WMP. LoRaWAN Protocol Stack and Data Structures

Rev.1.3

Revision History

Version	Date	Description
0.9	11.06.2024	Draft document revision
1.0	12.06.2024	First document revision
1.1	19.06.2024	New commands added, binary examples added, minor editorial changes
1.2	26.06.2024	Additional data readout payload examples added, sub-section “Conventions” added, minor editorial changes
1.3	06.08.2024	Changed algorithm of confirmation, added configuration parameters ACK_LIMIT and ACK_DELAY

Contents

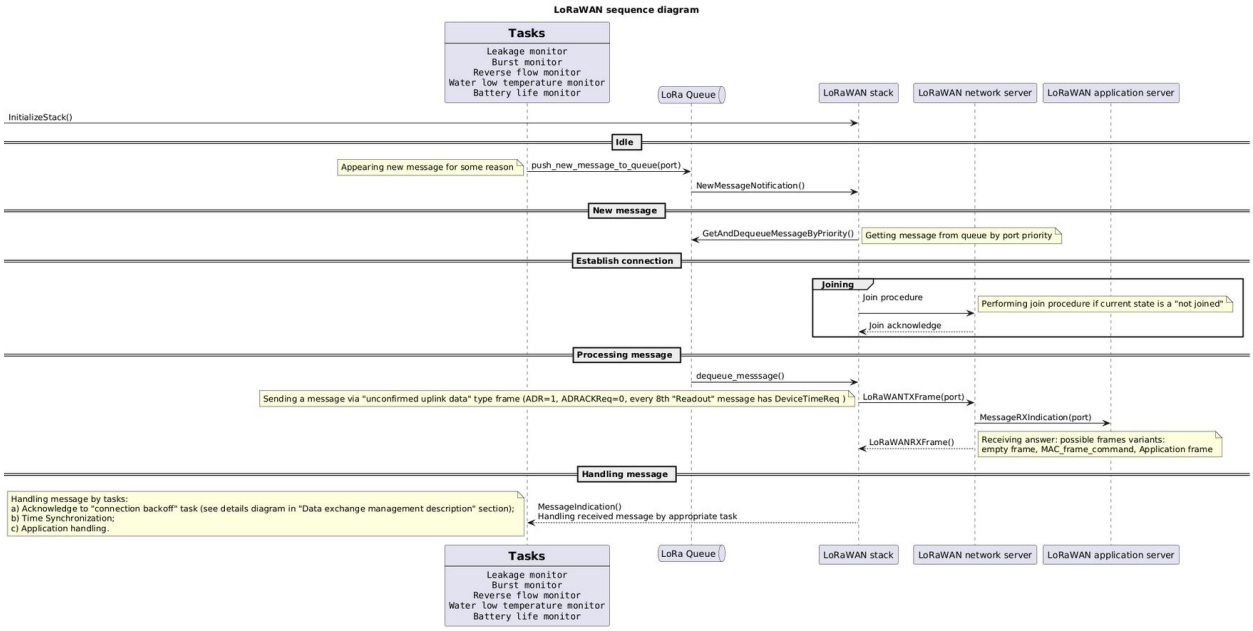
LoRaWAN Protocol Stack

LoRaWAN protocol stack has the following structure:

Application layer	Proprietary
Data Link layer	LoRaWAN Specification Version: V1.0.4 LoRaWAN Region: EU863-870 LoRaWAN Regional Parameters Version: REP002-V1.0.4 Class of Operation: A
Physical Layer	LoRa PHY

LoRaWAN communication

LoRaWAN communication details are shown on UML message sequence diagram below.



Text presentation of this diagram can be found in Appendix A.

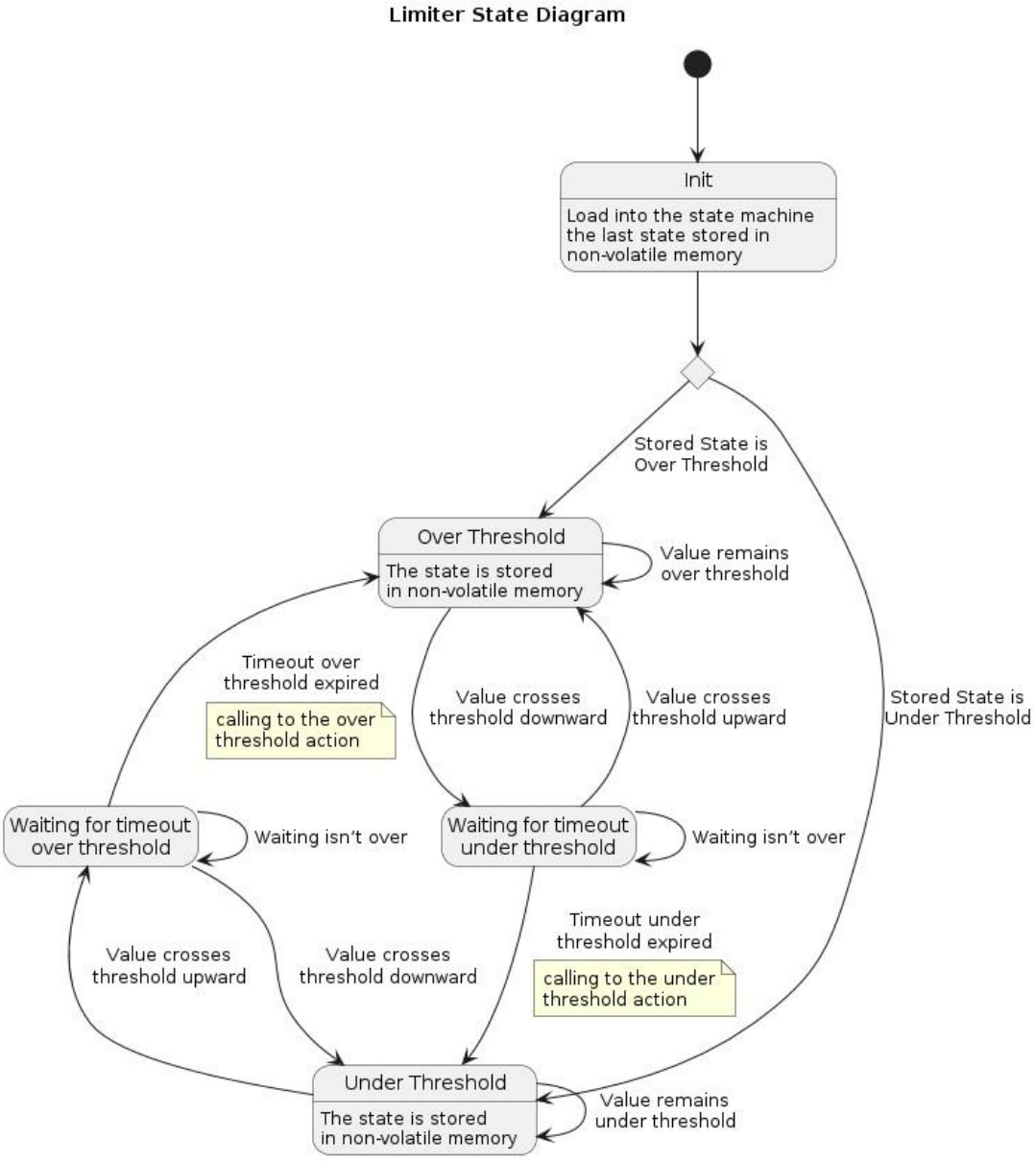
Alarm Management

Water meter periodically monitors set of physical values (such as flow rates, temperature, etc. At some conditions it raises an alarm and sends alarm message via LoRaWAN.

Alarm management logic is based on so called Limiter concept (the term comes from eponymous DLMS/COSEM interface class). For each type of limiter the following parameters can be set up locally via BLE port or remotely via LoRaWAN:

THRESHOLD VALUE

OVER THRESHOLD DURATION
UNDER THRESHOLD DURATION
VALVE ACTION OVER THRESHOLD
VALVE ACTION UNDER THRESHOLD
If the monitored physical value (e.g., water temperature) crosses THRESHOLD VALUE upward for at least OVER THRESHOLD DURATION, defined VALVE ACTION OVER THRESHOLD is invoked.
If the monitored physical value (e.g., water temperature) crosses THRESHOLD VALUE downward for at least OVER THRESHOLD DURATION, defined VALVE ACTION OVER THRESHOLD is invoked.
UML state diagram for limiter logic is shown below:



Text presentation of the Limiter state diagram can be found in Appendix A.

Possible actions:
NO ACTION,
OPEN/CLOSE VALVE (IF EXISTS)
GENERATE AN EVENT IN EVENT LOG.
The following configurable limiter types rare implemented:
0 – Leakage

1 – Burst
2 – Reverse flow
3 – Water temperature
4 – Battery lifetime
Each limiter type can send alarm message, if it is configured in the Alarm Messages Filter. Limiter types 1 to 3 generate and send alarm messages when corresponding physical value crosses define threshold upward, the rest two – when crossing downward.
Format of Command and alarm messages are described in section "LoRaWAN Application Layer Protocol".

LoRaWAN Application Layer Protocol

Introduction

The following message types are supported for communication over LaRaWAN: periodical information (Readout) message, Alarms message and Commands message.
Also, meter supports all MAC commands and periodically performs Clock Synchronization and connection checking procedures.

Conventions

In all message data fields in this document byte sequence is little-endian. Some comments may use C-like designation 0xABCD, these values have big endian byte sequence.

List of Messages

Name	Direction	Port	Purpose
Readout message	Out	100	Periodic message that contains the measurements, alarms and battery status.
Alarm message	Out	103	Asynchronous message that is sent every time an alarm is triggered on the meter.
Valve control	In	103	Command that is used for changing the state of optional valve.
Clear Alarms	In	103	Command that is used for clearing the alarm status on the meter. Does not affect the irreversible alarms.
Set wM-Bus "activity hours"	In/Out	104	Sets the wM-Bus transmission period, and begin and end hours of the transmission window.
Get wM-Bus "activity hours"	In/Out	104	Gets the wM-Bus transmission period, and begin and end hours of the transmission window.
Set "Limiters"	In/Out	104	Sets "Limiter" parameters: threshold value, time over and under threshold, actions over and under the threshold.
Get "Limiters"	In/Out	104	Gets "Limiter" parameters: threshold value, time over and under threshold, actions over and under the threshold.
Get Firmware version	In/Out	104	Gets the firmware version string.
Set Alarm Filter	In/Out	104	Sets the alarm filter mask. Does not affect the irreversible alarms.
Get Alarm Filter	In/Out	104	Gets the alarm filter mask.
Set "Readout message" transmission parameters	In/Out	104	Sets transmission parameters for the Readout message, such as the periodicity, number of

			repetitions, first package and repeat package randomization periods.
Get “Readout message” transmission parameters	In/Out	104	Gets transmission parameters for the Readout message.
Set ACK_LIMIT and ACK_DELAY parameters	In/Out	104	Sets ACK_LIMIT and ACK_DELAY parameters used for checking presents and restoring communication with the network.
Get ACK_LIMIT and ACK_DELAY parameters	In/Out	104	Gets ACK_LIMIT and ACK_DELAY parameters.

Data exchange management description

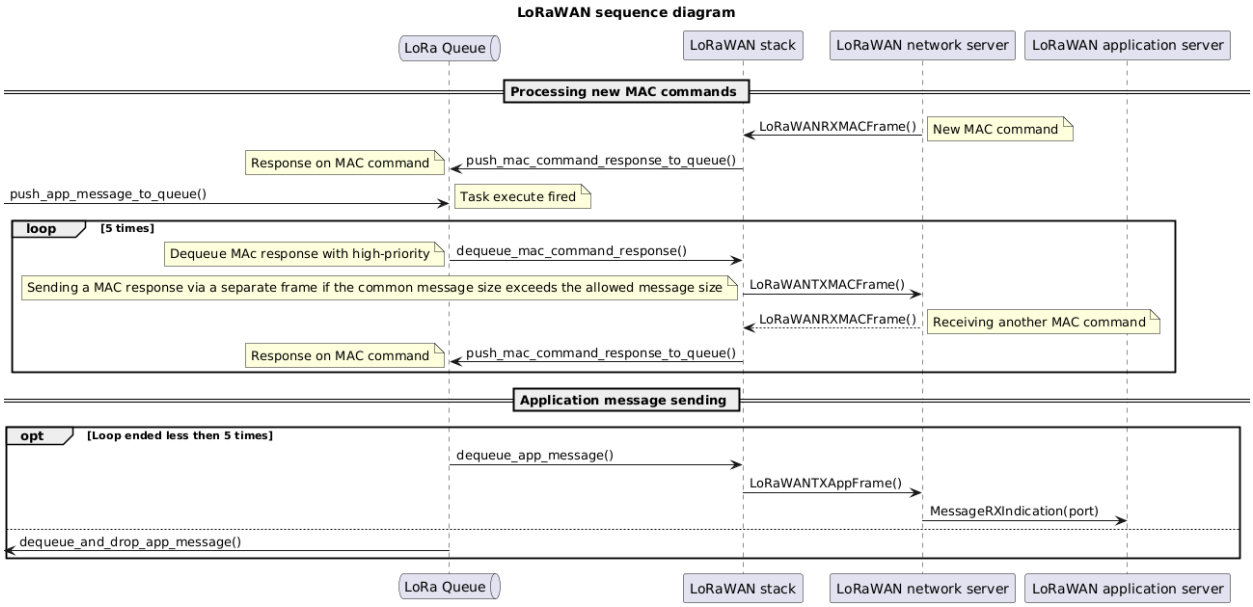
All uplink messages are transmitted by unconfirmed data uplink frame type. By default, ADR procedure is switched on, it can be switched off through local interface (BLE). NbTrans is statically set to 1.
“Connection lost backoff” procedure is executed to check for connectivity loss. Every N-th (equal to ACK_LIMIT parameter) Readout message contains MAC command DeviceTimeReq for Clock Synchronization request. If meter receives an answer, the counter of packets, sent without answer, resets to zero and clock synchronization is performed, otherwise ACKcnt counter is incremented.
If ACKcnt is equal to (ACK_LIMIT + ACK_DELAY), meter resets TX power to default value. If count of errors is equal to (ACK_LIMIT + 2*ACK_DELAY), meter resets Data Rate to default value. On the next step meter resets NbTrans to 1 and channels mask to default value. At last meters goes to un-joined state for OTAA mode.

The table below provides an example of the connection backoff procedure for ACK_LIMIT=8 and ACK_DELAY=4 parameters.

ACKcnt	**DeviceTimeReq**	**Data Rate**	**TX Power**	**NbTrans**	**Channel Mask**
0 to 7	No	DRx	Max – K	1 or >1	Normal operations channel mask
8 to 11	Yes	No change	No change	No change	No change
12 to 15	Yes	No change	Reset to Default	No change	No change
16 to 19	Yes	Reset to default	Default	No change	No change
20 to 23	Yes	Default	Default	Set to 1	Re-enable default channels
24	Performing Re-join (For OTAA mode)				

In case of receiving MAC commands, and when reply message exceeds the allowed message size (such MAC commands as NewChannelReq, LinkADRReq, etc), meter performs up to 5 additional sending attempts. To avoid additional power consumption, the network server should minimize MAC command requests and combine multiple commands into one frame.

Details are shown on UML message sequence diagram below



Readout Message

Readout message is transmitted periodically over port 100 by using unconfirmed data uplink frame type. Transmission period can be configured though meter local port or by command “Set “Readout message” transmission parameters”. For each N-th Readout message in the frame set DeviceTimeReq command to request Clock Synchronization. For this request meter waits for answer from the LoRaWAN network server (at the MAC layer). See detailed description in “Data exchange management description” section.

Data packet has static format:

Offset, bytes	Length in bytes	Description
0	4	Transmission date and time
4	3	Valve Status/Alarms
7	1	Remaining battery lifetime (in months)
8	4	Current forward volume
12	4	Current backward volume
16	4	Log date and time
20	4	Volume at log date and time
24	2	Delta volume 1
26	2	Delta volume 2
28	2	Delta volume 3
30	2	Delta volume 4
32	2	Delta volume 5
34	2	Delta volume 6
36	2	Delta volume 7
38	2	Delta volume 8
40	2	Delta volume 9
42	2	Delta volume 10
44	2	Delta volume 11

46	2	Delta volume 12
Total	48	

"Current date and time" and "Log date and time" fields have UNIX data-time format. For example, value 0x5AE46015 is April 28, 2018 11:50:45 UTC.
"Valve Status/Alarms" field contains information about actual water valve state and alarms. Field format is described in the section "Alarm Message".
The message contains 12 values of hourly water consumption. In the field "Log date and time" data/time start time (beginning of hour) is set, and in the field "Volume at log date and time" corresponding values of hourly water consumption are presented.
Values of hourly water consumption are presented in 0.001 m3 (liters).

Readout message example 1:

10 44 6F 66 81 44 40 08 70 16 00 00 00 00 00 00 D0 00 6E 66 80 13 00 00 0A 00 00 00 00 00 00 00 00 00 08 00 15 00 2D 00 2E 00 2E 00 2C 00 21 00

10_h 44_h $6F_h$ 66_h	Transmission Date/Time in UNIX time format: 0x666F4410 = 1718567952 = Sunday, 16 June 2024 19:59:12 UTC (corresponds to Sunday, 16 June 2024 22:59:12 GMT+03:00 DST)
81_h 44_h 40_h	Valve Status/Alarms: WV opened 100%, WV communication error, low battery, tamper opened, dry
08_h	Remaining battery lifetime: 8 months
70_h 16_h 00_h 00_h	Forward volume on Sun Jun 16 2024 22:59:12: 5744 liters
00_h 00_h 00_h 00_h	Reverse volume on Sun Jun 16 2024 22:59:12: 0 liters
$D0_h$ 00_h $6E_h$ 66_h	Log Date/Time in UNIX time format: 0x666E00D0 = 1718485200 = Saturday, 15 June 2024 г., 21:00:00 UTC (corresponds to Sunday, 16 June 2024 00:00:00 GMT+03:00 DST)
80_h 13_h 00_h 00_h	Forward volume at Sun Jun 16 2024 00:00:00: 4996 liters
$0A_h$ 00_h	Delta forward volume at 00:00:00-01:00:00 Jun 16 2024: 10 liters
00_h 00_h	Delta forward volume at 01:00:00-02:00:00 Jun 16 2024: 0 liters
00_h 00_h	Delta forward volume at 02:00:00-03:00:00 Jun 16 2024: 0 liters
00_h 00_h	Delta forward volume at 03:00:00-04:00:00 Jun 16 2024: 0 liters
00_h 00_h	Delta forward volume at 04:00:00-05:00:00 Jun 16 2024: 0 liters
08_h 00_h	Delta forward volume at 05:00:00-06:00:00 Jun 16 2024: 8 liters
15_h 00_h	Delta forward volume at 06:00:00-07:00:00 Jun 16 2024: 21 liters
$2D_h$ 00_h	Delta forward volume at 07:00:00-08:00:00 Jun 16 2024: 45 liters
$2E_h$ 00_h	Delta forward volume at 08:00:00-09:00:00 Jun 16 2024: 46 liters
$2E_h$ 00_h	Delta forward volume at 09:00:00-10:00:00 Jun 16 2024: 46 liters
$2C_h$ 00_h	Delta forward volume at 10:00:00-11:00:00 Jun 16 2024: 44 liters
21_h 00_h	Delta forward volume at 11:00:00-12:00:00 Jun 16 2024: 33 liters

Readout message example 2:

1C 9F 75 66 01 02 40 9A ED 07 00 00 00 00 00 00 50 98 74 66 ED 07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

$1C_h$ $9F_h$ 75_h 66_h	Transmission Date/Time in UNIX time format: 1718984476 = Friday, 21 June 2024 15:41:16 UTC (corresponds to Friday, 21 June 2024 18:41:16 GMT+03:00 DST)
01_h 02_h 40_h	Valve Status/Alarms:

	WV opened 100%, firmware changed, dry
$9A_h$	Remaining battery lifetime: 154 months
ED_h 07_h 00_h 00_h	Forward volume: 2029 liters
00_h 00_h 00_h 00_h	Reverse volume: 0 liters
50_h 98_h 74_h 66_h	Log Date/Time in UNIX time format: 1718917200 = Thursday, 20 June 2024 21:00:00 UTC (corresponds to Friday, 21 June 2024 00:00:00 GMT+03:00 DST)
ED_h 07_h 00_h 00_h	Forward volume at log Date/Time: 2029 liters
00_h 00_h	Delta forward volume at 00:00:00-01:00:00: 0 liters
00_h 00_h	Delta forward volume at 01:00:00-02:00:00: 0 liters
00_h 00_h	Delta forward volume at 02:00:00-03:00:00: 0 liters
00_h 00_h	Delta forward volume at 03:00:00-04:00:00: 0 liters
00_h 00_h	Delta forward volume at 04:00:00-05:00:00: 0 liters
00_h 00_h	Delta forward volume at 05:00:00-06:00:00: 0 liters
00_h 00_h	Delta forward volume at 06:00:00-07:00:00: 0 liters
00_h 00_h	Delta forward volume at 07:00:00-08:00:00: 0 liters
00_h 00_h	Delta forward volume at 08:00:00-09:00:00: 0 liters
00_h 00_h	Delta forward volume at 09:00:00-10:00:00: 0 liters
00_h 00_h	Delta forward volume at 10:00:00-11:00:00: 0 liters
00_h 00_h	Delta forward volume at 11:00:00-12:00:00: 0 liters

Readout message example 3:

A3 FF 75 66 01 02 40 9A ED 07 00 00 00 00 00 00 10 41 75 66 ED 07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

$A3_h$ FF_h 75_h 66_h	Transmission Date/Time in UNIX time format: 1719009187 = Friday, 21 June 2024 22:33:07 UTC (corresponds to Saturday, 22 June 2024 01:33:07 GMT+03:00 DST)
01_h 02_h 40_h	Valve Status/Alarms: WV opened 100%, firmware changed, dry
$9A_h$	Remaining battery lifetime: 154 months
ED_h 07_h 00_h 00_h	Forward volume: 2029 liters
00_h 00_h 00_h 00_h	Reverse volume: 0 liters
10_h 41_h 75_h 66_h	Log Date/Time in UNIX time format: 1718960400 = Friday, 21 June 2024 09:00:00 UTC (corresponds to Friday, 21 June 2024 12:00:00 GMT+03:00 DST)
ED_h 07_h 00_h 00_h	Forward volume at log Date/Time: 2029 liters
00_h 00_h	Delta forward volume at 12:00:00-13:00:00: 0 liters
00_h 00_h	Delta forward volume at 13:00:00-14:00:00: 0 liters
00_h 00_h	Delta forward volume at 14:00:00-15:00:00: 0 liters
00_h 00_h	Delta forward volume at 15:00:00-16:00:00: 0 liters
00_h 00_h	Delta forward volume at 16:00:00-17:00:00: 0 liters
00_h 00_h	Delta forward volume at 17:00:00-18:00:00: 0 liters
00_h 00_h	Delta forward volume at 18:00:00-19:00:00: 0 liters
00_h 00_h	Delta forward volume at 19:00:00-20:00:00: 0 liters
00_h 00_h	Delta forward volume at 20:00:00-21:00:00: 0 liters
00_h 00_h	Delta forward volume at 21:00:00-22:00:00: 0 liters
00_h 00_h	Delta forward volume at 22:00:00-23:00:00: 0 liters
00_h 00_h	Delta forward volume at 23:00:00-24:00:00: 0 liters

Readout message example 4:

67 FA 76 66 01 02 40 9A ED 07 00 00 00 00 00 00 D0 E9 75 66 ED 07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

67$_h$ FA$_h$ 76$_h$ 66$_h$	Transmission Date/Time in UNIX time format: 1719073383 = Saturday, 22 June 2024 16:23:03 UTC (corresponds to Saturday, 22 June 2024 19:23:03 GMT+03:00 DST)
01$_h$ 02$_h$ 40$_h$	Valve Status/Alarms: WV opened 100%, firmware changed, dry
9A$_h$	Remaining battery lifetime: 154 months
ED$_h$ 07$_h$ 00$_h$ 00$_h$	Forward volume: 2029 liters
00$_h$ 00$_h$ 00$_h$ 00$_h$	Reverse volume: 0 liters
D0$_h$ E9$_h$ 75$_h$ 66$_h$	Log Date/Time in UNIX time format: 1719003600 = Friday, 21 June 2024 21:00:00 UTC (corresponds to Saturday, 22 June 2024 00:00:00 GMT+03:00 DST)
ED$_h$ 07$_h$ 00$_h$ 00$_h$	Forward volume at log Date/Time: 2029 liters
00$_h$ 00$_h$	Delta forward volume at 00:00:00-01:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 01:00:00-02:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 02:00:00-03:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 03:00:00-04:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 04:00:00-05:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 05:00:00-06:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 06:00:00-07:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 07:00:00-08:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 08:00:00-09:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 09:00:00-10:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 10:00:00-11:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 11:00:00-12:00:00: 0 liters

Readout message example 5:

23 57 77 66 01 02 40 9A ED 07 00 00 00 00 00 00 90 92 76 66 ED 07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

23$_h$ 57$_h$ 77$_h$ 66$_h$	Transmission Date/Time in UNIX time format: 1719097123 = Saturday, 22 June 2024 22:58:43 UTC (corresponds to Sunday, 23 June 2024 01:58:43 GMT+03:00 DST)
01$_h$ 02$_h$ 40$_h$	Valve Status/Alarms: WV opened 100%, firmware changed, dry
9A$_h$	Remaining battery lifetime: 154 months
ED$_h$ 07$_h$ 00$_h$ 00$_h$	Forward volume: 2029 liters
00$_h$ 00$_h$ 00$_h$ 00$_h$	Reverse volume: 0 liters
90$_h$ 92$_h$ 76$_h$ 66$_h$	Log Date/Time in UNIX time format: 1719046800 = Saturday, 22 June 2024 09:00:00 UTC (corresponds to Saturday, 22 June 2024 12:00:00 GMT+03:00 DST)
ED$_h$ 07$_h$ 00$_h$ 00$_h$	Forward volume at log Date/Time: 2029 liters
00$_h$ 00$_h$	Delta forward volume at 12:00:00-13:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 13:00:00-14:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 14:00:00-15:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 15:00:00-16:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 16:00:00-17:00:00: 0 liters
00$_h$ 00$_h$	Delta forward volume at 17:00:00-18:00:00: 0 liters

00_h 00_h	Delta forward volume at 18:00:00-19:00:00: 0 liters
00_h 00_h	Delta forward volume at 19:00:00-20:00:00: 0 liters
00_h 00_h	Delta forward volume at 20:00:00-21:00:00: 0 liters
00_h 00_h	Delta forward volume at 21:00:00-22:00:00: 0 liters
00_h 00_h	Delta forward volume at 22:00:00-23:00:00: 0 liters
00_h 00_h	Delta forward volume at 23:00:00-24:00:00: 0 liters

Readout message example 6:

D4 79 78 66 01 02 40 9A ED 07 00 00 00 00 00 00 50 3B 77 66 ED 07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

$D4_h$ 79_h 78_h 66_h	Transmission Date/Time in UNIX time format: 1719171540 = Sunday, 23 June 2024 19:39:00 UTC (corresponds to Sunday, 23 June 2024 22:39:00 GMT+03:00 DST)
01_h 02_h 40_h	Valve Status/Alarms: WV opened 100%, firmware changed, dry
$9A_h$	Remaining battery lifetime: 154 months
ED_h 07_h 00_h 00_h	Forward volume: 2029 liters
00_h 00_h 00_h 00_h	Reverse volume: 0 liters
50_h $3B_h$ 77_h 66_h	Log Date/Time in UNIX time format: 1719090000 = Saturday, 22 June 2024 21:00:00 UTC (corresponds to Sunday, 23 June 2024 00:00:00 GMT+03:00 DST)
ED_h 07_h 00_h 00_h	Forward volume at log Date/Time: 2029 liters
00_h 00_h	Delta forward volume at 00:00:00-01:00:00: 0 liters
00_h 00_h	Delta forward volume at 01:00:00-02:00:00: 0 liters
00_h 00_h	Delta forward volume at 02:00:00-03:00:00: 0 liters
00_h 00_h	Delta forward volume at 03:00:00-04:00:00: 0 liters
00_h 00_h	Delta forward volume at 04:00:00-05:00:00: 0 liters
00_h 00_h	Delta forward volume at 05:00:00-06:00:00: 0 liters
00_h 00_h	Delta forward volume at 06:00:00-07:00:00: 0 liters
00_h 00_h	Delta forward volume at 07:00:00-08:00:00: 0 liters
00_h 00_h	Delta forward volume at 08:00:00-09:00:00: 0 liters
00_h 00_h	Delta forward volume at 09:00:00-10:00:00: 0 liters
00_h 00_h	Delta forward volume at 10:00:00-11:00:00: 0 liters
00_h 00_h	Delta forward volume at 11:00:00-12:00:00: 0 liters

Readout message example 7:

E5 00 79 66 01 02 40 9A ED 07 00 00 00 00 00 00 10 E4 77 66 ED 07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

$E5_h$ 00_h 79_h 66_h	Transmission Date/Time in UNIX time format: 1719206117 = Monday, 24 June 2024 05:15:17 UTC (corresponds to Monday, 24 June 2024 08:15:17 GMT+03:00 DST)
01_h 02_h 40_h	Valve Status/Alarms: WV opened 100%, firmware changed, dry
$9A_h$	Remaining battery lifetime: 154 months
ED_h 07_h 00_h 00_h	Forward volume: 2029 liters
00_h 00_h 00_h 00_h	Reverse volume: 0 liters
10_h $E4_h$ 77_h 66_h	Log Date/Time in UNIX time format:

	1719133200 = Sunday, 23 June 2024 09:00:00 UTC (corresponds to Sunday, 23 June 2024 12:00:00 GMT+03:00 DST)
ED_h 07_h 00_h 00_h	Forward volume at log Date/Time: 2029 liters
00_h 00_h	Delta forward volume at 12:00:00-13:00:00: 0 liters
00_h 00_h	Delta forward volume at 13:00:00-14:00:00: 0 liters
00_h 00_h	Delta forward volume at 14:00:00-15:00:00: 0 liters
00_h 00_h	Delta forward volume at 15:00:00-16:00:00: 0 liters
00_h 00_h	Delta forward volume at 16:00:00-17:00:00: 0 liters
00_h 00_h	Delta forward volume at 17:00:00-18:00:00: 0 liters
00_h 00_h	Delta forward volume at 18:00:00-19:00:00: 0 liters
00_h 00_h	Delta forward volume at 19:00:00-20:00:00: 0 liters
00_h 00_h	Delta forward volume at 20:00:00-21:00:00: 0 liters
00_h 00_h	Delta forward volume at 21:00:00-22:00:00: 0 liters
00_h 00_h	Delta forward volume at 22:00:00-23:00:00: 0 liters
00_h 00_h	Delta forward volume at 23:00:00-24:00:00: 0 liters

Readout message example 8:

7C D1 79 66 01 02 00 9A 58 08 00 00 00 00 00 00 D0 8C 78 66 ED 07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

$7C_h$ $D1_h$ 79_h 66_h	Transmission Date/Time in UNIX time format: 1719259516 = Monday, 24 June 2024 20:05:16 UTC (corresponds to Monday, 24 June 2024 23:05:16 GMT+03:00 DST)
01_h 02_h 00_h	Valve Status/Alarms: WV opened 100%, firmware changed
$9A_h$	Remaining battery lifetime: 154 months
58_h 08_h 00_h 00_h	Forward volume: 2136 liters
00_h 00_h 00_h 00_h	Reverse volume: 0 liters
$D0_h$ $8C_h$ 78_h 66_h	Log Date/Time in UNIX time format: 1719176400 = Sunday, 23 June 2024 21:00:00 UTC (corresponds to Monday, 24 June 2024 00:00:00 GMT+03:00 DST)
ED_h 07_h 00_h 00_h	Forward volume at log Date/Time: 2029 liters
00_h 00_h	Delta forward volume at 00:00:00-01:00:00: 0 liters
00_h 00_h	Delta forward volume at 01:00:00-02:00:00: 0 liters
00_h 00_h	Delta forward volume at 02:00:00-03:00:00: 0 liters
00_h 00_h	Delta forward volume at 03:00:00-04:00:00: 0 liters
00_h 00_h	Delta forward volume at 04:00:00-05:00:00: 0 liters
00_h 00_h	Delta forward volume at 05:00:00-06:00:00: 0 liters
00_h 00_h	Delta forward volume at 06:00:00-07:00:00: 0 liters
00_h 00_h	Delta forward volume at 07:00:00-08:00:00: 0 liters
00_h 00_h	Delta forward volume at 08:00:00-09:00:00: 0 liters
00_h 00_h	Delta forward volume at 09:00:00-10:00:00: 0 liters
00_h 00_h	Delta forward volume at 10:00:00-11:00:00: 0 liters
00_h 00_h	Delta forward volume at 11:00:00-12:00:00: 0 liters

Readout message example 9:

8A 28 7A 66 01 02 00 9A 58 08 00 00 00 00 00 00 90 35 79 66 ED 07 00 00 21 00 0A 00 29 00 17 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

$8A_h$ 28_h $7A_h$ 66_h	Transmission Date/Time in UNIX time format: 1719281802 = Tuesday, 25 June 2024 02:16:42 UTC (corresponds to Tuesday, 25 June 2024 05:16:42 GMT+03:00 DST)
01_h 02_h 00_h	Valve Status/Alarms: WV opened 100%, firmware changed
$9A_h$	Remaining battery lifetime: 154 months
58_h 08_h 00_h 00_h	Forward volume: 2136 liters
00_h 00_h 00_h 00_h	Reverse volume: 0 liters
90_h 35_h 79_h 66_h	Log Date/Time in UNIX time format: 1719219600 = Monday, 24 June 2024 09:00:00 UTC (corresponds to Monday, 24 June 2024 12:00:00 GMT+03:00 DST)
ED_h 07_h 00_h 00_h	Forward volume at log Date/Time: 2029 liters
21_h 00_h	Delta forward volume at 12:00:00-13:00:00: 33 liters
$0A_h$ 00_h	Delta forward volume at 13:00:00-14:00:00: 10 liters
29_h 00_h	Delta forward volume at 14:00:00-15:00:00: 41 liters
17_h 00_h	Delta forward volume at 15:00:00-16:00:00: 23 liters
00_h 00_h	Delta forward volume at 16:00:00-17:00:00: 0 liters
00_h 00_h	Delta forward volume at 17:00:00-18:00:00: 0 liters
00_h 00_h	Delta forward volume at 18:00:00-19:00:00: 0 liters
00_h 00_h	Delta forward volume at 19:00:00-20:00:00: 0 liters
00_h 00_h	Delta forward volume at 20:00:00-21:00:00: 0 liters
00_h 00_h	Delta forward volume at 21:00:00-22:00:00: 0 liters
00_h 00_h	Delta forward volume at 22:00:00-23:00:00: 0 liters
00_h 00_h	Delta forward volume at 23:00:00-24:00:00: 0 liters

Readout message example 10:

2C 9A 7A 66 01 02 00 9A 58 08 00 00 00 00 00 00 50 DE 79 66 58 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

2C 9A 7A 66	Transmission Date/Time in UNIX time format: 1719310892 = Tuesday, 25 June 2024 10:21:32 UTC (corresponds to Tuesday, 25 June 2024 13:21:32 GMT+03:00 DST)
01_h 02_h 00_h	Valve Status/Alarms: WV opened 100%, firmware changed
$9A_h$	Remaining battery lifetime: 154 months
58_h 08_h 00_h 00_h	Forward volume: 2136 liters
00_h 00_h 00_h 00_h	Reverse volume: 0 liters
50_h DE_h 79_h 66_h	Log Date/Time in UNIX time format: 1719262800 = Monday, 24 June 2024 21:00:00 UTC (corresponds to Tuesday, 25 June 2024 00:00:00 GMT+03:00 DST)
58_h 08_h 00_h 00_h	Forward volume at log Date/Time: 2136 liters
00_h 00_h	Delta forward volume at 00:00:00-01:00:00: 0 liters
00_h 00_h	Delta forward volume at 01:00:00-02:00:00: 0 liters
00_h 00_h	Delta forward volume at 02:00:00-03:00:00: 0 liters
00_h 00_h	Delta forward volume at 03:00:00-04:00:00: 0 liters
00_h 00_h	Delta forward volume at 04:00:00-05:00:00: 0 liters
00_h 00_h	Delta forward volume at 05:00:00-06:00:00: 0 liters
00_h 00_h	Delta forward volume at 06:00:00-07:00:00: 0 liters
00_h 00_h	Delta forward volume at 07:00:00-08:00:00: 0 liters
00_h 00_h	Delta forward volume at 08:00:00-09:00:00: 0 liters

00_h 00_h Delta forward volume at 09:00:00-10:00:00: 0 liters
00_h 00_h Delta forward volume at 10:00:00-11:00:00: 0 liters
00_h 00_h Delta forward volume at 11:00:00-12:00:00: 0 liters

"Alarms" port

Port 103 is used to

- transmit unsolicited Alarms messages from meter to the LoRaWAN server,
- clear Alarm flags
- for managing Valve state (optional).

Port 103 has the higher priority, than Readout data transmission through port 100.
If an alarm (or more) occurs, meter raises the corresponding flag(s) in the Alarms message and sends it. All alarms are persistent and can be cleared with the use of Reset Alarms command.

Alarms message format is:

Offset	Number of bytes	Description
0	4	Date and time
4	3	Valve Status/Alarms
7	1	Remaining battery lifetime (in months)
8	4	Current volume
Total	12	

Field "Date and time" contains date/time value at the moment when the alarm(s) appeared. Value has UNIX Data/time format.
Field "Valve Status/Alarms" contains information about alarms and current water valve state. Format of field "Valve Status/Alarms" is presented below:

Byte No.\Bit No.	7	6	5	4	3	2	1	0
0	WV COMM. ERROR	WV TAMPER	WV MAGNETIC FIELD	RESERVE	RESERVE	RESERVE	VALVE STATE: 0 – CLOSED, 1 – OPENED 100%, 2 – OPENED 10% 3- OPENED 50%	
1	CLOCK INVALID*	TAMPER*	MAGNETIC FIELD	RESERVE	RESERVE	LOW BAT*	FIRMWARE CHANGED	HARDWARE FAULT*
2	LEAKAGE	DRY	BACKFLOW	BURST	RESERVE	LOW TEMP	RESERVE	RESERVE

Alarms description:

"WV comm. error" – Water valve communication error.
"WV Tamper" – Water valve case opened.
"WV Magnetic field" – Magnetic field on water valve detected.
"Valve state" – Current water valve state.
"Clock invalid" – System time not valid.
"Tamper" – Meter case opened.
"Magnetic field" – Detect magnetic field.
"Low bat" – Remaining battery lifetime is lower than defined threshold.

"Hardware fault" – Meter internal Hardware fault.
"Firmware changed" – Firmware version was updated.
"Leakage" – Water flow during more than defined duration detected.
"Dry" – Water is absent during long time.
"Backflow" – Reverse water flow more than Q1 detected.
"Burst" – Water flow is higher that defined threshold during long time detected.
"Low temp" – Low flow temperature detected.

The Alarms marked with an asterisk (*) are permanent/irreversible and cannot be reset via the "Clear alarms" command.

Unsolicited Alarms message example:

DD 81 3f 65 01 00 00 90 CE 12 00 00

DD_h 81_h $3F_h$ 65_h	Date/Time in UNIX format: 0x653f81DD = 1698660829 = Mon Oct 30 2023 10:13:49
01_h 00_h 00_h	Valve Status/Alarms: WV opened 100%, no alarms
90_h	Remaining battery lifetime: 144 months
CE_h 12_h 00h 00h	Forward volume on Mon Oct 30 2023 10:13:49: 0x12CE = 4814 liters = 4.814 m^3

Commands format

One packet may contain several commands, but packet size shall not exceed 48 bytes. All commands have static length. If during packet handling wrong value is detected, packet execution is stopped. Command format is:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	COMMAND								COMMAND
N	VALUE								COMMAND VALUES

Supported commands:
0 – Valve settings
1 – Clear alarms

Valve settings command

Format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	0								0 – VALVE SETTINGS
1	VALUE								0 – VALVE CLOSED, 1 – VALVE OPENED 100%, 2 – VALVE OPENED 10% 3 – VALVE OPENED 50%

Example request:

00 01

00_h Command header
01_h Valve Setting (fully open)

In case of change “Valve state/Alarms” meter sends Alarms message with new Valve state value on port 103.

Clear alarms command format

Format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	1								1 – CLEAR ALARMS
1	WV comm. Error	WV Tamper	WV Magnetic field	n/a	n/a	n/a	n/a	n/a	ALARMS TO CLEAR
1	Clock invalid	Tamper	Magnetic field	n/a	n/a	Low bat	FW changed	Hardware Fault	
1	Leakage	Dry	Backflow	Burst	n/a	Low temp	n/a	n/a	

Alarm description is presented in the section “Alarms Messages”. To clear an alarm “1” value must be set to the corresponding bit.

Example request:

01 E0 02 44

01_h Command header
$E0_h$ 02_h 44_h Alarm mask. Resets all water valve related alarm, as well as “Dry” and “Low temperature” Alarms.

High priority port “Commands”

High priority port 104 is used to receive commands from LoRaWAN Application Server and transmit replies from the meter. Port 104 has the highest priority.
One packet may contain only one command. Command format is:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	COMMAND								COMMAND
N	VALUE								COMMAND VALUES

Command List:
0,1,2 – Reserved
3 – Set WM-Bus “activity hours” configuration
4 – Get WM-Bus “activity hours” configuration
5 – Set “Limiters” configuration
6 – Get “Limiters” configuration

7 – Get Firmware version command
8 – Set Alarm Filter command
9 – Get Alarm Filter command
10 – Set transmission parameters for the Readout message
11 – Get transmission parameters for the Readout message

Set WM-Bus "activity hours" configuration command

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	3								SET WM-BUS "ACTIVITY HOURS" CONFIGURATION COMMAND
2	TRANSMISSION PERIOD, S								Default:20 s
1	START HOUR								0…23 Default: 8
1	FINISH HOUR								0…23 Default: 18

Example request:

03 14 00 08 12

03_h Command header
$14_h\ 00_h$ Transmission period (20 s)
08_h Start hour (08:00)
12_h End hour (18:00)

If Start hour is equal to Finish hour – wM-Bus messages transmission is disabled.

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	3								RESPONSE ON SET WM-BUS "ACTIVITY HOURS" CONFIGURATION COMMAND
1	STATUS (0 -SUCCESS, !0 = ERRORS)								STATUS COMMAND EXECUTION

Example response:

03 00

03_h Command header
00_h Command successful

Get WM-Bus "activity hours" configuration command

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	4								GET WM-BUS "ACTIVITY HOURS" CONFIGURATION COMMAND

Request example:

04

04_h Command header

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	4								RESPONSE ON GET WM-BUS "ACTIVITY HOURS" CONFIGURATION COMMAND
2	TRANSMISSION PERIOD, S								Default:20 s
1	START HOUR								0…23 Default: 8
1	FINISH HOUR								0…23 Default: 18

Response example:

04 14 00 09 12

04_h Command header
$14_h\,00_h$ Transmission period (20s)
09_h Start hour (09:00)
12_h End hour (18:00)

Set "Limiters" configuration command

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	5								SET "LIMITERS" CONFIGURATION COMMAND
1	TYPE OF LIMITER								0 – LEAKAGE 1 – BURST 2 – REVERSE FLOW 3 – WATER TEMPERATURE 4 – BATTERY LIFETIME
4	THRESHOLD VALUE								DEPENDS ON TYPE OF LIMITER: 0, 1, 2 – FLOW RATE IN MILLILITERS PER HOUR, 3 – WATER TEMPERATURE IN ^{0}C, 4 – TIME DURATION IN MONTHS

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
4	OVER THRESHOLD DURATION								INTERVAL, S
4	UNDER THRESHOLD DURATION								INTERVAL, S
1	VALVE ACTION OVER THRESHOLD								0 = NO ACTION 1 = CLOSE VALVE 2 = OPEN VALVE
1	VALVE ACTION UNDER THRESHOLD								0 = NO ACTION 1 = CLOSE VALVE 2 = OPEN VALVE

Request example:

05 01 0C 00 00 00 0C 00 00 00 0C 00 00 00 02 01

05_h	Command header
01_h	Limiter type (Burst)
$0C_h\ 00_h\ 00_h\ 00_h$	Threshold value (12 ml/h)
$0C_h\ 00_h\ 00_h\ 00_h$	Over threshold duration (12 s)
$0C_h\ 00_h\ 00_h\ 00_h$	Under threshold duration (13 s)
02_h	Over threshold action (open valve)
01_h	Under threshold action (close valve)

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	5								RESPONSE ON SET "LIMITERS" CONFIGURATION COMMAND
1	STATUS (0 -SUCCESS, !0 = ERRORS)								STATUS COMMAND EXECUTION

Response example:

05 00

05_h	Command header
00_h	Command successful

Get "Limiters" configuration command

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	6								GET "LIMITERS" CONFIGURATION COMMAND
1	TYPE OF LIMITER								0 – LEAKAGE 1 – BURST 2 – REVERSE FLOW 3 – WATER TEMPERATURE 4 – BATTERY LIFETIME

Request example:

06 00

06_h Command header
00_h Limiter Type (Leakage)

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	6								RESPONSE ON GET "LIMITERS" CONFIGURATION COMMAND
1	TYPE OF LIMITER								0 – LEAKAGE 1 – BURST 2 – REVERSE FLOW 3 – WATER TEMPERATURE 4 – BATTERY LIFETIME
4	THRESHOLD VALUE								DEPENDS ON TYPE OF LIMITER: 0, 1, 2 – FLOW RATE IN MILLILITERS PER HOUR, 3 – WATER TEMPERATURE IN ^{0}C, 4 – TIME DURATION IN MONTHS
4	OVER THRESHOLD DURATION								INTERVAL, S
4	UNDER THRESHOLD DURATION								INTERVAL, S
1	VALVE ACTION OVER THRESHOLD								0 = NO ACTION 1 = CLOSE VALVE 2 = OPEN VALVE
1	VALVE ACTION UNDER THRESHOLD								0 = NO ACTION 1 = CLOSE VALVE 2 = OPEN VALVE

Response example:

06 00 0C 00 00 00 0C 00 00 00 0D 00 00 01 00

06_h Command header
00_h Limiter type (Burst)
$0C_h\ 00_h\ 00_h\ 00_h$ Threshold value (12 ml/h)
$0C_h\ 00_h\ 00_h\ 00_h$ Over threshold duration (12 s)
$0D_h\ 00_h\ 00_h\ 00_h$ Under threshold duration (13 s)
01_h Over threshold action (close valve)
00_h Under threshold action (no action)

Get Firmware version command

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	7								GET FIRMWARE VERSION COMMAND

Request example:

07

07_h Command header

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	7								GET FIRMWARE VERSION COMMAND
6	VERSION STRING								

Response example:

07 76 38 31 33 38 61

07_h Command header
$76_h\ 38_h\ 31_h\ 33_h\ 38_h\ 61_h$ Version string “v8138a”

Set Alarm Filter command

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	8								SET ALARM FILTER
1	WV comm. error	WV Tamper	WV Magnetic field	n/a	n/a	n/a	n/a	n/a	SETTING A BIT TO 1 ENABLES THE ALARM, WHILE SETTING IT TO 0 DISABLES IT.
1	Clock invalid	Tamper	Magnetic field	n/a	n/a	Low bat	FW changed	Hardware Fault	
1	Leakage	Dry	Backflow	Burst	n/a	Low temp	n/a	n/a	

Request example:

08 B0 E5 E0

08_h Command header
$B0_h\ E5_h\ E0_h$ Alarm filter mask. Ignores the “Dry”, “Low temperature”, and “FW changed” alarms.

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	8								SET ALARM FILTER COMMAND
1	STATUS (0 -SUCCESS, !0 = ERRORS)								

Response example:

08 00

08_h Command header
00_h Command successful

Get Alarm Filter command

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	9								GET ALARM FILTER COMMAND

Request example:

09

09_h Command header

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	9								GET ALARM FILTER
1	WV comm. error	WV Tamper	WV Magnetic field	n/a	n/a	n/a	n/a	n/a	ALARM FILTER VALUES
1	Clock invalid	Tamper	Magnetic field	n/a	n/a	Low bat	FW changed	Hardware Fault	
1	Leakage	Dry	Backflow	Burst	n/a	Low temp	n/a	n/a	

Response example:

09 B0 E5 E0
09_h Command header
$B0_h$ $E5_h$ $E0_h$ Alarm filter mask. “Dry”, “Low temperature”, and “FW changed” alarms are ignored.

Set Readout message transmission parameters

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	10								SET READOUT MESSAGE CONFIGURATION

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
4	TRANSMISSION PERIOD, S								Allowed Transmission period values: 0 – Turned off. 300 – 5 minutes. 600 – 10 minutes. 900 – 15 minutes. 1200 – 20 min. 1800 – 30 min. 3600 – 1 hour. 7200 – 2 hours. 10800 – 3 hours. 14400 – 4 hours. 21600 – 6 hours 43200 – 12 hours. 86400 – 24 hours. Default :43200 – 12 hrs
4	RANDOMIZATION START INTERVAL								Min: 300 s Default: 21600 s Max: 65535 s
1	NUMBER OF REPETITIONS								Min: 0 Max:10
4	REPETITION DELAY								Min: 0 s Max: 65535s

Request example:

0A 30 2A 00 00 10 0E 00 00 05 A0 05 00 00

$0A_h$	Command header
$30_h\ 2A_h\ 00_h\ 00_h$	Transmission period of 10800 s (3 hours)
$10_h\ 0E_h\ 00_h\ 00_h$	Randomization start interval 3600s (1 hour)
05_h	Number of repetitions (5)
$A0_h\ 05_h\ 00_h\ 00_h$	Repetition Delay 1440s (24 min)

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	10								SET READOUT MESSAGE CONFIGURATION COMMAND
1	STATUS (0 -SUCCESS, !0 = ERRORS)								STATUS COMMAND EXECUTION

Response example:

0A 00

$0A_h$	Command header
00_h	Command successful

Get “Readout message” transmission parameters

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	11								GET READOUT MESSAGE CONFIGURATION

Request example:

0B

$0B_h$ Command header

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	11								GET READOUT MESSAGE CONFIGURATION
4	TRANSMISSION PERIOD, S								Allowed Transmission period values: 0 – Turned off. 300 – 5 minutes. 600 – 10 minutes. 900 – 15 minutes. 1200 – 20 min. 1800 – 30 min. 3600 – 1 hour. 7200 – 2 hours. 10800 – 3 hours. 14400 – 4 hours. 21600 – 6 hours 43200 – 12 hours. 86400 – 24 hours. Default: 43200 – 12 hours.
4	RANDOMIZATION START INTERVAL								Min: 300 s Default: 21600 s Max: 65535 s
1	NUMBER OF REPETITIONS								Min: 0 Max:10
4	REPETITION DELAY								Min: 0 s Max: 65535s

Response example:

0B C0 A8 00 00 60 54 00 00 00 00 00 00 00

$0B_h$	Command header
$C0_h$ $A8_h$ 00_h 00_h	Transmission period of 43200 s (12 hours)
60_h 54_h 00_h 00_h	Randomization start interval 21600s (6 hours)
00_h	Number of repetitions (no repetitions)
00_h 00_h 00_h 00_h	Repetition Delay (off)

Set ACK_LIMIT and ACK_DELAY parameters

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	12								SET "CONNECTION BACKOFF" PARAMETERS COMMAND

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	ACK LIMIT								ACK Limit – number of frames sending without ACK requirements. Allowed values: Min: 0 (sending every message with ACK request), Max:64. Default value: 8
1	ACK DELAY								Number of frames for repetition requests. Min: 1, Max:64. Default value: 4

Request example:

0C 08 04

$0C_h$ Command header
08_h ACK Limit equal to 8
04_h ACK DELAY equal to 4

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	12								SET "CONNECTION BACKOFF" PARAMETERS COMMAND
1	STATUS (0 -SUCCESS, !0 = ERRORS)								STATUS COMMAND EXECUTION

Response example:

0C 00

$0C_h$ Command header
00_h Command successful

Get ACK_LIMIT and ACK_DELAY parameters

Request format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	13								GET "CONNECTION BACKOFF" PARAMETERS COMMAND

Request example:

0D

$0D_h$ Command header

Response format:

LENGTH	BITS								COMMENTS
	7	6	5	4	3	2	1	0	
1	13								GET "CONNECTION BACKOFF" PARAMETERS COMMAND
1	ACK LIMIT								Current value of ACK Limit.
1	ACK DELAY								Current value of ACK Delay.

Response example:

0D 08 04

$0D_h$	Command header
08_h	ACK LIMIT is equal to 8
04_h	ACK DELAY is equal to 4

Appendix A

This section contains text representation of UML diagrams made by PlantUML tool https://www.plantuml.com/plantuml/uml.

Limiter state machine

```
@startuml

title "Limiter State Diagram"
hide empty description

state "Over Threshold" as Over_Threshold
state "Under Threshold" as Under_Threshold
state "Waiting for timeout\nover threshold" as Waiting_For_Timeout_Over_Threshold
state "Waiting for timeout\nunder threshold" as Waiting_For_Timeout_Under_Threshold

[*] --> Init
Init: Load into the state machine\nthe last state stored in\nnon-volatile memory

state c <<choice>>
c <-d- Init
c -d-> Over_Threshold: Stored State is\nOver Threshold
c -d-> Under_Threshold: Stored State is\nUnder Threshold

Over_Threshold: The state is stored\nin non-volatile memory
Under_Threshold: The state is stored\nin non-volatile memory

Under_Threshold --> Under_Threshold: Value remains\nunder threshold
Under_Threshold -u-> Waiting_For_Timeout_Over_Threshold: Value crosses\nthreshold upward
Under_Threshold <-d- Waiting_For_Timeout_Over_Threshold: Value crosses\nthreshold
downward
Over_Threshold <-u- Waiting_For_Timeout_Over_Threshold: Timeout over\nthreshold expired
```

```
  note on link: calling to the over\nthreshold action
Waiting_For_Timeout_Over_Threshold --> Waiting_For_Timeout_Over_Threshold: Waiting isn't
over
Over_Threshold --> Over_Threshold : Value remains\nover threshold
Over_Threshold -d-> Waiting_For_Timeout_Under_Threshold: Value crosses\nthreshold
downward
Over_Threshold <-u- Waiting_For_Timeout_Under_Threshold: Value crosses\nthreshold upward
Under_Threshold <-d- Waiting_For_Timeout_Under_Threshold: Timeout under\nthreshold
expired
  note on link: calling to the under\nthreshold action
Waiting_For_Timeout_Under_Threshold --> Waiting_For_Timeout_Under_Threshold: Waiting
isn't over

@enduml
```

LoRaWAN stack sequence main diagram

```
@startuml
title "LoRaWAN sequence diagram"

participant task [
   =Tasks
   ----
   ""Leakage monitor""
   ""Burst monitor""
   ""Reverse flow monitor""
   ""Water low temperature monitor""
   ""Battery life monitor""
]

queue "LoRa Queue" as queue
participant "LoRaWAN stack" as module
participant "LoRaWAN network server" as net_s
participant "LoRaWAN application server" as app_s


[-> module : InitializeStack()
== Idle ==

task -> queue: push_new_message_to_queue(port)
note left: Appearing new message for some reason

queue -> module: NewMessageNotification()


== New message ==
queue <- module: GetAndDequeueMessageByPriority()
note right: Getting message from queue by port priority

== Establish connection ==
```

```
group Joining
module -> net_s: Join procedure\n
note right: Performing join procedure if current state is a "not joined"
module <-- net_s: Join acknowledge
end

== Processing message ==

queue -> module: dequeue_messsage()

module -> net_s: LoRaWANTXFrame(port)
note left: Sending a message via "unconfirmed uplink data" type frame (ADR=1, ADRACKReq=0, every 8th "Readout" message has DeviceTimeReq )

net_s -> app_s: MessageRXIndication(port)

module <-- net_s: LoRaWANRXFrame()
note right: Receiving answer: possible frames variants:\nempty frame, MAC_frame_command, Application frame

== Handling message ==

task <-- module: MessageIndication()\nHandling received message by appropriate task
note left: Handling message by tasks:\na) Acknowledge to "connection backoff" task (see details diagram in "Data exchange management description" section);\nb) Time Synchronization;\nc) Application handling.
@enduml
```

LoRaWAN stack sequence MAC commands exchange diagram

```
@startuml
title "LoRaWAN sequence diagram"

queue "LoRa Queue" as queue
participant "LoRaWAN stack" as module
participant "LoRaWAN network server" as net_s
participant "LoRaWAN application server" as app_s

== Processing new MAC commands ==

net_s -> module: LoRaWANRXMACFrame()
note right: New MAC command

module-> queue: push_mac_command_response_to_queue()
note left: Response on MAC command

-> queue: push_app_message_to_queue()
note right: Task execute fired

loop 5 times
```

```
queue -> module: dequeue_mac_command_response()
note left: Dequeue MAc response with high-priority

module -> net_s: LoRaWANTXMACFrame()
note left: Sending a MAC response via a separate frame if the common message size exceeds the
allowed message size

module <-- net_s: LoRaWANRXMACFrame()
note right: Receiving another MAC command

module-> queue: push_mac_command_response_to_queue()
note left: Response on MAC command

end

== Application message sending ==
opt Loop ended less then 5 times

queue -> module: dequeue_app_message()
module -> net_s: LoRaWANTXAppFrame()
net_s -> app_s: MessageRXIndication(port)

else

<- queue: dequeue_and_drop_app_message()
end

@enduml
```