IoT Lab

Lukas Pirl

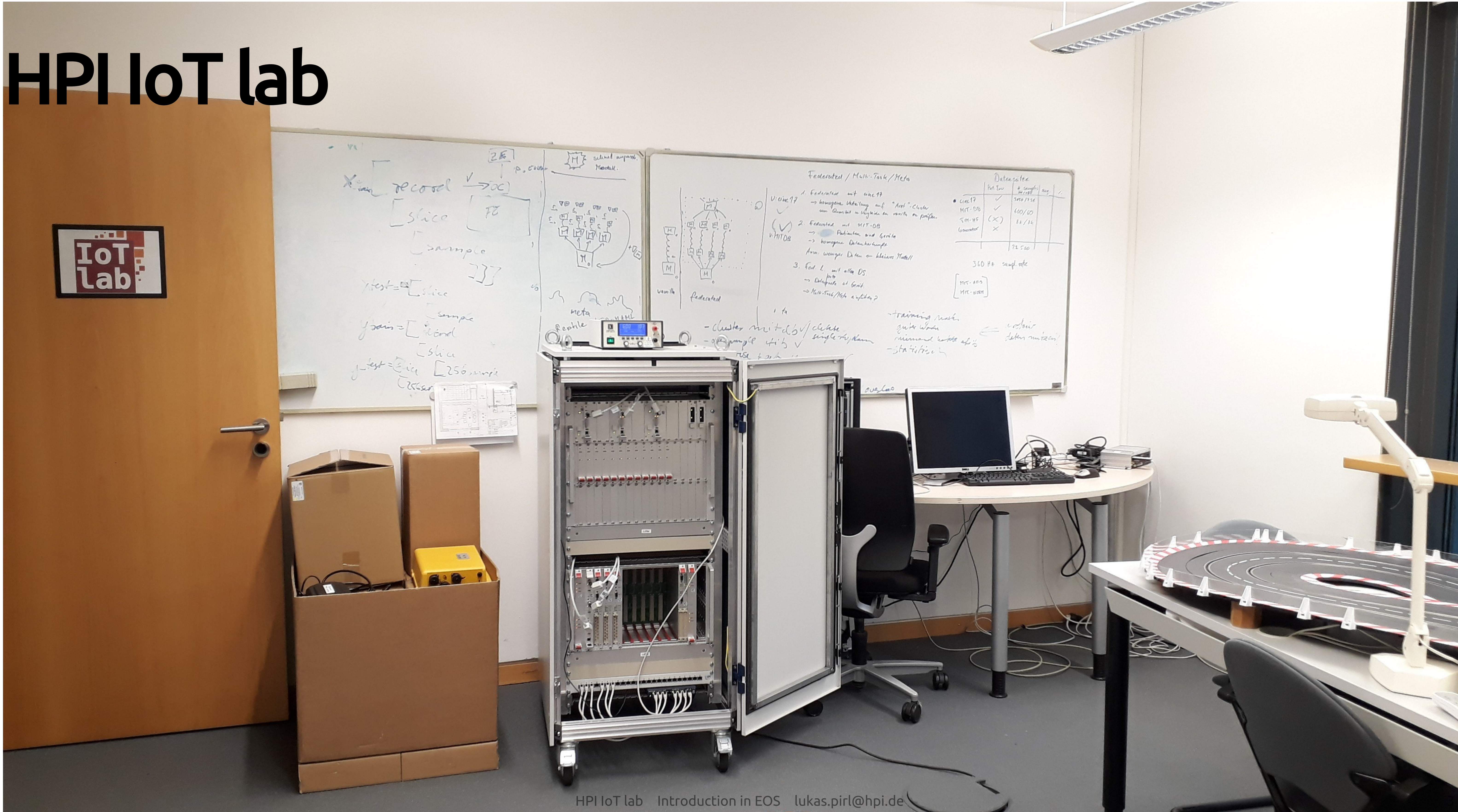
Introduction of IoT Lab in Lecture on Embedded Operating Systems

Professorship for Operating Systems and Middleware of Prof. Andreas Polze

Hasso Plattner Institute, University of Potsdam

HPI IoT lab

HPI IoT lab



HPI IoT lab

workshop

general tools

soldering

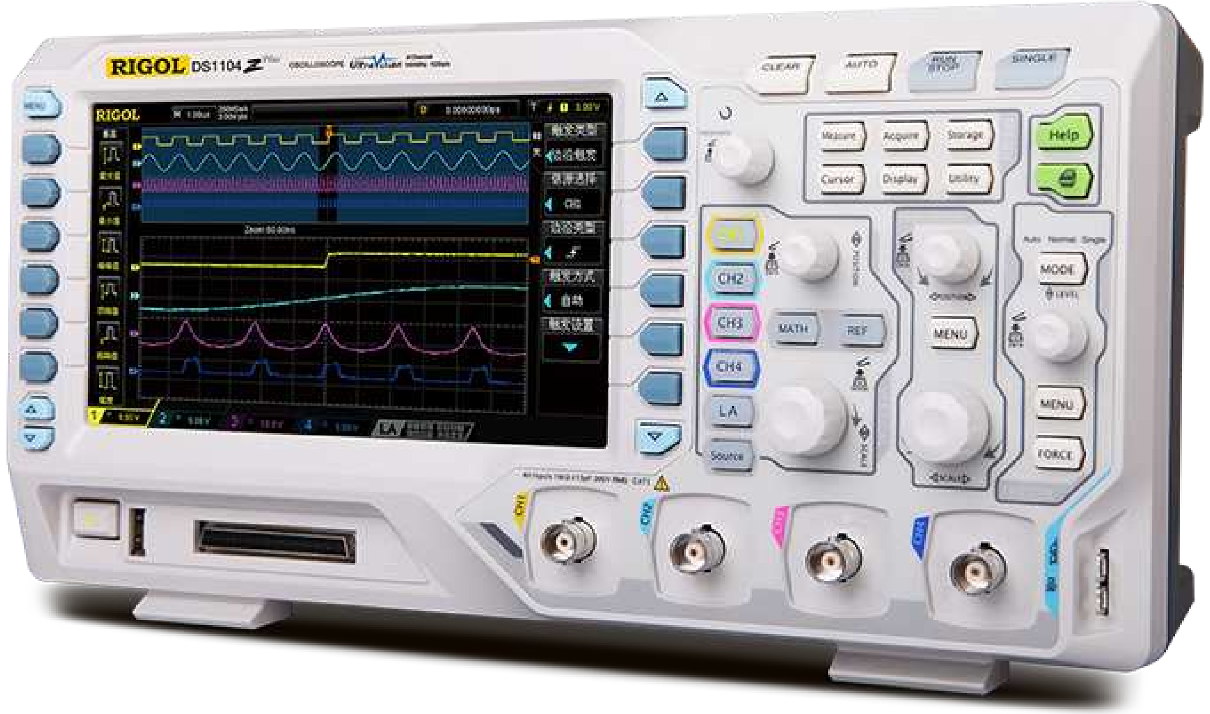
electronics components

bulk & DIY cables, connectors, etc.

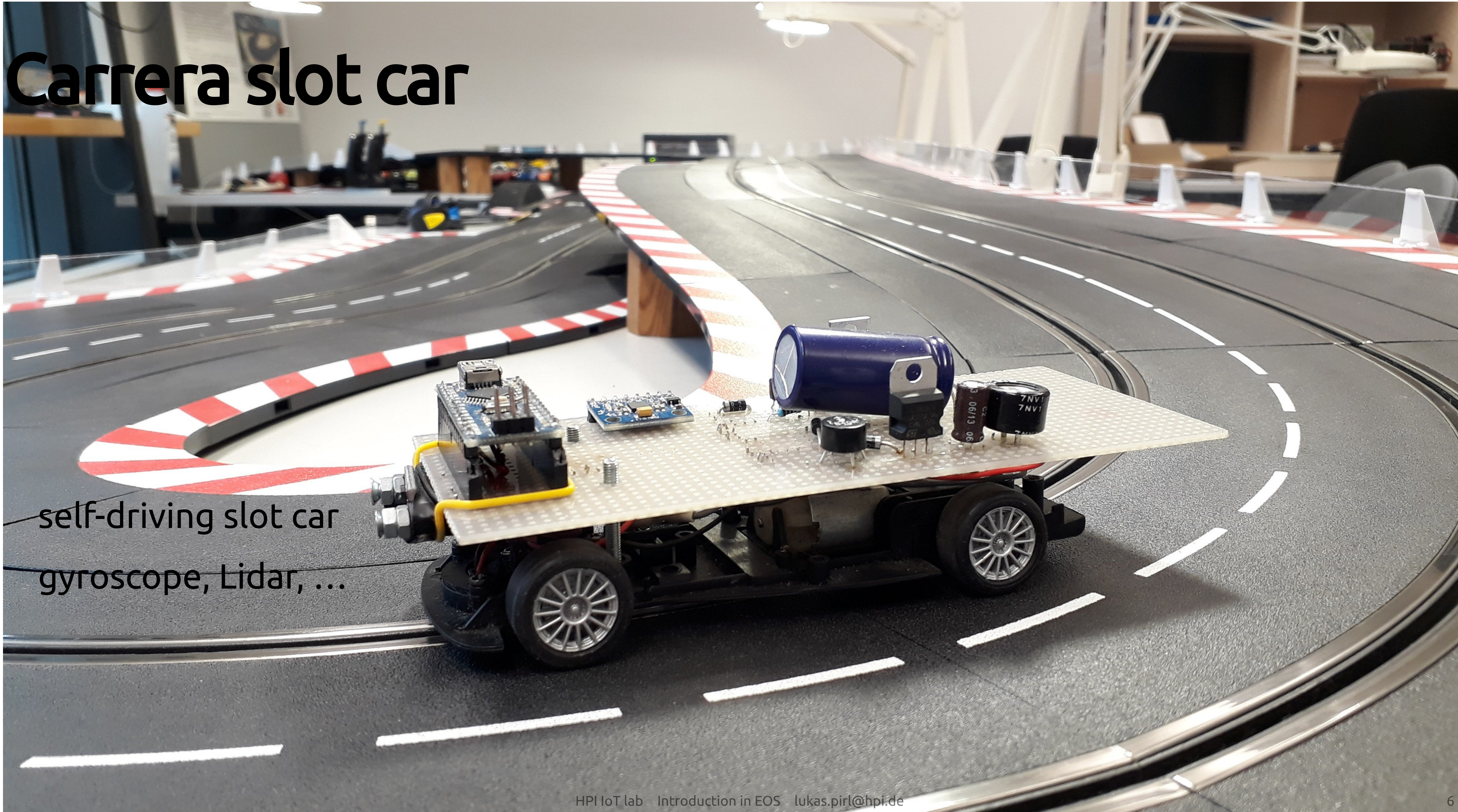
power supply

measurement

…



Carrera slot car

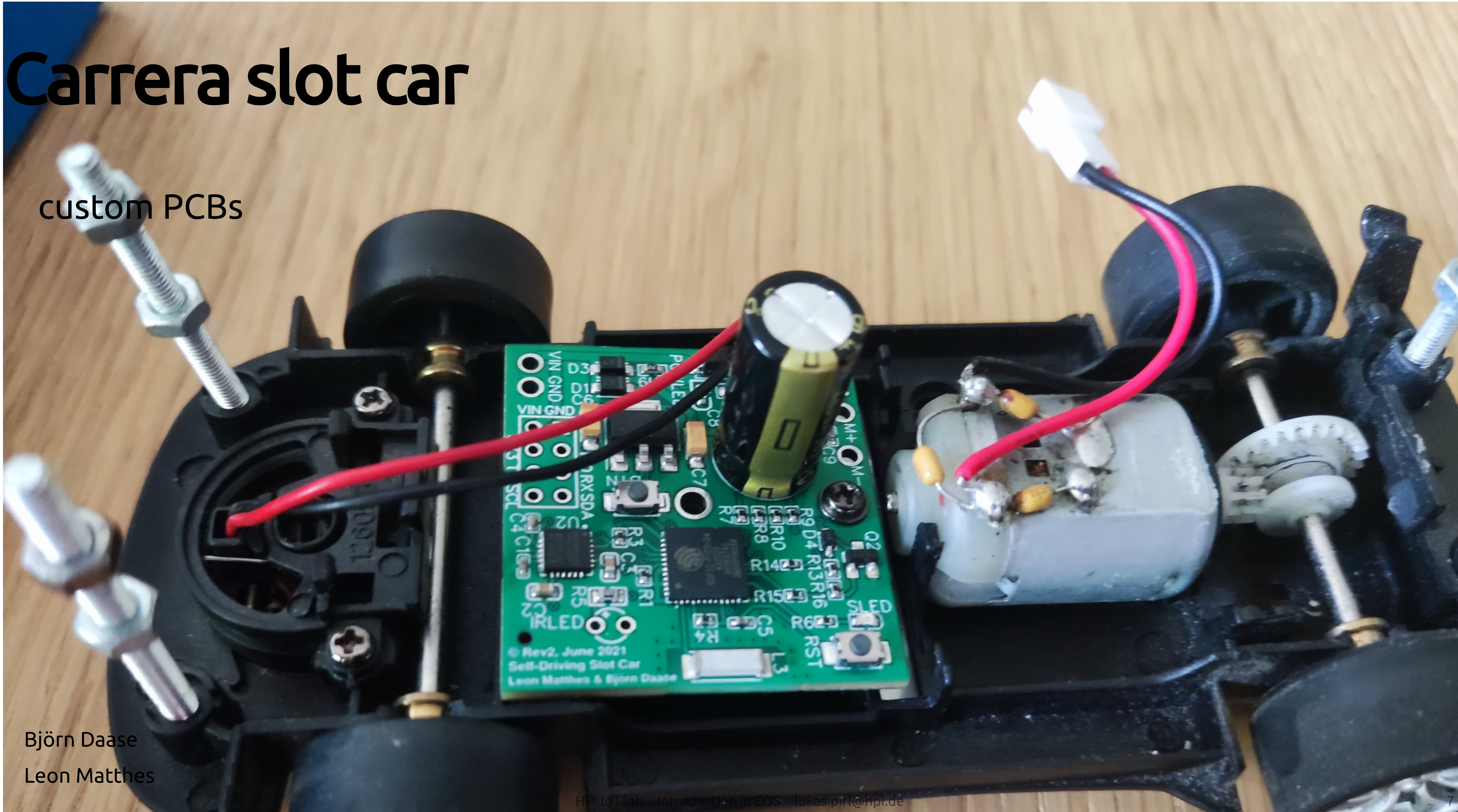


self-driving slot car

gyroscope, Lidar, …

Carrera slot car

custom PCBs

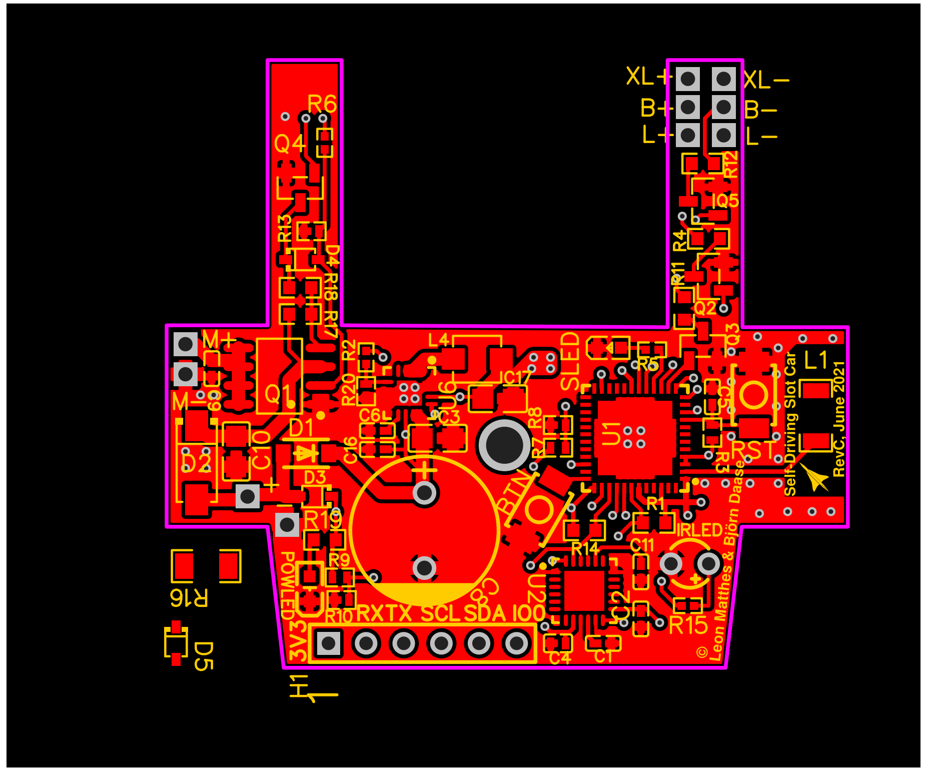


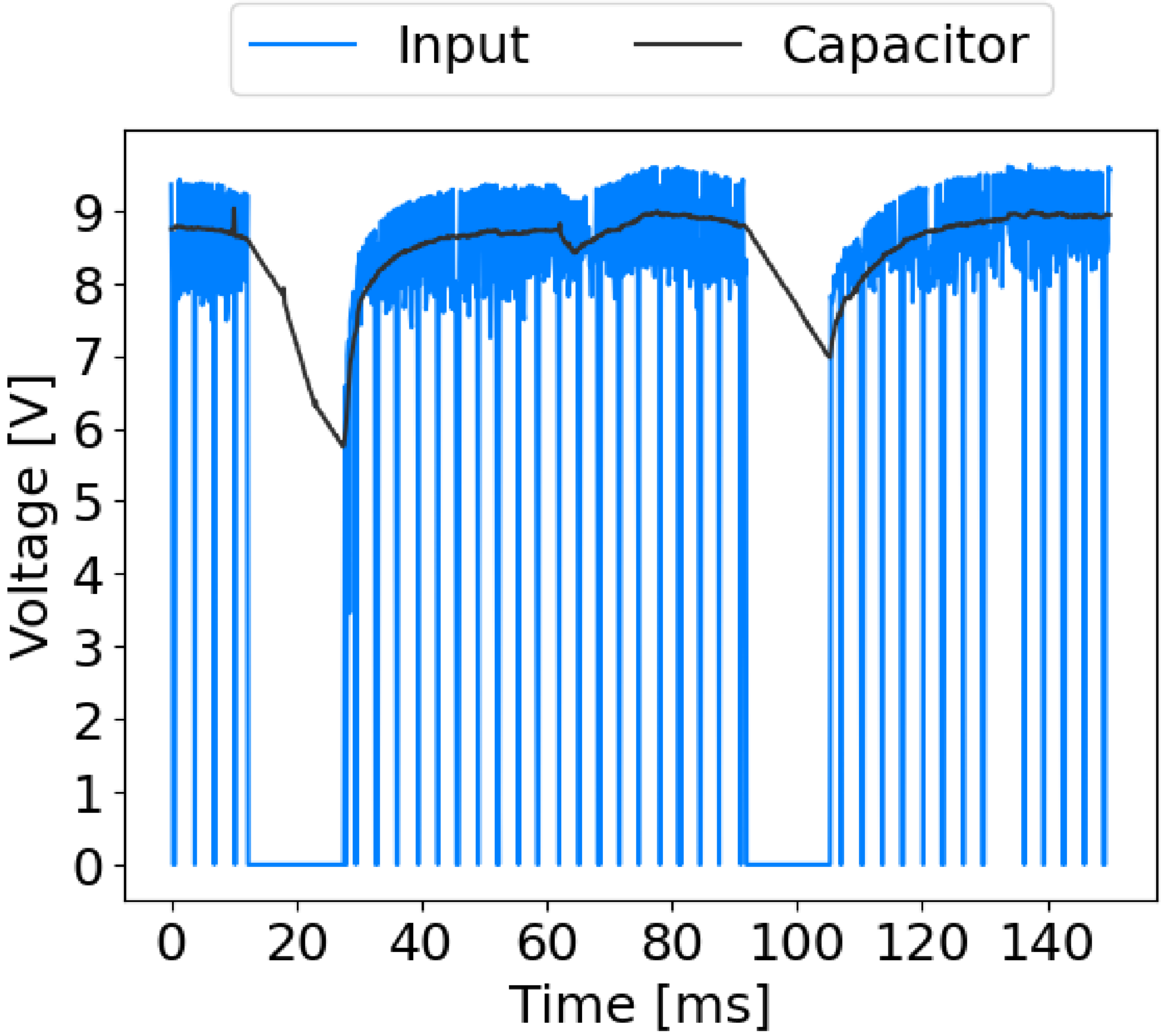
Björn Daase

Leon Matthes

Carrera slot car

- challenges
    - unusual power supply characteristics
    - remote/mobile debugging
- PCB design





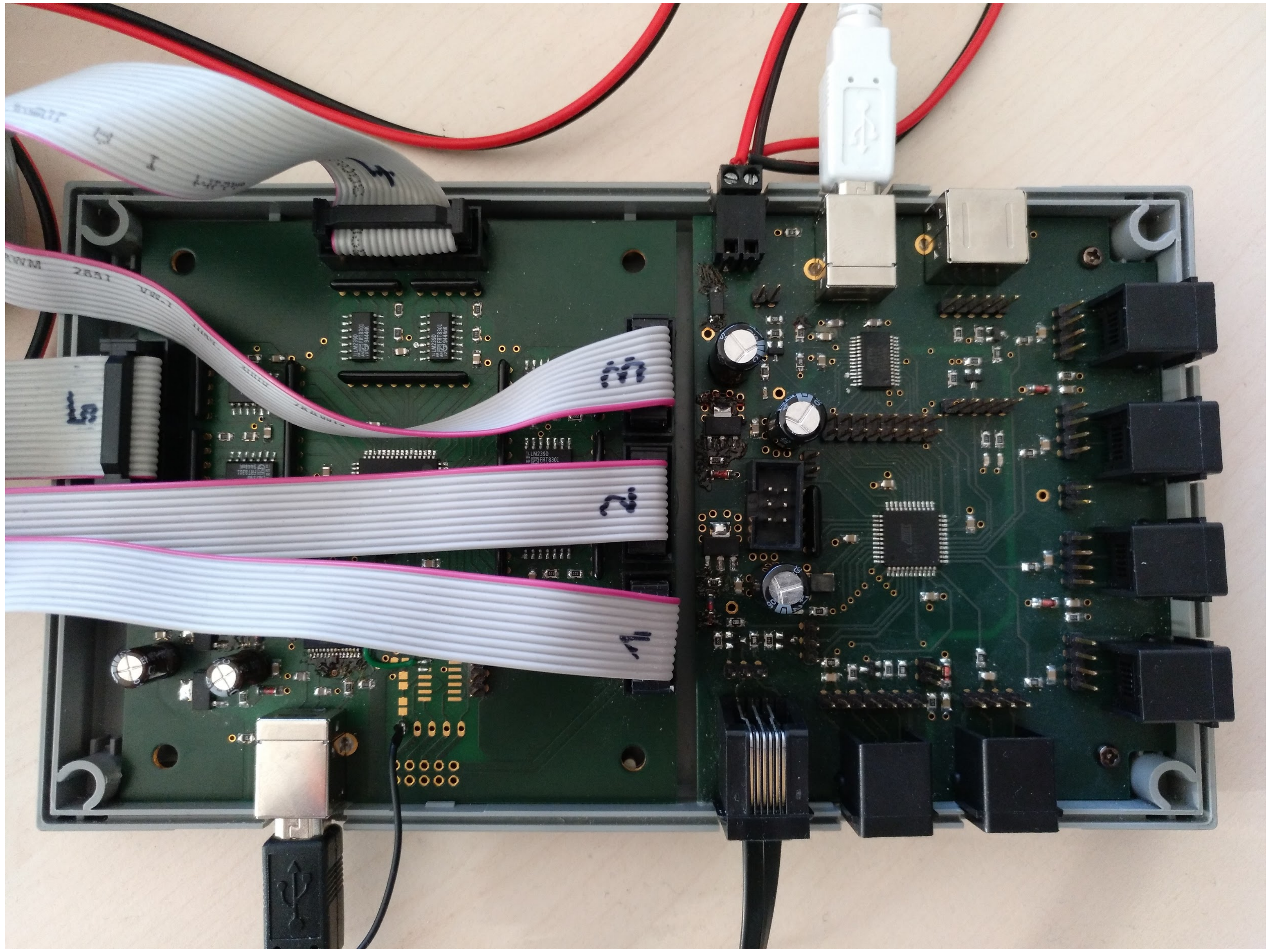
Daase, B., Matthes, L., Pirl, L., & Wenzel, L. Observing a Moving Target – Reliable Transmission of Debug Logs from Embedded Mobile Devices.

Carrera sensor & actuator board

working with the digital protocol

firmware level

e.g., prevent overtaking the safety car



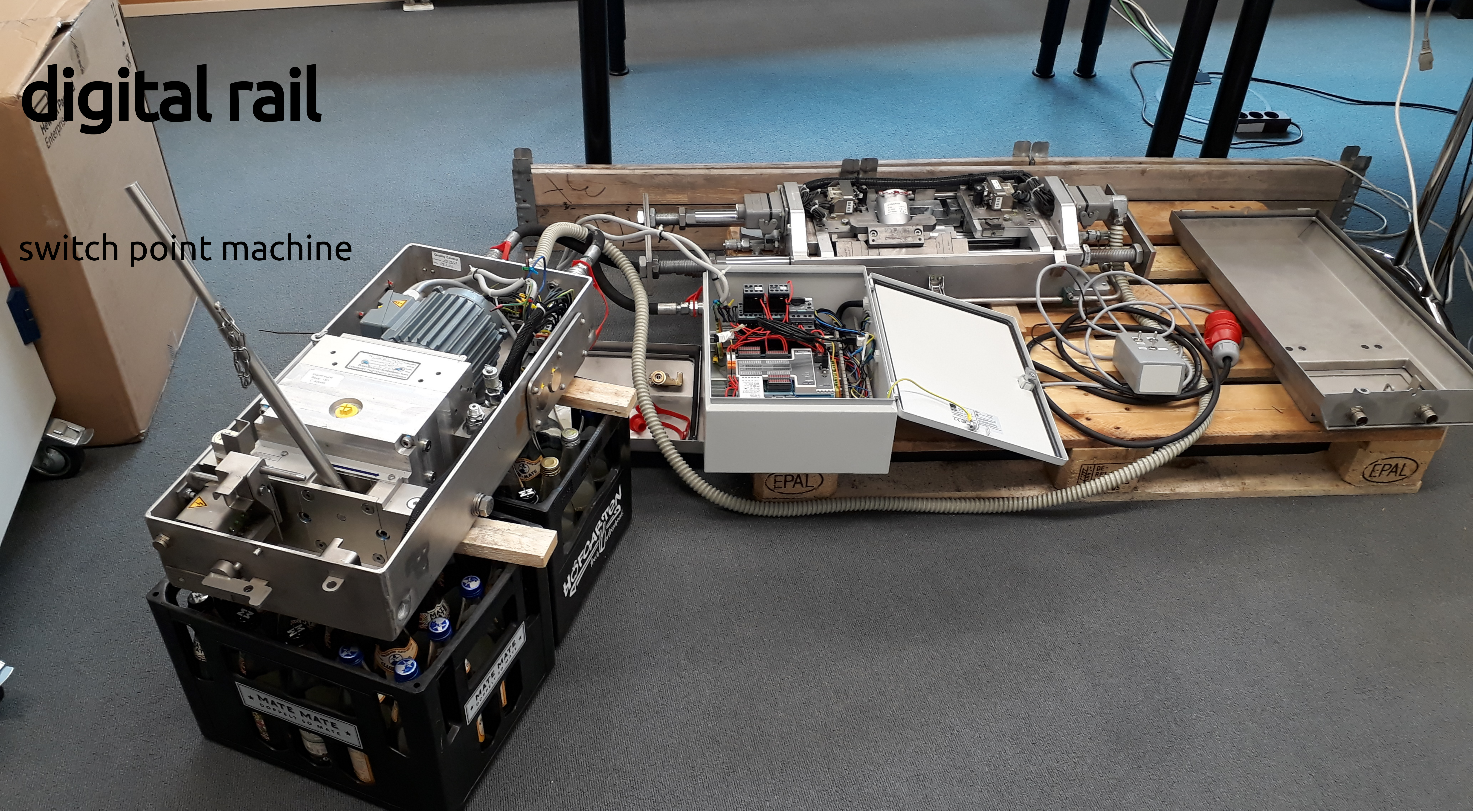
single-board computers

- distributed computing
- energy-aware computing
- heterogeneous computing
  - (GP)GPU, big.LITTLE, …

list of experiment hardware
https://osm.hpi.de/iot-lab/docs/hardware/generated-overview-of-experiment-hardware-list.html

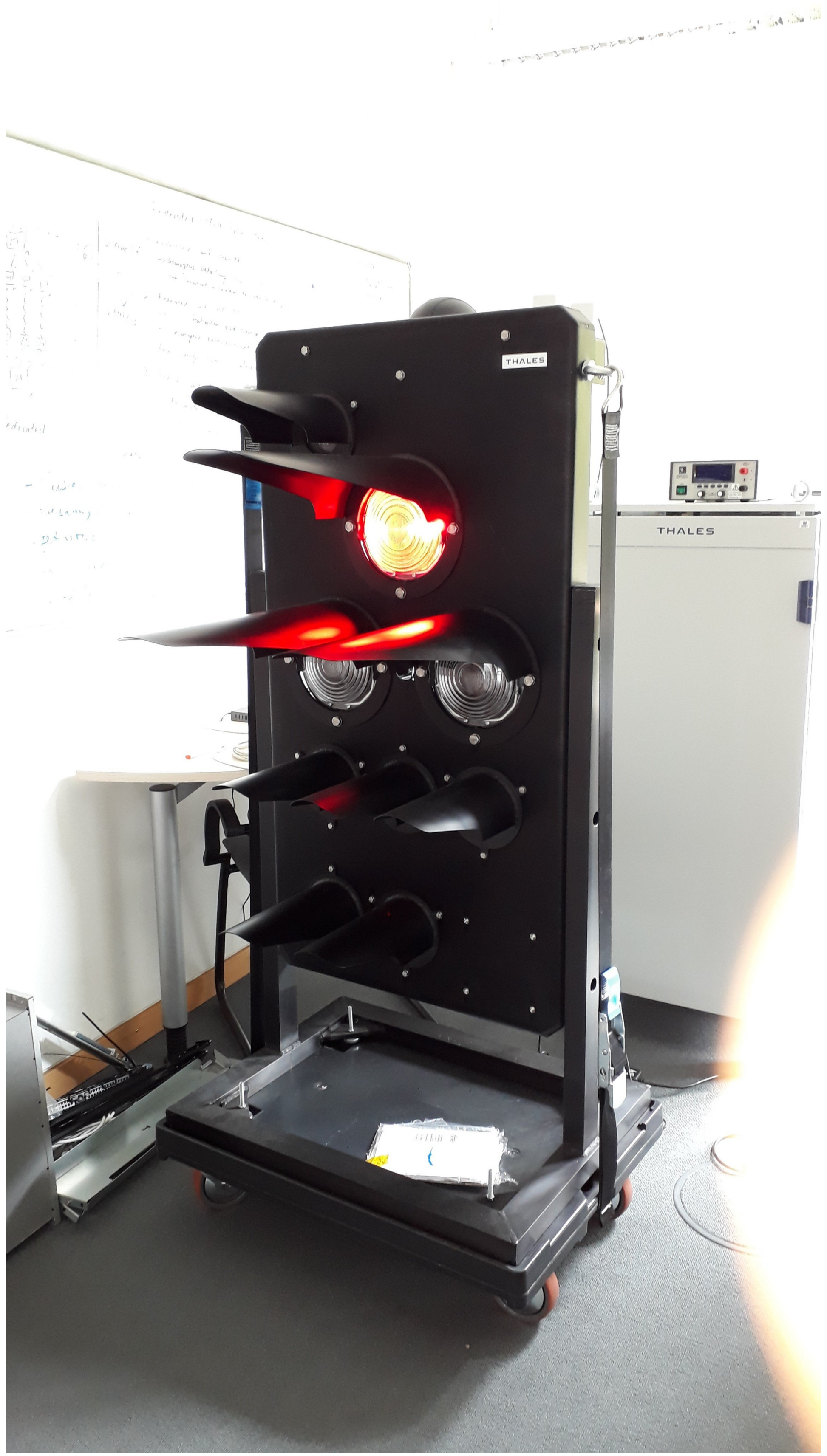
digital rail

switch point machine

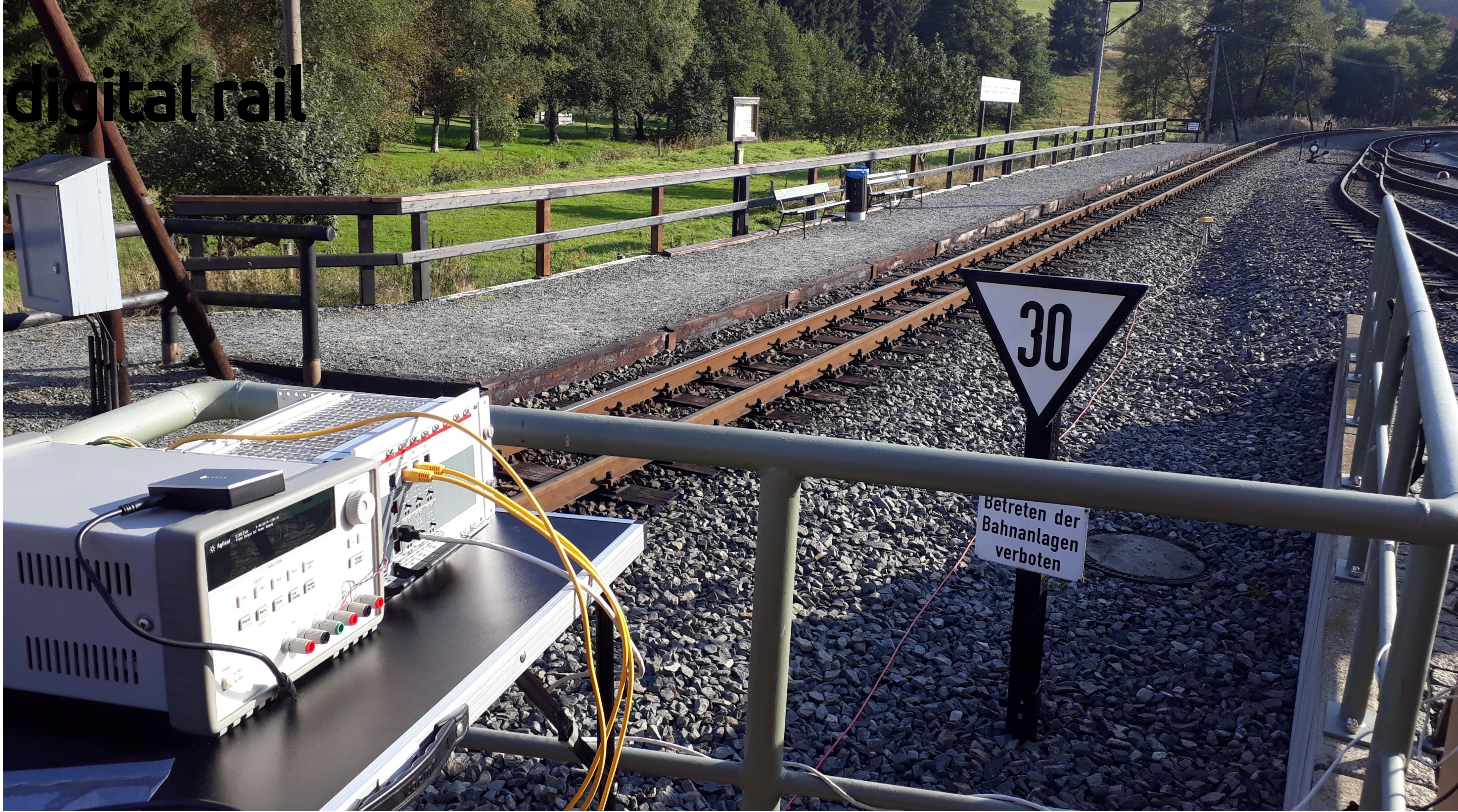


digital rail

color light signal (Ks)



digital rail



digital rail

digital rail

model-generated code counts axles and controls signal

digital rail

DRSS

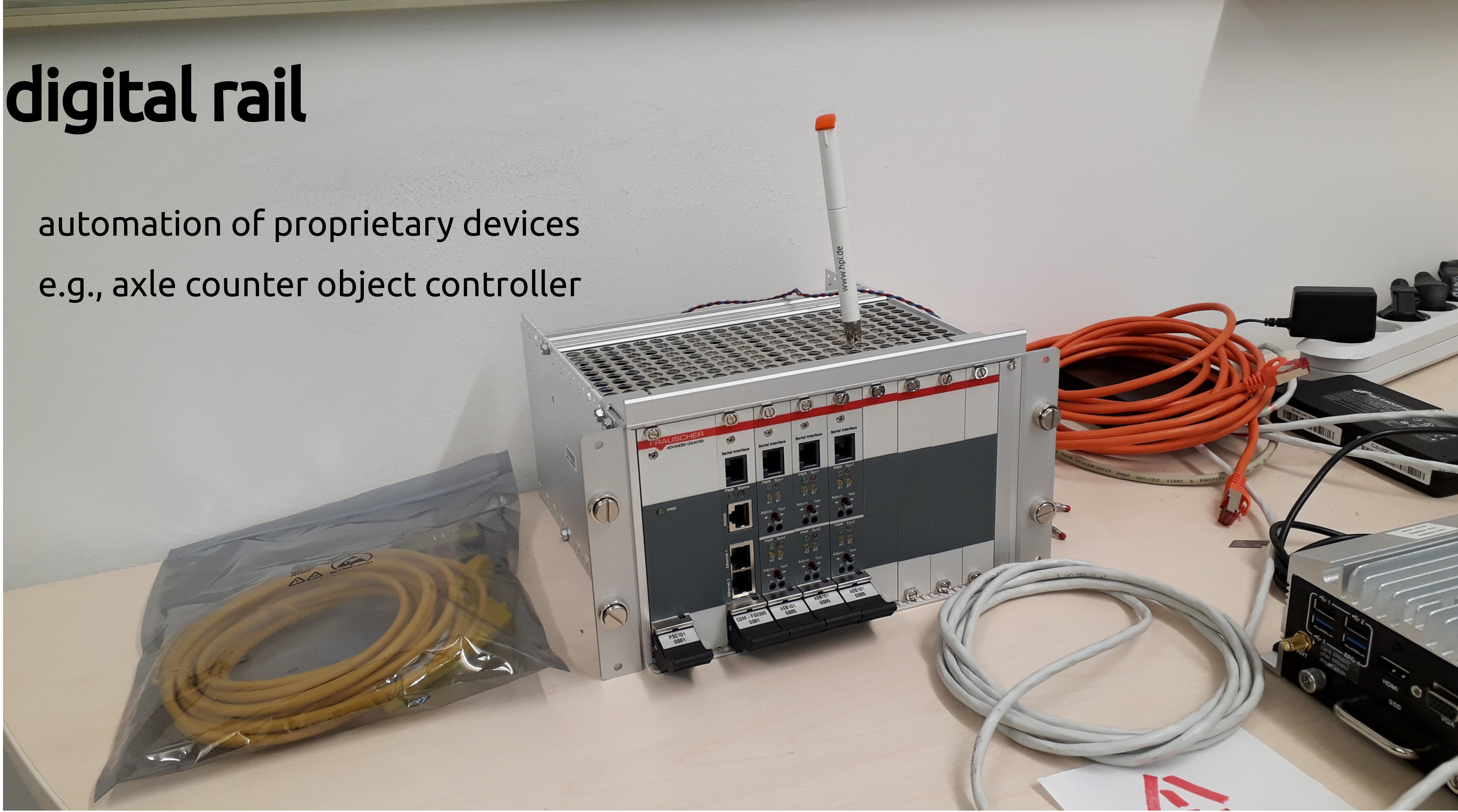
Digital Rail
Summer School

https://hpi.de/drss

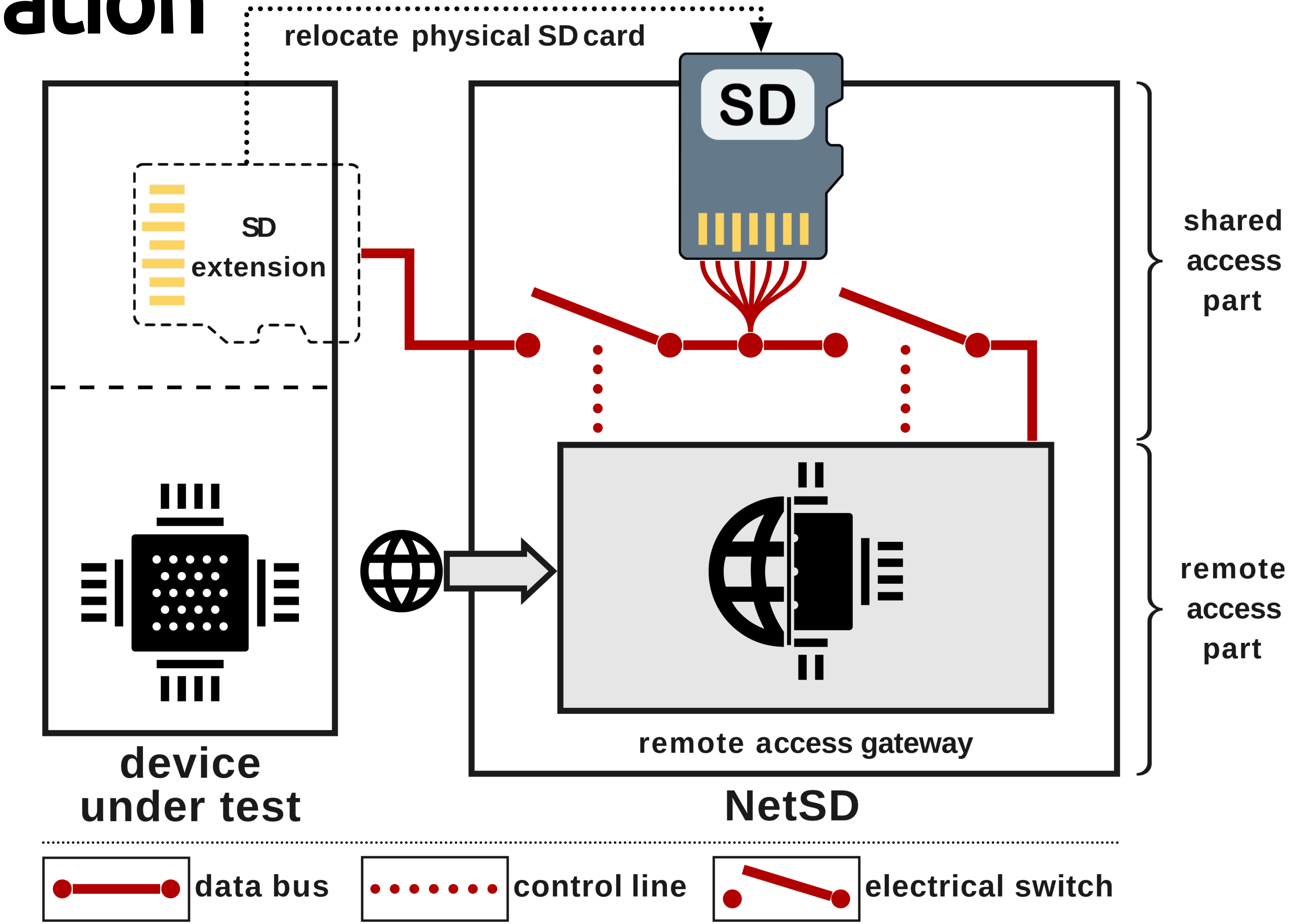
DRSS 2021 already done, join 2022! :)

digital rail

- automation of proprietary devices
- e.g., axle counter object controller

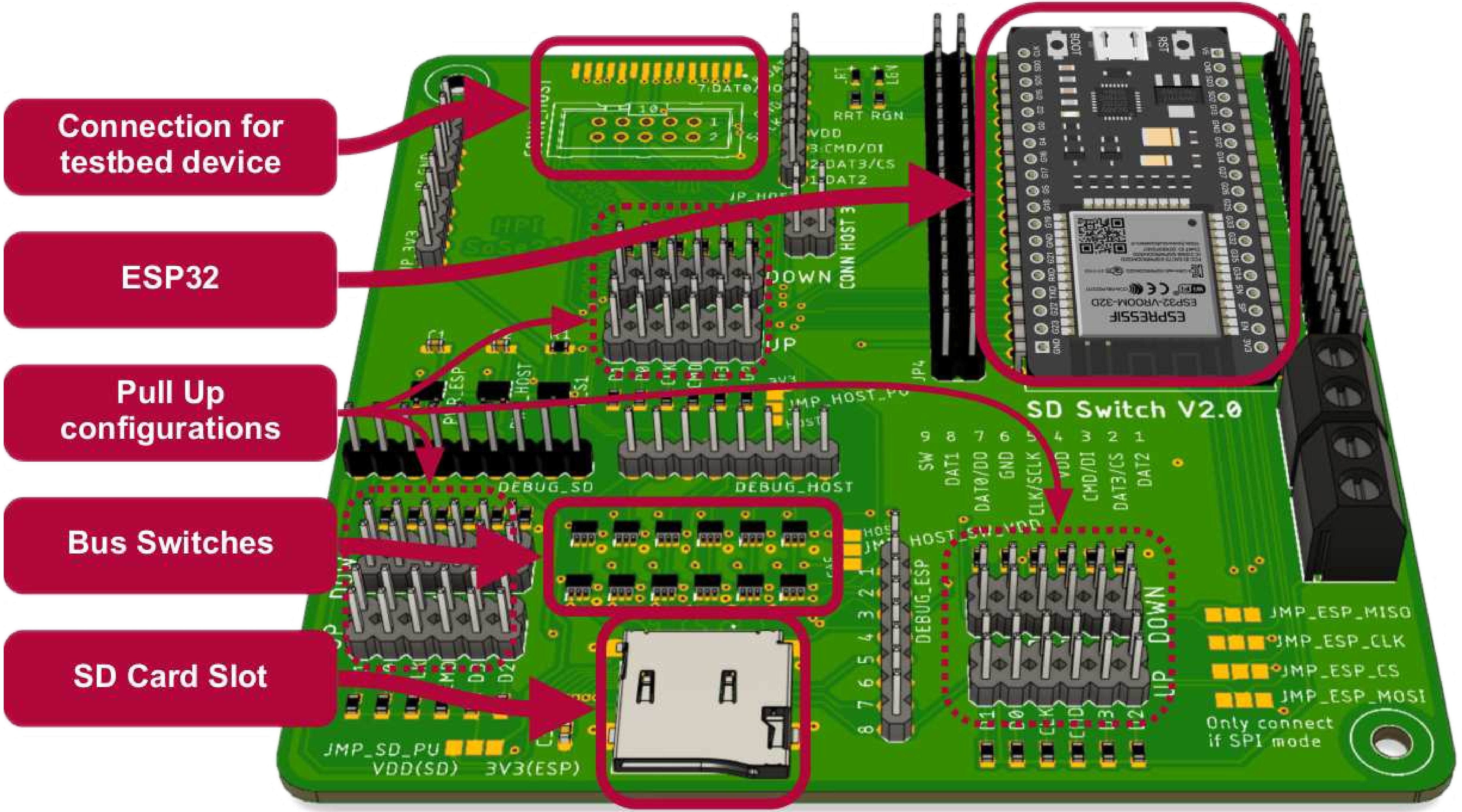


testbed automation



Schröter, V., Boockmeyer, A., & Pirl, L.
NetSD: Remote Access to Integrated
SD Cards of Embedded Devices.

testbed automation



Connection for testbed device

ESP32

Pull Up configurations

Bus Switches

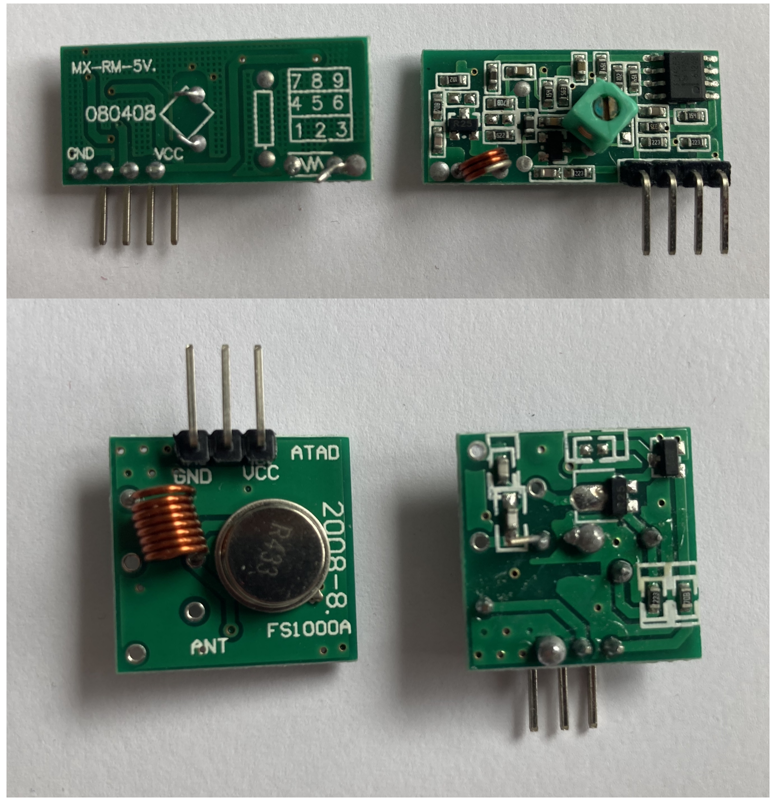
SD Card Slot

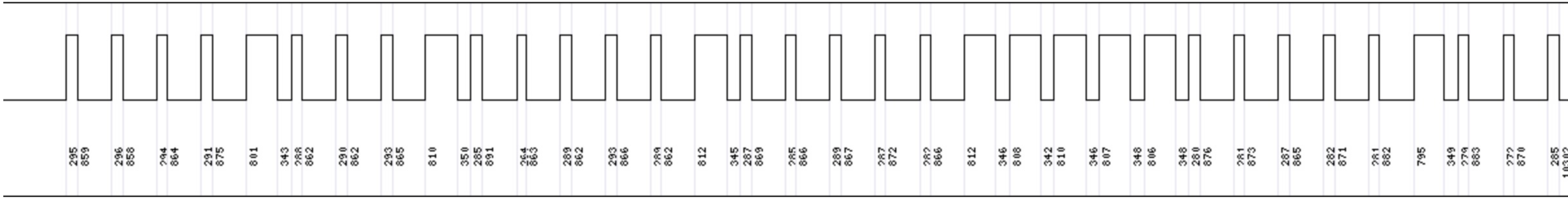
Valentin Schröter
Tobias Zagorni

Maximilian Diez

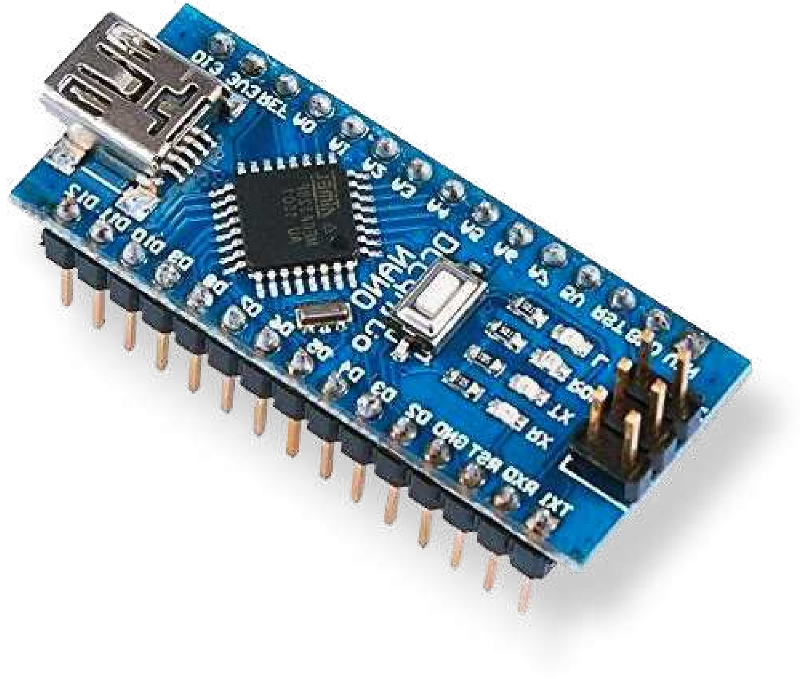
testbed automation

reverse engineering of switchable power sockets

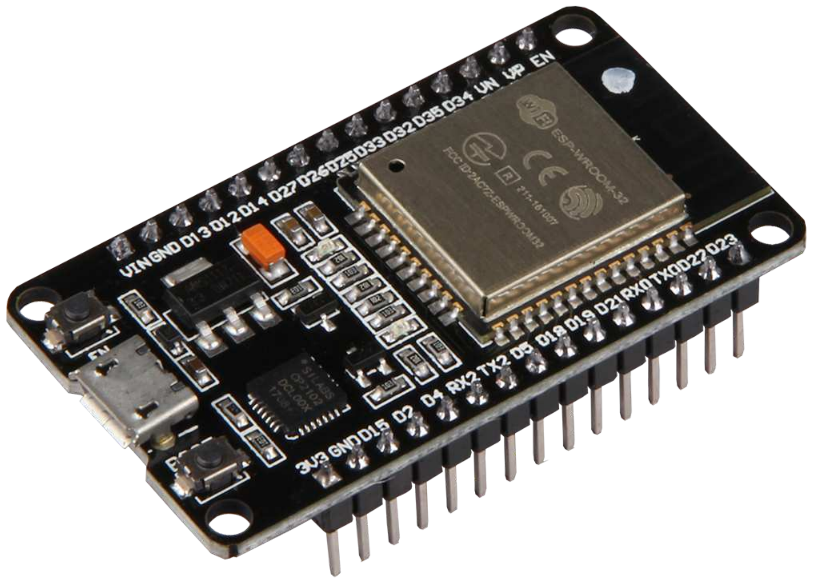




embedded devices & OS



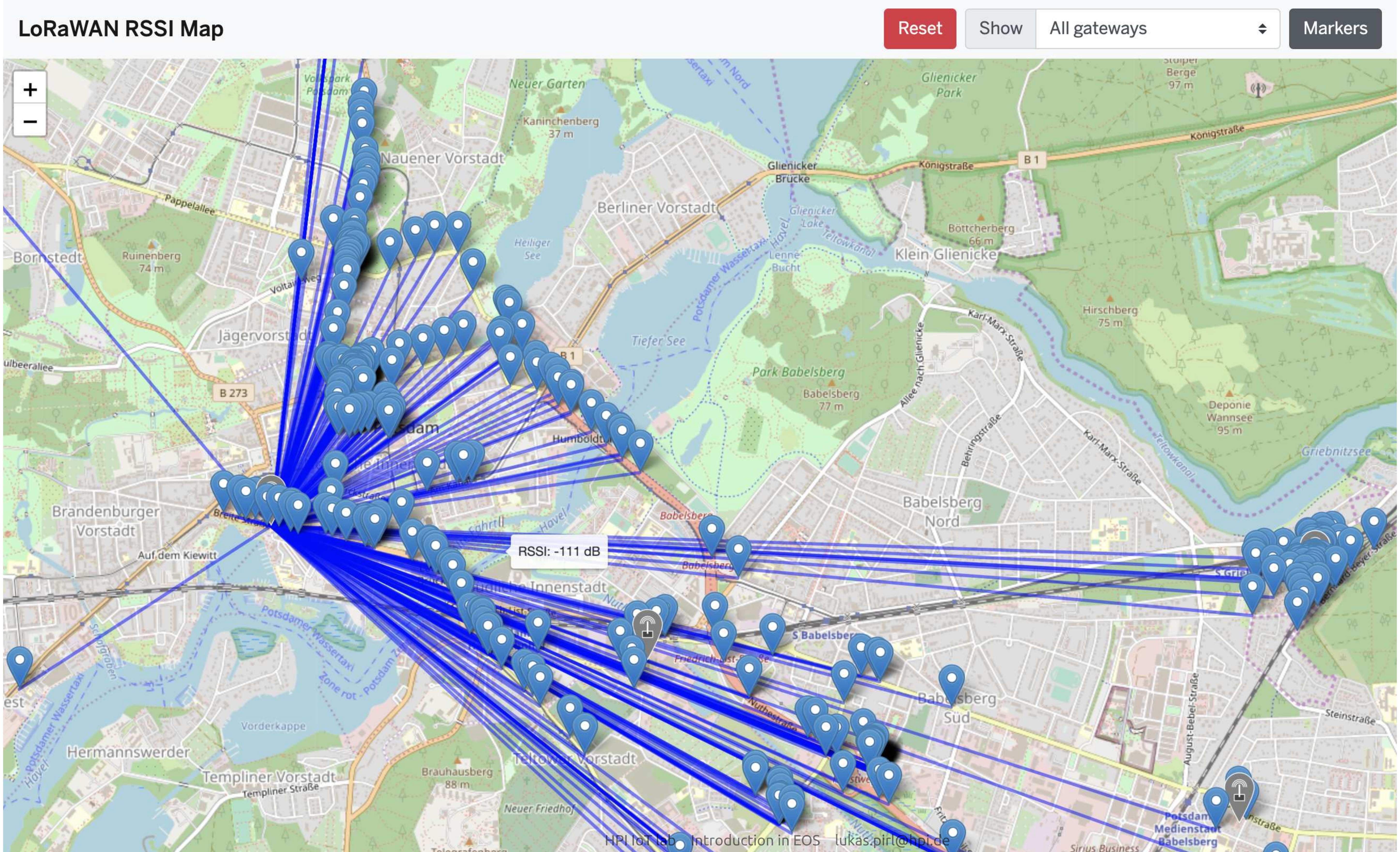
- devices
  - Arduino
  - ESP32
  - Beckhoff SPS
  - Lego
  - Fischertechnik
  - … *open to suggestions!* :)
    - incl. designing own PCBs
- operating systems
  - RIOT, *RTOS, OpenWRT, embedded Linux, Contiki, Android, …



radio technology

LoRa-WAN

SDR



Sebastian Kliem

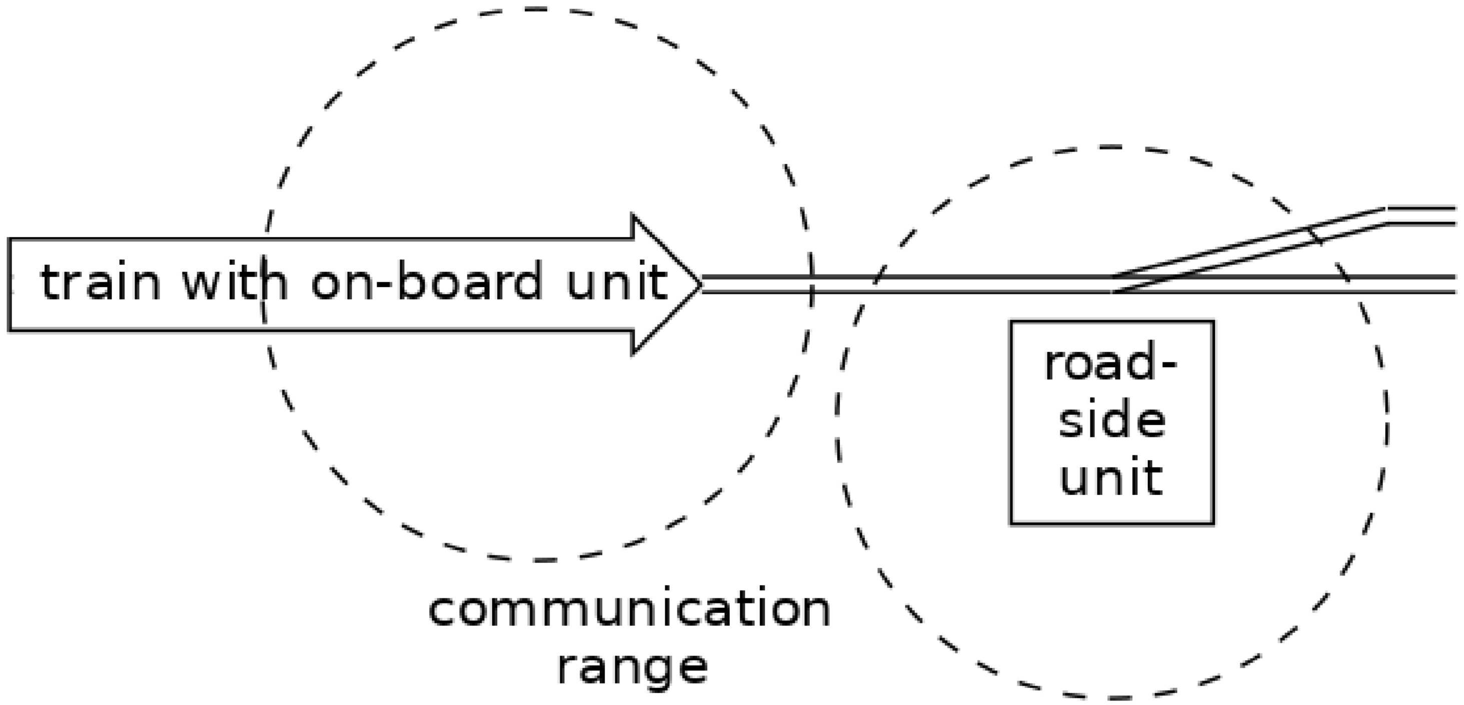
radio technology

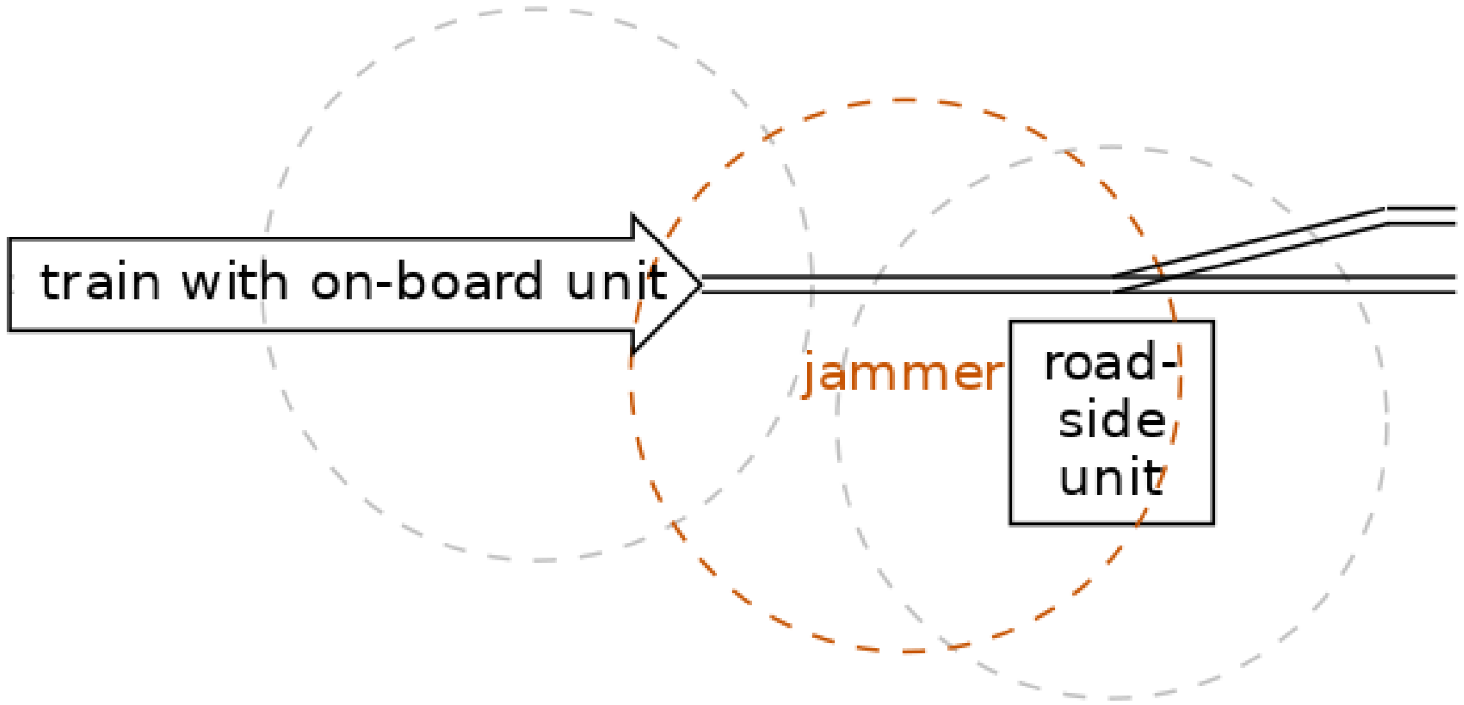
IEEE 802.11p

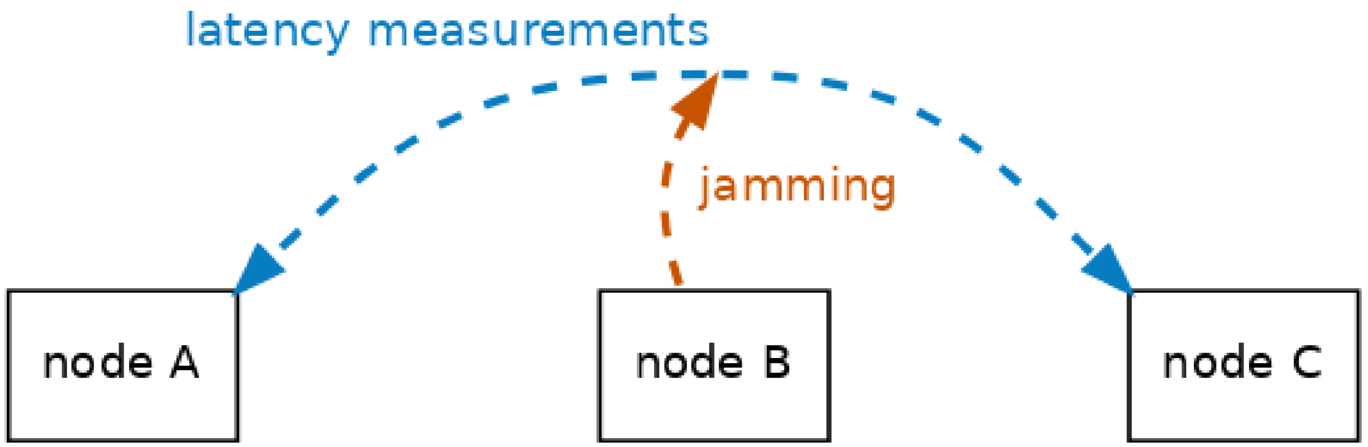
Rail2X

- Vehicle-to-X communication (V2X) for railways (Rail2X)
  - smart mobility through interconnection of vehicles & infrastructure
  - analogue: Car2X, Ship2X, Airplane2X
- V2X (hence, Rail2X) uses specialized WiFi standard IEEE 802.11p
  - pre-defined messages (e.g., emergency vehicle alert)
  - focus on low latency (compared to, e.g., 802.11n)
  - no access points (similar to ad-hoc mode)
  - higher range (up to 1 km)

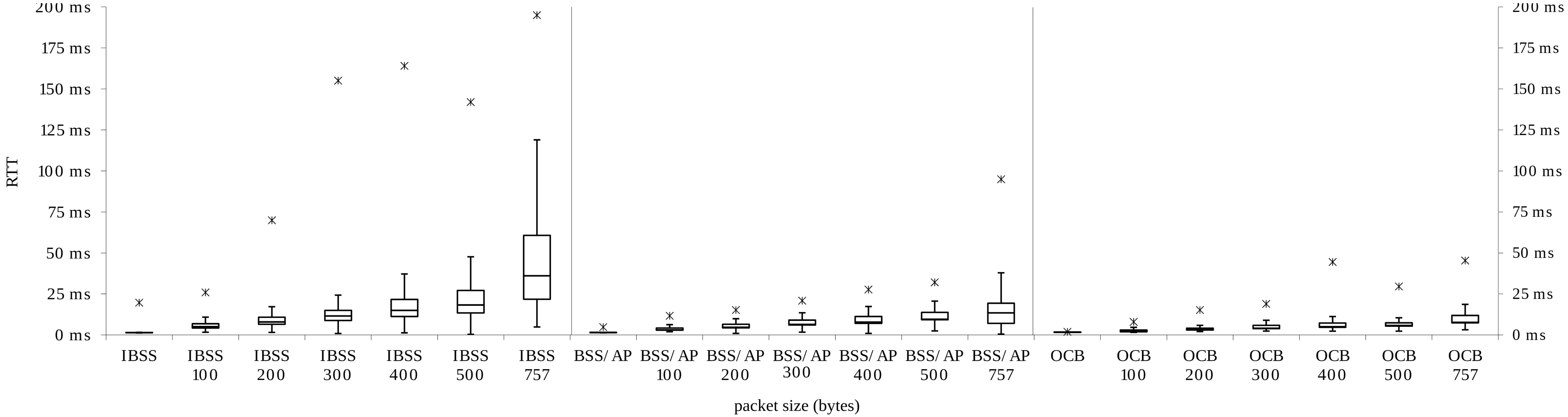
Rail2X in the IoT Lab







IEEE 802.11p packet round trip times while jamming

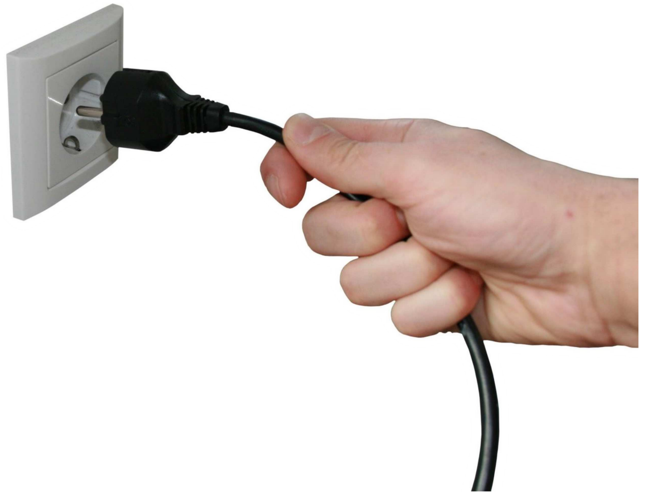


- packet round trip times are lowest using IEEE 802.11p OCB mode
  - esp. with lowest standard deviation
    - desirable for soft real-time applications

Richter D, Pirl L, Beilharz J, Werling C, Polze A. Performance of Real-TimeWireless Communication for Railway Environments with IEEE 802.11p.

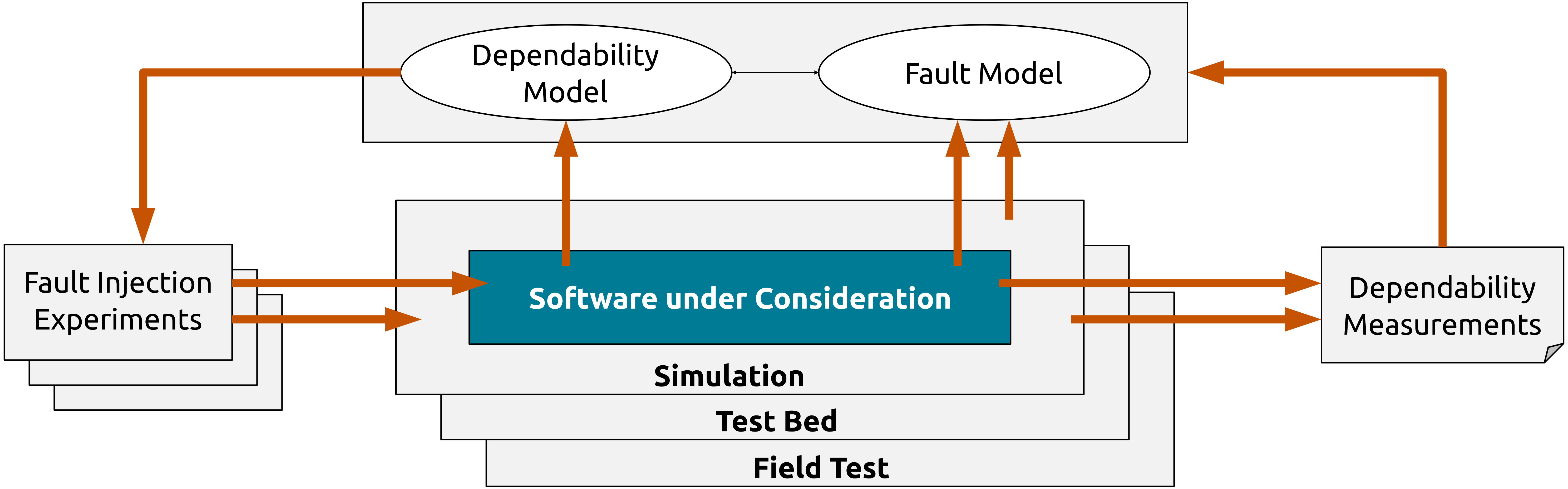
fault injection

- experimental dependability assessment
  - promises lower complexity
    - compared, e.g., to formal verification
- fault injection ⊂ testing
- try to prove the system wrong
  - instead of trying to prove the system correct as with “traditional” testing
  - counter developers’ bias towards happy cases
- concept
  1. forcefully activate (“inject”) suspected error causes (“faults”)
  2. assess delivered quality of service



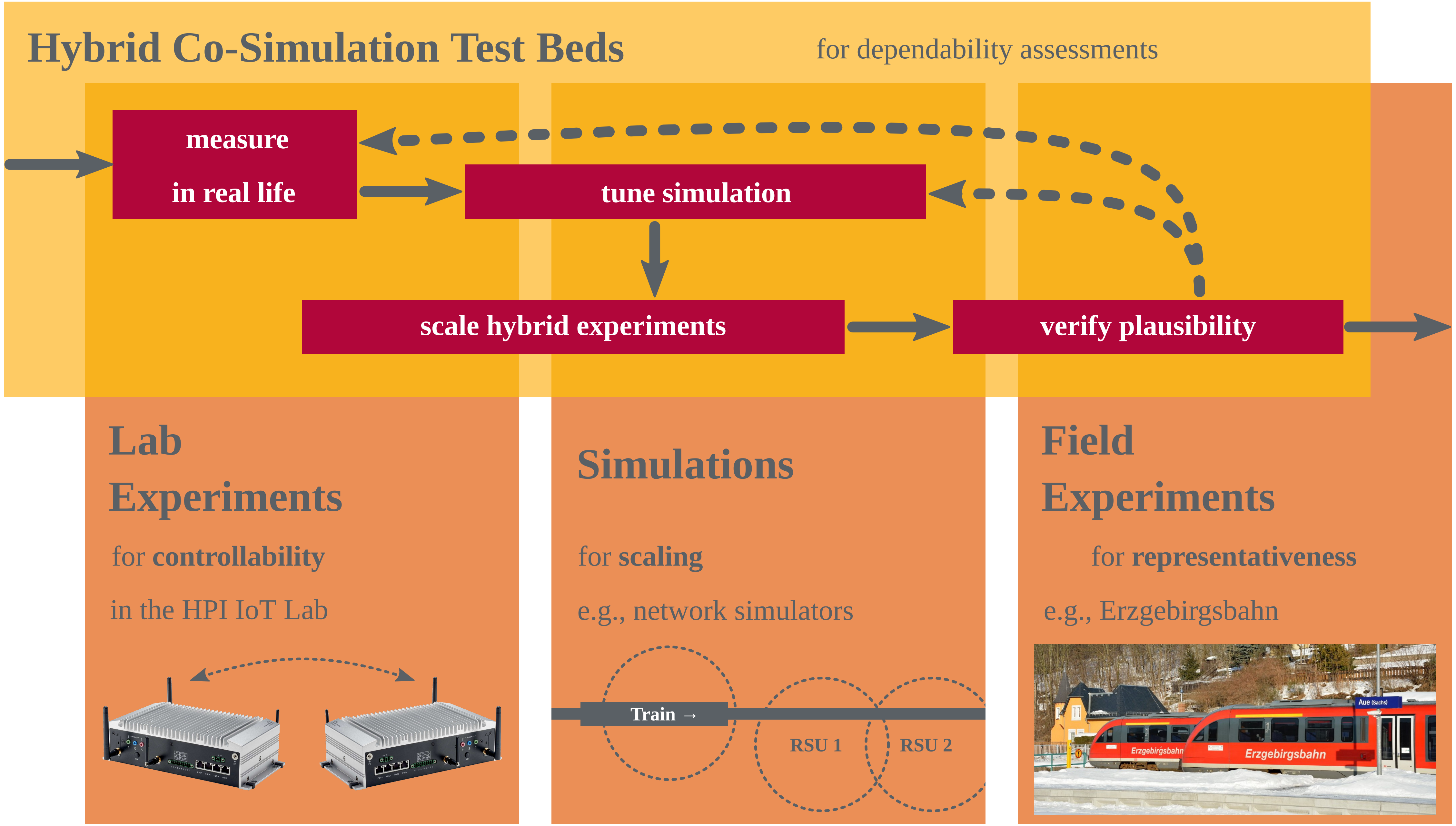
development of methodologies

fault-injection-driven development


Dependability Model
Fault Model
Fault Injection Experiments
Software under Consideration
Simulation
Test Bed
Field Test
Dependability Measurements

Dr. Lena Feinbube

development of methodologies



Hybrid Co-Simulation Test Beds

for dependability assessments

measure in real life

tune simulation

scale hybrid experiments

verify plausibility

Lab Experiments

for **controllability**

in the HPI IoT Lab

Simulations

for **scaling**

e.g., network simulators

Field Experiments

for **representativeness**

e.g., Erzgebirgsbahn

hybrid testbeds & co-simulation

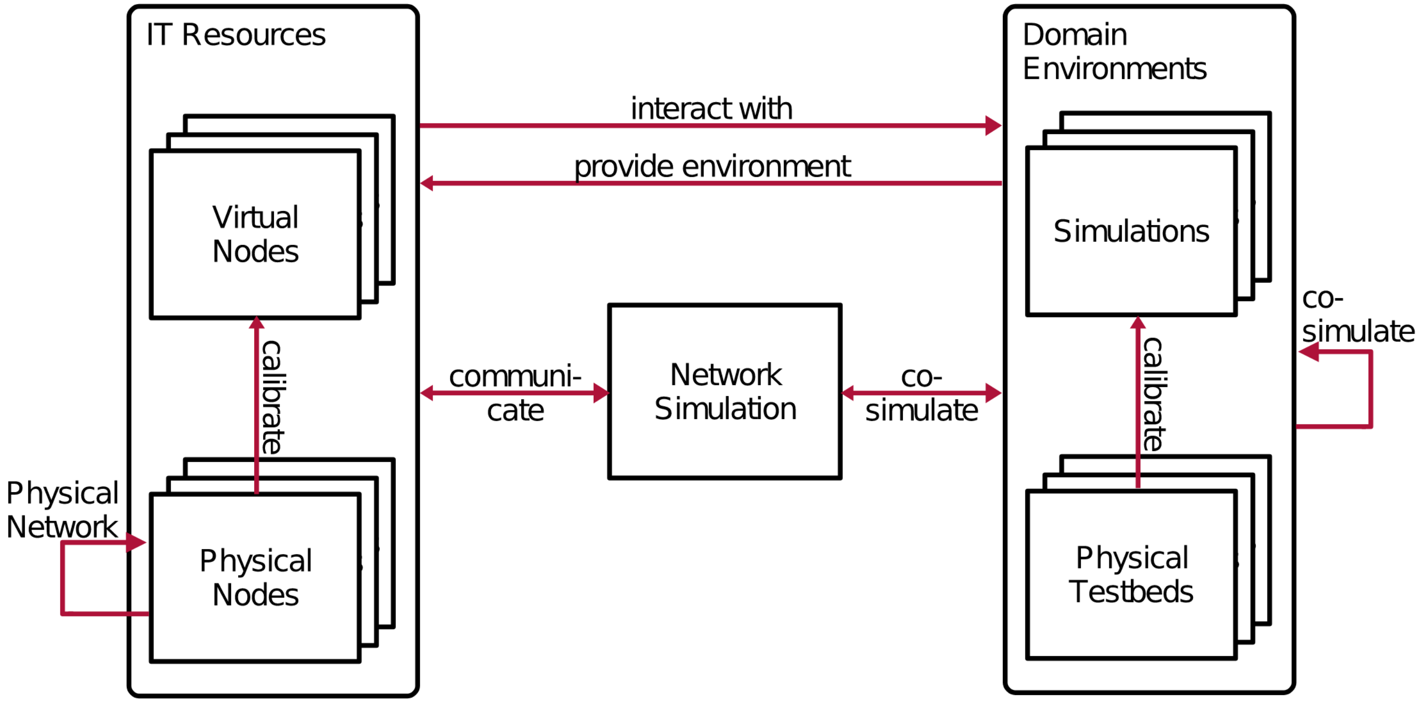
hybrid: software, hardware, and models “in-the-loop”

- e.g., simulated wireless & physical wireless network

co-simulation: coupling of multiple domain-specific simulations

- e.g., *SUMO* for traffic & *ns-3* for networking

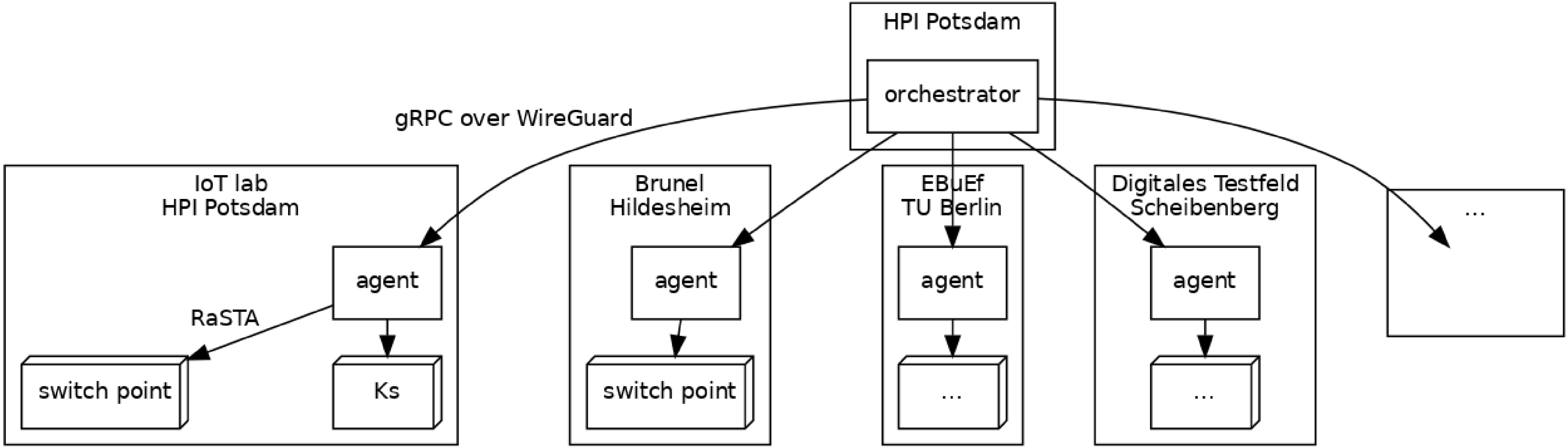
https://github.com/diselab/marvis



distributed testbeds

EULYNX live lab: distributed test environment

Kubernetes + Akri, generated interlocking software, automated tests, …



HPI IoT lab

… an environment for prototyping and assessments

- building, DIY, testing, …
- hybrid, co-simulated, and distributed setups
- across/coupling of different domains
- model-driven and -supported approaches
- alternatives to specialized (test) hardware
- hardware, software and model “in the loop”
- dependability
  - (e.g., through fault injection)

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