WiMOD ExtLoRaWAN EndNode Modem HCI Specification

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Aim of this Document

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

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1. Introduction

1.1 Overview

This document is an extension to the WiMOD LoRaWAN EndNode Modem HCI document [1], covering the additional services and changes included in the WiMOD ExtLoRaWAN EndNode Modem firmware.

2. Additional Firmware Services

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

2.1 Device Management Services

The Device Management endpoint provides general services for module configuration, module identification, and everything which is not related to the data exchange via radio link. The following additional services are available:

- Radio Stack Selection
- Device Configuration

Additionally, following features have been changed with respect to [1]:

- Device Status: the device status information related to the proprietary stack has been appended in the response message.

2.1.1 Radio Stack Selection

The WiMOD ExtLoRaWAN EndNode Modem firmware supports two different radio modes, a LoRaWAN operation mode and a proprietary mode based on the WiMOD LR Base firmware. This feature allows to switch between both radio stacks.

Note: the LoRaWAN stack will be automatically selected after a power-up reset. A switch to the proprietary stack is only allowed if no LoRaWAN tasks are pending (e.g. receive windows expired and no uplink to server pending).

2.1.1.1 Set Radio Stack

This service can be used to select the radio stack.

Command Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_SET_RADIO_STACK_REQ	Set Radio Stack Request
Length	1	1 octets
Payload[0]	Radio Stack	0x00: LoRaWAN 0x01: proprietary (based on LR Base)

Response Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_SET_RADIO_STACK_REQ	Set Radio Stack Response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

2.1.1.2 Get Radio Stack

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

Command Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_GET_RADIO_STACK_REQ	Get Radio Stack Request
Length	0	no payload

Response Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_GET_RADIO_STACK_REQ	Get Radio Stack Response
Length	2	2 octets
Payload[0]	Status Byte	see appendix
Payload[1]	Radio Stack	0x00: LoRaWAN 0x01: proprietary (based on LR Base)

2.1.2 Device Configuration

Both radio stacks provide some common features and parameters which can be configured via HCI:

- **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.
- **LED Control**
  this feature allows the configuration of the LED control with different options.
- **Miscellaneous Options**
  this function enables the configuration of a HCI Power-Up indication, which is sent to the host when the module is ready to communicate after a power-up reset.

2.1.2.1 Set Device Configuration

This service can be used to configure the device configuration. The new parameters will be saved directly in the non-volatile flash memory.

Command Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_SET_DEVICE_CONFIG_REQ	Set Device Configuration Request
Length	4	4 octets
Payload[0]	Reserved	Reserved
Payload[1]	Power Saving Mode	0x00 : off 0x01 : automatic
Payload[2]	LED Control	Bit 0: 0 = no GPIO access 1 = toggle LED D3 as "Rx indicator" Bit 1: 0 = no GPIO access 1 = toggle LED D2 as "Tx indicator" Bit 2: 0 = no GPIO access 1 = toggle LED D4 as "Alive indicator"
Payload [3]	Miscellaneous Options	Bit 3: HCI Power-Up Indication 0 = disabled 1 = enabled

Response Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_SET_DEVICE_CONFIG_REQ	Set Device Configuration Response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

2.1.2.2 Get Device Configuration

This service can be used to read the current device configuration.

Command Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_GET_DEVICE_CONFIG_REQ	Get Device Configuration Request
Length	0	no payload

Response Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_GET_DEVICE_CONFIG_REQ	Get Device Configuration Response
Length	5	5 octets
Payload[0]	Status Byte	see appendix
Payload[1]	Reserved	Reserved
Payload[2]	Power Saving Mode	0x00 : off 0x01 : automatic
Payload[3]	LED Control	Bit 0: 0 = no GPIO access 1 = toggle LED D3 as "Rx indicator" Bit 1: 0 = no GPIO access 1 = toggle LED D2 as "Tx indicator" Bit 2: 0 = no GPIO access 1 = toggle LED D4 as "Alive indicator"
Payload [4]	Miscellaneous Options	Bit 3: HCI Power-Up Indication 0 = disabled 1 = enabled

2.1.2.3 Reset Device Configuration

This message can be used to restore the default device configuration.

Command Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_RESET_DEVICE_CONFIG_REQ	Reset Device Configuration Request
Length	0	no payload

Response Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_RESET_DEVICE_CONFIG_RSP	Reset Device Configuration Response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

2.1.2.4 Default Device Configuration

The following table lists the default device configuration used if no configuration is stored in the non-volatile memory.

Parameter	Value
Automatic Power Saving	0 = off
LED Control	7 = Alive Indicator + Rx Indicator + Tx Indicator
Miscellaneous Options	0 = HCI Power-Up Indication disabled

2.1.3 Device Status

The radio firmware provides some status information elements which can be read at any time. This feature has been modified with respect to [1].

2.1.3.1 Get Device Status

This message can be used to read the current device status.

Command Message

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_GET_DEVICE_STATUS_REQ	Get Device Status Request
Length	0	no payload

Response Message

This response message contains the requested information elements.

Field	Content	Description
Endpoint ID	DEVMGMT_ID	Endpoint Identifier
Msg ID	DEVMGMT_MSG_GET_DEVICE_STATUS_RSP	Get Device Status Response
Length	84	84 octets
Payload[0]	Status Byte	see appendix
Payload[1..15]	Device Status Field - Common	see below
Payload[16..59]	Device Status Field - LoRaWAN Stack	see below
Payload[60..83]	Device Status Field - Proprietary Stack	see below

2.1.3.2 Device Status Field – Common

The Device Status Field common for both stacks includes the following information elements:

Offset	Size	Name	Description
0	1	System Tick Resolution	System Tick Resolution in milliseconds (e.g.: 5 = 5ms)
1	4	System Ticks	System Ticks since last start-up/reset
5	4	Target Time	RTC Time (see RTC Time Format)
9	2	NVM Status	Bit field for non-volatile memory blocks: Bit 0 = System Configuration Block, contains Operation Mode, Device ID Bit 1 = Radio Configuration Block, contains Radio Parameter and AES Key Bit Values : 0 = OK, block ok 1 = ERROR, block corrupt
11	2	Battery Level	Measured Supply Voltage in mV
13	2	Extra Status	Reserved Bit Field

2.1.3.3 Device Status Field – LoRaWAN Stack

The Device Status Field related to the LoRaWAN stack includes the following information elements:

Offset	Size	Name	Description
0	4	Tx U-Data	Number of unreliable radio packets transmitted
4	4	Tx C-Data	Number of reliable radio packets transmitted
8	4	Tx Error	Number of radio packets not transmitted due to an error
12	4	Rx1 U-Data	Number of unreliable radio packets received in 1st window
16	4	Rx1 C-Data	Number of reliable radio packets received in 1st window
20	4	Rx1 MIC-Error	Number of radio packets received in 1st window with MIC error
24	4	Rx2 U-Data	Number of unreliable radio packets received in 2nd window
28	4	Rx2 C-Data	Number of reliable radio packets received in 2nd window
32	4	Rx2 MIC-Error	Number of radio packets received in 2nd window with MIC error
36	4	Tx Join	Number of join request radio packets transmitted
40	4	Rx Accept	Number of join accept radio packets received

2.1.3.4 Device Status Field – Proprietary Stack

The Device Status Field related to the proprietary stack includes the following information elements:

Offset	Size	Name	Description
0	4	Rx Packets	Number of received radio packets with CRC OK
4	4	Rx Address Match	Number of received radio packets with CRC and Address OK
8	4	Rx CRC Error	Number of received radio packets with CRC Error
12	4	Tx Packets	Number of transmitted radio packets
16	4	Tx Error	Number of not transmitted radio packets
20	4	Tx Media Busy Events	Number of not transmitted packets due to LBT result “media busy”

2.2 Radio Link Services

The Radio Link Service Access Point provides functions for configuration and transmission and reception of radio link messages. These services apply only to the proprietary stack.

The radio firmware part operates in Standard Mode, including support for unreliable and confirmed radio message exchange with address filtering and listen before talk option.

2.2.1 Radio Configuration

The radio firmware supports several configurable parameters which are stored in the non-volatile flash memory. The following items can be configured:

Item	Description
Radio Mode	Determines the radio module operation. Currently limited to **Standard** mode.
Group Address	Used to separate groups of radio modules. This value is compared against the ***TxGroupAddress*** field of a received radio message to filter radio packets in **Standard** mode (0xFF = BROADCAST address).
Tx Group Address	Reserved for future use
Device Address	Used to address a specific radio device. This value is compared against the ***TxDeviceAddress*** field of a received radio message to filter radio packets in **Standard** mode (0xFFFF = BROADCAST address).
Tx Device Address	Reserved for future use
Modulation	0 = LoRa, 1 = FSK (50000 bps)
RF Carrier Frequency	Defines the used radio frequency. See [2] for further details.
LoRa Signal Bandwidth	Defines the LoRa signal bandwidth 0 = 125 kHz, 1 = 250 kHz, 2 = 500 kHz
LoRa Spreading Factor	Defines the LoRa spreading factor 0 – 7 = SF7, 8 = SF8, 9 = SF9, 10 = SF10, 11 = SF11, 12 = SF12
Error Coding	Defines the radio error coding format 0 = 4/5, 1 = 4/5, 2 = 4/6, 3 = 4/7, 4 = 4/8
Power Level	Defines the transmit power level from 5 dBm to 20 dBm: 0 – 5 = 5 dBm, 6 = 6 dBm, ... , 20 = 20 dBm
Tx Control	Transmitter Control Option: Bit 0: 0 = Tx Narrow Filter off 1 = Tx Narrow Filter on Bit 1: 0 = Listen Before Talk (LBT) off 1 = Listen Before Talk (LBT) on See [2] for further details.
Rx Control	Receiver Control Option: 0 = Receiver off 1 = Receiver always on (except during packet transmission) 2 = Receiver on for limited time defined by Rx Window parameter

Rx Window Time	Configurable time for radio receive mode after radio packet transmission. Note: Rx Window option must be enabled in the ***Rx Control*** parameter. A value of zero (0) disables the receive mode.
Misc. Options	Bit field to configure further radio firmware options: Bit 0: 0 = standard RF packet output format 1 = extended RF packet output format: attached RSSI, SNR and Timestamp Bit 2: HCI Tx Indication - this message is sent to the host after an RF message was sent over the air. 0 = disabled 1 = enabled
FSK Datarate	Determines the datarate if FSK modulation is enabled 0 = 50000bps 1 = 100000 bps 2 = 250000 bps
Listen Before Talk (LBT) Threshold	Defines the LBT Threshold in dBm. Typical range -120 to 0 dBm

2.2.1.1 Get Radio Configuration

This message can be used to read the configuration parameters.

Command Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_GET_RADIO_CONFIG_REQ	Get Radio Configuration Request
Length	0	no payload

Response Message

The response message contains the current radio configuration. The Radio Configuration Field is described in more detail below.

Field	Content	Description
Endpoint ID	RADIOLINK _ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_GET_RADIO_CONFIG_RSP	Get Radio Configuration Response
Length	26	26 octets
Payload[0]	Status Byte	see appendix
Payload[1..25]	Radio Configuration Field	see Radio Configuration Field

2.2.1.2 Set Radio Configuration

This function can be used to change several radio parameters. The function allows to change parameter directly and to save them optionally in the non-volatile flash memory.

Command Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SET_RADIO_CONFIG_REQ	Set Radio Configuration Request
Length	26	26 octets
Payload[0]	Store NVM Flag 0x00 : change configuration only temporary (RAM) 0x01 : save configuration also in NVM	non-volatile memory flag
Payload[1..25]	Radio Configuration Field	see Radio Configuration Field

Response Message

This message acknowledges the Set Radio Configuration Request message.

Field	Content	Description
Endpoint ID	RADIOLINK _ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SET_RADIO_CONFIG_RSP	Get Radio Configuration Response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

2.2.1.3 Radio Configuration Field

The Radio Configuration Field contains the following configurable radio parameters:

Offset	Size	Name	Description
0	1	Radio Mode	0x00 = Standard mode: Device & Group address used for packet filtering
1	1	Group Address	Own group address (0x01 – 0xFE) for packet filtering (0xFF reserved as BROADCAST address)
2	1	Tx Group Address	Reserved for future use
3	2	Device Address	Own device address (0x0001 – 0xFFFE) for packet filtering (0xFFFF reserved as BROADCAST address)
5	2	Tx Device Address	Reserved for future use
7	1	Modulation	0 = LoRa, 1 = FSK (50000 bps)
8	1	RF Carrier Frequency Least Significant Bits	Defines the used radio frequency. See [2] for details.
9	1	RF Carrier Frequency Intermediate Bits	Defines the used radio frequency. See [2] for details.
10	1	RF Carrier Frequency Most Significant Bits	Defines the used radio frequency. See [2] for details.

11	1	LoRa Signal Bandwidth	0 = 125 kHz, 1 = 250 kHz, 2 = 500 kHz
12	1	LoRa Spreading Factor	0 – 7 = SF7 8 = SF8 9 = SF9 10 = SF10 11 = SF11 12 = SF12
13	1	Error Coding	0 = 4/5 1 = 4/5 2 = 4/6 3 = 4/7 4 = 4/8
14	1	Power Level	0 – 5 = 5 dBm 6 = 6 dBm 7 = 7 dBm ... 20 = 20 dBm
15	1	Tx Control	Transmitter Control Option: Bit 0: 0 = Tx Narrow Filter off 1 = Tx Narrow Filter on Bit 1: 0 = LBT off 1 = LBT on See [2] for details.
16	1	Rx Control	Receiver Control Option: 0 = Receiver off 1 = Receiver always on (except during packet transmission) 2 = Receiver on for limited time defined by Rx Window parameter
17	2	Rx Window Time	0 = receiver disabled, no Rx Window 1 – 65535 = 1 - 65535 ms
19	1	Reserved	Reserved
20	1	Misc. Options	Bit 0: 0 = standard RF packet output format 1 = extended RF packet output format: attached RSSI, SNR and Timestamp Bit 2: 0 = HCI Tx Indication disabled 1 = HCI Tx Indication enabled
21	1	FSK Datarate	0 = 50000 bps 1 = 100000 bps 2 = 250000 bps
22	1	Reserved	Reserved
23	2	LBT Threshold	16 Bit signed Integer (LSB first) -120 to 0 [dBm]

2.2.1.4 Reset Radio Configuration

This message can be used to restore the default radio settings.

Command Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_RESET_RADIO_CONFIG_REQ	Reset Radio Config Request
Length	0	no payload

Response Message

This message acknowledges the Reset Radio Configuration Request message.

Field	Content	Description
Endpoint ID	RADIOLINK _ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_RESET_RADIO_CONFIG_RSP	Reset Radio Config Response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

2.2.1.5 Default Configuration

The following table lists the default configuration.

Parameter	Value
Radio Mode	0 = Standard Mode
Group Address	0x10
Tx Group Address	0x10
Device Address	0x1234
Tx Device Address	0xFFFF
Modulation	0 = LoRa
RF Carrier Frequency	869.525 MHz
Signal Bandwidth	0 = 125 kHz
Spreading Factor	7 = SF11
Error Coding	2 = 4/6
Power Level	17 = 17 dBm
Tx Control	0 = - Tx Narrow filter off - LBT off
Rx Control	1 = Rx always on
Rx-Window Time	3000 = 3000ms
Misc. Options	0x01: - extended RF packet output format enabled - HCI Tx Indication disabled

FSK Datarate	0 = 50000 bps
LBT Threshold	-90 [dBm] (V1.10)

2.2.2 Unreliable Data Exchange

This service can be used to exchange radio messages in an unreliable way, i.e. it is not guaranteed that a transmitted message will be received on a peer radio device. There is no automatic acknowledgement or retry mechanism implemented combined with this function.

2.2.2.1 Send Unreliable Message

This command can be used to send a radio message either as broadcast message to all other radios in range or to a certain radio device with given address. Depending on the chosen radio settings, the transmission of a single radio message can take several hundred milliseconds. The firmware supports an HCI Tx Indication message which is sent to the host controller when the radio transmission has finished.

Command Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SEND_U_DATA_REQ	Send unreliable radio message request
Length	N	n octets
Payload	Tx Radio Message Field	see below

Response Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SEND_U_DATA_RSP	Send unreliable radio message response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

Event Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_U_DATA_TX_IND	Unreliable radio message transmission finished
Length	7	7 octets
Payload[0]	Status Byte	see appendix
Payload[1..2]	Tx Event Counter	Incremented for every Tx event
Payload[3..6]	RF Message Airtime	32-Bit Airtime in milliseconds of transmitted radio message

2.2.2.2 Tx Radio Message Field

The following figure outlines the relationship between the HCI message, sent from the host controller and the radio message, sent from the radio module.

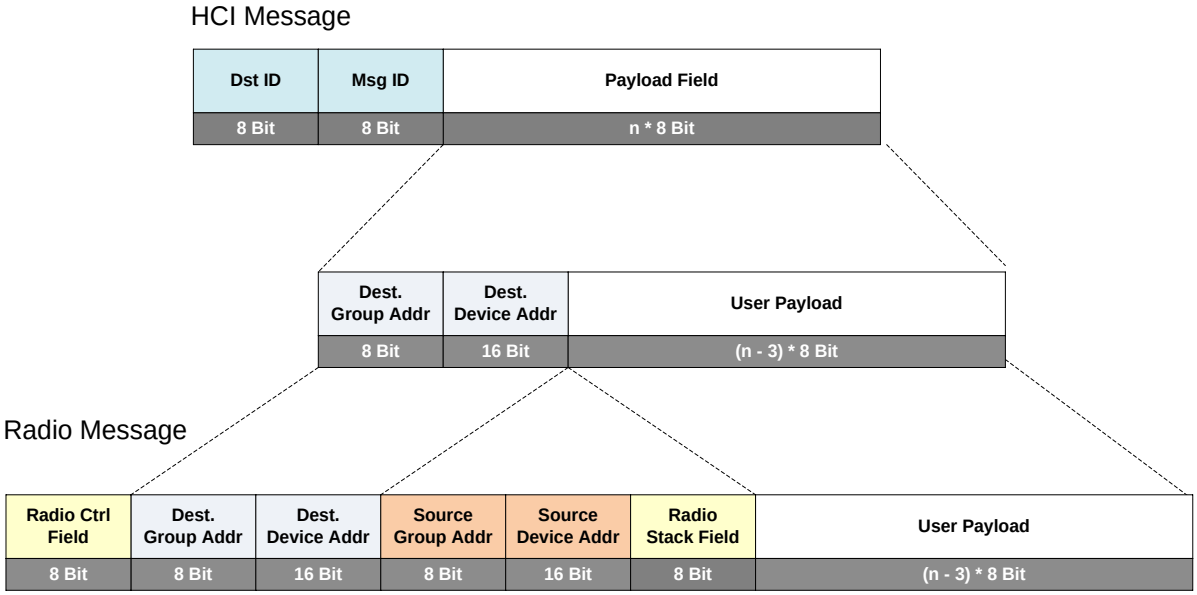

Fig. 2-1: Tx Radio Message and HCI Message

The Radio Ctrl Field (see below), Radio Stack Field and Source Address Fields are automatically added by the firmware itself.

The HCI Payload field content is defined as follows:

Offset	Size	Name	Description
0	1	Dest. Group Address	Destination Group Address (0xFF = BROADCAST) of message receiver
1	2	Dest. Device Address	Destination Device Address (0xFFFF = BROADCAST) of message receiver
3	N	User Payload	N bytes user defined payload with 1 <= N <= N1 N1 = 255 – 8 = 247 bytes (LoRa Mode) N1 = 63 – 8 = 55 bytes (FSK Mode)

2.2.2.3 Unreliable Radio Message Reception

The radio module is able to receive messages as long as the receiver is enabled. The receive mode is configurable (see Radio Configuration) and can be:

- disabled (off, Rx-Window = 0)
- always on (except during packet transmission)
- enabled for a limited Rx-Window after a transmitted message

While operating in Standard Mode, the received messages are forwarded to the host controller when they contain a BROADCAST address or the specific device address of the receiver.

Event Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_U_DATA_RX_IND	Unreliable message indication
Length	n	n octets
Payload	Rx Radio Message Field	see below

2.2.2.4 Rx Radio Message Field

The following figure outlines the relationship between the radio message, received on the radio module and the forwarded HCI message.

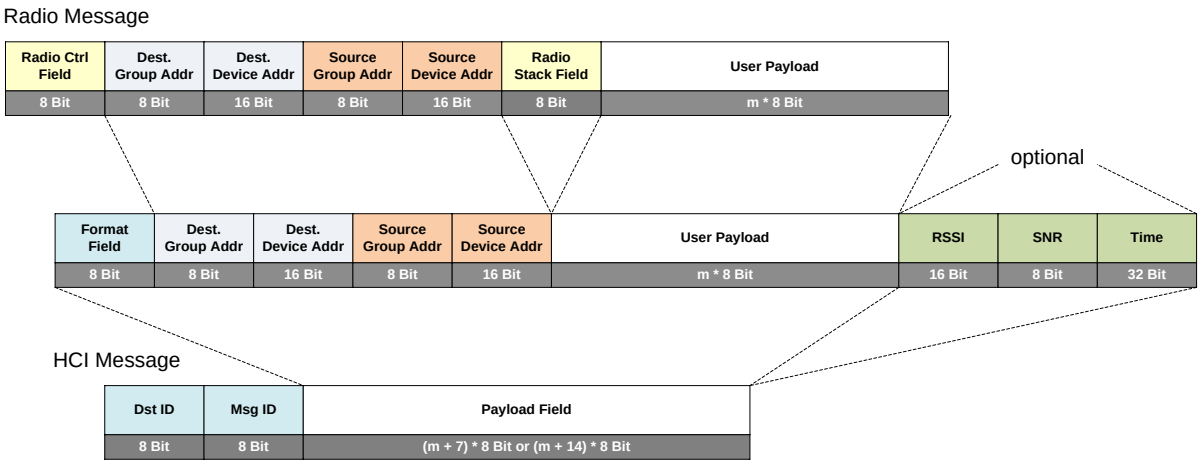

Fig. 2-2: Rx Radio Message and HCI Message

The HCI Payload Field has the following content:

Offset	Size	Name	Description
0	1	Format & Status Field	Defines the packet output format (see chap. HCI Format & Status Field)
1	1	Dest. Group Address	Destination Group Address (0xFF = BROADCAST) of message receiver
2	2	Dest. Device Address	Destination Device Address (0xFFFF = BROADCAST) of message receiver
4	1	Source Group Address	Group Address of message sender
5	2	Source Device Address	Device Address of message sender
7	N	Payload	user defined payload
7+N	2	RSSI (optional)	Received Signal Strength Indicator [dBm], signed integer
9+N	1	SNR (optional)	Signal to Noise Ratio [dB], signed integer
10+N	4	Rx Time (optional)	Timestamp from RTC

2.2.2.5 Radio Control Field

The Radio Control Field in each radio packet has the following meaning:

Bit	Name	Description
0	ACK REQUEST BIT	“1” : Acknowledgement requested from peer device This bit is set to: “0” : in unconfirmed radio messages “1” : in confirmed radio messages (see below)
1	ACK BIT	“1” : Indicates an ACK message
2 - 7	reserved	

2.2.2.6 HCI Format & Status Field

The HCI Format & Status Field has the following meaning:

Bit	Name	Description
0	EXTENDED_OUTPUT	“0” : standard output format, no attachment “1” : extended output format with attached RSSI, SNR and RTC Timestamp
1 - 7	Reserved	

2.2.3 Confirmed Data Exchange

This service can be used to exchange radio messages in a more reliable way, i.e. a received radio message will be acknowledged automatically by the peer device. The following figure outlines the sequence of possible HCI messages.

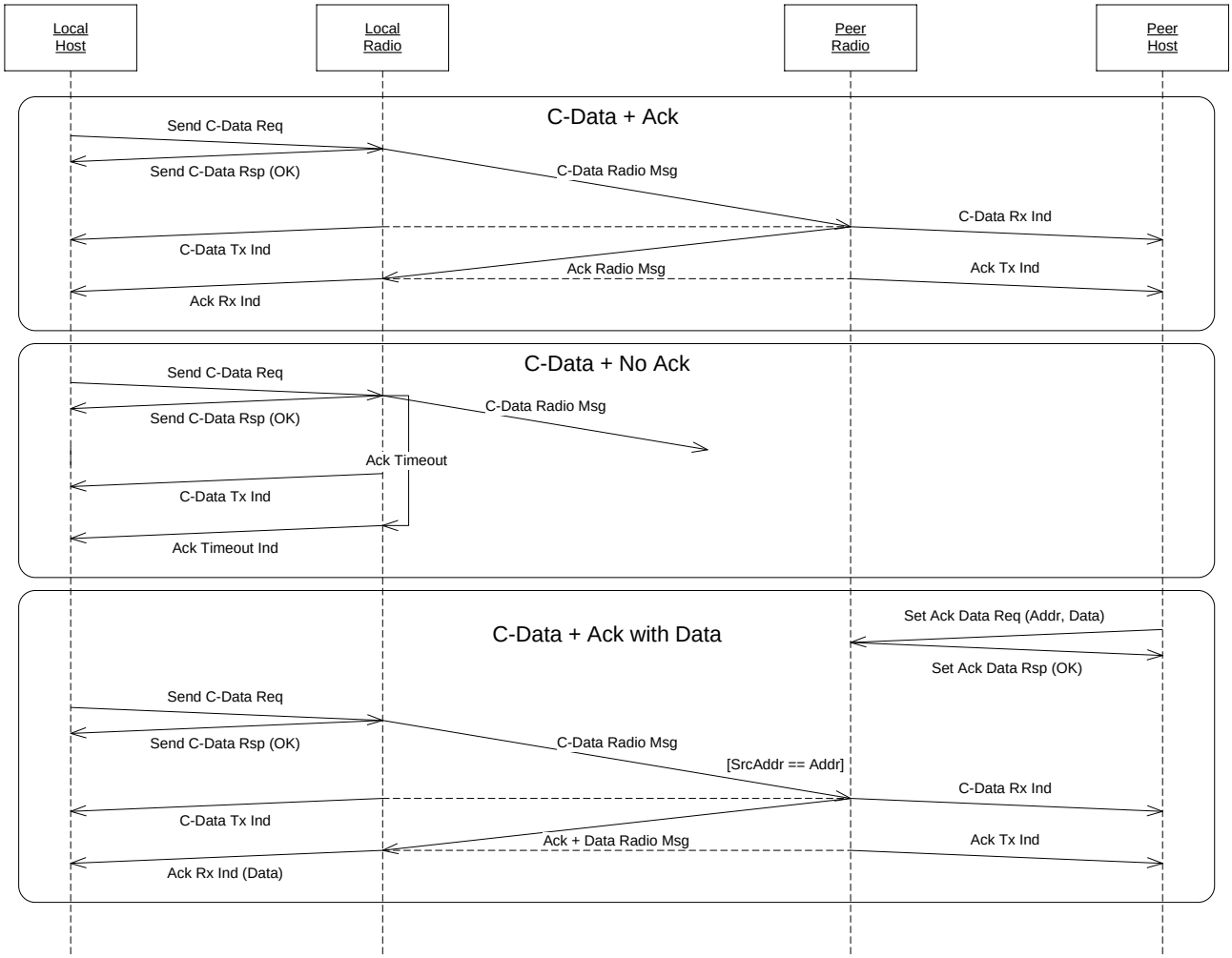

Fig. 2-3: Confirmed Data Exchange

2.2.3.1 Send Confirmed Message

This command can be used to send a radio message to a certain radio device with given address (group cast and broadcast are not supported). Depending on the chosen radio settings, the transmission of a single radio message can take several hundred milliseconds. An optional HCI Tx Indication message is sent to the host controller when the radio transmission has finished. A further ACK Indication message is sent to the host after reception of an acknowledgement from the peer device. The ACK message may contain optional payload data from the peer side. If no acknowledgement has been received within a given time, an ACK Timeout indication is sent to the host.

Command Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SEND_C_DATA_REQ	Send confirmed radio message request
Length	n	n octets
Payload	Tx Radio Message Field	see chapter Tx Radio Message Field

Response Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SEND_C_DATA_RSP	Send confirmed radio message response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

Event Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_C_DATA_TX_IND	confirmed radio message transmission finished
Length	7	7 octets
Payload[0]	Status Byte	see appendix
Payload[1..2]	Tx Event Counter	Incremented for every Tx event
Payload[3..6]	RF Message Airtime	32-Bit Airtime in milliseconds of transmitted radio message

Event Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_ACK_RX_IND	ACK radio message indication
Length	N	n octets
Payload	Rx Radio Message Field with optional payload from peer side	See chapter Rx Radio Message Field

Event Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_ACK_TIMEOUT_IND	ACK Timeout indication
Length	0	No payload

2.2.3.2 Confirmed Radio Message Reception

The radio module is able to receive messages as long as the receiver is enabled. While operating in Standard Mode, the received messages are forwarded to the host controller when they contain the specific device address of the receiver.

Note: The receiver of a confirmed radio message will automatically send an acknowledgement to the initiator side. This ACK message can contain further user payload (see Set ACK Data).

Event Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_C_DATA_RX_IND	confirmed message indication
Length	N	n octets
Payload	Rx Radio Message Field	see chapter Rx Radio Message Field

The following message is sent to the host after transmission of an ACK message.

Event Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_ACK_TX_IND	ACK message transmission finished indication
Length	1	1 octet
Payload	Status Byte	see appendix

2.2.3.3 Set ACK Data

This message can be used to pre-set a limited number of additional payload octets for the next transmitted ACK message. The payload can be set for a limited number of device addresses which have to match to the source address of a confirmed radio message.

Command Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SET_ACK_DATA_REQ	Set ACK Data request
Length	n	n octets
Payload[0]	Destination Group Address	
Payload[1..2]	Destination Device Address	
Payload[3..10]	Max. 8 Byte Ack Data	

Response Message

Field	Content	Description
Endpoint ID	RADIOLINK_ID	Endpoint Identifier
Msg ID	RADIOLINK_MSG_SET_ACK_DATA_RSP	Set ACK Data response
Length	1	1 octet
Payload[0]	Status Byte	see appendix

2.3 LoRaWAN Radio Link 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 Automatic Power Saving feature has been removed, as this is configurable via the common device configuration under the Device Management services.

2.3.1 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**
  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]).
- **Duty Cycle Control**
  this function can be disabled for test purpose.
- **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 Command to the corresponding host.
- **Extended HCI Output Support**
  this feature enables extended RF packet output format, where the Tx/Rx channel info is attached.
- **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. In case a change in the radio band is requested, the end-device will be automatically deactivated.

2.3.1.1 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	6	6 octets
Payload[0]	Default Data Rate Index	see appendix
Payload[1]	Default TX Power Level	Tx Power value in dBm (parameter range: 0 dBm to 20 dBm 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 Bit 2: 0 = Class A selected 1 = Class C selected 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]	Reserved	Reserved
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)

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 octet
Payload[0]	Status Byte	see appendix

2.3.1.3 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	7	7 octets
Payload[0]	Status Byte	see appendix
Payload[1]	Default Data Rate Index	see appendix
Payload[2]	Default TX Power Level	Tx Power value in dBm (parameter range: 0 dBm to 20 dBm 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 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]	Reserved	Reserved
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)

2.3.1.4 Default Radio Stack Configuration

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

Parameter	Value
Band Index	1 (EU 868 MHz)
Data Rate Index	3 (SF9 / BW125 kHz)
TX Power Level	14 dBm
Adaptive Data Rate	Enabled
Duty Cycle Control	Enabled
Class C Support	Disabled (Class A selected)
MAC Events Support	Enabled
Extended HCI Output Support	Enabled
Number of Retransmissions	7

3. Appendix

3.1 List of Constants

3.1.1 List of Endpoint Identifier

Name	Value
DEVMGMT_ID	0x01
RADIOLINK_ID	0x03
LORAWAN_ID	0x10

3.1.2 Device Management Endpoint Identifier

3.1.2.1 Device Management Endpoint Message Identifier

Name	Value
DEVMGMT_MSG_GET_DEVICE_STATUS_REQ	0x17
DEVMGMT_MSG_GET_DEVICE_STATUS_RSP	0x18
DEVMGMT_MSG_SET_DEVICE_CONFIG_REQ	0x25
DEVMGMT_MSG_SET_DEVICE_CONFIG_RSP	0x26
DEVMGMT_MSG_GET_DEVICE_CONFIG_REQ	0x27
DEVMGMT_MSG_GET_DEVICE_CONFIG_RSP	0x28
DEVMGMT_MSG_RESET_DEVICE_CONFIG_REQ	0x29
DEVMGMT_MSG_RESET_DEVICE_CONFIG_RSP	0x2A
DEVMGMT_MSG_SET_RADIO_STACK_REQ	0x39
DEVMGMT_MSG_SET_RADIO_STACK_RSP	0x3A
DEVMGMT_MSG_GET_RADIO_STACK_REQ	0x3B
DEVMGMT_MSG_GET_RADIO_STACK_RSP	0x3C

3.1.2.2 Device Management Endpoint Status Byte

Name	Value	Description
DEVMGMT_STATUS_OK	0x00	Operation successful
DEVMGMT_STATUS_ERROR	0x01	Operation failed
DEVMGMT_STATUS_CMD_NOT_SUPPORTED	0x02	Command is not supported
DEVMGMT_STATUS_WRONG_PARAMETER	0x03	HCI message contains wrong parameter

3.1.3 Radio Link Endpoint Identifier

3.1.3.1 Radio Link Endpoint Message Identifier

Name	Value
RADIOLINK_MSG_SEND_U_DATA_REQ	0x01
RADIOLINK_MSG_SEND_U_DATA_RSP	0x02
RADIOLINK_MSG_U_DATA_RX_IND	0x04
RADIOLINK_MSG_U_DATA_TX_IND	0x06
RADIOLINK_MSG_SEND_C_DATA_REQ	0x09
RADIOLINK_MSG_SEND_C_DATA_RSP	0x0A
RADIOLINK_MSG_C_DATA_RX_IND	0x0C
RADIOLINK_MSG_C_DATA_TX_IND	0x0E
RADIOLINK_MSG_ACK_RX_IND	0x10
RADIOLINK_MSG_ACK_TIMEOUT_IND	0x12
RADIOLINK_MSG_ACK_TX_IND	0x14
RADIOLINK_MSG_SET_ACK_DATA_REQ	0x15
RADIOLINK_MSG_SET_ACK_DATA_RSP	0x16
RADIOLINK_MSG_SET_RADIO_CONFIG_REQ	0x17
RADIOLINK_MSG_SET_RADIO_CONFIG_RSP	0x18
RADIOLINK_MSG_GET_RADIO_CONFIG_REQ	0x19
RADIOLINK_MSG_GET_RADIO_CONFIG_RSP	0x1A
RADIOLINK_MSG_RESET_RADIO_CONFIG_REQ	0x1B
RADIOLINK_MSG_RESET_RADIO_CONFIG_RSP	0x1C

3.1.3.2 Radio Link Endpoint Status Byte

Name	Value	Description
RADIOLINK_STATUS_OK	0x00	Operation successful
RADIOLINK_STATUS_ERROR	0x01	Operation failed
RADOLINK_STATUS_CMD_NOT_SUPPORTED	0x02	Command is not supported (check system operation mode)
RADIOLINK_STATUS_WRONG_PARAMETER	0x03	HCI message contains wrong parameter
RADIOLINK_STATUS_WRONG_RADIO_MODE	0x04	Module operates in wrong radio mode
RADIOLINK_STATUS_MEDIA_BUSY	0x05	Transmission not possible due to LBT result: “Media Busy”
RADIOLINK_STATUS_BUFFER_FULL	0x07	No buffer for radio transmission available
RADIOLINK_STATUS_LENGTH_ERROR	0x08	Radio packet length invalid

3.1.4 LoRaWAN Endpoint Identifier

3.1.4.1 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

3.1.4.2 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
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)

3.2 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

3.3 List of References

[1] WiMOD_LoRaWAN_EndNode_Modem_HCI_Spec.pdf.

[2] iM880A_AN012_RFSettings.pdf.

3.4 List of Figures

4. Regulatory Compliance Information

The use of radio frequencies is limited by national regulations. The radio module has been designed to comply with the European Union's R&TTE (Radio & Telecommunications Terminal Equipment) directive 1999/5/EC and can be used free of charge within the European Union. Nevertheless, restrictions in terms of maximum allowed RF power or duty cycle may apply.

The radio module has been designed to be embedded into other products (referred as "final products"). According to the R&TTE directive, the declaration of compliance with essential requirements of the R&TTE directive is within the responsibility of the manufacturer of the final product. A declaration of conformity for the radio module is available from IMST GmbH on request.

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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