LoRaWAN® Stack

Reference Guide

Introduction

This application note describes information to use the LoRaWAN® stack and its APIs.

Target Device

MCU: RL78/G23 (R7F100GSN, R7F100GLG), RL78/G22 (R7F102GGE), RL78/L23 (R7F100LPL),
RL78/G14 (R5F104ML),
RA2E1 (R7FA2E1A9xxFM), RA2L1 (R7FA2L1AB2DFP), RA0E1 (R7FA0E1073CFJ) or
RA0E2 (R7FA0E2094CFM)
Transceiver: Semtech SX1261 or SX1262

Note: When using RL78/G22 or RA0E1, there are some limitations of LoRaWAN functions. See chapter 6.

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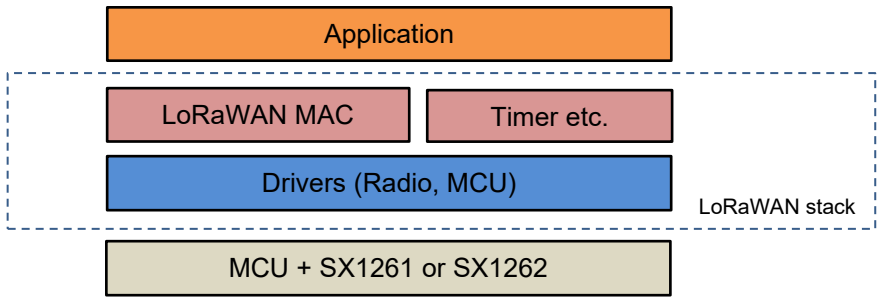
1. Overview

This application note contains API references and other information to use the LoRaWAN stack. The LoRaWAN stack includes LoRaWAN interface which implements LoRaWAN protocol (Class A/B/C) specified in the specification version 1.0.4 and 1.0.3 which encompasses version 1.0.2.
The LoRaWAN interfaces are described in chapter 2. The Timer interface is described in chapter 3. Application can also use Timer APIs, although they are used in the stack.

Note: Limitations of LoRaWAN functionality by RL78/G22 and RA0E1 are described in chapter 6.

1.1 LoRaWAN Stack Block Diagram

Figure 1 shows a block diagram of the LoRaWAN Stack.



Note: This document covers LoRaWAN MAC and Timer.

Figure 1. LoRaWAN Stack Block Diagram

1.2 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, RL78/G22 and RL78/L23)
src/mac	LoRaWAN MAC 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, RL78/G22 and RL78/L23 generated by RL78 Smart Configurator. * <ProjectDir> is a folder for e2studio/CS+ project.

1.3 Resource Usage Example

Please refer to [3] for RL78 and [4] for RA in the following folder for the resource usage such as memory and peripherals.

Folder: `(package top)\documents\`

1.4 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

1.5 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/L23, 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]	R11AN0937	Smart Configurator Usage for RL78 LoRa®-based Wireless Software Reference Guide	Renesas Electronics	English

2. LoRaWAN Interface

This section describes the LoRaWAN stack interfaces.

2.1 Macros

This section includes the following enumeration types.

2.1.1 Data Rate

This section includes Data rate index definitions. Actual parameters are defined for each region.

Table 3. Data Rate Index Definitions

Macro	Value	Description
DR_0	0	DR0 (Data rate 0)
DR_1	1	DR1 (Data rate 1)
DR_2	2	DR2 (Data rate 2)
DR_3	3	DR3 (Data rate 3)
DR_4	4	DR4 (Data rate 4)
DR_5	5	DR5 (Data rate 5)
DR_6	6	DR6 (Data rate 6)
DR_7	7	DR7 (Data rate 7)
DR_8	8	DR8 (Data rate 8)
DR_9	9	DR9 (Data rate 9)
DR_10	10	DR10 (Data rate 10)
DR_11	11	DR11 (Data rate 11)
DR_12	12	DR12 (Data rate 12)
DR_13	13	DR13 (Data rate 13)
DR_14	14	DR14 (Data rate 14)
DR_15	15	DR15 (Data rate 15)

Table 4. AS923 Data Rate

Data Rate	Configuration	Indicative physical bit rate
DR0	LoRa®: SF12 - BW125 kHz	250 bps
DR1	LoRa®: SF11 - BW125 kHz	440 bps
DR2	LoRa®: SF10 - BW125 kHz	980 bps
DR3	LoRa®: SF9 - BW125 kHz	1760 bps
DR4	LoRa®: SF8 - BW125 kHz	3125 bps
DR5	LoRa®: SF7 - BW125 kHz	5470 bps
DR6	LoRa®: SF7 - BW250 kHz	11000 bps
DR7	FSK	50 kbps
DR8 - DR14	RFU	RFU
DR15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.	

Table 5. EU868 Data Rate

Data Rate	Configuration	Indicative physical bit rate
DR0	LoRa®: SF12 - BW125 kHz	250 bps
DR1	LoRa®: SF11 - BW125 kHz	440 bps
DR2	LoRa®: SF10 - BW125 kHz	980 bps
DR3	LoRa®: SF9 - BW125 kHz	1760 bps
DR4	LoRa®: SF8 - BW125 kHz	3125 bps
DR5	LoRa®: SF7 - BW125 kHz	5470 bps

Data Rate	Configuration	Indicative physical bit rate
DR6	LoRa®: SF7 - BW250 kHz	11000 bps
DR7	FSK	50 kbps
DR8 - DR14	RFU	RFU
DR15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.	

Table 6. US915 Data Rate

Data Rate	Configuration	Indicative physical bit rate
DR0	LoRa®: SF10 - BW125 kHz	980 bps
DR1	LoRa®: SF9 - BW125 kHz	1760 bps
DR2	LoRa®: SF8 - BW125 kHz	3125 bps
DR3	LoRa®: SF7 - BW125 kHz	5470 bps
DR4	LoRa®: SF8 - BW500 kHz	12500 bps
DR5 - DR7	RFU	RFU
DR8	LoRa®: SF12 - BW500 kHz	980 bps
DR9	LoRa®: SF11 - BW500 kHz	1760 bps
DR10	LoRa®: SF10 - BW500 kHz	3900 bps
DR11	LoRa®: SF9 - BW500 kHz	7000 bps
DR12	LoRa®: SF8 - BW500 kHz	12500 bps
DR13	LoRa®: SF7 - BW500 kHz	21900 bps
DR14	RFU	RFU
DR15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.	

Table 7. IN865 Data Rate

Data Rate	Configuration	Indicative physical bit rate
DR0	LoRa®: SF12 - BW125 kHz	250 bps
DR1	LoRa®: SF11 - BW125 kHz	440 bps
DR2	LoRa®: SF10 - BW125 kHz	980 bps
DR3	LoRa®: SF9 - BW125 kHz	1760 bps
DR4	LoRa®: SF8 - BW125 kHz	3125 bps
DR5	LoRa®: SF7 - BW125 kHz	5470 bps
DR6	RFU	RFU
DR7	FSK	50 kbps
DR8 - DR14	RFU	-
DR15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.	

Table 8. AU915 Data Rate

Data Rate	Configuration	Indicative physical bit rate
DR0	LoRa®: SF12 - BW125 kHz	250 bps
DR1	LoRa®: SF11 - BW125 kHz	440 bps
DR2	LoRa®: SF10 - BW125 kHz	980 bps
DR3	LoRa®: SF9 - BW125 kHz	1760 bps
DR4	LoRa®: SF8 - BW125 kHz	3125 bps
DR5	LoRa®: SF7 - BW125 kHz	5470 bps
DR6	LoRa®: SF8 - BW500 kHz	12500 bps
DR7	RFU	RFU
DR8	LoRa®: SF12 - BW500 kHz	980 bps
DR9	LoRa®: SF11 - BW500 kHz	1760 bps
DR10	LoRa®: SF10 - BW500 kHz	3900 bps

DR11	LoRa®: SF9 - BW500 kHz	7000 bps
DR12	LoRa®: SF8 - BW500 kHz	12500 bps
DR13	LoRa®: SF7 - BW500 kHz	21900 bps
DR14	RFU	RFU
DR15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.	

Table 9. KR920 Data Rate

Data Rate	Configuration	Indicative physical bit rate
DR0	LoRa®: SF12 - BW125 kHz	250 bps
DR1	LoRa®: SF11 - BW125 kHz	440 bps
DR2	LoRa®: SF10 - BW125 kHz	980 bps
DR3	LoRa®: SF9 - BW125 kHz	1760 bps
DR4	LoRa®: SF8 - BW125 kHz	3125 bps
DR5	LoRa®: SF7 - BW125 kHz	5470 bps
DR6 - DR14	RFU	RFU
DR15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.	

2.1.2 Transmission Power

This subsection defines transmission power macros. Actual power levels corresponding to each value are region specific.

Table 10. Transmission Power Definitions

Macro	Value	Description
TX_POWER_0	0	TxPower0
TX_POWER_1	1	TxPower1
TX_POWER_2	2	TxPower2
TX_POWER_3	3	TxPower3
TX_POWER_4	4	TxPower4
TX_POWER_5	5	TxPower5
TX_POWER_6	6	TxPower6
TX_POWER_7	7	TxPower7
TX_POWER_8	8	TxPower8
TX_POWER_9	9	TxPower9
TX_POWER_10	10	TxPower10
TX_POWER_11	11	TxPower11
TX_POWER_12	12	TxPower12
TX_POWER_13	13	TxPower13
TX_POWER_14	14	TxPower14
TX_POWER_15	15	TxPower15

Table 11. AS923 Transmission Power

TxPower	Configuration (EIRP)
TxPower0	MaxEIRP By default MaxEIRP is considered to be +16dBm
TxPower1	MaxEIRP - 2dB
TxPower2	MaxEIRP - 4dB
TxPower3	MaxEIRP - 6dB
TxPower4	MaxEIRP - 8dB
TxPower5	MaxEIRP - 10dB

TxPower	Configuration (EIRP)
TxPower6	MaxEIRP - 12dB
TxPower7	MaxEIRP - 14dB
TxPower8 – TxPower14	RFU
TxPower15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.

Table 12. EU868 Transmission Power

TxPower	Configuration (EIRP)
TxPower0	MaxEIRP By default MaxEIRP is considered to be +16dBm
TxPower1	MaxEIRP - 2dB
TxPower2	MaxEIRP - 4dB
TxPower3	MaxEIRP - 6dB
TxPower4	MaxEIRP - 8dB
TxPower5	MaxEIRP - 10dB
TxPower6	MaxEIRP - 12dB
TxPower7	MaxEIRP - 14dB
TxPower8 – TxPower14	RFU
TxPower15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.

Table 13. US915 Transmission Power

TxPower	Configuration (conducted power)
TxPower0	30dBm
TxPower1	28dBm
TxPower2	26dBm
TxPower3	24dBm
TxPower4	22dBm
TxPower5	20dBm
TxPower6	18dBm
TxPower7	16dBm
TxPower8	14dBm
TxPower9	12dBm
TxPower10	10dBm
TxPower11	8dBm
TxPower12	6dBm
TxPower13	4dBm
TxPower14	2dBm
TxPower15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.

Table 14. IN865 Transmission Power

TxPower	Configuration (EIRP)
TxPower0	MaxEIRP By default MaxEIRP is considered to be +30 dBm
TxPower1	MaxEIRP - 2 dB
TxPower2	MaxEIRP - 4 dB
TxPower3	MaxEIRP - 6 dB
TxPower4	MaxEIRP - 8 dB
TxPower5	MaxEIRP - 10 dB
TxPower6	MaxEIRP - 12 dB

TxPower	Configuration (EIRP)
TxPower7	MaxEIRP - 14 dB
TxPower8	MaxEIRP - 16 dB
TxPower9	MaxEIRP - 18 dB
TxPower10	MaxEIRP - 20 dB
TxPower11 - TxPower14	RFU
TxPower15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.

Table 15. AU915 Transmission Power

TxPower	Configuration (EIRP)
TxPower0	MaxEIRP By default MaxEIRP is considered to be +30dBm
TxPower1	MaxEIRP - 2 dB
TxPower2	MaxEIRP - 4 dB
TxPower3	MaxEIRP - 6 dB
TxPower4	MaxEIRP - 8 dB
TxPower5	MaxEIRP - 10 dB
TxPower6	MaxEIRP - 12 dB
TxPower7	MaxEIRP - 14 dB
TxPower8	MaxEIRP - 16 dB
TxPower9	MaxEIRP - 18 dB
TxPower10	MaxEIRP - 20 dB
TxPower11	MaxEIRP - 22 dB
TxPower12	MaxEIRP - 24 dB
TxPower13	MaxEIRP - 26 dB
TxPower14	MaxEIRP - 28 dB
TxPower15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.

Table 16. KR920 Transmission Power

TxPower	Configuration (EIRP)
TxPower0	MaxEIRP By default MaxEIRP is considered to be +14 dBm
TxPower1	MaxEIRP - 2 dB
TxPower2	MaxEIRP - 4 dB
TxPower3	MaxEIRP - 6 dB
TxPower4	MaxEIRP - 8 dB
TxPower5	MaxEIRP - 10 dB
TxPower6	MaxEIRP - 12 dB
TxPower7	MaxEIRP - 14 dB
TxPower8 - TxPower14	RFU
TxPower15	Defined in the `LinkADRReq` MAC command of the LoRaWAN1.0.4 and subsequent specifications and were previously RFU.

2.1.3 Battery Level

This subsection defines the battery level indication macros. Values from 2 (0x02) to 253 (0xFD) are available for board specific battery levels and there's no macro defined for the values.

Table 17. Battery Level

Macro	Value	Description
BAT_LEVEL_EXT_SRC	0x00	External power source is used
BAT_LEVEL_EMPTY	0x01	Battery is empty
BAT_LEVEL_FULL	0xFE	Battery is full
BAT_LEVEL_NO_MEASURE	0xFF	Battery measurement is not available

2.1.4 Stack Settings

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

Table 18. Macros for Stack Setting

Macro	Description
REGION_AS923	Enable AS923 feature [LoRaWAN 1.0.4 only] Enables all groups of AS923 (AS923-1, AS923-2, AS923-3, AS923-4, and AS923-1 for Japan)
REGION_EU868	Enable EU868 feature
REGION_US915	Enable US915 feature
REGION_IN865	Enable IN865 feature
REGION_AU915	Enable AU915 feature
REGION_KR920	Enable KR920 feature
LORAMAC_CLASSB_ENABLED	Enable class B function
LORAWAN_VERSION_1_0_4	Support LoRaWAN protocol version 1.0.4 and LoRaWAN Regional Parameters RP002-1.0.3. (`LORAWAN_VERSION_1_0_3` cannot be specified simultaneously.)
LORAWAN_VERSION_1_0_3	Support LoRaWAN protocol version 1.0.3 which encompasses version 1.0.2 functions, and LoRaWAN 1.0.3 Regional Parameters Revision A. (It can be omitted, that is, default version is 1.0.3.)
RP_USE_RADIO_CFG_CHECK	Enable the regulatory function for each region in Radio Driver. Refer to [2].

2.1.5 Configuration

Parameters available for configuration in the LoRaWAN stack are defined in `LoRaMacConfig.h` and `LoRaMacClassBConfig.h`.

Table 19. Macros for Stack Configuration (LoRaMacConfig.h)

Macro	Range	Default	Description
LORAMAC_ENABLE_CCA_DEFAULT	false, true	true	Default configuration for AS923 CCA operation.
LORAMAC_STACK_PROCTIMEMS_RX1ON	> 0	7 (*1)(*2)(*4)(*6) 9 (*1)(*5) 6 (*1)(*3)(*7) 8 (*1)(*8)	Processing time from timer interrupt to RxWindow1 start. It is used to fine-tune the start timing of RxWindow1.
LORAMAC_STACK_PROCTIMEMS_RX2ON	> 0	7 (*1)(*2)(*4)(*6) 9 (*1)(*3)(*5) 6 (*1)(*7) 8 (*1)(*8)	Processing time from timer interrupt to RxWindow2 start. It is used to fine-tune the start timing of RxWindow2.
CLASSB_STACK_PROCTIMEMS_BEACON_ACQISITION	> 0	10 (*1)(*2)(*4) 11 (*1)(*3) 15 (*1)(*5) 13 (*1)(*8)	Processing time from timer interrupt to beacon window start for beacon acquisition. It is used to fine-tune the beacon receive timing in the beacon acquisition.
CLASSB_STACK_PROCTIMEMS_BEACON	> 0	10 (*1)(*2)(*4) 11 (*1)(*3) 15 (*1)(*5) 13 (*1)(*8)	Processing time from timer interrupt to beacon window start for beacon tracking. It is used to fine-tune the beacon receive timing in the beacon tracking.
CLASSB_STACK_PROCTIMEMS_PING_SLOT_SHORT_PERIOD	> 0	6 (*1)(*2)(*3)(*4) 10 (*1)(*5) 9 (*1)(*8)	Processing time from timer interrupt to ping slot window start for short periodicity. It is used to fine-tune the start timing of ping slot window.
CLASSB_STACK_PROCTIMEMS_PING_SLOT_LONG_PERIOD	> 0	10 (*1)(*2)(*4) 11 (*1)(*3) 15 (*1)(*5) 13 (*1)(*8)	Processing time from timer interrupt to ping slot window start for long periodicity. It is used to fine-tune the start timing of ping slot window.
CLASSB_BEACON_SYSTIMEDELTA_MAXERROR	> 0	(int32_t) (CLASSB_BEACON_INTERVAL * BOARD_CLOCK_ERROR_PPM / 1000000)	Maximum error of system time in a beacon interval [msec]. BOARD_CLOCK_ERROR_PPM defined in `board.h` is used as the typical clock error [ppm].
CLASSB_BEACON_SYSTIMEDELTA_MINERROR	< 0	(int32_t) (CLASSB_BEACON_SYSTIMEDELTA_MAXERROR * (-1))	Minimum error of system time in a beacon interval [msec].
CLASSB_BEACON_SYSTIMEDELTA_INITERROR	-	0	Initial error of system time in a beacon interval [msec].

*1) In case CPU clock is 8MHz, *2) In case of RL78/G23, *3) In case of RL78/L23, *4) In case of RL78/G14, *5) In case of RA2E1 and RA2L1, *6) In case of RL78/G22, *7) In case of RA0E1, *8) In case of RA0E2.

Table 20. Macros for Stack Configuration (LoRaMacClassBConfig.h)

Macro	Range	Default	Description
CLASSB_PING_SLOT_PERIODICITY_DEFAULT	4 - 7	7	Default ping slot periodicity
CLASSB_PING_SLOT_PERIODICITY_RFSLEEP_THRESHOLD	4 - 7	4	Threshold for the ping slot periodicity to select RF sleep mode. If the ping slot periodicity is set to the value of this threshold or more, the cold sleep is used for the RF sleep mode. Otherwise, the warm sleep is used for the RF sleep mode.

2.2 Enumerations

This section includes the following enumeration types.

Table 21. Enumerations

Types	Description
DeviceClass_t	LoRaWAN device class
LoRaMacRegion_t	Region and band
LoRaMacStatus_t	The status of the requested MAC services
LoRaMacEventInfoStatus_t	The status of the events of the MAC services
Mcps_t	MAC data service type
Mlme_t	MAC management service type
Mib_t	MAC Information Base (MIB) type
LoRaMacRxSlot_t	MAC receive window type
ActivationType_t	Activation type
LoRaMacErrorNotificationStatus_t	The status of the error notified by MacErrorNofity callback

2.2.1 DeviceClass_t

This enumeration type contains the following LoRaWAN device class definitions.

Table 22. DeviceClass_t

Enumerator	Description
CLASS_A	LoRaWAN device class A
CLASS_B	LoRaWAN device class B
CLASS_C	LoRaWAN device class C

2.2.2 LoRaMacRegion_t

This enumeration type contains the following MAC region and frequency bands.

Table 23. LoRaMacRegion_t

Enumerator	Description
LORAMAC_REGION_EU868	Europe, band 868 MHz
LORAMAC_REGION_US915	North America, band 915 MHz
LORAMAC_REGION_AS923	Asia, band 923 MHz, group AS923-1
LORAMAC_REGION_AS923_2	Asia, band 923 MHz, group AS923-2
LORAMAC_REGION_AS923_3	Asia, band 923 MHz, group AS923-3
LORAMAC_REGION_AS923_4	Asia, band 923 MHz, group AS923-4
LORAMAC_REGION_AS923_JPN	Asia, band 923 MHz, group AS923-1 for Japan
LORAMAC_REGION_IN865	India, band 865 MHz
LORAMAC_REGION_AU915	Australia, band 915 MHz
LORAMAC_REGION_KR920	South Korea, band 920 MHz

2.2.3 LoRaMacEventInfoStatus_t

This enumeration type contains the status of the operation of a MAC service as follows.

Table 24. LoRaMacEventInfoStatus_t

Enumerator	Description
LORAMAC_EVENT_INFO_STATUS_OK	Service performed successfully
LORAMAC_EVENT_INFO_STATUS_ERROR	An error occurred during the execution of the service
LORAMAC_EVENT_INFO_STATUS_TX_TIMEOUT	A Tx timeout occurred
LORAMAC_EVENT_INFO_STATUS_RX1_TIMEOUT	An Rx timeout occurred on receive window 1
LORAMAC_EVENT_INFO_STATUS_RX2_TIMEOUT	An Rx timeout occurred on receive window 2
LORAMAC_EVENT_INFO_STATUS_RX1_ERROR	An Rx error occurred on receive window 1
LORAMAC_EVENT_INFO_STATUS_RX2_ERROR	An Rx error occurred on receive window 2
LORAMAC_EVENT_INFO_STATUS_JOIN_FAIL	An error occurred in the join procedure
LORAMAC_EVENT_INFO_STATUS_JOIN_NONCE_FAIL	An error occurred in the join procedure (`AppNonce`(`JoinNonce`) value is same as the one previously received from the LoRaWAN server)
LORAMAC_EVENT_INFO_STATUS_DOWNLINK_REPEATED	A frame with an invalid downlink counter was received. The downlink counter of the frame was equal to the local copy of the downlink counter of the node.
LORAMAC_EVENT_INFO_STATUS_TX_DR_PAYLOAD_SIZE_ERROR	The MAC could not retransmit a frame since the MAC decreased the data rate. The payload size is not applicable for the data rate
LORAMAC_EVENT_INFO_STATUS_DOWNLINK_TOO_MANY_FRAMES_LOSS	The node has lost more than maximum number of lost frames
LORAMAC_EVENT_INFO_STATUS_ADDRESS_FAIL	An address error occurred
LORAMAC_EVENT_INFO_STATUS_MIC_FAIL	Message integrity check failure
LORAMAC_EVENT_INFO_STATUS_BEACON_LOCKED	Successfully received a beacon frame
LORAMAC_EVENT_INFO_STATUS_BEACON_NOT_FOUND	Beacon acquisition failure
LORAMAC_EVENT_INFO_BEACON_LOST	Could not receive a beacon frame

2.2.4 LoRaMacStatus_t

This enumeration type contains MAC status and indicates the result of requested MAC service as follows.

Table 25. LoRaMacStatus_t

Enumerator	Description
LORAMAC_STATUS_OK	Service started successfully
LORAMAC_STATUS_BUSY	Error - Processing request
LORAMAC_STATUS_SERVICE_UNKNOWN	Error - Unknown request
LORAMAC_STATUS_PARAMETER_INVALID	Error - Invalid parameter
LORAMAC_STATUS_FREQUENCY_INVALID	Error - Unacceptable frequency for the region
LORAMAC_STATUS_DATARATE_INVALID	Error - Unacceptable data rate for the region
LORAMAC_STATUS_FREQ_AND_DR_INVALID	Error - Unacceptable frequency and data rate for the region
LORAMAC_STATUS_NO_NETWORK_JOINED	Error - Device is not in a LoRaWAN network
LORAMAC_STATUS_LENGTH_ERROR	Error - FOpts and payload length is too long
LORAMAC_STATUS_REGION_NOT_SUPPORTED	Error - Specified region is not supported
LORAMAC_STATUS_SKIPPED_APP_DATA	Error - Only MAC commands have been sent. Need to retry sending application data
LORAMAC_STATUS_DUTYCYCLE_RESTRICTED	Error - Transmission was aborted due to duty cycle restriction
LORAMAC_STATUS_NO_CHANNEL_FOUND	Error - Data rate not supported by any channel
LORAMAC_STATUS_NO_FREE_CHANNEL_FOUND	Error - No free channel found by carrier sense
LORAMAC_STATUS_BUSY_BEACON_RESERVED_TIME	Error - Transmission was aborted due to overlap with beacon reserved time
LORAMAC_STATUS_BUSY_PING_SLOT_WINDOW_TIME	Error - Transmission was aborted due to an overlapping ping slot
LORAMAC_STATUS_BUSY_UPLINK_COLLISION	Error - Transmission was aborted due to overlap with beacon operation timing
LORAMAC_STATUS_MC_GROUP_UNDEFINED	Error - Multicast groups are undefined
LORAMAC_STATUS_ERROR	Error - Undefined error
LORAMAC_STATUS_RADIO_FAIL	Error - Radio driver initialization failure
LORAMAC_STATUS_RADIO_PARAMETER_INVALID	Error - Radio parameter configuration is invalid

2.2.5 Mcps_t

This enumeration type contains MAC data services. These are used to request a service or indicate the service of the response.

Table 26. Mcps_t

Enumerator	Description
MCPS_UNCONFIRMED	Unconfirmed Data frame
MCPS_CONFIRMED	Confirmed Data frame

2.2.6 Mlme_t

This enumeration type contains the following MAC management services.

Table 27. Mlme_t

Enumerator	Description
MLME_JOIN	Initiates the Over-the-Air activation
MLME_LINK_CHECK	Issues MAC command `LinkCheckReq` for connectivity validation
MLME_DEVICE_TIME	Issues MAC command `DeviceTimeReq` to request current GPS time
MLME_PING_SLOT_INFO	Issues MAC command `PingSlotInfoReq` to notify ping slot information
MLME_BEACON_ACQUISITION	Initiates beacon acquisition
MLME_SCHEDULE_UPLINK	Indicates that the application shall perform an uplink as soon as possible.
MLME_BEACON	Indicates whether a beacon was successfully received
MLME_BEACON_LOST	Indicates MAC layer fails to receive a beacon for 120 minutes

2.2.7 Mib_t

This enumeration type contains the information on the following LoRaWAN MAC Information Base (MIB). These are used to get or to set the parameters in LoRaWAN stack.

Table 28. Mib_t

Enumerator	Description
MIB_DEVICE_CLASS	LoRaWAN device class
MIB_NETWORK_ACTIVATION	Activation type
MIB_DEV_EUI	Device EUI (`DevEUI`)
MIB_APP_EUI	Application EUI (`AppEUI`)
MIB_ADR	Adaptive data rate
MIB_NET_ID	Network identifier (`NetID`)
MIB_DEV_ADDR	End-device address (`DevAddr`)
MIB_APP_KEY	Application key (`AppKey`) for OTAA
MIB_GEN_APP_KEY	Application root key for multicast
MIB_NWK_SKEY	Network session key (`NwkSKey`)
MIB_APP_SKEY	Application session key (`AppSKey`)
MIB_MC_NWK_S_KEY_n	Network session key for multicast (`McNwkSKey`). “n” means the index of the multicast group and an integer in 0 - 3.
MIB_MC_APP_S_KEY_n	Application session key for multicast (`McAppSKey`). “n” means the index of the multicast group and an integer in 0 - 3.
MIB_PUBLIC_NETWORK	Network type, public or private
MIB_CHANNELS	LoRaWAN channels
MIB_RX2_CHANNEL	Receive window 2 channel
MIB_RX2_DEFAULT_CHANNEL	Default receive window 2 channel
MIB_CHANNELS_NB_TRANS	Maximum number of frame retransmission for unconfirmed uplink transmission.
MIB_RECEIVE_DELAY_1	Receive delay 1 in [ms]
MIB_RECEIVE_DELAY_2	Receive delay 2 in [ms]
MIB_JOIN_ACCEPT_DELAY_1	Join accept delay 1 in [ms]
MIB_JOIN_ACCEPT_DELAY_2	Join accept delay 2 in [ms]
MIB_CHANNELS_MIN_TX_DATARATE	Minimum Tx data rate
MIB_CHANNELS_DATARATE	Data rate of a channel

Enumerator	Description
MIB_CHANNELS_TX_POWER	Transmission power of a channel
MIB_CHANNELS_DEFAULT_TX_POWER	Default transmission power of a channel
MIB_SYSTEM_MAX_RX_ERROR	System overall timing error in milliseconds.
MIB_ABP_LORAWAN_VERSION	LoRaWAN version
MIB_PING_SLOT_DATARATE	Ping slot data rate
MIB_PING_SLOT_PERIODICITY	Ping slot periodicity
MIB_AS923_ENABLE_CCA	CCA configuration for AS923 in bool. CCA enabled when true (default), and CCA disabled otherwise
MIB_IS_CERT_FPORT_ON	LoRaWAN certification FPort handling state
MIB_DEV_NONCE	Device nonce (`DevNonce`)
MIB_APP_NONCE	Application nonce (`AppNonce`) (or Join nonce (`JoinNonce`))
MIB_MAX_DCYCLE	Maximum duty cycle
MIB_RX1_DROFFSET	RX1 data rate offset (`RX1DRoffset`)
MIB_MAX_EIRP	Maximum allowed Effective Isotropic Radiated Power (`EIRP`)
MIB_DOWNLINK_DWELLTIME	Downlink dwell time (Maximum down link transmit duration)
MIB_UPLINK_DWELLTIME	Uplink dwell time (Maximum up link transmit duration)
MIB_DOWNLINK_FCNT	Downlink frame counter
MIB_UPLINK_FCNT	Uplink frame counter
MIB_RSSI_FREE_THRESHOLD	RSSI free channel threshold value (for AS923 and KR920 only)
MIB_CARRIER_SENSE_TIME	Carrier sense time value (for AS923 and KR920 only)

2.2.8 LoRaMacRxSlot_t

This enumeration type contains information on the receive window type.

Table 29. LoRaMacRxSlot_t

Enumerator	Description
RX_SLOT_WIN_1	Receive window 1
RX_SLOT_WIN_2	Receive window 2
RX_SLOT_WIN_CLASS_C	Receive window 2 for Class C, continuous listening.
RX_SLOT_WIN_CLASS_C_MULTICAST	Class C multicast downlink window
RX_SLOT_WIN_CLASS_B_MULTICAST_SLOT	Class B multicast ping slot window
RX_SLOT_WIN_CLASS_B_PING_SLOT	Class B unicast ping slot window
RX_SLOT_NONE	No active reception window

2.2.9 ActivationType_t

This enumeration type indicates end device activation types.

Table 30. ActivationType_t

Enumerator	Description
ACTIVATION_TYPE_NONE	None
ACTIVATION_TYPE_ABP	ABP
ACTIVATION_TYPE_OTAA	OTAA

2.2.10 LoRaMacErrorNotificationStatus_t

This enumeration type lists error information provided by MacErrorNofity callback.

Table 31. LoRaMacErrorNotificationStatus_t

Enumerator	Description
LORAMAC_ERROR_NOTIFICATION_STATUS_RADIO_CHECK_FAIL_RX_CFG	Radio RX parameter configuration failure

2.3 Structure Types

This section describes the following types.

Table 32. Structure Types

Types	Description
McpsReq_t	MCPS-Request primitive
McpsReqUnconfired_t	MCPS-Request for an unconfirmed frame
McpsReqConfirmed_t	MCPS-Request for a confirmed frame
McpsConfirm_t	MCPS-Confirm primitive
McpsIndication_t	MCPS-Indication primitive
MlmeReq_t	MLME-Request primitive
MlmeReqJoin_t	MLME-Request for Join service
MlmeConfirm_t	MLME-Confirm primitive
MlmeIndication_t	MLME-Indication primitive
MibRequestConfirm_t	MIB-RequestConfirm primitive
MibParam_t	MIB parameters related MIB type `MIB_*`
LoRaMacTxInfo_t	Tx information
RxChannelParams_t	Receive window channel parameters
McChannelSetup_t	Multicast channel parameter
McRxParams_t	Multicast reception parameter
LoRaMacCtxs_t	MAC operational context
BeaconInfo_t	Beacon information
MlmeReqPingSlotInfo_t	MLME-Request (ping slot info service)

2.3.1 McpsReq_t

This structure type contains information on MAC MCPS-Request.

Table 33. McpsReq_t

Member type	Member	Description	
Mcps_t	Type	MCPS-Request type. See section 2.2.5 `Mcps_t`.	
union sMcpsReq::uMcpsParam	Req	Parameters for each MCPS-Request set in Type. See the below in detail.	
RequestReturnParams_t	ReqReturn	Return parameter of MCPS-Request.	
		TimerTime_t DutyCycleWaitTime	Report the time in milliseconds which an application must wait before it is possible to send the next uplink.

Note: uMcpsParam is union containing MCPS-Request parameters.

Table 34. uMcpsParam

Member type	Member	Description
McpsReqUnconfirmed_t	Unconfirmed	Parameters for an unconfirmed frame. See section 2.3.2 `McpsReqUnconfirmed_t`.
McpsReqConfirmed_t	Confirmed	Parameters for a confirmed frame. See section 2.3.3 `McpsReqConfirmed_t`

2.3.2 McpsReqUnconfirmed_t

This structure type contains information on MAC MCPS-Request for an unconfirmed frame.

Table 35. McpsReqUnconfirmed_t

Member type	Member	Description
uint8_t	fPort	Frame port number. Must be set if the payload is not empty. As for application specific frame, set the value within the range of 1 to 223.
void *	fBuffer	Pointer to the buffer of the frame payload
uint16_t	fBufferSize	Size of the frame payload [0..250]
int8_t	Datarate	Uplink data rate if ADR is off. See section 2.1.1 Data Rate.

2.3.3 McpsReqConfirmed_t

This structure type contains information on MAC MCPS-Request for a confirmed frame.

Table 36. McpsReqConfirmed_t

Member type	Member	Description
uint8_t	fPort	Frame port number. Must be set if the payload is not empty. As for application specific frame, set the value within the range of 1 to 223.
void *	fBuffer	Pointer to the buffer of the frame payload
uint16_t	fBufferSize	Size of the frame payload [0..250]
int8_t	Datarate	Uplink data rate if ADR is off. See section 2.1.1 Data Rate.
uint8_t	NbTrials	Maximum number of trials to transmit the frame, if the MAC layer cannot receive an acknowledgment. The stack tries to send at least once even if this value is 0, and maximum 8 times even if this value is over 8.

2.3.4 McpsConfirm_t

This structure type contains information on MAC MCPS-Confirm.

Table 37. McpsConfirm_t

Member type	Member	Description
Mcps_t	McpsRequest	Holds the previously performed MCPS-Request
LoRaMacEventInfoStatus_t	Status	Status of the operation
uint8_t	Datarate	Uplink data rate
int8_t	TxPower	Transmission power
bool	AckReceived	Set if an acknowledgement was received
uint8_t	NbRetries	Provides the number of retransmissions
TimerTime_t	TxTimeOnAir	The transmission time on air of the frame
uint32_t	UpLinkCounter	The uplink counter value related to the frame
uint32_t	Channel	The uplink channel index related to the frame

2.3.5 McpsIndication_t

This structure type contains information on MAC MLME-Request for the join service.

Table 38. McpsIndication_t

Member type	Member	Description
Mcps_t	McpsIndication	MCPS-Indication type
LoRaMacEventInfoStatus_t	Status	Status of the operation
uint8_t	Multicast	Multicast
uint8_t	Port	Application port
uint8_t	RxDatarate	Downlink data rate
uint8_t	FramePending	Frame pending status
uint8_t *	Buffer	Pointer to the received data stream
uint8_t	BufferSize	Size of the received data stream
bool	RxData	Indicates if data is available [true: available, false: unavailable]
int16_t	Rssi	RSSI of the received packet
int8_t	Snr	SNR of the received packet
LoRaMacRxSlot_t	RxSlot	Receive window
bool	AckReceived	Indicates if an acknowledgement was received [true: Received, false: Not received]
uint32_t	DownLinkCounter	The downlink counter value for the received frame
uint32_t	DevAddress	End-device address
bool	DeviceTimeAnsReceived	Indicates if `DeviceTimeAns` MAC command is contained in the received frame [true: Received, false: Not received]
TimerTime_t	ResponseTimeout	[LoRaWAN 1.0.4 only] Response timeout in milliseconds for a class B/C when a confirmed downlink has been received.

2.3.6 MlmeReq_t

This structure type contains information on MAC MLME-Request.

Table 39. MlmeReq_t

Member type	Member	Description	
Mlme_t	Type	MLME_JOIN	Initiates the OTAA activation
		MLME_LINK_CHECK	Initiates MAC command `LinkCheckReq` to validate connectivity
		MLME_DEVICE_TIME	Initiates MAC command `DeviceTimeReq` to request current GPS time
		MLME_BEACON_ACQUISITION	Initiates beacon acquisition
		MLME_PING_SLOT_INFO	Initiates MAC command `PingSlotInfoReq` to notify ping slot information
union sMlmeReq::uMlmeParam	Req	MLME-Request parameters, see the following	
RequestReturnParams_t	ReqReturn	Return parameter of MLME-Request.	
		TimerTime_t DutyCycleWaitTime	Report the time in milliseconds which an application must wait before it is possible to send the next uplink.

Note: uMlmeParam is a union containing MLME-Request parameters.

Table 40. uMlmeParam

Member type	Member	Description
MlmeReqJoin_t	Join	`JoinRequest` parameters, when type is `MLME_JOIN`, use this member.
MlmeReqPingSlotInfo_t	PingSlotInfo	`PingSlotInfoReq` parameter. Set if MLME type is `MLME_PING_SLOT_INFO`. See section 2.3.18 `MlmeReqPingSlotInfo_t` for details.

2.3.7 MlmeReqJoin_t

This structure type contains information on MAC MLME-Request for the join service.

Table 41. MlmeReqJoin_t

Member type	Member	Description
uint8_t	Datarate	Data rate used for `JoinRequest`

2.3.8 MlmeConfirm_t

This structure type contains information on MAC MLME-Confirm primitive.

Table 42. MlmeConfirm_t

Member type	Member	Description
Mlme_t	MlmeRequest	Holds the previously performed MLME-Request
LoRaMacEventInfoStatus_t	Status	Status of the operation
TimerTime_t	TxTimeOnAir	The transmission time on air of the frame
uint8_t	DemodMargin	Demodulation margin. Contains the link margin [dB] of the last successfully received `LinkCheckReq`
uint8_t	NbGateways	Number of gateways which received the last `LinkCheckReq`
uint8_t	NbRetries	Number of retransmissions for confirmed uplink frame

2.3.9 MlmeIndication_t

This structure type contains information on MAC MLME-Indication primitive.

Table 43. MlmeIndication_t

Member type	Member	Description	
Mlme_t	MlmeIndication	MLME-Indication type	
		MLME_SCHEDULE_ UPLINK	The application shall perform an uplink as soon as possible.
		MLME_BEACON	Indicates whether a beacon was successfully received
		MLME_BEACON_LOST	Lost synchronization with Class B beacons. This indicates MAC layer fails to receive a beacon for 120 minutes.
LoRaMacEventInfo Status_t	Status	Status for `MLME_BEACON`. Indicates whether a beacon was successfully received.	
BeaconInfo_t	BeaconInfo	Beacon information for `MLME_BEACON` indication on successful beacon reception.	

2.3.10 MibRequestConfirm_t

This structure type contains information on MAC parameters. This is used to get or to set parameters in MAC.

Table 44 MibRequestConfirm_t

Member type	Member	Description
Mib_t	Type	MIB-Request type. See section 2.2.7 `Mib_t`.
MibParam_t	Param	MAC parameters for each Type. See section 2.3.11 `MibParam_t`.

2.3.11 MibParam_t

This union type contains MIB parameters. Each member type is a data structure for MIB listed in section 2.2.7 `Mib_t`.

Table 45. MibParam_t

Member type	Member	Description	
DeviceClass_t	Class	LoRaWAN device class for `MIB_DEVICE_CLASS`. See 2.2.1 `DeviceClass_t`. Note: The device class shall not be changed from A to B before the beacon acquisition is succeeded and the ping slot periodicity is set to the intended value.	
		CLASS_A	Device class A
		CLASS_B	Device class B
		CLASS_C	Device class C
ActivationType_t	NetworkActivation	Activation type. When operating in the OTAA mode, this parameter is automatically configured upon successful Join procedure and shall not be manually configured by `LoRaMacMibSetRequestConfirm()`.	
uint8_t *	DevEui	Pointer to device EUI, which is equivalent to `DevEUI` in LoRaWAN 1.0.x specification.	
uint8_t *	JoinEui	Pointer to join EUI, which is equivalent to `AppEUI` in LoRaWAN 1.0.x specification.	
bool	AdrEnable	Activation state of ADR for `MIB_ADR`.	
		true	ADR is enabled
		false	ADR is disabled
uint32_t	NetID	Network identifier for `MIB_NET_ID`.	
uint32_t	DevAddr	End-device address for `MIB_DEV_ADDR`.	
uint8_t *	GenAppKey	Pointer to application root key for multicast.	
uint8_t *	AppKey	Application key for `MIB_APP_KEY`.	
uint8_t *	NwkSKey	Pointer to Network session key for `MIB_NWK_SKEY`.	
uint8_t *	AppSKey	Pointer to Application session key for `MIB_APP_SKEY`.	
uint8_t *	McAppSKeyN (N = 0 - 3)	Pointer to Application session key for `MIB_MC_APP_S_KEY_n`. “N” means the index of the multicast group.	
uint8_t *	McNwkSKeyN (N = 0 - 3)	Pointer to Network session key for `MIB_MC_NWK_S_KEY_n`. “N” means the index of the multicast group.	
bool	EnablePublicNetwork	Enable or disable a public network for `MIB_PUBLIC_NETWORK`.	
		true	Public network is enabled
		false	Public network is disabled
ChannelParams_t *	ChannelList	LoRaWAN channels parameter list. See section 2.3.16 `ChannelParams_t`	
RxChannelParams_t	Rx2Channel	Channel parameters for the receive window 2 for `MIB_RX2_CHANNEL`. See section 2.3.13 `RxChannelParams_t`.	
RxChannelParams_t	Rx2DefaultChannel	Default channel parameters for the receive window 2 for `MIB_RX2_DEFAULT_CHANNEL`. See section 2.3.13 `RxChannelParams_t`.	
uint8_t	ChannelsNbTrans	Maximum number of retransmissions for Unconfirmed uplink transmission	
uint32_t	MaxRxWindow	Maximum receive window duration for `MIB_MAX_RX_WINDOW_DURATION`. [ms] [0: continuous, others: timeout]	

Member type	Member	Description
uint32_t	ReceiveDelay1	Receive delay 1 for MIB_RECEIVE_DELAY_1 [ms]. 1000 ms or larger is recommended.
uint32_t	ReceiveDelay2	Receive delay 2 for MIB_RECEIVE_DELAY_2 [ms]. This must be ReceiveDelay1 + 1s.
uint32_t	JoinAcceptDelay1	Join accept delay 1 for MIB_JOIN_ACCEPT_DELAY_1 [ms].
uint32_t	JoinAcceptDelay2	Join accept delay 2 for MIB_JOIN_ACCEPT_DELAY_2 [ms].
int8_t	ChannelsMinTxDatarate	Minimum Tx data rate.
int8_t	ChannelsDatarate	Data rate of a channel for MIB_CHANNELS_DATARATE.
int8_t	ChannelsDefaultTxPower	Default TX power for MIB_CHANNELS_DEFAULT_TX_POWER. [Range: TX_POWER_0 .. TX_POWER_15]
int8_t	ChannelsTxPower	TX power for MIB_CHANNELS_TX_POWER. [Range: TX_POWER_0 .. TX_POWER_15]
uint32_t	SystemMaxRxError	System overall timing error in milliseconds. [Range: 10 – 500]
Version_t	AbpLrWanVersion	LoRaWAN version. Set when operating in the ABP mode.
bool	EnableCca	Configuration for MIB_AS923_ENABLE_CCA. Enable (true) or disable (false) CCA for AS923.
int8_t	PingSlotDatarate	Ping slot data rate.
uint8_t	PingSlotPeriodicity	Ping slot periodicity. [Range: 4 - 7] Note: Ping slot periodicity is set to the default value at the timing as follows: - LoRaMacMlmeRequest() of MLME_JOIN is issued - Beacon acquisition fails - The device class is changed from class B to class A
bool	isCertPortOn	LoRaWAN certification FPort(=224) handling state. Enable (true) or disable (false) certification FPort.
uint16_t	devNonce	Device nonce (DevNonce)
uint32_t	appNonce	Application nonce (AppNonce) (or Join nonce (JoinNonce))
uint8_t	maxDcycle	Maximum duty cycle [Range: 0 - 15]
uint8_t	rx1DrOffset	RX1 data rate offset (RX1DRoffset) [Range: 0 - 15]
uint8_t	maxEirp	Maximum EIRP.
uint8_t	downlinkDwellTime	Downlink dwell time [Range: 0, 1]
uint8_t	uplinkDwellTime	Uplink dwell time [Range: 0, 1]
uint32_t	downlinkFCnt	Downlink frame counter
uint32_t	uplinkFCnt	Uplink frame counter
int16_t	RssiFreeThreshold	RSSI free channel threshold (for AS923 and KR920 only)
uint32_t	CarrierSenseTime	Carrier sense time (for AS923 and KR920 only)

2.3.12 LoRaMacTxInfo_t

This structure type contains information on MAC Tx information.

Table 46. LoRaMacTxInfo_t

Member type	Member	Description
unt8_t	MaxPossibleApplication DataSize	Maximum size of application data payload that can be sent in the next uplink transmission
uint8_t	CurrentPayloadSize	The current payload size, dependent on the current data rate

2.3.13 RxChannelParams_t

This structure type contains information on MAC receive window channel parameters.

Table 47. RxChannelParams_t

Member type	Member	Description
uint32_t	Frequency	Frequency in Hz
uint8_t	Datarate	Data rate. See 2.1.1 Data Rate.

2.3.14 McChannelSetup_t

This structure type contains information on multicast channel parameters to set up.

Table 48. McChannelSetup_t

Member type	Member	Description
AddressIdentifier_t	GroupID	Multicast group ID [Range: 0 - 3]
uint32_t	Address	Multicast group address
uint8_t *	McKeyE	Pointer to encrypted multicast key which is delivered from application server.
uint32_t	FCountMin	Minimum count of multicast frame counter
uint32_t	FCountMax	Maximum count of multicast frame counter

2.3.15 McRxParams_t

This union type contains information on multicast reception parameters.

Table 49. McRxParams_t

Member type	Member	Description
struct ClassB	uint32_t Frequency	Frequency in Hz
	int8_t DataRate	Data rate. See 2.1.1 Data Rate.
	uint8_t Periodicity	Periodicity of multicast slots (4 to 7). Actual interval between multicast slots is $(0.96 * 2^{Periodicity})$ seconds.
struct ClassC	uint32_t Frequency	Frequency in Hz
	int8_t DataRate	Data rate. See 2.1.1 Data Rate.

2.3.16 ChannelParams_t

This structure type contains information on channel parameters.

Table 50. ChannelParams_t

Member type	Member	Description
uint32_t	Frequency	Frequency in Hz
uint32_t	Rx1Frequency	Alternative frequency for RX window in Hz
union DrRange_t	DrRange.Value	Byte access to the following bits of Data rate definition
	DrRange.Fields.Min : 4	Minimum data rate
	DrRange.Fields.Max : 4	Maximum data rate
uint8_t	Band	Band index

2.3.17 BeaconInfo_t

The following table shows Class B beacon information structure.

Table 51. BeaconInfo_t

Member type	Member	Description	
SysTime_t	Time	Elapsed time since January 6, 1980 00:00:00 UTC (start of the GPS epoch)	
uint32_t	Frequency	Frequency in Hz	
uint8_t	Datarate	Data rate	
int16_t	Rssi	RSSI	
int8_t	Snr	SNR	
uint8_t	Param	[LoRaWAN 1.0.4 only] Precision of beacon's transmit time (0-3)	
bool	isValidGwSpecific	Indicate whether GwSpecific (in below) is available	
		true	GwSpecific is available
		false	GwSpecific is unavailable
struct sGwSpecific GwSpecific	InfoDesc	Information descriptor	
	Info[6]	Information field	

2.3.18 MlmeReqPingSlotInfo_t

The following tables show the structure for `PingSlotInfoReq` configurations.

Table 52. MlmeReqPingSlotInfo_t

Member type	Member	Description
PingSlotInfo_t	PingSlot	Union data structure for `PingSlotInfoReq`

Table 53. PingSlotInfo_t

Member type	Member	Description
uint8_t	Value	Parameter for byte access
struct sInfoField Fields	Periodicity: 3	Periodicity of ping slots (4 to 7). Actual interval between ping slots is ($0.96 * 2^{Periodicity}$) seconds.
	RFU: 5	(Reserved)

2.4 LoRaWAN APIs

This section contains the following functions.

Table 54. LoRaWAN APIs

function	Description
LoRaMacInitialization	Initialize the MAC layer.
LoRaMacMlmeRequest	Request the Mac Layer Management Entity to handle the management service.
LoRaMacMcpsRequest	Request the Mac Common Part Sublayer to handle the data services
LoRaMacMibGetRequestConfirm	Request the Mac Information Base service to get attribute of the Mac layer.
LoRaMacMibSetRequestConfirm	Request the Mac Information Base service to set attribute of the Mac layer.
LoRaMacQueryTxPossible	Query the Mac layer if it is possible to send the next frame with given payload size.
LoRaMacProcess	Process the interruption.
LoRaMacChannelAdd	Add a new channel.
LoRaMacChannelRemove	Remove a channel.
LoRaMacStart	Start MAC.
LoRaMacStop	Stop MAC.
LoRaMacIsBusy	Check if MAC is busy.
LoRaMacMcChannelSetup	Configure multicast channel.
LoRaMacMcChannelDelete	Delete multicast channel.
LoRaMacMcChannelGetGroupId	Get multicast channel group ID.
LoRaMacMcChannelGetAddress	Get multicast address.
LoRaMacMcChannelSetupRxParams	Configure reception parameters of multicast channel.

2.4.1 LoRaMacInitialization

LoRaMacStatus_t LoRaMacInitialization(LoRaMacPrimitives_t *primitives, LoRaMacCallback_t * callbacks, LoRaMacRegion_t region)		
This function initializes MAC layer. Event handler functions to be set in 'primitive' are mandatory and user has to implement them. Callback function to be set 'events' is optional.		
Parameters		
[IN] primitives	Pointer to a structure defining the MAC event handler functions. Must set all handler functions. See section 2.5 in detail.	
[IN] callbacks	Pointer to a structure defining the MAC callback functions. Do not set NULL to this pointer while callback function pointers (structure members) may be set to NULL. See section 2.6 for details.	
[IN] region	The region to start. Following regions are supported in this version.	
	LORAMAC_REGION_EU868	Europe, band 868MHz
	LORAMAC_REGION_US915	North America, band 915MHz
	LORAMAC_REGION_AS923	Asia, band 923MHz, group AS923-1
	LORAMAC_REGION_AS923_2	[LoRaWAN 1.0.4 only] Asia, band 923MHz, group AS923-2
	LORAMAC_REGION_AS923_3	[LoRaWAN 1.0.4 only] Asia, band 923MHz, group AS923-3,
	LORAMAC_REGION_AS923_4	[LoRaWAN 1.0.4 only] Asia, band 923MHz, group AS923-4
	LORAMAC_REGION_AS923_JPN	Asia, band 923MHz, group AS923-1 for Japan.
	LORAMAC_REGION_IN865	India, band 865MHz
	LORAMAC_REGION_AU915	Australia, band 915MHz
	LORAMAC_REGION_KR920	South Korea, band 920MHz

Return	
LORAMAC_STATUS_OK	Initialization finished successfully.
LORAMAC_STATUS_PARAMETER_INVALID	A parameter set in primitives is invalid.
LORAMAC_STATUS_REGION_NOT_SUPPORTED	The region set in region is not supported
LORAMAC_STATUS_RADIO_FAIL	Radio driver initialization failure.

2.4.2 LoRaMacMibGetRequestConfirm

LoRaMacStatus_t LoRaMacMibGetRequestConfirm(MibRequestConfirm_t *mibRequest)		
This function is the MAC information base service to get attributes of the Mac layer. See the sample code how to use this function to get the parameter.		
Parameters		
mibRequest	[IN] Type	MAC attribute type to get. See 2.2.7 `Mib_t`
	[OUT] Param	Parameters got from MAC. See 2.3.11 `MibParam_t`

Return	
LORAMAC_STATUS_OK	The request is finished successfully
LORAMAC_STATUS_SERVICE_UNKNOWN	Requested attribute is unknown.
LORAMAC_STATUS_PARAMETER_INVALID	Requested parameter is invalid.

2.4.3 LoRaMacMibSetRequestConfirm

LoRaMacStatus_t LoRaMacMibSetRequestConfirm(MibRequestConfirm_t *mibSet)		
This function is the MAC information base service to set attributes of the MAC layer. Attributes cannot be changed when MAC service is running, from sending a Join-request or a data frame to closing a final Rx window. MIB parameters set by this function are initialized to their default values upon calling `LoRaMacInitialization()`.		
Parameters		
mibSet	[IN] Type	MAC attribute type to get. See section 2.2.7 `Mib_t`
	[IN] Param	Parameters got from MAC. See section 2.3.11 `MibParam_t`

Return	
LORAMAC_STATUS_OK	The request is finished successfully
LORAMAC_STATUS_SERVICE_UNKNOWN	Requested attribute is unknown
LORAMAC_STATUS_PARAMETER_INVALID	Requested parameter is invalid
LORAMAC_STATUS_BUSY	MAC is busy. Another service is running

2.4.4 LoRaMacMlmeRequest (MAC command)

LoRaMacStatus_t LoRaMacMlmeRequest(MlmeReq_t *mlmeRequest)

This function requests MAC MLME-Request. The MAC layer management entity handles management services. See section 5.5 and section 5.7 for the sample code how to use this function. When the process of the transmission and the reception finish, the callback function `MacMlmeConfirm()` in the `LoRaMacPrimitives_t` will be called. Except for `MLME_JOIN`, please do not call this function before activation.

Parameters

mlmeRequest	[IN] Type	MLME_JOIN		Initiates the Over-the-Air activation (*1)(*2)
		MLME_LINK_CHECK		Requests to send `LinkCheckReq` command to validate connectivity
		MLME_DEVICE_TIME		Requests to send the `DeviceTimeReq` command to request current GPS time (*1) (*3)
		MLME_BEACON_ACQUISITION		Initiates beacon acquisition (*1) (*3)
		MLME_PING_SLOT_INFO		Requests to send the `PingSlotInfoReq` command to notify ping slot information (*1)
	[IN] Req	Join	Datarate	Referenced data rate used for `JoinRequest` command. Actually, decided according to the region.
			EU868	This parameter is applied. [Range: `DR_0` .. `DR_5`]
			IN865	
			KR920	
			AS923	This parameter is ignored. DR2 is used.
			US915	This parameter is ignored. DR0 or DR4 is used according to Tx channel.
			AU915	This parameter is ignored. DR2 or DR6 is used according to Tx channel.
		PingSlotInfo	Field.Periodicity	Periodicity of ping slots. [Range: 4 to 7] See section 2.3.18 for details.

Return

See section 2.2.4 `LoRaMacStatus_t`

*1. The following MLME shall not be issued when the LoRaWAN stack operates in class B.
- `MLME_JOIN`
- `MLME_DEVICE_TIME`
- `MLME_BEACON_ACQUISITION`
- `MLME_PING_SLOT_INFO`

*2. The device class is set to Class A when this API function with Type set to `MLME_JOIN` returns `LORAMAC_STATUS_OK`. If Class C is used, the device class needs to be set to Class C after the completion of the joining.

*3. If GPS time is received via `MLME_DEVICE_TIME`, the LoRaWAN stack will open a receive window to acquire a beacon frame around the calculated beacon frame reception timing. If not, the LoRaWAN stack will open a receive window to acquire a beacon frame up to 128 seconds.

2.4.5 LoRaMacMcpsRequest (Data message)

LoRaMacStatus_t LoRaMacMcpsRequest(McpsReq_t *mcpsRequest)				
This function requests MAC MCPS-Request. The Mac Common Part Sublayer handles data services. See section 5.6 for the sample code sending Mac frame with this function. When the process of the transmission and the reception finish, the callback function `MacMcpsConfirm()` in the `LoRaMacPrimitives_t` will be called.				
Parameters				
	mcpsRequest	[IN] Type	MCPS_UNCONFIRMED	Unconfirmed Data frame
			MCPS_CONFIRMED	Confirmed Data frame
		[IN] Req	Unconfirmed	Parameters for Unconfirmed frame. See section 2.3.2 `McpsReqUnconfirmed_t`
			Confirmed	Parameters for Confirmed frame. See section 2.3.3 `McpsReqConfirmed_t`
Return				
	See section 2.2.4 `LoRaMacStatus_t`			

2.4.6 LoRaMacQueryTxPossible

LoRaMacStatus_t LoRaMacQueryTxPossible(uint8_t size, LoRaMacTxInfo_t *txInfo)			
This function queries the MAC if it is possible to send the next frame with a given payload size. The MAC takes scheduled MAC commands into account and reports, when the frame can be sent or not.			
Parameters			
	[IN] size	Size of applicative payload to be sent next.	
	[OUT] txInfo	MaxPossiblePayload	Size of the applicative payload which can be processed (according to the configured data rate or the next data rate according to ADR)
		CurrentPayloadSize	The current payload size, dependent on the current data rate
Return			
	LORAMAC_STATUS_OK		Finish this function successfully
	LORAMAC_STATUS_PARAMETER_INVALID		Invalid parameter, txInfo is NULL.
	LORAMAC_STATUS_LENGTH_ERROR		Payload length exceeds acceptable length to send.

2.4.7 LoRaMacProces

void LoRaMacProcess (void)
This function process events that the MAC may hold. Application must periodically call this function in its main loop at an interval as short as possible.
Parameters
-
Return
-

2.4.8 LoRaMacChannelAdd

LoRaMacStatus_t LoRaMacChannelAdd(uint8_t id, ChannelParams_t params)		
This function adds a new channel. It is available in all regions expect US915 and AU915. In case of US915 or AU915, `LORAMAC_STATUS_PARAMETER_INVALID` will be returned.		
Parameters		
[IN] id		Channel ID
params	[IN] Frequency	Frequency in Hz
	[IN] DrRange.Fields.Min	Minimum DR for this channel
	[IN] DrRange.Fileds.Max	Maximum DR for this channel
Return		
LORAMAC_STATUS_OK		Parameter was added successfully
LORAMAC_STATUS_BUSY		MAC is busy. Another service is running
LORAMAC_STATUS_PARAMETER_INVALID		Requested parameter is NULL
LORAMAC_STATUS_FREQUENCY_INVALID		Unacceptable frequency for the region
LORAMAC_STATUS_DATARATE_INVALID		Unacceptable data rate for the region
LORAMAC_STATUS_FREQ_AND_DR_INVALID		Unacceptable frequency and data rate for the region

2.4.9 LoRaMacChannelRemove

LoRaMacStatus_t LoRaMacChannelRemove(uint8_t id)	
Remove a channel. It is available in all regions expect US915 and AU915. In case of US915, `LORAMAC_STATUS_PARAMETER_INVALID` will be returned.	
Parameters	
[IN] id	ID of the channel to remove
Return	
LORAMAC_STATUS_OK	Parameter was added successfully
LORAMAC_STATUS_BUSY	MAC is busy. Another service is running.
LORAMAC_STATUS_PARAMETER_INVALID	Requested parameter is NULL

2.4.10 LoRaMacStart

LoRaMacStatus_t LoRaMacStart(void)	
Starts MAC	
Parameters	
-	
Return	
LORAMAC_STATUS_OK	MAC was started successfully

2.4.11 LoRaMacStop

LoRaMacStatus_t LoRaMacStop(void)	
Stops MAC.	
Parameters	
-	
Return	
LORAMAC_STATUS_OK	MAC was stopped successfully
LORAMAC_STATUS_BUSY	MAC is busy. Another service is running.

2.4.12 LoRaMacIsBusy

bool LoRaMacIsBusy(void)
Check if MAC is busy
Parameters
-
Return
true: MAC is in busy, or MAC is not started. false: MAC is in idle (not busy)

2.4.13 LoRaMacMcChannelSetup

LoRaMacStatus_t LoRaMacMcChannelSetup(McChannelSetup_t *setup)	
Configure multicast channel. If "`setup->McKeyE`" is set (for example, remote setup), `MIB_GEN_APP_KEY` must be set before calling this function. If "`setup->McKeyE`" is NULL (for example, local setup), `MIB_MC_APP_S_KEY_n` and `MIB_MC_NWK_S_KEY_n` must be set before starting multicast communication.	
Parameters	
[IN]setup	Multicast channel to configure. See section 2.3.14 `McChannelSetup_t`.
Return	
LORAMAC_STATUS_OK	Parameter was added successfully
LORAMAC_STATUS_BUSY	MAC is busy. Another service is running.
LORAMAC_STATUS_PARAMETER_INVALID	Requested parameter is NULL.
LORAMAC_STATUS_MC_GROUP_UNDEFINED	Multicast group is not defined.

2.4.14 LoRaMacMcChannelDelete

LoRaMacStatus_t LoRaMacMcChannelDelete(AddressIdentifier_t groupID)	
Delete multicast channel.	
Parameters	
[IN]groupID	Multicast channel ID to delete. [Range: 0 - 3]
Return	
LORAMAC_STATUS_OK	Parameter was deleted successfully
LORAMAC_STATUS_BUSY	MAC is busy. Another service is running.
LORAMAC_STATUS_MC_GROUP_UNDEFINED	Specified multicast channel ID is not defined.

2.4.15 LoRaMacMcChannelGetGroupId

uint8_t LoRaMacMcChannelGetGroupId(uint32_t mcAddress)		
Look up the multicast group ID for a multicast address.		
Parameters		
	[IN] mcAddress	Multicast address
Return		
	groupID	Multicast group ID associated to the multicast address. Returns 0xFF if the multicast address is not found.

2.4.16 LoRaMacMcChannelGetAddress

LoRaMacStatus_t LoRaMacMcChannelGetAddress(AddressIdentifier_t groupID, uint32_t *mcAddress)		
Get multicast group address associated with the groupID.		
Parameters		
	[IN]groupID	Multicast group ID. [Range: 0 - 3]
	[OUT]mcAddress	Multicast group address associated with the groupID
Return		
	LORAMAC_STATUS_OK	Parameter was added successfully
	LORAMAC_STATUS_PARAMETER_INVALID	Requested parameter is NULL.
	LORAMAC_STATUS_MC_GROUP_UNDEFINED	Multicast group is not defined.

2.4.17 LoRaMacMcChannelSetupRxParams

LoRaMacStatus_t LoRaMacMcChannelSetupRxParams(AddressIdentifier_t groupID, DeviceClass_t mcClass, McRxParams_t *rxParams, uint8_t *status)		
Configures reception parameters for a multicast channel. When preparing multiple channels for class C, the frequency and data rate must be the same.		
Parameters		
	[IN]groupID	Multicast channel ID to be configured. [Range: 0 - 3]
	[IN]mcClass	Multicast session class. `CLASS_B` or `CLASS_C` can be set.
	[IN]rxParams	Reception parameters to set. See section 2.3.15 `McRxParams_t`
	[OUT]status	Status mask. bit7-5: RFU (b'000) bit4 : McGroup Undefined if set bit3 : Freq Error if set bit2 : DR Error if set bit1-0 : Multicast group (0…3)
Return		
	LORAMAC_STATUS_OK	Parameter was added successfully
	LORAMAC_STATUS_BUSY	MAC is busy. Another service is running.
	LORAMAC_STATUS_PARAMETER_INVALID	Requested parameter is invalid or NULL.
	LORAMAC_STATUS_MC_GROUP_UNDEFINED	Specified multicast group is not defined.

2.5 LoRaWAN Primitive Callback Handler (LoRaMacPrimitives_t)

This type is a structure containing MAC events handler functions used to notify upper layers MAC primitive events. This structure includes the following member functions. These members must be set before calling `LoRaMacInitialization()`.

Table 55. LoRaMacPrimitives_t

Member	Description
void (*MacMcpsConfirm)(McpsConfirm_t *)	Notify `LoRaMacMcpsRequest()` processed.
void (*MacMcpsIndication)(McpsIndication_t *)	Notify the payload received.
void (*MacMlmeConfirm)(MlmeConfirm_t *)	Notify `LoRaMacMlmeRequest()` was accepted.
void (*MacMlmeIndication)(MlmeIndication_t *)	Notify the uplink message requested.

2.5.1 MacMcpsConfirm

void (*MacMcpsConfirm)(McpsConfirm_t *mcpsConfirm)			
This function notify that `LoRaMacMcpsRequest()` processed.			
Parameters			
mcpsConfirm	[IN] McpsRequest	Requested MAC data service.	
		MCPS_UNCONFIRMED	Unconfirmed Data frame
		MCPS_CONFIRMED	Confirmed Data frame
	[IN] Status	Status of the operation of a MAC service. See section 2.2.3 `LoRaMacEventInfoStatus_t`.	
	[IN] Datarate	Uplink data rate, `DR_0` .. `DR_15`. See 2.1.1 Data Rate.	
	[IN] TxPower	Transmission Power, `TX_POWER_0` .. `TX_POWER_15`. See section 2.1.2 Transmission Power.	
	[IN] AckReceived	Received ack or not, true: received, false: not receive	
	[IN] NbRetries	Number of retransmissions	
	[IN] TxTimeOnAir	The transmission time on air of the frame in ms.	
	[IN] UpLinkCounter	The uplink counter value related to the frame	
	[IN] Channel	The uplink channel related to the frame.	
Return			
-			

2.5.2 MacMlmeConfirm

void (*MacMlmeConfirm)(MlmeConfirm_t *mlmeConfirm)			
This function notifies `LoRaMacMlmeRequest()` was completed			
Parameters			
mlmeConfirm	[IN] MlmeRequest	MLME_JOIN	Completed OTAA process
		MLME_LINK_CHECK	Completed to request to send MAC command `LinkCheckReq`
		MLME_DEVICE_TIME	Completed to request to send MAC command `DeviceTimeReq`
		MLME_BEACON _ACQUISITION	Completed beacon acquisition
		MLME_PING_SLOT _INFO	Completed to requested to send MAC command `PingSlotInfoReq`
	[IN] Status	Status of the operation of a MAC service. See section 2.2.3 `LoRaMacEventInfoStatus_t`.	
	[IN] TxTimeOnAir	The transmission time on air of the frame. [ms]	
	[IN] DemodMargin	Demodulation margin. Contains the link margin [dB] of `LinkCheckReq` last successfully received by the network.	
		0	0 dB or no margin
		1..254	1 dB .. 254 dB
		255	Reserved
	[IN] NbGateways	Number of gateways which received the last `LinkCheckReq`	
	[IN] NbRetries	Number of retransmissions for confirmed uplink transmission.	
Return			
-			

2.5.3 MacMcpsIndication

void (*MacMcpsIndication)(McpsIndication_t *mcpsIndication)			
This function notifies the received payload			
Parameters			
mcpsIndication	This function notifies the received payload		
	[IN] McpsIndication	MCPS_UNCONFIRMED	Unconfirmed data frame
		MCPS_CONFIRMED	Confirmed data frame
	[IN] Status	Status of the operation of a MAC service. See section 2.2.3 `LoRaMacEventInfoStatus_t`.	
	[IN] Port	The port that received message sent on.	
		0	MAC commands
		1..223	Application specific port
		224	Mac layer test protocol
		225..255	Reserved for standardized application extensions
	[IN] RxDatarate	Downlink data rate. `DR_0` ..`DR_15`. See section 2.1.1 Data Rate.	
	[IN] FramePending	Indicates gateway has more data pending to be sent. [0: No pending frame, 1: Pending frame exists]	
	[IN] Buffer	Pointer to the received data stream.	
	[IN] BufferSize	Size of the received data stream. 0..255 [bytes]	
	[IN] RxData	Indicates if data is available. [true: Available, false: Unavailable]	
	[IN] Rssi	RSSI of the received packet. [dBm]	
	[IN] Snr	SNR of the received packet [dBm]	
	[IN] RxSlot	Receive window for the received message. See section 2.2.8 `LoRaMacRxSlot_t`	
	[IN] AckReceived	Indicates if an ack was received. [true: Received, false: Not received]	
	[IN] DownlinkCounter	The downlink counter value for the received frame	
	[IN] DevAddress	Device address (`DevAddr`)	
	[IN] DeviceTimeAns Received	Indicates if the `DeviceTimeAns` command is received. [true: Received, false: Not received]	
Return			
-			

2.5.4 MacMlmeIndication

void (*MacMlmeIndication)(MlmeIndication_t *mlmeIndication)			
This function notifies MAC MLME-Indication primitive			
Parameters			
mlmeIndication	[IN] MlmeIndication	MLME_SCHEDULE_UPLINK	The application shall perform an uplink as soon as possible. ** Don't send an uplink in this indication. Application has to send uplink message in its main loop.
		MLME_BEACON	Indicates whether a beacon was successfully received
		MLME_BEACON_LOST	Lost synchronization with Class B beacons. This indicates MAC layer fails to receive a beacon for 120 minutes.
	[IN] Status	Operation status in case of `MLME_BEACON`	
		LORAMAC_EVENT_INFO_STATUS_BEACON_LOCKED	Successfully received a beacon frame
		LORAMAC_EVENT_INFO_STATUS_BEACON_LOST	Could not receive a beacon frame
	[IN] BeaconInfo	Beacon information	
Return			
-			

2.6 LoRaWAN Callback Handler (LoRaMacCallback_t)

This type is a structure containing MAC events handler functions used to notify upper layers. This structure includes following member functions. The Application must set pointers to user functions or NULL into the structure.

Table 56. LoRaMacCallback_t

Member	Description
uint8_t (*GetBatteryLevel)(void)	Pointer to callback function to be called when measured battery level is requested by MAC
void (*NvmContextChange)(uint32_t notifyMibFlags)	Pointer to callback function to be called when an attribute in one of the non-volatile contexts changed.
void (*MacProcssNotify)(void)	Reserved.
void (*MacErrorNotify) (LoRaMacErrorNotificationStatus_t status)	Pinter to callback function to be called when an error is notified to application
float (*GetTemperatureLevel)(void)	Reserved. Set NULL.

2.6.1 GetBatteryLevel

uint8_t (*GetBatteryLevel)(void)		
This function will be called on reception of `DevStatusReq` command by MAC. Application has to measure the battery level in this function and return it. When the application assign NULL as this function, LoRaWAN stack returns `BAT_LEVEL_NO_MEASURE` to the network.		
Parameters		
	-	
Return		
	BAT_LEVEL_EXT_SRC	Node is connected to an external power source
	BAT_LEVEL_EMPTY	Battery level empty
	2..253	Battery level, where 2 is the minimum
	BAT_LEVEL_FULL	Battery level full
	BAT_LEVEL_NO_MEASURE	The node was not able to measure the battery level

2.6.2 NvmContextChange

void (*NvmContextChange)(uint32_t notifyMibFlags)	
Called when the attribute(s) in the non-volatile context changes.	
Parameters	
notifyMibFlags	Changed attribute(s). One or more of the following parameters will be set. ● LORAMAC_NVM_MIBFLG_DEV_NONCE (0x00000001) `DevNonce` is changed. ● LORAMAC_NVM_MIBFLG_APP_NONCE (0x00000002) `AppNonce` (or `JoinNonce`) is changed. ● LORAMAC_NVM_MIBFLG_DOWNLINK_FCNT (0x00000004) Downlink frame counter is changed. ● LORAMAC_NVM_MIBFLG_UPLINK_FCNT (0x00000008) Uplink frame counter is changed. ● LORAMAC_NVM_MIBFLG_CHANNELS (0x00000010) Channel (frequency and data rate) information is changed. ● LORAMAC_NVM_MIBFLG_CHANNELS_MASK (0x00000020) Channel mask is changed. ● LORAMAC_NVM_MIBFLG_CHANNELS_DATARATE (0x00000040) Data rate is changed by ADR. ● LORAMAC_NVM_MIBFLG_CHANNELS_NB_TRANS (0x00000080) NbTrans is changed. ● LORAMAC_NVM_MIBFLG_CHANNELS_TXPOWER (0x00000100) TxPower is changed. ● LORAMAC_NVM_MIBFLG_MAX_DCYCLE (0x00000200) Maximum duty cycle is changed. ● LORAMAC_NVM_MIBFLG_RX1_DROFFSET (0x00000400) RX1DRoffset is changed. ● LORAMAC_NVM_MIBFLG_RX2_FREQUENCY (0x00000800) RX2 frequency is changed. ● LORAMAC_NVM_MIBFLG_RX2_DATARATE (0x00001000) RX2 data rate is changed. ● LORAMAC_NVM_MIBFLG_RECEIVE_DELAY_1 (0x00002000) RX1 received delay is changed. ● LORAMAC_NVM_MIBFLG_MAX_EIRP (0x00004000) Maximum `EIRP` is changed. ● LORAMAC_NVM_MIBFLG_DOWNLINK_DWELLTIME (0x00008000) Downlink dwell time is changed. ● LORAMAC_NVM_MIBFLG_UPLINK_DWELLTIME (0x00010000) Uplink dwell time is changed. ● LORAMAC_NVM_MIBFLG_PING_SLOT_DATARATE (0x00020000) PingSlot data rate is changed.
Return	
-	

2.6.3 MacErrorNotify

void (*MacErrorNotify)(LoRaMacErrorNotificationStatus_t status)	
Called when an error is notified to applications	
Parameters	
status	Error status. This parameter can take of the following value. ● LORAMAC_ERROR_NOTIFICATION_STATUS_RADIO_CHECK_FAIL_RX_CFG Radio RX parameter configuration failure
Return	
-	

3. Timer

Timer provides timer event and a system time value.
For more details, please refer to [1].

4. Power Saving

4.1 LoRaMacSetLowPower

LoRaMacStatus_t LoRaMacSetLowPower(void)	
This function sets MCU to the low power mode. Application can call this function when it can be in the low power mode. In this function, MCU will be in the low power mode if LoRaWAN is not busy. This function is not available for LoRaWAN Class C devices.	
Parameters	
-	
Return	
LORAMAC_STATUS_OK	MCU could be set to the low power mode and returned to the normal mode successfully.
LORAMAC_STATUS_BUSY	MCU cannot be set to the low power mode due to the following reasons: - LoRaWAN is busy. - Application disallows MCU to be set to low power mode. (See below) - Device is in LoRaWAN Class C mode.
Additional explanation	
Application can allow/disallow MCU low power by using `BoardIsLowPowerAllowed()` function. It is called before MCU will be in the low power mode. `[board.c] bool BoardIsLowPowerAllowed( void )` Please make `BoardIsLowPowerAllowed` return true if MCU can be set to the low power mode, false if not.	

5. Sample Code (Informative)

5.1 Initialize the LoRaWAN MAC

The following code-snippet shows how to use the API to initialize the MAC.

```
#Include "LoRaMac.h"
#include "Region.h"

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

static void AppNvmContextChange( uint32_t notifyMibFlags );

LoRaMacPrimitives_t LoRaMacPrimitives;
LoRaMacCallback_t LoRaMacCallbacks;

/* set mac primitives      */
LoRaMacPrimitives.MacMcpsConfirm = McpsConfirm;
LoRaMacPrimitives.MacMcpsIndication = McpsIndication;
LoRaMacPrimitives.MacMlmeConfirm = MlmeConfirm;
LoRaMacPrimitives.MacMlmeIndication = MlmeIndication;

/* set the getter of board information       */
LoRaMacCallbacks.GetBatteryLebel = BoardGetBatteryLevel;     /* maybe implemented for each board     */
LoRaMacCallbacks.GetTemperatureLevel = NULL;
LoRaMacCallbacks.NvmContextChange =  AppNvmContextChange;
LoRaMacCallbacks.MacProcessNotify = NULL;
LoRaMacCallbacks.MacErrorNotify = OnMacErrorNotify;

/* initialize MAC */
LoRaMacInitialization(&LoRaMacPrimitives, &LoRaMacCallbacks, LORAMAC_REGION_AS923);
```

5.2 Set a MIB Parameter

The following code-snippet shows how to use the API to set the parameter `DevAddr`.

```
MibRequestConfirm_t    mibReq;
LoRaMacStatus_t    status;

mibReq.Type = MIB_DEV_ADDR;
mibReq.Param.DevAddr = appLorawanSettings.devAddr;
status = LoRaMacMibSetRequestConfirm( &mibReq );
```

5.3 Get a MIB Parameter

The following code-snippet shows how to use the API to get the parameter `DevAddr`.

```
MibRequestConfirm_t    mibGet;
LoRaMacStatus_t    status;

mibGet.Type = MIB_DEV_ADDR;
stat = LoRaMacMibGetRequestConfirm(&mibGet);
```

5.4 Activation by Personalization (ABP)

The following code-snippet shows how to use the API to activate by personalization.

```
static uint8_t NwkSKey[] = { 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x03, 0x0f };
static uint8_t AppSKey[] = { 0x2B, 0x7E, 0x15, 0x16, 0x28, 0xAE, 0xD2, 0xA6, 0xAB, 0xF7, 0x15, 0x88,
0x09, 0xCF, 0x4F, 0x3C };
static uint32_t DevAddr = ( uint32_t )0x01020304;
MibRequestConfirm_t    mibReq;

mibReq.Type = MIB_ABP_LORAWAN_VERSION;
mibReq.Param.AbpLrWanVersion = 0x01000300;          // 0x01000300 = LoRaWAN 1.0.3
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_NET_ID;
mibReq.Param.NetID = 0;
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_DEV_ADDR;
mibReq.Param.DevAddr = DevAddr;
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_NWK_SKEY;
mibReq.Param.NwkSKey = NwkSKey;
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_APP_SKEY;
mibReq.Param.AppSKey = AppSKey;
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_DEVICE_CLASS;
mibReq.Param.Class = CLASS_A;
LoRaMacMibSetRequestConfirm(&mibReq);      // Switch the device class to Class A

mibReq.Type = MIB_NETWORK_ACTIVATION;
```

```
mibReq.param.NetworkActivation = ACTIVATION_TYPE_ABP;
LoRaMacMibSetRequestConfirm( &mibReq );
```

5.5 Over The Air Activation (OTAA)

The following code-snippet shows how to use the API to perform a network join request.

```
static uint8_t    DevEui[] = {  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x09, 0x0F };
static uint8_t    AppEui[] = {  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x0A, 0x0B };
static uint8_t    AppKey[] = {  0x2B, 0x7E, 0x15, 0x16, 0x28, 0xAE, 0xD2, 0xA6, 0xAB, 0xF7, 0x15, 0x88,
0x09, 0xCF, 0x4F, 0x3C };
MibRequestConfirm_t    mibReq;
MlmeReq_t     mlmeReq;

mibReq.Type = MIB_DEV_EUI;
mibReq.Param.DevEui = DevEUI;
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_APP_EUI;
mibReq.Param.AppEui = AppEUI;
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_APP_KEY;
mibReq.Param.AppKey = AppKey;
LoRaMacMibSetRequestConfirm( &mibReq );

mibReq.Type = MIB_DEVICE_CLASS;
mibReq.Param.Class = CLASS_A;
LoRaMacMibSetRequestConfirm(&mibReq);       // Switch the device class to Class A

mlmeReq.Type = MLME_JOIN;
mlmeReq.Req.Join.Datarate = DR_2;     // Ignored in case of AS923
if( LoRaMacMlmeRequest( &mlmeReq ) == LORAMAC_STATUS_OK )
{
  // Service started successfully. Waiting for the Mlme-Confirm event
}
```

5.6 Send Unconfirmed Data Frame

The following code-snippet shows how to use the API to send an unconfirmed data frame.

```
uint8_t    myBuffer[] = { 1, 2, 3 };
McpsReq_t    mcpsReq;

mcpsReq.Type = MCPS_UNCONFIRMED;
mcpsReq.Req.Unconfirmed.fPort = 1;
mcpsReq.Req.Unconfirmed.fBuffer = myBuffer;
mcpsReq.Req.Unconfirmed.fBufferSize = sizeof( myBuffer );

if( LoRaMacMcpsRequest( &mcpsReq ) == LORAMAC_STATUS_OK )
{
  // Service started successfully. Waiting for the MCPS-Confirm event
}
```

5.7 Switching to Class B

The following code-snippet shows an example API sequence to switch an end device from Class A to Class B. Please make sure you have the same ping slot periodicity configuration on the device and server when you set the ping slot periodicity without publishing the MAC command `PingSlotInfoReq`.

```
MlmeReq_t    mlmeReq;
MibRequestConfirm_t    mibReq;

mlmeReq.Type = MLME_DEVICE_TIME;
if( LoRaMacMlmeRequest( &mlmeReq ) == LORAMAC_STATUS_OK )   // Request DeviceTimeAns
{
// Service started successfully. Waiting for the Mlme-Confirm event
}

mlmeReq.Type = MLME_BEACON_ACQUISITION
if( LoRaMacMlmeRequest( &mlmeReq ) == LORAMAC_STATUS_OK )   // Initiate beacon acquisition
{
 // Service started successfully. Waiting for the Mlme-Confirm event
}

mibReq.Type = MIB_PING_SLOT_PERIODICITY;
mibReq.Param.PingSlotPeriodicity = 5;
LoRaMacMibSetRequestConfirm( &mibReq );     // Set the ping slot periodicity to 5

mibReq.Type = MIB_DEVICE_CLASS;
mibReq.Param.Class = CLASS_B;
LoRaMacMibSetRequestConfirm(&mibReq);       // Switch the device class to Class B

// Device starts Class B operation, opening ping slots at the periodicity of 5.
```

```
// Make sure you have the same ping slot periodicity configuration on the device and server when you
// set the ping slot periodicity without publishing the MAC command PingSlotInfoReq.

// Notifies LoRaWAN server that currently it is operating in Class B
// LinkCheckReq command which requests response is used for example.

mlmeReq.Type = MLME_LINK_CHECK;
if( LoRaMacMlmeRequest( &mlmeReq ) == LORAMAC_STATUS_OK )   // Request LinkCheckAns
{
 // Service started successfully. Waiting for the Mlme-Confirm event
}
```

5.8 Switching to Class C

The following code-snippet shows an example API sequence to switch an end device from Class A to Class C. If the Class C feature is necessary, you need to switch the device class to Class C after completion of joining.

```
MibRequestConfirm_t    mibReq;

// Switch the device class from Class A to Class C after completion of the joining.
mibReq.Type = MIB_DEVICE_CLASS;
mibReq.Param.Class = CLASS_C;
LoRaMacMibSetRequestConfirm(&mibReq);       // Switch the device class to Class C
```

5.9 Timer

The following code-snippet shows how to use asynchronous timer.

```
static TimerEvent_t AsyncTimer;          /* timer event object      */
static OnAsyncTimerEvent(void);          /* timer event handler     */

int main(void)
{
        /* initialize Timer object  */
        TimerInit(&AsyncTimer, OnAsyncTimerEvent);
        TimerSetValue(&AsyncTimer, 25);                    /* set timeout value to 25ms       */

        /* start timer      */
        TimerStart(&AsyncTimer);
}
```

5.10 Timer Time

The following code-snippet shows an example to use timer value functions.

```
/* example to repeat some process for 10ms       */
TimerTime_t startTime = TimerGetCurrentTime();

while (TimerGetElapsedTime(startTime) < 10) {
        /* code to repeat           */
}
```

6. Limitations to LoRaWAN Functions for RL78/G22 and RA0E1

When using RL78/G22 or RA0E1, there are some limitations to LoRaWAN functionality to fit the internal memories.

Limited functions	Outline
Region	Only one region can be set in the project build option.
ABP	Not supported.
Multicast	RL78/G22 does not support multicast. RA0E1 supports it.
Class B functions	Not supported.
Channel parameter	In case of US915 or AU915, Rx1Frequency parameter in ChannelParam_t is removed because it is unnecessary.

6.1 Region

When using RL78/G22 or RA0E1, only one region can be supported.

6.1.1 Stack Settings

In section 2.1.4 (Table 18), stack configurations macros to enable each region's feature (REGION_xxxxx) are described.

When using RL78/G22 or RA0E1, only one region's feature can be specified in the project build option. If specified more than one region's feature, build error will occur.

6.2 Activation by Personalization (ABP)

When using RL78/G22 or RA0E1, ABP is not supported.

6.2.1 MIB

Mib_t (enumeration type contains MIB) is described in section 2.2.7 (Table 28) and MibParams_t (union type contains MIB parameters) is described in section 2.3.11 (Table 45).

When using RL78/G22 or RA0E1, the following MIBs for ABP are not supported (Table 57).

Table 57. Unsupported MIBs (ABP)

Unsupported Mib_t enumerator	Unsupported member of MibParam_t structure	Description
MIB_NWK_SKEY	NwkSKey	Network session key (`NwkSKEY`)
MIB_APP_SKEY	AppSKey	Application session key (`AppSKey`)
MIB_ABP_LORAWAN_VERSION	AppLrWanVersion	LoRaWAN version

When using RL78/G22 or RA0E1, the following MIB for ABP cannot be set. (Table 58).

Table 58. Restricted MIBs (ABP)

Restricted Mib_t enumerator	Member of MibParam_t structure	Restriction
MIB_NETWORK_ACTIVATION	NetworkActivation	Activation type cannot be set.

6.2.2 LoRaWAN Callback Handler

In section 2.6.2, NvmContextChange() callback is described.

When using RL78/G22 or RA0E1, all parameters except LORAMAC_NVM_MIBFLG_DEV_NONCE (0x00000001) and LORAMAC_NVM_MIBFLG_APP_NONCE (0x00000002) are not supported.

6.3 Multicast

When using RL78/G22, multicast function is not supported. When using RA0E1, it is supported.

6.3.1 MIB

Mib_t (enumeration type contains MIB) is described in section 2.2.7 (Table 28), and MibParams_t (union type contains MIB parameters) is described in section 2.3.11 (Table 45).

When using RL78/G22, the following MIBs for multicast are not supported (Table 59).

Table 59. Unsupported MIBs (Multicast)

Unsupported Mib_t enumerator	Unsupported member of MibParam_t structure	Description
MIB_MC_NWK_S_KEY_n	NwkSKey	Network session key for multicast (`McNwkSKEY`). “n” means the index of the multicast group and an integer in 0 - 3.
MIB_MC_APP_S_KEY_n	AppSKey	Application session key for multicast (`McAppSKEY`). “n” means the index of the multicast group and an integer in 0 - 3.

6.3.2 LoRaWAN APIs

When using RL78/G22, following APIs are not supported (Table 60).

Table 60. Unsupported LoRaWAN APIs

LoRaMacMcChannelSetup	Configure multicast channel. (Section 2.4.13)
LoRaMacMcChannelDelete	Delete multicast channel. (Section 2.4.14)
LoRaMacMcChannelGetGroupId	Get multicast channel group ID. (Section 2.4.15)
LoRaMacMcChannelGetAddress	Get multicast address. (Section 2.4.16)
LoRaMacMcChannelSetupRxParams	Configure reception parameters of multicast channel. (Section 2.4.17)

LoRaMacMcChannelGetGroupId() always returns 0xFF, and the other APIs in Table 60 always return `LORAMAC_STATUS_SERVICE_UNKNOWN`.

6.4 Class B Functions

When using RL78/G22 or RA0E1, class B functions (beacon, ping-slot) are not supported.

6.4.1 Stack Settings

In section 2.1.4 (Table 18), stack configuration macro to enable class B feature (LORAMAC_CLASSB_ENABLED) is described.

When using RL78/G22 or RA0E1, the macro cannot be specified in the project build option. If specified, build error will occur.

6.4.2 Configuration

In section 2.1.5 (Table 19 and Table 20), parameters available for configuration in the LoRaWAN stack are described.

When using RL78/G22 or RA0E1, following configurations for Class B are not supported (Table 61 and Table 62).

Table 61. Unsupported Macros for Stack Configuration (LoRaMacConfig.h)

Unsupported Macro	Description
CLASSB_STACK_PROCTIMEMS_BEACON_ACQISITION	Processing time from timer interrupt to beacon window start for beacon acquisition.
CLASSB_STACK_PROCTIMEMS_BEACON	Processing time from timer interrupt to beacon window start for beacon tracking.
CLASSB_STACK_PROCTIMEMS_PING_SLOT_SHORT_PERIOD	Processing time from timer interrupt to ping slot window start for short periodicity.
CLASSB_STACK_PROCTIMEMS_PING_SLOT_LONG_PERIOD	Processing time from timer interrupt to ping slot window start for long periodicity.
CLASSB_BEACON_SYSTIMEDELTA_MAXERROR	Maximum error of system time in a beacon interval
CLASSB_BEACON_SYSTIMEDELTA_MINERROR	Minimum error of system time in a beacon interval.
CLASSB_BEACON_SYSTIMEDELTA_INITERROR	Initial error of system time in a beacon interval.

Table 62. Unsupported Macros for Stack Configuration (LoRaMacClassBConfig.h)

Unsupported Macro	Description
CLASSB_PING_SLOT_PERIODICITY_DEFAULT	Default ping slot periodicity
CLASSB_PING_SLOT_PERIODICITY_RFSLEEP_THRESHOLD	Threshold for the ping slot periodicity to select RF sleep mode.

6.4.3 MIB

Mib_t (enumeration type contains MIB) is described in section 2.2.7 (Table 28), and MibParams_t (union type contains MIB parameters) is described in section 2.3.11 (Table 45).

When using RL78/G22 or RA0E1, the following MIBs for Class B are not supported (Table 63).

Table 63. Unsupported MIBs (Class B)

Unsupported Mib_t enumerator	Unsupported member of MibParam_t structure	Description
MIB_PING_SLOT_DATARATE	PingSlotDatarate	Ping slot data rate
MIB_PING_SLOT_PERIODICITY	PingSlotPeriodicity	Ping slot periodicity

When using RL78/G22 or RA0E1, the following MIB for Class B are restricted (Table 64).

Table 64. Restricted MIB (Class B)

Mib_t enumerator	Member of MibParam_t structure	Restriction
MIB_DEVICE_CLASS	Class	`CLASS_B` cannot be set.

6.4.4 LoRaWAN API

In section 2.4.4, LoRaMacMlmeRequest() function is described.

When using RL78/G22 or RA0E1, `MLME_BEACON_ACQUISITION` and `MLME_PING_SLOT_INFO` for Class B cannot be specified in `mlmeRequest->Type`. If specified, this function returns `LORAMAC_STATUS_SERVICE_UNKNOWN`.

6.4.5 LoRaWAN Primitive Callback Handler

In section 2.5.2, MacMlmeConfirm() callback is described.

When using RL78/G22 or RA0E1, `MLME_BEACON_ACQUISITION` and `MLME_PING_SLOT_INFO` for Class B are not set in `mlmeConfirm->MlmeRequest`.

In section 2.5.4, MacMlmeIndication() callback is described.

When using RL78/G22 or RA0E1, `MLME_BEACON` and `MLME_BEACON_LOST` for Class B are not set in `mlmeIndication->MlmeIndication`.

6.5 ChannelParam_t in case of US915 or AU915

In section 2.3.16, ChannelParam_t structure is described. If the region is US915 or AU915, `Rx1Frequency` member is unnecessary. So, it is removed to reduce the memory usage.

Table 65. ChannelParams_t in case of US915 or AU915

Member type	Member	Description
uint32_t	Frequency	Frequency in Hz
uint32_t	Rx1Frequency	This member is removed only in case of US915 or AU915.
union DrRange_t	DrRange.Value	Byte access to the following bits of Data rate definition
	DrRange.Fields.Min : 4	Minimum data rate
	DrRange.Fields.Max : 4	Maximum data rate
uint8_t	Band	Band index

Revision History

Rev.	Date	Description	
		Section	Summary
01.00	Jan.31.19	-	Initial Release
01.10	Nov.29.19	-	Changed target device from 'RL78/G14 (R5F104JJ)' to 'RL78/G14 (R5F104ML)'
		1.3	Changed CSI21 to CSI31 Deleted UART1 because UART1 is not necessary for the stack.
		2.2.5, 2.3.1, 2.4.4, 2.5.1, 2.5.2	Changed proprietary frame transmission and reception as 'reserved' (not supported)
		2.2.7	Added MIB_APP_KEY
		6	Remove this section due to the information in the section is for older version of the stack
02.10	Jul.10.20	-	Supported for Class B and Multicast functions. Added related APIs, IBs, structures, enumerators and macros.
		2.1.4	Added LORAMAC_CLASSB_ENABLED to select whether to use Class B functions
		2.3.1	Added RequestReturnParams_t to McpsReq_t to report duty cycle wait time
		2.3.6	Added RequestReturnParams_t to MlmeReq_t to report duty cycle wait time
		2.4	Added LoRaMacStart() and LoRaMacStop()
		2.6	Added NvmContextChange(), MacProcessNotify(), and MacErrorNotify()
		3	Deleted description for Timer. Added reference document for Timer.
		5.7	Added sample code for Class B
03.00	Mar.26.21	-	Supported RL78/G23 (R7F100GLG) as a target device
03.10	Sep.30.21	-	Supported for LoRaWAN protocol specified in the specification version 1.0.4.
		-	Supported RL78/G23 (R7F100GSN) as a target device
		1.4	Added region definition in Table 1-5, Group AS923-1,2,3,4, and AS923-Japan
		2.1.4	- Added LORAWAN_VERSION_1_0_3 and LORAWAN_VERSION_1_0_4 - Added description of REGION_AS923
		2.2	Deleted LoRaMacNvmCtxModule_t
		2.2.2	Added the enumerators; LORAMAC_REGION_AS923_2 LORAMAC_REGION_AS923_3 LORAMAC_REGION_AS923_4 LORAMAC_REGION_AS923_JPN
		2.2.3	Added the enumerator; LORAMAC_EVENT_INFO_STATUS_JOIN_NONCE_FAIL
		2.2.7 2.3.11	Added MIB (2.2.7) and the members of MibParam_t (2.3.11); MIB_CHANNELS, MIB_IS_CERT_FPORT_ON, MIB_DEV_NONCE, MIB_APP_NONCE, MIB_MAX_DCYCLE, MIB_RX1_DROFFSET, MIB_MAX_EIRP, MIB_DOWNLINK_DWELLTIME, MIB_UPLINK_DWELLTIME, MIB_DOWNLINK_FCNT, and MIB_UPLINK_FCNT

		2.4.1	Added the enumerators which can be set in region parameter.
		2.6 2.6.2	Changed the argument of NvmContextChange() callback function.
03.12	Jan.21.22	Table 2	Removed ‘Real Time Clock (RTC)’ for correction.
		Table 3	Removed ‘Real Time Clock (RTC)’ for correction.
		Table 5	Modified RFU to value of TxPower in case of US915, TX_POWER_10 to TX_POWER_14 for correction.
		Table 7	Added ‘AS923-1 for Japan’ for REGION_AS923. Added ‘LoRaWAN Regional Parameters RP002-1.0.3’ for LORAWAN_VERSION_1_0_4. Added ‘LoRaWAN 1.0.3 Regional Parameters Revision A’ for LORAWAN_VERSION_1_0_3.
04.00	Aug.29.22	-	Supported RA2E1 (R7FA2E1A9xxFM) as a target device
		-	Supported IN865, AU915 and KR920 regions for RA2E1
		2.1.1	Modified data rate index definitions (Table 3) and added data rate tables for each region (Table 4 to Table 10).
		2.1.2	Modified transmission power definitions (Table 11) and added transmission power table for each region (Table 12 to Table 17).
		Table 19	Added macros for IN865, AU915 and KR920 regions
		2.1.5	Added default configuration for RA2E1
		Table 24	Added enumerators for added regions; IN865, AU915, KR920
		Table 29	Added enumerator; MIB_CHANNELS_MIN_TX_DATARATE
		Table 46	Added member; ChannelsMinTxDatarate
		2.4.1	Updated description of parameters for IN865, AU915 and KR920 regions
		2.4.4	Updated description of Join.Datarate parameters for IN865, AU915 and KR920 regions
		2.4.8	Updated description about available regions.
		2.4.9	Updated description about available regions.
04.10	Nov.29.22	-	Supported IN865, AU915 and KR920 regions for RL78/G14 and RL78/G23
		1.6	Removed restriction about supported regions.
		2.1.5	Updated default value
		Table 29	Removed restriction; MIB_CHANNELS_MIN_TX_DATARATE
		Table 46	Removed restriction; ChannelsMinTxDatarate
04.20	Mar.31.23	-	Supported RA2L1 (R7FA2L1AB2DFP) as a target device
		2.2.7 2.3.11	Added MIB (2.2.7) and the members of MibParam_t (2.3.11) ; MIB_SYSTEM_MAX_RX_ERROR MIB_RSSI_FREE_THRESHOLD MIB_CARRIER_SENSE_TIME
		2.4.4	Added description about MLME_JOIN in case of Class C.
		2.4.11	Added restriction of LoRaMacStop().
		2.4.12	Updated description about return value.
		2.6 2.6.3	Changed MacProcessNotify() to reserved, and delete 2.6.3
		5.8	Added section and described the example to switch Class C.
04.30	Jun.30.23	-	Supported RL78/G22 (R7F102GGE) as a target device
		6	Added section to describe the limitations to LoRaWAN functions for RL78/G22.

04.40	Dec.22.23	1.5	Replaced related document [2].
		Table 18	Updated description about RP_USE_CFG_CHECK.
		2.4.1	Updated description about LORAMAC_REGION_AS923_JP in region parameter.
		2.4.11	Removed restriction of device class.
04.50	May.24.24	-	Supported RA0E1 (R7FA0E1073CFJ) as a target device.
		2.1.5	Updated default value
		6	Added RA0E1 to the section.
04.60	Sep.27.24	1.2	Updated directories.
		1.5	Added related document [5].
04.70	Apr.18.25	-	Supported RA0E2 (R7FA0E2094CFM) as a target device.
04.80	Aug.21.25	-	Supported RL78/L23 (R7F100LPL) 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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