Your IoT Sensor Could Last 5 Years Instead of 14 Months. Here's the Math.

Why data compression — not bigger batteries — is the real answer to IoT's energy crisis.

The Problem Nobody Talks About

Every IoT deployment hits the same wall: batteries die too fast. The industry's answer has been predictable — better chipsets, bigger batteries, lower duty cycles. But there's an elephant in the room that very few people address: **the data itself.**

A LoRa radio consumes 120 mA during transmission but only 0.2 μA in sleep mode.

That's a 600,000× difference.

Every millisecond your radio spends transmitting is the equivalent of 10 minutes of sleeping. The implication is profound: **if you send half the bytes, your battery lasts roughly twice as long.** Not because of a new chip. Not because of a bigger cell. Simply because the radio sleeps more.

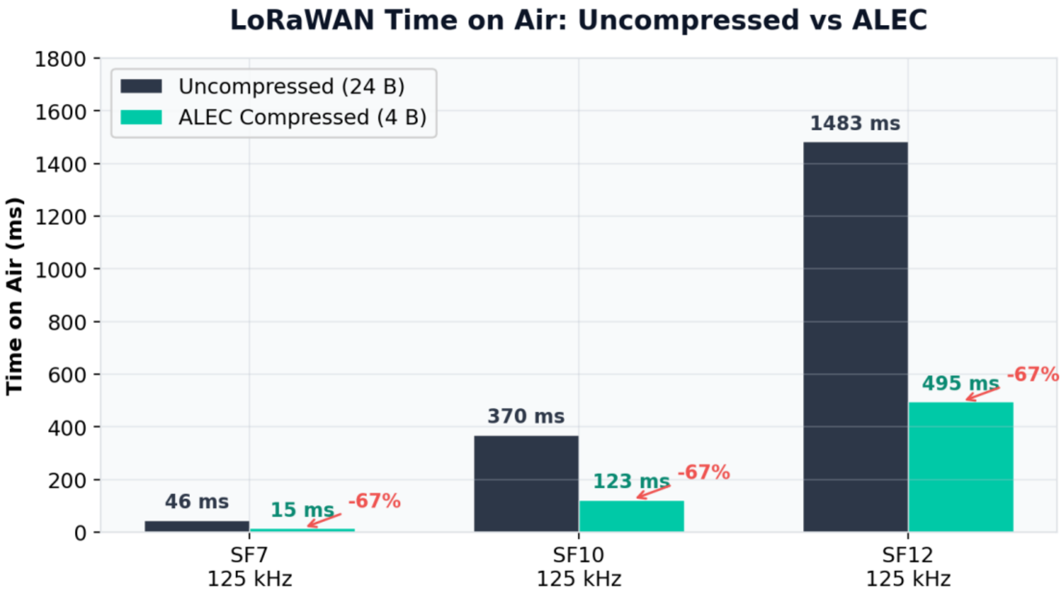
This article presents hard numbers. We benchmarked ALEC — a compression codec designed specifically for IoT sensor data — against uncompressed transmission on two protocols: LoRaWAN and Iridium SBD. The results are striking.

The Physics: Why Bytes = Battery

LoRaWAN: Time on Air Is Everything

In LoRaWAN, the radio's active time — called Time on Air (ToA) — is directly proportional to the number of bytes transmitted. The relationship is governed by spreading factor (SF) and bandwidth (BW). Higher spreading factors extend range but dramatically increase transmission time.

Payload	SF7 / 125 kHz	SF10 / 125 kHz	SF12 / 125 kHz
24 bytes (raw)	46 ms	370 ms	1,483 ms
4 bytes (ALEC)	**15 ms**	**123 ms**	**495 ms**
Reduction	**-67%**	**-67%**	**-67%**



At SF12 — used for maximum range in rural and agricultural deployments — a single uncompressed reading keeps the radio active for nearly 1.5 seconds. With ALEC compression, that drops to under 500 milliseconds. The energy cost per transmission at 3.3V with the Semtech SX1276:

- **Uncompressed (24 B, SF12):** 120 mA × 1.483 s × 3.3 V = 587 mJ
- **ALEC compressed (4 B, SF12):** 120 mA × 0.495 s × 3.3 V = 196 mJ

That's 391 millijoules saved per single transmission. Multiply by 96 transmissions per day (every 15 minutes) and you save 37.5 joules per day — enough to power the MCU for an additional 10+ hours.

Iridium SBD: Every Session Is Expensive

Satellite IoT is a different beast. With the Iridium 9603N, each Short Burst Data session has a fixed overhead of 20–30 seconds, regardless of payload size. The modem draws an average of 158 mA at 5V during transmission. Compression benefits satellite in two ways: more data per message (fitting 50+ readings into a single 340-byte SBD instead of 14), and fewer modem sessions (each avoided session saves ~2.8 ampere-seconds = 14 joules at 5V).

Scenario	Without ALEC	With ALEC
Bytes per reading	24	**4**
Total daily data (96 readings)	2,304 bytes	**384 bytes**
SBD messages needed	7	**2**
Daily energy (modem only)	98 J	**28 J**
Daily savings	—	**70 J (71%)**

The Benchmark: 2× AA Batteries, One Sensor, How Long?

Setup: Temperature + humidity sensor (SHT30), sampling every 15 minutes. Payload: 8 bytes raw (2× float16), 24 bytes with LoRaWAN framing. Radio: Semtech SX1276 on EU868. MCU: STM32L0 (3.5 µA stop mode). Battery: 2× AA lithium (Energizer L91), 3,000 mAh @ 3.0V = 32,400 J total energy budget.

Energy Budget per Cycle

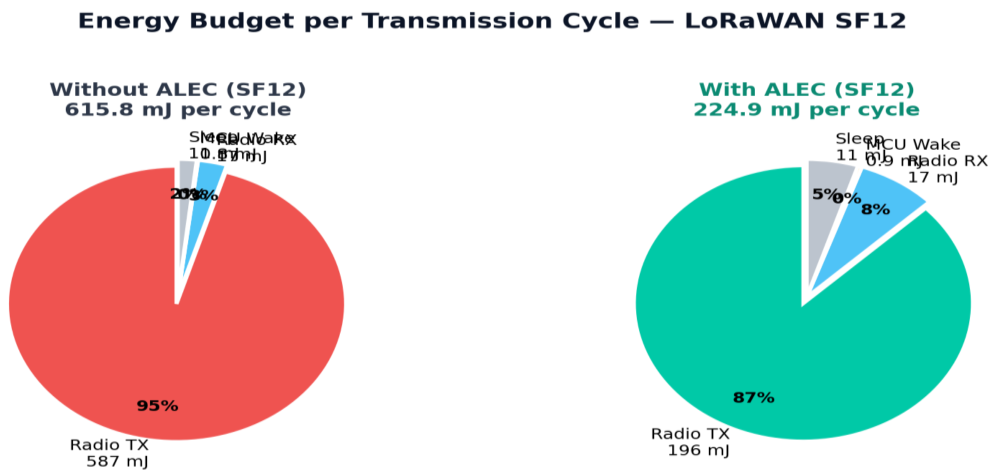
Uncompressed — 24 bytes, SF10:

Phase	Current	Duration	Energy
Wake + sample	5 mA	50 ms	0.83 mJ
Radio TX (24 B, SF10)	120 mA	370 ms	146.5 mJ
Radio RX1 window	10.3 mA	500 ms	17.0 mJ
Sleep (14 min 59 s)	3.7 µA	899 s	11.0 mJ
Total per cycle			**175.3 mJ**

ALEC Compressed — 4 bytes, SF10:

Phase	Current	Duration	Energy
Wake + sample + compress	5 mA	52 ms	0.86 mJ
Radio TX (4 B, SF10)	120 mA	123 ms	**48.7 mJ**
Radio RX1 window	10.3 mA	500 ms	17.0 mJ
Sleep (14 min 59 s)	3.7 µA	899 s	11.0 mJ
Total per cycle			**77.6 mJ**

Note: ALEC compression adds only ~2 ms of processing time on an ARM Cortex-M0+. The energy cost of compression (0.03 mJ) is negligible — 900× less than the energy saved on radio transmission.



Battery Life Results

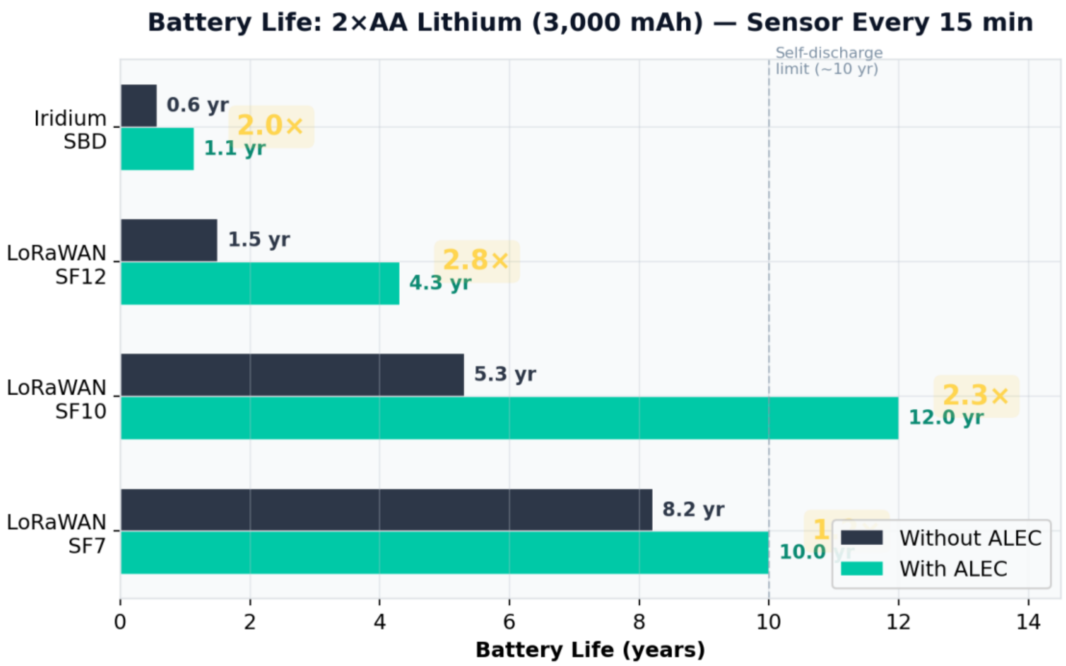
	Without ALEC	With ALEC	Improvement

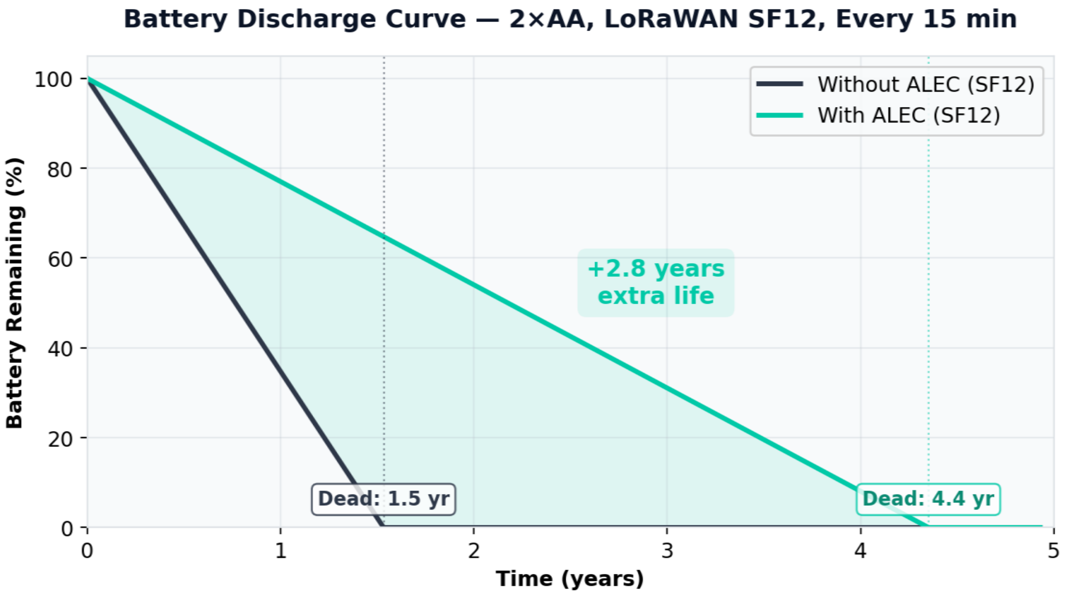
Energy per cycle (SF10)	175.3 mJ	**77.6 mJ**	**-56%**
Daily energy	16.8 J	**7.4 J**	**-56%**
Battery life	5.3 years	**12.0 years**	**2.3×**

At SF12 (long range), the impact is even greater:

	Without ALEC	With ALEC	Improvement
Energy per TX (SF12)	587 mJ	**196 mJ**	**-67%**
Daily energy	57.9 J	**20.4 J**	**-65%**
Battery life	1.5 years	**4.3 years**	**2.8×**

At SF12 without compression, 2×AA batteries last barely 18 months — which is why many long-range deployments use expensive D-cell batteries or solar panels. **ALEC transforms a 1.5-year deployment into a 4.3-year deployment on the same AA batteries.**



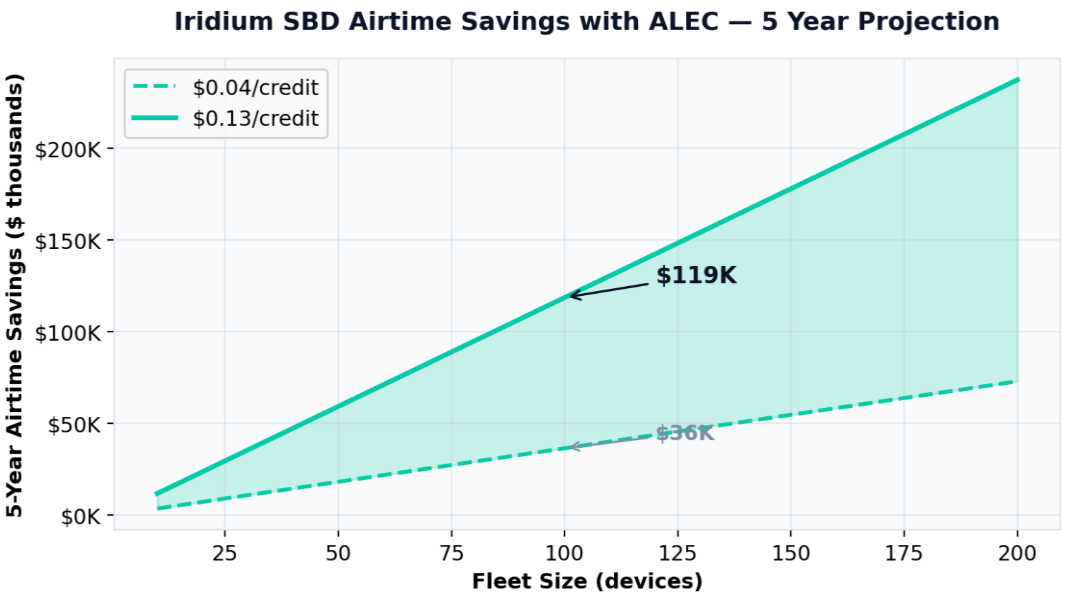

Battery Discharge Curve — 2×AA, LoRaWAN SF12, Every 15 min
Without ALEC (SF12)
With ALEC (SF12)
+2.8 years
extra life
Dead: 1.5 yr
Dead: 4.4 yr
Battery Remaining (%)
100
80
60
40
20
0
0
1
2
3
4
5
Time (years)

The Satellite Benchmark

For satellite IoT, we modeled a remote asset tracker using the Iridium 9603N modem (via RockBLOCK 9603). Sensors: GPS + temperature + battery voltage, reporting hourly. Raw payload: 18 bytes per reading. Battery: 3.7V 6,000 mAh Li-Ion.

	Without ALEC	With ALEC (10×)
Readings per SBD message	18	**170**
Messages per day (24 readings)	2	**1**
Battery life (modem only)	205 days	**411 days**
Improvement	—	**2.0×**

But the real value for satellite IoT isn't just battery — it's airtime cost. **At $0.04–$0.13 per SBD credit, halving the message count halves operational expenditure. Over a 5-year deployment with 100 devices, that's $15,000–$47,000 in airtime savings alone.**

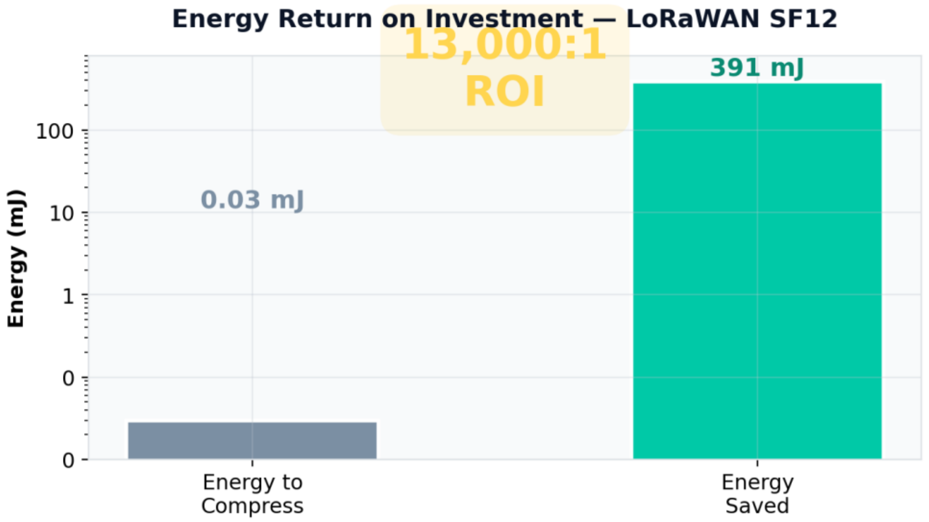


Why Not Just Send Less Often?

The obvious question: "Why not just increase the reporting interval instead of compressing?" Because there's a fundamental trade-off. Reducing reporting frequency means missing events. A temperature excursion that lasted 20 minutes won't appear in hourly data. A pressure anomaly between readings is lost forever.

ALEC preserves the original reporting interval and data resolution while reducing the transmission cost. You get the same data fidelity at a fraction of the energy.

Bonus: ALEC's adaptive context tracks patterns in your sensor data. When the compression ratio suddenly drops — meaning the data has become unpredictable — that's often an early indicator of an anomaly. You get a free monitoring signal from the compression process itself.



Key Takeaways

1. **Radio transmission dominates IoT energy budgets.** At SF12, a single LoRa transmission consumes the equivalent of 27 minutes of sleep current.
2. **Compression directly reduces Time on Air.** ALEC's 6–15× compression on streaming sensor data translates to 56–67% less radio energy per cycle.
3. **Battery life scales with compression.** On 2×AA batteries with LoRaWAN SF10, ALEC extends sensor life from 5.3 to 12.0 years (2.3×). At SF12, from 1.5 to 4.3 years (2.8×).
4. **For satellite IoT, compression reduces both battery drain and airtime costs.** Fewer modem sessions = longer battery life + lower OPEX.
5. **Compression costs almost nothing.** ALEC runs in 2 KB of RAM, adds ~2 ms per compression on a Cortex-M0+, and costs 900× less energy than it saves.

The IoT industry has spent a decade optimizing radios and batteries.

It's time to optimize what we send through them.

Sources & Methodology

Benchmarks computed using datasheet specifications from Semtech (SX1276 Rev.4), Iridium (9603N Developer's Guide Rev.3.1), STMicroelectronics (STM32L0 datasheet), and RockBLOCK 9603 power consumption guide. ALEC compression ratios based on measured performance with real-world sensor data streams. Time on Air calculated using standard LoRaWAN formulas for EU868.

ALEC Codec: alec-codec.com | crates.io/crates/alec-codec | DOI: 10.5281/zenodo.15046801