Wireless M-BUS Solutions
SPIRIT1 & STM32L
What is Wireless M-BUS?

- Open standard for Automatic Meter Reading at sub 1 GHz
- Metering Bus (or in short "M-Bus") is a basis for new Advanced Metering Infrastructure (AMI) installations. It defines the communication between meters for water, gas, heat and the data concentrators.
- Wireless M-Bus standard defines the wireless communication between meters.

Relevant standards documents are the following:
- European standard prEN13757-4:2011 Wireless meter readout
- European standard EN13757-3:2004 Dedicated application layer
- ETSI EN 300 220 v2.3.1
Wireless M-BUS scenario

- Automatic meters reading to:
  - Stationary data collectors
  - Mobile data collectors
- Meters are working without any operator’s intervention or need for battery replacement.
ST Wireless M-BUS Stack features (1/2)

• Development based on:
  • STM32L152 MCU ARM 32bit
  • SPIRIT transceiver Sub GHz
• WMBUS protocol stack EN113757-4:2011.10
• Mode supported are: S, T, R, N
  (except N2g which requires 4-GFSK modulation)
• Device Type: Meter and Concentrator
  → PHY and LINK layer implementation provided as binary library for STM32L (ARM Cortex-M3).
  → Example application layer provided in source form for user customization.
  Sniffer Type under development
• Wireless M-BUS PC GUI over USB Interface
ST Wireless M-BUS Stack features (2/2)

WMBUS Mode supported are:

- S, T, R @ 868 MHz
- N @ 169 MHz

(except N2g (*) which requires 4-GFSK modulation)

Main features are:

- Auto acknowledgment
- CRC check
- Installation mode/data mode
- Management of a simple meter database based on linked list
- Packet filtering based on registered meters
- Meter and Other roles
- Non blocking API
- AES CTR support
- AT Command (**) 

Notes: (*) N2g is multi Hop repeater, (**) Underdevelopment, Q1 / ’13
Wireless M-BUS Modes
## Wireless M-BUS modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>Direction</th>
<th>Frequency band</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Stationary mode</td>
<td>One (s1) Two way (S2)</td>
<td>868 MHz</td>
<td>Communication between meter and stationary/mobile concentrator. Manchester encoding</td>
</tr>
<tr>
<td>T</td>
<td>Frequent Transmit mode</td>
<td>One(T1) Two way (T2)</td>
<td>868 MHz</td>
<td>The meter transmits a very short frame (typically 3 ms to 8 ms) every few second's Walk-by and/or drive-by readout. Manchester and “3 out of 6 encoding”.</td>
</tr>
<tr>
<td>R</td>
<td>Frequent Receive mode</td>
<td>Two way</td>
<td>868 MHz</td>
<td>the meter listens every few seconds for the reception of a wakeup message from a mobile transceiver. Manchester encoding</td>
</tr>
<tr>
<td>C (*)</td>
<td>Compact</td>
<td>One/two way</td>
<td>868 MHz</td>
<td>Similar T, but send more info with the same energy</td>
</tr>
<tr>
<td>N</td>
<td>Narrowband VHF</td>
<td>One/two way</td>
<td>169 MHz</td>
<td>Optimized for narrowband and long range. NRZ-encoded</td>
</tr>
<tr>
<td>F (*)</td>
<td>Frequent TX &amp; RX</td>
<td>Two way</td>
<td>433 MHz</td>
<td>Wake up message from a stationary or mobile device. NRZ-encoded</td>
</tr>
</tbody>
</table>

(*) Not available in current ST WMBUS implementation
## Wireless M-BUS submodes S, T, R

<table>
<thead>
<tr>
<th>Mode</th>
<th>Direction</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>One way</td>
<td>Communication between meter and <em>stationary</em> concentrator with long header. Single channel. Format A only</td>
</tr>
<tr>
<td>S1-m</td>
<td>One way</td>
<td>Communication specialized between meter and <em>mobile</em> concentrator with short header. Single channel. Format A only</td>
</tr>
<tr>
<td>S2</td>
<td>Two way</td>
<td>Meter unit with a receiver either continuously enabled or synchronized requiring no extended preamble for wakeup. A long header is optional. Single channel. Format A only</td>
</tr>
<tr>
<td>T1</td>
<td>One way</td>
<td>Transmit only with short data bursts typically 3.8 ms every few seconds. Single channel. Format A only</td>
</tr>
<tr>
<td>T2</td>
<td>Two way</td>
<td>Transmit similar to T1 and establish two way link if ack is received. Single channel, asymmetric. Format A only</td>
</tr>
<tr>
<td>R2</td>
<td>Two way</td>
<td>Transmit regularly and wait for a wakeup message which establish a two way communication. Multichannel support. Format A only</td>
</tr>
<tr>
<td>Mode</td>
<td>Direction</td>
<td>Usage</td>
</tr>
<tr>
<td>-------</td>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>C1 (*)</td>
<td>One way</td>
<td>Transmit only, on a regular basis, with short data bursts &lt;22ms. Manchester encoded. Format A and B.</td>
</tr>
<tr>
<td>C2 (*)</td>
<td>Two way</td>
<td>Transmits like C1. Its receiver is enabled for a short period after the end of each transmission and locks on if a proper preamble and synchronization word is detected. Format A and B.</td>
</tr>
<tr>
<td>N1a-f</td>
<td>One way</td>
<td>Transmits like N1a-f. Its receiver is enabled for a short period after the end of each transmission and locks on if a proper preamble and synchronization word is detected. Format A only.</td>
</tr>
<tr>
<td>N2a-f</td>
<td>Two way</td>
<td>Transmits like N1a-f. Its receiver is enabled for a short period after the end of each transmission and locks on if a proper preamble and synchronization word is detected. Format A only.</td>
</tr>
<tr>
<td>F2-m (*)</td>
<td>Two way</td>
<td>Meter receiver with possible battery economizer, requiring extended preamble for wake-up. Single Channel. Format A and B.</td>
</tr>
<tr>
<td>F2 (*)</td>
<td>Two way</td>
<td>Meter unit transmits on a regular basis. Its receiver is enabled for a short period after the end of each transmission. It locks on if a proper preamble and synchronization word is detected. Single Channel. Format A and B.</td>
</tr>
</tbody>
</table>

(*) Not available in current ST Wireless M-BUS implementation
STM32L role:
- Wireless M-Bus (WMBUS) Application Layer
- Wireless M-Bus Link Layer
  - MAC packet
  - CRC handling
  - Encryption/Decryption initiate/read.
  - Services to application layer
- Wireless M-Bus PHY API
  - Init PHY for Wireless M-Bus
  - Command/Data exchange APIs
  - Interrupt Services
  - Power Management
  - SPIRIT Mode Management

SPIRIT1 role:
- Wireless M-Bus Modes
- Header, Sync and trailer fields
- Manchester/3-out-of-6-encoding
- Sync detection
- Tx and RX FIFO
1. The PHY payload block will be implemented in Firmware.
2. Header, Sync and Post-amble will be only configured using STM32L.
3. Data encoding and decoding at PHY level is managed by SPIRIT depending on mode selection.
4. Manchester and 3-out of 6 encoding
**PHY Layer: SPIRIT1 Packet Handler Engine**

**SPIRIT1 Embedded packet format:**

<table>
<thead>
<tr>
<th>STack</th>
<th>WM-Bus</th>
<th>BASIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preamble</td>
<td>Sync</td>
<td>Length</td>
</tr>
<tr>
<td>Preamble</td>
<td>Sync</td>
<td>Payload</td>
</tr>
<tr>
<td>Preamble</td>
<td>Sync</td>
<td>Length</td>
</tr>
</tbody>
</table>

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The WM-Bus protocol is chosen by the sub-mode selected:

- **Sub-mode 0**: Manchester code; preamble length = 279*; sync at 0x7696 (18 bits);
  
  Supports the modes **S1**, **S2** long header.

- **Sub-mode 1**: Manchester code; preamble length = 15*; sync at 0x7696 (18 bits).
  
  Supports the modes **S1-m**, **S2**, **T2** other to meter.

- **Sub-mode 3**: uses 3-out-of-6 code; preamble length = 19*; sync at 0x3D (in 10 bits)
  
  Supports the modes **T1**, **T2** meter to other.

- **Sub-mode 5**: Manchester code; preamble length = 39*; sync at 0x7696 (in 18 bits).
  
  Supports the mode **R2** short header.

- **Through the direct mode and specific configuration of the BASIC packet format (NRZ data coding)**, the SPIRIT1 supports the last sub mode: **C1**, **C2**, **N1a-f**, **N2a-f**, **F2**, **F2m**.

(*) = in ‘01’ sequence
PHY Layer: SPIRIT1 WMBUS packet structure

**PAYLOAD**
- The data to transmit are stored in this field. The length is from 0 to 65536 bytes.
- The payload length is set as: \( PCKTLEN1 \times 256 + PCKTLEN0 \).

**POSTAMPLE**
- The postamble added at the end of the packet according to the WMBus standard.
- The number of ‘01’ sequences added to the postamble is set with the \( MBUS\_PSTMBL\_CTRL \).
The WM-Bus link layer is compliant with 13757-4:2011.10
- Provides services that transfer data between PHY and Application layer
- Generate Outgoing CRC and verify CRCs for incoming messages
- Provide WM-Bus addressing
- Acknowledge transfers for bidirectional communication modes
- WM-Bus frame formation and verification of incoming frames
- Two frame formats exist A and B and they are identified by the preamble/synch bits sequence.
Frame Formats

Packets in format A and B are composed of several blocks:

- First block which contains frame length (L-field), the control information (C-field), and the senders address (Link Layer Address)
- Second block which contains CI field and payload information
- Other(s) optional blocks (max 1 for format B)

**Frame Format A**

<table>
<thead>
<tr>
<th>Block Type</th>
<th>L-field</th>
<th>C-field</th>
<th>M-field</th>
<th>A-field</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Block</td>
<td>1 byte</td>
<td>1 byte</td>
<td>2 bytes</td>
<td>6 bytes</td>
</tr>
<tr>
<td>Second Block</td>
<td>1 byte</td>
<td>15 or if it is the last block (((L-9) modulo 15) - 1) bytes</td>
<td>2 bytes</td>
<td></td>
</tr>
<tr>
<td>Optional Block</td>
<td>Data-field</td>
<td>CRC-field</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(L-129) bytes</td>
<td>2 bytes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Frame Format B**

<table>
<thead>
<tr>
<th>Block Type</th>
<th>L-field</th>
<th>C-field</th>
<th>M-field</th>
<th>A-field</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Block</td>
<td>1 byte</td>
<td>1 byte</td>
<td>2 bytes</td>
<td>6 bytes</td>
</tr>
<tr>
<td>Second Block</td>
<td>1 byte</td>
<td>115 or if it is the last block (L-12) bytes</td>
<td>2 bytes</td>
<td></td>
</tr>
<tr>
<td>Optional Block</td>
<td>Data-field</td>
<td>CRC-field</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 or if it is the last block (((L-9) modulo 16) bytes</td>
<td>2 bytes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- L-field = frame Length
- C-filed = control field
- M-field = Manufacturer ID
- A-field = Address sender
- CI-Field = Control Information field, specifies the type of data-filed
- CRC-field = Cyclic redundancy check
• Concentrator should be in installation mode (manually initiated).
• Meter send SND-IR messages to concentrator (manually initiated). The meter is doing retries in case of no response.
• Concentrator send CNF-IR to meter, subject to approval policy. A message can be also sent to the installer.
• From now on the meter is registered with concentrator and it can leave installation mode.
• Concentrator is requiring manual intervention or timeout to leave installation mode.

Note: Meter can be also preinstalled requiring no installation messages.

Meter sending data example (unidirectional mode)
• Applicable to S1, T1, C1, N1
• SND/NR Send unsolicited/periodical application data without request

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STM32L WM-BUS Firmware library

- **wmbus_appli.c**
  - Application layer provided as an example in source code
- **wmbus_link.c**
  - Link layer provided in library format
- **wmbus_phy.c**
  - PHY layer provided in library format

**MEM Footprint:**
- 2.1K RAM, 9.1KBytes FLASH (IAR optimization high (size))
- 2.1K RAM, 18 KB Flash (not optimized)
## ST WM-BUS library LINK Layer APIs

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMBus_LinkGetAttribute</td>
<td>Read attribute from link layer</td>
</tr>
<tr>
<td>WMBus_LinkSetAttribute</td>
<td>Set attribute in link layer</td>
</tr>
<tr>
<td>WMBus_LinkServicesInit</td>
<td>Init the link service layer</td>
</tr>
<tr>
<td>WMBus_LinkServicesReset</td>
<td>Reset the link service layer</td>
</tr>
<tr>
<td>WMBus_LinkRadioPowerOn</td>
<td>Power on radio</td>
</tr>
<tr>
<td>WMBus_LinkRadioPowerOff</td>
<td>Power off radio</td>
</tr>
<tr>
<td>WMBus_LinkRadioStandby</td>
<td>Put the radio in standby</td>
</tr>
<tr>
<td>WMBus_LinkRadioResume</td>
<td>Resume radio from standby</td>
</tr>
<tr>
<td>WMBus_LinkServicesRequestsCallbackMode</td>
<td>This function processes a request service primitive, generates a valid C-field by setting the FCV, FCB, and PRM bits, transmits the request frame, checks for confirm/response is applicable, and retries data transmission when appropriate (Send/Confirm, Request/Respond when valid ack/nack is not received).</td>
</tr>
<tr>
<td>WMBus_LinkServicesIndicationCallbackMode</td>
<td>Receive message within a specific timeout</td>
</tr>
<tr>
<td>WMBus_LinkServicesResponseCallbackMode</td>
<td>This function attempts to transmit the response to the indication frame received.</td>
</tr>
</tbody>
</table>
WMBUS PC GUI application

The PC GUI is available in different windows:
- Device Configuration
- Meter Application
- Monitoring
References

- EN 13757-4:2005, *Communication systems for meters and remote reading of meters - Part 4: Wireless meter readout (Radio meter reading for operation in the 868 MHz to 870 MHz SRD 10 band)*

WMBUS ST tools:
1) SPIRIT1 development kit
2) Smart GAS Meter evaluation board
SPIRIT1 development kit

- Hardware:
  - 2 Motherboards (STM32L)
  - 2 SPIRIT1 modules, antenna connector
  - 2 antennas

- Programmable through GUI
  - SPIRIT1 performance can be easily checked/tested

- Highly portable driver available
  - Examples
  - Documentation
  - User manual
ST evaluation board at 169 MHz +27 dBm

- Specifically designed to meet Wireless-MBUS requirements @ 169 MHz.
- Reference design based on external PA SkyWorks SKY66100-11
- Saw Filter TAI-SAW Technology TA0437A to respect emission regulations
  - $F_c = 169$ MHz, $BW = 8.8$ MHz typ.
  - $IL = 1.5$ dB typ., $Atten = 52$ dB typ.
- CEL uPD5740T6N external LNA to improve sensitivity about 9 dB
- TCXO 25 MHz NDK NT2016SB
Smart GAS Meter evaluation board

- STM32L162: 32-bit MCU (ARM Cortex-M3) Ultra Low Power
- SPIRIT1: Sub GHz RF transceiver
- LIS3DH: Accelerometer for Earthquake
- M24LR64: DUAL EEPROM RFID/I2C
- M24M02: EEPROM
- M41T62: external RTC
- STTS751: Temperature Sensor
- **Omron GAS Sensor** (OMRON and ST co-development)

Android Application is available to read/write gas meter parameter by RFID/NFC
Smart GAS Meter – Evaluation Board

preliminary

OMRON sensor

Solution
Under Development

STM32L162
M24LR64
LIS3DH
M41T62
STTS751
SPIRIT1 module

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SPIRIT1 – Sub 1-GHz RF Transceiver

- **Frequency bands**: 300-348 MHz, 387-470 MHz, 779-956 MHz
- **Modulation schemes**: FSK, GFSK, MSK, OOK, and ASK
- **Air data rate** from 1 to **500 kbps**
- Programmable **output power**: from -30dBm to +12dBm
- Low current consumption (8mA RX, 433 MHz, FSK, 38.4kbps)
- Programmable **channel spacing** (12.5 kHz min). Compatibility with **narrow band system**
- **Frequency Hopping** is allowed
- Automatic acknowledgement, retransmission, and timeout protocol engine
- **AES 128-bit encryption** co-processor
- **Antenna diversity** algorithm
- Package: **QFN20 4x4 mm**
  - Three packet configurations
    - Basic
    - STack
    - Wireless M-BUS
  - Link quality indicators and received signal qualifier (RSSI, LQI, PQI, SQI, CS)
  - Supports CSMA/CA

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# SPIRIT1: Key features

**Antenna Diversity Algorithm**
- An external switch is controlled to select the antenna with the highest RSSI.
- While receiving the preamble, the antennas are repeatedly switched until the RSSI threshold.
- The switch is then disabled and the selected antenna is used.

**Operating Modes/Consumption**
- **SHUTDOWN** (20mA)
- **STAND-BY** (300mA)
- **READY** (500mA)
- **SLEEP** (600mA)

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## COMPETITION BENCHMARKING

<table>
<thead>
<tr>
<th></th>
<th>SPIRIT1</th>
<th>BEST IN CLASS COMPETITOR</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER CONSUMPTION (@3V)</strong></td>
<td>24mW</td>
<td>W/O DC-DC converter</td>
<td>45mW from 30% to 50% power saving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W/ EXT DC-DC converter</td>
<td>32mW</td>
</tr>
<tr>
<td><strong>SENSITIVITY (@1.2kbps)</strong></td>
<td>-120dBm</td>
<td>-111dBm</td>
<td></td>
</tr>
<tr>
<td><strong>PROGRAMMABLE CHANNEL SPACING</strong></td>
<td>YES, 12.5kHz</td>
<td>YES but 200kHz only</td>
<td>Can't design NARROW BAND SYSTEMS</td>
</tr>
<tr>
<td><strong>ANTENNA DIVERSITY</strong></td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Automatic ACK, retransmission and timeout protocol engine</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>

---

## CSMA/CA algorithm

**NODE A**
- \( T_{TX} \) = PACKET
- \( T_{RX} \) = PACKET

**NODE B**
- **BO** = Back-off time [BO]
- \( T_{LISTEN} \) = TX request
- \( T_{LISTEN} = [1 \ldots 15] \times T_{CCA} \)

**NODE C**
- **BO**
- **BO**
- **BO**
- \( T_{LISTEN} \) = PACKET

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STM32L - Ultra-low power STM32

- Energy saving
  - ARM Cortex-M3 core @ 32 MHz
  - -40 to 125 °C
  - Ultra-low power in dynamic and static modes

- Power supply:
  - 1.65 to 3.6V without BOR
  - 1.8 to 3.6V with BOR

- Special features
  - 32 to 128-Kbyte Flash
  - 10 to 16-Kbyte SRAM
  - 4-Kbyte data EEPROM
  - Segment LCD 8x40
  - Comparator

- Pin-to-pin compatible with STM32 family
STM32L: Advanced ultra-low-power MCU

Optimized Run mode with Voltage scaling

Safe start-up with BOR

Security & Safety

- Memory Protection Unit
- Anti tamper
- Reset circuitry
- CRC 32-bit
- Back-up clock
- Back-up registers
- Flash protection
- Dual watchdog
- Unique ID
- I/O looking
- Supply monitoring
- Dual stack pointer
- NV memories with ECC
- JTAG fuse

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