FlockLab 2

ETH zürich

FlockLab 2: Multi-Modal Testing and Validation for Wireless IoT

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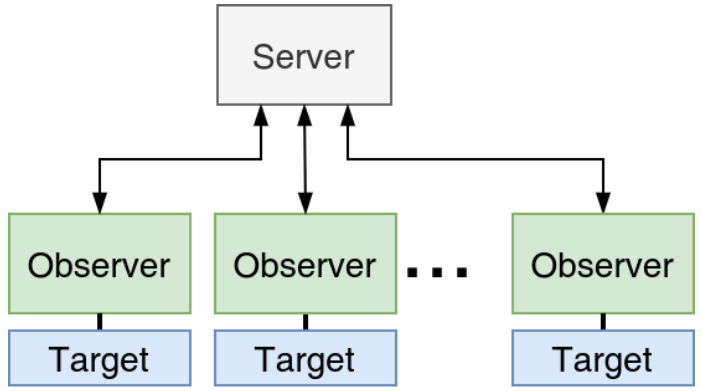
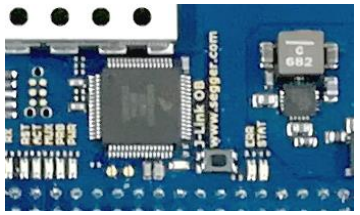
Today's Requirements for Testbeds

- **Power tracing** with **high-dynamic range** to support
  - sub-microampere low-power sleep currents
  - high-power TX operations
- On-chip **debugging hardware support**
- Global **time-synchronization** with support for
  - sub-microsecond accuracy
  - large distance between testbed nodes



FlockLab 2 Testbed



Make use of **debug infrastructure** built-in into modern MCUs

Rocket Logger

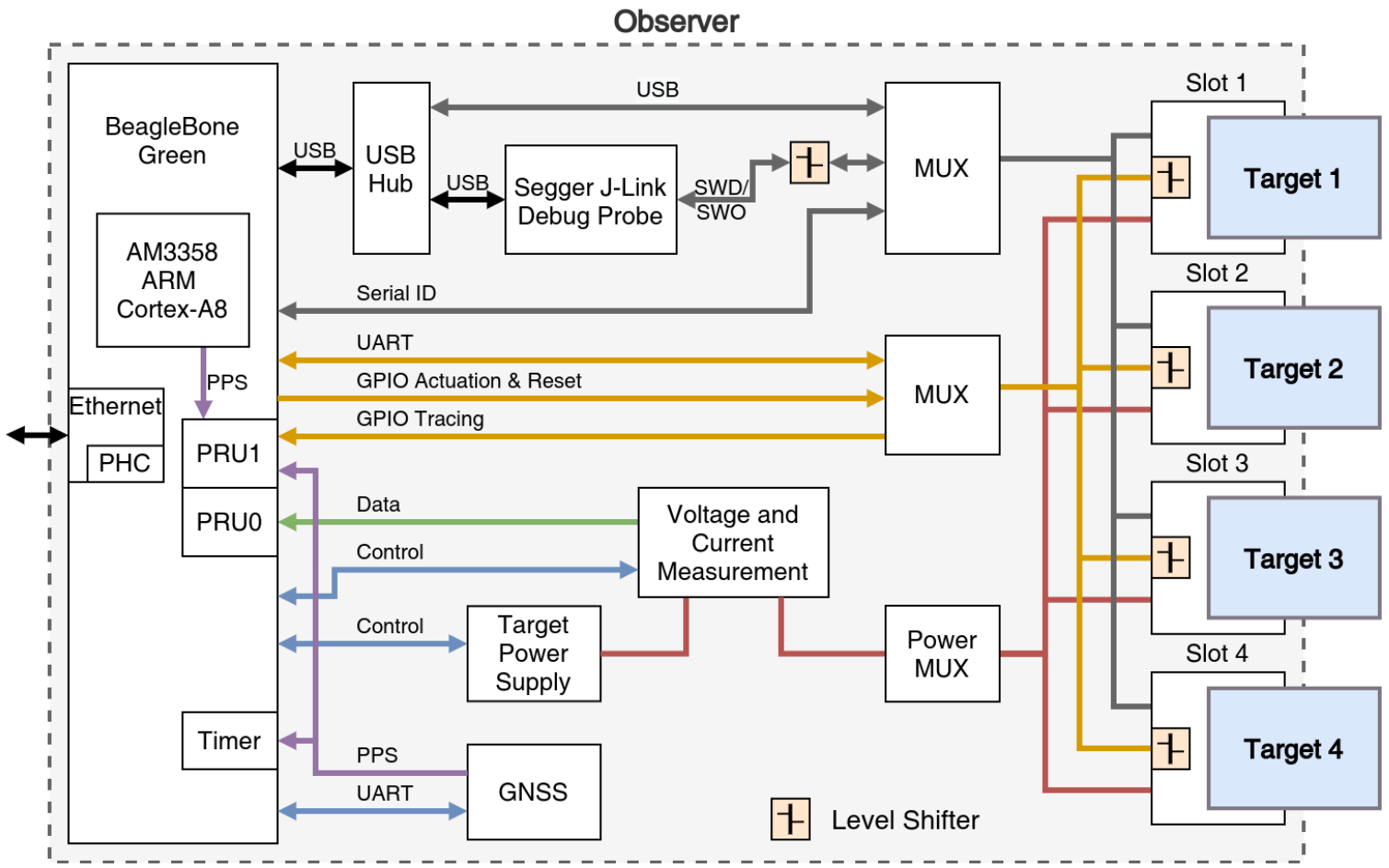
Accurate and high-dynamic range power tracing based on the RocketLogger

Precise **time synchronization** based on **GNSS & PTP** without disturbing the measurements

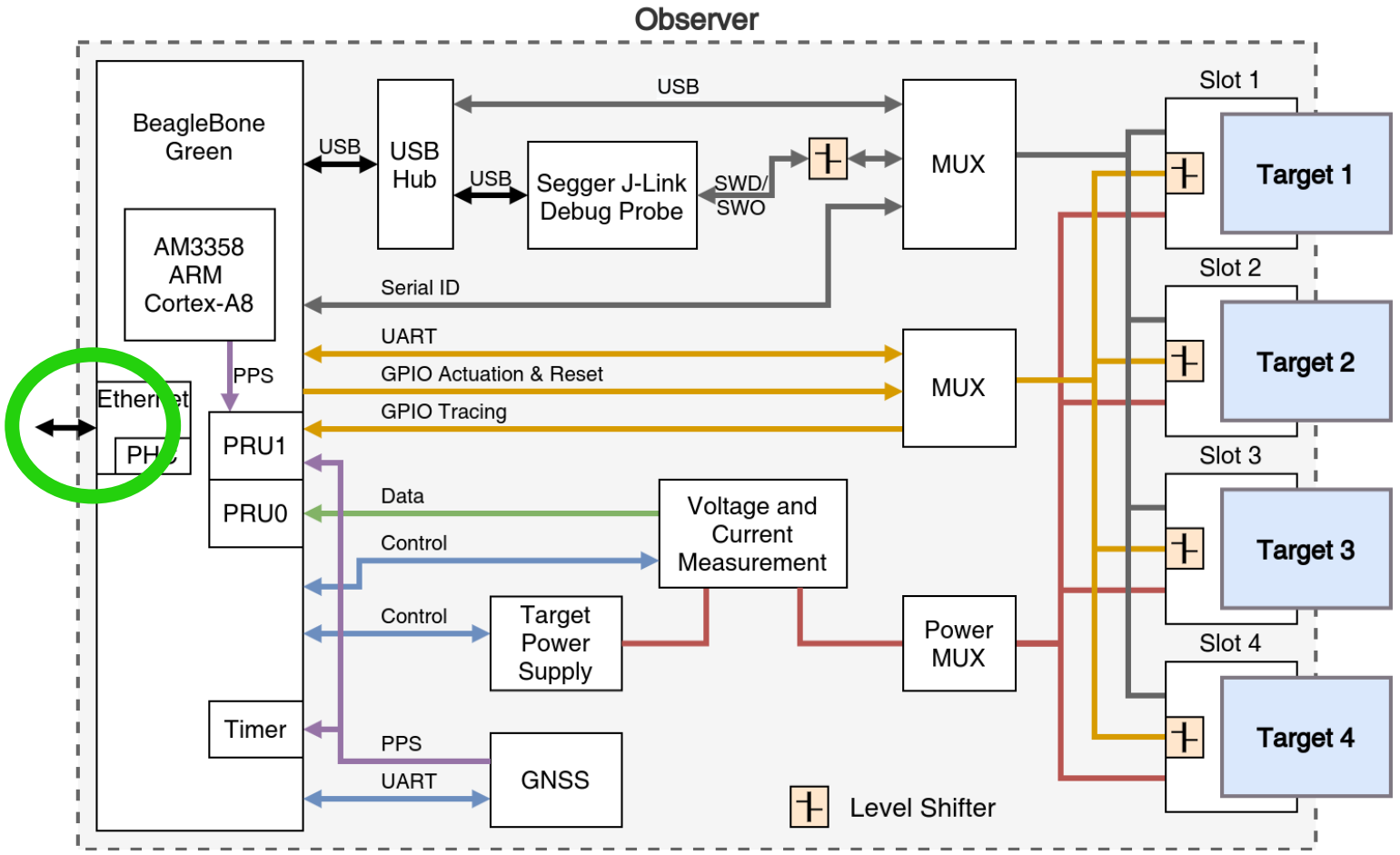
Single-board computer with **performance reserves**

Satellite by Guillermo Vera from the Noun Project
Raspberry Pi B+ by fredley from the Noun Project

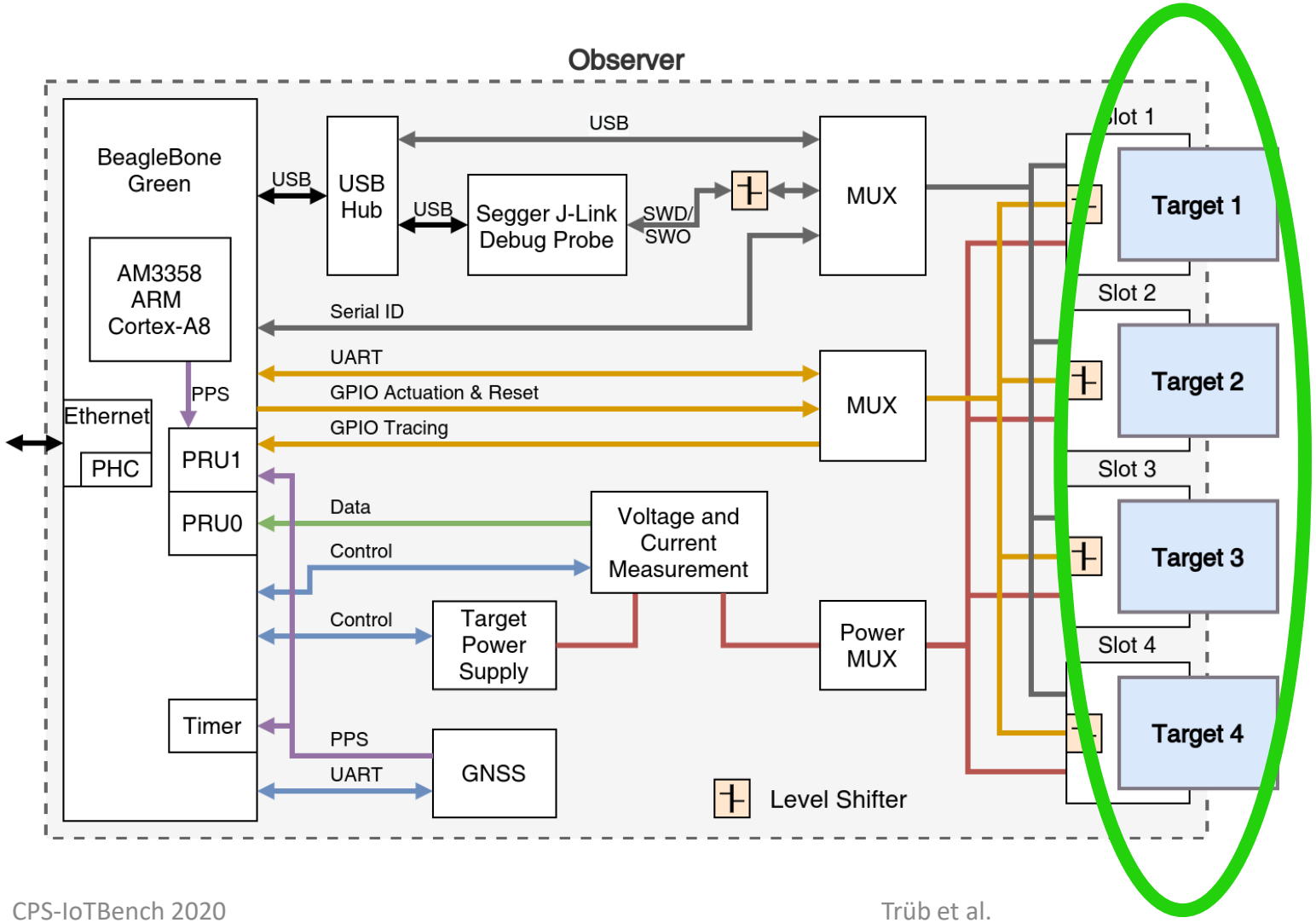
Observer Architecture



Connection to Server



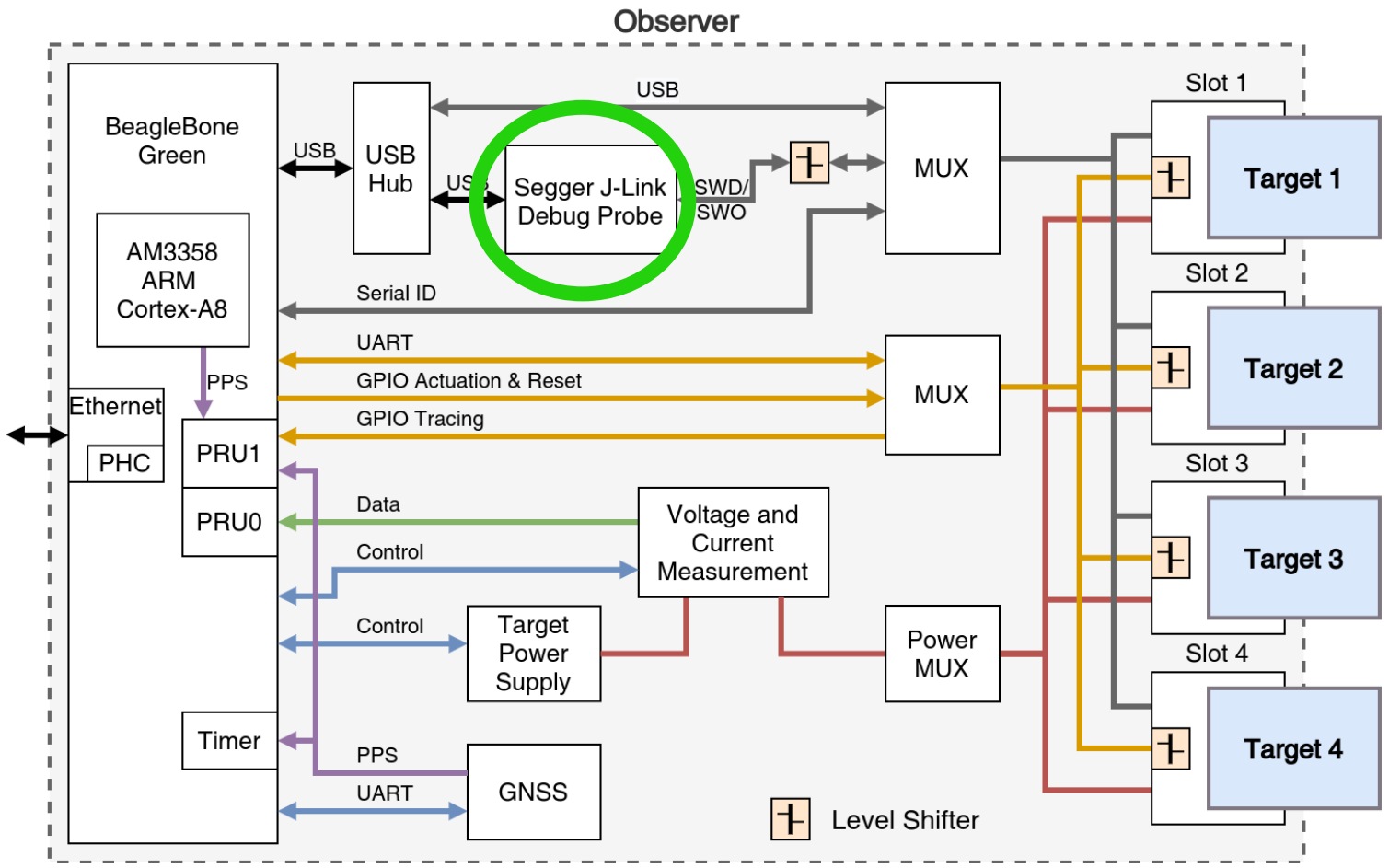
4 Target Slots



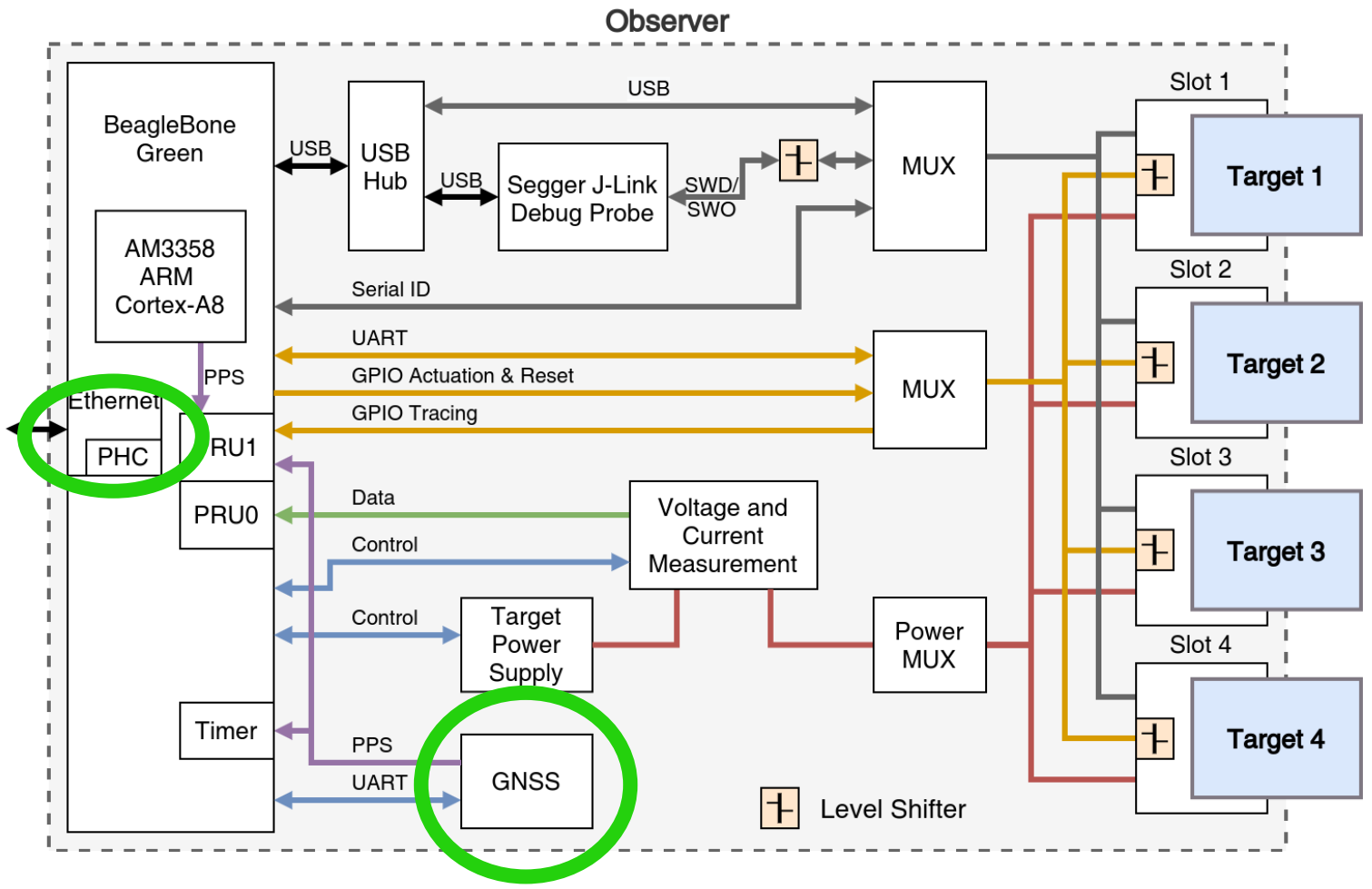
2x12 header connector

- Voltage: 1.1 – 3.6 V
- Current: <500 mA
- Serial (UART)
- GPIO pins
- On-chip debugging

Native Hardware Assisted Debugging

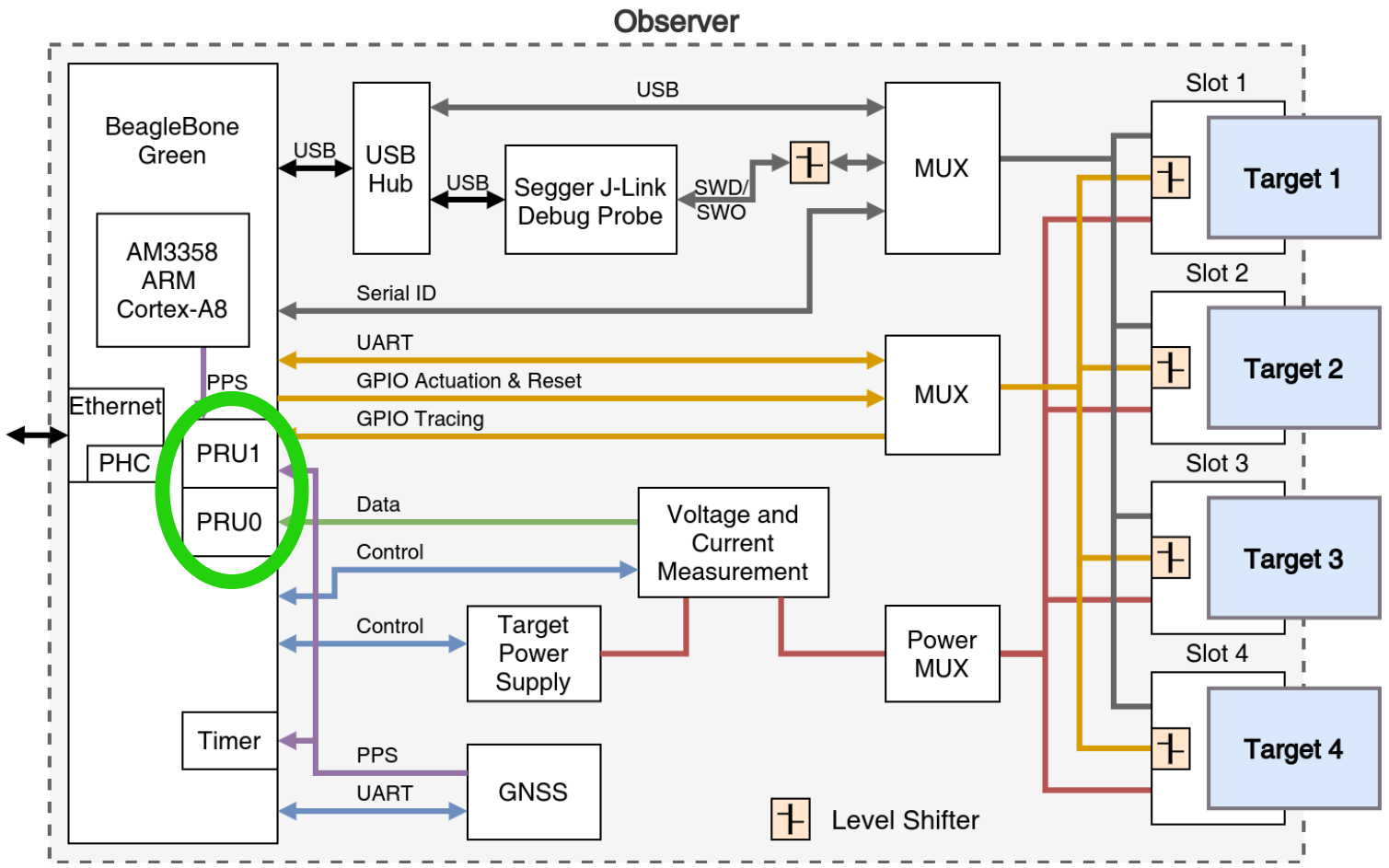


Time Synchronization



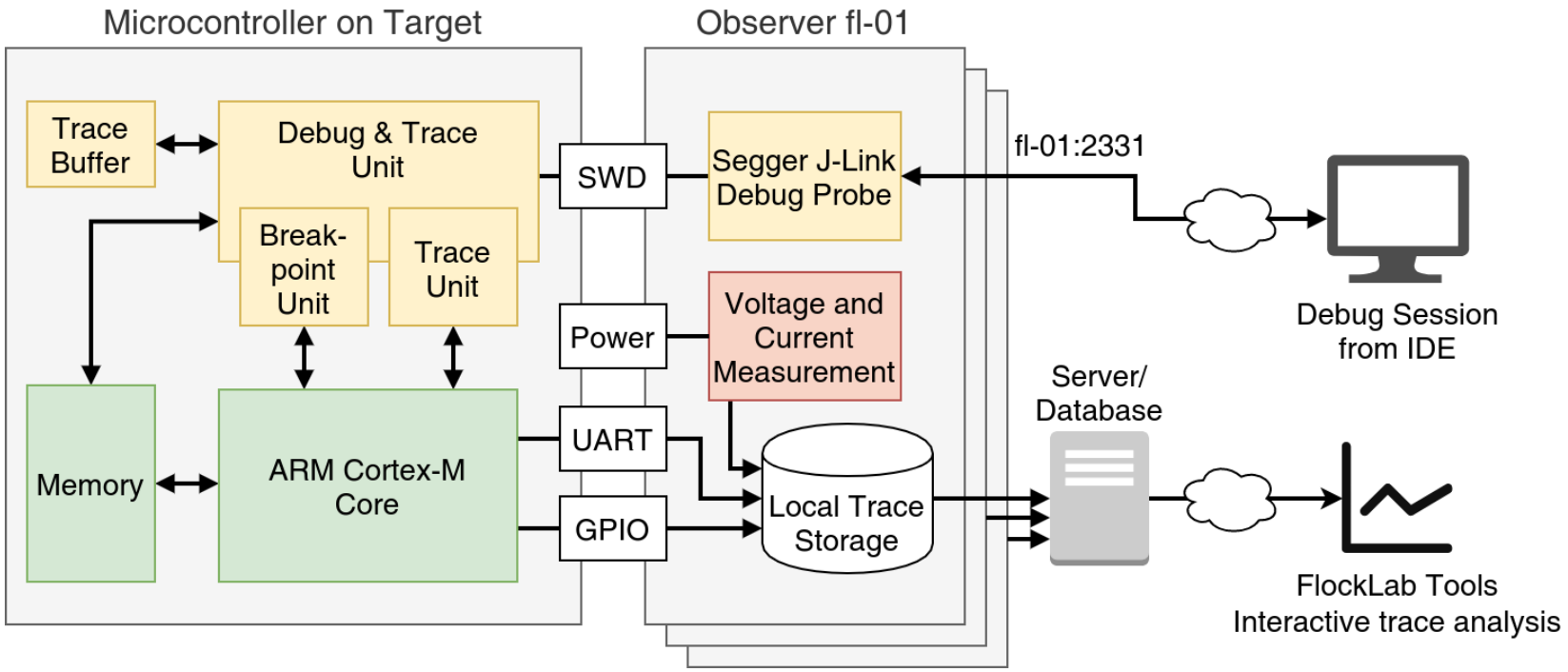
- Global Navigation Satellite System (GNSS)
- Precision Time Protocol (PTP)

Programmable Real-Time Units (PRUs)



- Collecting power measurements
- Logic tracing

Testbed-Wide Tracing

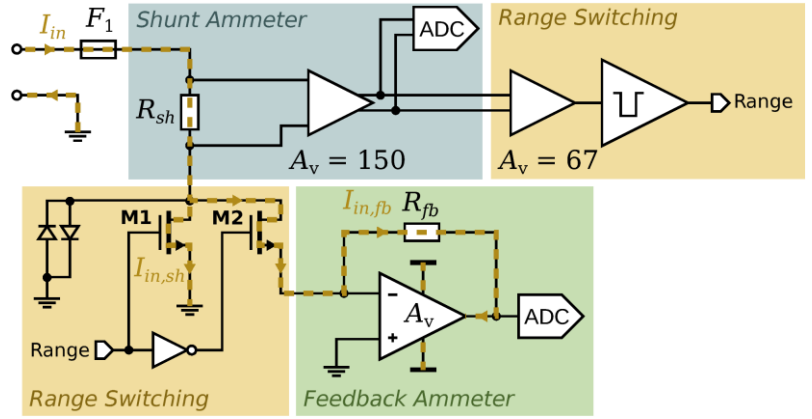


Remote access to native ARM hardware debugging

Interaction-free tracing of power, serial, and logic

Power Measurement

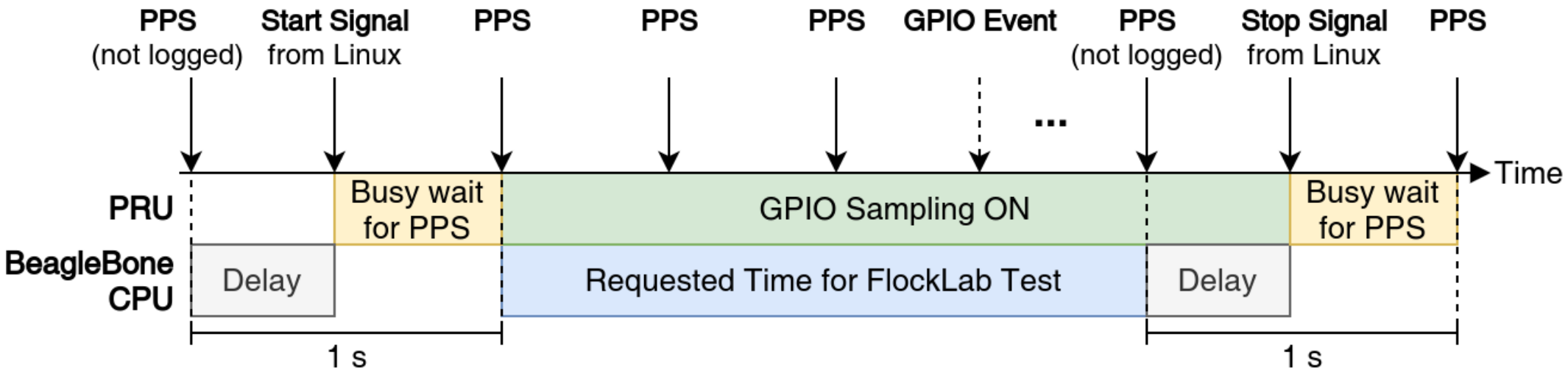
- High-dynamic range is required
  - Sub µA sleep current of modern MCUs
  - 100s mA for long-range radio in TX mode
- RocketLogger[1] is integrated
  - Low current range (0 – 2 mA): feedback ammeter
  - High current range (2 – 500 mA): shunt ammeter



Maximum sampling rate:	64 kHz
Maximum current measurement accuracy:	60 nA

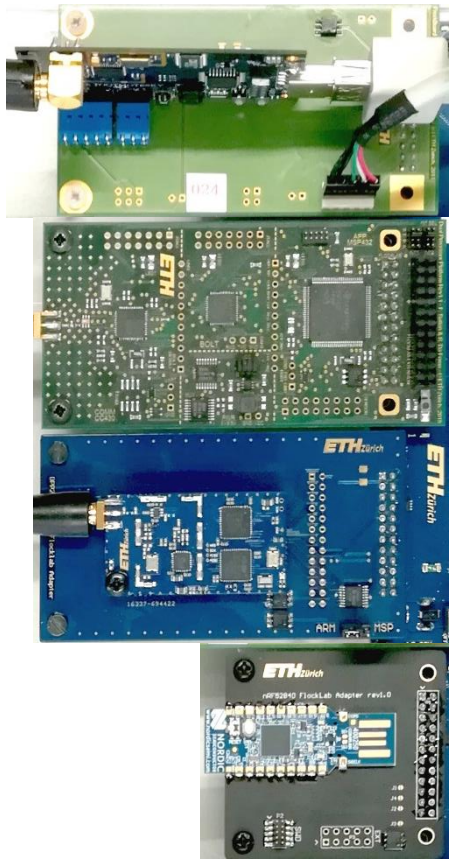
[1] Sigrist et al.; RocketLogger: Mobile Power Logger for Prototyping IoT Devices; SenSys '16.
https://rocketlogger.ethz.ch/

Testbed-Wide Event Tracing



Max burst event rate (<2000 edges):	10 MHz
Max continuous event rate:	900 kHz
Time deviation between any 2 observers (GNSS):	<0.25 µs (20 clock cycles @80 MHz)

Supported Sensor Nodes



Target Name	Microcontroller	Architecture	Radio
Tmote Sky / TelosB	MSP430F1611	MSP430	CC2420, 802.15.4, 2.4 GHz
DPP2 CC430	CC430F5147	MSP430	CC430 SoC, CC1101-based, 868 MHz
DPP2 LoRa	STM32L433	ARM Cortex-M4	SX1262, LoRa/FSK, 868 MHz
nRF52840 Dongle	nRF52840	ARM Cortex-M4	nRF52 SoC, 802.15.4/BLE, 2.4 GHz

Wide Range of Link Distances: 4 m – 2 km

12 indoor nodes
(office building)

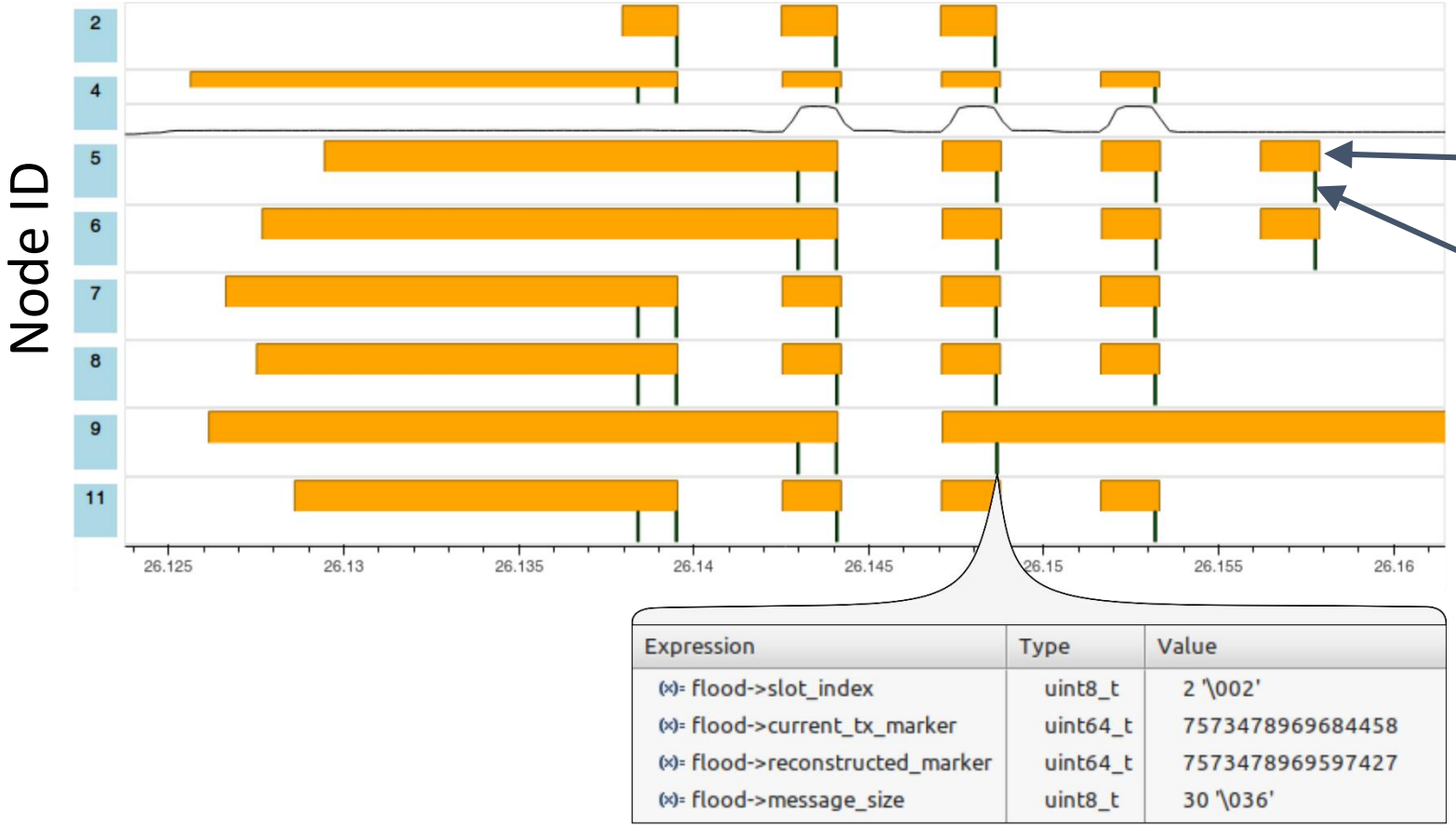
3 rooftop nodes

Interface & Usage

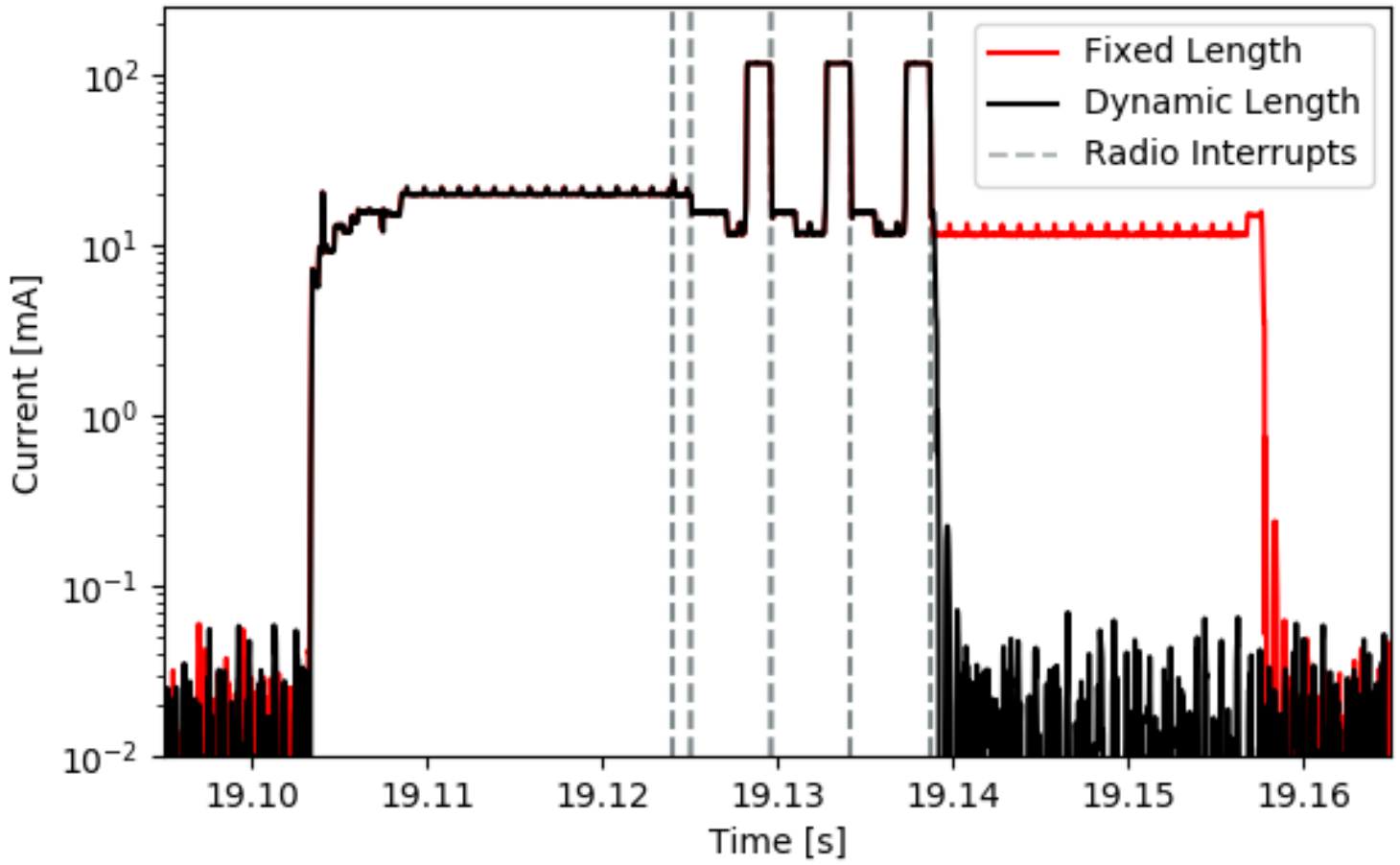
1. Preparation of *xml file* with
   - Testbed configuration
   - Settings for tracing and actuation services
   - Binary image of sensor node software
2. Upload xml via web-interface or API
3. Test is executed
   - Connection to debug probes
   - Connection to serial port
4. Download of test results for analysis and visualization

```
<testConf xmlns="http://www.flocklab.ethz.ch">
    <generalConf>
        <name>FlockLab XML template</name>
        <schedule><duration>60</duration></schedule>
    </generalConf>
    <targetConf>
        <obsIds>2 4 6 7 9</obsIds>
        <voltage>3.3</voltage>
        <embeddedImageId>Image_1</embeddedImageId>
    </targetConf>
    <serialConf>
        <obsIds>2 4 6 7 9</obsIds>
        <baudrate>115200</baudrate>
    </serialConf>
    <powerProfilingConf>
        <obsIds>2 4</obsIds>
        <samplingRate>1000</samplingRate>
    </powerProfilingConf>
</testConf>
```

Extracting Internal State While Running Synchronous Transmission Protocol



Optimizing Low-Power Behavior



Dynamically switching to low-power sleep-mode

Conclusions & Future Work

FlockLab 2 combines

- **native** hardware **debug and trace** support
- accurate **high-dynamic power measurements**
- accurate **time synchronization** based on GNSS or PTP

Future Work

- Facilitate use of network-wide on-chip debugging
- Extend testbed to 30+ nodes

FlockLab 2

Public Testbed
→ Getting started:
https://flocklab.ethz.ch

Open-Source
→ Server Software
→ Observer Software
→ Hardware Design
https://flocklab.ethz.ch