

Building quality LoRaWAN networks for longer sensor battery life

A practical guide to planning, configuring and operating sensor networks.

Version B, October 2026. Replaces version A (March 2025).

A battery-powered sensor can operate for many years, but its lifetime depends on the complete system around it. Radio coverage, reporting frequency, measurement activity and retry behaviour all affect how quickly the battery is used.

The most effective approach is to provide dependable coverage, send only the data the application needs and monitor the network throughout its life. Adding or repositioning a gateway can improve reliability and reduce sensor energy use without increasing the size of the sensor battery.

Who this guide is for

This whitepaper is for organisations deploying or operating LoRaWAN sensors in buildings, cities, utilities and industrial sites. It explains the decisions that matter most, from selecting gateway locations to diagnosing missing data.

The examples focus on EU868 and battery-powered Class A devices. Protocol details use LoRaWAN 1.0.x, particularly 1.0.4; other versions and regions may behave differently. The battery calculation is an illustrative model, not a product lifetime specification.

THE MAIN RECOMMENDATIONS

- **Design for both uplinks and downlinks.** Receiving sensor data does not prove that the sensor can receive a network response.
- **Use the fastest data rate that maintains a suitable reliability margin.** Long airtime increases energy use and occupies the shared radio channel.
- **Separate measurement frequency from reporting frequency.** A sensor can measure frequently and report less often, if its firmware supports this.
- **Keep routine traffic efficient and use acknowledgements selectively.** Limit retries and avoid repeated join attempts.
- **Track delivery, radio quality and battery trends together.** Investigate changes before they become widespread failures.

How to use the guide

Sections 1 to 3 explain the network, radio coverage and downlink constraints. Sections 4 to 7 cover sensor settings, practical applications and battery calculations. Sections 8 to 10 provide deployment, monitoring and recovery guidance. Section 11 summarises the checks and technical references.

1 How a LoRaWAN network works

LoRa is the radio modulation. LoRaWAN is the protocol that connects devices through gateways to network and application services. It is suited to small, intermittent messages over long distances, with low energy use. [1]

One transmission can reach several gateways

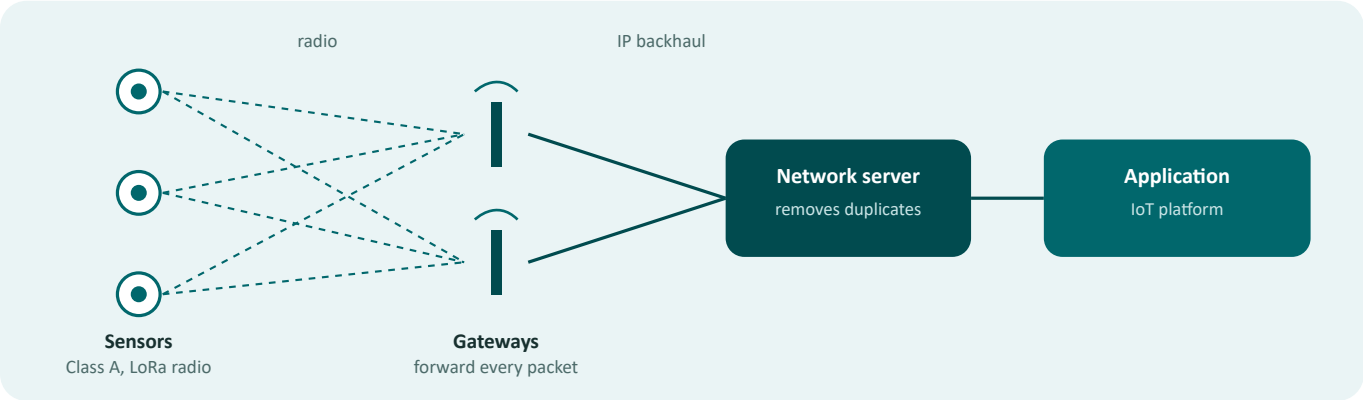


Figure 1. A LoRaWAN network. Every gateway that receives an uplink forwards it; the network server removes duplicate copies and passes the payload to the application server and IoT platform.

LoRaWAN uses a star-of-stars architecture. A sensor transmits a packet, and each connected gateway that successfully receives it forwards it over an IP connection. The network server removes duplicate copies and manages radio communication. The application server handles the sensor payload, which an IoT platform can store, display or use for automation.

A sensor is not normally tied to one gateway. Overlapping gateway coverage improves resilience without requiring an extra transmission from the sensor. This differs from a mesh network, where intermediate devices forward packets and consume energy doing so.

Class A keeps listening time short

Class A devices open receive windows after an uplink and can sleep between activities. The second window is used when no valid message for the device has been received in the first. Unconfirmed uplinks also create these receive opportunities. [1]

Class B adds scheduled receive opportunities. Class C listens almost continuously when it is not transmitting and normally requires a larger energy budget. For many battery-powered sensors, Class A is the appropriate choice.

Downlinks depend on timing

Normal Class A receive windows default to one and two seconds after an uplink. A gateway using SIM-based 4G/5G backhaul may experience higher or variable latency. The uplink must reach the network server and its response return to the gateway before the scheduled downlink. A late ACK can be missed even when the uplink arrived, causing the device to retry. OTAA join uses separate defaults of five and six seconds. [2, 9]

Security and joining

Over-the-air activation, or OTAA, establishes a device session using provisioned credentials. Join requests do not universally use SF12: the permitted channels, data rates and retry strategy depend on the region and device implementation. Repeated failed joins should trigger investigation, not indefinite rapid retries. [3]

In LoRaWAN 1.0.x, AppSKey encrypts application data and NwkSKey supports message integrity and network functions. DevAddr is visible in the frame header. Payload encryption does not replace secure credential handling, protected server interfaces or application access control. LoRaWAN 1.1 uses a different network-key structure. [1]

2 Understanding radio coverage

Distance alone is a poor predictor of coverage. Building materials, antenna placement, terrain and interference can make nearby devices harder to reach than devices several kilometres away.

Read RSSI and SNR together

RSSI, the Received Signal Strength Indicator, describes signal strength, usually in dBm. A less negative value generally means a stronger signal. SNR, the Signal-to-Noise Ratio, describes the signal relative to noise, in dB. Neither metric alone proves a link is reliable.

LoRa can decode signals below the noise floor, so negative SNR is not automatically a fault. Compare the measured SNR with the requirement for the current spreading factor and assess packet delivery over time. Uplink measurements at a gateway also do not establish the quality of downlinks at the sensor. [4]

Spreading factor trades airtime for sensitivity

With the same bandwidth and payload, a higher spreading factor generally improves receiver sensitivity but increases airtime. EU868 DR0 to DR5 correspond to SF12 down to SF7 at 125 kHz. Use the lowest SF that provides enough margin for the real operating environment. [2]

Adaptive Data Rate, or ADR, allows the network to adjust data rate, transmit power and repetitions based on received traffic. It is especially useful for stationary devices. It adapts over time rather than guaranteeing an immediate response to every change. Mobile devices need a strategy suited to changing coverage.

Allow a margin for changing conditions

A link margin is the difference between received signal power and the receiver sensitivity at the selected settings. For example, –115 dBm at a receiver with –125 dBm sensitivity gives 10 dB of margin. A positive margin alone does not guarantee delivery: interference and fading can still cause loss.

Test the actual installation environment

Reinforced concrete, metal enclosures, foil insulation and metal-coated windows can strongly attenuate radio signals. Underground and near-ground installations are also challenging. Loss depends on material, thickness, moisture, geometry and frequency; universal dB-per-wall or dB-per-metre values are unsuitable for deployment acceptance.

Check antenna orientation and its radiation pattern. A high-gain omnidirectional antenna may provide good horizontal reach but weaker coverage directly above or below it. There is no fixed number of floors an indoor gateway will cover.

Interference can affect one or several channels. Sources include UHF-RFID systems operating at 865–868 MHz and nearby cellular base stations. Strong signals outside the LoRaWAN band can overload a receiver; unwanted emissions can also enter the band. Antenna separation and filtering matter. Confirm the source with measurements. [7, 8]

3 Bidirectional coverage and network capacity

Reliable communication requires a usable radio path in both directions and enough time and capacity to deliver the response. Three different problems can look alike: a downlink can be too weak to decode, arrive too late or never be transmitted because the gateway cannot schedule it.

The gateway may hear more than the sensor

A gateway and a sensor can have different antenna performance, receiver sensitivity and local interference. For example, a rooftop gateway may receive an uplink clearly while a sensor beside a strong transmitter cannot decode the downlink. Gateway RSSI and SNR describe uplink reception at that gateway; they do not measure the noise environment at the sensor.

Check the downlink data rate, frequency and selected gateway as well as the uplink. Where the device exposes downlink signal measurements, use them. Otherwise, test supported commands and confirmations repeatedly at the actual installation location.

Downlink capacity is shared

Acknowledgements, ADR commands, configuration changes and join responses compete for gateway transmission opportunities. Duty-cycle limits and scheduling conflicts can prevent a downlink even when the radio path is good. EU868 limits depend on the sub-band and applicable rules; there is no single percentage for all traffic. [10]

Avoid routine confirmed traffic where periodic unconfirmed reports meet the application need. Spread non-urgent configuration changes over time. Monitor rejected and late downlink scheduling separately from radio packet loss, and include busy periods in the pilot.

Antenna height and the space around the path

Radio propagation depends on a volume around the direct path, called the Fresnel zone. A visually clear line of sight can still have poor clearance if the antennas are low and the ground, vegetation or buildings intrude into that volume. Reflections can also partially cancel the direct signal. [12]

Raise or reposition antennas where practical, maintain the intended orientation and keep them away from metal surfaces. Use suitable outdoor enclosures and check cable losses. Test the final sensor mounting as well as gateway placement: moving either end can improve the link. Measure the improvement at the site; gains and range depend on the installation.

Distinguish the cause before applying the remedy

For weak or interfered reception, improve placement or filtering. For late responses over SIM backhaul, check latency and coordinated RX timing. For capacity limits, reduce unnecessary downlinks and improve the network design. Raising NbTrans alone does not remove any of these causes.

4 Configure sensors for the application

Start with the information the application needs: how quickly changes must be detected, how much missing data is acceptable and how often a status update is necessary. Then select measurement, reporting and retry settings that meet those requirements.

Measure and report at different intervals

Measurement consumes energy even when no radio message is sent. Some sensors can sample frequently, process changes locally and send periodic summaries or threshold events. Others have less flexible firmware. Confirm the supported behaviour before estimating battery life.

For slowly changing conditions, longer reporting intervals may be appropriate. For occupancy or leak detection, event reporting can provide timely information. Add a periodic status report so the application can distinguish an unchanged value from a device that has stopped communicating.

Use confirmations where they add value

An unconfirmed uplink does not request a LoRaWAN acknowledgement. It is often suitable for periodic data that will soon be refreshed. A confirmed uplink requests an acknowledgement and can support delivery tracking for selected events. [5]

A confirmed uplink does not guarantee delivery or prove that an application has processed the event. The acknowledgement may be lost even when the uplink arrives. Retries must be bounded, and critical workflows may need application-level acknowledgement or escalation.

For larger deployments, frequent confirmed messages can also consume scarce downlink capacity. Select the strategy from the required reliability and measured network performance, rather than making all events confirmed by default.

Control repetitions and join attempts

Packet loss on one or more interfered channels can lead the network server to increase NbTrans. Repeating an uplink on different enabled channels improves the chance of reception but consumes more battery charge and airtime. NbTrans above 1 is a reason to check channel performance, not proof of interference: weak coverage and other losses can also justify repetitions. Handling depends on the LoRaWAN version and message type. [5]

Four transmissions use approximately four times the transmit charge of one. Total device consumption rises by a different amount because sensing, standby and receive activities also contribute. Therefore a fixed percentage reduction in battery lifetime cannot be stated without an energy model.

Missing acknowledgements do not inherently require a new join. Rejoining is device-dependent recovery behaviour. Use sensible backoff and preserve session state correctly; a normal network-server restart should not require every device to join again.

Set power within the regional limits

ADR can reduce transmit power when the link has sufficient margin. Use the regionally supported power settings and account for antenna gain. The radio hardware may support additional output levels that are not available through the standard regional ADR power table. [2]

5 Reporting examples for common applications

These examples show how application requirements translate into sensor settings. They are illustrative configurations, not Sensative product defaults or guaranteed battery specifications. Confirm the device firmware supports the intended measurement and reporting behaviour.

Temperature monitoring

A sensor might measure every five minutes and report every 30 minutes, with an earlier report when the temperature changes beyond a defined threshold. Measurement and transmission remain separate loads. The threshold should match the required accuracy and the rate of change the application must detect.

Periodic unconfirmed reports can suit comfort monitoring, where a later value refreshes the information. Refrigeration or process monitoring may require shorter intervals, locally detected threshold events and an escalation rule for missing data. Temperature data can be critical too.

Water leak detection

Use a low-power sensing method that detects water within the required time. Report a detected leak promptly and include periodic health reports. A confirmed alarm may help track network receipt, with a bounded number of retries. The application must still manage notification, acknowledgement and the required response.

Avoid unlimited repeated alarm messages while the sensor stays wet. Define a supported repeat or reminder policy, and report when the condition clears. During the pilot, test the complete chain from detection to the person or system expected to act.

Desk or room occupancy

Measure presence at the frequency needed to detect meaningful changes. Report an occupancy transition and add periodic state refreshes. A short stability period can reduce repeated messages caused by brief movements or changes near a detection threshold, but must not delay the information beyond the application requirement.

For utilisation analytics, unconfirmed transitions plus periodic refreshes may be sufficient. Booking release or operational control may need stricter delivery and freshness checks. Choose confirmations from the measured reliability requirement rather than confirming every change automatically.

Keep reports small and spread them over time

Send the fields the application needs in a compact payload, and combine measurements where useful. More bytes can increase airtime, particularly at higher SF. Preserve required timestamps and meaning; do not save bytes by making data ambiguous.

Avoid having many devices report or join at exactly the same instant. Where supported, use randomised timing and retry backoff while maintaining required event latency. Check network behaviour after a shared power restoration or server maintenance. [1]

6 Calculate the battery budget

Battery lifetime depends on usable battery capacity divided by average device current. The average must include standby, sensing, processing, transmission, receive windows, joins and retries. Battery ageing, temperature and pulse-load behaviour also affect the usable capacity.

A transparent radio example

The table isolates the effect of spreading factor using the same transmit current at every SF. It assumes a 500 mAh battery, 1.5 µA standby current, 40 mA transmit current and one uplink every 15 minutes, or 96 per day.

Airtime is calculated for 10 application bytes plus 13 bytes of LoRaWAN overhead, with no FOpts: 125 kHz bandwidth, coding rate 4/5, an 8-symbol preamble, explicit header, uplink CRC and low data rate optimisation at SF11 and SF12. [6]

Spreading factor	Airtime, ms	Average current, µA	Idealised lifetime, years
SF7	61.7	4.2	13.5
SF8	113.2	6.5	8.7
SF9	205.8	10.6	5.4
SF10	370.7	18.0	3.2
SF11	823.3	38.1	1.5
SF12	1,482.8	67.4	0.85

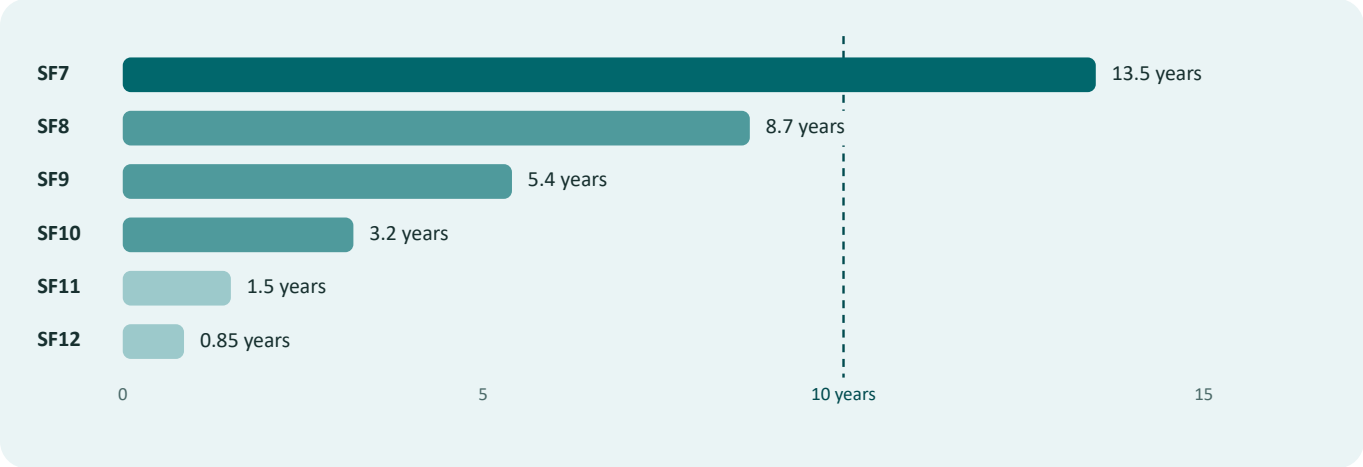


Figure 2. Idealised lifetime of a 500 mAh sensor reporting every 15 minutes, by spreading factor. Radio and standby only; the dashed line marks a ten-year design life.

These are upper-bound estimates for this simplified model, not expected field lifetimes. Receive current, sensing, processing, retries, joins, self-discharge and capacity derating are excluded. The SF7 and SF8 figures exceed a typical ten-year design life and are theoretical upper bounds; calendar ageing is not modelled.

Why SF12 changes the result so much

At SF12, transmitting uses about 1.58 mAh per day. Standby adds about 0.036 mAh per day. The 500 mAh battery therefore lasts approximately 309 days in this model, before the excluded loads are added. At SF7, airtime is about 24 times shorter, substantially reducing the radio contribution.

Build a product estimate from measurements

Measure charge per sensing cycle, uplink, receive cycle and join attempt on the actual device. Multiply each by its expected frequency, then add standby consumption. Apply a usable-capacity allowance for the intended temperature range, ageing and end-of-life voltage. Validate the estimate against pilot data.

Voltage alone may be a weak remaining-capacity indicator for batteries with flat discharge curves. Combine voltage and load response with a validated consumption model when supported. Both replaceable and built-in batteries can use advanced monitoring; the method depends on the design and chemistry.

7 An example of the complete operating budget

The earlier table isolates radio airtime. This example adds sensing and receive activity so their contribution is visible. It uses assumed values for a generic device; a product estimate must replace them with measured charge and battery data.

Assumptions for the comparison

Assume a nominal 500 mAh battery, with 400 mAh treated as usable for this example. The 80 percent allowance is an illustration, not a universal derating rule. Standby is 1.5 µA. The sensor measures once a minute, using an additional 5 mA for 20 ms per measurement.

An application report is sent every 15 minutes. The payload, modulation and 40 mA transmit current match the preceding airtime table. Each transmission attempt adds a total of 250 ms of receiver activity at 5 mA across its receive windows. Actual durations depend on data rate, clock tolerance, downlink traffic and firmware.

Compare one transmission at SF7, one at SF12 and three at SF12 for every application report. For the third case, all attempts occur; no downlink stops them early. There are no routine joins in these scenarios. Standby is counted continuously, a small conservative approximation.

Daily load, mAh	SF7, one attempt	SF12, one attempt	SF12, three attempts
Standby	0.036	0.036	0.036
Measurements	0.040	0.040	0.040
Transmissions	0.066	1.582	4.745
Receive activity	0.033	0.033	0.100
Routine joins	0	0	0
Total	0.175	1.691	4.921
Calculated operating time	2,284 days	237 days	81 days

The calculated times are approximately 6.3 years, 237 days and 81 days. They are arithmetic estimates, not promised lifetimes. Calendar ageing and self-discharge are not modelled; include them separately using the battery supplier data and validate temperature and pulse-load limits.

Account for failed joins and changing conditions

For every join attempt, add the measured transmit and receive charge. Then multiply by the expected attempts per day. Use the same approach for link checks and other extra activity. A prolonged outage or intermittent coverage can change these frequencies substantially.

For perspective, one additional 40 mA transmission lasting 1.483 seconds uses about 0.0165 mAh, before reception. Fifty such transmissions add about 0.82 mAh per day. This illustrates why controlled recovery and alerts for repeated failures matter even when normal reporting is infrequent.

8 Plan and validate the deployment

A successful pilot tests the worst locations and the complete path from sensor to application. Good reception at an outdoor gateway is not enough to accept devices installed behind metal-coated windows, in basements or inside equipment.

Define the acceptance criteria first

Agree the required reporting interval, event latency, delivery rate, outage detection time and battery operating assumptions. Specify how performance will be measured and over what period. Include downlink success when remote configuration, joining or confirmations are required.

Place gateways for the real environment

Use elevated, unobstructed antenna locations where they improve coverage. Check cable losses, connectors, weather protection and the antenna radiation pattern. In buildings, an indoor gateway can be more effective than increasing the power of an outdoor installation.

Provide overlapping coverage where continuity matters. Check shared dependencies: two gateways on the same power circuit or backhaul can fail together. Verify the backhaul is stable and fast enough for scheduled downlinks.

Run a representative pilot

- Install sensors in difficult locations, including basements, upper floors, plant rooms and metal enclosures where relevant.

- Measure application delivery as well as gateway RSSI, SNR, data rate and gateway diversity. Record repetitions and join attempts.
- Test normal operating conditions, including occupancy changes, closed doors, equipment activity and changing sensor orientations.
- Send supported downlink commands and confirm that the devices apply them. Check join success independently of normal downlink timing.
- Simulate a gateway outage and verify the required reporting continues through other gateways.

Correct the cause before scaling

Persistent high SF, frequent repetitions or failed joins should prompt investigation. Check coverage and configuration before increasing reporting intervals to hide excessive consumption. Improving gateway placement may resolve both reliability and battery problems.

For SIM-connected gateways, check latency and late downlinks under load. Configure a suitable normal RX1 delay in the network server, for example five seconds with RX2 at six seconds. Set it via JoinAccept or RXTimingSetupReq as appropriate; device and server timing must agree. This gives the backhaul more time, but does not change OTAA join timing or fix outages. Verify downlinks afterwards. [1, 9]

Keep a deployment record

Record device identity, model, firmware, location, region, reporting configuration and gateway details. Maintain secure credential records and a clear owner for each operational issue. Use the measured pilot configuration as the reference for future changes.

9 Operate and troubleshoot the network

Monitor the service continuously, because buildings and radio environments change. A device that was reliable at installation can become marginal after a renovation, gateway relocation or change in nearby equipment.

Monitor outcomes and supporting indicators

Track expected versus received application reports, time since last report and event latency. Review these alongside SF, RSSI, SNR, receiving gateway count, repetitions, join frequency and battery trends. Compare changes for individual devices and groups.

Compare packet delivery, RSSI and SNR per channel over time. One or several channels performing worse can indicate interference and help explain higher NbTrans. Channel imbalance alone is not proof: account for channel configuration and sample size. Frame-counter gaps also need interpretation with resets, repetitions and application filtering in mind.

Verify gateway packet forwarding and backhaul latency, not just ping availability. For SIM-connected gateways, track variable delays and late downlinks. Protect session state and record configuration changes. Use remote firmware updates only where supported.

A practical diagnostic sequence

Symptom	First checks
Cannot join	Region and credentials; JoinRequest and JoinAccept logs; separate join timing; antenna health and SIM/ backhaul latency.
Persistent high SF	Antenna placement and losses; obstacles; interference; ADR settings and sufficient traffic history.
Missing reports	Application path and decoding; gateway forwarding; device schedule; coverage; battery condition.
Many retries or joins	Late or missed ACKs; SIM/backhaul latency and RX timing; packet loss per channel; interference; retry and session settings.
Unexpected battery drain	Measured sensing load; report frequency; SF and transmit power; repetitions; joins; temperature and battery ageing.

Isolate the problem before changing settings

Locate the loss: at the gateway, network server or application. Compare affected and healthy devices, and correlate the issue with time, channels and gateway status.

Inspect antennas, cables and obstructions. For losses on particular channels, measure the spectrum and check nearby UHF-RFID readers or cellular transmitters. Consider antenna separation, filtering or a coordinated channel-plan change. Change one setting at a time and verify delivery and energy use.

10 Link checks and controlled recovery

A device needs a way to assess network contact without repeatedly starting new sessions. Combine application monitoring with the supported LoRaWAN link-management functions. The correct recovery policy depends on the device, protocol version and application.

Unconfirmed traffic still needs downlink support

Unconfirmed uplinks avoid requesting an ACK for each report, but the device still needs downlinks for network management. ADR commands, timing changes and other MAC responses must reach it. A network can therefore appear healthy in an application dashboard while a downlink problem remains hidden.

With ADR enabled, a device that receives no valid downlinks for the defined number of uplinks can enter ADR backoff. It increases transmit power and, if contact is not restored, reduces data rate in stages. Longer airtime and higher power can raise battery consumption even though the application uses unconfirmed reports. The procedure and thresholds depend on the applicable specification. [11]

Investigate an unexplained trend towards higher SF alongside downlink scheduling, gateway backhaul and interference at the sensor. Do not assume that the uplink coverage has simply become weaker.

Use link checks deliberately

Where supported, a device can send LinkCheckReq and receive LinkCheckAns. The answer provides the network estimate of uplink demodulation margin and the number of gateways that received the request. Receiving the answer also demonstrates a successful downlink for that exchange. It does not prove the application has processed sensor data. [1]

Choose the frequency from the required fault-detection time and energy budget. Checks may share an uplink with application data where supported, but still require downlink capacity. Daily checks are not a universal recommendation, and frequent checks do not compensate for poor network design.

Rejoin only when the recovery policy requires it

A missed ACK or a temporary gateway outage does not inherently invalidate a session. Use bounded retries, increasing or randomised delays and the supported ADR recovery procedure before unnecessary joins. If a new activation is required, preserve security counters and nonces according to the protocol.

Persist server-side session state across restarts and planned maintenance. Coordinate device reprovisioning or network migration. A normal server restart should not trigger mass joining or reset security state.

Define an outage response

- Set alerts for prolonged missing reports, repeated joins, rising SF and excessive repetitions.
- Test how devices behave during a gateway outage and how they recover afterwards.
- Record both the normal daily consumption and the recovery consumption during faults.
- After restoration, verify delivery, downlinks and efficient radio settings have recovered.

WHERE SENSATIVE FITS

- **Built-in batteries.** Strips and Square sensors carry a sealed, built-in lithium cell — 480 mAh in Strips, up to 6,000 mAh in Square — so a battery estimate rests on one known chemistry rather than whichever cell was fitted.
- **Settings that follow the application.** Square, Square Xtreme, Puck and Prism are configured on site over NFC (Android) and over the air, so measurement and reporting intervals can be set for each use and changed later.
- **Monitoring in Yggio.** Yggio, the open operational layer, shows radio-coverage analysis on the map and a connectivity view of every device, and its rule engine can raise an alert on a missed report — the checks in sections 9 and 10, without extra tools.

11 Deployment checklist and references

Before rollout

- Application requirements and measurable acceptance criteria are agreed.
- Worst-case device locations have been tested for uplink and required downlink functions.
- Gateway coverage, SIM/backhaul latency, downlink capacity and redundancy have been validated.
- Measurement, reporting, RX timing, confirmation, repetition and recovery settings are documented.
- Battery estimates include the actual sensor load and realistic usable capacity.

During operation

- Missing reports, gateway failures and abnormal consumption generate actionable alerts.
- SF, channel performance, downlink failures, repetitions and joins are reviewed after changes.
- Configuration history, device inventory and secure credential management are maintained.

Technical references

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For help with LoRaWAN network settings, sensor configuration or coverage in radio-dense buildings, contact Sensative support at sensative.com/support.html or support@sensative.com.