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Bidirectional integration of a KNX equipped energy efficiency test bench building with the OGC SensorThings standard

KNX Scientific Conference 2023, 09/10/2023

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Wilhemshaven/Oldenburg/Elsfleth

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Agenda

- Presentation title explained – what does it even mean?
- Motivation
- Context – research project “Wärmewende Nordwest”
- The energy efficiency test bench building
- Research objectives
- Data Lake
- OGC SensorThings standard
- Tasking and MQTT
- Connection via Gira X1 and RevPi
- First results
- Conclusions and outlook

What this talk is about

“Bidirectional integration of a KNX equipped **energy efficiency test bench building** with the OGC SensorThings standard”

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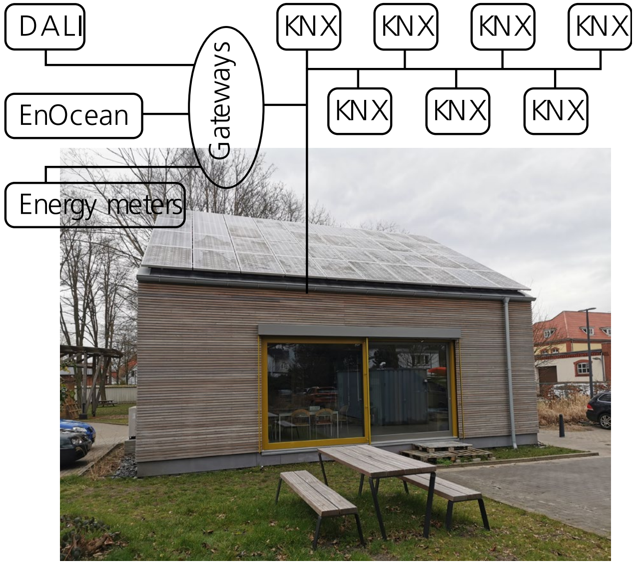

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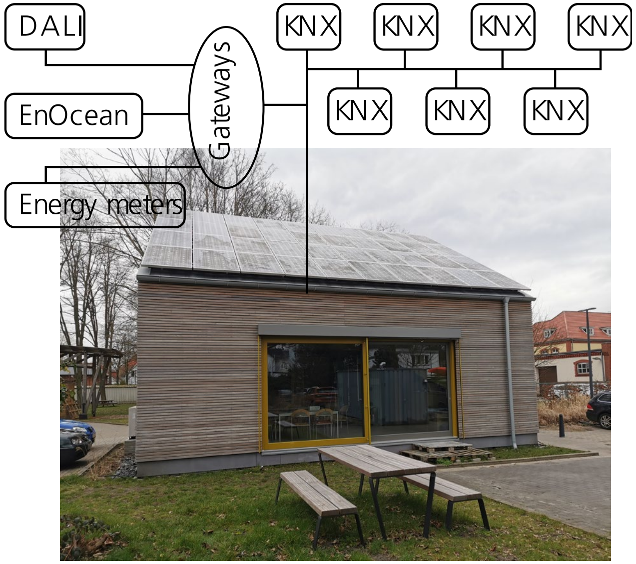

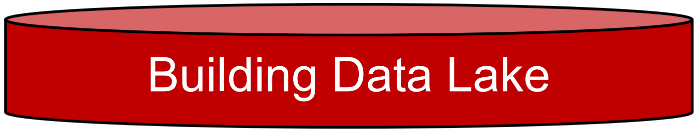

“a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems” [3]

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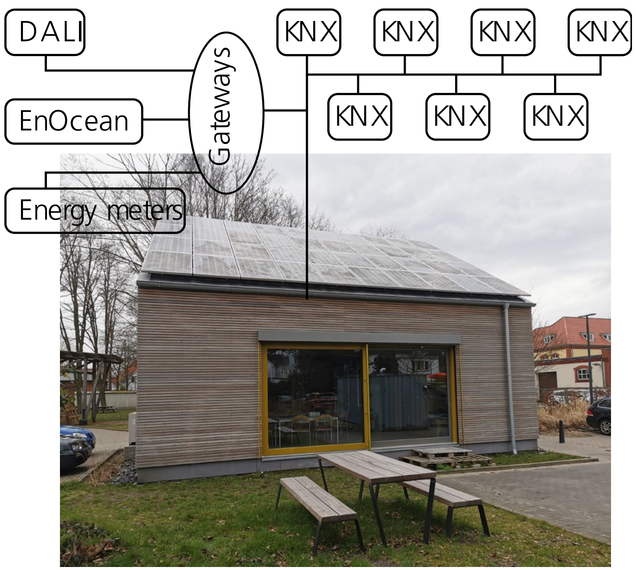
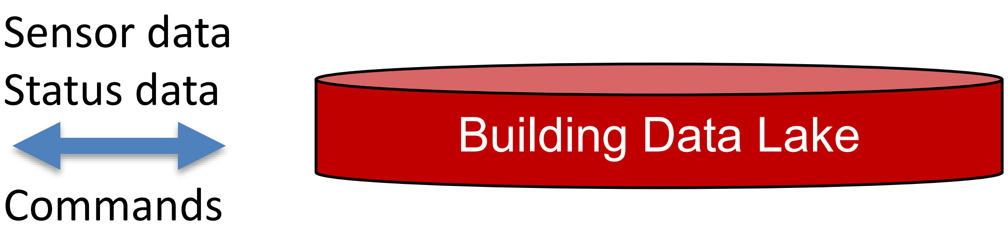




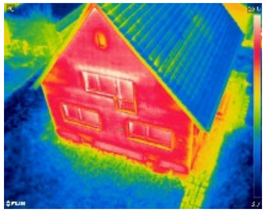
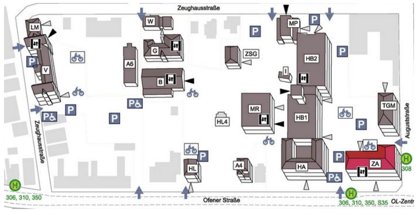
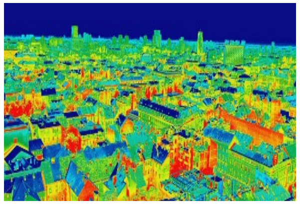
"a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems" [3]

Motivation

- Scarcity of resources, climate impact, and rising costs call for energy efficiency
- Overall goal of our project „Wärmewende Nordwest“: leveraging digitalization for the „heat transition“ – i.e. decarbonization and efficiency optimization of the heat supply on building, campus, quarter and commune scale
- Building scale: energy efficiency, human well-being, and building structure health are – sometimes competing – objectives
- Building and campus scale: connect distributed sensors and controllable building technology devices of several buildings with a reliable and organized infrastructure.
- Need for integration of a the KNX system into the infrastructure

Digitalization for the heat transition in northwestern Germany [1]

An interdisciplinary research project running 5 years (11/2020 – 11/2025)

Building scale	Campus scale	Quarter scale	Commune scale
			

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DLR Deutsches Zentrum für Luft- und Raumfahrt
Institut für Vernetzte Energiesysteme

BFE Bundestechnologiezentrum für Elektro- und Informationstechnik

Carl von Ossietzky universität OLDENBURG

JADE HOCHSCHULE Wilhelmshaven Oldenburg Elsfleth

OLEC Energie bewegt den Nordwesten

Universität Bremen

BTC

TAS SICHERHEITS- UND KOMMUNIKATIONSTECHNIK

WDY worldiety

HSB Hochschule Bremen City University of Applied Sciences

GSG Bauen & Wohnen in und um Oldenburg

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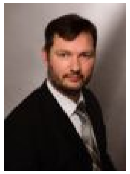
Wärmewende Nordwest

- Team „Digital experimental campus – building physics“ at the Jade University of applied science:

Scientific lead:

- Prof. Dr. Sascha Koch (Computer Science, data analysis)

- Prof. Dr.-Ing. Jan Middelberg (Building physics)



- Dr. Pavel Paulau (Data science)

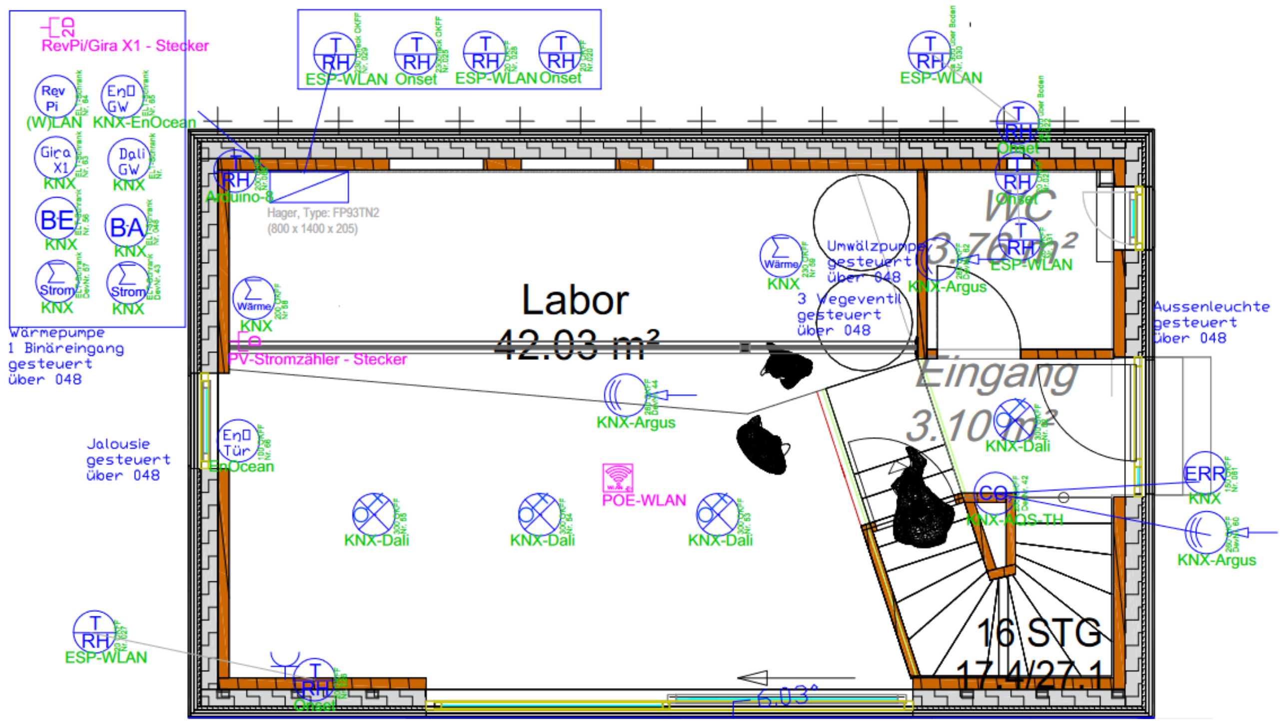
- Johannes Hurka (Building pysics)

Energy efficiency test bench building

- Purposes:
  - Teaching and experiments with Construction and Architecture students
  - Public information events
  - Testing of optimized control strategies
- Photovoltaic roof
- Air-water heat pump
- Storage tanks for heated water
- Controlled ventilation with heat recovery

Energy efficiency test bench building

- Main room on ground floor
- Small bathroom with toilet and shower
- Open gallery and small kitchen on upper level
- Other research: long-term evaluation of an insulation material made from „cattail“



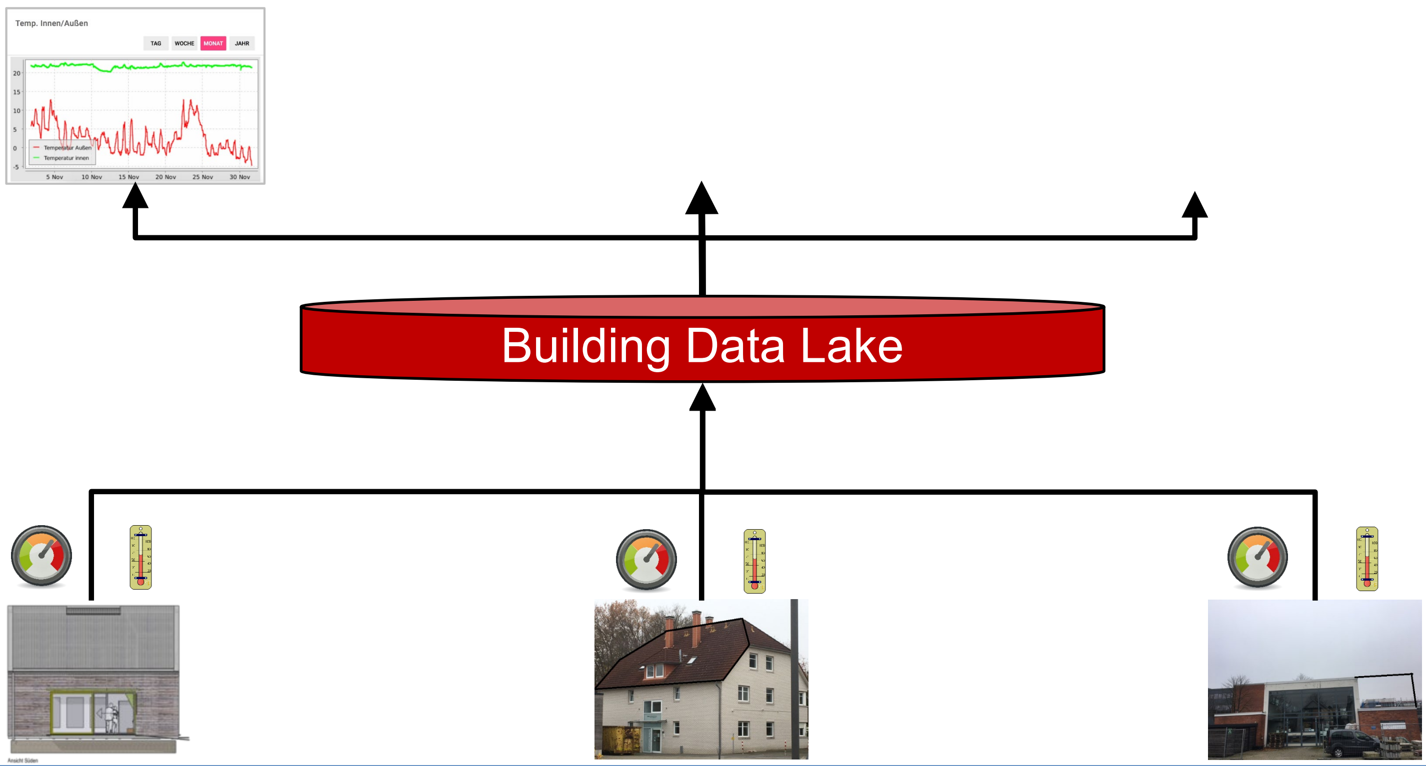
Energy efficiency test bench building

KNX devices in the building:

- Presence and light sensors
- Temperature, humidity and CO_2 sensors
- Interfaces for electricity meters
- Interfaces for heat flow meters
- Binary input sensors
- EnOcean gateway
- Ventilation gateway
- Binary and shading actuators
- Glass push button panels
- GPS weather station
- DALI gateway
- X1 server (image source: www.gira.com)

Research objectives

- Long-term monitoring and building data stories



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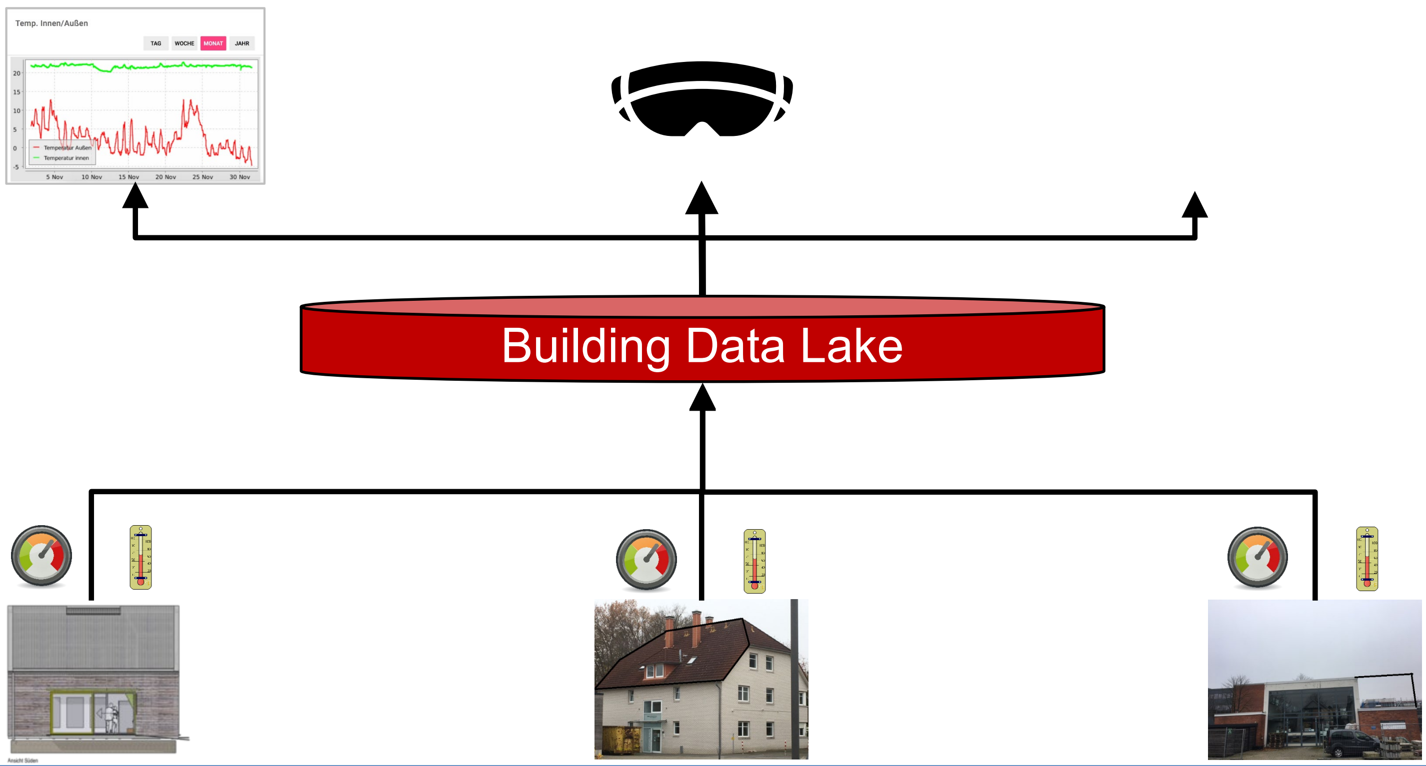
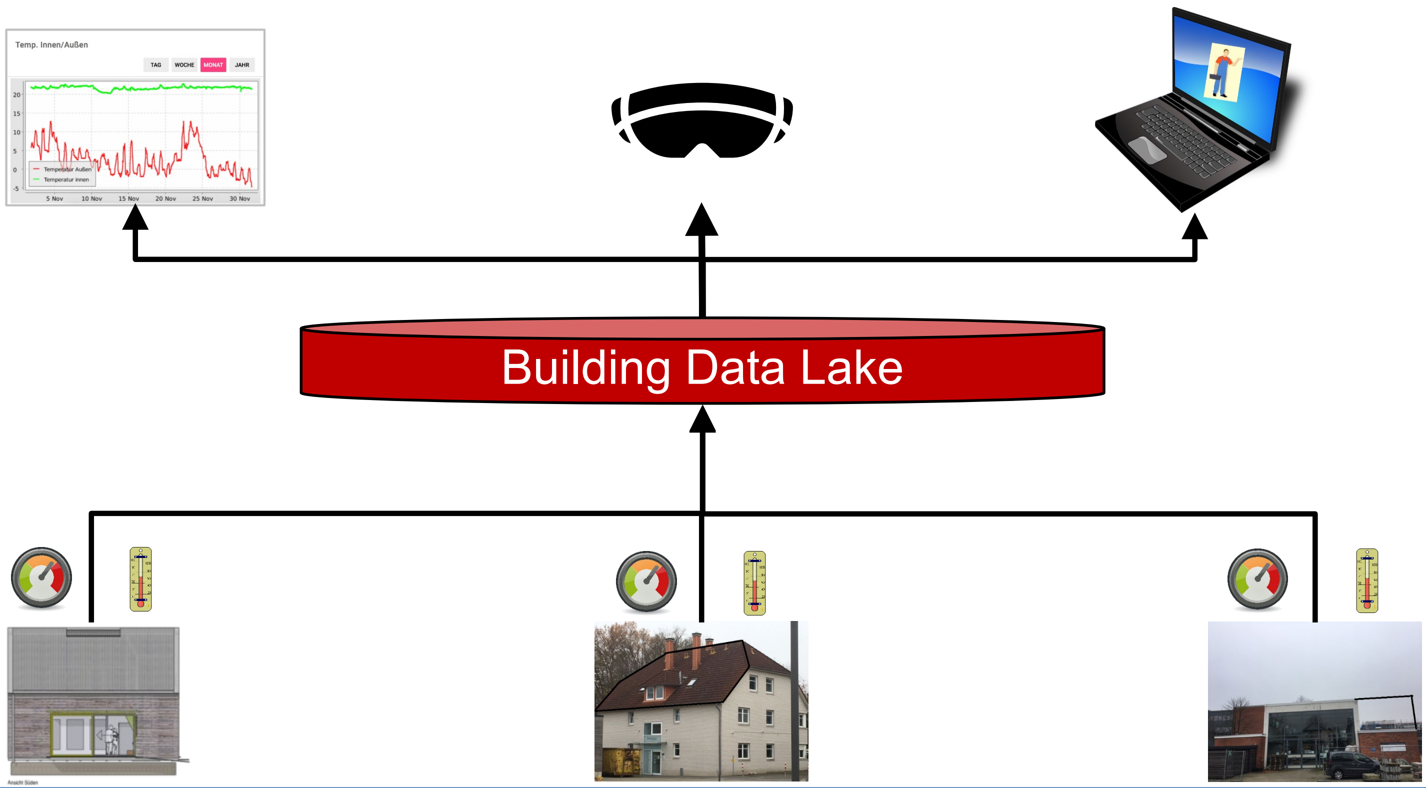
Research objectives

- Long-term monitoring and building data stories
- Education formats for sustainable development



Research objectives

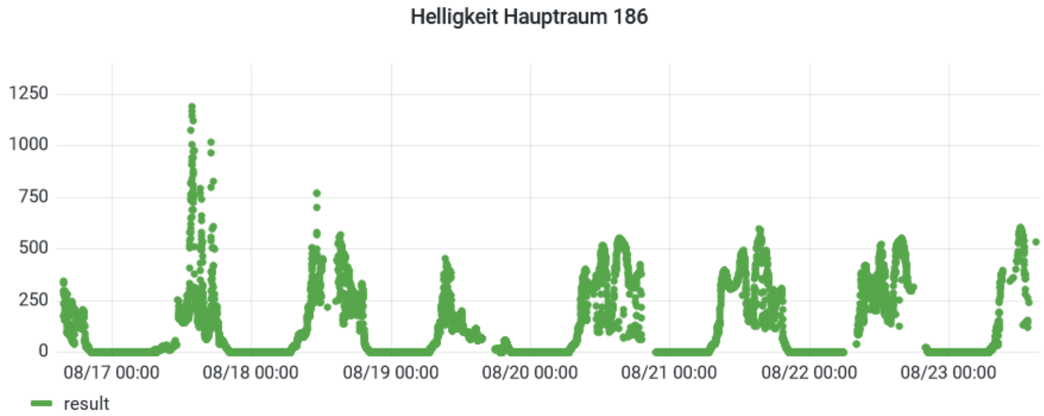
- Long-term monitoring and building data stories
- Education formats for sustainable development
- Digital janitor



Research objectives

Long-term monitoring and building data stories:

- Long term monitoring of sensor data:
  - Temperature
  - Relative humidity
  - CO_2 concentration
  - PV energy production
  - Energy consumption
  - Weather
  - Occupancy
- and status information of the systems



- Visualization dashboards; curated data sets significant for special phenomena

- Demand: structured storage of and easy access to many time series

Research objectives

Education formats for sustainable development:

- Similar to building data stories
- Data subsets typical of certain situations or concepts will be prepared
- For immersive experience in a 3-dimensional virtual representation of the energy efficiency test bench building

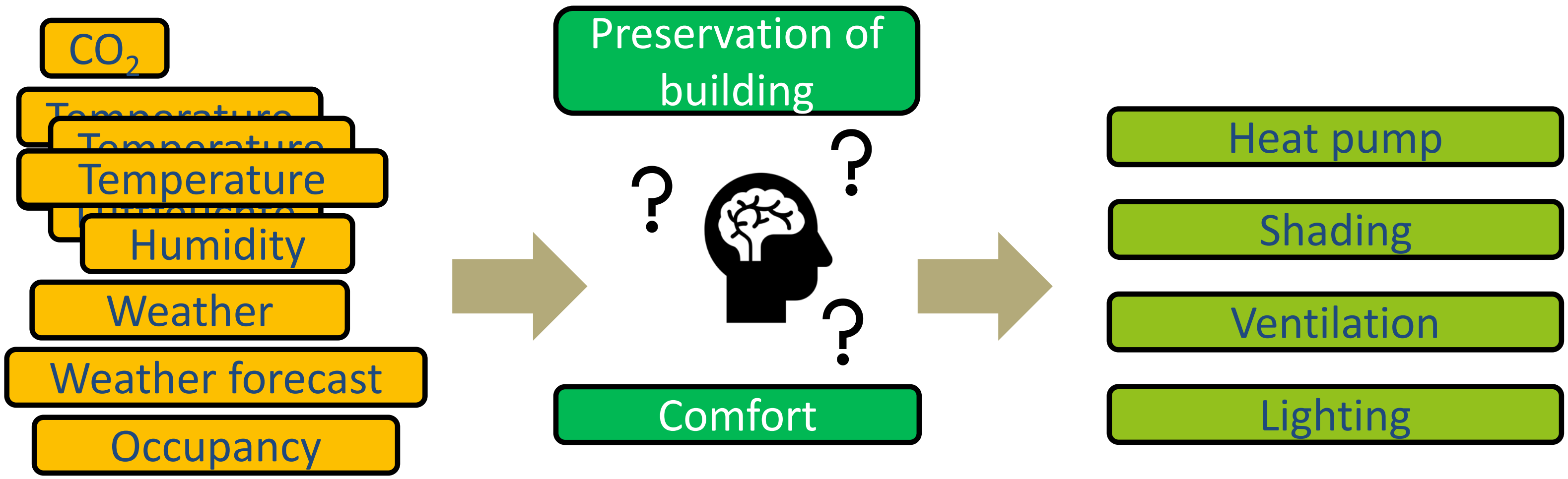
- This will enable students, professionals, or interested citizens to explore the situation in their own pace and perspective.

- Demand: structured storage of and easy access to many timeseries

Research objectives

Digital janitor:

- Machine learning approach (reinforcement learning)
- Optimized control of building technology systems to achieve better efficiency, comfort, and “health” of the buildings (c.f. [2] for an example)



- Demand: structured storage of and easy access to many timeseries
- And: structured control interface for software solutions to building technology components

Data lake

A central data storage with versatile reading and writing interfaces

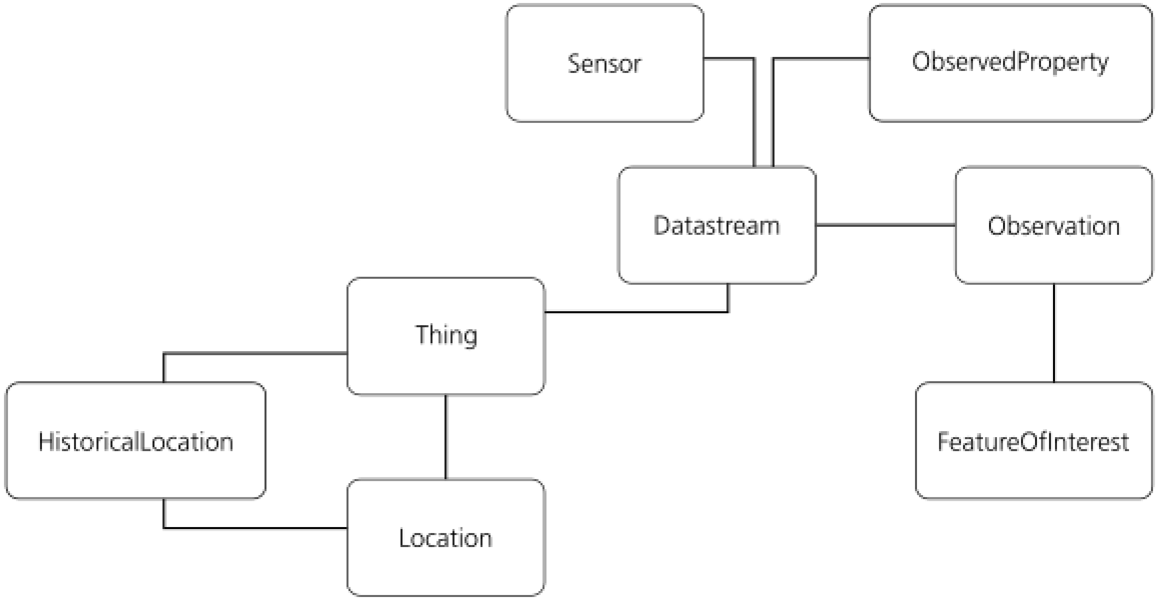
Requirements:

- As much documentation within the system as possible – organization of data as part of the documentation
- Interface for accessing, finding, and filtering of data – manually and by machine
- Each data point has to be identifiable in time and space domains
- Easy to extract time series, spatially or thematically connected data sets
- Good performance in real-time mode – many data nodes sending values all the time, clients need access to data
- Data archive

OGC SensorThings API

Data structuring concept for IoT device data [3]

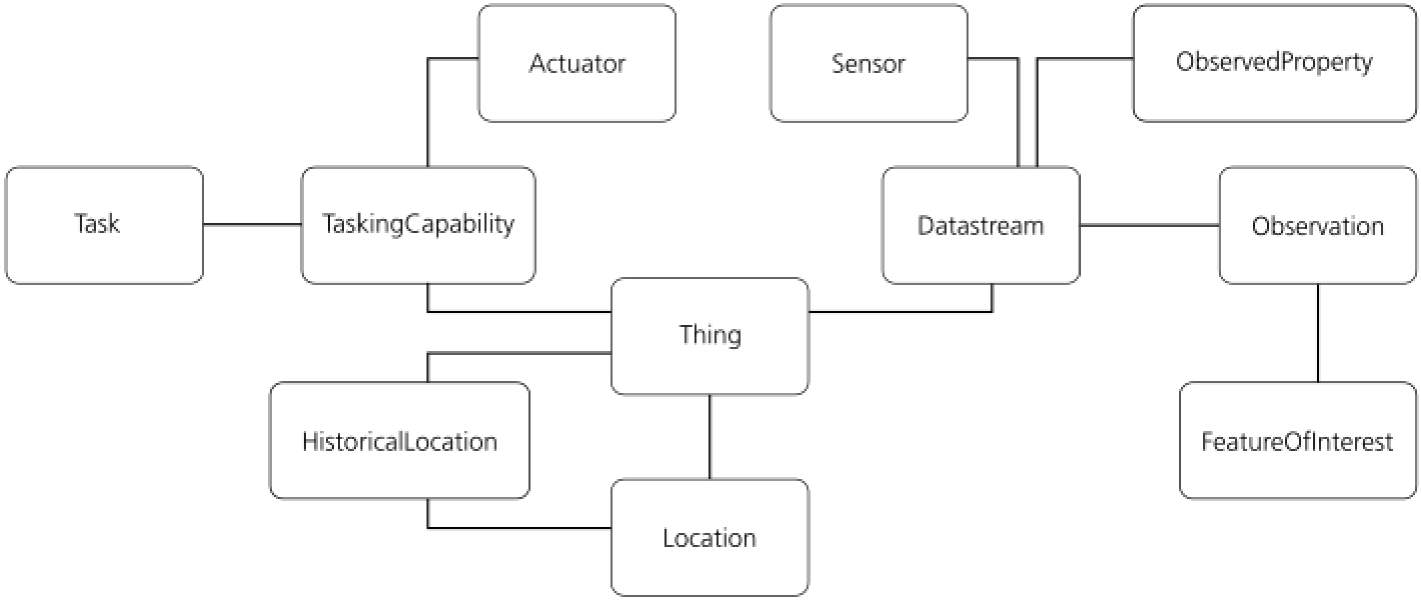
- Centered around “Things”
- HTTP access in JSON format
- MQTT interface



Tasking

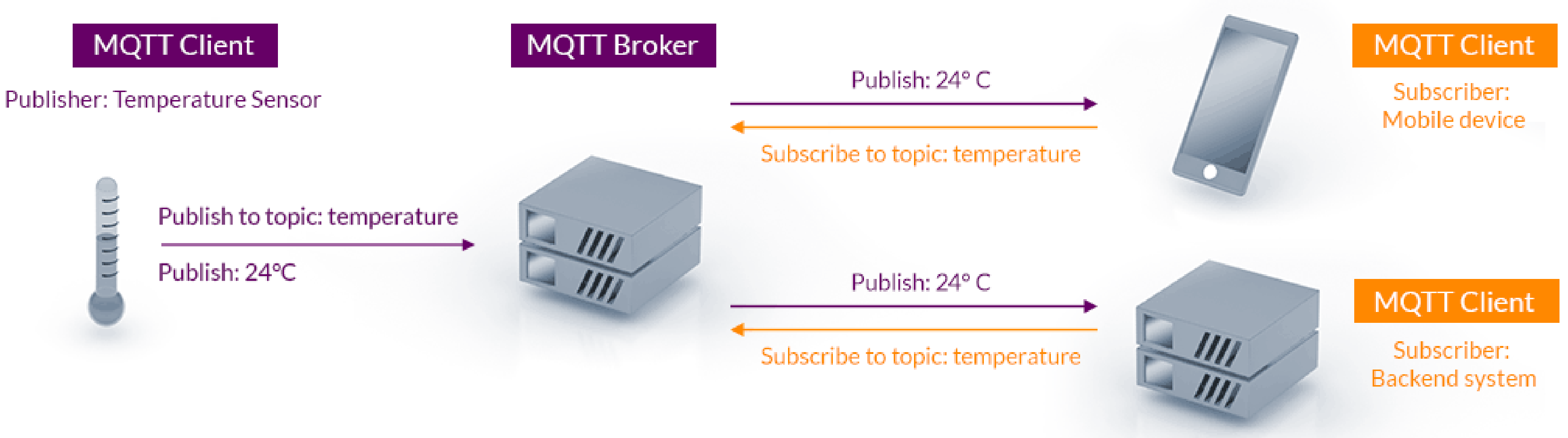
Data structuring concept for IoT device data [3]

- Centered around "Things"
- HTTP access in JSON format
- MQTT interface
- Part 2 introduces "Tasking" – for parameterizing devices [4]



MQTT

- Lightweight bi-directional messaging
- Ideal for small clients
- Works with clients that are not always online
- Good scalability



(image source: mqtt.org)

FROST server

- We use the FROST server implementation of the OGC SensorThings API [5]
- Open source software from Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB
- “Actuation” plugin provides the tasking part
- Basic authentication (user name / password)
- Running on docker
- Depending on PostgreSQL and postgis

- Design decision:
  - Unique names for sensors and actuators, for example

    Nr.042.EEP.EG.innenluft08.KNX-AQS-TH and

    Nr.042.EEP.EG.innenluft08.KNX-AQS-TH.T for temperature;

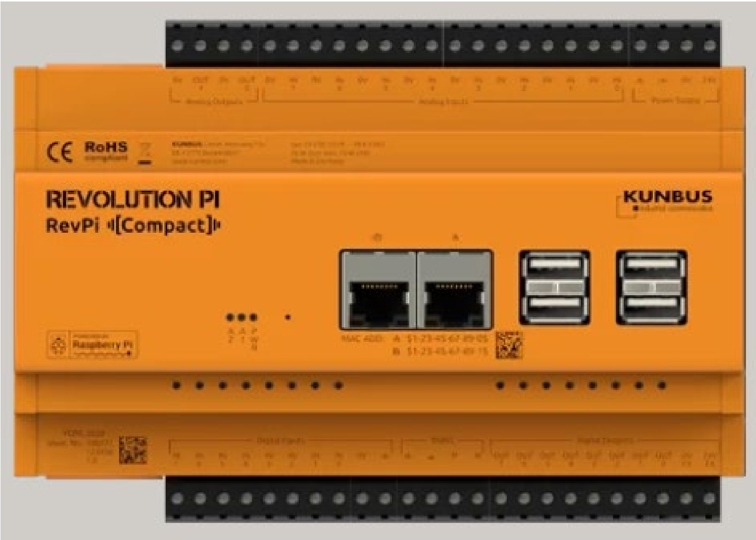
    Nr.042.EEP.EG.innenluft08.KNX-AQS-TH.H for humidity;

    Nr.042.EEP.EG.innenluft08.KNX-AQS-TH.CO2 and CO_2 datastreams

Connection via Gira X1 and RevPi

- Problem: there is no direct connection between KNX bus and FROST server
- Idea: making use of the already integrated Gira X1 visualization server and the Gira IoT REST API [6]
- For each KNX data source, a status display function with the unique name is created and connected to the group address and internally gets an uid.
- Both X1 and FROST speak JSON over HTTP(S), but the “dialects” are not compatible

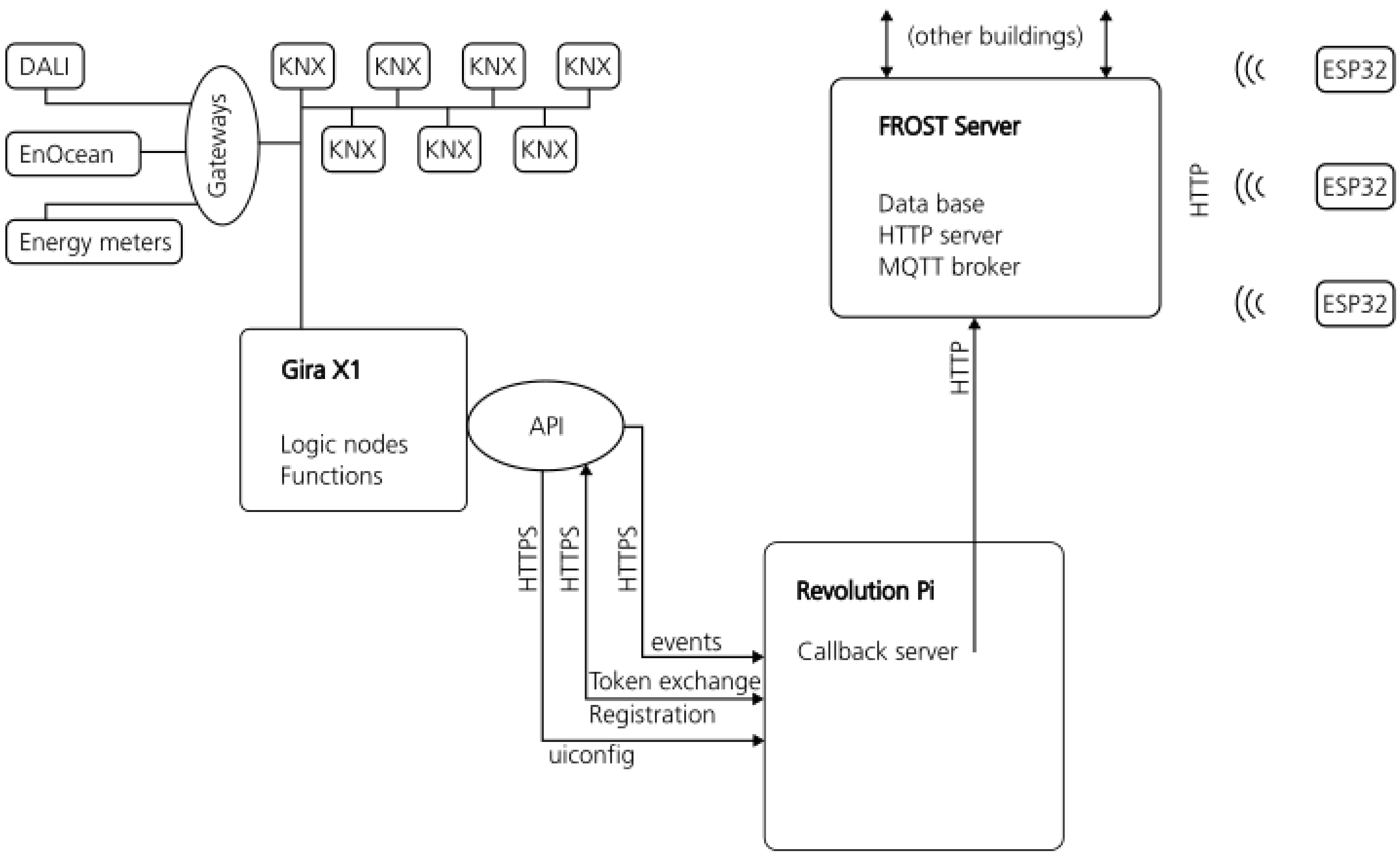
- Another computing device is needed for translation:
- Revolution Pi compact (based on the Raspberry Pi computing module) for top-hat rail installation



(image source: revolutionpi.de)

Connection via Gira X1 and RevPi

Hardware and software architecture for sensing part:



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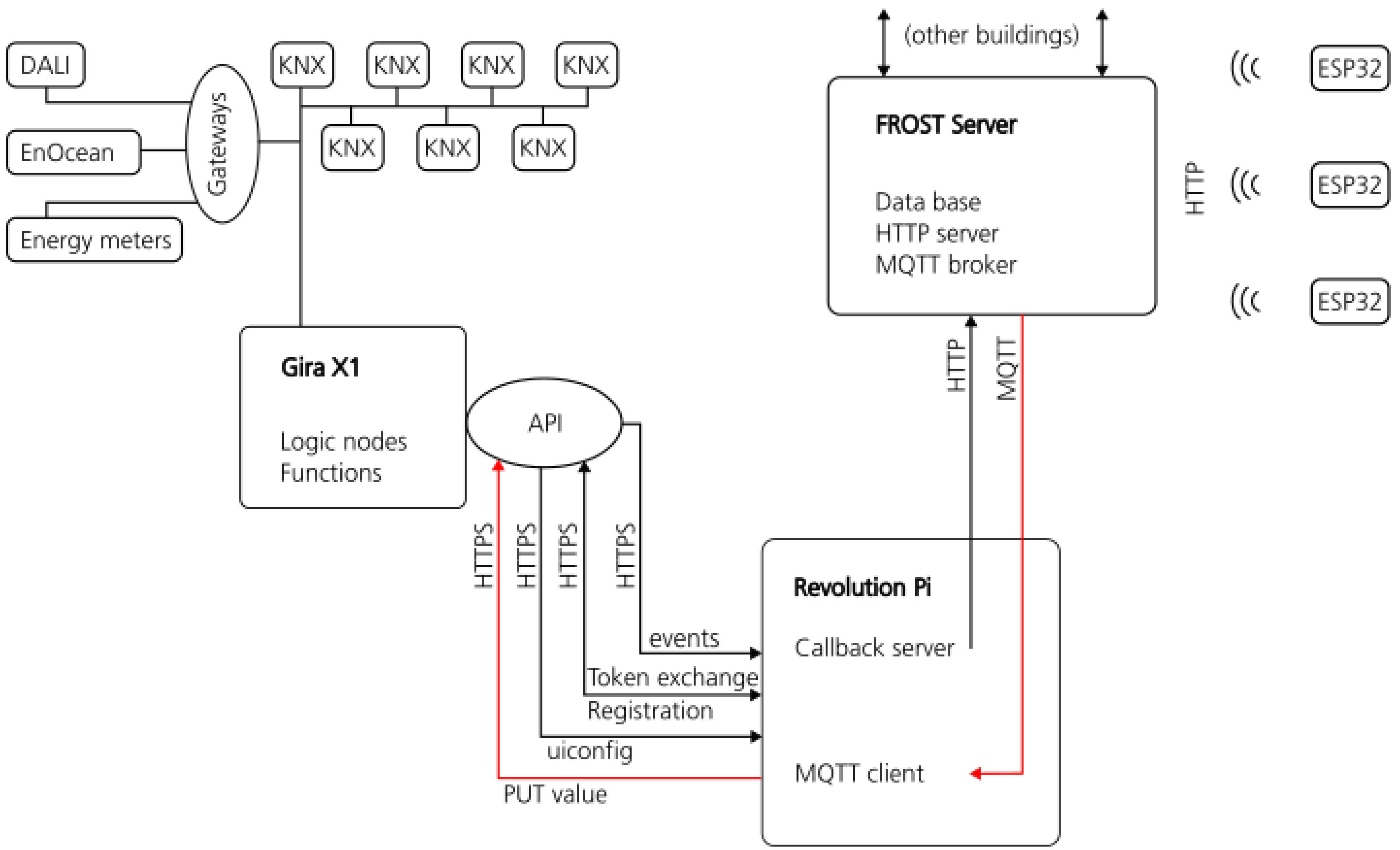
Connection via Gira X1 and RevPi

Python software for sensing part running on the Revolution Pi :

- connects to the X1 with user name and password to identify itself as an API client and to receive a communication token.
- requests the latest “uiconfig.xml”, containing function names and uids
- parses the uiconfig and saves uid / name pairs in a Python dictionary.
- connects to FROST server and for each name in the dictionary retrieves the ID of the belonging Datastream.
- registers itself as a “valueCallback” server for the X1.
  Subsequently, X1 sends a JSON message to the callback server whenever it receives a KNX telegram. The message contains an “event” block consisting of a “uid” and a “value” field.
- uses the dictionaries to match the uid to the name, and the name to the Datastream ID, for each incoming message. The “value” is then embedded into an Observation message, which is sent to the specific Datastream of the FROST server.

Hardware and software architecture extended for tasking part:



Connection via Gira X1 and RevPi

Another Python software running on the Revolution Pi – for tasking:

- connects to the X1 with user name and password to identify itself as an API client and to receive a communication token.
- requests the latest "uiconfig.xml", containing function names and uids
- parses the uiconfig and saves **name / uid** pairs in a Python dictionary.
- registers itself as a client with the FROST MQTT broker.
- subscribes to each MQTT "TaskingCapability" topic defined in our settings files.
- parses each incoming MQTT message for the unique name of the "TaskingCapability" and matches this name with the corresponding function uid on X1, using the Python dictionary.
- generates a HTTPS PUT request to the X1, with the correct uid in the URL and the command value in the payload.

First results

Sensing part:

- Whenever there are several telegrams in fast succession, only one of the messages from X1 is completely received by the Revolution Pi.
- Problem occurs during the ssl handshake – message gets truncated
- Serious drawback, concerning multi-sensors and weather station

First results

Tasking part:

- More complex functions need several group addresses, but get only one uid.
- Command is bound to only one group address.
- Therefore, more functions are needed – which show up on the smartphone interface but won‘t work there.

User experience:

- Smartphone interface is cluttered with many functions
- „Name“ field of X1 configuration is the only place for unique names. But they don‘t even fit on the smartphone screen…

Conclusions and outlook

- Bidirectional data transfer works in principle.
- But the presented mechanism ist **not robust**.
- Dual use of X1: not optimal for data transfer and not optimal for user experience
- Need for an extra inbetween computing node leads to higher failure potential and management overhead

- Next idea: using a Raspberry Pi with kBerry HAT:
  - Direct connection to KNX bus
  - MQTT translation in both directions

(image source: weinzierl.de)

Sources

[1] C. Rosinger and S. Lehnhoff. “Wärmewende Nordwest - Project homepage: Mit Digitalisierung die Wärmewende im Nordwesten schaffen.” https://www.waermewende-nordwest.de/ (accessed Sep. 27, 2023).

[2] E. Lesnyak et al., "Applied Digital Twin Concepts Contributing to Heat Transition in Building, Campus, Neighborhood, and Urban Scale,", BDCC, vol. 7, no. 3, p. 145, 2023, doi: 10.3390/bdcc7030145.

[3] S. Liang, T. Khalafbeigi, and H. (. van der Schaaf. “OGC SensorThings API Part 1: Sensing Version 1.1.” https://docs.ogc.org/is/18-088/18-088.html (accessed Sep. 27, 2023).

[4] S. Liang and Khalafbeigi, Tania (Editors). “OGC SensorThings API Part 2 – Tasking Core.” https://docs.ogc.org/is/17-079r1/17-079r1.html (accessed Sep. 27, 2023).

[5] H. van der Schaaf. “FROST®-Server: An open source implementation of OGC SensorThings API.” https://www.iosb.fraunhofer.de/en/projects-and-products/frost-server.html (accessed Sep. 27, 2023).

[6] Gira Giersiepen GmbH & Co. KG. “Gira IoT REST API Dokumentation.” https://partner.gira.de/data3/Gira_IoT_REST_API_v2_DE.pdf (accessed Sep. 29, 2023).

Thank you for your attention!