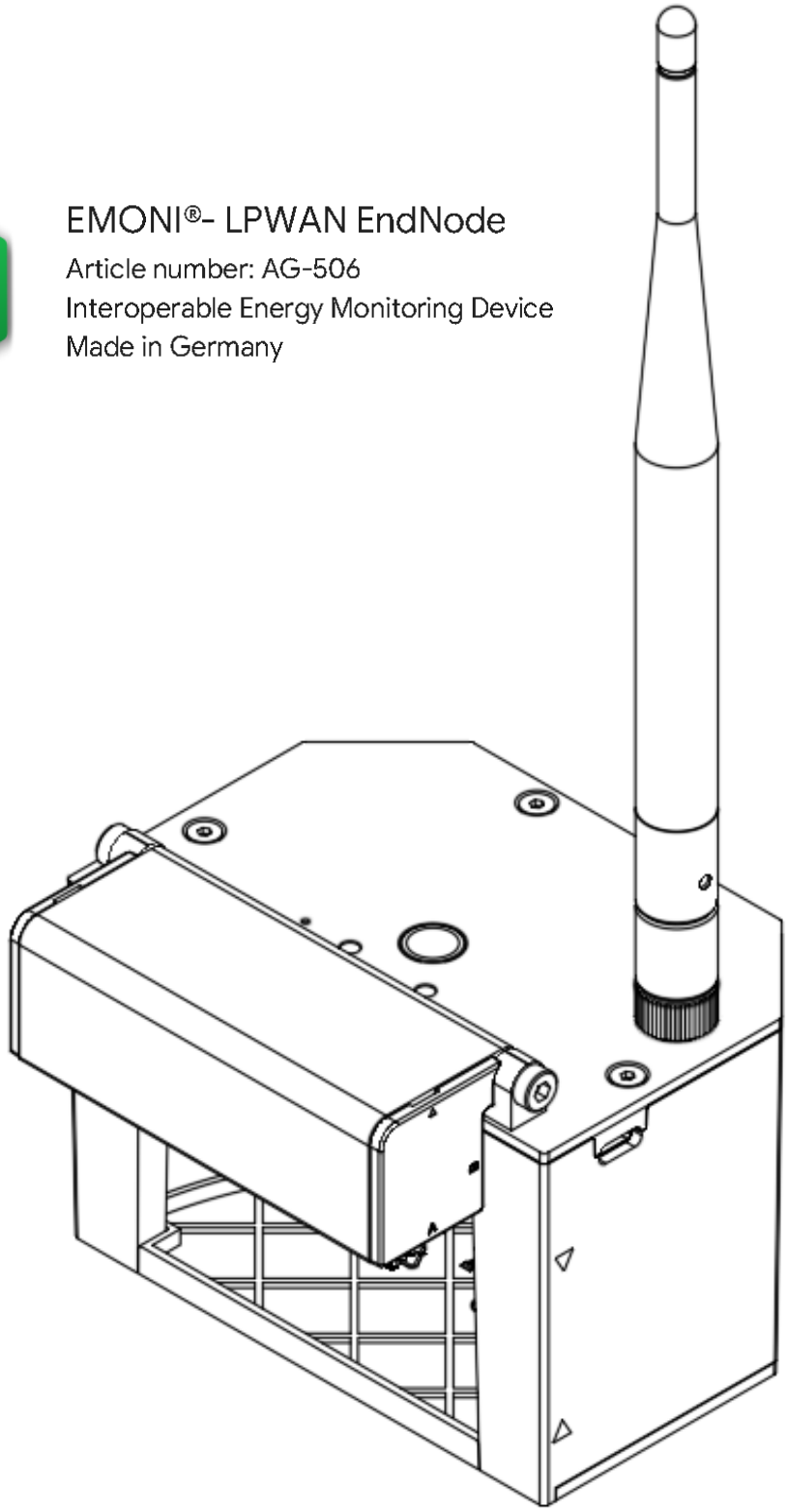
EMONI®- LPWAN EndNode

Article number: AG-506

Interoperable Energy Monitoring Device

Made in Germany



EMONI – Technical Reference Manual

This manual describes the EMONI LPWAN-Endnode for network engineers, integrators and service technicians: radio interfaces, LoRaWAN behaviour, uplink payload, downlink commands, firmware updates over LoRaWAN, integration into the EMONI Cloud, power supply and battery, security and the technical characteristics. Installation and calibration are described in the User Manual and the Calibration Guide.

Document	Contents
AG-506 User Manual v1.1	Intended use, safety, installation, buttons and LEDs, conformity
EMONI Calibration Guide v1.0	Calibration menu, drawing the reading area, examples per meter type
Payload codec (emoni.cloud/downloads)	Decoder and encoder for The Things Stack and ChirpStack
Energizer L91 datasheet (form L91GL1222)	Cell data used in section 7

Symbols and Signal Words Used



WARNING
Ignoring this deletes data or the calibration.



CAUTION
Ignoring this leads to wrong meter readings or a shorter battery life.



NOTE
Additional information that makes the task easier.

System Overview

1.1 Device

Block	Function
Camera with LED illumination	Picture of the meter counter (480 × 320)
Main controller	On-device recognition of the digits, plausibility check, Wi-Fi for calibration
Radio module	LoRaWAN EU868
Motion sensor	Tilt, fall and movement detection; wake on motion (optional, by downlink)
Power	4 × AA lithium cells; a USB-C 5 V supply takes over when connected
User interface	Button and a red and a green LED (1.4)

1.2 Communication

The device sends each reading over LoRaWAN to the customer's network server, which forwards it to the EMONI Cloud or to the customer's own application (section 6). Firmware updates reach the device over LoRaWAN (section 5) or over Wi-Fi on-site.

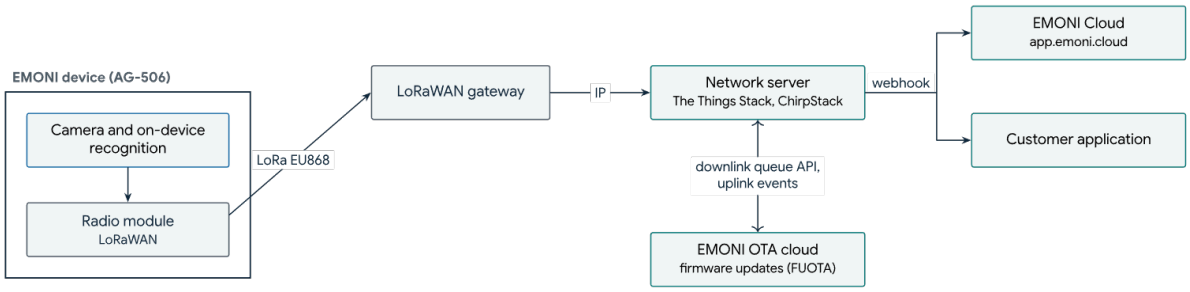


Figure 1: System overview.

1.3 Operating cycle

Every wake-up runs the same cycle. Between cycles the device is in deep sleep.

1.3.1 **Wake** by timer (upload interval), button or, if switched on, motion sensor.

1.3.2 **Capture** a picture of the counter.

1.3.3 **Recognise** the digits on the device. Images are never sent over LoRaWAN.

1.3.4 **Validate** the reading: it must not be lower than the last accepted value and must not rise faster than Qmax (or the maximum power) allows. Implausible readings are retried.

1.3.5 **Send** one uplink with the reading, battery voltage, an event code and the motion data (section 3).

1.3.6 **Receive** a downlink, if the network sends one, and apply it (section 4).

1.3.7 **Sleep** for the upload interval: 1 min to 72 h, 3 h by default.

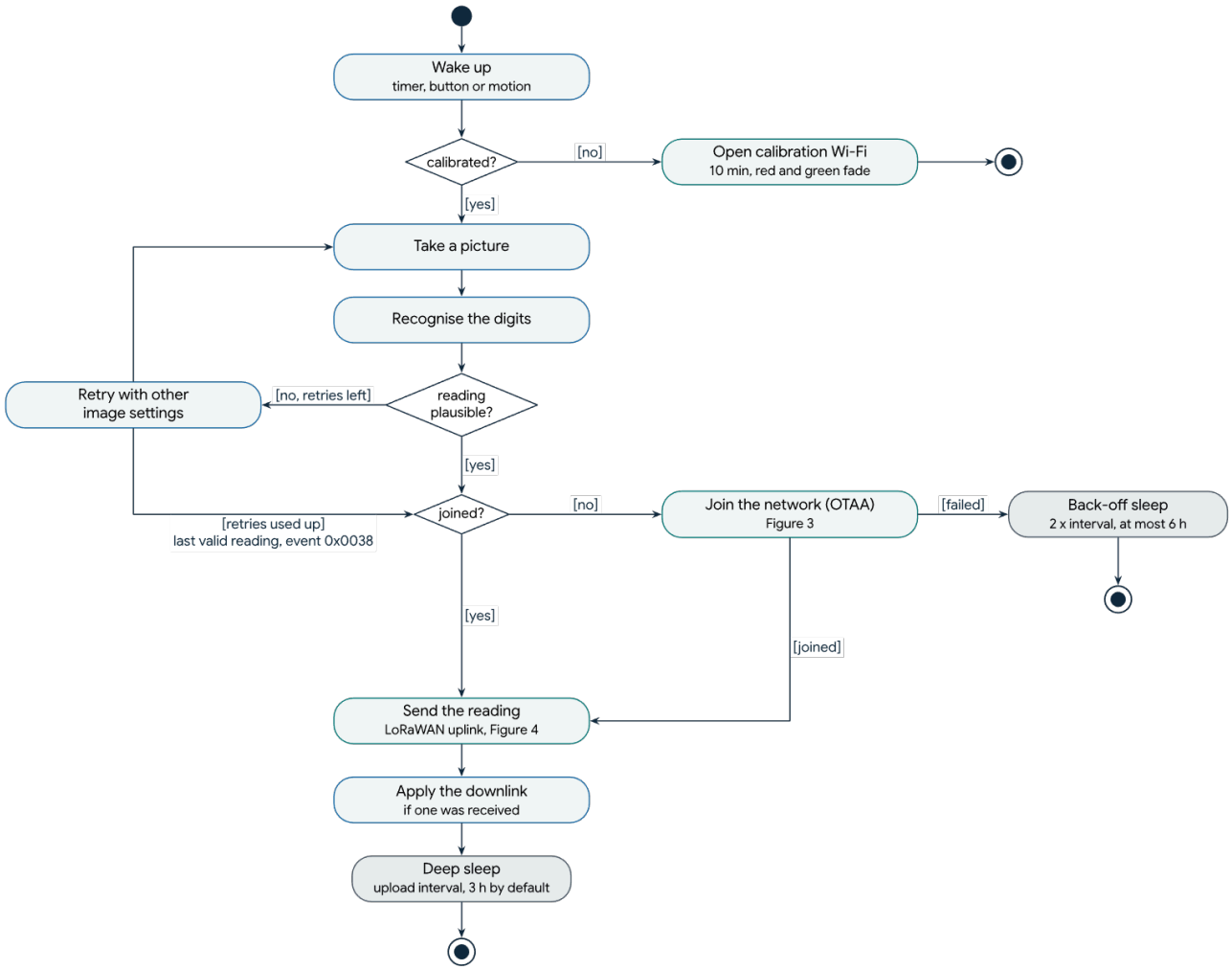


Figure 2: Device activity per wake-up.

1.4 Status LEDs

LED	Pattern	Meaning
Green	Blinking slowly	Device starting
Green	Fading	Joining the LoRaWAN network
Green	On	Joined, device active
Red	On	Taking a picture
Red	Short fast flash	Reading sent
Red + green	Fading together	Not calibrated, calibration Wi-Fi open
Red + green	Blinking together	Firmware update in progress
Red + green	Blinking fast	Factory reset, the device restarts
Red	Blinking fast for 5 s	Battery too low to open the calibration Wi-Fi

LoRaWAN

2.1 Parameters

Parameter	Value
LoRaWAN version	MAC 1.0.2
Regional parameters	EU868, RP001 Regional Parameters 1.0.2 revision B
Device class	Class A
Activation	OTAA with a per-device 128-bit AppKey; JoinEUI 0000000000000000 unless stated otherwise
Join data rate	DR0 (SF12)
Adaptive data rate	On (ADR)
TX power	14 dBm (EU868 limit)
RX2	869.525 MHz; data rate set by the network in the JoinAccept (DR3 on the TTN plan, DR0 on ChirpStack by default)
Application port	FPort 8
Firmware update port	FPort 150 (section 5)
Uplink interval	3 h by default (1 min – 72 h)
Largest downlink	242 bytes

2.2 Network server device profile

Register the device on the network server with this profile:

Profile setting	Value
MAC version	LoRaWAN 1.0.2
Regional parameters revision	RP001-1.0.2 rev. B
Region / frequency plan	EU868 (on TTN: "Europe 863-870 MHz (SF9 for RX2 – recommended)")
Class / activation	Class A, OTAA; no class B or C, no ABP
Expected uplink interval	3 h, or the upload interval set on the device. ChirpStack uses it to decide when a device counts as inactive.
Payload codec	EMONI codec (6.1)

2.2.1 **Moving a device to another network server:** delete it on the old server first, on The Things Network in particular: while it is registered there, the DevEUI stays claimed and the device can still join TTN wherever a TTN gateway hears it. Then register it on the new server with the same keys. The device notices the change by the missing acknowledgements and rejoins on its own (2.3).

2.3 Join and session handling

Figure 3 shows the join, Figure 4 the uplink with its acknowledgement and the liveness check.

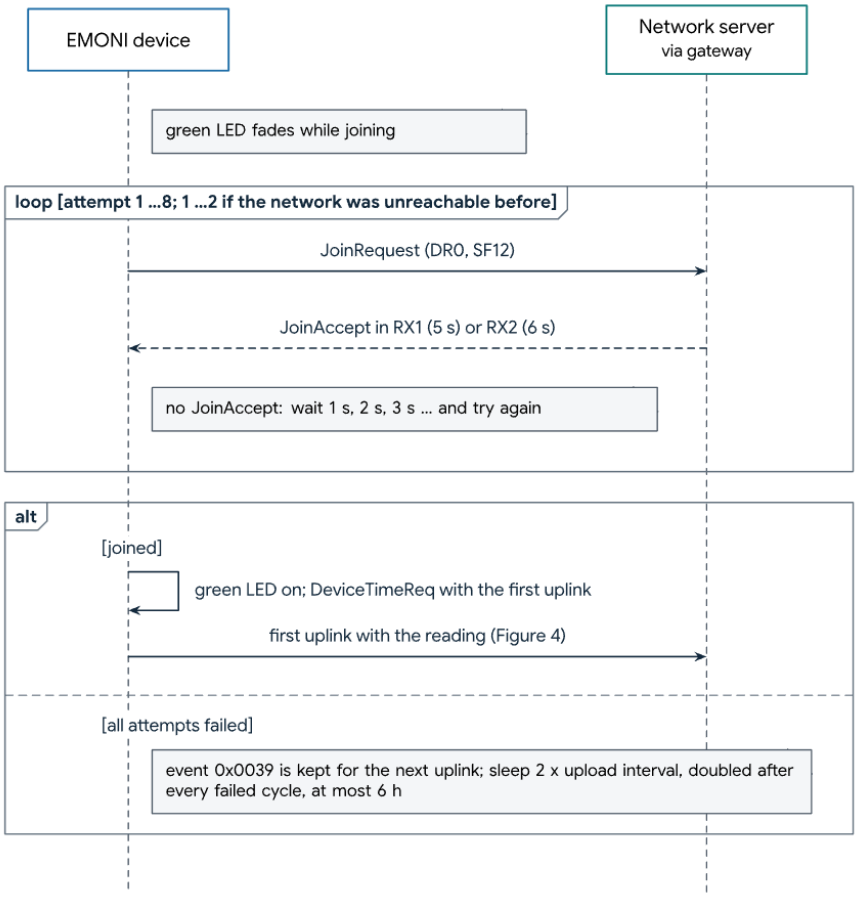


Figure 3: Join (OTAA).

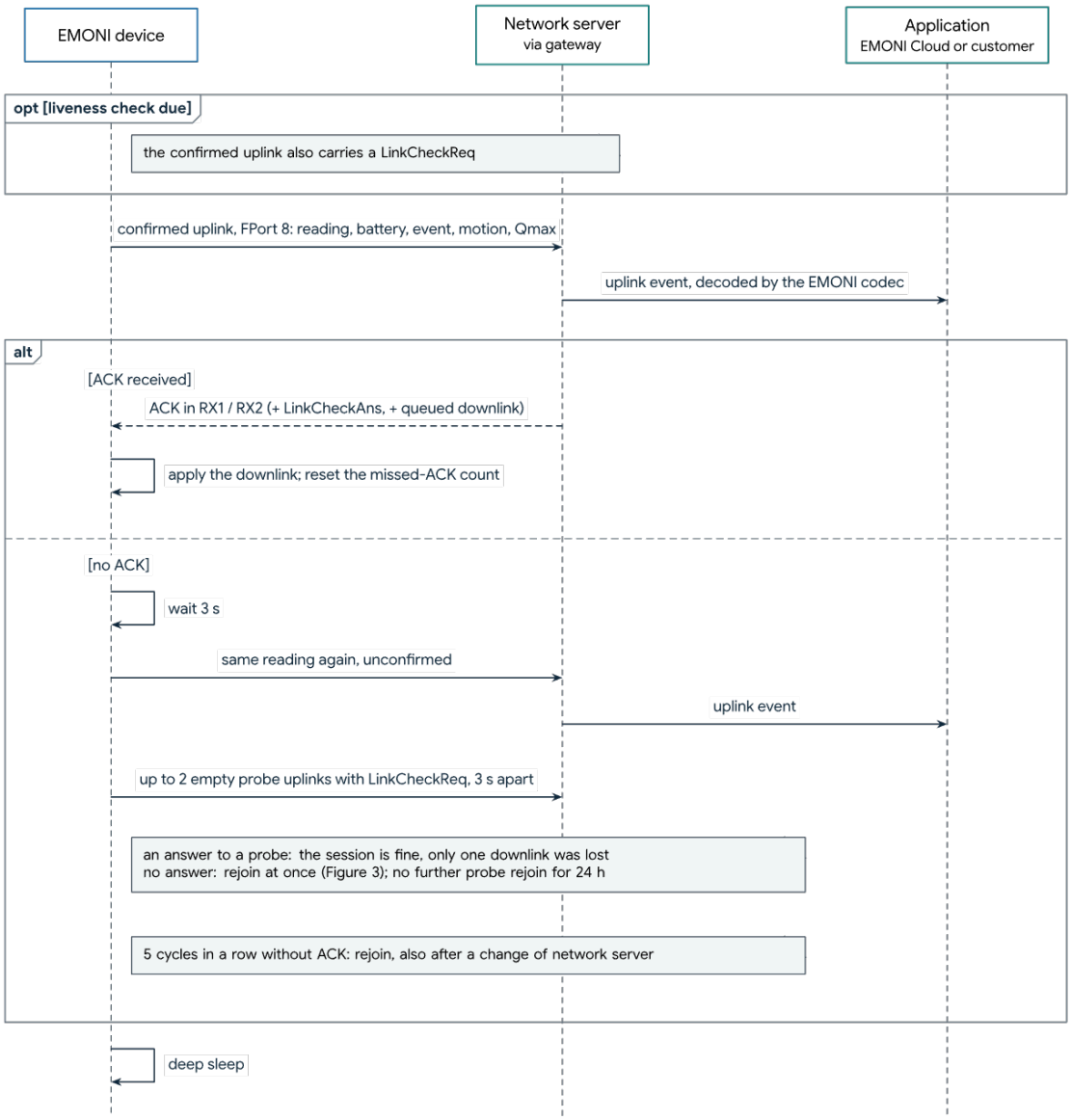


Figure 4: Uplink, acknowledgement and session check.

2.3.1 A first join makes up to 8 attempts. When the network was already unreachable in an earlier cycle, a join makes 2 attempts and the next wake tries again.

2.3.2 After a cycle with a failed join, the sleep time doubles (2 × upload interval, 4 ×, ...) up to 6 hours, so a network outage costs about 4 short wakes a day. Example at 15 min: 30 min, 1 h, 2 h, 4 h, then 6 h.

2.3.3 The device rejoins after 5 consecutive confirmed uplinks without an acknowledgement. **This also covers a change of network server.**

2.3.4 Liveness check: a confirmed uplink carries a `LinkCheckReq`. If neither the acknowledgement nor the `LinkCheckAns` arrives, up to 2 empty probe uplinks follow in the same wake; if none is answered, the device rejoins at once. After such a rejoin, probes do not trigger another rejoin for 24 hours.

2.3.5 After a failed confirmed uplink, the same reading is sent once more unconfirmed (3 s later), so it still reaches the network server.

2.4 Confirmed uplinks

Network	Default	Change by downlink
Self-hosted or private network server	Every uplink confirmed	`{"confirm_min":N}` – one confirmed uplink every N minutes
Public The Things Network (DevAddr of NetID 000013)	One confirmed uplink every 4 hours (fair use: 10 downlinks a day)	`{"confirm_min":0}` every uplink, `{"confirm_min":65535}` back to default

2.4.1 The network is told apart by the `DevAddr`: addresses of NetID 000013 (The Things Network) get the public policy, every other network, ChirpStack included, the private one.

2.4.2 Every acknowledgement is a downlink from the gateway. A gateway may transmit at most 10 % of the time on 869.525 MHz (RX2) and 1 % on the RX1 channels, so confirming every uplink limits the number of devices one gateway can serve. On networks with many devices per gateway, lower the load with `{"confirm_min":N}`.

Uplink Payload

The reading is sent as a compact binary frame on FPort 8: 16 bytes for 9 digits. The EMONI codec decodes it (6.1); this section is for integrators who decode the frame themselves.

3.1 Binary frame

Bits are packed most significant first, without gaps; the last byte is padded with zeros.

Field	Bits	Content
Frame marker	3	100 – a first byte ≥ 0x80 marks the binary frame
Digit count	5	Number of digits in the reading, 1–31
Comma	5	Digits before the comma + 1
Battery	13	Battery voltage in mV, 0–8191 (7.3)
Event	8	Event code of this cycle (3.4); 0x00 = no event
Motion x, y, z	3 × 16	Acceleration, signed raw sensor values
Qmax × 10	16	Configured maximum flow (0.1 m^3/h) or power (0.1 kW)
Digits	10 / 7 / 4	Groups of three digits as 10 bits (000–999); a rest of two digits as 7 bits, of one digit as 4 bits

Length: 98 bits of header fields plus 10 bits per three digits, rounded up to whole bytes. Eight and nine digits take 16 bytes.

3.2 Example

Gas meter reading 17798,856 m^3 (5 digits before the comma), battery 6729 mV, no event, motion (–12, 35, 1021), Qmax 6.0 m^3/h:

```
88 36 92 40 3F FD 00 08 C0 FF 40 0F 0B 1F 71 C0
```

Decoded by the EMONI codec:

```
{ "meterValue": "17798,856", "comma_pos": 5, "total_digits": 8, "battery_mv": 6729,
  "error_event_hex": "0000", "imu_ax": -12, "imu_ay": 35, "imu_az": 1021, "qmax": 6 }
```

3.3 Text frame (older firmware)

Devices with older firmware send ASCII text, fields separated by "|": comma | digits | battery mV | event (hex) | motion x | motion y | motion z | Qmax. The codec recognises it by a first byte below 0x80.

3.4 Event codes

Each uplink carries the most important event of the cycle. Errors take priority over warnings, warnings over information. Events marked *deferred* are reported in the next uplink.

Code	Event	Meaning
`0x0000`	–	No event
`0x0010`	Update failed	Firmware download or check failed (deferred)
`0x001A`	Device moved	The device has moved since calibration (tamper or position)
`0x0031`	Value out of range	Reading failed the plausibility check
`0x0032`	Reading area mismatch	Recognised digits do not match the calibrated reading area
`0x0034`	Battery low	Battery critically low
`0x0038`	Recognition failed	No valid reading in this cycle; the last valid reading is sent
`0x0039`	Join failed	OTAA join failed (deferred)
`0x003A`	Send failed	Uplink failed (deferred)
`0x0042`	Update rolled back	The device returned to the previous firmware (deferred)
`0x0048`	Factory reset	Long-press reset after calibration
`0x00A0`	Reading re-baselined	Stored reading re-baselined (deferred)
`0x00A1`	Update installed	New firmware confirmed on first start (deferred)
`0x00A2`	Downlink applied	A configuration downlink was applied (deferred)
`0x00A6`	Motion wake	Woke from deep sleep on motion
`0x00A7`	Reading corrected	Stored reading corrected downward after confirming readings
`0x00A8`	High consumption confirmed	A reading above the Qmax limit was confirmed and accepted

Downlink Commands

Downlinks are sent on FPort 8 and applied after the next uplink. A configuration downlink is reported as event 0x00A2 in the following uplink. The codec builds the bytes from the JSON object shown.

Command	Bytes on air	Codec input	Effect
Upload interval (minutes)	01 + uint16 little endian; 3 h = 01 B4 00	`{"upload_interval": 180}`	1–4320 min (72 h)
Upload interval (seconds)	JSON text	`{"upload_interval_sec":10800}`	60 s – 72 h
Confirmed-uplink period	JSON text	`{"confirm_min":240}`	One confirmed uplink every N min; 0 = every uplink, 65535 = network default (2.4)

Command	Bytes on air	Codec input	Effect
Re-baseline reading	JSON text	`{"recalibrate":1}`	Re-baselines the stored reading from the next recognition; keeps the calibration; restarts
Motion sensor mode	JSON text	`{"imu_mode":1}`	0 off; 1 tilt and displacement check at every wake, sensor asleep in between (default); 2 also wake on motion. From the next deep sleep; battery life: 7.5

A full re-calibration cannot be started over the air; it needs the device on site (calibration menu). Firmware updates are installed over LoRaWAN (section 5) or over Wi-Fi on site.

Firmware Update over LoRaWAN (FUOTA)

EMONI devices receive firmware updates over LoRaWAN class A. Only the difference to the firmware the device runs is sent (delta update), in small downlinks on FPort 150. The update is prepared and driven by the EMONI OTA cloud through the customer's network server; the customer provides API access to that server and does not handle firmware files (see section 5.4 – 5.6).

5.1 FUOTA Cycle

5.1.1 **Release.** EMONI releases a firmware for FUOTA to selected devices of a batch. For each device the OTA cloud checks that it can take the update (5.2) and estimates the duration; it builds, for each running firmware version, the patch to the new version.

5.1.2 **Setup.** The OTA cloud queues a setup downlink. The device receives it after its next regular uplink and prepares the storage for the update in the same wake. A setup that is not acknowledged is sent again, up to 5 times.

5.1.3 **Transfer.** The network server keeps the next parts (chunks) of the patch queued in order. Each downlink carries one chunk and answers an uplink of the device. After its regular reading the device sends up to 5 short extra uplinks in the same wake, each fetching one more chunk, so it does not wake more often. The device lowers this number by itself: none under 15 % battery, one under 30 % battery or at a slow data rate (DR0–DR2). On USB power the battery limits do not apply; the limit of one extra uplink at DR0–DR2 still does.

5.1.4 **Robustness.** Every chunk is written to flash at once, so deep sleep, a network outage or a battery change do not lose the progress. A lost chunk is sent again; when the device is not heard for hours, the OTA cloud asks it for its status at the next wake and continues from there. Readings are sent as usual during the whole update.

5.1.5 **Installation.** When the last chunk has arrived, the device checks the complete file, applies the patch and restarts into the new firmware.

5.1.6 **Result.** After the restart the device sends a result frame on FPort 150 (installed, failed or rolled back, with the identifier of the firmware that now runs), and the next reading carries the event code: 0x00A1 installed, 0x0010 failed, 0x0042 rolled back to the previous firmware. A failed update is tried once more; after that the device is updated over Wi-Fi. If no result arrives within 4 readings, the update is marked as unknown and checked by EMONI.

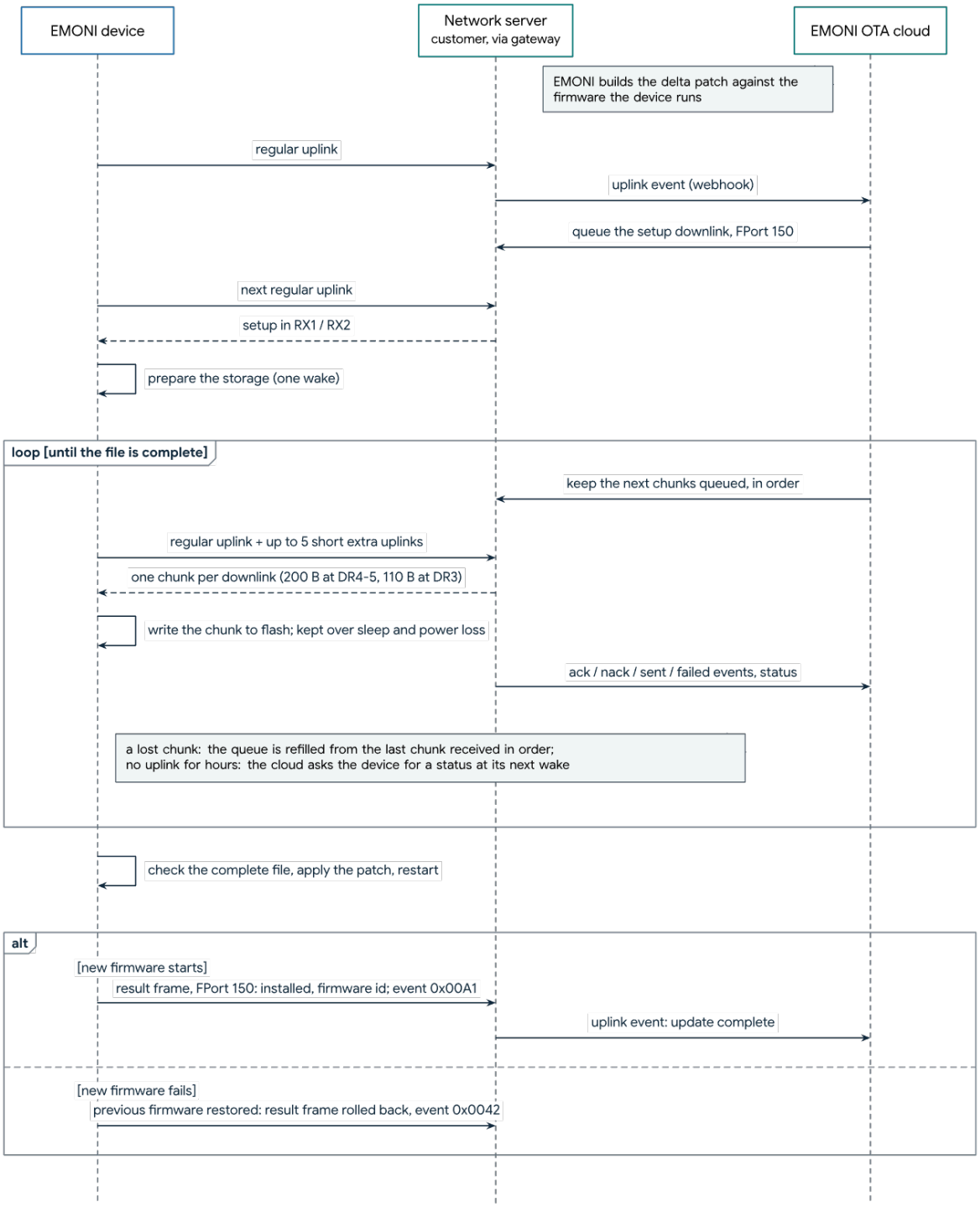


Figure 5: Firmware update over LoRaWAN (FUOTA).

5.2 Which devices can be updated

5.2.1 The device runs a FUOTA-capable firmware (October 2026 or later). Older devices receive one update over Wi-Fi first.

5.2.2 The device sends at DR3 (SF9) or faster. At DR0–DR2 the OTA cloud sends no chunks and waits until the data rate improves: a chunk would be only 46 bytes and take the gateway's

airtime for little progress.

5.2.3 The battery is above the minimum set for the update; the device itself stops the extra uplinks under 15 % battery.

5.2.4 The estimated duration is acceptable. Patches up to 64 KB that complete within 7 days are sent as they are; for longer transfers EMONI sets a shorter upload interval by hand for the time of the update, with an upload-interval downlink on FPort 8 (section 4, 5.3), or installs the update over Wi-Fi on site. The OTA cloud does not change the interval by itself. The largest patch sent over LoRaWAN is 100 KB.

5.3 Duration and what to expect

The chunk size follows the data rate of the downlink:

Downlink data rate (EU868)	Chunk size	Per wake (5 extra uplinks)
DR4–DR5 (SF8–SF7)	200 bytes	1.1–1.2 KB
DR3 (SF9)	110 bytes	about 0.6 KB
DR0–DR2 (SF12–SF10)	no chunks	the update waits for DR3 or faster

Duration = patch size / data per wake × upload interval. A small correction gives a patch of a few KB, a typical release 30 to 40 KB, a larger change to the recognition about 90 KB:

Upload interval	30 KB at DR5	30 KB at DR3	90 KB at DR5	90 KB at DR3
5 min (for the update)	about 2.5 h	about 4.5 h	about 7 h	about 13 h
15 min	about 7 h	about 13 h	about 21 h	about 1.6 days
1 h	about 1.2 days	about 2.1 days	about 3.5 days	about 6.5 days
3 h (default)	about 3.5 days	about 6.5 days	about 10 days	about 19 days

NOTE
To speed up an update, EMONI can set a shorter upload interval for the time of the update with an upload-interval downlink on FPort 8 (section 4), and the original interval again afterwards. This is done by hand; the OTA cloud does not change the interval by itself. Each extra wake and extra uplink costs battery; see the figures below.

Expected figures for a **30 KB update** at DR5 with 5 extra uplinks per wake:

Quantity	Value
Wakes with transfer	About 27 (patch size / 1.1–1.2 KB), plus the wake that receives the setup
Uplinks	About 160: one reading per wake (FPort 8, confirmed, 16 B) and up to 5 status uplinks per wake (FPort 150, unconfirmed, 6 B), plus one result frame (FPort 150, 11 B) after the restart
Uplink airtime	About 0.07 s per reading and 0.05 s per status uplink at DR5; about 9 s in total
Downlinks	One setup and about 150 chunks of 200 B; a lost chunk is sent again
Gateway downlink airtime	About 0.34 s per chunk at DR5; about 52 s in total, about 2 s per wake
Wake length	About 11 s longer per wake: the status uplinks follow the reading about 2.2 s apart

Quantity	Value
Installation	Restart into the new firmware within about 40 s after the last chunk; the next reading carries 0x00A1
Readings during the update	Unchanged: every wake still sends its reading, events and confirmed uplink
Battery	The extra uplinks and the longer wakes are the only additional consumption; no change of the battery voltage is visible in field use

5.4 Network server requirements

FUOTA is not tied to a particular network server. The OTA cloud needs two things from it: an API to queue downlinks for a device, and a report of every uplink and downlink event (webhook or event stream).

Network server	Support	Connection
The Things Stack (self-hosted or a private instance)	Supported, in field use	Downlink queue over the API, events by webhook
ChirpStack v4	Supported	Device queue over the gRPC(-web) API, events by HTTP integration
Any other server	Through a relay	The customer runs a relay that queues the downlinks (5.6)



CAUTION
Public The Things Network is not suitable. Its fair-use policy allows about 10 downlinks a day per device, while a 30 KB patch needs about 150 downlinks. Use a self-hosted The Things Stack or ChirpStack.

5.5 Network load

5.5.1 Every chunk is one gateway downlink. A gateway may transmit 1 % of the time on the RX1 channels (36s an hour), and the same airtime carries the acknowledgements and join-accepts of all devices.

5.5.2 FUOTA therefore uses only an agreed share of each gateway's airtime: 25 % by default, set per network server. Updates can be limited to agreed hours, e.g. at night.

5.5.3 A gateway that reports duty-cycle or scheduling failures, loses more than half of its last 20 chunks, or whose devices start rejoining (more than 5 joins in an hour) is paused for a while and its share reduced.

5.6 Customer integration

To update devices on the customer's own network server, the customer provides:

	The Things Stack	ChirpStack v4	Other server (relay)
Server URL	e.g. https://lns.customer.de	gRPC(-web) endpoint	URL of their relay that queues downlinks

	The Things Stack	ChirpStack v4	Other server (relay)
API key	Application API key with the rights "Write downlink application traffic" and "Read application traffic" (the connection test reads the downlink queue)	API token with access to the device queue	Whatever the relay expects, sent in a configurable header
Application ID	Optional, learned from the first uplink	Not needed (addressed by DevEUI)	Not needed
Region / RX2	EU868, RX2 DR3 on the TTN plan	EU868, RX2 DR0	As configured on their server
Airtime	Share of the gateway airtime for FUOTA (default 25 %), optional update hours	same	same

5.6.1 **What EMONI provides:** a webhook address of the OTA cloud for this network server and a secret, sent in the `X-OTA-Secret` header. The network server forwards to it every uplink of the devices and the downlink events ack, nack, sent and failed. Of the forwarded uplinks the OTA cloud keeps only the FUOTA traffic, the event code and the battery voltage.

5.6.2 **Relay for other servers:** for each downlink the OTA cloud sends `POST <url>` with `{ devEui, fPort, confirmed, data (hex), dataBase64, ref }` and expects a 2xx answer, optionally with { id } of the queue item. An optional POST <flushUrl> with { devEui } empties the device queue. The relay reports the ack, nack or failure of each downlink to the webhook with its ref.

5.6.3 A web-application firewall or proxy in front of the network server (e.g. Cloudflare) must let the OTA cloud's API requests through.

Conditions on the customer's network:

5.6.4 not public The Things Network;

5.6.5 FPort 150 is passed through and not used by the customer's own application;

5.6.6 the customer's own downlink queue for the device stays free during the update;

5.6.7 to see the result in their own system, the customer's decoder knows the event codes 0x00A1 (update installed), 0x0010 (update failed) and 0x0042 (rolled back); the EMONI codec does.

The customer does not need multicast, class C, a FUOTA server, clock synchronisation or firmware files. EMONI builds each patch against the firmware the device runs; a device running a different firmware refuses it.

5.7 Receiving updates from EMONI: step by step

The customer connects the network server once; EMONI then runs every update. The steps:

Step	Customer	EMONI
1. Request	Asks EMONI for updates over LoRaWAN and names the network server and the devices.	Checks each device (firmware, data rate, battery) and sends an estimate of the duration per device (5.2, 5.3).
2. Access	Creates an API key with the rights in 5.6 and sends it with the server URL to EMONI over a secure channel.	Registers the network server in the OTA cloud and tests the connection.

Step	Customer	EMONI
3. Webhook	Adds the webhook to the network server: address and secret from EMONI, uplinks and the downlink events ack, nack, sent and failed.	Sends the webhook address and secret; confirms that events arrive.
4. Agreement	Agrees the airtime share (default 25 %), optional update hours, the number of devices updated at a time (default 5) and, if needed, a shorter upload interval during the update.	Sets these values for the network server and the release.
5. Update	Leaves FPort 150 and the device downlink queues free; readings continue as usual.	Releases the firmware, follows the progress and intervenes if a gateway or device stalls.
6. Result	Sees 0x00A1 (or 0x0010, 0x0042) in the next reading of each device.	Reports the result per device; devices that could not be updated over LoRaWAN are updated over Wi-Fi.
7. Afterwards	Keeps the integration for later updates, or revokes the API key and removes the webhook.	Deletes the network server and its key from the OTA cloud on request.



NOTE
Create the API key with only the rights listed in 5.6 and only for the application of the EMONI devices. Revoke or rotate it when no further updates are planned.

Integration

6.1 Payload codec

6.1.1 The codec is available at `https://emoni.cloud/downloads` for The Things Stack v3 and ChirpStack v4 (decodeUplink, encodeDownlink, decodeDownlink) and for ChirpStack v3 (Decode, Encode). Install it as the payload formatter of the device or application.

6.1.2 Output fields: `meterValue (text with comma), comma_pos, total_digits, battery_mv, error_event_hex, imu_ax, imu_ay, imu_az, qmax`.

6.1.3 The encoders build the downlinks of section 4 from their JSON objects.

6.2 EMONI Cloud (app.emoni.cloud)

The EMONI Cloud shows the readings, consumption and device status of LoRaWAN devices next to the other EMONI devices. The network server forwards the decoded uplinks to it by webhook.

6.2.1 Sign in at `https://app.emoni.cloud` and open the LoRaWAN setup.

6.2.2 Create an application. The EMONI Cloud shows its API key once and the webhook address https://app.emoni.cloud/lns/v1/uplink. Keep the key safe; a new key can be created at any time.

6.2.3 On the network server, install the EMONI codec (6.1) and add a webhook to this address that sends uplink messages as JSON with the header `X-API-Key: <API key>`. The Things Stack: Integrations, Webhooks, Custom webhook. ChirpStack: application, Integrations, HTTP.

6.2.4 In the EMONI Cloud, add each device to the application: meter type (gas, water, electricity), name of the metering point, DevEUI and location.

6.2.5 The readings appear with the next uplink. Uplinks of unknown DevEUIs or of devices that belong to another application are ignored; a repeated uplink with the same frame counter is counted once.

6.3 Own application

Any application can receive the decoded uplinks from the network server (webhook, MQTT or the server's own integrations) and send downlinks through it. EMONI does not need access to the customer's network server, except for firmware updates over LoRaWAN (5.6).

Power Supply and Battery

7.1 Power path

7.1.1 Four AA cells in series: 6.0 V nominal, about 7 V with fresh lithium cells. The device reports about 6.7 V under load (7.3).

7.1.2 A USB-C 5 V supply takes over automatically and disconnects the battery while it is connected.

7.2 Recommended cell: Energizer L91

Use four lithium iron disulfide cells, Energizer L91 or an equivalent FR6 cell. Lithium cells keep their voltage under the current peaks of the radio and the camera; alkaline cells (LR6) are not recommended.

L91 property (datasheet)	Cell	EMONI pack (4 in series)
Chemistry	Lithium / iron disulfide (Li/FeS2), FR6	–
Nominal voltage	1.5 V	6.0 V
Capacity at 25 mA to 0.9 V (read from the datasheet chart)	≈ 3500 mAh	≈ 3500 mAh
Typical internal resistance	120–240 mΩ	0.5–1.0 Ω
Maximum discharge	2.5 A continuous, 4 A pulse (2 s on / 8 s off)	same
Operating temperature	−40 °C to +60 °C	device: +5 °C to +45 °C
Shelf life	25 years at 21 °C	–
Weight	15 g	60 g

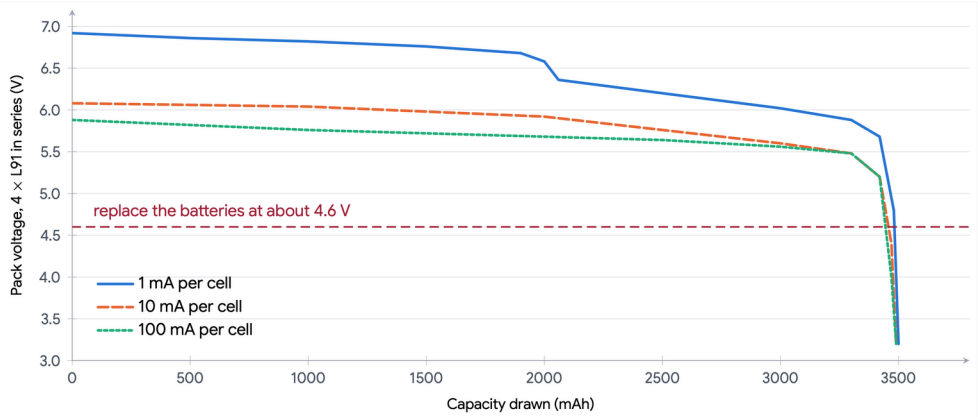


Figure 6: Energizer L91 constant-current discharge, scaled to the pack of four cells in series (cell voltage × 4). The voltage stays between about 7 V and 5.5 V for most of the capacity and falls steeply in the last few percent.
Source: Energizer L91 datasheet, 21 °C, values read off the published chart (approximate).

7.3 Battery measurement

7.3.1 The battery voltage is measured once per wake, under load. It is a few hundred mV below the open-circuit voltage, and single readings scatter by several hundred mV; evaluate the daily mean, not a single uplink.

7.3.2 A reading of 7515 mV or more is the full scale of the measurement, not a real voltage. A single reading below 3000 mV is taken during a brief supply dip, not the battery voltage.

7.4 Battery replacement

7.4.1 Replace the batteries when the daily mean of the reported voltage falls to about 4.6 V. Below about 4.0 V the pack is empty within a day.

7.4.2 The voltage gives little advance warning: it stays high for most of the battery life and falls steeply at the end (Figure 6). Plan the replacement from the expected battery life (7.5).

7.4.3 Always replace all four cells at the same time, with new cells of the same type.

7.5 Battery life

Expected battery life of a pack of four Energizer L91 cells from full to empty, for a typical site and, in brackets, a difficult one, both based on a field installation measured over five days of hourly uplinks. The end of discharge is included.

Upload interval	Motion wake off (default): typical site (difficult site)	Motion wake on: typical site (difficult site)
1 min	1 month (1 month)	1 month (1 month)
5 min	5 months (5 months)	5 months (5 months)
15 min	1.2 years (1.1 years)	1.0 year (1.0 year)
30 min	2.1 years (2.0 years)	1.6 years (1.6 years)
1 h	3.5 years (3.4 years)	2.3 years (2.2 years)
2 h	5.2 years (5.1 years)	2.9 years (2.9 years)
3 h (default)	**6.2 years (6.0 years)**	**3.2 years (3.2 years)**
6 h	> 7.5 years (> 7.5 years)	3.5 years (3.5 years)
12 h	> 7.5 years (> 7.5 years)	3.8 years (3.7 years)
24 h	> 7.5 years (> 7.5 years)	3.9 years (3.9 years)

Typical site: like the water meter of the measured installation, 4 % more energy per wake than on the bench. Difficult site: like its gas meter (signal down to −112 dBm, about 3 % of the readings rejected by the plausibility check, longer receive phases after one uplink in six, a missed acknowledgement with a resend), 9 % more energy

per wake. Sites that need SF10 to SF12 are not covered.

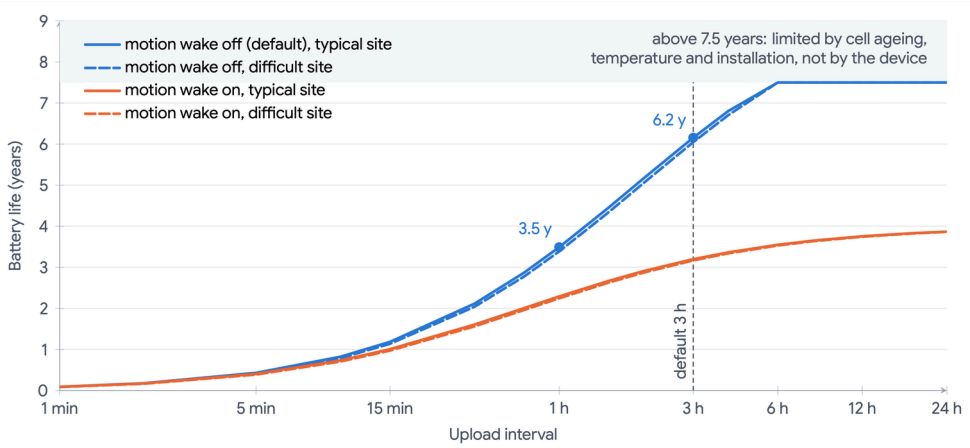


Figure 7: Battery life against the upload interval, four Energizer L91 cells from full to empty. Solid: typical site, dashed: difficult site; both measured in the field and close together. Above 7.5 years the cells and the installation set the limit.
Source: field model on bench measurements of the AG-506 (deep sleep, wake, supply range), 7.5.

At 5 V input	Motion wake off (default)	Motion wake on
Deep sleep current	40 µA (planning value; measured 29 µA)	107 µA
Deep sleep power	0.20 mW	0.53 mW
One wake (picture, recognition, uplink, receive windows)	5.4 s, 1.4 J, 0.26 W mean	5.4 s, 1.4 J

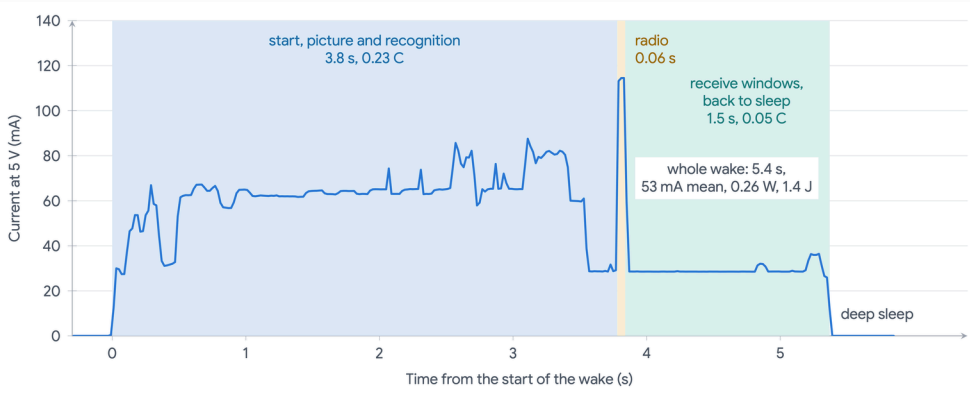


Figure 8: Current of one normal wake at 5 V input: start, picture and recognition, radio transmission, receive windows, then deep sleep.
Source: bench measurement at 10 kS/s, shown as 20 ms means.

7.5.1 **Basis:** sleep and wake measured on the bench across the input voltage range of the pack, applied along the L91 discharge curve (1 mA per cell, Figure 6). Derated for the field: 3000 mAh usable instead of 3500 mAh (low room temperature, voltage dips under load at the end of life, the weakest of the four cells), self-discharge of 1 % of the capacity per year, and 1.05 times the bench energy per wake (1.1 times for a difficult site), measured on a field installation. The deep-sleep value keeps a margin over the measurement for device

spread and temperature.

7.5.2 **Field factor:** the bench wake is a first-time recognition sent at SF7 with the acknowledgement in the first receive window. On the measured installation (two meters, 1 h interval, SF7, five days) the uplink times show the extra effort: receive phases about 3 s longer after one uplink in six to ten, readings rejected by the plausibility check in up to 3 % of the wakes, and one missed acknowledgement with a resend. Together this is 4 % (water meter) to 9 % (gas meter) more energy per wake; the model uses 1.05 and 1.1. A network with a 5 s first receive window adds about 10 %.

7.5.3 **Motion wake:** off by default. The motion sensor then checks tilt and displacement at every wake and sleeps in between. With the downlink {"imu_mode":2} (section 4) it stays active to wake the device on motion, which roughly halves the battery life from 3 h upwards.

7.5.4 **Not included:** sites that need SF10 to SF12 (each transmission up to 25 times longer than at SF7, up to half the battery life at 1 h), firmware updates over LoRaWAN, repeated calibrations and long radio outages, which each cost the energy of many wakes; temperatures below +5 °C.

7.5.5 **Estimates:** model values, to one decimal (months below 1 year). From 12 h upwards the battery life is set by factors outside the device: ageing and self-discharge of the cells, room temperature and the installation. Model values above 7.5 years are shown as "> 7.5 years".

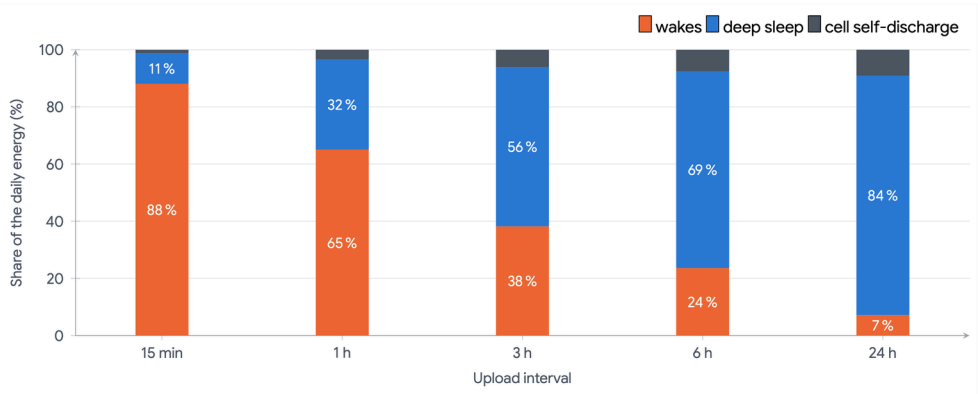


Figure 9: Share of the daily energy (typical site, motion wake off). From 3 h upwards deep sleep and the self-discharge of the cells dominate, so longer intervals add little battery life.

Source: field model, 7.5.

CAUTION

The values are estimates from the model above. A site that needs SF10 to SF12, frequent firmware updates or long radio outages shortens the battery life.

Security

8.1 Calibration menu and Wi-Fi

8.1.1 The device opens a Wi-Fi access point only while it is not calibrated: on first start and after a factory reset. The access point closes after 10 minutes. A new calibration starts with a factory reset.

8.1.2 Access point: SSID EMONI-XXXX, WPA2. The menu at 10.10.10.1 needs a login.

8.1.3 Login: user admin, password = the last 8 characters of the device AppKey, lowercase; capitals are accepted too.

8.1.4 After 5 wrong passwords in a row, every login is refused for 60 seconds and the login page says so.

8.2 LoRaWAN

8.2.1 OTAA with a per-device 128-bit AppKey; LoRaWAN encrypts all application data (AES-128) and protects every frame with a message integrity code.

8.2.2 Device keys are sent to the customer separately by email. The AppKey is not shown in the menu.

8.3 Firmware

8.3.1 Production devices start only firmware signed by ISIS IC (Secure Boot) and keep firmware and stored data encrypted in flash (flash encryption).

8.3.2 Every update, over Wi-Fi or LoRaWAN, is checked before it is installed. A new firmware must confirm itself on its first start; otherwise the device returns to the previous firmware.

8.4 Factory reset

8.4.1 Holding the button for 3 seconds deletes the calibration, the meter type and the stored Wi-Fi settings. Use it before handing the device over or disposing of it.

Technical Characteristics

9.1 Radio

Parameter	Value
Radio module	Sub-GHz radio module for LoRaWAN, 868 MHz band
LoRaWAN	863–870 MHz (EU868), ≤ 14 dBm, Class A, MAC 1.0.2
Channels	868.1 / 868.3 / 868.5 MHz plus network-defined channels
RX2	869.525 MHz, data rate set by the network
Wi-Fi module	In the main controller; used for calibration and firmware updates on site
Wi-Fi	IEEE 802.11 b/g/n, 2400–2483.5 MHz, 13 ± 2 dBm (HT20, MCS7), WPA2
Antenna	External antenna, must not be modified or replaced

9.2 Electrical

Parameter	Value
Battery	4 × 1.5 V AA, lithium (Energizer L91 recommended)
External supply	USB-C, 5 V, 1 A maximum
Power consumption, deep sleep	≈ 0.20 mW at 5 V (0.53 mW with the motion wake on)
Power consumption, active	≈ 0.26 W at 5 V, mean of a wake (5.4 s, 1.4 J)
Upload interval	1 min to 72 h, 3 h by default; adjustable on site and by downlink

9.3 Environment, camera and mechanics

Parameter	Value
Operating temperature	+5 °C to +45 °C
Storage temperature	−20 °C to +70 °C (max. 70 % RH)

Parameter	Value
Humidity	0–95 %, non-condensing
Camera	480 × 320, 1/5 inch lens
Weight	196 g without batteries
Dimensions (H × L × W)	80 × 72 × 107 mm
Housing	ABS, IK07, opened with tools only
Mounting	3M adhesive tape with hinge
Protection class	IP20, indoor use only

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Made in Germany