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Wireless M-Bus Gateway Firmware

Host Controller Interface Protocol

Version 2.4

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History

Version	Date	Comment
1.0	17.09.2021	Initial Version
1.1	16.11.2021	Encrypt and Send WM-Bus Message added (see Encrypt and Send WM-Bus Message)
1.2	12.01.2023	Configuration for Rx-/Tx- Packet signals (see WM-Bus Gateway Active Configuration and WM-Bus Gateway Configuration Services)
1.3	25.01.2023	Updates with respect to latest firmware (Build Count 29) Reset Default Configuation service added (see WM-Bus Gateway Configuration Services) Changed Message IDs for Status Report (see Gateway Status Report) Changed Message IDs for Radio Control Configurtion (see Radio Control Configuration) New Encryption Mode Identfier added (see WM-Bus Packet Received Notification) Chapter firmware I/O Usage added (see Firmware I/O - Usage (only for iM881A-XL, iM891A-XL))
1.4	08.03.2023	Update for ***Append WM-Bus Device List Items*** response message (see Configurable WM-Bus Device List)
1.5	25.07.2023	Updates with respect to BC50 (Firmware V1.1) • New: new services for firmware operation mode handling (see Firmware Operation Mode Services) and table with supported firmware operation modes (see Device Management - HCI Protocol Constants) added • New: Encryption Mode "Extended Link Layer (ELL) AES CTR Mode added (see Encrypt and Send WM-Bus Message) • New: Service Access Point for Approval Tests added (see Approval Test Services (only for iM881A-XL, iM891A-XL))
1.6	20.11.2023	New feature **Scan Mode** added (WM-Bus Packet Scan Mode, Gateway Status Report)
1.7	29.11.2023	New feature **WM-Bus Address** added (WM-Bus Address Configuration (only for iU891A-XL), Gateway Status Report) New "Send Message" services added (Send WM-Bus Message (without encryption), Encrypt and Send WM-Bus Message)
1.8	20.12.2023	Updates with respect to new hardware variants iM891A-XL (radio module), iU891A-XL (USB-Stick)
1.9	05.01.2024	New configurable feature **Startup Indication** (see Restart Device & Startup Indication) added
2.0	21.03.2024	• WM-Bus Gateway Configuration: selectable C-Mode added (see WM-Bus Gateway Configuration Services) • Enhanced T-Mode configuration added (see WM-Bus Gateway Configuration Services and WM-Bus Packet Received Notification) • WM-Bus Gateway Configuration: Radio Re-Calibration Option + Timeout for radio transceiver re-calibration added (see WM-Bus Gateway Configuration Services) • WM-Bus Scan Mode : selectable C-Mode added (see WM-Bus Packet Scan Mode) • WM-Bus Application Status: Reserved Info for debugging purpose added (see Gateway Status Report)
2.1	26.08.2024	• Approval Test Updates for iM891A-XL (see Approval Test Services (only for iM881A-XL, iM891A-XL)) • Firmware I/O Usage Updates for iM891A-XL (Firmware I/O - Usage (only for iM881A-XL, iM891A-XL))
2.2	08.10.2024	• Multiple links to Chapter Firmware I/O - Usage (only for iM881A-XL, iM891A-XL) added
2.3	14.11.2024	• Updates for iU891A-XL (see Send WM-Bus Message (without encryption), Encrypt and Send WM-Bus Message)
2.4	03.06.2026	• Update for iU893A-XL • WM-Bus Gateway Configuration: selectable Custom C / T - Mode added (see WM-Bus Gateway Configuration Services) • Custom C / T - Mode added (see WM-Bus Packet Received Notification) • WM-Bus Scan Mode : selectable Custom C / T - Mode added (see WM-Bus Packet Scan Mode)

Aim of this document

This document includes a description of the Host Controller Interface Protocol which is supported by the WM-Bus Gateway Firmware.

Chapter 1 outlines the general WiMOD HCI Protocol terms and format, which is also used in other products of IMST GmbH.

In Chapter 2 the format of the application specific messages is given.

Additional Notes

- **API Example Code**
  IMST offers C/C++ and Python example code, including message encoders and decoders for HCI messages outlined in this document.

- **Firmware and Hardware Variants**

The documented HCI messages and parameters may vary depending on the firmware version and hardware variant in use.

- **Supported Hardware**
  The WM-Bus Gateway Firmware is available for the following hardware variants:
  - iM881A-XL (radio module for system integration)
  - iM891A-XL (radio module for system integration)
  - iU891A-XL (ready to use USB stick)

- **WM-Bus Gateway Firmware Applications**
  - **Target Devices**
    This firmware is specifically intended for WM-Bus devices that fall under the category of "Other". This likely refers to devices that are not typically meters (e.g., data concentrators, repeaters, or other communication modules within the WM-Bus network). With other words: this firmware is used to receive wireless M-Bus messages from devices operating as “meters”. Please refer to the OMS specification (https://oms-group.org) for more details.

  - **Support for Meter Devices**
    If the device you're working with is classified as a "Meter" type (such as water, gas, electricity meters), the current firmware may not be suitable. You are encouraged to contact the support team for the appropriate firmware or assistance.

Important Notes

- **Software and Hardware Reset**
  In case of unexpected behavior or malfunction of the radio module or USB stick, at first a software reset by means of a HCI Message must be intitiated by the host. If this is not successful, then a reset by means of the **hardware reset signal** should be performed afterward. In case of an USB-Stick the control of the reset pin must be implemented via USB. IMST provides C/C++ example code for this.

- **Firmware Update Support**
  Additionally, it is highly recommended that the host has the capability to conduct a firmware update utilizing the integrated bootloader of both the radio-module and USB stick. To facilitate this, the necessary bootloading protocol (from ST) and control over hardware reset and boot signals must be integrated on the host controller side. For USB sticks, the hardware signals can be managed via USB. IMST offers C/C++ example code for the entire firmware update process.

Important Notice Regarding Data Input

Please ensure that all input data is consistent and in the expected format. Inconsistent or incorrect input data may result in unpredictable behavior of the firmware, leading to unexpected system states.

Important Notice on Duty Cycle Compliance:

Please ensure that the transmission of data packets adheres to the regulatory duty cycle limits. Exceeding the allowed duty cycles can result in non-compliance with regulations and may lead to legal consequences or communication issues.

Notation Info

Suffix "b" = binary data

Suffix "h" = hexadecimal data

Without suffix = decimal data

Multi byte / octet fields are considered to be treated as unsigned integers with **L**east **S**ignificant **B**yte first unless explicitly noted.

Content

Host Controller Interface Overview

The information exchanged between a host controller and the target device (e.g. iM881A-XL, iU891A-XL) is based on serial messages.

There are three different HCI messages used in general:

- **Request Messages**
  These are messages sent from the host controller to the connected target device.
- **Response Messages**
  These are the correponding response messages which should be expected by the host controller in very short time (less than a second) as a result for a request message.
- **Event Messages**
  These are messages transmitted by the target device as a result of an interrupt.

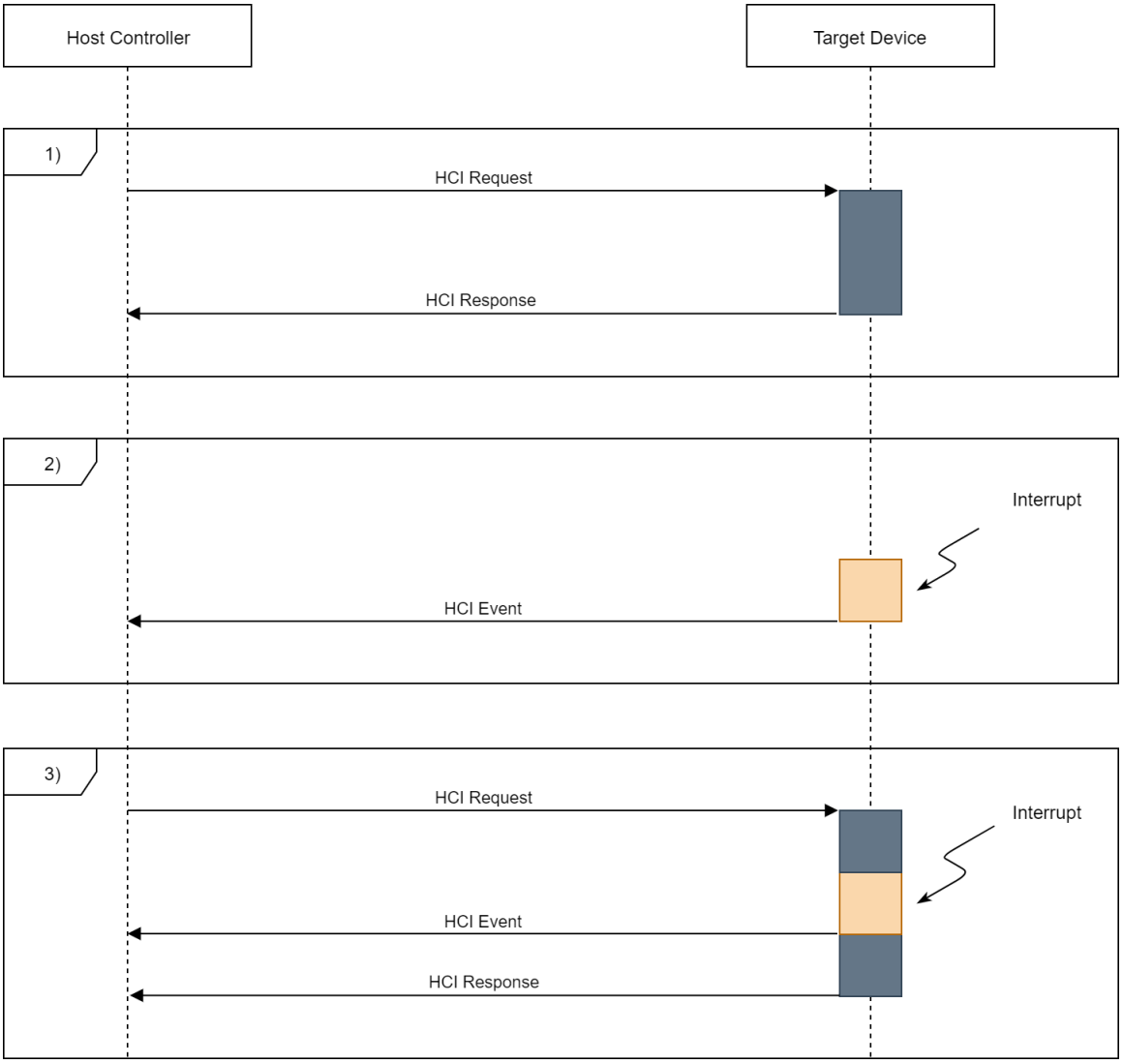

Figure : HCI Message Flow

Note
A host controller should be ready to receive event messages at any time.

General Message Format

The next figure outlines the generic message format:

HCI Message			
SAP ID	Msg ID	Message Payload	FCS Field
8 Bit	8 Bit	n * 8 Bit	2 * Bit

Figure : HCI Message Format

A message includes the following fields:

- **Service Access Point Identifier (SAP ID)**
  Identifies a logical message endpoint.

- **Message Identifier (Msg ID)**
  Defines the type of a message.

- **Message Payload**
  The Message Payload field contains optional data. The length of this field is variable (0...max. 500 Octets).

- **FCS Field**
  The Frame Check Sequence field contains a CRC-16/IBM-SDLC (https://reveng.sourceforge.io/crc-catalogue/16.htm#crc.cat-bits.16) for bit error detection.
  Parameter: width=16 poly=0x1021 init=0xffff refin=true refout=true xorout=0xffff check=0x906e residue=0xf0b8 name="CRC-16/IBM-SDLC"
  Alias: CRC-16/ISO-HDLC, CRC-16/ISO-IEC-14443-3-B, CRC-16/X-25, CRC-B, X-25

Info
The CRC is helpful in noisy environments and in case of battery powered devices when supply voltages are getting low and single octets may get lost.

Physical Interface

In most cases the radio module provides a standard UART interface for communication purposes with the following settings:

Baudrate	Start Bits	Data Bits	Parity	Stop Bits	Short
115200 bps	1	8	None	1	8N1

Table : UART Parameters

Framing Protocol

For proper message exchange the widely used SLIP Framing Protocol (https://en.wikipedia.org/wiki/Serial_Line_Internet_Protocol, RFC1055) is implemented. This protocol ensures a secure synchronization between a message sender and a message receiver.

The following figure shows the relationship between a single HCI message and the resulting SLIP message which may include some additional stuffing octets (SLIP ESC) to mark the special reserved SLIP END octets which might occur within a HCI message.

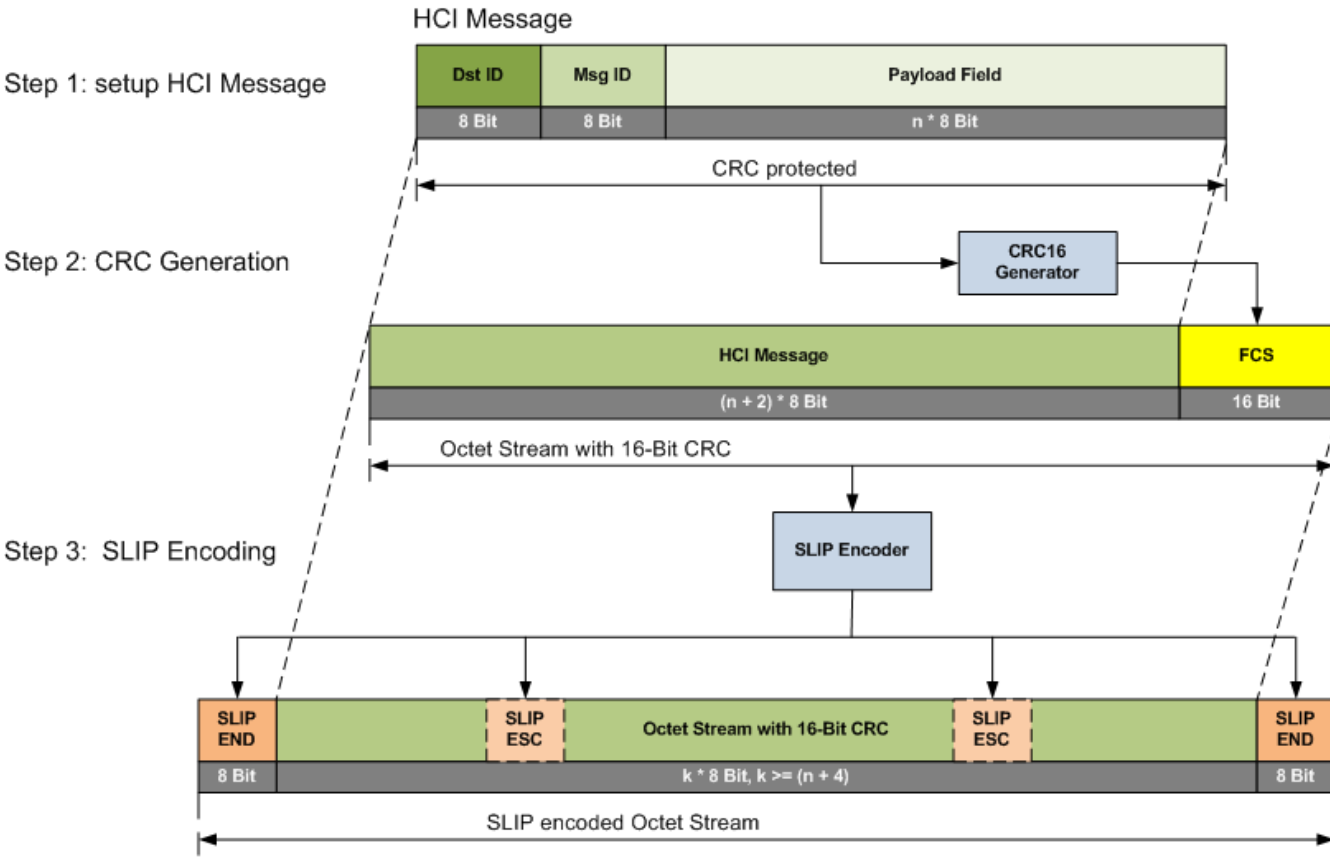

Figure : SLIP Message for communication over UART

Note
The variable length of a message is not explicitly transmitted. Therefore it must be returned as a result form the SLIP decoder.

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WM-Bus Gateway Firmware Service Access Points

The supported application messages are grouped to so called **S**ervice **A**ccess **P**oints (SAP).

	HCI Message		
	SAP ID	**MSG ID**	**Payload**

Name	**SAP ID**	**Description**
Device Management Services	01_h	Provides general services for hardware and firmware identification
WM-Bus Gateway Services	09_h	Provides specific services of this application
Approval Test Services	20_h	Services for Approval Tests (only available if firmware is running in "Approval Test Mode")

Table : Service Access Points

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Device Management Services

This Service Access Point includes messages for general firmware and hardware identification and for general configuration purposes:

Name	Description
Ping	For simple connection test purposes
Get Device Information	Provides hardware related information for identification purposes
Get Firmware Information	Provides firmware specific information for identification purposes
Date and Time Services	Setter and getter for Date & Time
Restart Device & Startup Indication	Initiate a device restart
Firmware Operation Mode Services	Services for reading and changing of operation modes
Firmware System Options	Messages for configuration of common system features
Device Management - HCI Protocol Constants	Protocol constants for this service access point

Table : Device Management Services

Back to WM-Bus Gateway Firmware Service Access Points

Ping

This message can be used to test the serial connection between the host controller and the target device. The host should expect a response within a very short time interval.

HCI Message							
Request	**Msg ID**	**Payload**					
	8 Bit	none					
	01_h						
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	02_h	see Status Codes					

Note
The SLIP encoded Ping Request and Ping Response HCI messages including SLIP protocol bytes and CRC16 look like this:

Request : C0 01 01 16 07 C0

Response: C0 01 02 00 A0 AF C0

Back to Device Management Services

Get Device Information

This message can be used to retrieve some information about the hardware of the connected device.

HCI Message																
Request	**Msg ID**	**Payload**														
	8 Bit	none														
	03_h															
Response	**Msg ID**	**Status**	**Module Type**			**Module ID**			**Product Type (optional[1])**			**Product ID (optional[1])**		
	8 Bit	8 Bit	8 Bit			32 Bit, LSB First			4 Octets, MSB first			4 Octets, MSB first		
	04_h	see Status Codes	see Module Types			unique ID of embedded radio module			unique product type identifier			unique product identfier (serial number)		

[1] provided in firmware version 1.0 and later

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Get Firmware Information

This message can be used to retrieve some information about the firmware of the connected device.

HCI Message						
Request	**Msg ID**	**Payload**				
	8 Bit	none				
	05_h					
Response	**Msg ID**	**Status**	**Firmware Version**	**Build Count**	**Build Date**	**Firmware Name**
	8 Bit	8 Bit	2 x 8 Bit, Minor version first	16 Bit, LSB first	10 Octets, ASCII String without terminating "0"	n remaining Octets of message ASCII String, without terminating "0"
	06_h	see Status Codes	e.g. (09 00)	e.g. (37 00)$_h$	e.g. (30 39 2E 30 34 2E 32 30 32 30)$_h$	e.g. (57 4D 42 75 73 ... 65 72)$_h$
			=> Version 0.9	=> Build Count 55	"09.04.2020"	"WMBus_Range_Extender"

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Date and Time Services

The following messages can be used to read and write the current date and time of the connected target device.

Get Date and Time

This message can be used to retrieve the current RTC date and time.

HCI Message			
Request	**Msg ID**	**Payload**	
	8 Bit	none	
	$0F_h$		
Response	**Msg ID**	**Status**	**Date and Time (UTC)**
	8 Bit	8 Bit	32 Bit, LSB first
	10_h	see Status Codes	e.g. (19 9E 64 5F)$_h$
			$5F649E19_h$ = 1.600.429.593 seconds since 01.01.1970, 00:00:00 "2020-09-18 11:46:33"

Set Date and Time

This message can be used to configure the embeded RTC.

HCI Message		
Request	**Msg ID**	**Date and Time (UTC)**
	8 Bit	32 Bit, LSB first
	$0D_h$	e.g. (19 9E 64 5F)$_h$
		$5F649E19_h$ = 1.600.429.593 seconds since 01.01.1970, 00:00:00 "2020-09-18 11:46:33"
Response	**Msg ID**	**Status**	**Payload**
	8 Bit	8 Bit	none
	$0E_h$	see Status Codes	

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Restart Device & Startup Indication

Restart Device

This message can be used to initiate a device restart. The device will return a response message **immediately** and performs a software reset after approx. 200 ms. A **Startup Indication** message can be configured (see System Options) which will be sent to the host to indicate a successful startup.

HCI Message							
Request	**Msg ID**	**Payload**					
	8 Bit	none					
	07_h						
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	08_h	see Status Codes					

Startup Indication

This optional event message can be configured (see System Options). It will be transmitted to the host controller after successful startup to indicate that the device is ready for operation.

HCI Message										
Event	**Msg ID**	**Reserved**	**Module Type**	**Module ID**	**Product Type**	**Product ID**	**Firmware Version**	**Build Count**	**Build Date**	**Firmware Name**
	8 Bit	32 Bit	8 Bit	32 Bit, LSB first	4 Octets, MSB first	4 Octets, MSB first	2 x 8 Bit, Minor version first	16 Bit, LSB first	10 Octets, ASCII String without terminating "0"	n remaining Octets of message ASCII String, without terminating "0"
	00_h	reserved status bits for future usage	see Module Types	unique ID or serial number of radio module	unique product type identifier	unique product identifier / serial number	see Get Firmware Information			

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Firmware Operation Mode Services

The following messages can be used to read and write the current operation mode.

Get Operation Mode

This message can be used to retrieve the current operation mode.

HCI Message			
Request	**Msg ID**	**Payload**	
	8 Bit	none	
	$0B_h$		
Response	**Msg ID**	**Status**	**Operation Mode**
	8 Bit	8 Bit	8 Bit
	$0C_h$	see Status Codes	see Firmware Operation Modes

Set Operation Mode

This message can be used to set the next operation mode.

> **Note**
> The next operation mode is written into the NVM. The device will send the response and performs a device restart after ~200ms.

HCI Message			
Request	**Msg ID**	**Operation Mode**	
	8 Bit	8 Bit	
	09_h	see Firmware Operation Modes	
Response	**Msg ID**	**Status**	**Payload**
	8 Bit	8 Bit	none
	$0A_h$	see Status Codes	

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Firmware System Options

The following messages can be used to configure some common firmware system features.

Note
Dependent on module and firmware type some features might not be available or can't be configured.

Get System Options

This message can be used to read the status of the system options.

HCI Message			
Request	**Msg ID**	**Payload**	
	8 Bit	none	
	$F9_h$		
Response	**Msg ID**	**Status**	**System Options**
	8 Bit	8 Bit	32 Bit, LSB first
	FA_h	see Status Codes	see System Options

Set System Options

This message can be used to modify the system options.

Note
The configuration will be stored in the non volatile memory.

HCI Message				
Request	**Msg ID**	**System Options Mask**	**System Options Values**	
	8 Bit	32 Bit, LSB first	32 Bit, LSB first	
	$F7_h$	defines which feature-bits should be changed see System Options	defines the new feature-bits values '0' or '1' see System Options	
Response	**Msg ID**	**Status**	**Payload**	
	8 Bit	8 Bit	none	
	$F8_h$	see Status Codes		

System Options

System Options
Option Bits
32 Bit, LSB First

Options Bits

This field includes several configuration bits:

- Bit 0 : Automatic Power Saving (APS, not used in gateway firmware)

- Bit 1 : Trace Output
  0 = Disabled (recommended)
  1 = Enabled, internal trace messages will be transmitted to the host controller for debugging purpose.

- Bit 2 : Real Time Clock (RTC)
  0 = Disabled (might be locked)
  1 = Enabled (recommended)

- Bit 3 : Watch-Dog
  0 = Disabled (might be locked)
  1 = Enabled (recommended)

- Bit 4 : Startup Event Message
  0 = Disabled
  1 = Enabled, a HCI event message (see Restart Device & Startup Indication) will be transmitted after successful firmware startup to indicate that the device is ready for operation.

- Bit 5 - 31 : reserved for future

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Device Management - HCI Protocol Constants

- Device Management - Message IDs
- Device Management - Status Codes
- Device Management - Firmware Operation Modes
- Device Management - Module Types

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Device Management - Message IDs

ID	Message
00_h	Startup Ind
01_h	Ping Req
02_h	Ping Rsp
03_h	Get Device Information Req
04_h	Get Device Information Rsp
05_h	Get Firmware Version Req
06_h	Get Firmware Version Rsp
07_h	Restart Req
08_h	Restart Rsp
09_h	Set System Operation Mode Req
$0A_h$	Set System Operation Mode Rsp
$0B_h$	Get System Operation Mode Req
$0C_h$	Get System Operation Mode Rsp
$0D_h$	Set System Date & Time Req
$0E_h$	Set System Date & Time Rsp
$0F_h$	Get System Date & Time Req
10_h	Get System Date & Time Rsp
$F7_h$	Set System Options Req
$F8_h$	Set System Options Rsp
$F9_h$	Get System Options Req
FA_h	Get System Options Rsp

Table : Device Management - Message IDs

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Device Management - Status Codes

Status	Beschreibung
00_h	ok
01_h	error
02_h	command not supported
03_h	wrong parameter
04_h	wrong application / device mode
05_h	reserved
06_h	application / device busy, try later
07_h	wrong message length
08_h	NVM write error
09_h	NVM read error (NVM content is invalid)
$0A_h$	command rejected
$0B_h$	reserved
$0C_h$	unexpected message format

Table : Device Management - Status Codes

NVM = none-volatile memory

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Device Management - Firmware Operation Modes

Mode	Name	Description
0	Application Mode	Default Application Mode
6	Approval Test Mode	Special mode for approval tests

Table: Device Management - System Operation Modes

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Device Management - Module Types

The following table lists the names of available WiMOD radio modules or USB sticks.

Value	Module Type	Comment
109	iM891A-XL	Radio module for integration
110	iU891A-XL	USB-Stick
163	iM881A-XL	Radio module for integration

Table : Module Types

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WM-Bus Gateway Services

This Service Access Point includes all WM-Bus related messages.

Name	Description
WM-Bus Gateway Configuration Services	Getter and setter messages for firmware configuration
WM-Bus Packet Scan Mode	Messages for Packet Scan Mode
Gateway Status Report	Getter and setter messages for firmware status report
Configurable WM-Bus Device List	Messages for maintaining the WM-Bus Device list for packet filtering, decryption and encryption
WM-Bus Packet Received Notification	Notification including received WM-Bus packet
WM-Bus Packet Field Format	Detailed WM-Bus Packet Field Format
Send WM-Bus Message (without encryption)	Packet transmission without encryption
Encrypt and Send WM-Bus Message	Packet transmission with encryption
WM-Bus Address Configuration (only for iU891A-XL)	Getter and setter messages for WM-Bus Address configuration
Radio Control Configuration	Getter and setter messages for radio-subsystem parameters
WM-Bus Gateway SAP - HCI Protocol Constants	Tables with protocol constants for this Service Access Point

Table : WM-Bus Gateway Services

Back to WM-Bus Gateway Firmware Service Access Points

WM-Bus Gateway Configuration Services

The following messages can be used to read and to modify the active and default WM-Bus Gateway configuration.

Get Active Configuration

This message can be used to read out the active configuration which is currently in use.

HCI Message			
Request	**Msg ID**	**Payload**	
	8 Bit	none	
	01_h		
Response	**Msg ID**	**Status**	**Active Configuration**
	8 Bit	8 Bit	n * 8 Bits
	02_h	see Status Codes	see Gateway Configuration

Set Active Configuration

This message can be used to set the active configuration. Note: this configuration is only stored in RAM and might be different after a restart.

HCI Message			
Request	**Msg ID**	**Active Configuration**	
	8 Bit	n * 8 Bits	
	03_h	see Gateway Configuration	
Response	**Msg ID**	**Status**	
	8 Bit	8 Bit	
	04_h	see Status Codes	

Get Default Configuration

This message can be used to read out the default configuration which is stored in the non-volatile memory and used after startup.

HCI Message				
Request	**Msg ID**	**Payload**		
	8 Bit	none		
	05_h			
Response	**Msg ID**	**Status**	**Default Configuration**	
	8 Bit	8 Bit	n * 8 Bits	
	06_h	see Status Codes	see Gateway Configuration	

Set Default Configuration

This message is used to set the default configuration which will be loaded after each restart. Note: the device will perform a restart afterwards and the new configuration will be loaded.

HCI Message			
Request	**Msg ID**	**Default Configuration**	

	8 Bit	n * 8 Bits						
	07_h	see Gateway Configuration						
Response	**Msg ID**	**Status**						
	8 Bit	8 Bit						
	08_h	see Status Codes						

Reset Default Configuration

This message is used to reset the default configuration to hard coded factory values. Note: the device will perform a restart afterwards and the hard-coded default values will be loaded.

HCI Message							
Request	**Msg ID**	**Payload**					
	8 Bit	none					
	09_h						
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	$0A_h$	see Status Codes					

Gateway Configuration

This information element includes configuration parameters which control the behaviour of the WM-Bus Gateway Firmware.

Default Configuration							
Link Mode	**Option Bits**	**UI Option Bits**	**LED Flash Timing**	**Radio Re-Calibration Timeout in ms** **T >= 100 ms**			
8 Bit	16 Bit, LSB first	16 Bit, LSB first	16 Bit, LSB first	32 Bit, LSB first			

- **Link Mode**
  This parameter defines the current WM-Bus link mode for packet reception:
  - 0 : Off (receiver off)
  - 1 : S - Mode
  - 2 : T - Mode
  - 3 : C / T - Mode (combined reception of T and C Mode messages)
  - 5 : C - Mode (100kbps)
  - 6 : Enhanced T - Mode
  - 7 : Custom C / T - Mode (compatible with several Engelmann meter)

- **Options Bits**
  This field includes several configuration bits:
  - Bit 0 : Apply WM-Bus Address Filter
    0 = Disabled: all received packets will be forwarded to the host controller
    1 = Enabled: only packets with addresses in WM-Bus Device List will be forwarded to the host controller
  - Bit 1 : WM-Bus Packet Receive Notification (via HCI)
    0 = Disabled
    1 = Enabled, forwards receive WM-Bus messages to the connected host controller
  - Bit 2 : WM-Bus Packet Sent Notification (via HCI)
    0 = Disabled
    1 = Enabled, a HCI message will be transmitted to the host controller after each WM-Bus packet transmission
  - Bit 3 : Radio Re-Calibration Service
    0 = Disabled
    1 = Enabled, a radio re-calibration will be initiated after a configurable Re-Calibraton Timeout period.

    It is recommended to enable this option to prevent any receiver PLL drifts.

- **UI Options Bits**
  This field includes several bits for configuration of digital outputs
  - Bit 0 : WM-Bus Packet Receive Notification Signal (via GPIO / LED)
    0 = Disabled
    1 = Enabled, a digital output pin (see Firmware I/O - Usage) will be asserted for a configurable time after a successful packet reception with valid CRC(s). The active level polarity can be configured too (see next Bit).
    Note: this feature must not be used in combination with the **External Rx-Switch Control Signal** which can be activated for the same GPIO pin (see Radio Control Configuration) .
  - Bit 1 : WM-Bus Packet Receive Notification Signal Polarity (for GPIO / LED)
    0 = standard polarity : inactive = 0, active = 1
    1 = inverted polarity : inactive = 1, active = 0
  - Bit 2 : WM-Bus Packet Sent Notification Signal (via GPIO / LED)
    0 = Disabled
    1 = Enabled, a digital output pin (see Firmware I/O - Usage) will be asserted for a configurable time after a successful packet transmission. The active level polarity can be configured too (see next Bit).
    Note: this feature must **not** be used in combination with the **External Tx-Switch Control Signal** which can be activated for the same GPIO pin (see Radio Control Configuration) .
  - Bit 3 : WM-Bus Packet Sent Notification Signal Polarity (for GPIO / LED)
    0 = standard polarity : inactive = 0, active = 1

1 = inverted polarity : inactive = 1, active = 0

- Bit 4 : Blinking Alive LED
  0 = Disabled
  1 = Enabled, a digital output pin (see Firmware I/O - Usage) toggles with 1000ms period to indicate a "running" firmware.

- **LED Flash Timing**
  This parameter defines the on/off timing for the Rx-/Tx-Indicatior LEDs. The range is 5 ms to 5000 ms. The default value is 50 ms.

- **Radio Re-Calibration Timeout**
  This parameter defines the maximum Rx-Window in milliseconds before a re-calibration of the radio transceiver is initiated.

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WM-Bus Packet Scan Mode

The following messages can be used to enable / disable the WM-Bus Packet Scan Mode.

Set WM-Bus Packet Scan Mode

This message can be used to enable / disable the WM-Bus Packet Scan Mode.

HCI Message							
Request	**Msg ID**	**Link Modes**	**Scan Period**				
	8 Bit	8 Bit	16 Bit, LSB first				
	21_h	see below	scan time in seconds				
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	22_h	see Status Codes					

- **Link Modes**
  This parameter defines the used WM-Bus link modes during packet scan mode:
  - Bit 0 : 1 = S - Mode
  - Bit 1 : 1 = T - Mode
  - Bit 2 : 1 = C / T - Mode (combined reception of T and C Mode messages)
  - Bit 3 : 1 = C - Mode (100 kbps)
  - Bit 4 : 1 = Custom C / T - Mode (compatible with some Engelmann Meter)

  Note: If all bits are zero, packet scan mode will be disabled and the **last configured Link Mode** (by Active Configuration or Default Configuration) is set.
- **Scan Period**
  This parameter is only relevant when more than one **Link Mode** is selected. The **Scan Period** parameter defines how many seconds a **Link Mode** gets applied before it will be changed.

WM-Bus Packet Scan Notification

This message is forwarded to the connected host controller to notify about a scanned WM-Bus Packet.

HCI Message						
Event	**Msg ID**	**Date and Time (UTC)**	**Packet Info**	**Packet RSSI**	**WM-Bus Packet Info**	
	8 Bit	32 Bit, LSB first	8 Bit	8 Bit, signed integer	10 x 8 Bit	
	24_h	see Date and Time Services	see below	RSSI in dBm	see WM-Bus Packet Info	

- **Date Time**
  This field includes a 32 Bit time stamp in UTC format which indicates the time of packet reception.
- **Packet Info**
  This field includes information about the original received WM-Bus message:
  1 : S-Mode
  2 : T-Mode
  4 : C-Mode, 50.000 bps, Format A
  5 : C-Mode, 100.000 bps, Format A
  6 : Reserved
  7 : Custom T-Mode

8 : Custom C-Mode, 100 000 bps, Format A
20 : C-Mode, 50.000 bps, Format B
21 : C-Mode, 100.000 bps, Format B
24 : Custom C-Mode, 100 000 bps, Format B

- **RSSI**
  This field includes the RSSI in dBm for the received packet.

- **WM-Bus Packet Info**
  This parameter includes the original WM-Bus Packet Link Layer Header which incudes the type, length and packet address.

WM-Bus Packet Info

The next figure outlines the detailed format of the WM-Bus Packet Info Item

WM-Bus Packet Info Item					
L - Field	C - Field	WM-Bus Address Field [1]			
		Manufacturer ID	Device ID	Version	Type
8 Bit	8 Bit	16 Bit	32 Bit	8 Bit	8 Bit

Note
[1] The byte ordering of the multi byte fields **Manufacturer ID** and **Device ID** is litte-endian (LSB first) as transmitted over the air!

Back to WM-Bus Gateway Servcies

Gateway Status Report

This section includes HCI messages for reading and resetting the Gateway Status Report.

Get Gateway Status Report

The following message can be used to retrieve the Gateway Status.

HCI Message													
Request	**Msg ID**	**Payload**											
	8 Bit	none											
	41_h												
Response	**Msg ID**	**HCI Status**	**Date and Time (UTC)**	**Last Sync Time**	**WM-Bus Link Mode**	**Status**	**Reset Counter** [1]	**WM-Bus Rx-Packet Counter** [2]	**WM-Bus Rx-Reject Counter** [2]	**WM-Bus Rx-Error Counter** [2]	**WM-Bus Tx-Packets Counter** [2]	**WM-Bus Tx-Error Counter** [2]	**Reserved Info**
	8 Bit	8 Bit	32 Bit, LSB first	32 Bit, LSB first	8 Bit	16 Bit, LSB first	32 Bit, LSB first	32 Bit, LSB first	32 Bit, LSB first	32 Bit, LSB first	32 Bit, LSB first	32 Bit, LSB first	32 Bit
	42_h	see Status Codes	see Date and Time Services										

- **Date and Time**
  Contains the current date and time in seconds since 01.01.1970 00:00:00
- **Last Sync Time**
  Contains the time stamp of the latest sychronization via local serial interface
- **WM-Bus Link Mode**
  Indicates the currently used link mode for packet reception
- **Status**
  This field includes several Status Bits:
  - Bit 0 : System Time Status
    1 = synchronized by host after last start-up, 0 = not synchronized by host, RTC runs with last date from NVM.
  - Bit 1 : Default Configuration (NVM) Status
    1 = valid, 0 = invalid (CRC error)
  - Bit 2 : WM-Bus Device List (NVM) Status
    1 = valid, 0 = invalid (CRC error)
  - Bit 3 : Radio Control Configuration
    1 = valid, 0 = invalid (CRC error)
  - Bit 4 : Radio Access
    1 = valid, 0 = limited access, radio parts disabled due to firmware protection error
  - Bit 5 : Scan Mode
    1 = active, 0 = inactive
  - Bit 6 : WM-Bus Address Configuration
    1 = valid, 0 = invalid (CRC error)
- **Reset Counter[1)]**
  Contains the number of device resets
- **WM-Bus Rx-Packet Counter[2)]**
  Total received WM-Bus packets before any packet filtering since last counter reset
- **WM-Bus Rx-Reject Counter[2)]**
  Total number of received but rejected WM-Bus packets since last counter reset

- **WM-Bus Rx-Error Counter**[2)]
  Total number of receiver errors (e.g.: CRC or decoding errors, but not decryption errors)
- **WM-Bus Tx-Packet Counter**[2)]
  Number of transmitted WM-Bus packets
- **WM-Bus Tx-Error Counter**[2)]
  Number of not transmitted WM-Bus packets due to internal errors
- **Reserved Info**
  This information is only for debug purposes and may contain different information bits depending on the given firmware version.

Info
[1)] The Reset Counter is copied to the non-volatile memory no earlier than 30 seconds (or 412 seconds for iU891A-XL and iM891A-XL) after the system starts.

[2)] The WM-Bus packet counters are written into the non-volatile memory no earlier than 30 seconds (or 412 seconds for iU891A-XL and iM891A-XL) after last increment. These counters can be reset by means of message Reset Gateway Status Report .

Reset Gateway Status Report

The following message can be used to reset some Gateway Status elements, e.g. all WM-Bus packet counters.

HCI Message			
Request	**Msg ID**	**Payload**	
	8 Bit	none	
	43_h		
Response	**Msg ID**	**HCI Status**	
	8 Bit	8 Bit	
	44_h	see Status Codes	

Back to WM-Bus Gateway Servcies

Configurable WM-Bus Device List

The following messages are used to read and write the list of WM-Bus Device items. A single list item consists of a full 64-Bit WM-Bus Device Address (Man-ID, Device-Id, Version, Type) and a corresponding 128-Bit Device Key.

The list is used in the following ways:

1. For packet decryption / encryption the 128-Bit Device Key is selected according to the given WM-Bus Device Address which is included either in the WM-Bus Link Layer Header or in the WM-Bus Transport-Layer depending on the Transport Layer type.
2. Furthermore this list can be used as a positve filter list, i.e. only WM-Bus packets with listed WM-Bus Device Address will be forwarded to the connected host. Note: this second feature is configurable.

The maximum number of list items which can be stored in the non-volatile memory (NVM) depends on the given firmware and radio modul (see WM-Bus Device List Size). During startup the list be loaded from NVM into RAM for further operation. All further configuration reading- and writing commands are pimarily applied to the list in RAM. A dedicated command will be shown which can be used to store the list from RAM into the non-volatile memory.

Clear WM-Bus Device List

This message is used to clear the WM-Bus Device list in RAM.

Note
The list in NVM is not affected by this command.

HCI Message			
Request	**Msg ID**	**Payload**	
	8 Bit	none	
	11_h		
Response	**Msg ID**	**Status**	
	8 Bit	8 Bit	
	12_h	see Status Codes	

Append WM-Bus Device List Items

This message can be used to append multiple WM-Bus Device List items to the list in RAM. The number of items per HCI message should not exceed 10. The items of a single HCI message will always be appended to the list in RAM until the maximum capacity of the list is reached.

Note
The list in NVM is not affected by this command.

HCI Message							
Request	**Msg ID**	**WM-Bus Device List Item #1**	**...**	**WM-Bus Device List Item #N**			
	8 Bit	192 Bits (24 octets)	...	192 Bits (24 octets)			
	13_h	see WM-Bus Device List Item					
		0 < N <= 10					
Response	**Msg ID**	**Status**	**Appended Items**	**Free Space**			
	8 Bit	8 Bit	16 Bit, LSB first	16 Bit, LSB first			
	14_h	see Status Codes	number of appended items	number of remaining free items			

Save WM-Bus Device List from RAM into NVM

This message is used save / copy the list in RAM into the non-volatile memory. Due to the slow NVM memory technology this operation may take a few seconds depending on the number of items to save. The HCI response message will be transmitted when the save operation has finished.

> **Note**
> It is also possible to write an empty (cleared) list into the NVM to delete all existing entries.

HCI Message							
Request	**Msg ID**	**Payload**					
	8 Bit	none					
	17_h						
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	18_h	see Status Codes					

Load WM-Bus Device List from NVM into RAM

This message can be used to re-load the list stored in NVM into the RAM. This message is mainly used for test-purpose since the list will automatically be loaded during each startup.

HCI Message							
Request	**Msg ID**	**Payload**					
	8 Bit	none					
	19_h						
Response	**Msg ID**	**Status**	**Number of List Items**				
	8 Bit	8 Bit	16 Bit, LSB first				
	$1A_h$	see Status Codes	0 <= N <= **WM-BUS DEVICE LIST SIZE** (see WM-Bus Device List Size)				

Read WM-Bus Device List Items

This message can be used to read out the current WM-Bus Device List. A complete read process my take multiple HCI messages due to the limited message payload capacity. Note: a proceeding "Read" HCI message should not be send before a "Read" HCI response message have been received. For error handling a timout of 200ms might be applied.

HCI Message							
Request	**Msg ID**	**Read Index**		**Maximum Items**			
	8 Bit	8 Bit		8 Bit			
	15_h	0 <= **Read Index** < **WM-BUS DEVICE LIST SIZE** (see WM-Bus Device List Size)		1 < **Maximum Items** <= 10			
Response	**Msg ID**	**Status**		**WM-Bus Device List Item #1**	**...**	**WM-Bus Device List #N**	
	8 Bit	8 Bit		192 Bits (24 octets)	...	192 Bits (24 octets)	
	16_h	see Status Codes		see WM-Bus Device List Item			
			0 <= N <= 10				

- **Read Index**
  This parameter defines the index of the first item to read. The first item of the list in RAM has index zero (0).

- **Maximum Items**
  This parameter defines the maximum number of list items which should be read per request, starting at parameter **Read Index**. Note the response message may contain less items due to the fact that the end of the list has been reached. Therfore a receiver must calculate the number of items from the received message length.

WM-Bus Device List Item

The next figure outlines the detailed format of a single WM-Bus Device List Item

WM-Bus Device List Item				
WM-Bus Address Fields[1)]				**Device Key**
Manufacturer ID	**Device ID**	**Version**	**Type**	
16 Bit	32 Bit	8 Bit	8 Bit	128 Bit, MSB first

Note
[1)] The byte ordering of the multi byte fields **Manufacturer ID** and **Device ID** must be litte-endian (LSB first) as transmitted over the air!

- **WM-Bus Address Fields**
  A sequence of 8 bytes in total which are transmitted in the WM-Bus Link Layer or Transport Layer header of each Wireless M-Bus packet.

- **Device Key**
  A 128 Bit key which is used for encryption / decryption purposes.

Back to WM-Bus Gateway Servcies

WM-Bus Packet Received Notification

This message is sent to the connected host controller to notify a received WM-Bus packet. Note. This message can be enabled / disabled.

HCI Message											
Event	**Msg ID**	**Date and Time (UTC)**	**Decryption Status**	**Encryption Mode**	**Packet Info**	**Packet RSSI**	**WM-Bus Packet Field**				
	8 Bit	32 Bit, LSB first	8 Bit	8 Bit	8 Bit	8 Bit, signed integer	n * 8 Bit				
	20_h	see Date and Time Services	see below	see below	see below	RSSI in dBm	see WM-Bus Packet Field Format				

- **Date Time**
  This field includes a 32 Bit time stamp in UTC format which indicates the time of packet reception.

- **Decryption Status**
  This field includes the decryption state of the attached WM-Bus packet data:
  0 : packet is not encrypted
  1 : packet decyryption successful
  2 : packet not decrypted, no key found for WM-Bus address
  3 : packet not decrypted, decryption mode not supported
  4 : packet not decrypted, decryption error, key might be wrong

- **Encryption Mode**
  This field indicates the packet encryption mode:
  0 : None
  5 : Mode 5
  7 : Mode 7
  128 : Extended Link Layer AES Counter Mode
  129 : Custom Encryption Mode
  255 : Mode not not support

- **Packet Info**
  This field includes information about the original received WM-Bus message:
  1 : S-Mode
  2 : T-Mode
  4 : C-Mode, 50.000 bps, Format A
  5 : C-Mode, 100.000 bps, Format A
  6 : Enhanced T-Mode
  7 : Custom T-Mode
  8 : Custom C-Mode, 100 000 bps, Format A
  20 : C-Mode, 50.000 bps, Format B
  21 : C-Mode, 100.000 bps, Format B
  24 : Custom C-Mode, 100 000 bps, Format B

- **RSSI**
  This field includes the RSSI in dBm for the received packet

- **WM-Bus Packet**
  Thies field contains the received WM-Bus message. The detailed format is expained below.

WM-Bus Packet Field Format

The WM-Bus Field Format used on the local serial interface looks as follows:

WM-Bus Packet

Link Layer Header						Further Data
L-Field	C-Field	Man ID Field	Device ID Field	Version	Type	
8 Bit	8 Bit	16 Bit	32 Bit	8 Bit	8 Bit	n * 8 Bit

The firmware is able to support decoding and CRC validation for both required WM-Bus Frame formats A + B.

The following figure outlines the relation between the incoming received WM-Bus frames using Format A and B and the resulting outgoing WM-Bus Packet Field Format which is transmitted in combination with additional meta data (like RSSI, Timestamp).

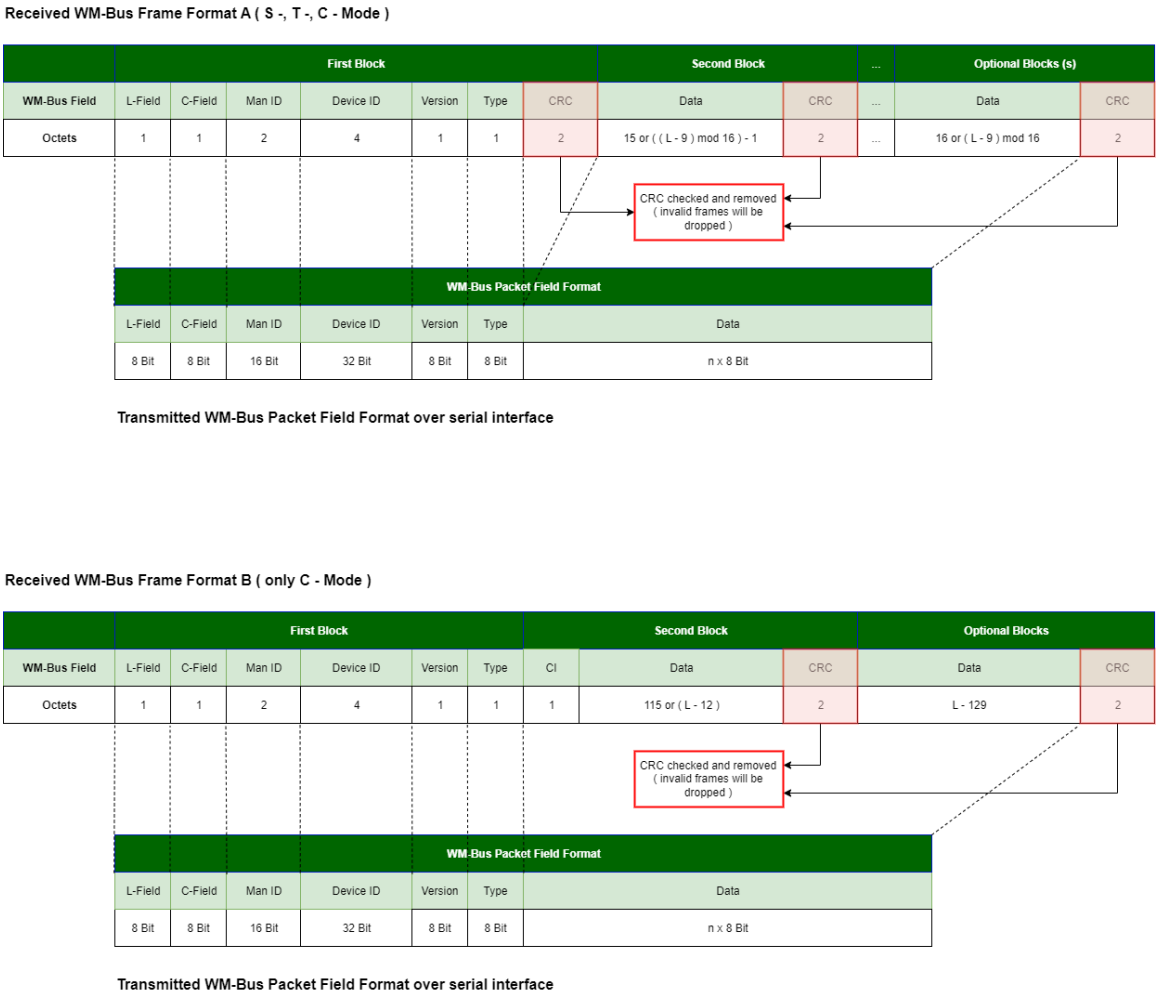


Figure: Resulting WM-Bus Packet Field Format

As it can be seen above, the original WM-Bus CRCs which protects the WM-Bus Physical Layer will be removed for further transportation over serial interface, since the this host controller interface protocol provides its own 16-Bit CRC.

All other data fields will remain the same. For Packet Format B a simple correction of the L-Field value (Packet Length) by 2 CRC bytes is automatically done.

Back to WM-Bus Gateway Servcies

Send WM-Bus Message (without encryption)

The following messages are used for unencrypted WM-Bus message transmission.

> **Important Notice Regarding Data Input**
>
> Please ensure that all input data is consistent and in the expected format. Inconsistent or incorrect input data may result in unpredictable behavior of the firmware, leading to unexpected system states.
>
> **Important Notice on Duty Cycle Compliance:**
>
> Please ensure that the transmission of data packets adheres to the regulatory duty cycle limits. Exceeding the allowed duty cycles can result in non-compliance with regulations and may lead to legal consequences or communication issues.

Send WM-Bus Message - I (iM881A-XL, iM891A-XL, iU891A-XL)

This message is used to send a WM-Bus message.

HCI Message							
Request	**Msg ID**	**Packet Mode**	**Power Level**	**WM-Bus Packet Content - I**			
	8 Bit	8 Bit	8 Bit, signed	n * 8 Bit			
	31_h	see below	Tx Power Level in dBm	see below			
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	32_h	see Status Codes					

- **Packet Mode**
  This field defines the WM-Bus Link Mode and Packet Format which should be applied for transmission:
  - 01_h : S - Mode, Packet Format A
  - 02_h : T - Mode, Packet Format A
  - 04_h : C - Mode, 50.000 bps, Format A
  - 05_h : C - Mode, 100.000 bps, Format A
  - 14_h : C - Mode, 50.000 bps, Format B
  - 15_h : C - Mode, 100.000 bps, Format B

- **Power Level**
  This field defines the power level used for transmission. The possible range is hardware and firmware dependend and outlined here.

- **WM-Bus Packet Content - I**
  The format of the WM-Bus Packet Content Field looks as follows:

Link Layer Header					Transport Layer		Other Layer
C - Field	**Manufacturer ID**	**Device ID**	**Version**	**Type**	**CI - Field**	**Further Transport Layer Data**	**Further Data**
8 Bit	16 Bit, LSB first	32 Bit, LSB first	8 Bit	8 Bit	8 Bit	n * 8 Bit	m * 8 Bit

> **Note**
> The **Length-Field** and **CRC-Fields** of each WM-Bus packet are calculated and inserted internally!
> The byte ordering of the multi byte fields **Manufacturer ID** and **Device ID** must be litte-endian (LSB first) as transnmitted over the air!

Send WM-Bus Message - II (iU891A-XL only)

This message is used to send a WM-Bus message including the module's internally stored WM-Bus Address. The stored WM-Bus Address w ill be inserted between the WM-Bus C-Field and WM-Bus CI-Field before passing to the next encoding layer.

HCI Message					
Request	**Msg ID**	**Packet Mode**	**Power Level**	**WM-Bus Packet Content - II**	
	8 Bit	8 Bit	8 Bit, signed	n * 8 Bit	
	39_h	see below	Tx Power Level in dBm	see below	
Response	**Msg ID**	**Status**			
	8 Bit	8 Bit			
	$3A_h$	see Status Codes			

- **Packet Mode**
  This field defines the WM-Bus Link Mode and Packet Format which should be applied for transmission:
  - 01_h : S - Mode, Packet Format A
  - 02_h : T - Mode, Packet Format A
  - 04_h : C - Mode, 50.000 bps, Format A
  - 05_h : C - Mode, 100.000 bps, Format A
  - 14_h : C - Mode, 50.000 bps, Format B
  - 15_h : C - Mode, 100.000 bps, Format B

- **Power Level**
  This field defines the power level used for transmission. The range for iM880A-XL is - 1 dBm to +13 dBm.

- **WM-Bus Packet Content - II**
  The format of the WM-Bus Packet Content Field looks as follows:

Link Layer Header	Transport Layer		Other Layer
C - Field	**CI - Field**	**Further Transport Layer Data**	**Further Data**
8 Bit	8 Bit	n * 8 Bit	m * 8 Bit

> **Note**
> The **Length-Field**, **WM-Bus Address** and **CRC-Fields** of each WM-Bus packet are calculated and inserted internally!
> The byte ordering of the multi byte fields **Manufacturer ID** and **Device ID** must be litte-endian (LSB first) as transmitted over the air!

WM-Bus Packet Transmit Notification

This message is used to indicate the status of a packet transmission. Note. This message can be enabled or disabled.

HCI Message							
Event	**Msg ID**	**Date and Time (UTC)**	**Transmission Status**				
	8 Bit	32 Bit, LSB first	8 Bit				
	34_h	see Date and Time Services	see below				

- **Date and Time**
  This field includes a 32 bit time stamp in UTC format which indicates the end of transmission.

- **Transmission Status**
  This field includes a status code which indicates the success or failure of the packet transmission.
  0 : success, packet transmitted
  1 : internal error, packet not transmitted

Back to WM-Bus Gateway Services

Encrypt and Send WM-Bus Message

The following HCI messages are used for encrypted WM-Bus message transmission.

> **Important Notice Regarding Data Input**
>
> Please ensure that all input data is consistent and in the expected format. Inconsistent or incorrect input data may result in unpredictable behavior of the firmware, leading to unexpected system states.
>
> **Important Notice on Duty Cycle Compliance:**
>
> Please ensure that the transmission of data packets adheres to the regulatory duty cycle limits. Exceeding the allowed duty cycles can result in non-compliance with regulations and may lead to legal consequences or communication issues.

Encrypt and Send WM-Bus Message - I (iM881A-XL, iM891A-XL, iU891A-XL)

This message can be used to trigger a WM-Bus packet encryption and packet transmission. The required encryption key will be selected according to the device address which is present either in the WM-Bus link layer or transport layer part.

> **Note**
> Depending on the selected encryption mode several encryption parameters (e.g. Access Number, Frame Counter, ...) and WM-Bus layer parts must already be present in the given WM-Bus packet. Otherwise the encryption process will cancel the operation and return a corresponding Status code. For more details please read the sections below.

HCI Message							
Request	**Msg ID**	**Encryption Mode**	**Packet Mode**	**Power Level**	**WM-Bus Packet Content - I (including encryption parameters)**		
	8 Bit	8 bit	8 Bit	8 Bit, signed	n * 8 Bit		
	35_h	see below	see below	Tx Power Level in dBm	see below		
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	36_h	see Status Codes					

- **Enryption Mode**
  This field includes the encryption mode which should be applied before packet transmission. The following modes are supported:
  - 05_h : Mode 5
  - 07_h : Mode 7
  - 80_h : Mode ELL AES CTR
- **Packet Mode**
  This field defines the WM-Bus Link Mode and Packet Format which should be applied for transmission:
  - 01_h : S - Mode, Packet Format A
  - 02_h : T - Mode, Packet Format A
  - 04_h : C - Mode, 50.000 bps, Format A
  - 05_h : C - Mode, 100.000 bps, Format A
  - 14_h : C - Mode, 50.000 bps, Format B
  - 15_h : C - Mode, 100.000 bps, Format B
- **Power Level**
  This field defines the power level used for transmission. The range for iM881A-XL is - 1 dBm to +13 dBm.

- **WM-Bus Packet Content - I**
  The format of the WM-Bus Packet Content Field looks as follows:

Link Layer Header					optional Extended Link Layer (ELL) and / or Authentication and Fragmentation Layer (AFL)		Transport Layer		Other Layer
C - Field	**Manufacturer ID**	**Device ID**	**Version**	**Type**	**CI-Field**	**Layer Data**	**CI - Field**	**Transport Layer Data**	**Further Data**
8 Bit	16 Bit, LSB first	32 Bit, LSB first	8 Bit	8 Bit	8 Bit	k * 8 bit	8 Bit	n * 8 Bit	m * 8 Bit

> **Note**
> The Length - Field and CRC-Fields of each WM-Bus packet are calculated and inserted internally!
> The byte ordering of the multi byte fields **Manufacturer ID** and **Device ID** must be litte-endian (LSB first) as transnmitted over the air!

Encrypt and Send WM-Bus Message - II (iU891A-XL only)

This message can be used to trigger a WM-Bus packet encryption and packet transmission including the module's internally stored WM-Bus Address. The required encryption key must be configured before.

> **Note**
> Depending on the selected encryption mode several encryption parameters (e.g. Access Number, Frame Counter, ...) and WM-Bus layer parts must already be present in the given WM-Bus packet. Otherwise the encryption process will cancel the operation and return a corresponding Status code. For more details please read the sections below.

HCI Message							
Request	**Msg ID**	**Encryption Mode**	**Packet Mode**	**Power Level**	**WM-Bus Packet Content - II (without WM-Bus Address, including encryption parameters)**		
	8 Bit	8 bit	8 Bit	8 Bit, signed	n * 8 Bit		
	$3B_h$	see below	see below	Tx Power Level in dBm	see below		
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	$3C_h$	see Status Codes					

- **Enryption Mode**
  This field includes the encryption mode which should be applied before packet transmission. The following modes are supported:
  - 05_h : Mode 5
  - 07_h : Mode 7
  - 80_h : Mode ELL AES CTR

- **Packet Mode**
  This field defines the WM-Bus Link Mode and Packet Format which should be applied for transmission:
  - 01_h : S - Mode, Packet Format A
  - 02_h : T - Mode, Packet Format A
  - 04_h : C - Mode, 50.000 bps, Format A
  - 05_h : C - Mode, 100.000 bps, Format A
  - 14_h : C - Mode, 50.000 bps, Format B
  - 15_h : C - Mode, 100.000 bps, Format B

- **Power Level**

This field defines the power level used for transmission. The range for iM880A-XL is - 1 dBm to +13 dBm.

- **WM-Bus Packet Content - II**
  The format of the WM-Bus Packet Content Field looks as follows:

Link Layer Header	optional Extended Link Layer (ELL) and / or Authentication and Fragmentation Layer (AFL)		Transport Layer		Other Layer
C - Field	**CI-Field**	**Layer Data**	**CI - Field**	**Transport Layer Data**	**Further Data**
8 Bit	8 Bit	k * 8 bit	8 Bit	n * 8 Bit	m * 8 Bit

> **Note**
> The Length - Field, WM-Bua Address and CRC-Fields of each WM-Bus packet are calculated and inserted internally!
> The byte ordering of the multi byte fields **Manufacturer ID** and **Device ID** must be litte-endian (LSB first) as transnmitted over the air!

Encrypted WM-Bus Packet Transmit Notification

This message is used to indicate the status of a packet transmission. Note. This message can be enabled / disabled.

HCI Message							
Event	**Msg ID**	**Date and Time (UTC)**	**Transmission Status**				
	8 Bit	32 Bit, LSB first	8 Bit				
	38_h	see Date and Time Services	see below				

- **Date and Time**
  This field includes a 32 bit time stamp in UTC format which indicates the end of transmission.
- **Transmission Status**
  This field includes a status code which indicates the success or failure of the packet transmission.
  0 : success, packet transmitted
  1 : internal error, packet not transmitted

Mode 5 Encryption and Encoding

The following WM-Bus Layers and information elements must already be present in the given WM-Bus Packet for propper Mode 5 Encryption:

1. WM-Bus Transport Layer Field with long format (12 octets) which contains the destination Meter Address. This Meter Address will be used for key selection.
2. The Access Number will be taken from Transpor Layer for nonce initialisation. Note: this value must be maintained by the host and will not be updated.

Encoding and Encryption Process:

1. The encoder verifies if a long Transport Layer with Meter Address is present and selects the corresponding key for encryption.
2. The encoder checks if the required verification octets "2F 2F" at the beginning of the Application Layer are already present. If not, theses two octets will be inserted automatically before start of encryption process.
3. The encoder will append additional $2F_h$ octets to fulfill the required block size of 16 bytes.
4. The encoder will update the encryption configuration octets of the Transport Layer according to Mode 5 (Mode Information + Number of Encrypted Blocks)
5. The encryption process will finaly encrypt the application layer data.

The following figure describes the input and output data of the Mode 5 Encryption & Encoding process.

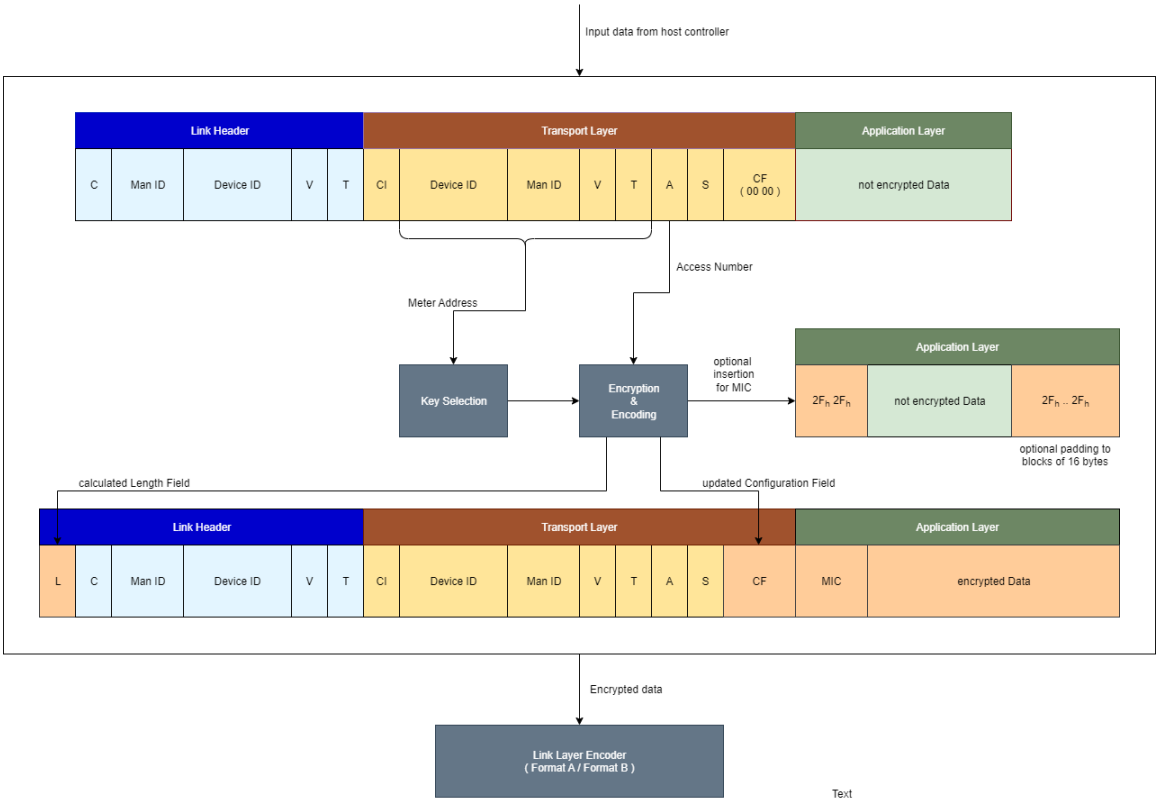


Figure : Mode 5 Encryption example with long Transport Layer

Mode 7 Encryption and Encoding

The following WM-Bus Layers and information elements must be present in the given WM-Bus Packet for propper Mode 7 Encryption:

1. WM-Bus Transport Layer Field with long format (12 + 1 octets) which contains the destination Meter Address. This Meter Address will be used for key selection.
2. The Transport Layer must already include a 24 bit wide Configuration Field (1 byte extra) which can be filled with zeros.
3. WM-Bus Authentication and Fragmentation Layer (**AFL**) which contains at least the Message Counter field which is needed for the key derivation function.
4. For optional MAC generation the cooresponding **MAC Present Bit** in **FCL** should be set to 1 and the additional eight octet should be reseserved and filled with zeros.

Encoding and Encryption Process:

1. The encoder verifies if a long Transport Layer wiht Meter Address is present and selects the corresponding key as a **Master Key** for the key derivation function.
2. The encoder checks if the required verification octets "2F 2F" at the beginning of the Application Layer are already present. If not, theses two octets will be inserted automatically before start of encryption process.
3. The encoder will append additional $2F_h$ octets to fulfill the required block size of 16 bytes.
4. The encoder will update the encryption configuration octets of the Transport Layer according to Mode 7 (Mode Information + Number of Encrypted Blocks + KDF)
5. The encoder will check if an Authentication & Fragmentation Layer with Message Counter is present.
6. The encryption process will execute the key derivation function to obtain a new encryption key.
7. The encryption process will finaly encrypt the application layer data.
8. In case the MAC Present Bit is set, the encryption process will generate the MAC and update the MAC field of the the AFL.

The following figure describes the input and output data of the Mode 7 Encryption & Encoding process.

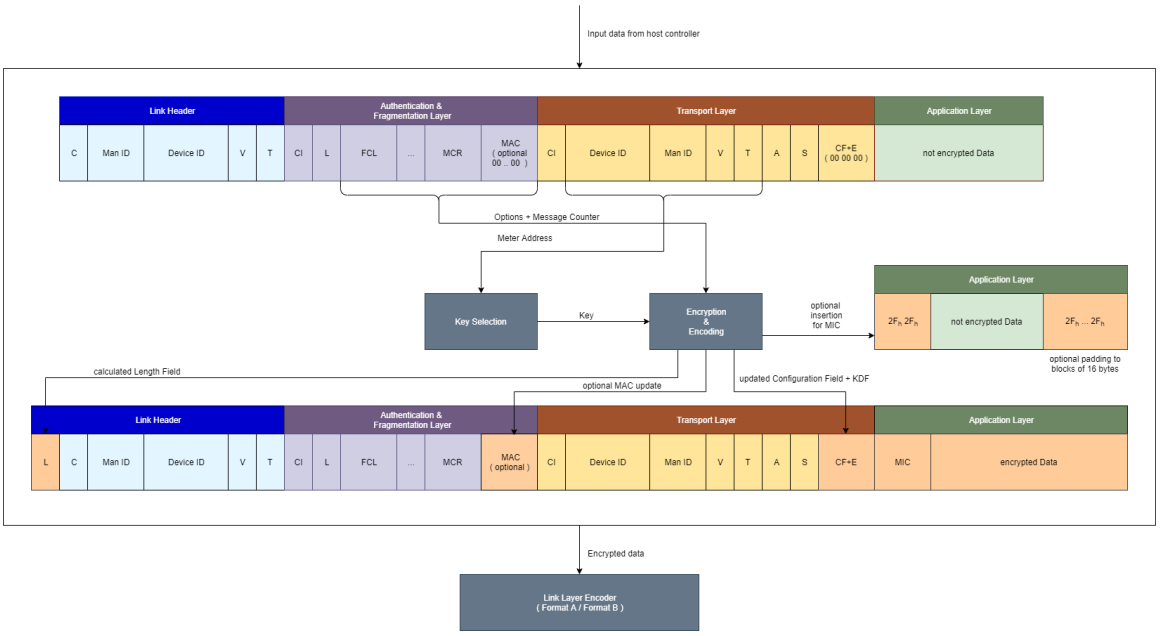


Figure : Mode 7 Encryption example with Authentication and Fragmentation Layer and long Transport Layer.

Extended Link Layer AES Counter Mode Encryption and Encoding

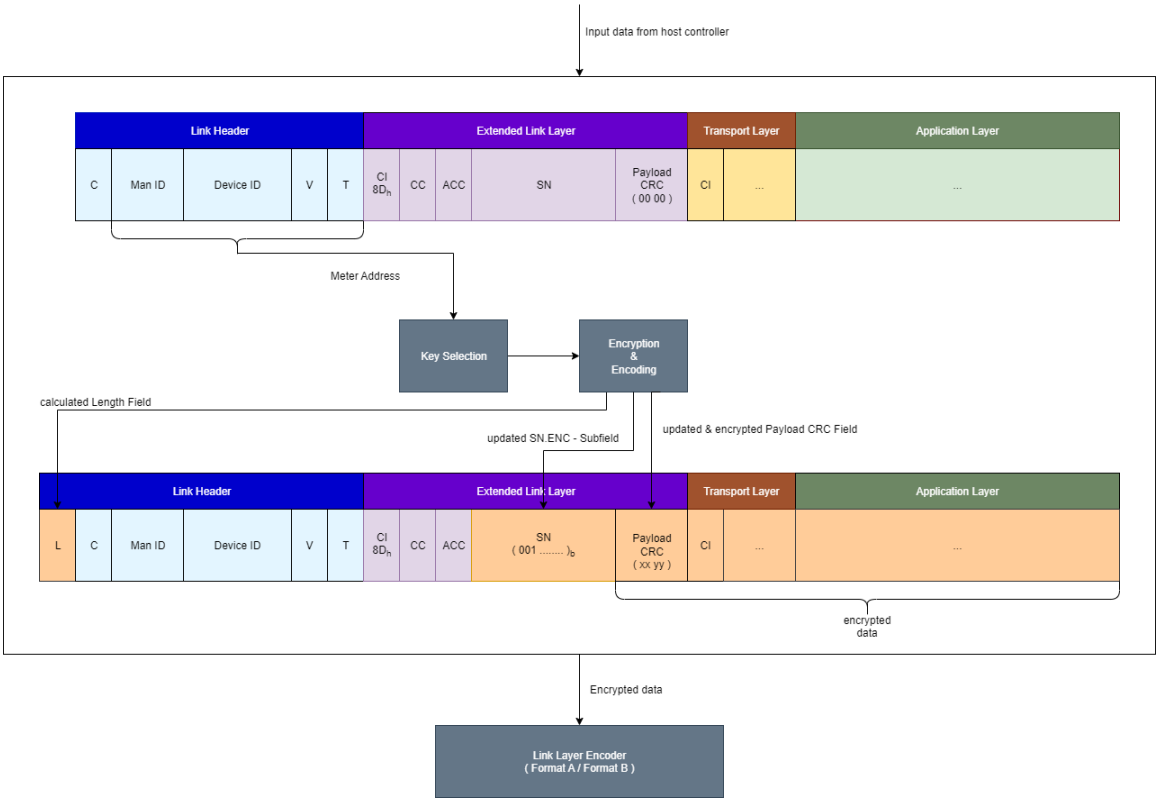
The following WM-Bus Layers and information elements must already be present in the given WM-Bus Packet for propper ELL AES Counter Mode Encryption:

1. WM-Bus Extended Link Layer Field with CI = $8D_h$ (8 octets) or CI = $8F_h$ (16 octets) which will transport the encryption subfield (ENC) 16 Bit Payload CRC.
2. In case of CI = $8F_h$ the meter address for key selection is taken from the Extended Link Layer Fields.

Encoding and Encryption Process:

1. The encoder verifies which kind of Extended Link Layer is present and selects the corresponding key for encryption. The meter address for key selection is either taken from the ELL (CI = $8F_h$) or Data Link Layer (CI = $8D_h$).
2. The encoder updates the SN.ENC subfield to notify AES 128 Bit CTR Mode encryption.
3. The encoder calculates and updates the Payload CRC.
4. The encryption process will finaly encrypt the WM-Bus Packet data starting with the Payload CRC field.

The following figure describes the input and output data of the Extended Link Layer AES Counter Mode Encryption & Encoding process.



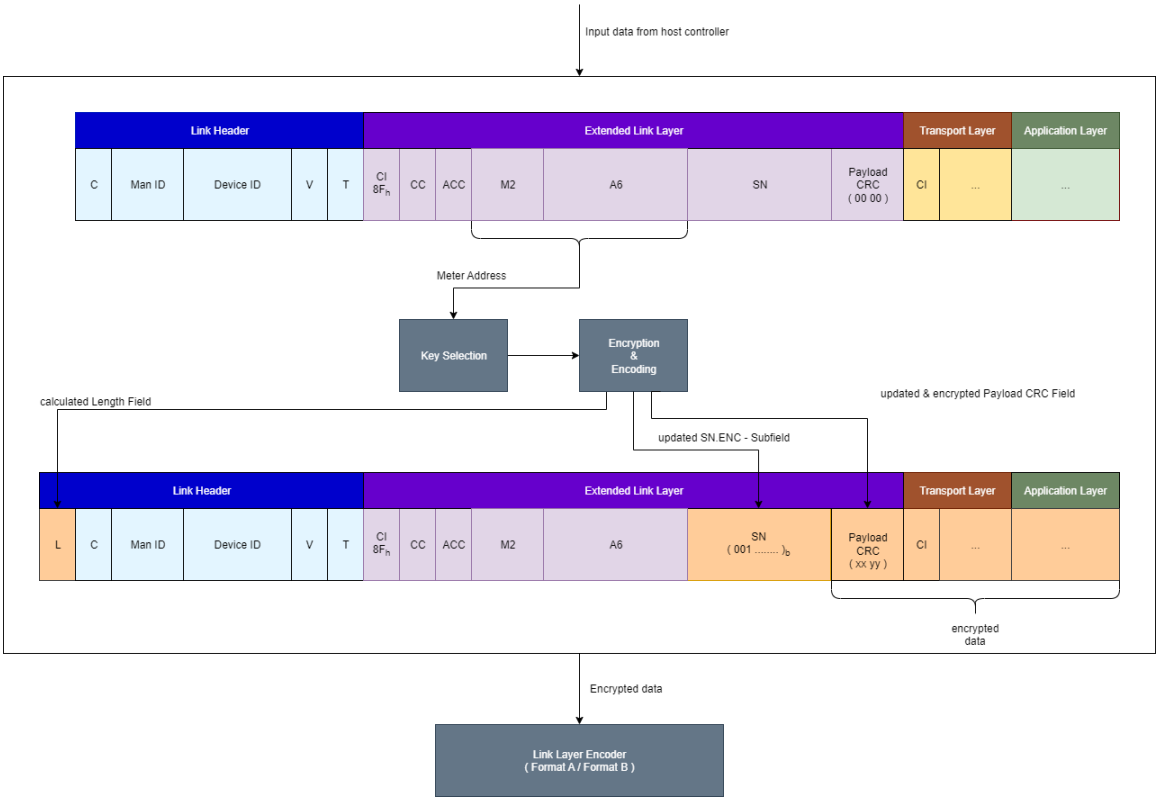


Figure : Extended Link Layer AES Counter Mode Encryption example with CI = 8D$_h$ and CI = 8F$_h$

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WM-Bus Address Configuration (only for iU891A-XL)

The following messages can be used to read the WM-Bus address which is used within the WM-Bus Link Layer Header to indicate the sender of a WM-Bus packet.

Get WM-Bus Address

This message is used to read out the WM-Bus Address from the non volatile memory.

HCI Message							
Request	**Msg ID**	**Payload**					
	8 Bit	none					
	81_h						
Response	**Msg ID**	**Status**	**WM-Bus Address**				
	8 Bit	8 Bit	8 * 8 Bits				
	82_h	see Status Codes	see WM-Bus Address				

WM-Bus Address

The WM-Bus Address item consists of the following fields.

WM-Bus Address Field [1)]			
Manufacturer ID	**Device ID**	**Version**	**Type**
16 Bit	32 Bit	8 Bit	8 Bit

Note
[1)] The byte ordering of the multi byte fields **Manufacturer ID** and **Device ID** is litte-endian (LSB first) as transnmitted over the air!

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Radio Control Configuration (only for iM881A-XL, iM891A-XL)

The following messages can be used to read and write the configuration parameters which belong to the radio-subsystem.

Get Radio Control Configuration

This message is used to read out the radio control configuration

HCI Message							
Request	**Msg ID**	**Payload**					
	8 Bit	none					
	51_h						
Response	**Msg ID**	**Status**	**Radio Control Configuration**				
	8 Bit	8 Bit	n * 8 Bits				
	52_h	see Status Codes	see Radio Control Configuration				

Set Radio Control Configuration

This message is used to set the radio control configuration. Note: this configuration is stored in non-volatile memory and loaded at each startup.

HCI Message							
Request	**Msg ID**	**Radio Control Configuration**					
	8 Bit	n * 8 Bits					
	53_h	see Radio Control Configuration					
Response	**Msg ID**	**Status**					
	8 Bit	8 Bit					
	54_h	see Status Codes					

Radio Control Configuration

This resource provides some configuration parameters which control the behaviour of the radio-subsystem.

Radio Control Configuration	
Option Bits	**Tx-Control Delay in microseconds**
32 Bit, LSB first	16 Bit, LSB first

- **Options Bits**
  This field includes several configuration bits:
  - Bit 0 : External Rx-Switch Control
    0 = Disabled
    1 = Enabled: indicates via digital output pin (see Firmware I/O - Usage) when the radio receiver is enabled

- Bit 1 : External Tx-Switch Control
  0 = Disabled
  1 = Enabled, indicates via digital output pin (see Firmware I/O - Usage) when the radio transmits a packet
- Bit 2 - 31 : reserved for future

- **Tx-Control Delay**
  This parameter defines a delay in microseconds between the external tx switch signal and the start of tx burst. The minimum delay value is about 120 us.

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WM-Bus Gateway SAP - HCI Protocol Constants

- WM-Bus Gateway SAP - Message IDs
- WM-Bus Gateway SAP - Status Codes
- WM-Bus Gateway SAP - WM-Bus Device List Sizes
- WM-Bus Gateway SAP - WM-Bus Device Power Levels

Back to WM-Bus Gateway Services

WM-Bus Gateway SAP - Message IDs

Status	Beschreibung
01_h	Get Active Configuration Req
02_h	Get Active Configuration Rsp
03_h	Set Active Configuration Req
04_h	Set Active Configuration Rsp
05_h	Get Default Configuration Req
06_h	Get Default Configuration Rsp
07_h	Set Default Configuration Req
08_h	Set Default Configuration Rsp
09_h	Reset Default Configuration Req
$0A_h$	Reset Default Configuration Req
11_h	Clear WM-Bus Device List Req
12_h	Clear WM-Bus Device List Rsp
13_h	Append WM-Bus Device List Req
14_h	Append WM-Bus Device List Rsp
15_h	Read WM-Bus Device List Req
16_h	Read WM-Bus Device List Rsp
17_h	Save WM-Bus Device List Req
18_h	Save WM-Bus Device List Rsp
19_h	Load WM-Bus Device List Req
$1A_h$	Load WM-Bus Device List Rsp
20_h	WM-Bus Rx Message Ind
21_h	Enable / Disable Scan Mode Req
22_h	Enable / Disable Scan Mode Rsp
24_h	Scan Mode Packet Ind
31_h	Send Message Req (only iM881A-XL, iM891A-XL)
32_h	Send Message Rsp (only iM881A-XL, iM891A-XL)
34_h	Message / Packet Transmitted Ind

35_h	Encrypt and Send Message Req (only iM881A-XL, iM891A-XL)
36_h	Encrypt and Send Message Rsp (only iM881A-XL, iM891A-XL)
38_h	Encrypted Message / Packet Transmitted Ind
39_h	Send Packet Req (only iU891A-XL)
$3A_h$	Send Packet Rsp (only iU891A-XL)
$3B_h$	Encrypt and Send Packet Req (only iU891A-XL)
$3C_h$	Encrypt and Send Packet Rsp (only iU891A-XL)
41_h	Get Application Status Req
42_h	Get Application Status Rsp
43_h	Reset Application Status Req
44_h	Reset Application Status Rsp
51_h	Get Radio Control Config Req (only iM881A-XL, iM891A-XL)
52_h	Get Radio Control Config Rsp (only iM881A-XL, iM891A-XL)
53_h	Set Radio Control Config Req (only iM881A-XL, iM891A-XL)
54_h	Set Radio Control Config Rsp (only iM881A-XL, iM891A-XL)
81_h	Get WM-Bus Address Req (only iU891A-XL)
82_h	Get WM-Bus Address Rsp (only iU891A-XL)

Table: WM-Bus Gateway SAP - Message Identifier

Back to WM-Bus Gateway Services

WM-Bus Gateway SAP - Status Codes

The following table lists the possible status codes for this Service Access Point.

Status	Beschreibung
00_h	ok
01_h	error
02_h	command not supported
03_h	wrong parameter
04_h	wrong application mode
05_h	no more data
06_h	application busy, try later
07_h	wrong message length
08_h	NVM write error
09_h	NVM read error (NVM content is invalid)
$0A_h$	command rejected, execution not possible in current application state
$0B_h$	access denied, operation may need another system operation mode
$0C_h$	data truncated
$0D_h$	unsuported encryption mode
$0E_h$	no encryption key found for given meter address
$0F_h$	encryption info / parameter missing
10_h	encryption error

Table : WM-Bus Gateway SAP - Status Codes

NVM = none-volatile memory

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WM-Bus Gateway SAP - WM-Bus Device List Sizes

The maximum number of list items depends on the firmware and radio module. The following table gives an overview:

#	Module / USB-Stick	Size
1	iM881A-XL	8
2	iM891A-XL	8
3	iU891A-XL	8

Table: Maximum number of WM-Bus Device List items

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WM-Bus Gateway SAP - WM-Bus Device Power Levels

The power level range depends on the firmware and radio module. The following table gives an overview:

#	Module / USB-Stick	Minimum Power Level	Maximum Power Level
1	iM881A-XL	-1 dBm	+13 dBm
2	iM891A-XL	TBD	TBD
3	iU891A-XL	TBD	TBD

Table: Power Level Range

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Approval Test Services (only for iM881A-XL, iM891A-XL)

This Service Access Point includes messages for approval tests.

> **Caution:** The following test functions are intended for use **only** during certification tests in the appropriate environment (e.g., test lab).

> Please ensure that the firmware operation mode is set to **"Approval Test"** and return to **"Application Mode"** after the tests are finished. Failure to do so may result in the unavailability of the required message handlers.
>
> You can find the corresonding HCI message here : Firmware Operation Mode Services

Name	Description
Reset Test	Message to reset a running test
Enable WM-Bus CW Mode	Carrier Wave Signal test
Enable WM-Bus PN9 Tx Mode	PN9 tx sequence test
Approval Test - HCI Protocol Constants	List of constants

Table : Approval Test Services

Back to WM-Bus Gateway Firmware Service Access Points

Reset Test

This message can be used to stop any never ending test (e.g. CW, PN9). The device will return a response message immediately and performs a software reset after approx. 200 ms.

HCI Message		
Request	**Msg ID**	**Payload**
	8 Bit	none
	01_h	
Response	**Msg ID**	**Status**
	8 Bit	8 Bit
	02_h	see Status Codes

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Enable WM-Bus CW Mode

This service can be used to enable a never ending carrier wave signal (CW) . The test can only be stopped by means of a power cyle.

HCI Message							
Request	**Msg ID**	**Radio Index**	**Link Mode**	**Power Level**			
	8 Bit	8 Bit	8 Bit	8 Bit, signed			
	$C1_h$	0 .. 3	S_Mode = 1 T_Mode = 2 CT_Mode = 3, same as T_Mode C50_Mode = 4 C100_Mode = 5	in dBm			
Response	**Msg ID**	**Status**	**Payload**				
	8 Bit	8 Bit	none				
	$C2_h$	see Status Codes					

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Enable WM-Bus PN9 Tx Mode

This service can be used to enable a never ending PN9 Tx Mode. The test can only be stopped by means of a power cyle.

HCI Message							
Request	**Msg ID**	**Radio Index**	**Link Mode**	**Power Level**			
	8 Bit	8 Bit	8 Bit	8 Bit, signed			
	$C3_h$	0 .. 3	S_Mode = 1 T_Mode = 2 CT_Mode = 3 C50_Mode = 4 C100_Mode = 5	in dBm			
Response	**Msg ID**	**Status**	**Payload**				
	8 Bit	8 Bit	none				
	$C4_h$	see Status Codes					

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Approval Test - HCI Protocol Constants

- Approval Test - Message IDs
- Approval Test - Status Codes

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Approval Test - Message IDs

ID	Message
01_h	Reset Test Req
02_h	Reset Test Rsp
...	
$C1_h$	Enable WMBus CW Mode Req
$C2_h$	Enable WMBus CW Mode Rsp
$C3_h$	Enable WMBus PN9 Mode Req
$C4_h$	Enable WMBus PN9 Mode Rsp

Tabelle : Approval Test - Message IDs

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Approval Test - Status Codes

Status	Beschreibung
00_h	ok
01_h	error
02_h	command not supported
03_h	wrong parameter
04_h	wrong application / device mode
05_h	media busy
06_h	application / device busy, try later
07_h	wrong message length
08_h	NVM write error
09_h	NVM read error (NVM content is invalid)
$0A_h$	command rejected
$0B_h$	radio busy
$0C_h$	unexpected message format
$0D_h$	wrong radio mode
$0E_h$	wrong Radio Index

Tabelle : Approval Test - Status Codes

NVM = none-volatile memory

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Firmware I/O - Usage (only for iM881A-XL, iM891A-XL)

The following table outlines I/O Pins used by the firmware. Most of the pins can be configured (see WM-Bus Gateway Configuration Services)

iM881A-XL Signals

#	Module Pin / Pad	Default Function	Configuration Option 1 see **WM-Bus Gateway Configuration Services**	Configuration Option 2 see **Radio Control Configuration**
1	20	none	Firmware "Alive" indication	n.a.
2	24	none	Packet received indication	Rx Switch Control
3	25	none	Packet transmitted indicaton	Tx Switch Control
4	29	Firmware / Configuration Error	n.a.	n.a.

iM891A-XL Signals

#	Module Pin / Pad	Default Function	Configuration Option 1 see **WM-Bus Gateway Configuration Services**	Configuration Option 2 see **Radio Control Configuration**
1	1	none	Firmware "Alive" indication	n.a.
2	11	none	n.a.	Rx Switch Control
3	10	none	n.a.	Tx Switch Control
4	7	Firmware / Configuration Error	n.a.	n.a.