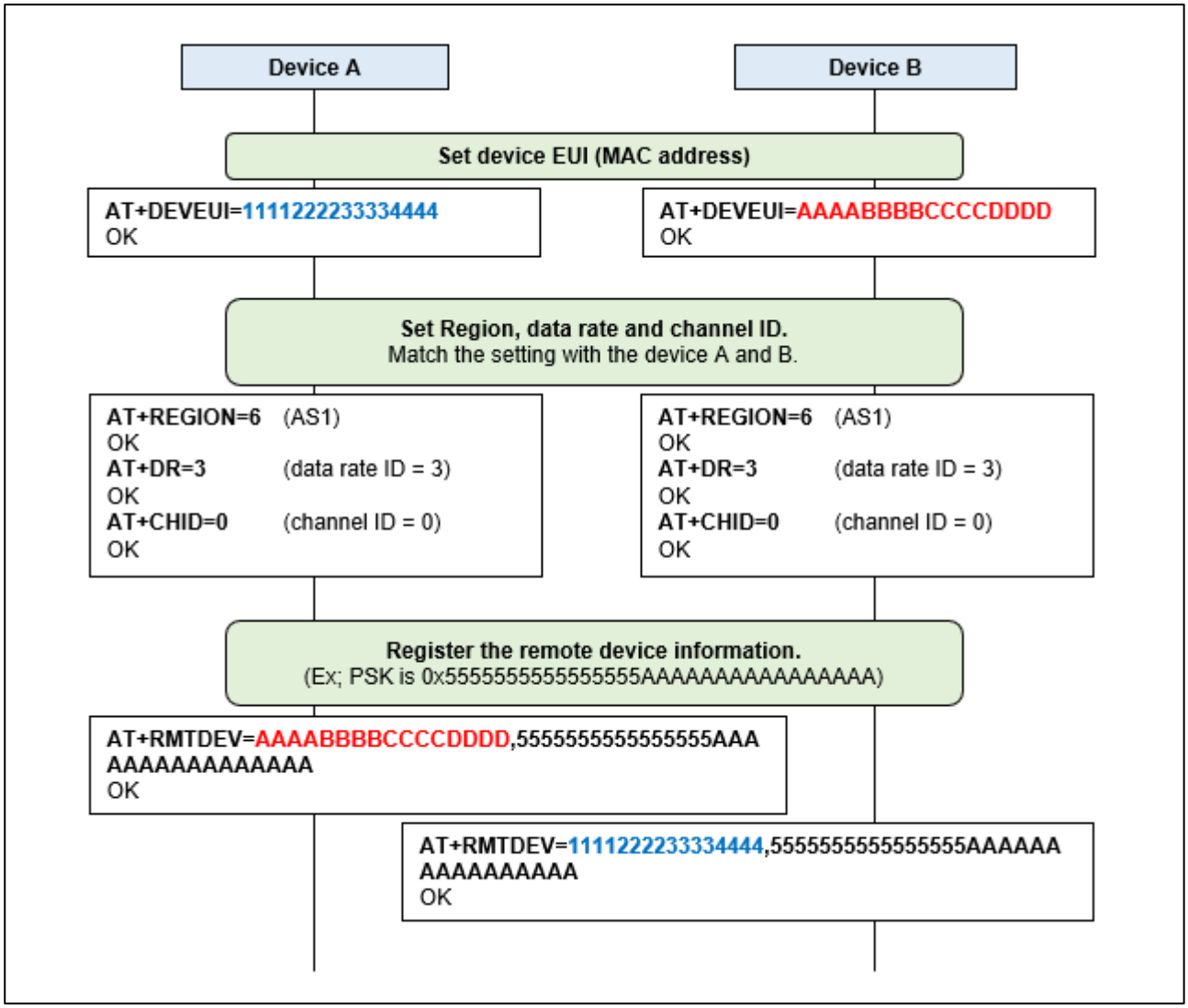
The object files of the sample application need to write to the code flash memory of MCU. As for the operations for the flash programing, please refer to [4] and [5].

4.2 Example Operations

This section describes the example operation of Private LoRa device such as the initial settings, data transmission/reception, and command transmission/reception.

4.2.1 Initial Setting

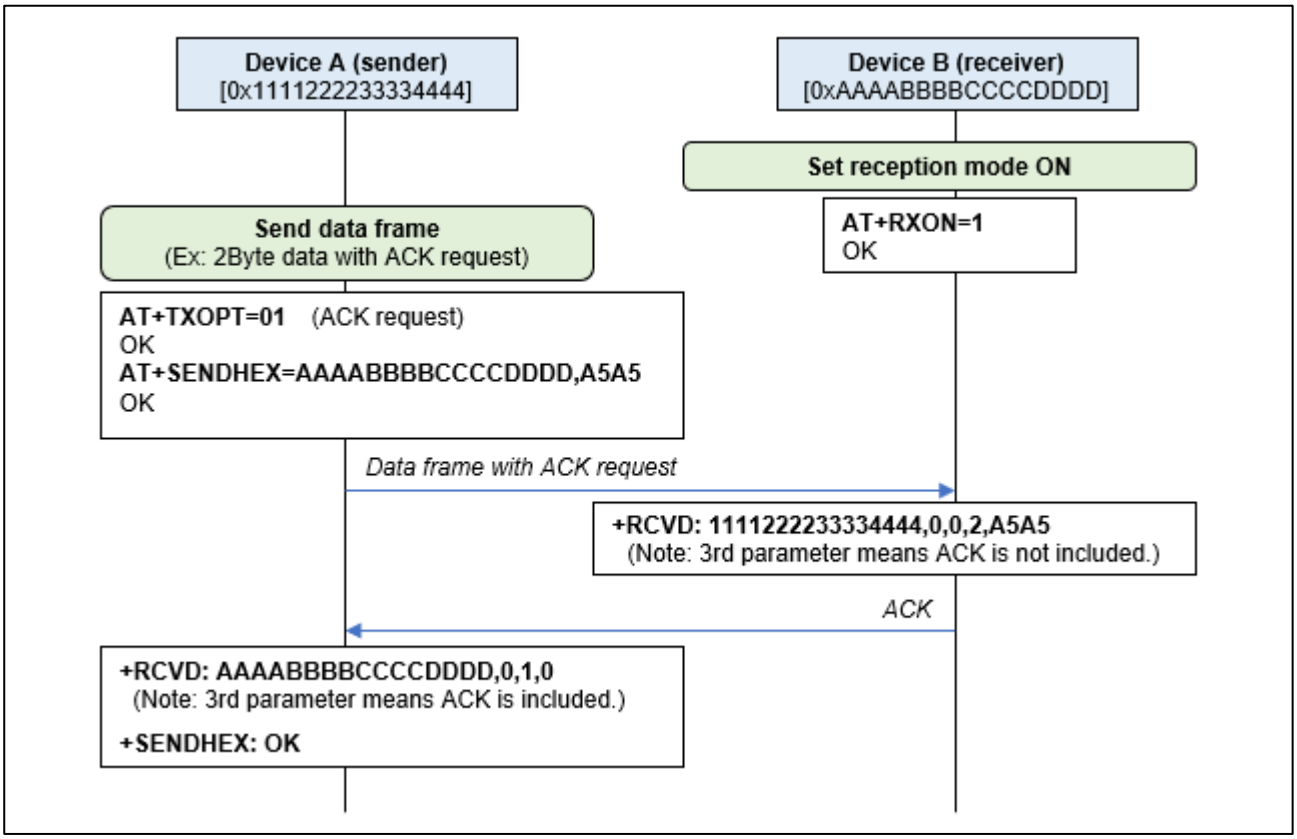
The following command sequence is an example to initialize the device. Parameters for each command are just samples and need to be modified according to application program specifications.



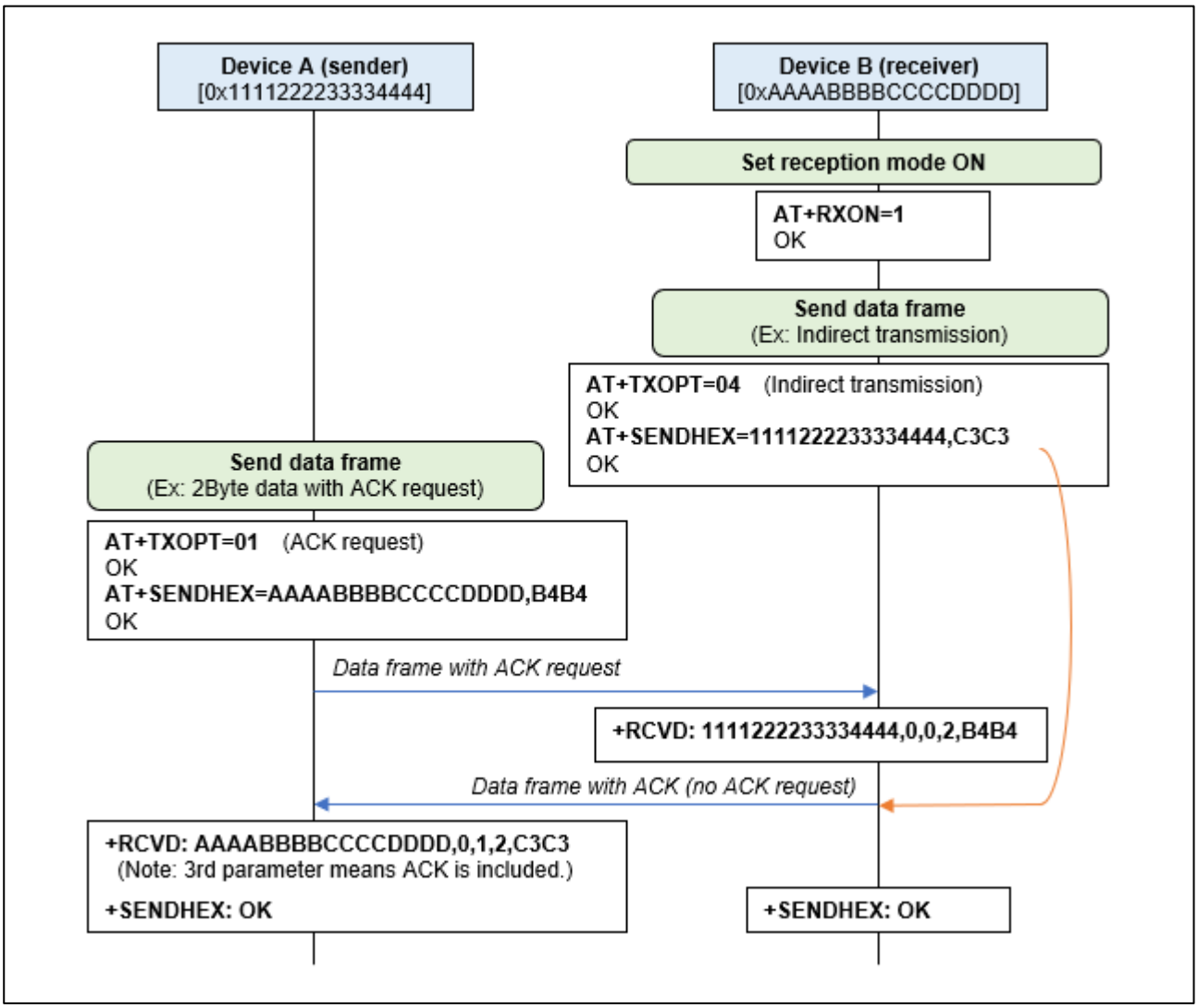
4.2.2 Send / Receive Data

The following command sequence is an example to send / receive data message. The first command sequence is direct transmission, and second command sequence is indirect transmission.

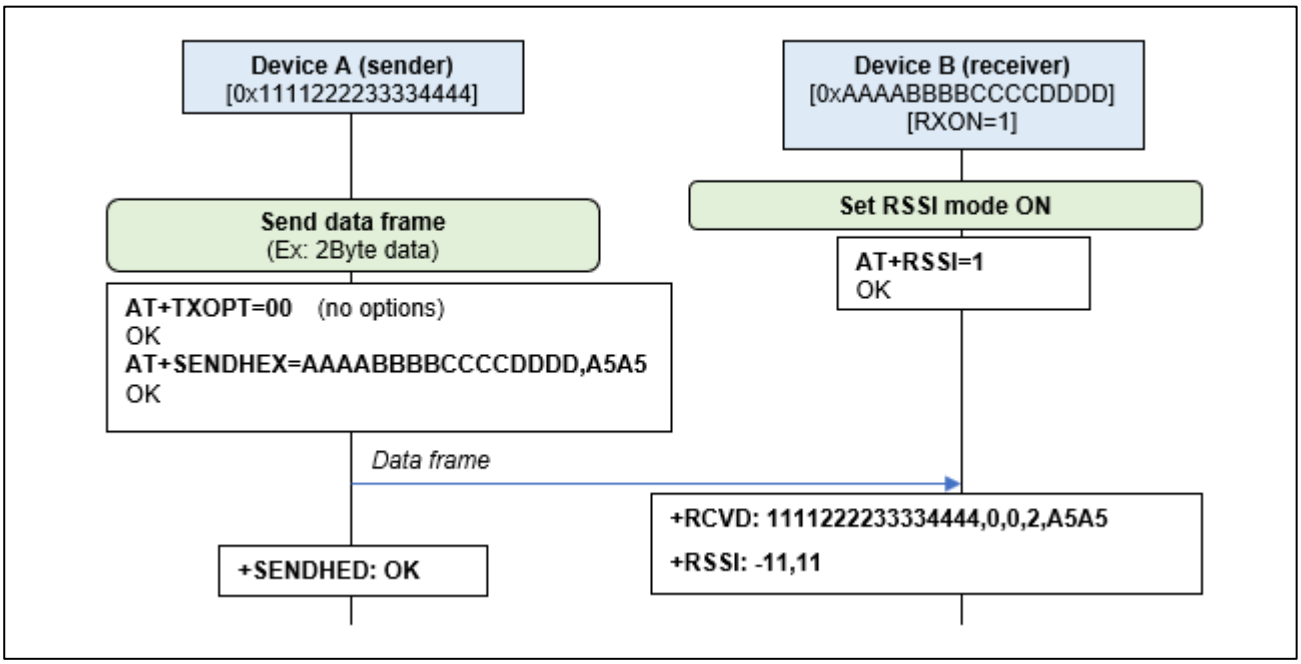
- Direct Transmission



- Indirect Transmission

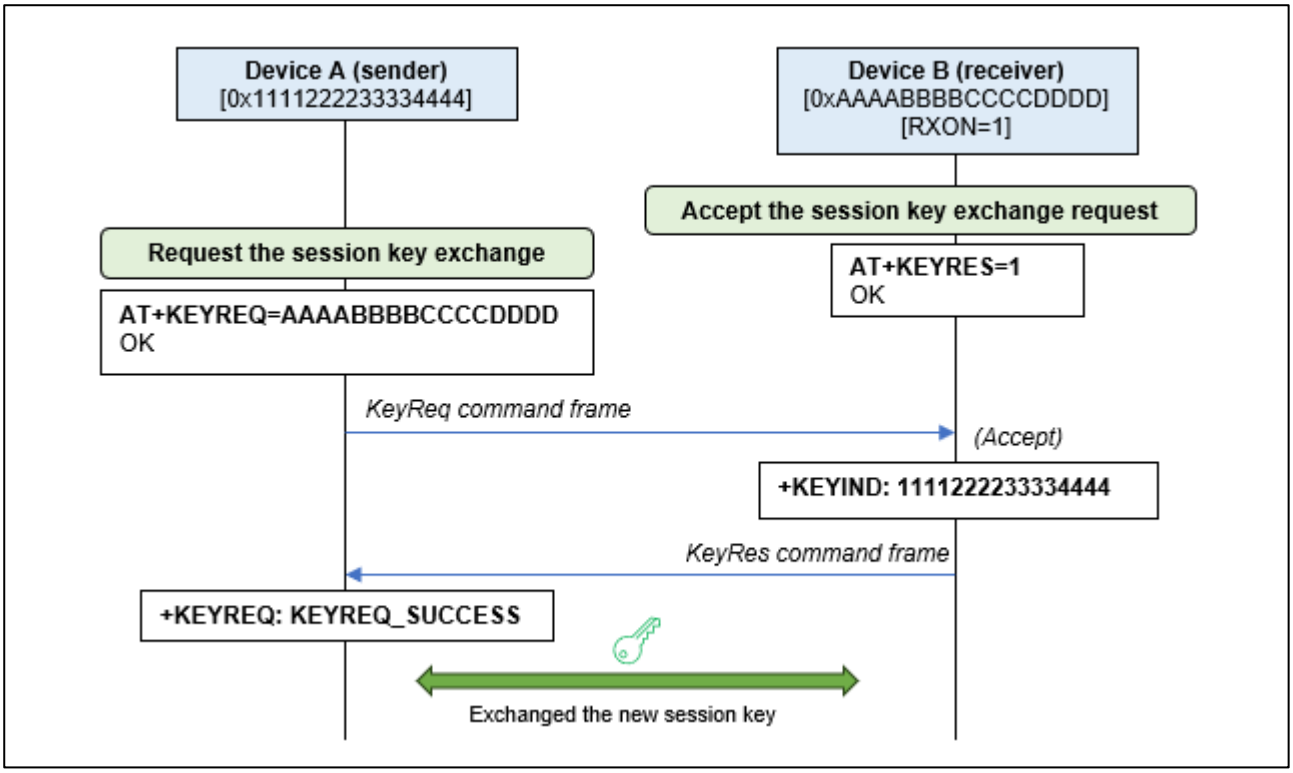


When RSSI mode is ON, RSSI and SNR values of received data message are notified.



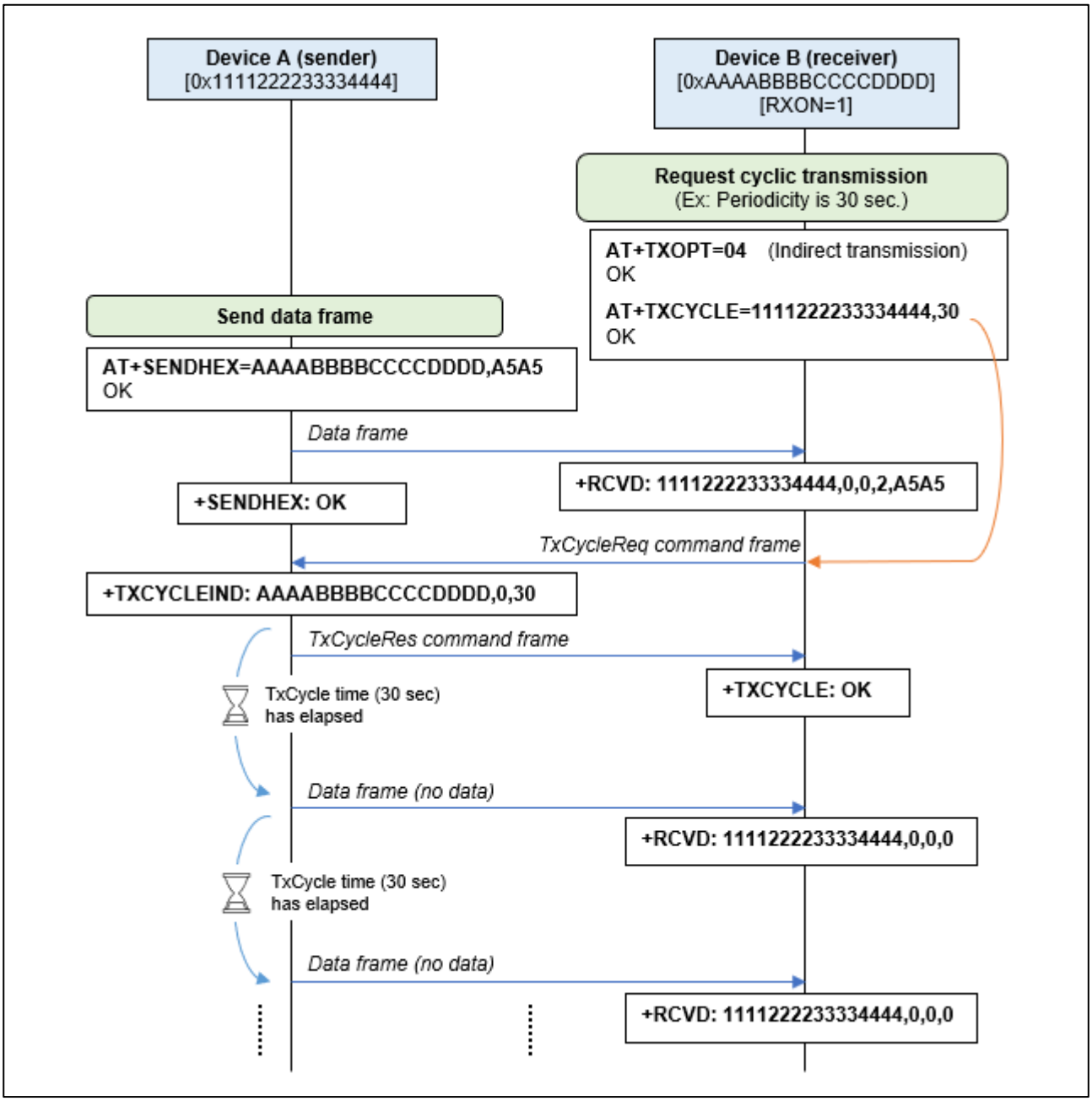
4.2.3 Exchange the Session Key

The following command sequence is an example how to exchange the new session key.



4.2.4 Cyclic Transmission

The following command sequence is an example of cyclic transmission. Cyclic transmission can be stopped by setting the periodicity (second parameter of `AT+TXCYCLE`) to 0.



Revision History

Rev.	Date	Description	
		Page	Summary
04.40	Dec 22.23	-	Initial Release
04.50	May.24.24	-	Supported RA0E1 (R7FA0E1073CFJ) as a target device.
04.60	Sep.27.24	1.3	Updated directories.
		1.6	Added related document [6].
04.70	Apr.18.25	-	Supported RA0E2 (R7FA0E2094CFM) as a target device.

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

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

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

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

3. Input of signal during power-off state

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

4. Handling of unused pins

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

5. Clock signals

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

6. Voltage application waveform at input pin

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

7. Prohibition of access to reserved addresses

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

8. Differences between products

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

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