



**IMST GmbH**

Carl-Friedrich-Gauß-Str. 2-4, D-47475 Kamp-Lintfort

# Wireless M-Bus Range Extender

## User Manual

Version 2.3

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## History

Version	Date	Chapter	Comment
1.0	June 2020	All	Initial Version
1.1	October 2020	All	Updates with respect to firmware version 1.0
1.2	February 2021	<a href="#">Range Extender Status Information</a>	<ul style="list-style-type: none"> <li>Missing Status Bit 3 for LoRaWAN Activation Procedure added to Range Extender Status Information</li> <li>Chapter Packet Decoding and Reassembly removed, see AN036 for further details</li> </ul>
1.3	April 2021	<a href="#">LED Usage</a>	Missing LED signal "LoRaWAN activation successful ( 3 x Green )" added
1.4	September 2021	<a href="#">Range Extender Status Information</a> <a href="#">Application Messages and LoRaWAN® Ports</a> <a href="#">WM-Bus Packet Message with RSSI</a>	Updates with respect to firmware V1.1 <ul style="list-style-type: none"> <li>Status Message extended by battery voltage</li> <li>New WM-Bus Message upload including RSSI ( <a href="#">Application Messages and LoRaWAN® Ports</a>, <a href="#">WM-Bus Packet Message with RSSI</a> )</li> </ul>
1.5	October 2021	<a href="#">Default Settings</a>	Chapter <a href="#">Default Settings</a> added
1.6	November 2021	<a href="#">Technical Characteristics</a>	Adjusted technical characteristics
1.7	April 2022	<a href="#">Range Extender Startup</a>	Update of Step 3 LoRaWAN Stack Activation added.
1.8	January 2023	<a href="#">Range Extender Status Information</a>	Updates with respect to firmware V1.3 <ul style="list-style-type: none"> <li>Status Message extended by minimum battery voltage</li> </ul>
1.9	January 2024	<a href="#">Automatic LoRaWAN 'Re-Join' Battery Voltage Measurement</a>	<ul style="list-style-type: none"> <li>Chapter <a href="#">Automatic LoRaWAN 'Re-Join'</a> added</li> <li>Chapter <a href="#">Battery Voltage Measurement</a> added</li> </ul>
2.0	March 2024	<a href="#">Range Extender Status Information</a> <a href="#">WM-Bus Packet Field Format</a> <a href="#">Upload of Application Data</a> <a href="#">Transport Protocol Details</a>	<ul style="list-style-type: none"> <li>Chapter <a href="#">Range Extender Status Information</a> updated with respect to firmware V1.4</li> <li>Chapter <a href="#">WM-Bus Packet Field Format</a> added</li> <li>Chapter <a href="#">Confirmed Upload of Application Data</a>: new note about Status Information message added</li> <li>Chapter <a href="#">Transport Protocol Details</a> : figur updated</li> </ul>
		<a href="#">Application Messages and LoRaWAN® Ports</a>	<ul style="list-style-type: none"> <li>Comments for not used LoRaWAN® Ports added</li> </ul>
		<a href="#">Recording of Wireless M-Bus Packets</a>	<ul style="list-style-type: none"> <li>Duplicate filter size increased from 16 to 64 entries ( firmware V1.4, BC192 ff.)</li> </ul>
2.1	August 2024	<a href="#">Automatic LoRaWAN 'Re-Join'</a>	<ul style="list-style-type: none"> <li>Timing for LoRaWAN Re-Join procedure increased from 12 hours to 18 hours to meet duty cycle requirements</li> </ul>
2.2	June 2025	<a href="#">Technical Characteristics</a>	<ul style="list-style-type: none"> <li>IP Rating added</li> </ul>
2.3	December 2025	<a href="#">Range Extender Startup</a>	<ul style="list-style-type: none"> <li>Added new Battery Test and Startup-Delay</li> </ul>
		<a href="#">Battery Voltage Measurement</a>	<ul style="list-style-type: none"> <li>Added Low Battery Warning Indication and Battery Level Estimation</li> </ul>
		<a href="#">Range Extender Status Information</a>	
		<a href="#">Wireless M-Bus Packet Filter</a>	<ul style="list-style-type: none"> <li>New Mode for Duplicate Packet Filter and new Reject-Filter stage added</li> </ul>
		<a href="#">Upload of Application Data</a>	<ul style="list-style-type: none"> <li>New Unconfirmed Upload Method added for firmware V1.5 ff.</li> </ul>
		<a href="#">Default Settings</a>	<ul style="list-style-type: none"> <li>WM-Bus RSSI Information, LoRaWAN® Tx Retries &amp; Data rate, Unconfirmed Uploads, Calendar Eventlist,...</li> </ul>
		<a href="#">Initial Setup</a>	<ul style="list-style-type: none"> <li>New Password Protection of Serial Configuration Interface added</li> </ul>
		<a href="#">Calendar Events</a>	<ul style="list-style-type: none"> <li>Added description about Event Handling and new Default Events</li> </ul>
		All	<ul style="list-style-type: none"> <li>Additional version of the device with modified housing, battery incl. new battery connector, and no LED. Part-nbr. 404608</li> </ul>

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# General User Information / Disposal

This document has to be treated confidentially. The content must not be published, duplicated or passed to third parties without our express permission.

Read this documentation attentively before initial operation or use of the Wireless M-Bus Range Extender.

Observe the safety instructions and warnings in this documentation.

Keep the user manual for future reference.

## Product Information

**Device:** Wireless M-Bus Range Extender

**Proper use:** The Wireless M-Bus Range Extender is a compact and cost-effective device that collects wireless M-Bus messages from utility meters and forwards them to a LoRaWAN® network.

### Order Numbers:

There are two versions of the device. The part-nbr. 404600 will be replaced by part.nbr. 404608.

404600 housing dimensions: 145mm x 92mm x 55 mm

404608 housing dimensions: 157.7mm x 92mm x 58.6 mm

Essentially, the side mounting tabs are only slightly larger for the housing 404608.

**Battery:** The device is shipped with the battery disconnected. Please be aware that an unused Li-SOCL2 battery can become passivated over time. Please avoid prolonged storage and store the device in a cool (<22°C) and ventilated room.

### Manufacturer:

IMST GmbH

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

## Disposal of the Device



Do not dispose this product at the end of its life in the household waste, but in the designated places for recycling old electrical equipment.

Do not dispose the battery cell in the household waste, but in the designated areas for recycling old batteries.

## Disclaimer

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# Safety

## General

Read this safety information attentively before using and operation of the Wireless M-Bus Range Extender

Do not make any changes to the product. The housing may only be opened for the initial configuration of the Wireless M-Bus Range Extender and only by qualified specialist personnel. The housing must then be closed again for further operation.

Please do not use the device, if it appears to be damaged.

## Battery Instructions

The Wireless M-Bus Range Extender is equipped with a non-rechargeable, 3.6V lithium battery cell with a typical capacitance of 19Ah. The battery must be treated as **dangerous good**.



**Please note the following information.**

- Only use the admitted battery cell (see [Technical Characteristics](#))
- Battery cells with a nominal voltage of more than 3.6V are not allowed.
- Do not recharge the battery cell.
- Do not disassemble the battery cell.
- Do not heat the battery cell above 100 °C.
- Keep batteries away from the reach of children.

## Transport Notes

The Wireless M-Bus Range Extender is equipped with a non-rechargeable 3.6V lithium battery cell with a typical capacitance of 19Ah. The battery must be treated as **dangerous good**, UN3091 Class 9.



**Please note the following information regarding transport of the Wireless M-Bus Range Extender.**

- Certain transport and packaging regulations must be observed.
  - Use special packaging (best case the same package where you received the Wireless M-Bus Range Extender with).
  - Mark the package with a appropriate sticker regarding the mode of transportation (street, train, ...).
- Disconnect the battery cell connector from the power supply connector of the PCB.
- Place a protection tape at the battery cell connector to avoid short circuit.
- If you are uncertain about the transport please contact the vendor.
- Transport within airplanes is not allowed

## Overview

The Wireless M-Bus standard (EN 13757-4) is used in many wireless sensor and smart meter applications. These meters and sensors are communicating according to defined radio operation modes based on a standard FSK modulation with more or less range to the corresponding receiving unit.

The LoRa® modulation has become the standard wireless technology for outdoor and indoor applications which require a perfect trade-off among communication range and battery life. Therefore it is a perfect means to increase the range of wireless communication systems. The Wireless M-Bus Range Extender in the following referred to as Range Extender combines the two modulation technics and communication protocol stacks in one single device.

A typical usecase for the Range Extender is the forwarding of Wireless M-Bus messages of a configurable group of sensor / meter devices. The Range Extender offers a flexible way to define hourly, daily, weekly or monthly reception windows for sampling of WM-Bus messages and a large data memory for temporary buffering. Even large WM-Bus messages with maximum payload size can be forwarded within LoRaWAN® radio packets by means of an integrated segmentation & reassembly protocol.

Configuration of firmware parameters like LoRaWAN® settings, calendar events, packet filters can be easily managed via serial USB link and PC-Tool. Calendar events and packet filters can furthermore be updated over the air.

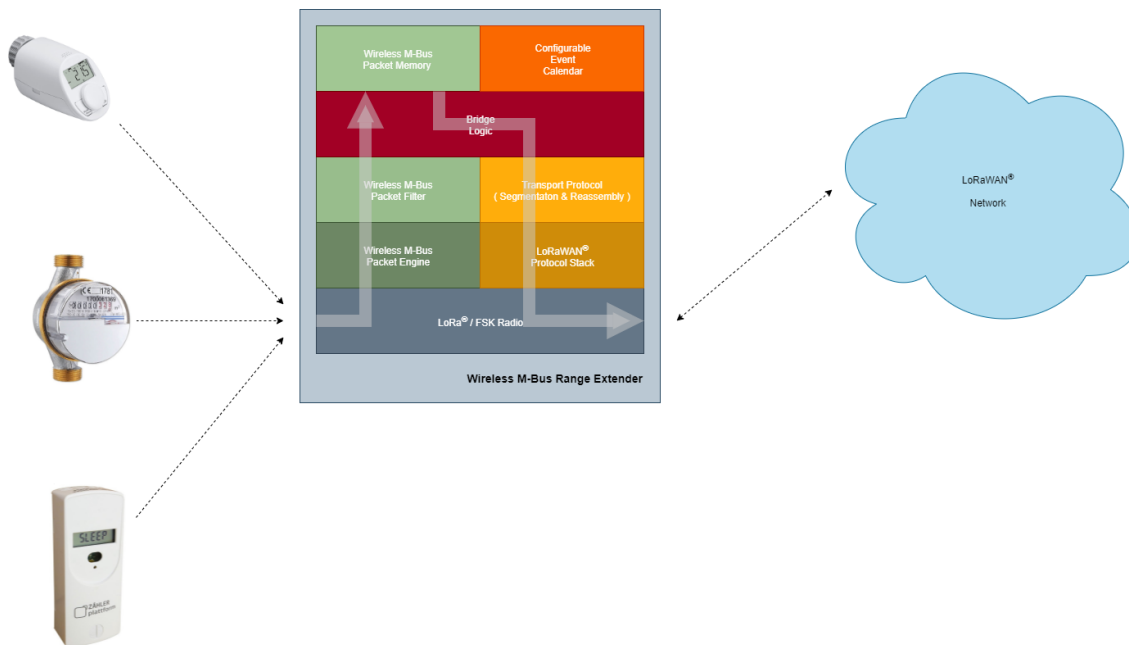

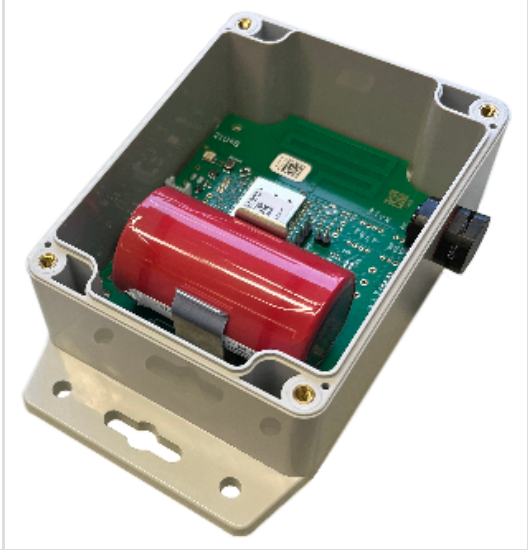


Figure: Overview

# Range Extender Hardware

Wireless M-Bus Range Extender without cover



Part-nbr: 404600	Part-nbr: 404608
	

## Hardware Features

- Power supply via Battery.
- Radio module including TRX,  $\mu$ C and additional PCB antenna.
- Data memory
- User interface for configuration and signalling

The following explains some hardware features, necessary for the user to power and configure the Range Extender.

## Power Supply

Part-nbr: 404600	Part-nbr: 404608
Power for the Range Extender is supplied via the 2-pin connector JST B2B-PH-K-S.	Power for the Range Extender is supplied via the 2-pin connector JST B2B EH-A
	
Figure: Power Connector	Figure: Power Connector
Power source is one non-rechargeable 3.6V LTC (Lithium-Thionylchlorid, Li-SOCl <sub>2</sub> ) battery cell. It is equipped with a cable and the 2-pin connector JST PHR-2.	Power source is one non-rechargeable 3.6V LTC (Lithium-Thionylchlorid, Li-SOCl <sub>2</sub> ) battery cell. It is equipped with a cable and the 2-pin connector JST EHR-2.

Battery Notes



Battery cells with a nominal voltage of more than 3.6V are not allowed.

Do not recharge the battery cell.

Do not disassemble, or heat the battery cell above 100 °C.

Dispose the battery cell only in designated areas for recycling old batteries.



## User Interface

**Reed Sensor:** to be used as magnetic switch with a simple magnet for external user actions, without a need to open the housing.

**LED** for signalling. For part-nbr. 404608 the LED is no longer visible from the outside.

**Internal Reset Button** for manual Reset after configuration of LoRaWAN® settings.

### Internal Configuration Interface:

- Serial Configuration Interface (UART):
  - configuration of calendar events for WM-Bus reception intervals.
  - configuration of device filtering by Manufacturer ID, Device ID, ... (whitelist).
  - firmware upload via integrated bootloader (see [Firmware Update via Bootloader - Old](#)).
  - pin compatible to FTDI's **TTL-232R-3V3** (TTL to USB serial converter cable).
- 2 Pin-Header for activating the internal bootloader.

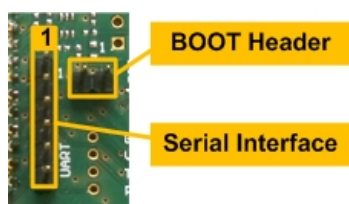


Figure: Configuration Interface

Serial Configuration Interface			
Pin	Name	Type	Description
1	GND	GND	
2	NC	-	currently not connected
3	NC	-	currently not connected
4	RxD	Input	UART receive data input of the radio module
5	TxD	Output	UART transmit data output of the radio module
6	NC	-	currently not connected

## Initial Setup

The Wireless M-Bus Range Extender requires an initial configuration before usage. This configuration can be done by means of a PC-Tool called **WS Configurator** which is connected via serial interface to the device.

The configuration includes the following steps:

1. Setup of LoRaWAN<sup>®</sup> protocol parameters including activation type for Over The Air Activation (**OTAA**) or Activation by Personalization (**ABP**) and the corresponding keys and identifiers
2. Reset of connected Range Extender
3. Synchronize the embedded RTC with the local PC time
4. Setup of calendar events which control the runtime behaviour of this device
5. Configuration of Wireless M-Bus address parameters for packet filtering

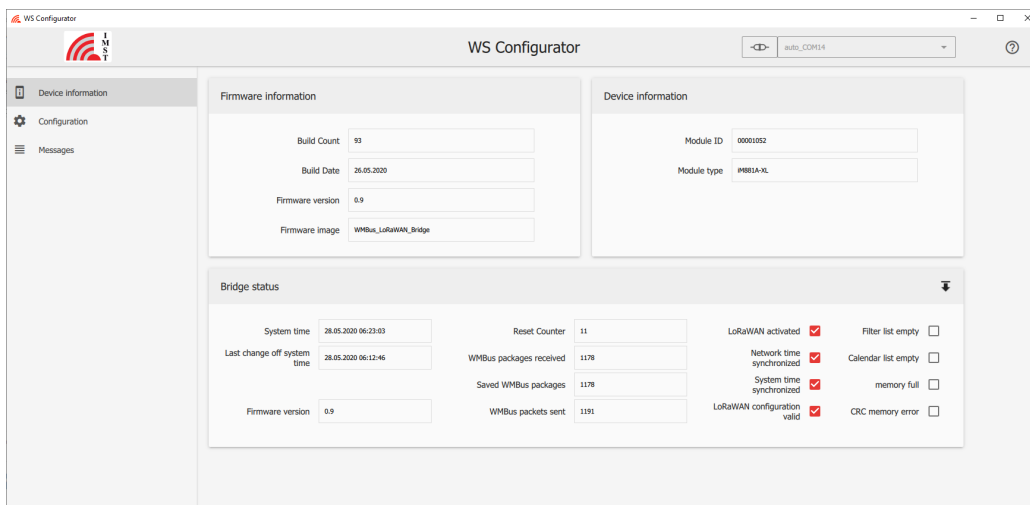


Figure : WS Configurator

For Firmware V0.9 it is recommended to perform a reset whenever the LoRaWAN<sup>®</sup> settings have been updated.  
Do not forget to synchronize the embedded RTC of the Range Extender with the PC time afterwards.

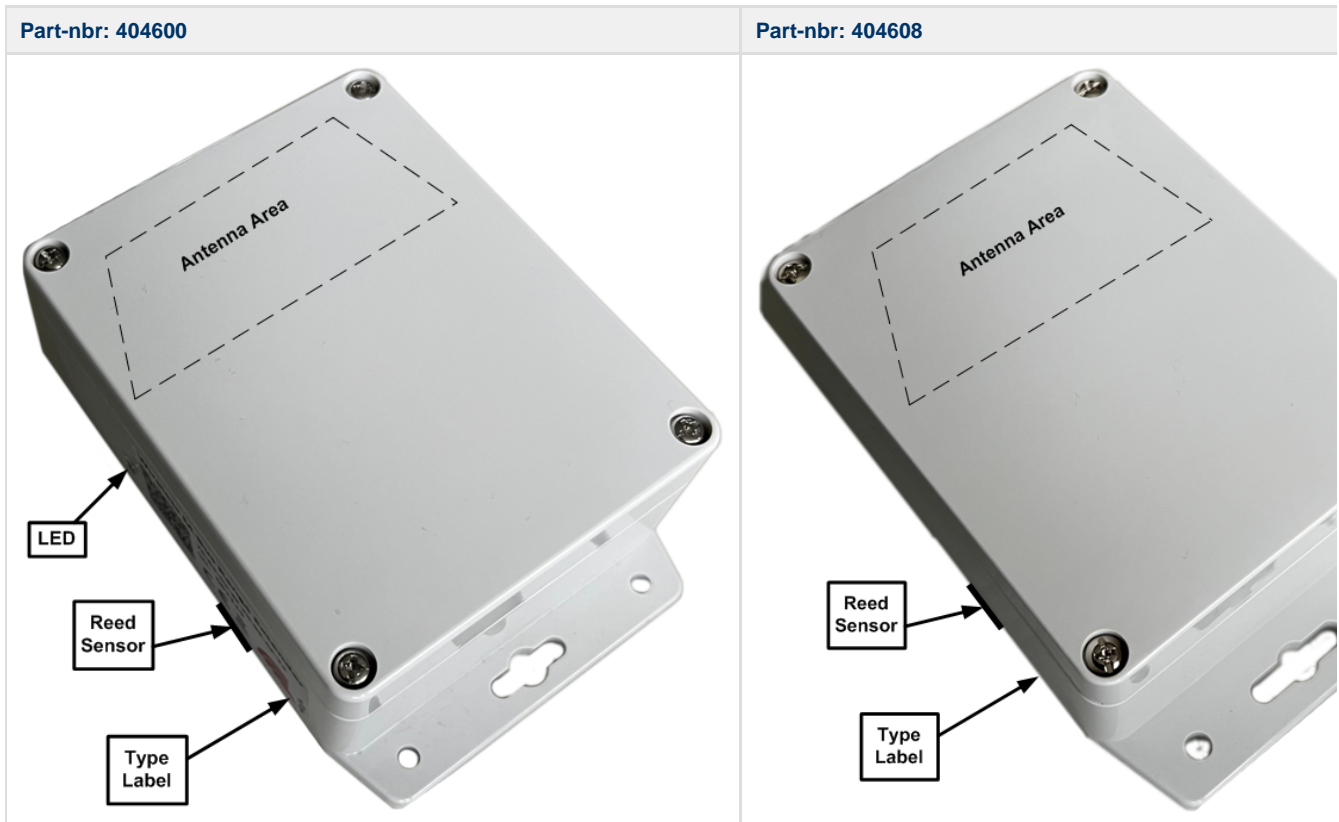
## Password Protection of the Serial Configuration Interface

From firmware version 1.5 onward, access to the serial configuration interface requires a password.  
The default password is **"000000"** (factory setting).  
Users are advised to change the password during initial setup to ensure security.

## Installation

The Wireless M-Bus Range Extender housing consists of mounting brackets for fastening on a flat surface. Installation height must not be higher than 2 meters above ground to avoid any risks in case of falling down.

The figure below shows the positions of the LED (only visible from outside for part-nbr. 404600), the Reed Sensor and especially the integrated PCB antenna. For optimal RF performance please avoid any metal obstacles near the antenna area. If possible, avoid to install the module directly next to other radio equipment.



After powering up the Wireless M-Bus Range Extender by connecting the battery cell to the power connector the device performs its startup procedure and starts working depending on the current configuration. Device activation and visualization of internal firmware status can be triggered by a magnet via reed sensor and will be signaled via led. For more details, please read the chapter [Functional Description](#).

# Functional Description

The following chapters explain the firmware features in more detail.

- [Range Extender Startup](#)
- [Calendar Events](#)
- [Real Time Clock Synchronization](#)
- [Wireless M-Bus Packet Filter](#)
- [Recording of Wireless M-Bus Packets](#)
- [Upload of Application Data](#)
- [Automatic LoRaWAN 'Re-Join'](#)
- [Battery Voltage Measurement](#)
- [LED Usage](#)

## Range Extender Startup

After a power cycle or reset the Range Extender performs a startup procedure which includes the following steps:

- **Step 1 : Battery Test & LoRaWAN Startup-Delay ( V1.5ff )**

After successful system startup the Range Extender performs a battery test which takes at least 10 seconds. This test is executed in parallel with the new startup delay for the LoRaWAN® join procedure. If the battery is too weak, the firmware remains in this state until the battery is replaced.

Note: the startup delay depends on the configured LoRaWAN® data rate and can take up to 147 seconds for SF12.

- **Step 2 : Software Module Configuration**

Following Step 1, the Range Extender reads and validates the required configuration settings.

- If the settings are valid, the corresponding firmware modules (LoRaWAN® Stack, Wireless M-Bus Packet Filter, Event Calendar) are configured.
- If the LoRaWAN® settings are missing, the Range Extender enters sleep mode and waits for further configuration (**Step 3**).

Every LoRaWAN® device must be activated before usage. If not already activated, the Range Extender enters sleep mode and waits for a trigger signal to start the LoRaWAN® activation procedure (**Step 4**). This trigger signal can be issued as follows:

- by means of a magnet and a pulse from the reed switch
- by means of an application event sent from a PC-Tool via local serial interface

- **Step 3 : Range Extender Configuration**

The initial Range Extender configuration must be handled via serial connection and PC-Tool. During configuration phase several parameters for LoRaWAN® activation, Calendar Events and WM-Bus Packet Filters have to be set to change the Range Extender behaviour.

Note: the LoRaWAN® Stack can be deactivated and reactivated again.

- **Step 4 : LoRaWAN® Stack Activation (OTAA or ABP)**

In case of Over The Air Activation (**OTAA**) the Range Extender initiates the LoRaWAN® join procedure. On success the Range Extender continues with the next step. In case of a failed over the air activation the system will repeat the join procedure after 18 hours by issuing a complete firmware reset. The join procedure and its final result will be signaled via [LED](#). If Activation By Personalization (**ABP**) is selected the LoRaWAN® Stack will be activated and the next step is directly initiated.

Note: from firmware version v1.1 ABP should only be used for test purpose.

- **Step 5 : Real Time Clock Synchronization**

For proper calendar operation the Range Extender requests the LoRaWAN® network time and synchronizes the internal real time clock (RTC).

- **Step 6 : Time Correction of Calendar**

In this final step the calendar unit is updated to handle the configured events which control the subsequent application behaviour.

The following flow chart outlines the Range Extender startup procedure and its single steps.

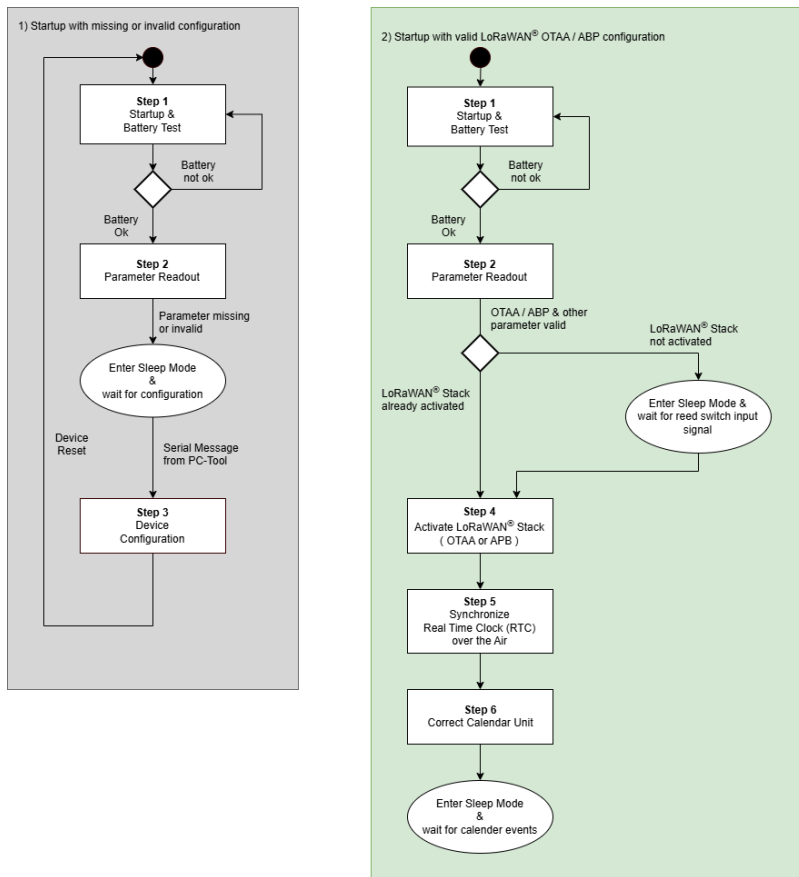


Figure : Range Extender Startup with invalid & valid configuration

## Calendar Events

Calendar Events are used to define the runtime behaviour of this application. The firmware provides space for **up to 32 configurable Calendar Events**.

A single Calendar Event item consists of the following three or four elements:

1. **Event Type**  
The event type defines the kind of action to be performed, e.g. "Record Wireless M-Bus Packets in S-Mode"
2. **Repetition Type**  
The repetition type defines the periodicity of an event e.g. monthly, every 2 weeks, daily, every 4 hours or none.
3. **Date / Time**  
The date / time element defines when an event should be scheduled for the first time. This information is stored in 32-Bit **unsigned integer** UTC format.
4. **Filter Group ID**  
This element defines a group of filters which are active during a Wireless M-Bus packet capture phase ( see [Wireless M-Bus Packet Filter](#) ).  
Note: this element is currently only used for Wireless M-Bus reception event types. A value of 255 (0xFF) is reserved and means that all configured Wireless M-Bus filters should be applied for that Calendar Event.

## Event Types

The following main event types are configurable:

- Enable recording of Wireless M-Bus packets in S-Mode or combined C-/T-Mode <sup>1) 2)</sup>
- Stop recording and start upload of recorded Wireless M-Bus packets <sup>1)</sup>
- Enable Wireless M-Bus reception in S-Mode or C-/T-Mode without recording but with filtering and direct packet forwarding over the local serial interface <sup>2)</sup>
- Disable Wireless M-Bus reception
- Get & Synchronize Network Time over LoRaWAN® <sup>1)</sup>
- Send Range Extender Status over LoRaWAN® <sup>1)</sup>
- Set LED on / off / blinking for simple Range Extender and calendar test purpose

<sup>1)</sup> Note: this event type requires an activated LoRaWAN® Stack.

<sup>2)</sup> Note: it is possible to change between S-Mode and C-/T-Mode on the fly without stopping a reception phase.

The Calendar module itself is connected to the embedded Real Time Clock ( RTC ). Please refer to chapter [Real Time Clock Synchronization](#) for further information.

## Handling of Calendar Events

An ongoing WM-Bus receive (Rx) phase is not interrupted or terminated by calendar events such as "**Send Status**" or "**Get Network Time**". The same applies to an ongoing upload phase, which is only completed after the transmission of the last stored WM-Bus message.

The duration of an upload phase is not deterministic, as it depends on various parameters such as the number of stored WM-Bus messages, the LoRaWAN® data rate, the number of required retransmissions for confirmed uplinks, etc.

Please take this into account when planning calendar events.

## Default Calendar Events

From Firmware V1.5 onwards, an hourly "Send Status" event is automatically issued by default when the Calendar Event List is empty.

In addition, if no "Send Status" event is configured, a daily "Send Status" event for 00:00:30 is added to the Calendar Event List.

## Real Time Clock Synchronization

The Range Extender features an embedded Real Time Clock ( RTC ) which is used to schedule configurable Calendar Events. For proper operation it is highly recommended to synchronize the RTC. The initial synchronization can be done by means of the WS-Configurator PC-Tool. On every synchronization the current time stamp is stored in the non volatile memory of the embedded radio module. After a power-cycle or system reset this stored value is used to initialize the RTC. If the value is invalid or less than 01.01.2000 00:00:00 the RTC will start at 01.01.2000 00:00:00.

After startup the device starts with a LoRaWAN<sup>®</sup> activation procedure ( OTAA or ABP ) and initiates a confirmed LoRaWAN<sup>®</sup> uplink MAC command to get the current data and time from the LoRaWAN<sup>®</sup> server. On success the received value is used to configure the RTC and is finally stored in the NVM for later usage after a system reset.

Due to the fact that some LoRaWAN server do not support the "Get Time MAC Command" a new fall back mechanism is implemented in firmware version V1.0. In case of no MAC command response the firmware transmits a "Get Date Time Request" application command via LoRaWAN<sup>®</sup> to the connected Application Server which might be able to answer this request. This request is transmitted 5 times.

The new "Get Date Time Request" looks as follows;

LoRaWAN Port: 32

LoRaWAN Payload Syntax:

Request < Get > < Resource ID >

Example:

< Get > < DateTime >

< 01<sub>h</sub> > < 01<sub>h</sub> >

The corresponding Get Date Time response must look like this:

LoRaWAN Port: 32

LoRaWAN Payload Syntax:

Response < Get Response > < Resource ID > < data >

Example:

< Get Response > < DateTime > < current date time as seconds since ( 1.1.1970, midnight UTC/GMT ), 00:00:00 as **unsigned** 32-Bit integer, LSB first , e.g.: "2020-09-18 11:46:33 >

< 02<sub>h</sub> > < 01<sub>h</sub> > < ( 19 9E 64 5F )<sub>h</sub> >

Due to the fact that the clock crystal frequency can drift over temperature it is recommended to synchronize the RTC via LoRaWAN<sup>®</sup> from time to time ( e.g. once per week ).



## Wireless M-Bus Packet Filter

The firmware V1.5 implements a new **three-stage packet filter**:



Figure : Three-Stage Packet Filter

### Stage 1 : Accept Filter

In this stage, received packets are checked against a configurable list of allowed addresses. Only packets with addresses included in this list are passed on; all others are discarded.

The list of this filter can store **up to 32 Wireless M-Bus address filter items** which should help to focus on those devices of interest during a Wireless M-Bus capture phase. The header fields mentioned here are present in the data link layer fields of each Wireless M-Bus packet.

A single packet filter item consists of the following fields:

1. **Manufacturer ID**  
Contains the 2 octet unique User/Manufacturer ID of the sender of a packet
2. **Device ID**  
Containing the first 4 octets of the address field which carry a 32-Bit unique device address
3. **Version**  
Single octet, containing a version number
4. **Type**  
Single octet, containing the type of the sender e.g. E-meter, Gas-meter, ...
5. **Filter Mask**  
Single octet, defines which of the given 8 octets of packet header must match exactly and which should be treated as "don't care"
6. **Filter Group ID**  
Single octet (range 0 - 255), defines a group to which this filter item belongs, see also [Calendar Events](#)

The Filter Group ID of a calendar event item must match with the Filter Group ID of a filter item to enable the filter during a capture phase.

The value 255 is reserved and means that a filter with this ID will be applied in every Wireless M-Bus reception phase.

### Stage 2 : Reject Filter

Packets whose addresses appear in this list are explicitly rejected. The configurable list of this filter can contain **up to 16 addresses**, using the same format as in the Accept Filter stage.

### Stage 3 : Duplicate Packet Filter

In the final stage, a configurable mechanism suppresses duplicate wm-bus packets received from the same sender.

The duplicate filter supports four different comparison modes to suppress packets:

1. **Off (Bypass):** The filter is disabled and does not apply.
2. **Simple Mode:** The first 10 bytes of the WM-Bus header are compared. This header includes the L-field, C-field, Manufacturer ID, Device ID, Type, and Version fields.
3. **Advanced Mode:** In addition to the 10-byte header comparison, a hash value is calculated over the subsequent message payload and compared.
4. **Single Station Mode:** Only 8 bytes are compared, consisting of the Manufacturer ID(2), Device ID(4), Version(1), and Type(1) fields.

For performance reasons, the duplicate filter uses the internal memory and is limited to a **maximum of 64 entries**. The filter is reinitialized with each wireless M-Bus receive window.

## Recording of Wireless M-Bus Packets

Two calendar event types are used to start a Wireless M-Bus packet capture phase either in S-Mode or combined C- / T-Mode. The received packets will be decoded according to the defined physical layer encoding Manchester, Three Out Of Six or NRZ. Every packet will be checked for CRC errors and only valid packets will be decoded according to the given frame format A or B. The Wireless M-Bus CRCs are stripped of to save memory and LoRa upload airtime. In the next step the packet has to pass the first filter stage which compares the WM-Bus packet header fields with a set of configured addresses. With firmware version 1.0 another filter stage for removing duplicated packets has been introduced. Firmware V1.5 introduces a further filter stage for blocking packets with given addresses. Finally the accepted packets are stored into an embedded flash memory. The flash memory will be automatically erased after each LoRa upload session.

The following figure outlines the connection between WM-Bus reception Calendar Events, Filter Group ID and the Wireless M-Bus Device Filters. The Duplicate Filter will be "emptied" on every reception window start and is updated automatically with information from the WM-Bus packet header of every new received packet. The filter compares the WM-Bus-Packet Header Fields and optionally a computed 16-Bit CRC to identify duplicated WM-Bus packets.

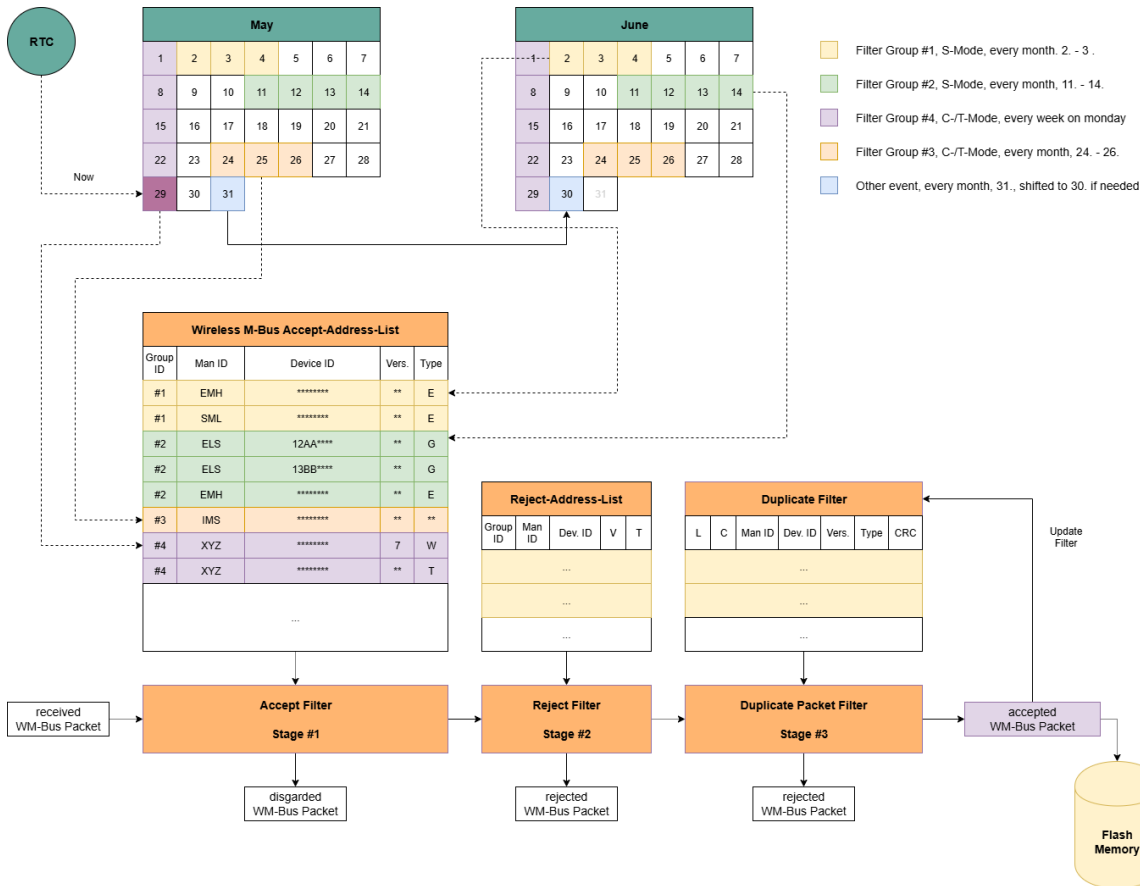


Figure : Example of Wireless M-Bus packet reception, Wireless M-Bus Packet Filter and Calendar Events

1. It is recommended to reserve some time after a reception phase for uploading of captured messages via LoRaWAN® network.
2. Monthly events which are scheduled for days that are not present in the current month e.g. 29.2, 30.2, 31.2, 31.4, 31.6, 31.9, 31.11 are scheduled for the last day of the month. Thus it is highly recommended not to schedule a Wireless M-Bus capture start or stop event for one of these days.

## Upload of Application Data

Starting with firmware version V1.5, the Wireless M-Bus Range Extender supports, in addition to the previously used Confirmed Application Data Upload, also the configurable method of Unconfirmed Uploads — i.e., sending data without requiring downlink acknowledgements from the server.

The following subchapters offer a detailed overview of the available services, transport protocol, and the structure of the implemented application-layer messages.

The duration of an upload phase is not deterministic, as it depends on various parameters such as the number of stored WM-Bus messages, the LoRaWAN® data rate, the number of required retransmissions for confirmed uplinks, etc.

- [Confirmed Upload of Application Data](#)
- [Unconfirmed Upload of WM-Bus Packets](#)
- [Transport Protocol Details](#)
- [Application Messages and LoRaWAN® Ports](#)

## Confirmed Upload of Application Data

The upload of application data like captured Wireless M-Bus packets is implemented by default using **confirmed** LoRaWAN® uplink packets. Due to the adaptive payload capacity of LoRaWAN® packets a complete Wireless M-Bus packet may require more than one LoRaWAN® uplink packets. In this case a simple segmentation protocol with minimal overhead of one single byte is used. The protocol supports both, spreading of WM-Bus packets over multiple LoRaWAN® packets and transmitting of multiple WM-Bus packets in a single LoRaWAN® packet.

Shorter messages like the [Range Extender Status Information](#) message may fit into a single LoRaWAN® uplink packet, and will be transmitted using a not segmented protocol.

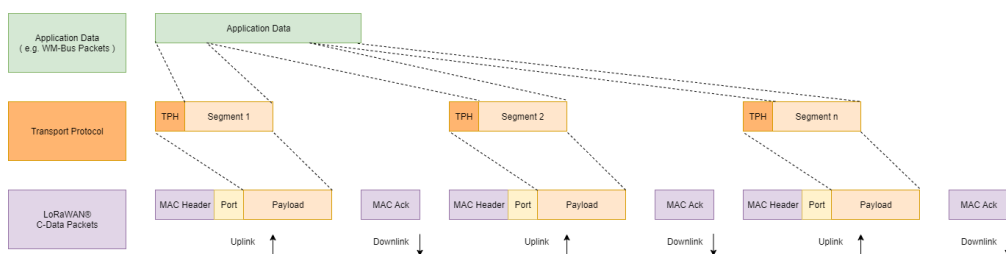
The type of message and protocol can be identified by means of the LoRaWAN® Port and is outlined in chapter [Application Messages and LoRaWAN® Ports](#).

### Note

Please note that in cases where an upload of Wireless M-Bus packets is scheduled via calendar event but no WM-Bus data could be recorded, a [Status Information](#) message including packet counters will be sent.

The following figure outlines packet uploads using the confirmed uplink service of LoRaWAN ( C-Data ):

WM-Bus Packet spreaded over several LoRaWAN Packets ( in case of large spreading factors )



Multiple WM-Bus Packets transmitted in one LoRaWAN Packet ( in case of small spreading factors )

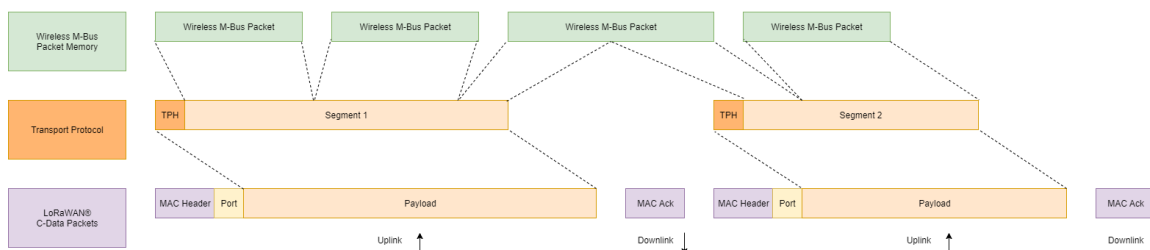


Figure : Confirmed Application Data Upload

# Unconfirmed Upload of WM-Bus Packets

Unconfirmed Data Upload differs from Confirmed Upload in that each segment carries at most a single Wireless M-Bus message. Shorter messages may fit into a single LoRaWAN® uplink packet, and will be transmitted using a not segmented protocol.

The type of message and protocol can be identified by means of the LoRaWAN® Port and is outlined in chapter [Application Messages and LoRaWAN® Ports](#).

**Note**

Please note that in cases where an upload of Wireless M-Bus packets is scheduled via calendar event but no WM-Bus data could be recorded, a [Status Information](#) message including packet counters will be sent.

The following figure outlines packet uploads using the unconfirmed uplink service of LoRaWAN ( U-Data ). In this case the transmission of the next segment is triggered no later than after the last LoRaWAN downlink time slot (RX2).

WM-Bus Packet spreaded over several LoRaWAN Packets ( in case of large spreading factors )

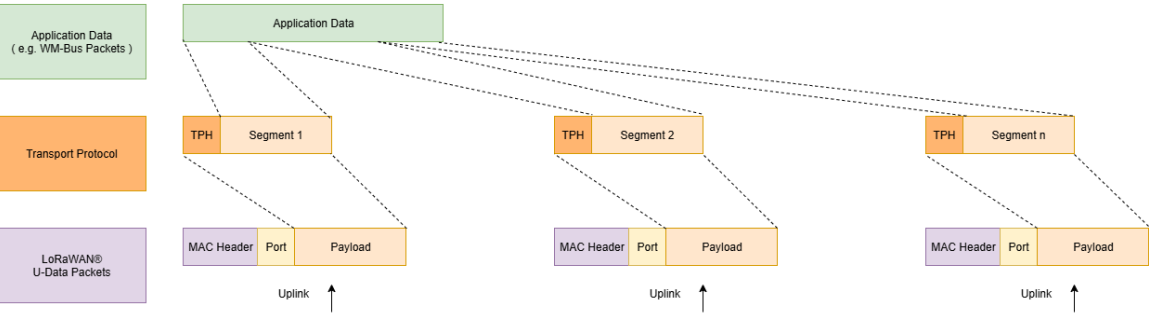


Figure : Unconfirmed Application Data Upload

## Transport Protocol Details

The transport protocol is used in uplink- and downlink direction on several LoRaWAN® ports which indicate the type of message content. The protocol uses a single octet header field with following format:

TP Header	
Bit 7	Bit 6 ... Bit 0
Last Segment	Segment Number 0 .. 127

Figure : Transport Protocol Header

- **Last Segment Indicator (Bit 7)**  
This bit indicates the last segment of a transmission if set to "1".
- **Segment Number (Bit 0 .. 6)**  
The segment number starts at zero for every new transmission and will be incremented by "1" for every new segment. On receiver side it might happen that duplicated segment number will appear due to missing downlink acknowledgements. In this case the receiver should simply ignore the duplicated segments. The segment number can wrap around from 127 to 0 in case of very large transmissions and tiny segments.

The following figure outlines a transmission consisting of four different segments and one re-transmitted segment, as typically occurs during a Confirmed Uplink scenario in LoRaWAN, where one segment did not receive an acknowledgment (ACK) in either RX1 or RX2 and was therefore retransmitted.

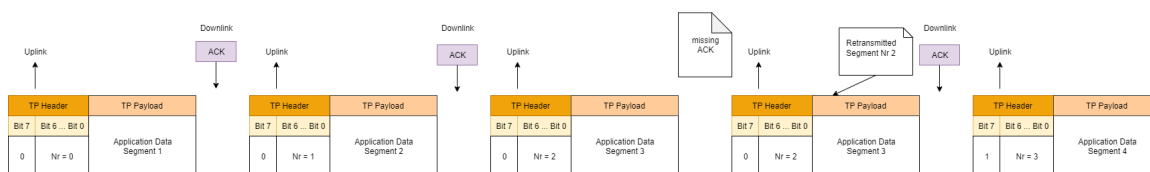


Figure : Example transmission sequence with four segments and one retransmission ( confirmed upload )

### Note

1. Due to the fact that the LoRaWAN protocol can change the uplink spreading factor the transport protocol handles automatically the resulting payload capacity changes.
2. A reliable serie of segments is ensured even if data needs to be retransmitted and payload capacity is changed at the same time.
3. When unconfirmed upload is selected, missing uplinks cannot be detected, and therefore no retransmissions will occur. As a result, an entire segmented packet sequence corresponding to a single Wireless M-Bus packet may be lost.

## Application Messages and LoRaWAN® Ports

The LoRaWAN® Protocol supports port numbers which are used within this application to identify different kind of messages.

The following ports are defined for unsegmented messages:

LoRaWAN® Port	Message Type	LoRaWAN® Service Type
03 <sub>h</sub>	<a href="#">Range Extender Status Information</a>	confirmed
04 <sub>h</sub>	<a href="#">WM-Bus Packet Message without RSSI</a>	unconfirmed
0B <sub>h</sub>	<a href="#">WM-Bus Packet Message with RSSI ( Firmware Version V1.1 ff. )</a>	unconfirmed
20 <sub>h</sub>	Remote Access Services ( see WMBus RangeExtender Remote Access Protocol.pdf )	confirmed

Table : LoRaWAN Ports for unsegmented messages

Note: unsegmented messages do not include a segmentation protocol header byte. The application data follows immediately after the port number.

The following ports are defined for segmented messages:

LoRaWAN® Port	Message Type	LoRaWAN® Service Type
43 <sub>h</sub>	<a href="#">Range Extender Status Information</a>	confirmed
44 <sub>h</sub>	<a href="#">WM-Bus Packet Message without RSSI</a>	confirmed / unconfirmed
4B <sub>h</sub>	<a href="#">WM-Bus Packet Message with RSSI ( Firmware Version V1.1 ff. )</a>	confirmed / unconfirmed
60 <sub>h</sub>	Remote Access Service ( see WMBus RangeExtender Remote Access Protocol.pdf )	confirmed

Table - LoRaWAN Ports for segmented messages

### Implemented Application Messages

- [Range Extender Status Information](#)
- [WM-Bus Packet Message without RSSI](#)
- [WM-Bus Packet Message with RSSI](#)
- [WM-Bus Packet Field Format](#)

## Range Extender Status Information

The Range Extender maintains some status information elements which can be transmitted over LoRaWAN® or requested via local serial interface. The transmission can be initiated by means of a calendar event.

System Time		Firmware Version		Last Sync		Status			WM-Bus Packet Counter			Firmware V1.1 ff.		Firmware V1.3 ff.	Firmware V1.4 ff.
UTC Format LSB first		Minor Version	Major Version	UTC Format LSB first		Reset Counter LSB first	Status Bits		Received Packets LSB first	Recorded Packets LSB first	Uploaded Packets LSB first	Battery Voltage in mV LSB first	Firmware Type	Minimum Battery Voltage in mV LSB first	Reserved Info
32 Bit		8 Bit	8 Bit	32 Bit		32 Bit	16 Bit		32 Bit	32 Bit	32 Bit	16 Bit	8 Bit	16 Bit	8 Bit

Figure: Range Extender Status Format

The Range Extender Status consists of the following elements:

- **Date and Time**  
Contains the current date and time in seconds since 01.01.1970 00:00:00
- **Firmware Version**  
Minor and major firmware version
- **Last Sync**  
Contains the time stamp of the latest synchronization via local or air interface
- **Reset Counter**  
Contains the number of device resets
- **Status / Error Bits**
  - Bit 0: LoRaWAN® Activation State  
1 = LoRaWAN® Stack is not activated  
0 = Stack is activated
  - Bit 1: Network Time Synchronization State  
1 = No synchronization via LoRaWAN®  
0 = Synchronized via LoRaWAN®
  - Bit 2: System Time Synchronization State  
1 = RTC not synchronized at all  
0 = RTC synchronized ( via local serial interface or LoRaWAN® )
  - Bit 3: LoRaWAN Activation Procedure State  
1 = Activation Procedure active  
0 = Procedure not active
  - Bit 4: LoRaWAN Configuration State  
1 = Configuration is invalid Activation not possible  
0 = Configuration is valid
  - Bit 5: Wireless M-Bus Address Filter List Configuration State  
1 = Whitelist is empty no recording possible  
0 = Whitelist contains at least one item
  - Bit 6: Calendar Event List Configuration State  
1 = List is empty, note: from Firmware 1.5 onwards, an hourly 'Get Network Time' event is automatically issued when the Calendar Event List is empty.  
0 = List contains at least one item
  - Bit 8: Flash Memory Full State  
1 = A flash memory full condition has been detected during capture phase this bit will be automatically cleared during the next recording phase  
0 = No error
  - Bit 9: Flash Memory CRC Error State  
1 = A file CRC error has been detected during read & upload operation this bit will be automatically cleared during the next recording phase  
0 = No error



- Bit 12: Low Battery detected ( Firmware V1.5 ff.) ( see also [Battery Voltage Measurement](#) )  
 1 = a voltage below 3000 mV was measured once  
 0 = no warning
  
- **Wireless M-Bus Packet Counters**
  - Number of received packets
  - Number of filtered and recorded packets
  - Number of uploaded packets

Note: these counters can be resetted via local serial interface
  
- **Battery Voltage**  
 The battery voltage is measured just before transmitting this status message. The value is returned in Millivolts.  
 A value of 0 or FFFF<sub>h</sub> is considered invalid because no measurement has been performed so far.
  
- **Firmware Type**  
 This element indicates different types of firmware version: e.g. official released version or field test beta version:  
 0 = Release  
 1 = Field Test Beta Version  
 X = Reserved
  
- **Minimum Battery Voltage ( Firmware 1.3 ff.)**  
 This field contains the minimum measured battery voltage. The voltage is periodically measured during WM-Bus Receiving / WM-Bus Recording windows. The value is returned in Millivolts.  
 A value of 0 or FFFF<sub>h</sub> is considered invalid because no measurement has been performed so far.

## WM-Bus Packet Message without RSSI

The following figure outlines the WM-Bus Packet Message format in more detail:

Timestamp Field	WM-Bus Packet Field						
UTC Format LSB first	Length Field	C Field	Man ID	Device ID	Version	Type	...
32 Bit	8 Bit	8 Bit	16 Bit	32 Bit	8 Bit	8 Bit	n * 8 Bit

Figure: Wireless M-Bus Packet Message Format

### Timestamp Field

Every recorded Wireless M-Bus packet is stored with a 32-Bit UTC timestamp derived from the internal RTC which indicates the time of reception.

### WM-Bus Packet Field

This field includes the WM-Bus Packet ( see [WM-Bus Packet Field Format](#) for details ) starting with original Length-Field. The original CRC fields for WM-Bus telegram format A and B has been removed, since LoRaWAN provides an own protection mechanism.

## WM-Bus Packet Message with RSSI

This message format is available in firmware version V1.1

The following figure outlines the WM-Bus Packet Message format with RSSI in more detail:

Timestamp Field	RSSI Field	WM-Bus Packet Field						
UTC Format LSB first	RSSI in dBm	Length Field	C Field	Man ID	Device ID	Version	Type	...
32 Bit	8 Bit	8 Bit	8 Bit	16 Bit	32 Bit	8 Bit	8 Bit	n * 8 Bit

Figure: Wireless M-Bus Packet Message Format including RSSI

### Timestamp Field

Every recorded Wireless M-Bus packet is stored with a 32-Bit UTC timestamp derived from the internal RTC which indicates the time of reception.

### RSSI Field

This field includes an RSSI value in dBm for the following WM-Bus Packet

### WM-Bus Packet Field

This field includes the WM-Bus Packet ( see [WM-Bus Packet Field Format](#) for details ) starting with original Length-Field. The original CRC fields for WM-Bus telegram format A and B have been removed, since LoRaWAN provides an own protection mechanism.

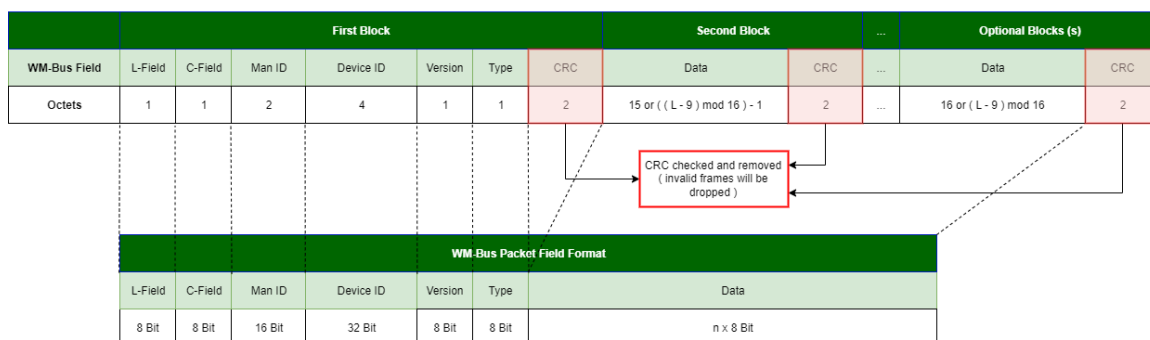


## WM-Bus Packet Field Format

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

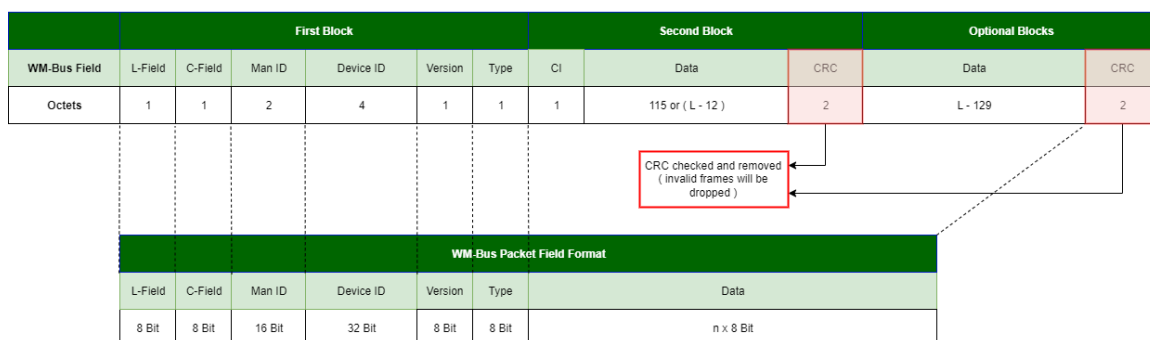
The following figure outlines the relation between the incoming received WM-Bus frames using Format A and B and the resulting outgoing WM-Bus Packet Field Format which is transmitted in combination with additional meta data (like RSSI, Timestamp) by means of the transport protocol.

Received WM-Bus Frame Format A ( S -, T -, C - Mode )



Transmitted WM-Bus Packet Field Format over LoRaWAN

Received WM-Bus Frame Format B ( only C - Mode )



Transmitted WM-Bus Packet Field Format over LoRaWAN

Figure: Resulting WM-Bus Packet Field Format

As it can be seen in the figure above, the original WM-Bus CRCs which protects the WM-Bus Physical Layer will be removed for further transportation over LoRaWAN, since LoRaWAN provides its own CRC and authentication mechanisms.

## Automatic LoRaWAN 'Re-Join'

The firmware initiates a process called LoRaWAN 'Re-Join' automatically. This typically involves a device re-establishing its connection with the LoRaWAN network. The trigger for this automatic Re-Join procedure is when no acknowledgment (downlink ack) is received after a maximum number of retransmissions. If the Re-Join procedure fails (presumably if the device is unable to re-establish a connection), the firmware schedules the next Re-Join attempt. In this case, it is set to occur after a specific time period of 18 hours by issuing a complete firmware reset.

## Battery Voltage Measurement

The firmware implements several mechanisms to monitor the battery voltage to ensure reliable operation:

- **Startup Check:**  
During system startup, the firmware measures the battery voltage before enabling the radio module. This prevents radio activation when the supply voltage is insufficient.
- **Status Report Measurement:**  
The battery voltage is also measured immediately before transmitting a *Range Extender Status Report*, when triggered either by a Calendar Event or via the WS-Configurator.  
*Note:* The measured voltage at this point may be slightly higher than the actual minimum voltage due to internal battery recovery effects.
- **Periodic Measurement During Operation:**  
The firmware periodically measures the battery voltage during each WM-Bus packet reception or recording window. This additional monitoring algorithm improves the detection of low-voltage conditions during periods of increased current consumption.

If the battery voltage drops below **2.6 V ( $V_{\min}$ )** in any of the above conditions, the firmware disables radio communication to maintain system stability and prevent malfunction.

Both the latest and minimum measured voltage values are included in the '[Range Extender Status Report](#)' to indicate the battery state.

From firmware version 1.5, an additional status bit in the 'Range Extender Status Report' is set to 1 as soon as the measured battery voltage falls below **3000 mV**.

This status bit is cleared (reset to 0) only after a device reset. It is not stored in non-volatile memory (NVM) but managed solely in RAM.

Additionally, the device issues a status report about this condition about 5 seconds after the WM-Bus reception or recording window closes.

### Note

It is highly recommended to schedule a '[Range Extender Status Report](#)', at least one time per day, to monitor the battery state.

## Simplified Battery Level Estimation

The battery level can be estimated using the following simplified equation:

State of Charge ( Soc )

$V_{\max} = 3600 \text{ mV}$

$V_{\text{low}} = 3000 \text{ mV}$

$V_{\min} = 2600 \text{ mV}$

V corresponds to the **Minimum Battery Voltage** field in the '[Range Extender Status Report](#)'.

$$SOC(V) = \begin{cases} 0 & V \leq V_{\min} \\ \frac{10}{V_{\text{low}} - V_{\min}} \cdot (V - V_{\min}) & V_{\min} < V < V_{\text{low}} \\ 10 + \frac{90}{V_{\max} - V_{\text{low}}} \cdot (V - V_{\text{low}}) & V_{\text{low}} \leq V \leq V_{\max} \\ 100 & V > V_{\max} \end{cases}$$

## LED Usage

The Wireless M-Bus Range Extender features a dual color led which is used to signal multiple states and activities. This LED is only visible from outside for part-nbr. 404600. Most of time the Range Extender will stay in a power saving state in which the led is switched off to save current. Visualization of internal Range Extender firmware state is done after power-up and can be triggered by means of a magnetic input signal via reed switch.

The following table outlines the Range Extender firmware states and the corresponding led signal:

State	Color	Timing	Action
LoRaWAN® stack activated, RTC synchronized, Calendar & Filter Lists configured	Green	2 x	nothing, Range Extender is ready
LoRaWAN® stack activated, RTC not synchronized	Red	1 x	synchronize RTC by means of local PC Tool or retry via LoRaWAN®
LoRaWAN® stack not activated, RTC not synchronized	Yellow	2 x	activate LoRaWAN® stack by means of magnetic input signal on reed switch
LoRaWAN® configuration, Calendar Configuration or WM-Bus Address Whitelist not valid	Red	3 x	connect Range Extender to PC and start configuration tool for settings update

The following table outlines the led usage during firmware activities:

Activity	Color	Timing
Startup	Yellow	on during initial battery state check ( firmware V1.5 ff )
LoRaWAN® activation	Red	continuously blinking
LoRaWAN® activation successful	Green	3 x
LoRaWAN® Network Time Synchronization	Yellow	continuously blinking
LoRaWAN® Network Time Synchronization successful	Green	2 x
LoRaWAN® Network Time Synchronization failed	Red	1 x
Wireless M-Bus capture phase	Off	none
Wireless M-Bus packet received	Green	1 x per packet
Wireless M-Bus packet received but not accepted by filter stage	Yellow	1 x per packet
Wireless M-Bus packet received but not stored due to memory full condition	Red	1 x per packet
Power Saving in Sleep Mode	Off	none

## Default Settings

The following table lists the default factory settings:

Parameter	Value
List of Calendar Events	empty  From Firmware 1.5 onwards, an hourly 'Send Status' event is automatically issued when the Calendar Event List is empty.  In addition, if no "Send Status Event" is configured a daily "Send Status" for 00:00:30 is added to the Calender Event List.
WM-Bus Accept Filter ( Device Address List )	empty, WM-Bus packet reception not possible
WM-Bus Reject Filter ( Device Address List )	empty
Duplicate Filter	enabled with additional 16 Bit Hash/CRC check
LED Status signaling	enabled
WM-Bus Message upload / output with RSSI	enabled
Unconfirmed Data Upload	disabled, confirmed uploads used
LoRaWAN Connection Settings <ul style="list-style-type: none"> <li>• Activation Type</li> <li>• 64-bit Device EUI</li> <li>• Application EUI / Join EUI</li> <li>• 128-bit Device Key</li> </ul>	Over The Air Activation ( OTAA ) pre-programmed valid IEEE Device EUI 00-00-00-00-00-00-00-00 <sub>h</sub> Pre-programmed key
LoRaWAN Stack Settings <ul style="list-style-type: none"> <li>• Adaptive Data Rate</li> <li>• Private / Public LoRaWAN Network</li> <li>• Duty Cycle check</li> <li>• Initial Data Rate</li> <li>• Initial Power Level</li> <li>• Number of Retransmission</li> <li>• MAC Header Command Capacity</li> </ul>	enabled public enabled SF7 13 dBm 6 15 bytes



## Firmware Update

When updating a device from the standard WM-Bus Range Extender firmware to any customer specific variant or vice versa, the data flash memory must be erased before operation, since the flash file system format is incompatible. Otherwise, undefined firmware behavior may occur.

Updating the Range Extender firmware can be managed very easily by means of the provided PC tool called **WS Configurator**.

# Technical Characteristics

Unless otherwise specified, all characteristics are applied for T = 25°C, VDD = 3.6V and are typical consumption values.

Electrical Characteristics	
Power Supply (VDD)	
Part-nbr: 404600	Lithium battery (Li-SOCl <sub>2</sub> ) SL-2880 with connector PHR-2
Part-nbr: 404608	Lithium battery (Li-SOCl <sub>2</sub> ) ER34615 with connector JST EHR-2
	3.6V, 19Ah, Size D
Current Consumption (typ.)	Transmit Mode: 45mA
	Receive Mode: 13mA ; 20mA during active packet reception
	Sleep Mode: 3µA (RTC on)
Data Memory	8 MBit Flash
Interface Characteristics	
Digital Input Voltage	high level: 0.7 x VDD to VDD
	low level: GND to 0.3 x VDD
Digital Output Voltage	high level: VDD - 0.45V to VDD
	low level: GND to 0.45V
UART Parameter	115.2 kbps, 8N1
RF Characteristics	
Frequency range	863 MHz to 870 MHz
RF output power	< 14 dBm ERP
Modulation	LoRa® Spread-Spectrum
	(G)FSK
Antenna	Integrated PCB antenna
LoRa® Protocol Characteristics	
LoRaWAN®	Certified and compliant to V.1.0.2 (firmware v1.0)
	Certified and compliant to V.1.0.4 (firmware v1.1)
Activation type	ABP <sup>1)</sup> (activation by personalization)
	OTAA (over the air activation)
Frequencies	Standard LoRaWAN frequencies
	Additional frequencies depend on LoRaWAN® network server
Wireless M-Bus Protocol Characteristics	
Operation Modes	S mode and combined C/T mode according to EN 13757-4
Frequencies	868.3 MHz, 868.95 MHz
Firmware Characteristics	
WM-Bus Accept Filter Size	max. 32 address entries
WM-Bus Reject Filter Size	max. 16 address entries

Duplicate Packet Filter Size	max. 64 entries
Calendar Events	max. 32 Calendar Events
<b>General Characteristics</b>	
Product	Wireless M-Bus Range Extender
Operating Temperature	typ. 5°C to 55°C
Dimension	
Part-nbr: 404600	145mm x 92mm x 55 mm
Part-nbr: 404608	157.7mm x 92mm x 58.6 mm
Installation Height	max. 2 m above ground
Housing	
Part-nbr: 404600	Polycarbonate UL94-HB, gray, -40°C to +120°C (Nema 1, 2, 4, 4x, 12, 13) (IP 65)
Part-nbr: 404608	ABS UL94-HB, gray, -30°C to +70°C (IP 67)
Certification	RED (2014/53/EC)
	RoHS Directive (2011/65/EC)
	LoRaWAN® 1.0.2 / LoRaWAN® 1.0.4

<sup>1)</sup> Note that from firmware v1.1 ABP should only be used for test purpose.

## FAQ

No.	Question	Answer
1	Range Extender LED blinks 2 x yellow after startup, but packet recording or upload is not possible	The Range Extender seems not be activated with respect to LoRaWAN. Please configure and activate the Range Extender first.
2	Range Extender LED blinks red and did not stop	The Over The Air Activation is active but it seems that no server response can be received. Please check if a LoRaWAN Gateway is in range.
3	Range Extender is receiving packets but no packet is stored or uploaded	Please verify the WM-Bus packet filter settings. The current configuration might not fit to the received packets.

