Fruity Twin – A Digital Platform for Processing Sensor Data in Food Cool Chains

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Goal: Optimizing fruit storage conditions

- **Digital Twin** for real-time 'live' monitoring and control

- **Humidity** as crucial influence to fruit quality

  > Relation of humidity – condensation – weight loss – fungi growth

- **Modelling** of condensation status

  > Direct measurement of condensation in practical application hardly feasible
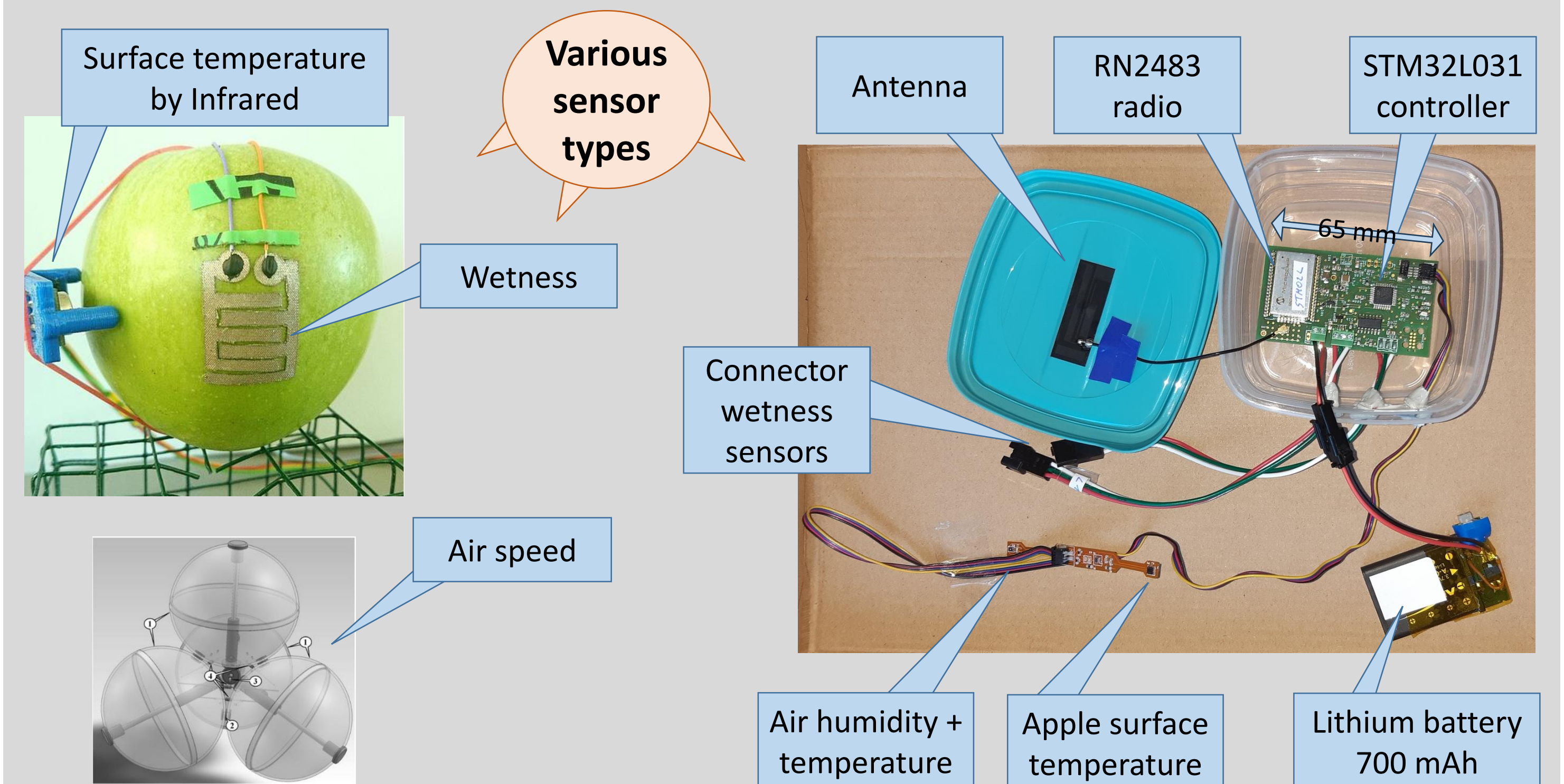
DFG Project
Fruity Twin
2024 - 2027

Sensor system

- Combining wired (USB) and wireless (Lora) sensors
- µController provides I²C + analog inputs
- Raspberry Pi forwards USB via Ethernet to data base

LoRa Sensor node

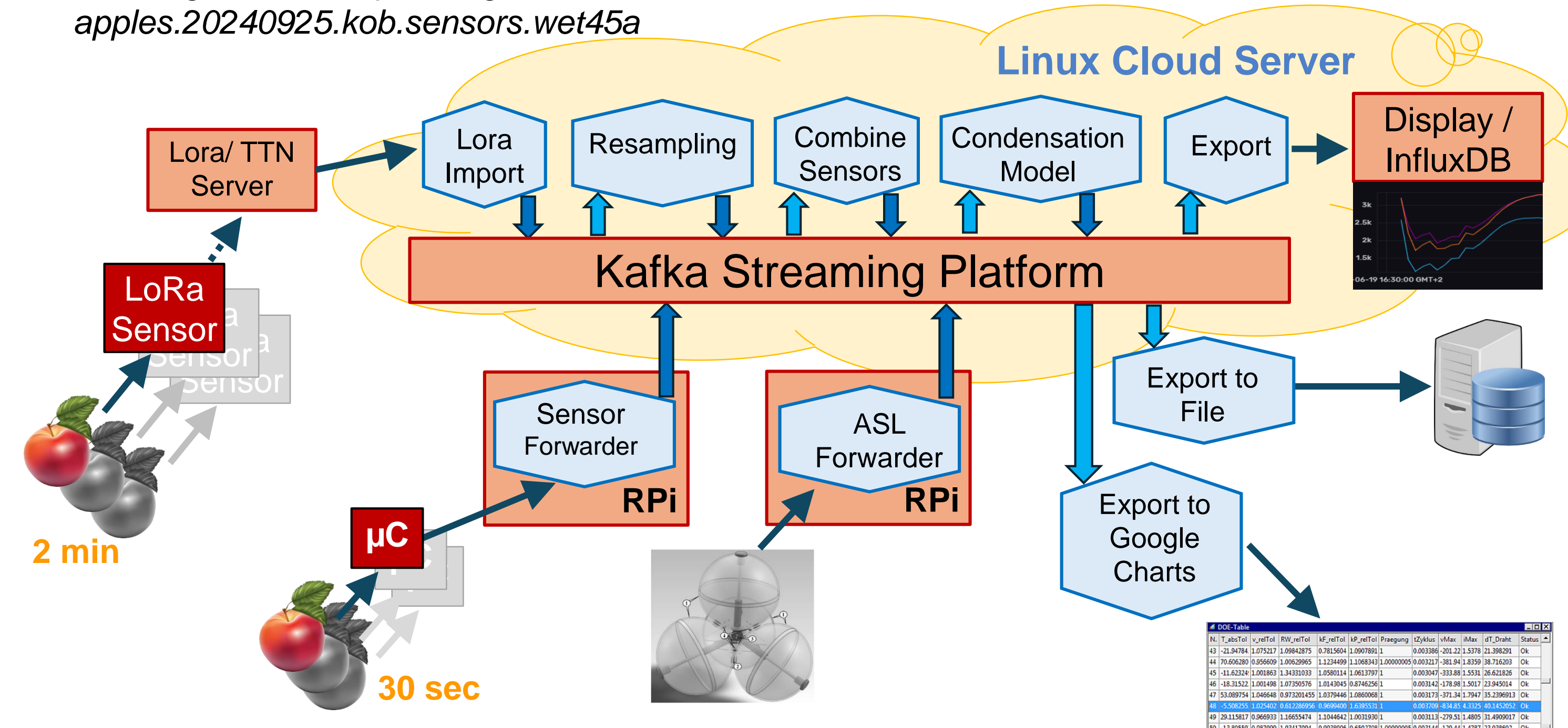- Custom made board to include project specific sensors

Surface temperature by Infrared
Various sensor types
Wetness
Air speed

Antenna
RN2483 radio
STM32L031 controller
65 mm
Connector wetness sensors
Air humidity + temperature
Apple surface temperature
Lithium battery 700 mAh

Test of remote live monitoring

standard bin (300 kg)
Cold storage room (40 t)
Tests with single apples

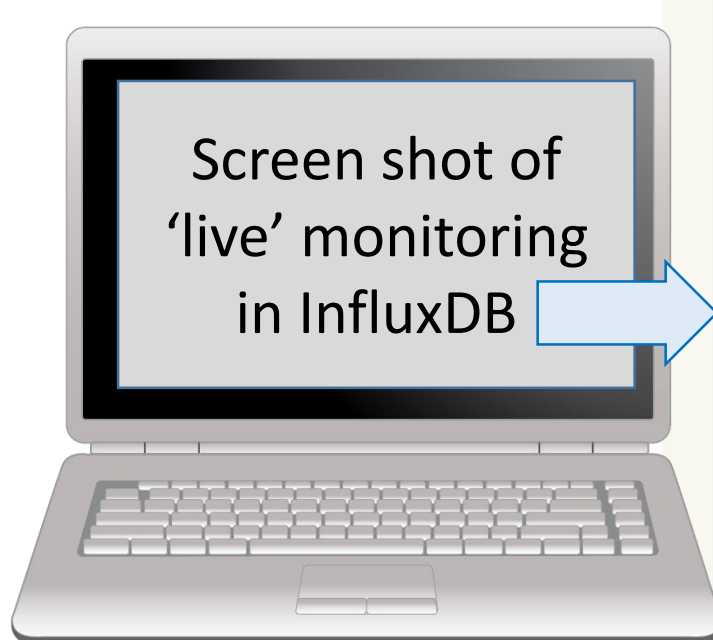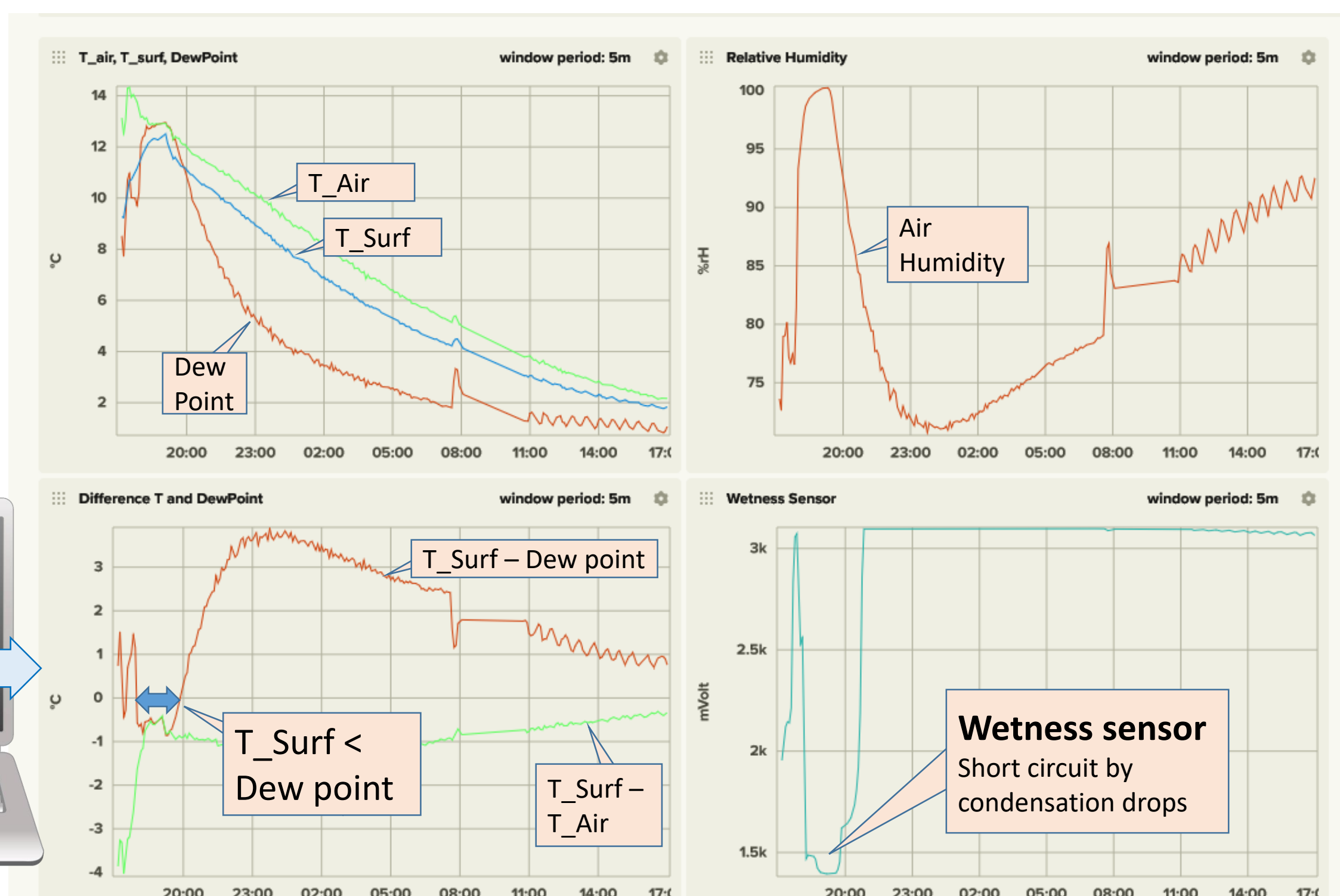## Digital Twin streaming platform

- Link any sensor to any model
- Based on Kafka / Linux / InfluxDB, Python, TSL Encryption
- Performance: More than 50 sensors + models can run on virtual machine with 4 cores
- Data organized in topics, e.g.: *apples.20240925.kob.sensors.wet45a*

Implemented as **Services**

Linux Cloud Server
Lora/ TTN Server
Lora Import
Resampling
Combine Sensors
Condensation Model
Export
Display / InfluxDB
LoRa Sensor
Kafka Streaming Platform
2 min
Sensor Forwarder RPi
ASL Forwarder RPi
Export to File
Export to Google Charts
µC
30 sec

Dew point and condensation model

- Compare Dew point and apple surface temperature
- Calculate mass transfer (completed for single apple)
- Model verified by wetness sensor and weighting scale

Screen shot of 'live' monitoring in InfluxDB

T_air, T_surf, DewPoint — window period: 5m
T_Air
T_Surf
Dew Point

Relative Humidity — window period: 5m
Air Humidity

Difference T and DewPoint — window period: 5m
T_Surf – Dew point
T_Surf < Dew point
T_Surf – T_Air

Wetness Sensor — window period: 5m
Wetness sensor
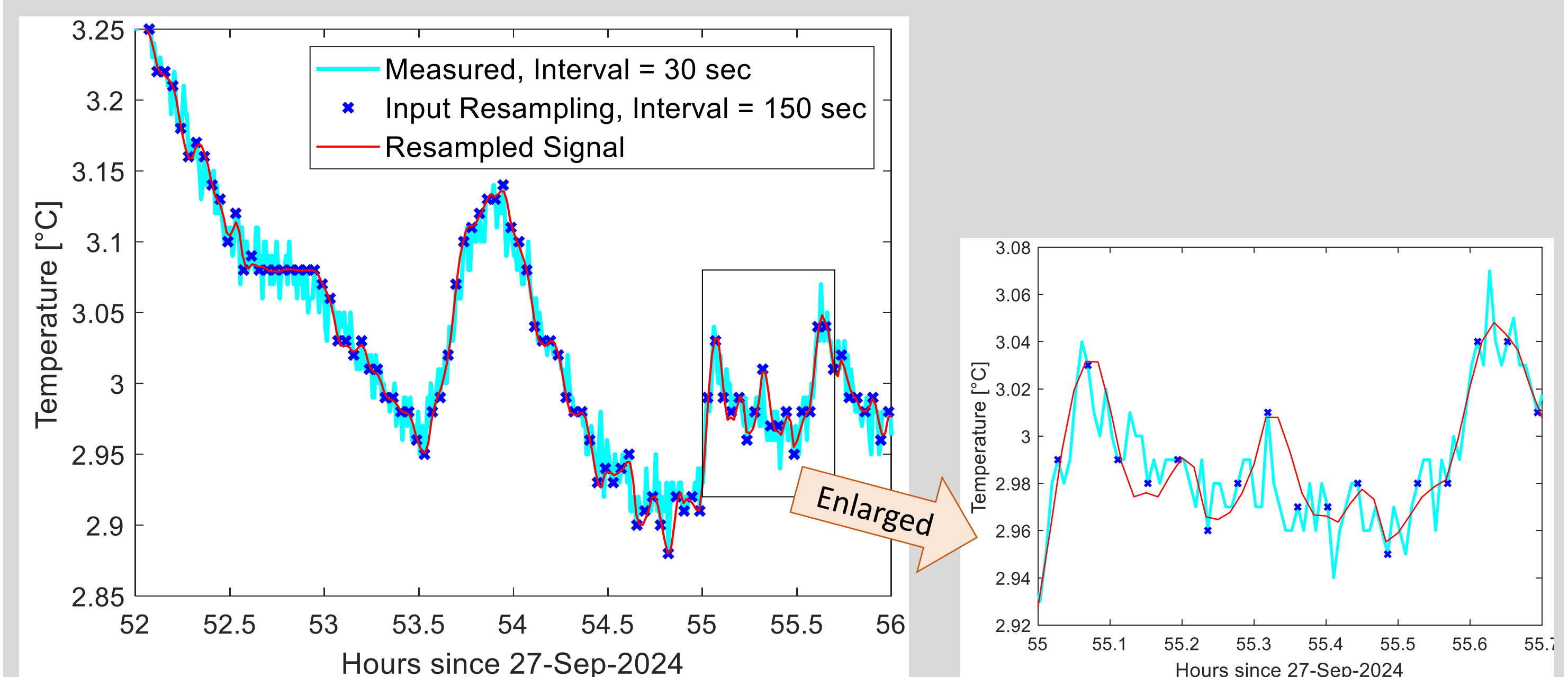Short circuit by condensation drops

Resampling

- Necessary because of different sampling intervals for USB and wireless sensors / missing samples
- Real-time resampling can use only 'past' samples → Symmetrical filters cannot be applied
- Interpolation by Kriging showed best performance in presence of noise

Test: Can resampling reconstruct the full signal by knowing only every 5th sample?

➡ Resampling smooths noise, error slightly larger than sensor quantisation (0.01 °C)

Measured, Interval = 30 sec
Input Resampling, Interval = 150 sec
Resampled Signal
Enlarged

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