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Sensor Networks for Forestry Applications operating with Limited Power Supply using LPWAN COTS Equipment

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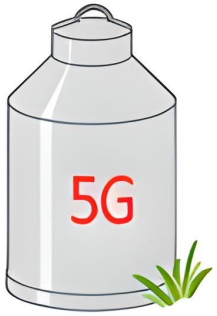
Martin Böhm and Diederich Wermser

Funded by 5G Smart Country (BMDV, FKZ: 45FGU117)



Smart Country

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Overview

- Context: Research Project *5G Smart Country*
- Problems of Forest Sensor Networks
- Synchronizing Transmission Intervals
- Implementation of Scheduled Gateway Operation
- Evaluation and Future Work

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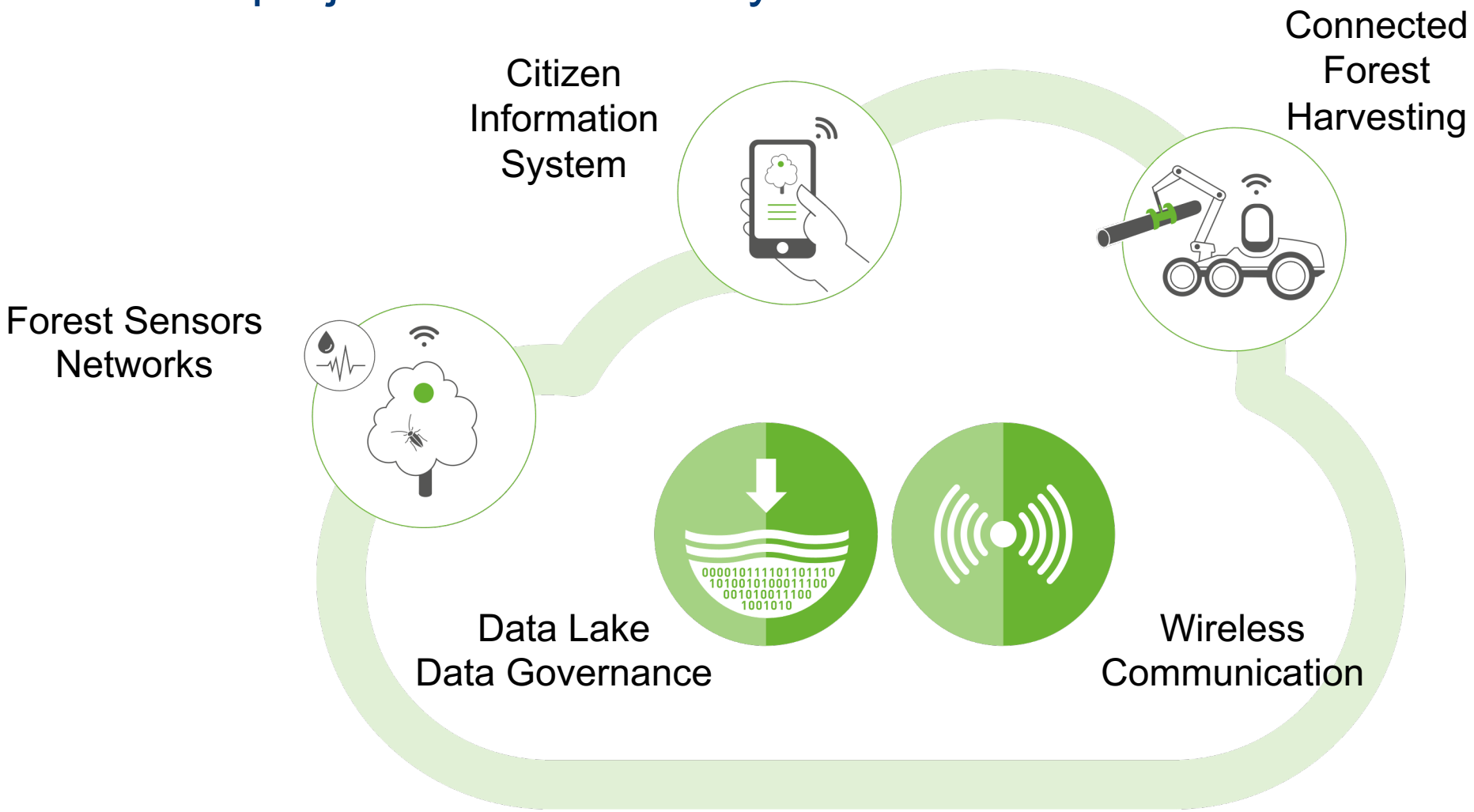
Overview Subproject Smart Forestry



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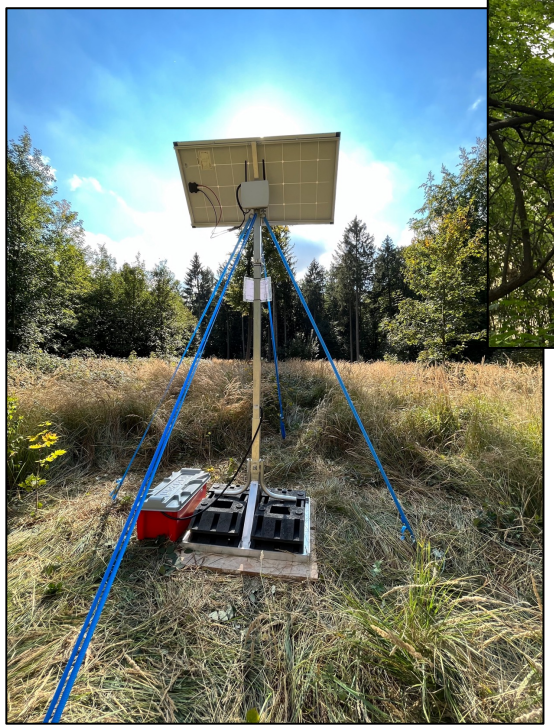
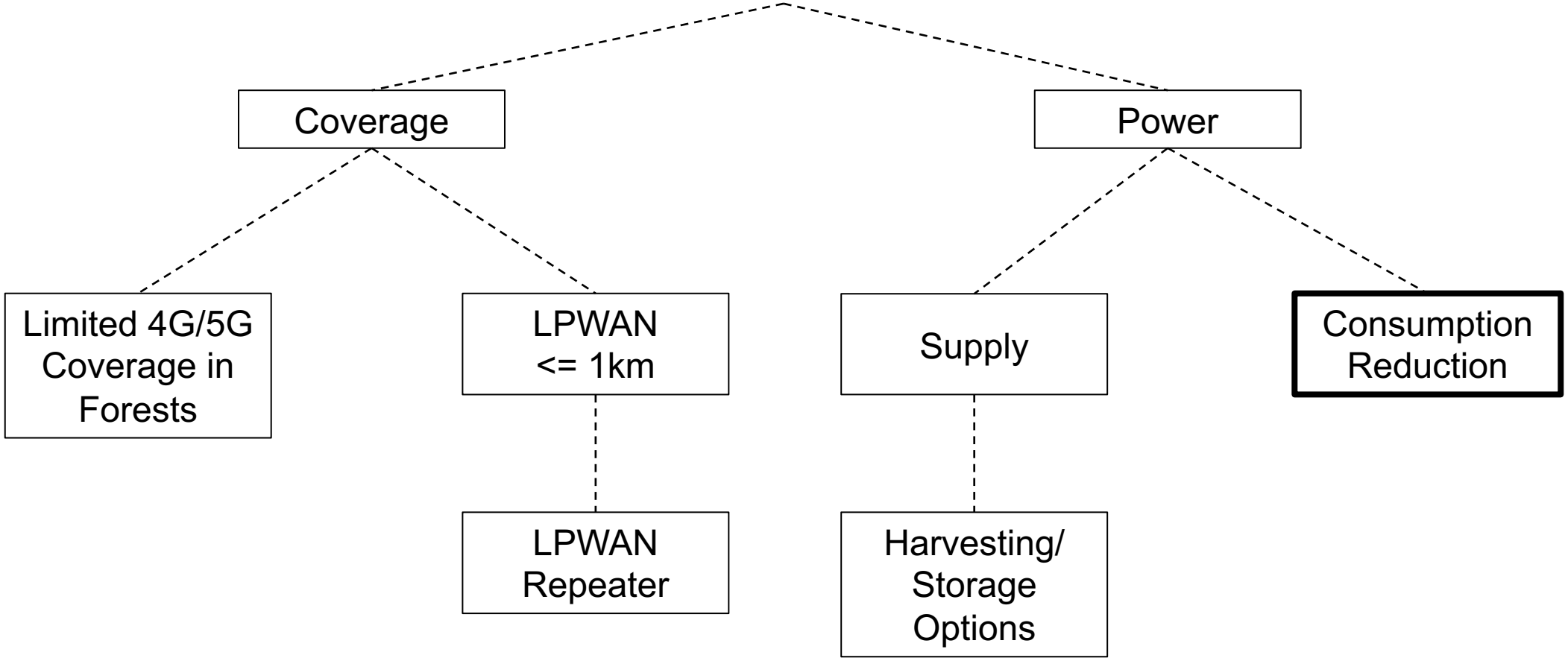
Forest Health Monitoring



Problems of
Forests Sensor Networks



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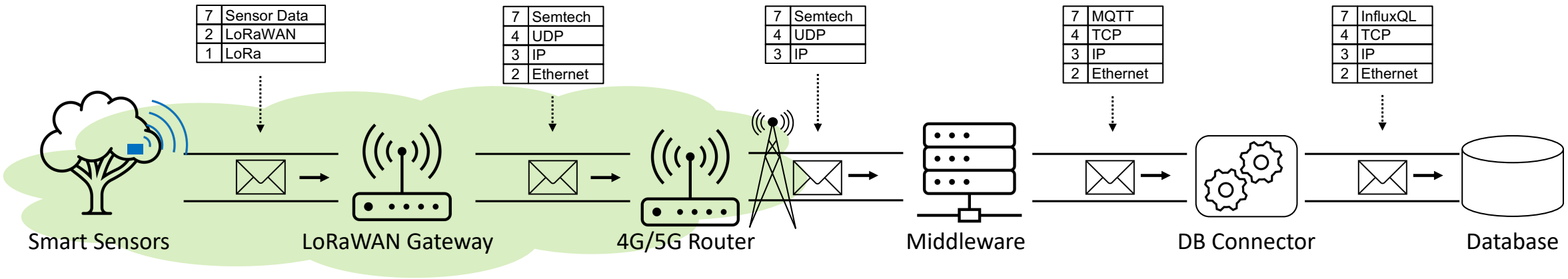
From Sensor to Database

- Exemplified with LoRaWAN, Semtech UDP Packet Forwarder, MQTT and InfluxDB



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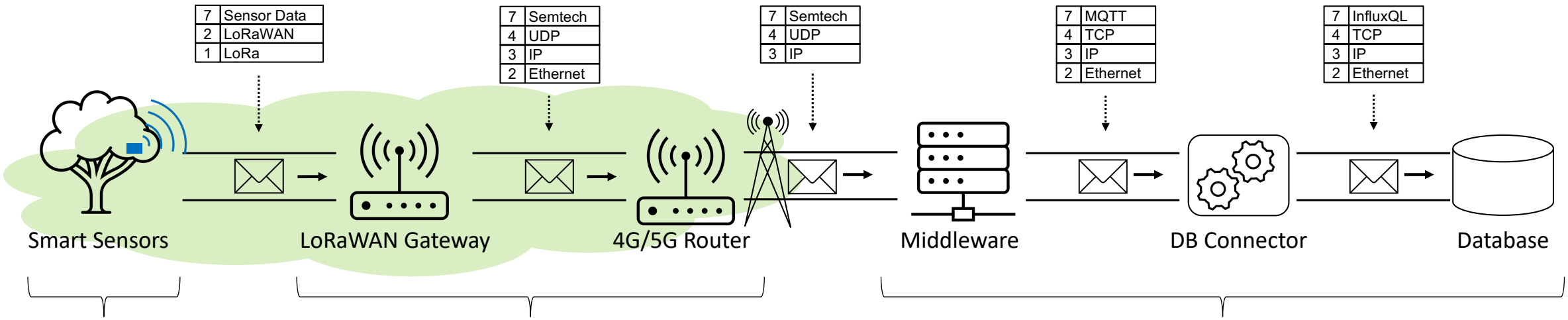
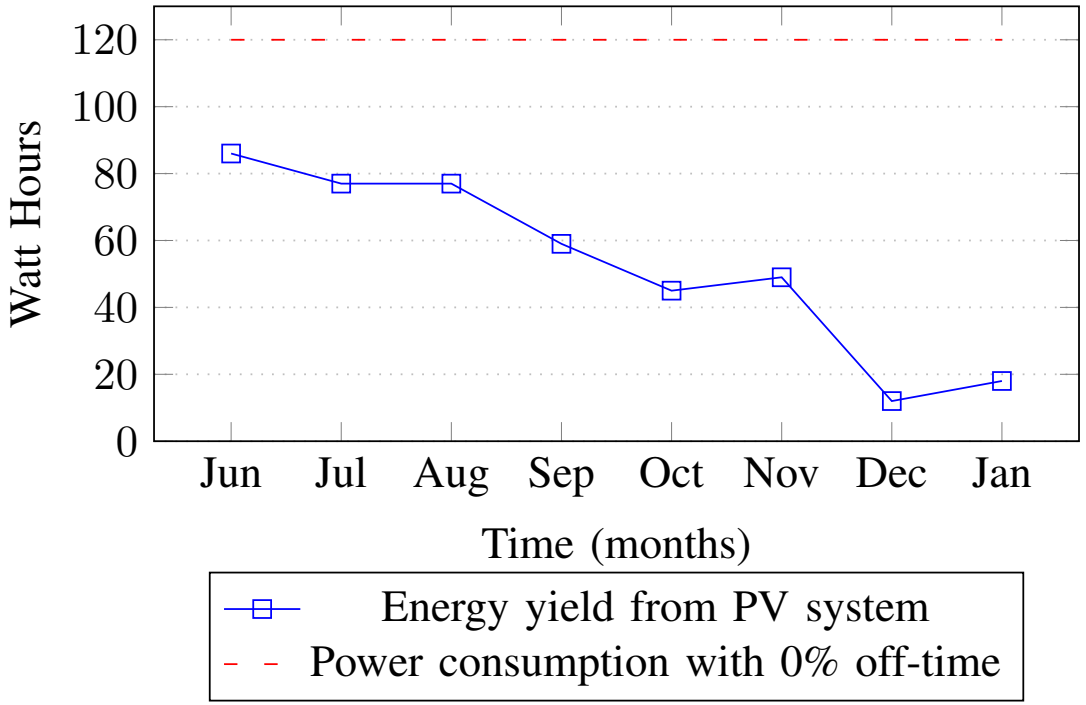


- Battery powered
- How long last batteries actually?

- Directly attached or combined as single device (LoRaWAN/4G/5G Gateway)
- Powered in the forest using energy harvesting options such as solar power with battery

Cloud applications

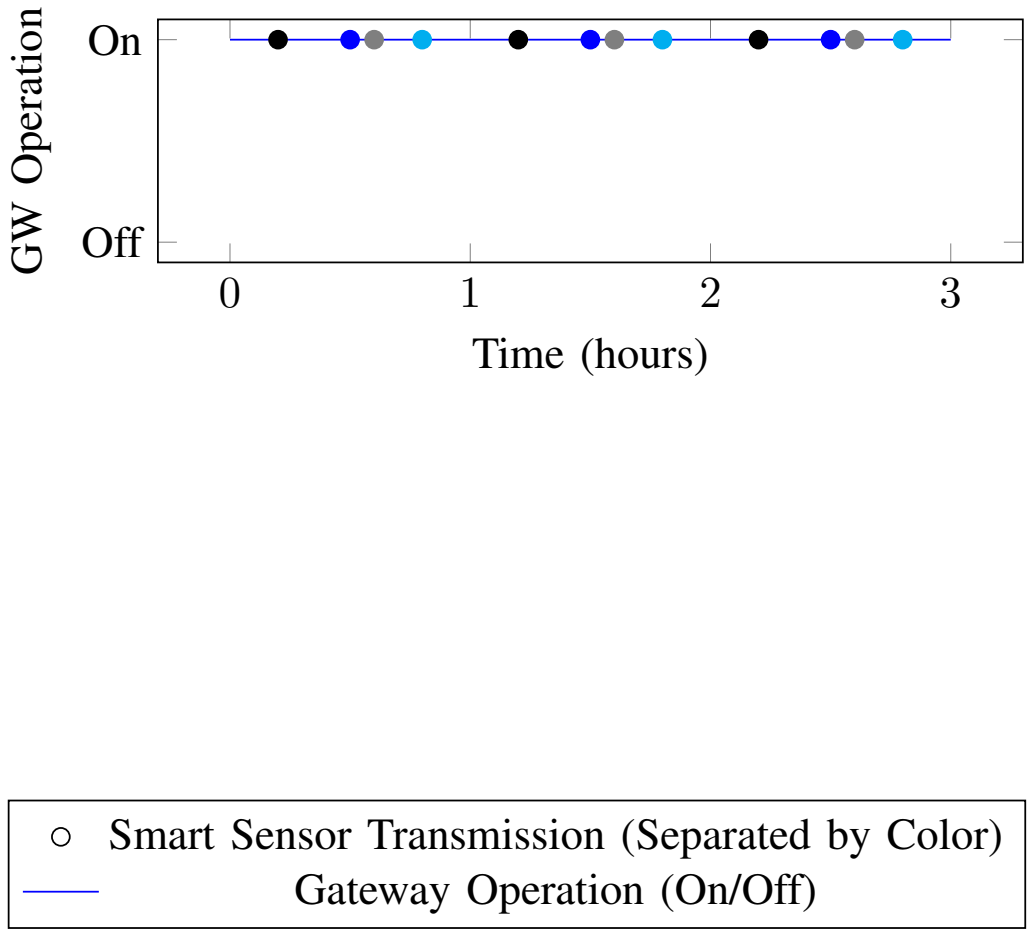
Energy Yield from PV System compared to Power Consumption of LoRaWAN Gateway/LTE Equipment



Average watt-hours actually generated and theoretically consumed per day, measured between June 2022 and January 2023.

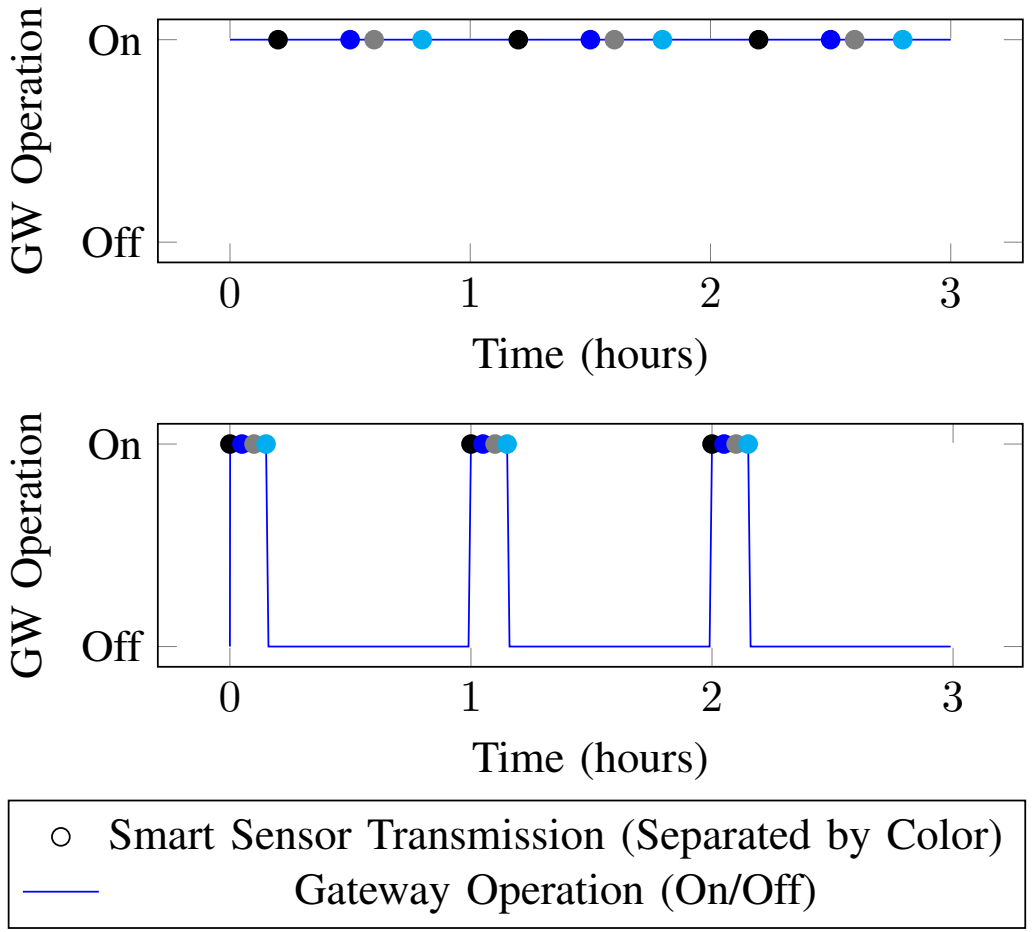
LoRaWAN Sensor Transmission Times

- Operational Phase
  - Random distribution of transmission times

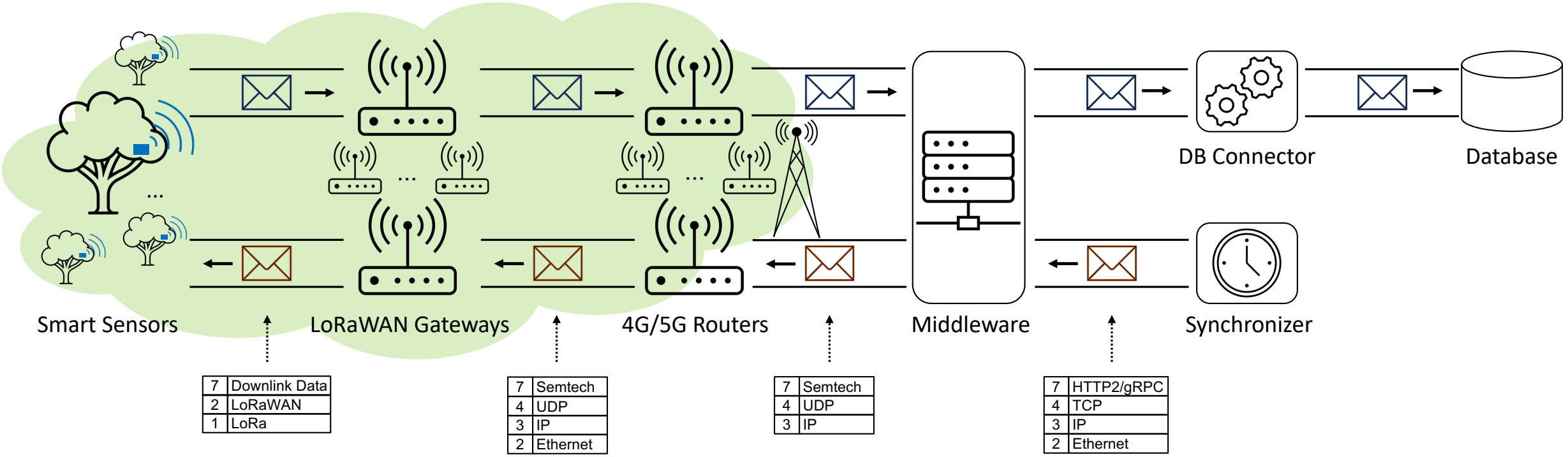


LoRaWAN Sensor Transmission Times

- Operational Phase
  - Random distribution of transmission times
  - Synchronized Operation
    - Gateway is activated and deactivated interval-based
    - Smart sensor transmission is synchronized to on-times
  - Gateway is completely switched off
    - E.g., 55 minutes off-time; 5 minutes on-time

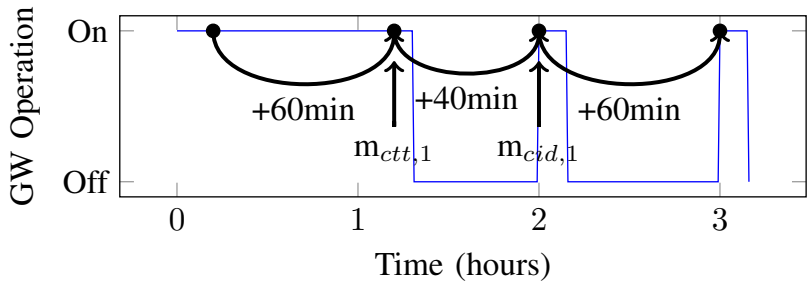


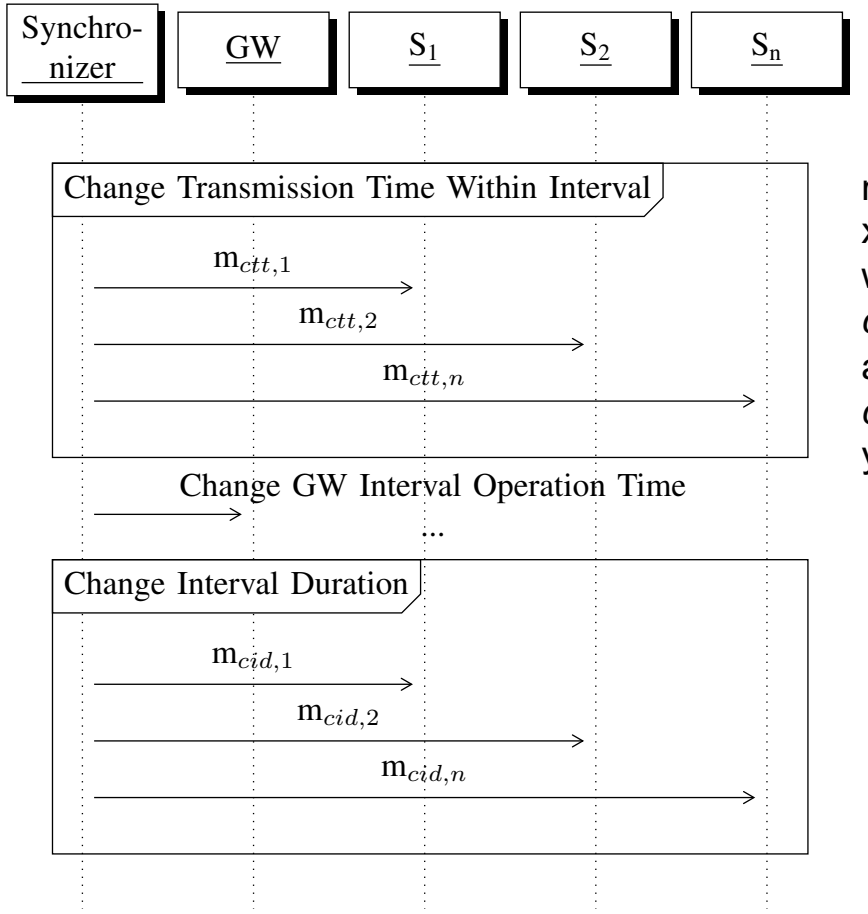
Centralized Synchronizer for widespread Sensor Networks with multiple Gateways



Synchronizing Transmission Intervals for COTS Smart Sensors

- COTS smart sensors usually provide changing the transmission interval using downlink messages
- Synchronization Phase:
  1. Change transmission time within interval of each smart sensor
  2. Change gateway operation time
  3. Change transmission time to interval duration

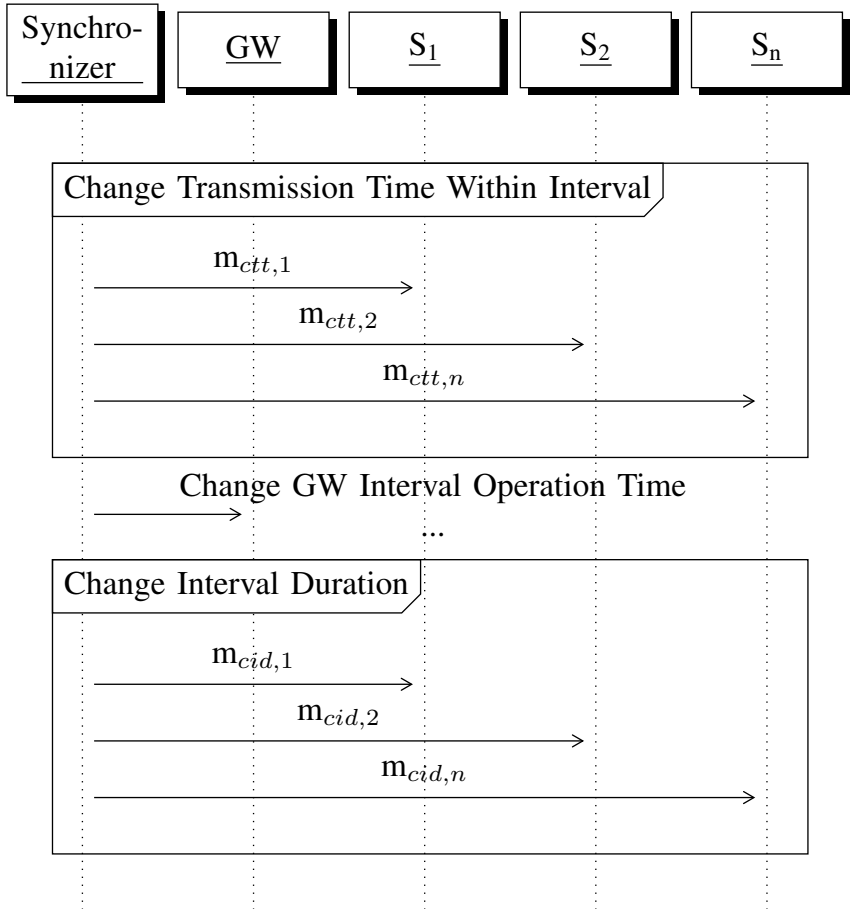




$m_{x,y}$ {m is the message;
x is the message type identifier where
ctt = change transmission time and
cid = change interval duration;
y is the smart sensor identifier}

Synchronizing Transmission Intervals for COTS Smart Sensors

- Distribute smart sensor transmission times to prevent interference
  - Especially with high density of sensors
- Length of the active window (on-time)
  - Bootup time LoRaWAN gateway + cellular communication
  - Distribution window of sensor transmissions
  - Transmission jitter



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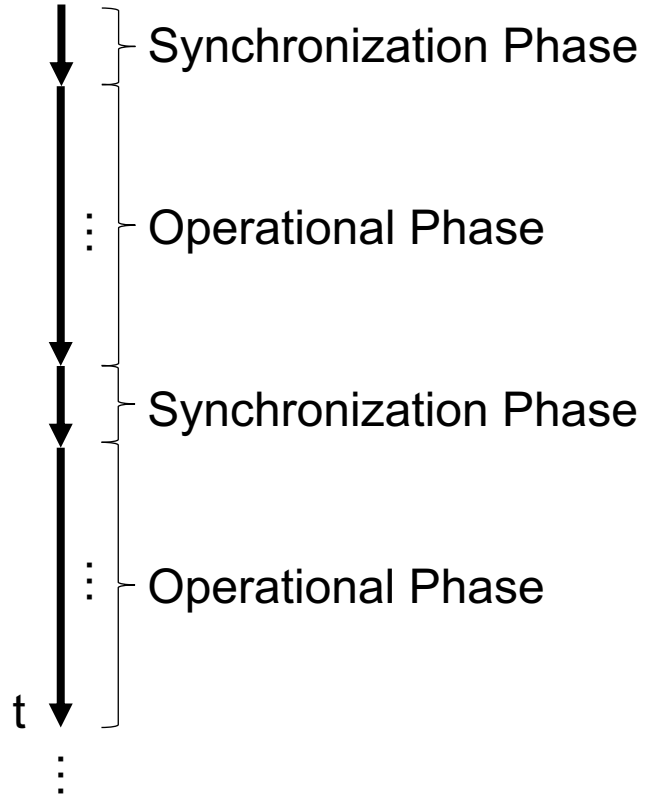
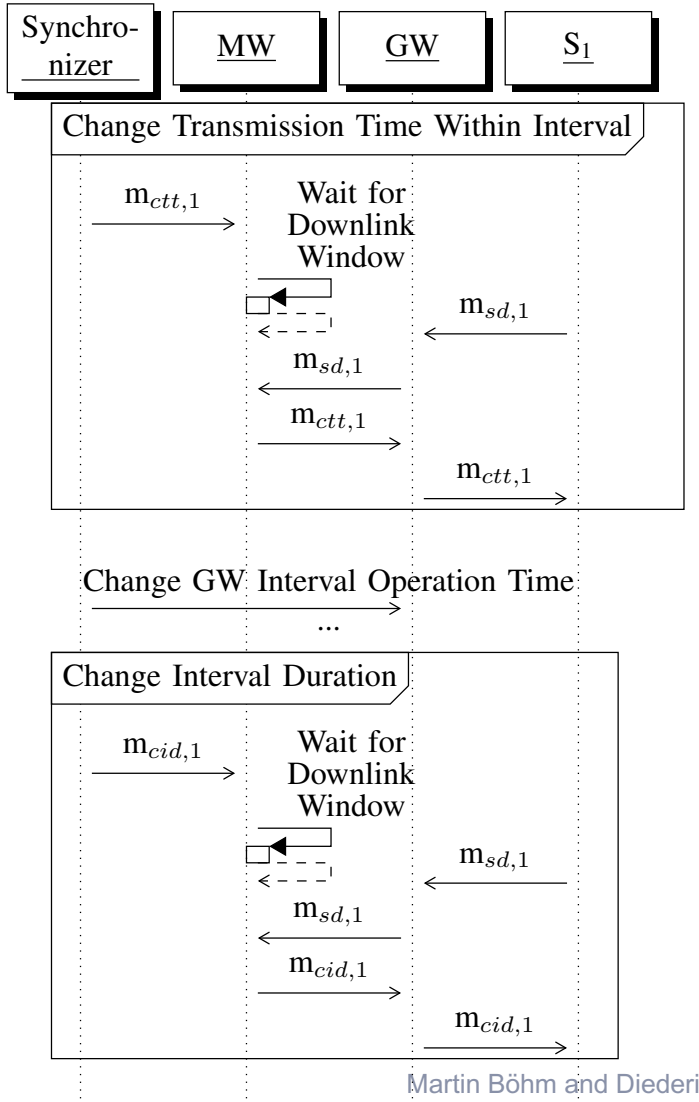
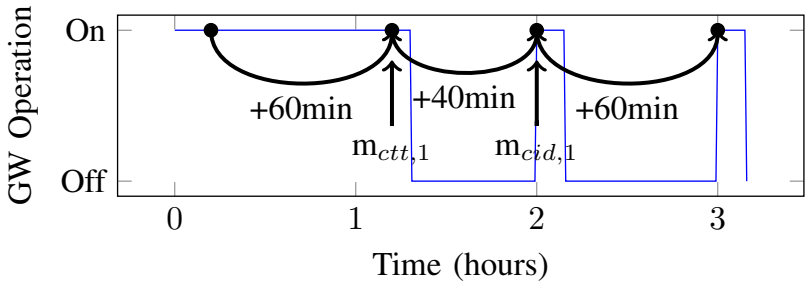
Synchronizing Transmission Intervals for COTS Smart Sensors

- Repeat synchronization phase in adequate time intervals
  - Transmission jitter and clock drift in smart sensors
  - Each synchronization phase consumes additional power of end-devices
  - Maximum possible time interval, given timing imprecision of COTS smart sensors?



Transmission of Synchronization Messages using LoRaWAN Downlink Mechanisms

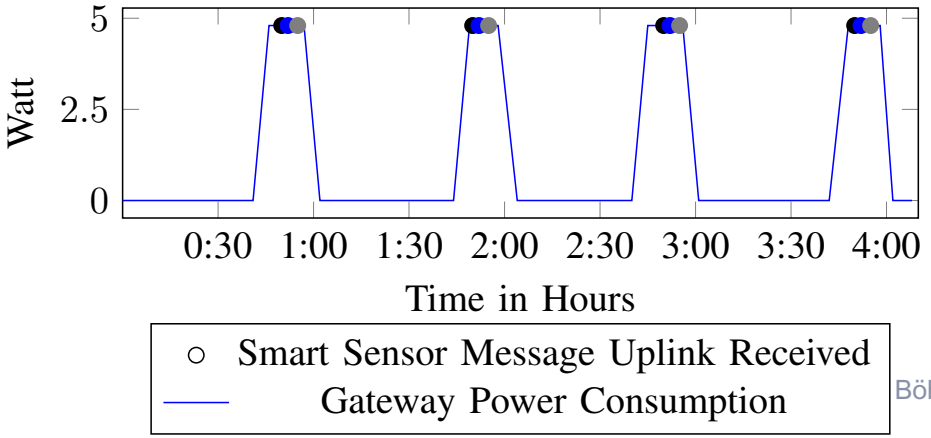


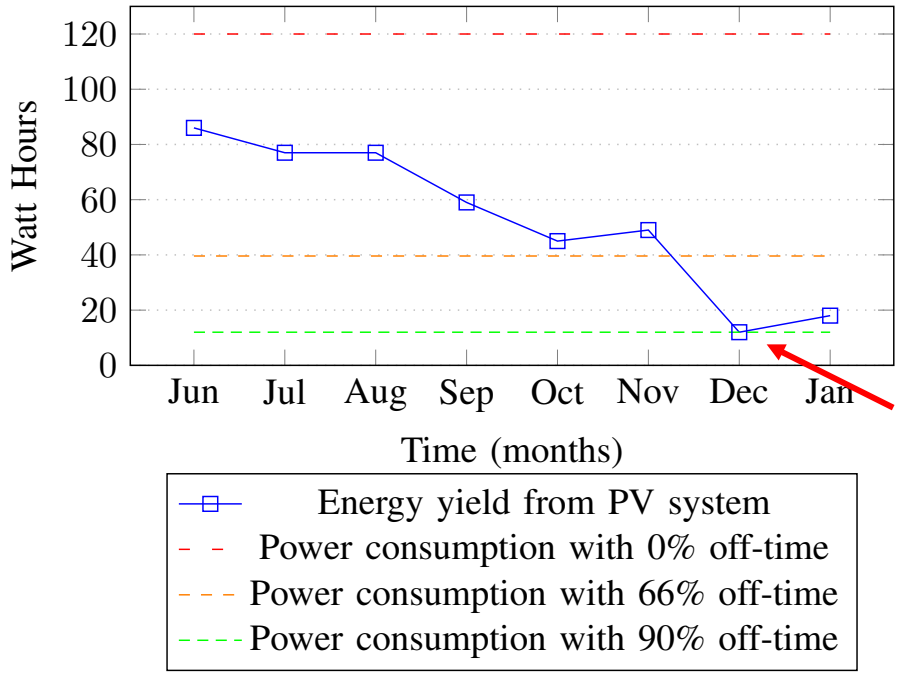


$m_{x,y}$ {m is the message;
x is the message type identifier where
ctt = change transmission time,
sd = sensor data, and
cid = change interval duration;
y is the smart sensor identifier}

Implementation of Scheduled Gateway Operation

- Experimental Setup mounted on a tree in a forest
  - 3x 30W, 60Ah battery
  - LoRaWAN/LTE Outdoor Gateway (Dragino DLOS8N)
  - Entire setup approx. consumes 4.8W
  - Charge controller is monitored at 5-minute interval
  - 2-3 minutes for the gateway to become active in Chirpstack (middleware) after powered on
- Interval switch
  - 15 minutes on-time, 45 minutes off-time (75% off-time)
  - Multiple synchronized COTS LoRaWAN sensors





Evaluation

- Variations in smart sensor transmission have been observed
  - Accuracy to the second to plus or minus several minutes
  - → Chose gateway operation window not too small
  - → Repeat synchronization phase
- Solution well-suited for periodical data collection
  - Not optimal for threshold-based sensors such as alarms e.g., wildfire monitoring
- Transmission interval can be reduced or increased based on amount of energy yielded

Summary and Future Work

- Average power consumption has been significantly further reduced
- Scheduled gateway operation and synchronized smart sensor transmission has been successfully implemented
- Compatible with existing COTS LoRaWAN gateways and smart sensors
  - No modification to (closed) firmware of the devices needed
- Distribute transmission intervals within on-time to prevent collisions

- Investigate impact of interval-based operation for …
  - large (forest) area monitoring with multiple gateways
  - range extenders such as LoRaWAN Relays