WiMOD LoRaWAN EndNode Modem HCI Specification (US915)

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IMST GmbH
Carl-Friedrich-Gauß-Str. 2-4
47475 KAMP-LINTFORT
GERMANY

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0.1	Created, Initial Version Reference: WiMOD LoRaWAN EndNode Modem HCI Spec V1.14
0.2	Reference: WiMOD LoRaWAN EndNode Modem HCI Spec V1.22 Chapter 2.1.1 updated for Radio Stack Configuration
0.3	Chapter 4 updated
0.4	Reference: WiMOD LoRaWAN EndNode Modem HCI Spec V1.26 Chapter 2.1.1 updated

Aim of this Document

This document describes the WiMOD LoRaWAN®[1] EndNode Modem Host Controller Interface (HCI) protocol which is part of the WiMOD LoRaWAN EndNode Modem firmware. This firmware can be used in combination with the WiMOD LoRa radio module family.

[1] LoRa is a registered trademark of Semtech Corporation. LoRaWAN is a registered trademark of the LoRa Alliance.

Table of Contents

1. Introduction

1.1 Overview

This document is an extension to the WiMOD LoRaWAN EndNode Modem HCI document [1], covering the changes included in the WiMOD LoRaWAN EndNode Modem firmware for US 902-928MHz ISM Band.

2. Firmware Services Modification

This chapter describes the message format for the changes on the firmware services in detail. The services are ordered according to their corresponding endpoint.

2.1 LoRaWAN Services

This section describes the changes on the HCI messages with respect to [1]. These affect to the following features:

- Radio Stack Configuration including Multi Band support: the band index is fixed for the US 915 MHz band. Additionally a sub-band mask selection is available.

2.1.1 Radio Stack Configuration

The radio stack provides several features and parameters which can be configured via HCI:

- **Data Rate**
  used for unreliable and confirmed data packets (not join message). This value is used in the next uplink and may change automatically during runtime or via LoRaWAN MAC commands from network server side.
- **TX Power Level (EIRP)** [1]
  this value is used in the next uplink and may change automatically.
- **Adaptive Date Rate**
  this feature can be enabled to allow an automatic data rate adaption from server side (see [2]).
- **Automatic Power Saving**
  this feature can be enabled to activate the automatic power saving mode. The module will enter a low power mode whenever possible. Wakeup via HCI message requires a sequence of ~40 additional wakeup characters (at 115200bps UART baud rate) “0xC0” prior to any SLIP encoded message.
- **Duty Cycle Control**
  this function can be disabled for test purpose.
  Note: this parameter can only be written in “Customer Mode” (see “System Operation Modes"), otherwise it will be ignored.
- **Class A & C Support**
  the radio can operate in one of these two modes.
- **MAC Events Support**
  this feature enables an event to forward the received MAC Commands to the corresponding host (for test purpose).
  If this feature is enabled, an additional HCI message will be sent to indicate the reception of MAC commands piggybacked in the header (see [1]) and the MAC commands will be available via the standard UDATA or CDATA HCI messages (see [1]) if these are received in port 0.
  Otherwise, if this feature is disabled, the MAC commands will not be visible to the corresponding host.
- **Extended HCI Output Support**
  this feature enables extended RF packet output format, where the Tx/Rx channel info is attached.
- **Private LoRaWAN Network Configuration**
  this feature enables the configuration of a private LoRaWAN network, which implies a change on the sync word.

[1] The RF Output Power may be limited by the radio module. For more information refer to the corresponding hardware datasheet (e.g. see [2]).

- **HCI Power-Up Indication**

  this feature enables a HCI message informing to the host when the module is ready to communicate after a power-up reset.
- **Number of Retransmissions**

  this value sets the maximum number of retries for a reliable radio packet where an acknowledgment is not received.
- **Band Index**

  used to configure the radio band to be used.
- **Header MAC Cmd Capacity**

  used to configure the maximum length of the MAC commands to be piggybacked in the header within the next uplink. If the length of the reply exceeds this value, they will be sent immediately using the port 0.
- **Sub-Band Mask1**

  used to select the 125 kHz bandwidth channels to be used for the transmission of the radio messages.
- **Sub-Band Mask2**

  used to select the 500 kHz bandwidth channels to be used for the transmission of the radio messages..

2.1.1.1 Set Radio Stack Configuration

This service can be used to configure the integrated radio stack.

Command Message

Field	Content	Description
Endpoint ID	LORAWAN_ID	Endpoint Identifier
Msg ID	LORAWAN_MSG_SET_RSTACK_CONFIG_REQ	Set Radio Stack Configuration Request
Length	9	9 octets
Payload[0]	Data Rate Index	see appendix
Payload[1]	TX Power Level (EIRP)	Tx Power value in dBm (parameter range: 0 dBm to max. EIRP allowed by the device in 1 dB steps)
Payload[2]	Options	Bit 0: 0 = Adaptive Data Rate disabled 1 = Adaptive Data Rate enabled Bit 1: 0 = Duty Cycle Control disabled 1 = Duty Cycle Control enabled *(Customer Mode required)* Bit 2: 0 = Class A selected 1 = Class C selected Bit 4: 0 = Power-Up Indication disabled 1 = Power-Up Indication enabled Bit 5: 0 = public LoRaWAN network 1 = private LoRaWAN network Bit 6: 0 = standard RF packet output format 1 = extended RF packet output format: Tx/Rx channel info attached Bit 7: 0 = Rx MAC Command Forwarding disabled 1 = Rx MAC Command Forwarding enabled
Payload [3]	Power Saving Mode	0x00 : off 0x01 : automatic
Payload [4]	Number of Retransmissions	Maximum number of retries for a reliable radio packet (parameter range: 0 to 254)
Payload [5]	Band Index	Radio Band Selection (see appendix)
Payload [6]	Header MAC Cmd Capacity	Maximum length of the MAC commands to be piggybacked in the header (parameter range: 0 to 15)
Payload [7]	Sub-band Mask1	Sub-band Selection for 125 kHz bandwidth channels (see appendix)
Payload [8]	Sub-band Mask2	Sub-band Selection for 500 kHz bandwidth channels (see appendix)

Response Message

Field	Content	Description
Endpoint ID	LORAWAN_ID	Endpoint Identifier
Msg ID	LORAWAN_MSG_SET_RSTACK_CONFIG_RSP	Set Radio Stack Configuration Response
Length	1 (+1)	1 (+1) octet
Payload[0]	Status Byte	see appendix
Payload[1]	Wrong Parameter Error Code	Bit 0: 0 = Correct Data Rate 1 = Wrong Data Rate Bit 1: 0 = Correct TX Power Level 1 = Wrong TX Power Level Bit 2-4: not used Bit 5: 0 = Correct Band Index 1 = Wrong Band Index Bit 6-7: not used Only sent if status byte contains LORAWAN_STATUS_WRONG_PARAMETER

2.1.1.2 Get Radio Stack Configuration

This service can be used to read the current radio stack configuration.

Command Message

Field	Content	Description
Endpoint ID	LORAWAN_ID	Endpoint Identifier
Msg ID	LORAWAN_MSG_GET_RSTACK_CONFIG_REQ	Get Radio Stack Configuration Request
Length	0	no payload

Response Message

Field	Content	Description
Endpoint ID	LORAWAN_ID	Endpoint Identifier
Msg ID	LORAWAN_MSG_GET_RSTACK_CONFIG_RSP	Get Radio Stack Configuration Response
Length	10	10 octets
Payload[0]	Status Byte	see appendix
Payload[1]	Data Rate Index	see appendix
Payload[2]	TX Power Level (EIRP)	Tx Power value in dBm (parameter range: 0 dBm to max. EIRP allowed by the device in 1 dB steps)
Payload[3]	Options	Bit 0: 0 = Adaptive Data Rate disabled 1 = Adaptive Data Rate enabled Bit 1: 0 = Duty Cycle Control disabled 1 = Duty Cycle Control enabled Bit 2 : 0 = Class A selected 1 = Class C selected Bit 4: 0 = Power-Up Indication disabled 1 = Power-Up Indication enabled Bit 5: 0 = public LoRaWAN network 1 = private LoRaWAN network Bit 6: 0 = standard RF packet output format 1 = extended RF packet output format: Tx/Rx channel info attached Bit 7: 0 = Rx MAC Command Forwarding disabled 1 = Rx MAC Command Forwarding enabled
Payload [4]	Power Saving Mode	0x00 : off 0x01 : automatic
Payload [5]	Number of Retransmissions	Maximum number of retries for a reliable radio packet (parameter range: 0 to 254)
Payload [6]	Band Index	Radio Band Selection (see appendix)
Payload [7]	Header MAC Cmd Capacity	Maximum length of the MAC commands to be piggybacked in the header (parameter range: 0 to 15)
Payload [8]	Sub-band Mask1	Sub-band Selection for 125 kHz bandwidth channels (see appendix)
Payload [9]	Sub-band Mask2	Sub-band Selection for 500 kHz bandwidth channels (see appendix)

2.1.1.3 Default Radio Stack Configuration

The following table lists the default radio stack configuration used if no factory settings are stored in the non-volatile memory.

Parameter	Value
Band Index	2 (US 915 MHz)
Sub-band Mask1	0xFF (all 125 kHz channels enabled)
Sub-band Mask2	0xFF (all 500 kHz channels enabled)
Data Rate Index	0 (SF10 / BW125 kHz)
TX Power Level (EIRP)	22 dBm
Adaptive Data Rate	Enabled
Duty Cycle Control	Enabled
Class C Support	Disabled (Class A selected)
Private LoRaWAN Network Configuration	Disabled (Public selected)
HCI Power-Up Indication	Disabled
MAC Events Support	Disabled
Extended HCI Output Support	Disabled
Automatic Power Saving	Enabled
Number of Retransmissions	7
Header MAC Cmd Capacity	15

3. Appendix

3.1 Multi Band Support

3.1.1 Radio Band Indices

Index	Band Description
2	US 915 MHz

3.1.2 US 915 MHz Band

Note that if this band is selected the LoRaWAN stack will disable any duty cycle restrictions automatically.

3.1.2.1 Data Rate Indices

Index	Data Rate / Spreading Factor	Bandwidth	Indicative physical bit rate [bit/s]
0	LoRa / SF10	125 kHz	980
1	LoRa / SF9	125 kHz	1760
2	LoRa / SF8	125 kHz	3125
3	LoRa / SF7	125 kHz	5470
4	LoRa / SF8	500 kHz	12500
8	LoRa / SF12	500 kHz	980
9	LoRa / SF11	500 kHz	1760
10	LoRa / SF10	500 kHz	3900
11	LoRa / SF9	500 kHz	7000
12	LoRa / SF8	500 kHz	12500
13	LoRa / SF7	500 kHz	21900

3.1.2.2 Uplink Channel Indices

Index	Frequency Channel	Comments
0 - 7	902.3 - 903.7 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 0
8 - 15	903.9 - 905.3 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 1
16 - 23	905.5 - 906.9 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 2
24 - 31	907.1 - 908.5 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 3
32 - 39	908.7 - 910.1 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 4
40 - 47	910.3 -911.7 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 5
48 - 55	911.9 -913.3 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 6
56 - 63	913.5 - 914.9 MHz (in steps of 200 kHz)	Data Rates 0 - 3 / Sub-band Mask1: Bit 7
64 - 71	903.0 - 914.2 MHz (in steps of 1.6 MHz)	Data Rates 4 / Sub-band Mask2: Bits 0-7

3.1.2.3 Downlink Channel Indices

Index	Frequency Channel	Comments
0 - 7	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
8 - 15	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
16 - 23	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
24 - 31	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
32 - 39	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
40 - 47	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
48 - 55	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
56 - 63	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
64 - 71	923.3 - 927.5 MHz (in steps of 600 kHz)	Data Rates 8 - 13
128	923 300 000Hz	Default Frequency for Rx2 Default Data Rate: 8

3.2 List of Constants

3.2.1 List of Endpoint Identifier

Name	Value
LORAWAN_ID	0x10

3.2.2 LoRaWAN Endpoint Identifier

3.2.2.1 LoRaWAN Endpoint Message Identifier

Name	Value
LORAWAN_MSG_SET_RSTACK_CONFIG_REQ	0x19
LORAWAN_MSG_SET_RSTACK_CONFIG_RSP	0x1A
LORAWAN_MSG_GET_RSTACK_CONFIG_REQ	0x1B
LORAWAN_MSG_GET_RSTACK_CONFIG_RSP	0x1C

3.2.2.2 LoRaWAN Endpoint Status Byte

Name	Value	Description
LORAWAN_STATUS_OK	0x00	Operation successful
LORAWAN_STATUS_ERROR	0x01	Operation failed
LORAWAN_STATUS_CMD_NOT_SUPPORTED	0x02	Command is not supported
LORAWAN_STATUS_WRONG_PARAMETER	0x03	HCI message contains wrong parameter
LORAWAN_STATUS_WRONG_DEVICE_MODE	0x04	Stack is running in a wrong mode
LORAWAN_STATUS_DEVICE_NOT_ACTIVATED	0x05	Device is not activated
LORAWAN_STATUS_DEVICE_BUSY	0x06	Device is busy, command rejected
LORAWAN_STATUS_QUEUE_FULL	0x07	Message queue is full, command rejected
LORAWAN_STATUS_LENGTH_ERROR	0x08	HCI message length is invalid or radio payload size is too large
LORAWAN_STATUS_NO_FACTORY_SETTINGS	0x09	Factory Settings EEPROM block missing or incompatible with current FW version
LORAWAN_STATUS_CHANNEL_BLOCKED	0x0A	Channel blocked by Duty Cycle
LORAWAN_STATUS_CHANNEL_NOT AVAILABLE	0x0B	No channel available (e.g. no channel defined for the configured spreading factor)

3.3 List of Abbreviations

FW	Firmware
HCI	Host Controller Interface
LR	Long Range
LoRa	Long Range
RAM	Random Access Memory
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
RTC	Real Time Clock
SLIP	Serial Line Internet Protocol
SNR	Signal to Noise Ratio
UART	Universal Asynchronous Receiver/Transmitter
WiMOD	Wireless Module by IMST

3.4 List of References

[1] WiMOD_LoRaWAN_EndNode_Modem_HCI_Spec.pdf.

[2] iM980A_Datasheet.pdf.

4. Regulatory Compliance Information

The use of radio frequencies is limited by national regulations. The applicable regulation requirements are subject to change. IMST GmbH does not take any responsibility for the correctness and accuracy of the aforementioned information. National laws and regulations, as well as their interpretation can vary with the country. In case of uncertainty, it is recommended to contact either IMST's accredited Test Center or to consult the local authorities of the relevant countries.

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5.2 Contact Information

IMST GmbH

Carl-Friedrich-Gauss-Str. 2-4
47475 Kamp-Lintfort
Germany

T +49 2842 981 0
F +49 2842 981 299
E wimod@imst.de
I www.wireless-solutions.de