Mobile Beehive Scale 2024

Cellular IoT with CoAP/DTLS 1.2 CID in the “wild”
May 2024, Achim Kraus
(October 2024 Update Links)

Speaker

- Followup of “DTLS 1.2 CID Meets Zephyr, 2023” (therefore +1 year)
- Achim Kraus
  - 25+1 years experience in software development and testing (Java/C),
  - 15+1 years experience with distributed device-systems (IP, RS485, ArcNet),
  - 7+1 years experience with IoT, CoAP/DTLS/LWM2M.
  - Committer
    - Eclipse/Californium
    - Eclipse/tinydtls
  - IETF co author of RFC 9146, DTLS 1.2 CID

Contents

- Short technical overview of the system
- Deployments in the “wild”
  - Mobile Bee-Hive-Scale
  - Battery Vampire
  - Wine Refrigerator Shepherd
- Q&A

CoAP-DTLS 1.2 CID

- CoAP, RFC 7252

  http like REST over UDP. Efficient and reliable.

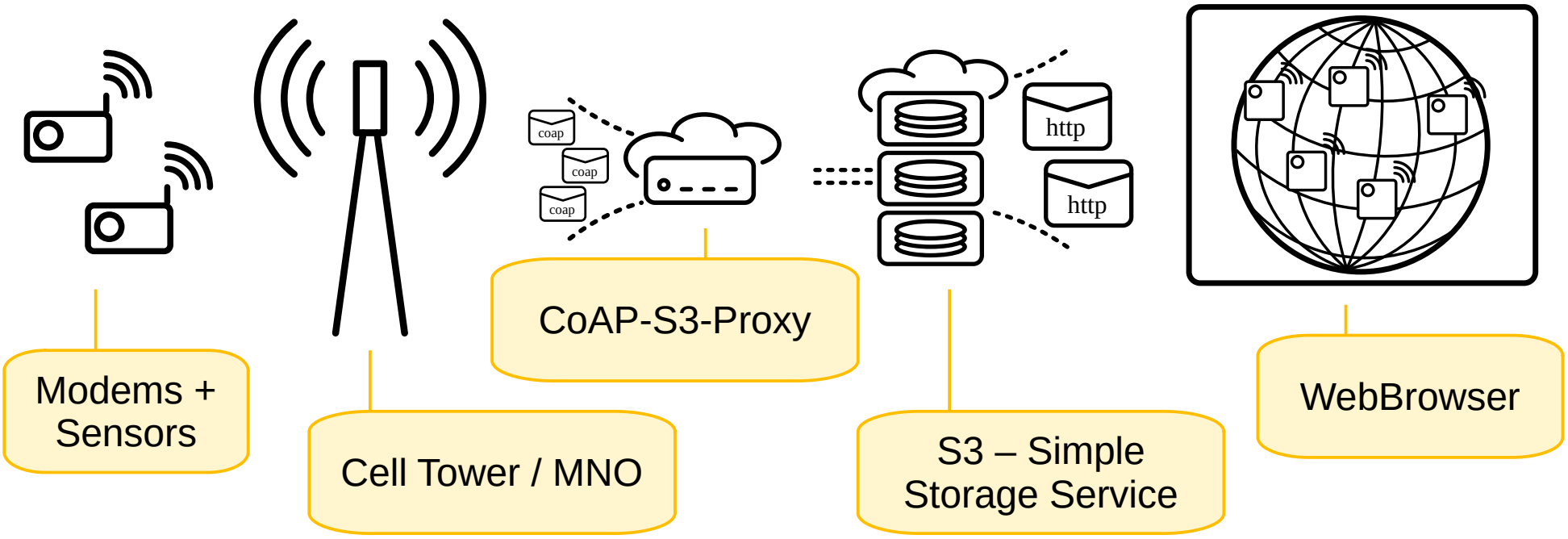
  Great match for radio-messages based communication.

- DTLS 1.2 CID, RFC 6347, RFC 9146

  TLS like encryption over UDP. CID (Connection ID) supporting quiet-phases unlocks the new power saving functions for radio messages based communication as PSM and RAI.

- Together a IETF standardized way to communicate efficient, reliable and secure over radio messages. Of course, it works on wires as well.

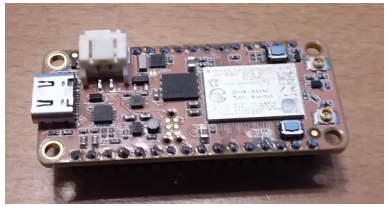
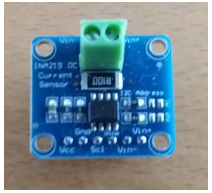
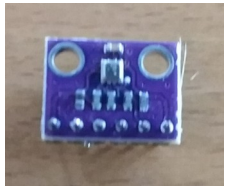
Overview - Building-Blocks



Modem

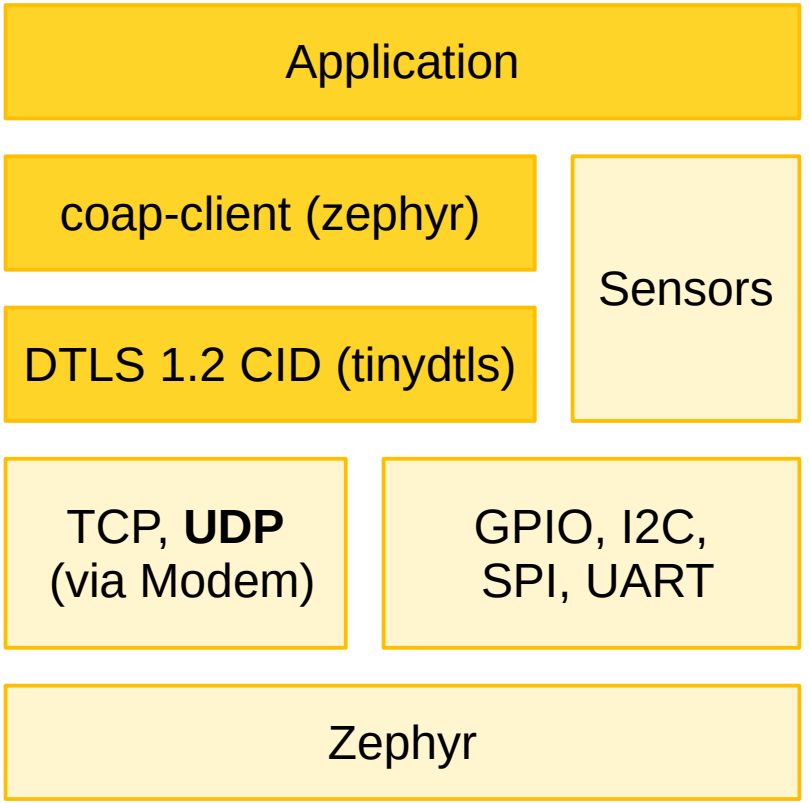
- HW: currently nRF9160 based device are supported, see

  https://github.com/boaks/zephyr-coaps-client?tab=readme-ov-file#supported-devices
- OS: Zephyr (+ Nordic Connect SDK)
- Sensors: growing selection, see https://github.com/zephyrproject-rtos/zephyr/tree/main/drivers/sensor

Modem

- OS: Zephyr (+ Nordic Connect SDK)
- SW: zephyr coap-client + tinydtls (DTLS 1.2 CID, open source)
- All together: customizable, highly efficient, reliable and secure open-source demo,
  - e.g. Thingy:91 ½ year, 1 message exchange every hour from internal battery (1350mAh).
  - https://github.com/boaks/zephyr-coaps-client



Cloud-CoAP

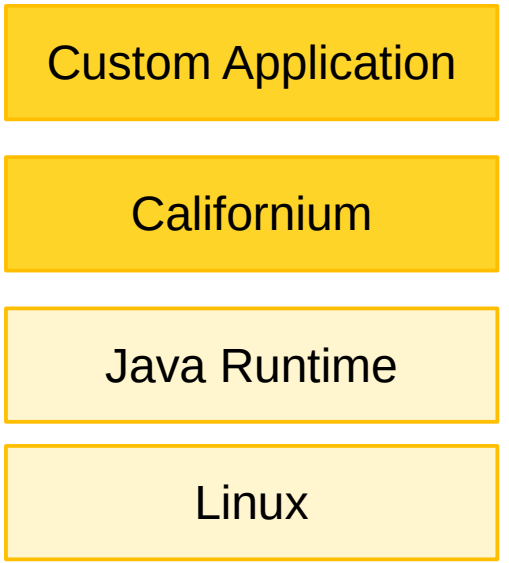
- HW: cloud-VM or own computing center.

  Starting at 2 cores and 2 GB RAM (Footprint Linux + Java)

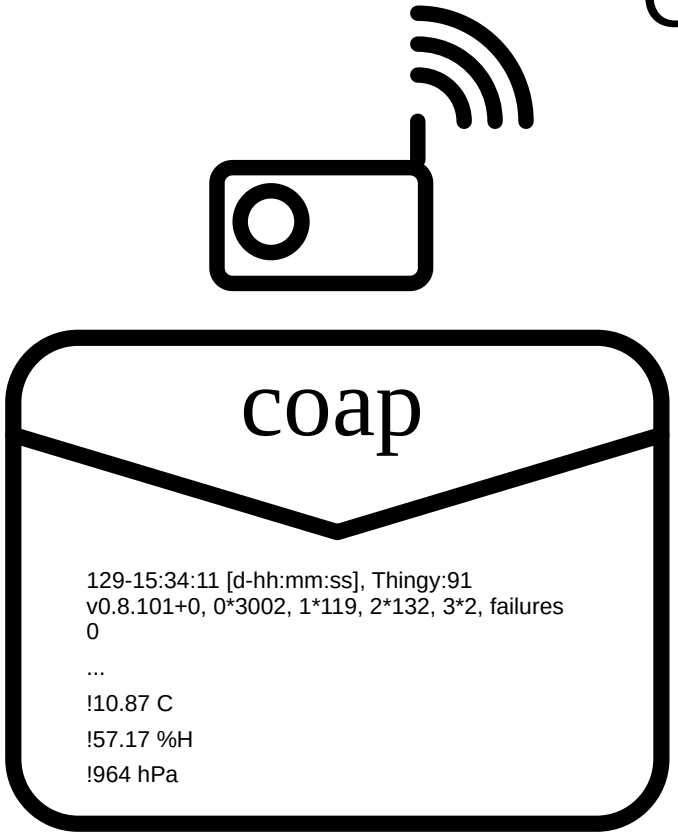
  (4 cores + 16 GB RAM handles about 1.000.000 concurrent devices with 50.000 messages per second)
- OS: Linux
- Software: Eclipse/Californium
  - java CoAP+DTLS 1.2 CID stack (open-source)

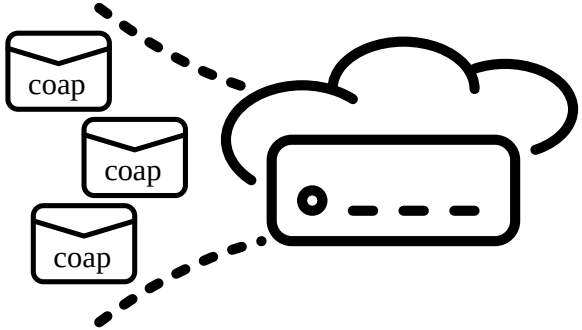
    Reliable, efficient, and e2e encrypted device communcation

    https://github.com/eclipse-californium/californium
- Java API for receiving and sending CoAP messages.



Cloud-CoAP



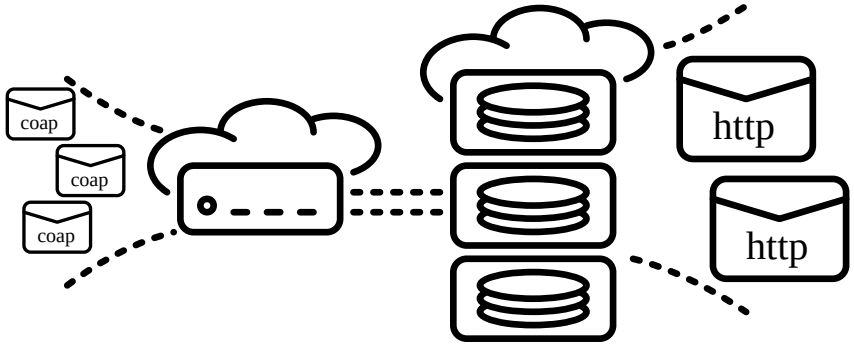



```
public void handlePOST(final CoapExchange exchange) {

exchange.getRequestPayload();

…

}
```

Demo Custom Application: CoAP-S3-Proxy

- The S3-proxy is one application on top of Cloud-CoAP as bridge into common cloud computing.
- S3 (Simple Storage Service), very common, available on different clouds. Keeps data received from devices and provides configuration for devices.

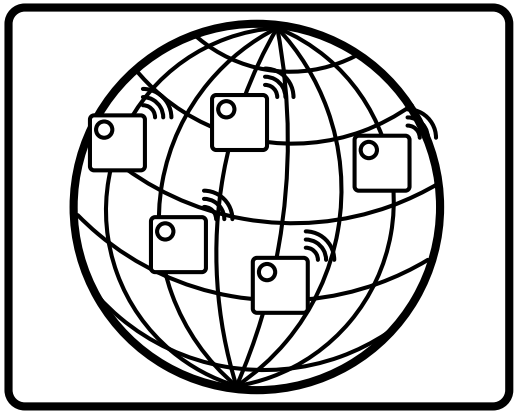
  Also used for FOTA
- Converts CoAP requests into S3 request.
- https://github.com/eclipse-californium/californium/tree/main/demo-apps/cf-s3-proxy-server



CoAP-S3-Proxy

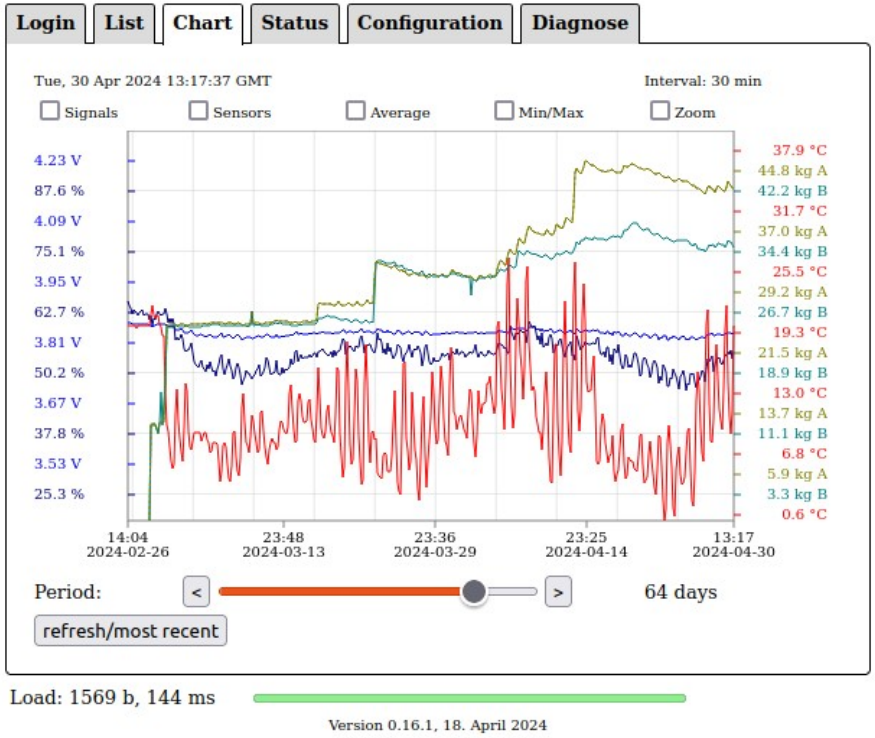
- S3 reduces the maximum number of messages per second (depends on S3-provider, 300-3000 messages per second and more).
- 1.000.000 devices, 1 message per hour => less than 300 messages per second.
- FOTA requires multiple CoAP request (e.g. 400 for 400KB) but 1 S3 request, there you benefit from Californium’s performance.
- Permission system for S3 is sometimes limited. Intended for backend systems, not users.
- The CoAP-S3-Proxy mitigates that by supporting multiple S3 buckets using different API-keys.
- Installation scripts for ExoScale, AWS, DigitalOcean. Or manual installation step-by-step.

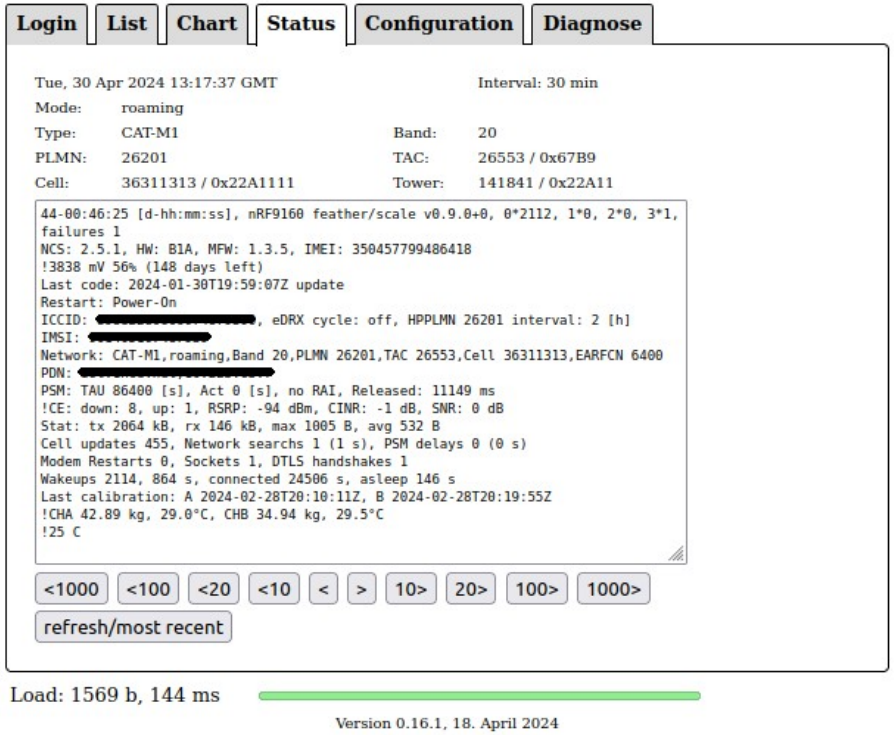
Web-Browser App



- HW: Smart Phone, Tablet, PC
- OS: Linux, Windows, iOS, Android
- Software: Java Script executed in Web-Browser
- Login via HTTPs service, possibly co-located at the CoAP-S3-Proxy. Return S3 credentials for login credentials.
- Direct S3 HTTPs request to fetch or write stored device data
- Simple charts based on device data.

Web-Browser App





Web-Browser App

- Permission system of S3 provides a basic access protection, but no fine-grained role-based grants. If S3 offers read/write grants, that used on bucket base for “user” and “admin” accounts.
- Intention of the system is to provide UDP experience with low initial invest. Not a “out-of-the-box” end-user-system.
- More sophisticated UI or backends are out of scope and requires additional project based development.

Mobile BeeHiveScale - Rational

- Bees are collecting pollen as food reserve.
- In good times the bees collecting more pollen than they eat.
- Spring and early summer are frequently good times.
- It depends a lot on the vegetation and weather, how much pollen the bees are able to collect.
- Comparing sites, e.g. orchards, and moving the bee-hives to good sites helps to optimize the honey production.

Mobile BeeHiveScale - Rational

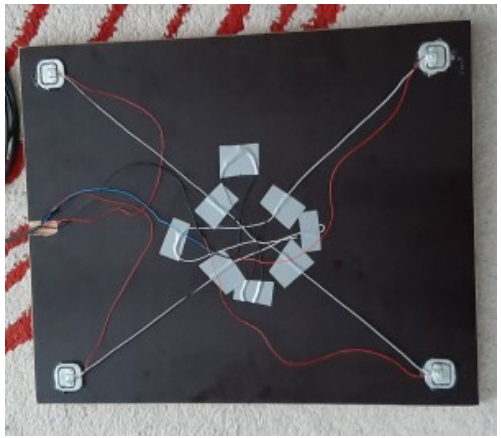
- On bad times it’s vice versa, the bees eats more than they colltect.
- Usually at the end of a blossom periods or in cold weather periods.
- Especially at the end of a blossom period it helps to optimize the honey quantity, if you know the timepoint, when more is eaten. It’s about 500g a day per hive, if you’re too late exchanging the honey with sugar-water.
- Therefore a mobile beehivescale helps to keep more honey.

BeeHiveScale

- No new idea, beehivescales are build since years
- Some open source / maker variants are available, e.g. https://beelogger.de/ or https://www.hiveeyes.org/
- Also commercial offerings are available
- The Mobile-BeeHiveScale present here is neither the cheapest, nor the most precise one. But it offers excellent cellular connectivity. It works well from 3x AA battery cells, sending every hour for 1 year. Of course, only if a cellular network is available, not every valley is covered.

  https://github.com/boaks/mobilebeehivescale

Mobile BeeHiveScale

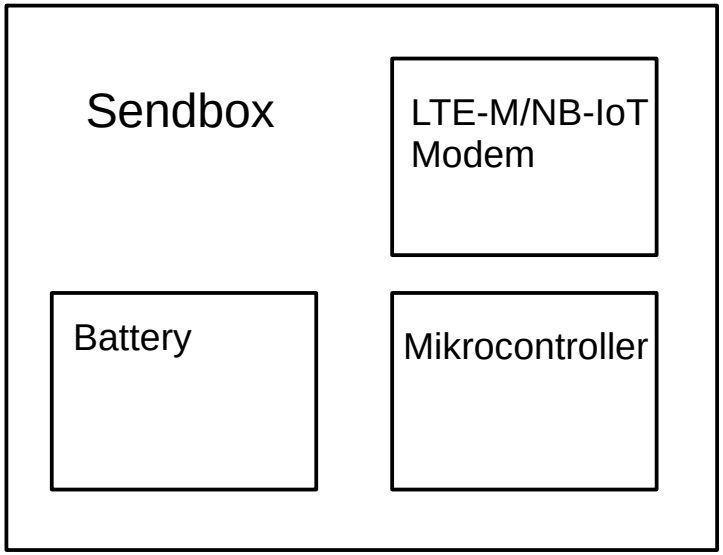


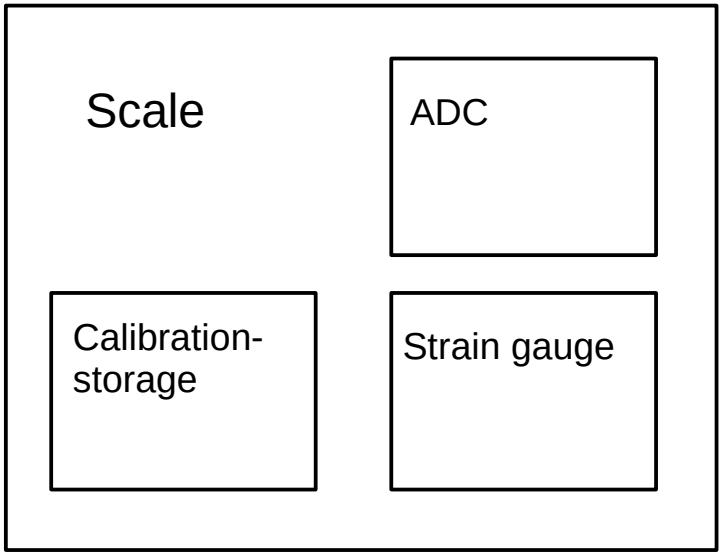
- V1.0 started January 2023
- First approach with simple load cells for “bath room scales”
- One year operating one sendbox, two scales

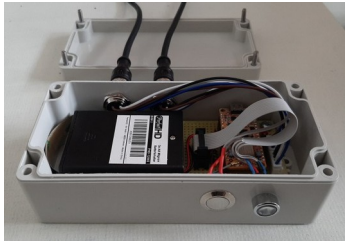
  Communication works reliable, but the measurements of that simple scale depends too much on the temperature, especially on sunshine.

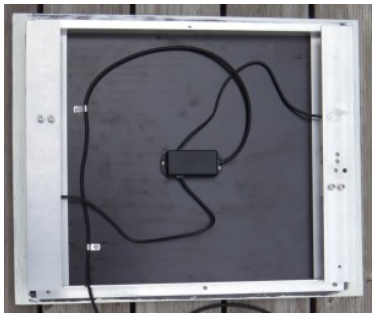
➲ V2.0, redesign solution, started September 2023

Mobile BeeHiveScale v2.0 – Building Blocks





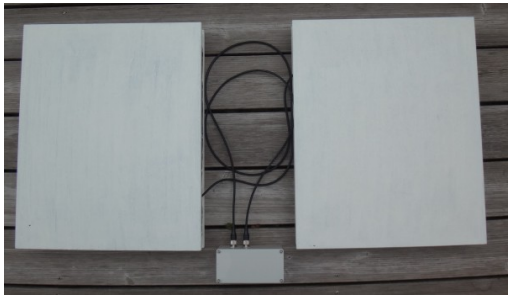




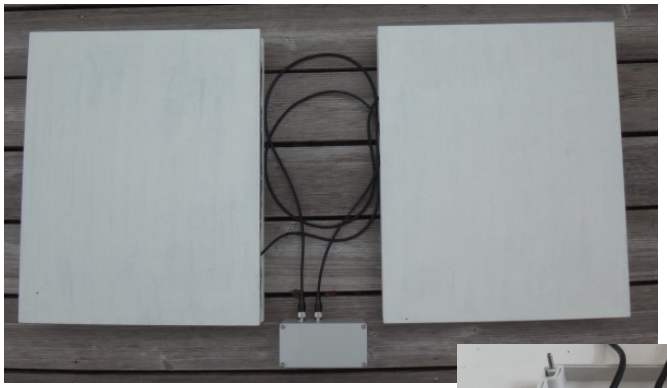
Mobile BeeHiveScale v2.0

- Move ADC (converts analog value into digital value) from sendbox to scale, short analog wires are less temperature affected
- Move calibration-storage from sendbox to scale (EEPROM), easier to exchange scales and sendboxes on moves and to calibrate the scales
- Use parallel beam load cell, these load cells comes with temperature compensation, which reduces the dependency on that.
- Test run for 6 months in my office and garden

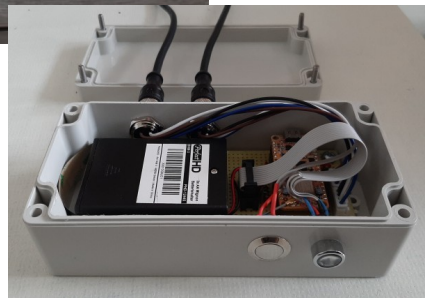
  now 1 month under the beehive.
- 2 sendboxes, 4 scales. More (2+4) on the way.



Mobile BeeHiveScale v2.0

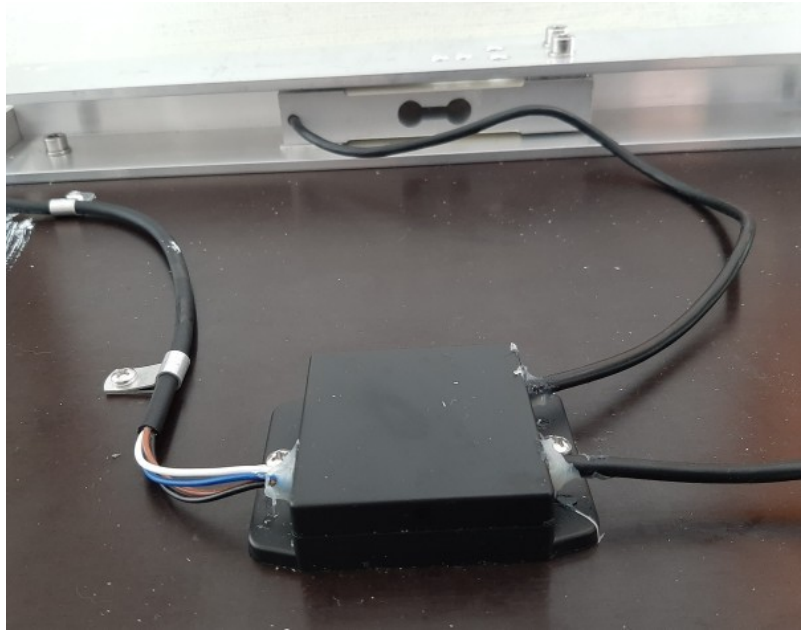


Scales

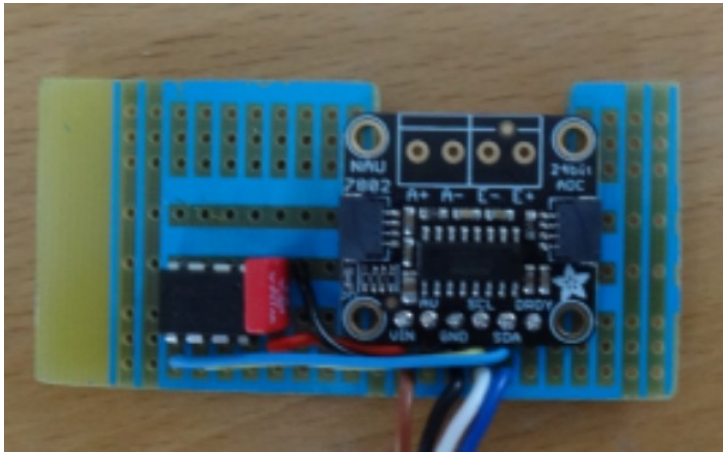


Sendbox

Mobile BeeHiveScale v2.0



Parallel beam load cell + ADC box

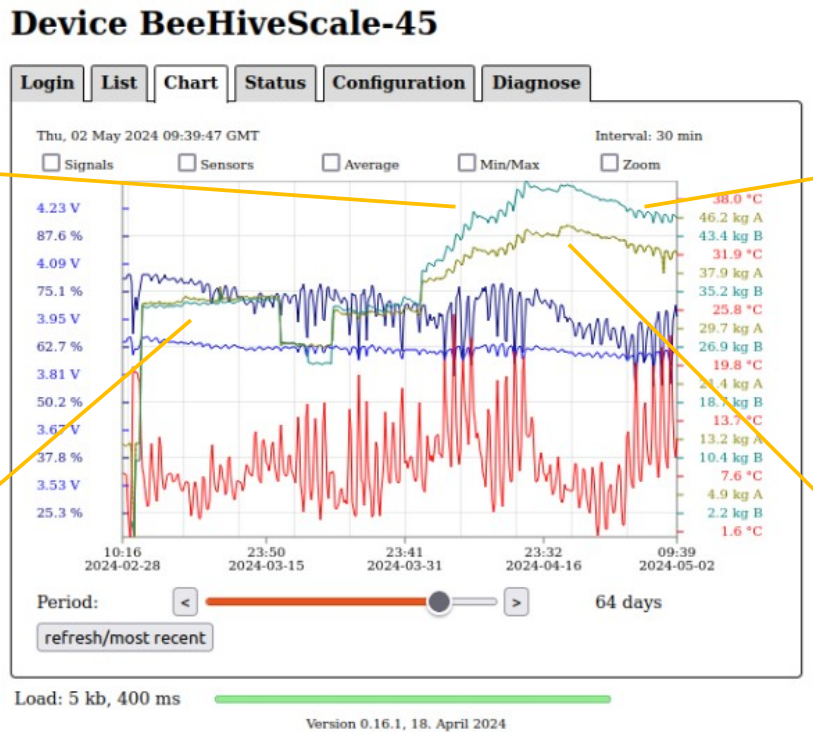


ADC board with EEPROM

Mobile BeeHiveScale v2.0

With bees
Larger ripples,
bees on the fly
pollen

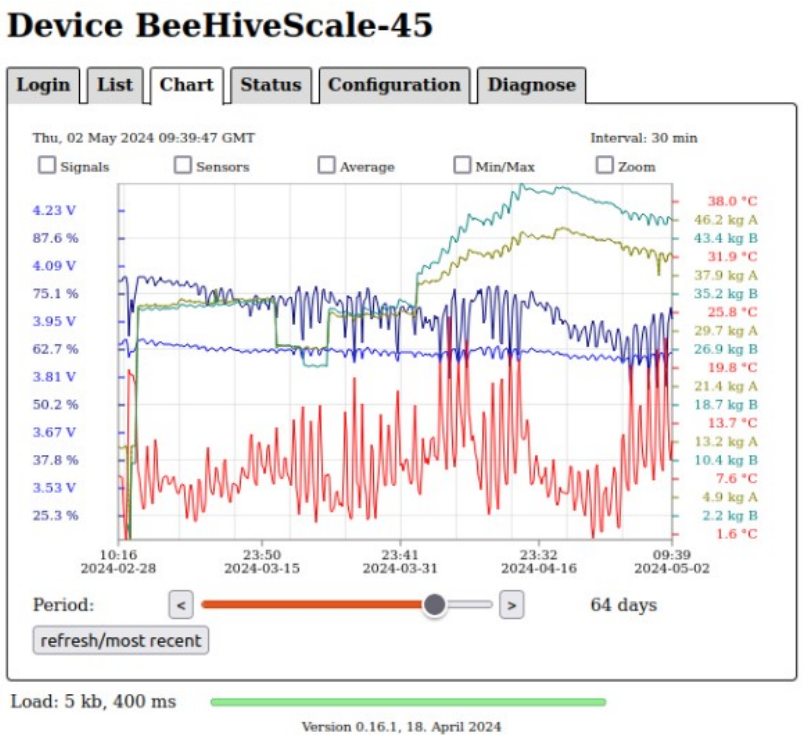
Test without bees
Small ripples

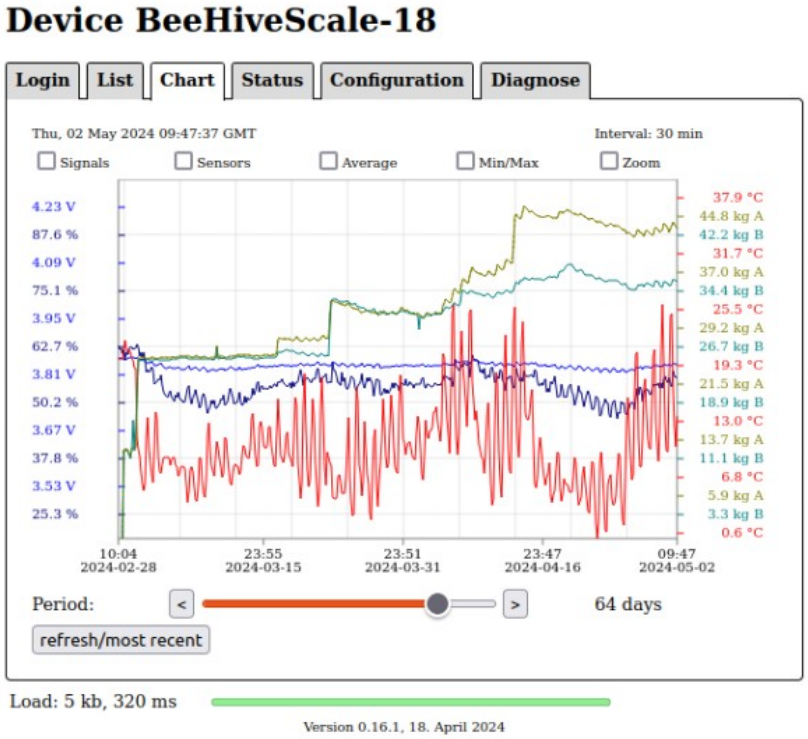


Good weather
Larger ripples,
bees on the fly
No pollen

Bad weather
Small ripples,
bees stay in hive

Mobile BeeHiveScale v2.0



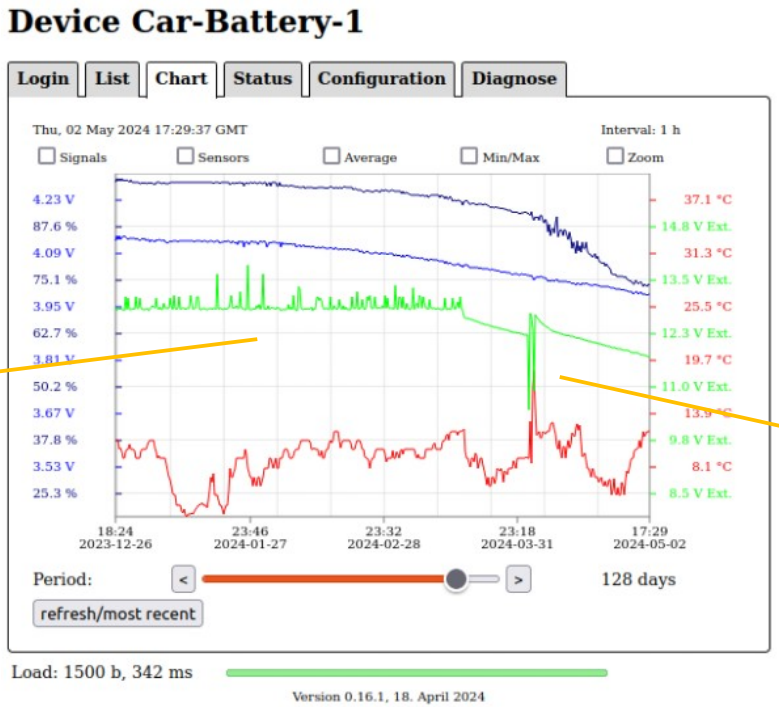


Battery Vampire

- German classic sports cars tends to have a pretty high battery discarge when not operated.
- The battery vampire measures the car-battery voltage and presents that as chart.
- The user sees, when it’s time to recharge the battery or drive the car.
- Even with permanent preservation charing, monitoring shows, that this isn’t interrupted
- Two cars monitored for a couple of months.

Battery Vampire

Garage with power supply



Garage without power supply

Wine Refrigerator Shepherd

- Thingy:91 monitors the temperature of a wine refrigerator
- Works “out-of-the-box”
- Shows:
  - refrigerator works well
  - Cellular network searchs are draining the battery a lot in that case (basement)

Cellular IoT Experience in the “Wild” Sum-up

- Running a cellular device from battery over longer time works.
- Use-case considered here is metering or monitoring. Smaller messages (couple of 100 bytes) are exchanged low frequently (e.g. every couple of hours).
- The energy consumption may be split in 3 domains:
  - sending
  - quiescent current
  - network searches

Cellular IoT Experience in the “Wild” Sum-up

- For sending the message with a couple of 100 bytes, the protocol and the interval is relevant. The amount of data gets in my experience only relevant, if some kilo bytes are reached.
- For the quiescent current the hardware design and the battery self discharge need to be considered. Using an efficient protocol the experience is, 1 message exchange takes the similar energy than 1-2h quiet phase. Therefore be careful: exchanging a message every day instead of every hour, doesn’t make the device run 10x times longer, it may stop after 3x times!
- Network searches are hard to predict. Low radio signals or moving devices need to consider an reasonable energy buffer for that.