



DigitalEnergyTestbed

An Open Testbed Prototype for Integrated Energy Systems

Edmund Widl

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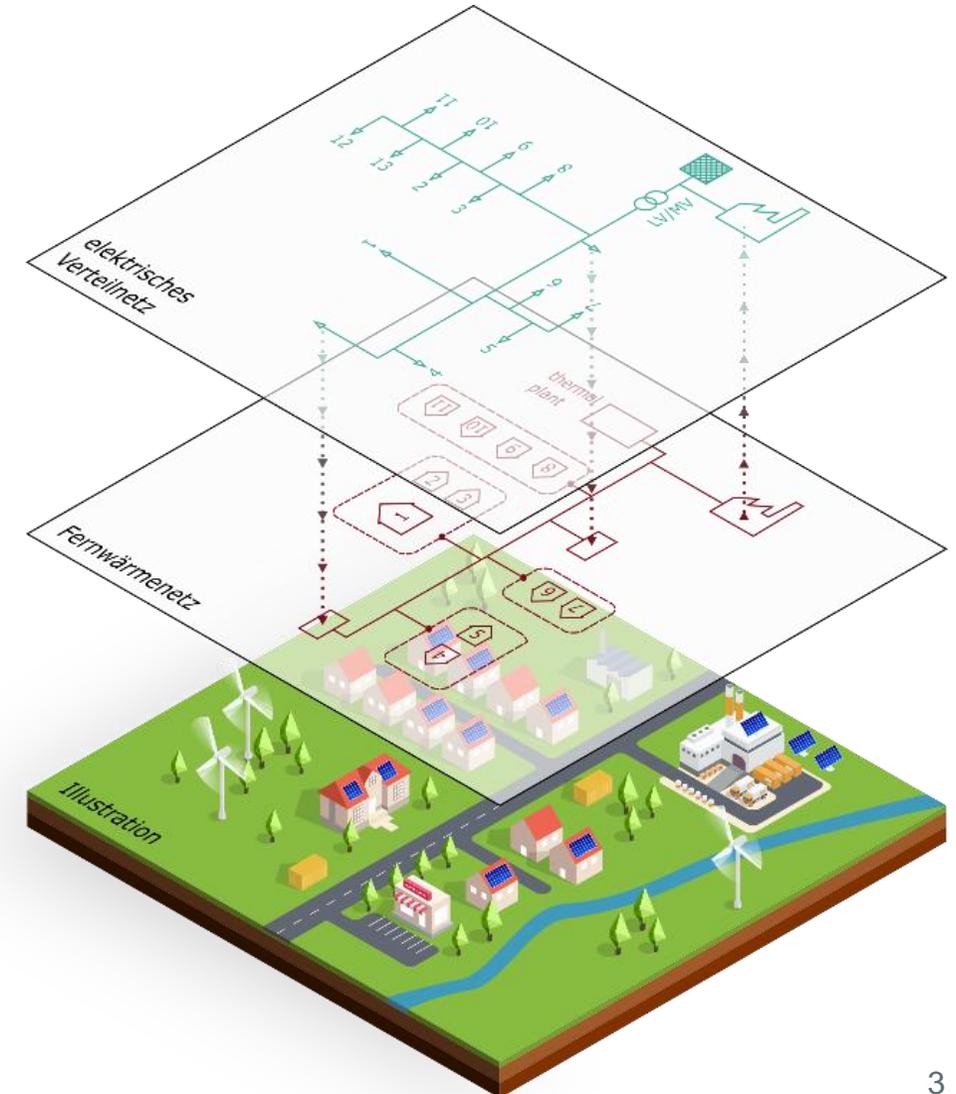


Motivation

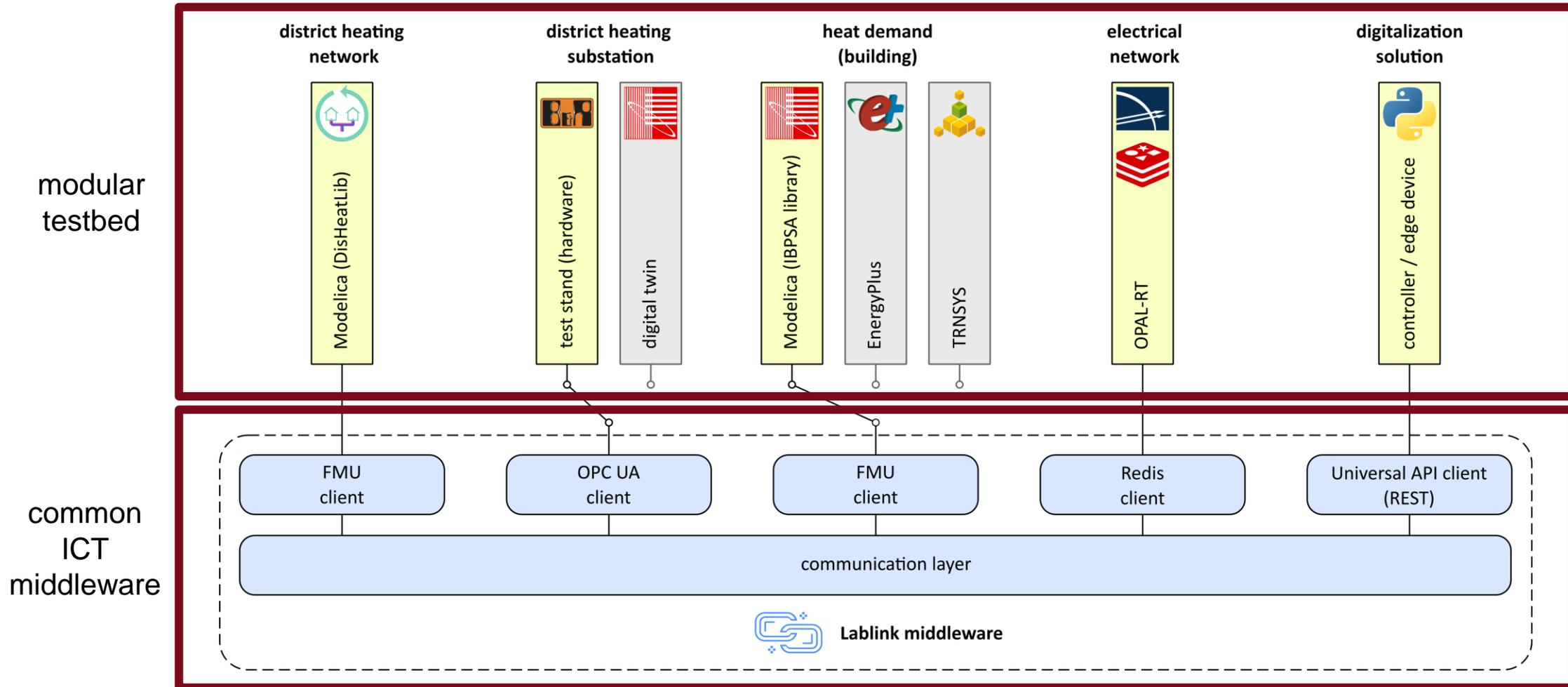
- 1. Enable the combined analysis of heat and power systems in a common test environment.**
 - simultaneous consideration of all relevant domains
- 2. Enable the digital integration of hardware and software components with a high level of interoperability.**
 - enable the integration of digital control concepts and ICT
 - combine physical lab infrastructure with simulation models
- 3. Foster the open development of and open access to the test environment.**
 - follow an “open” philosophy
 - use and further develop open software
 - publish developed solutions as open-source code

DigitalEnergyTestbed

- **testbed for integrated energy systems (IES)**
- realistic **multi-domain mapping** of:
 - consumption and generation components
 - network infrastructure
 - control systems
 - digitization solutions
- enable the **combination** of:
 - hardware-in-the-loop (HIL)
 - real-time simulators
 - simulation models



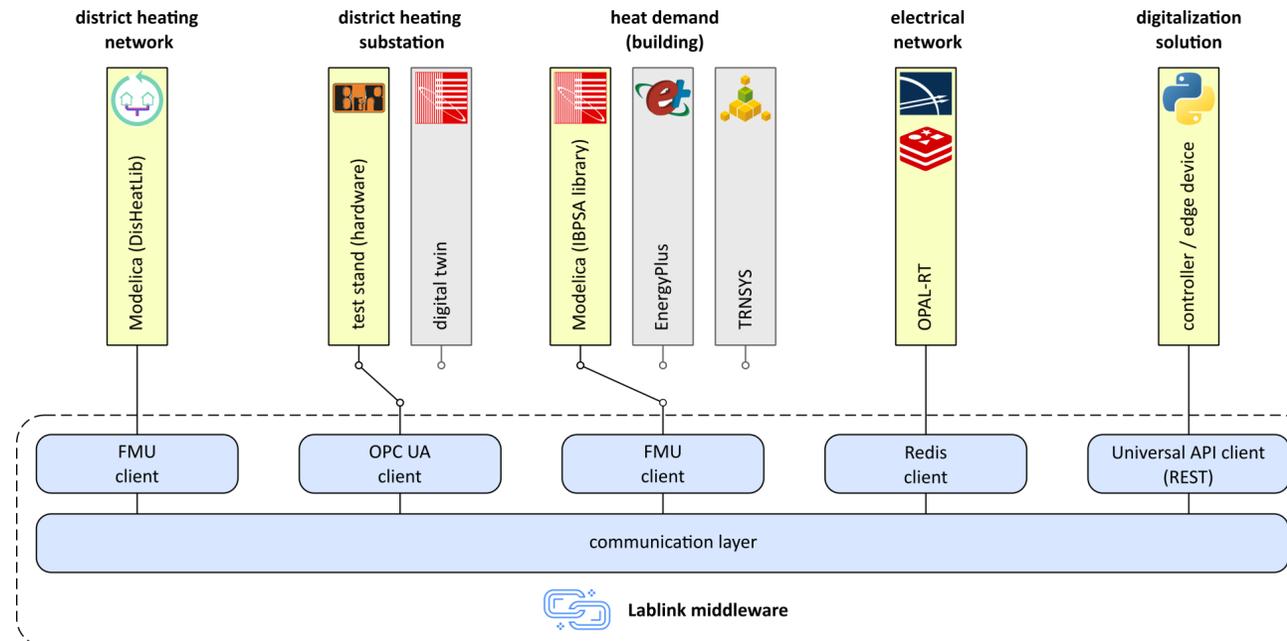
DigitalEnergyTestbed prototype



DigitalEnergyTestbed prototype

District heating (DH) network emulation

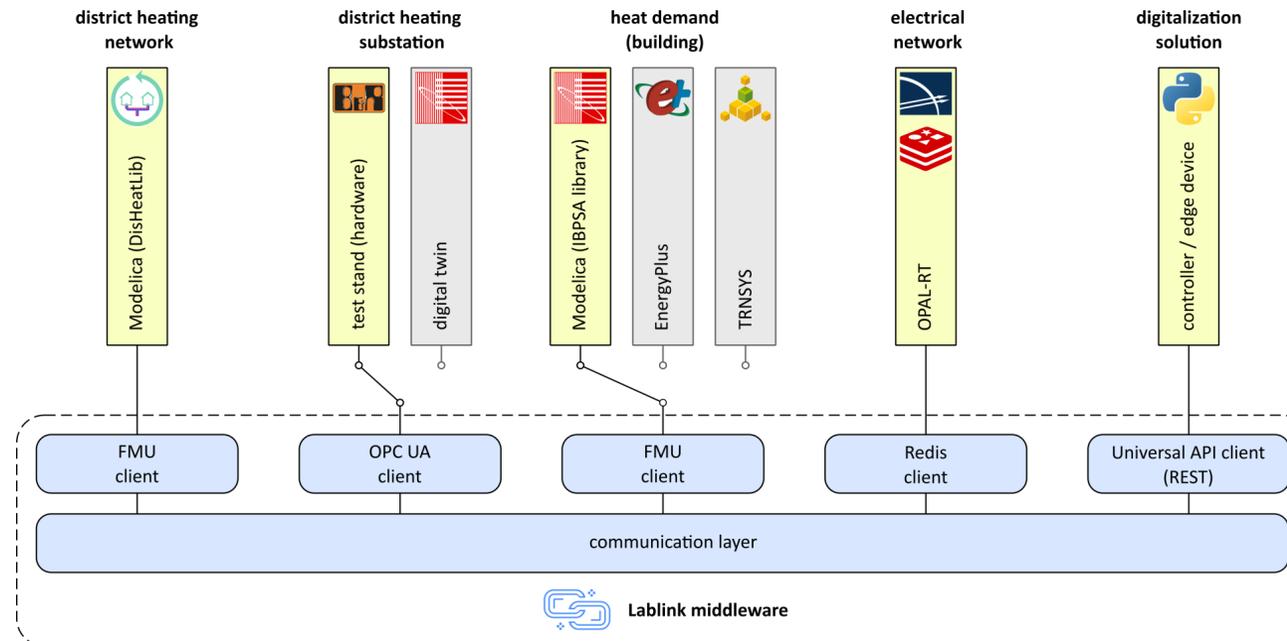
- based on open-source Modelica library DisHeatLib
- exported as Functional Mock-up Unit (FMU), synchronized to real time



DigitalEnergyTestbed prototype

Test stand for district DH substations

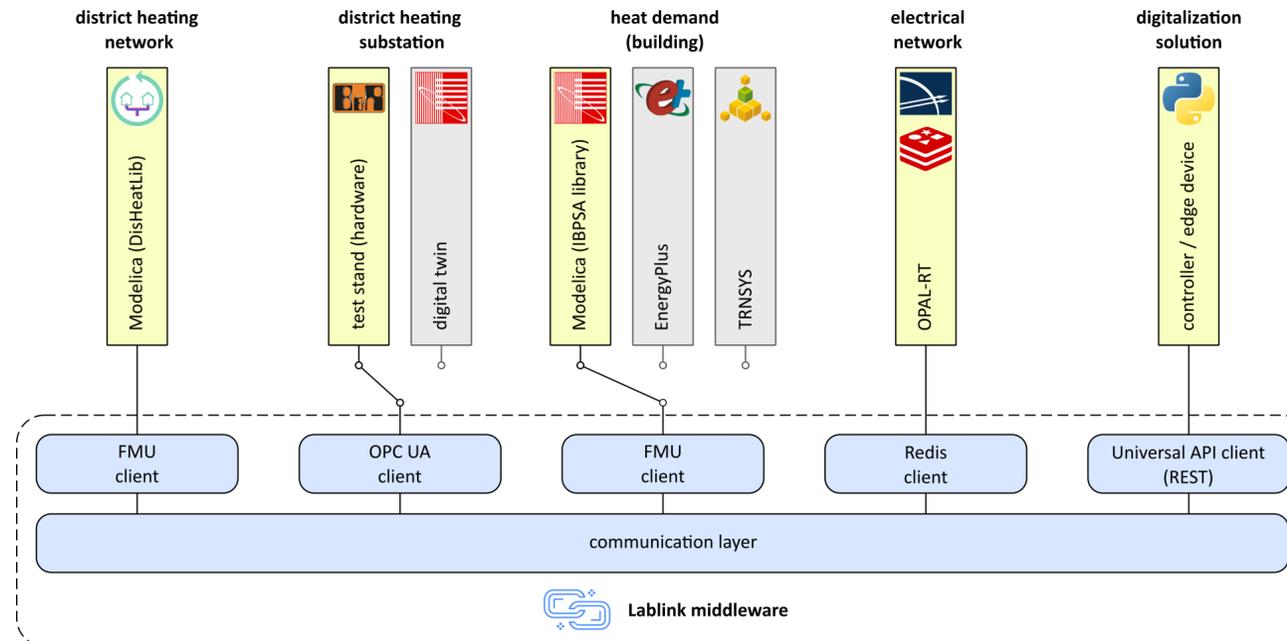
- hardware-in-the-loop target
- part of the laboratory infrastructure of the AIT Austrian Institute of Technology



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Heat demand (building) emulation

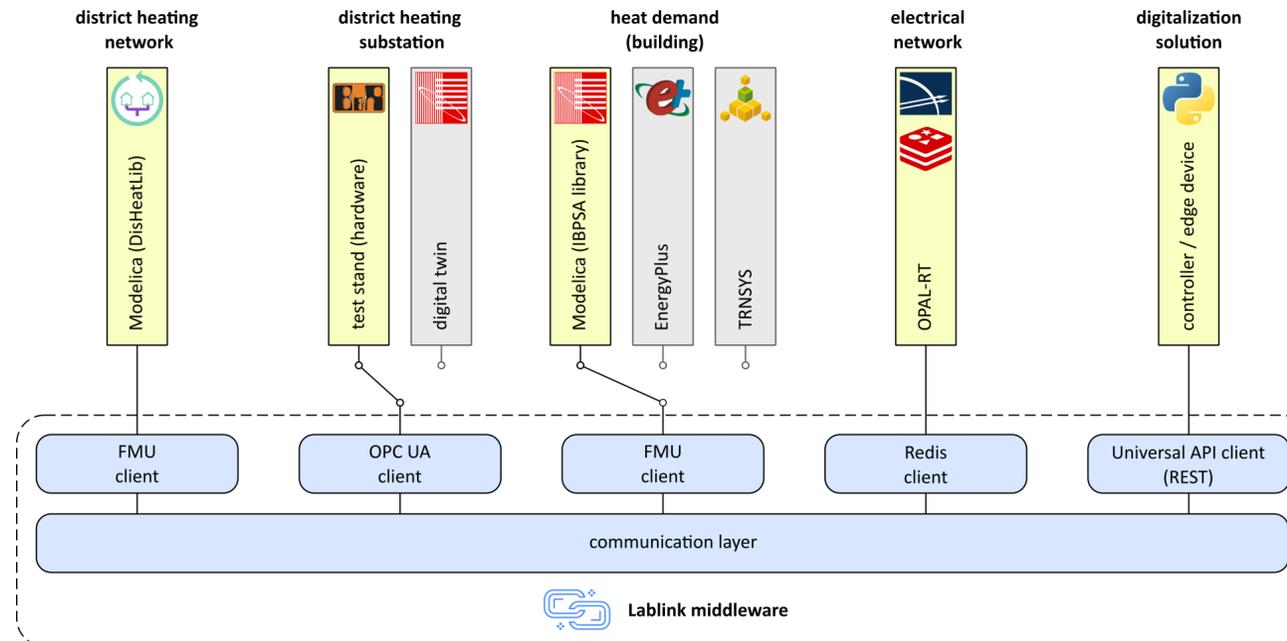
- based on open-source Modelica IBPSA & Buildings libraries
- exported as Functional Mock-up Unit (FMU), synchronized to real time



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Electrical network real-time simulator

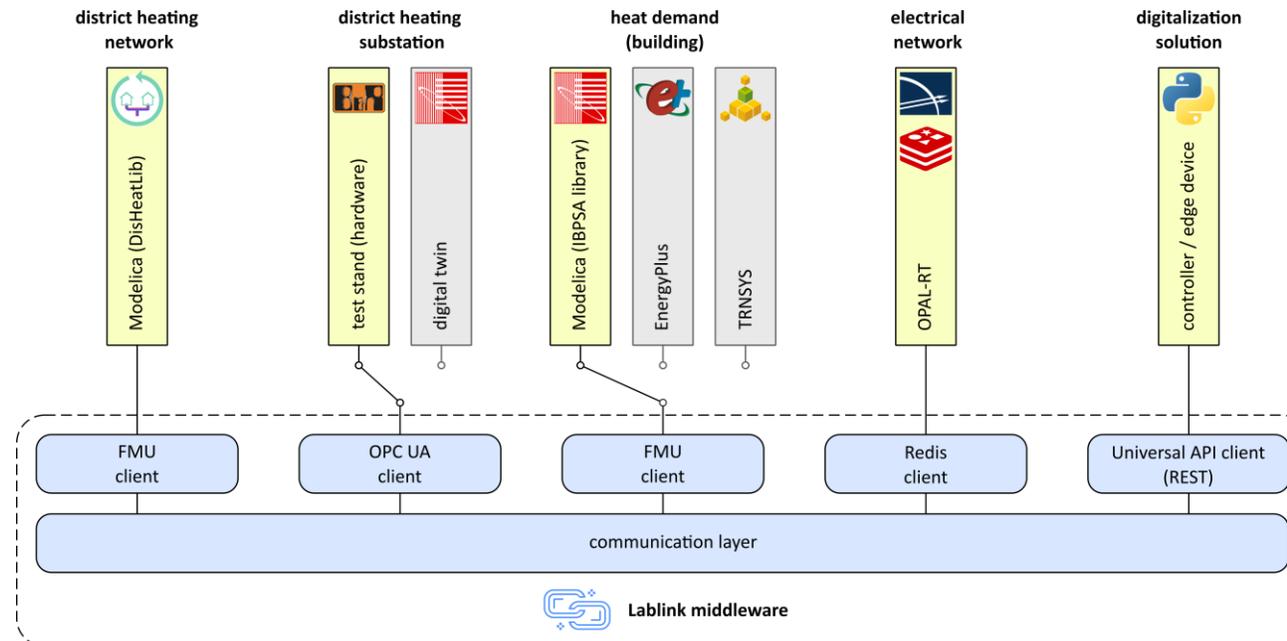
- electro-mechanical simulations, electromagnetic transients, power electronics circuits
- OPAL-RT real-time simulator



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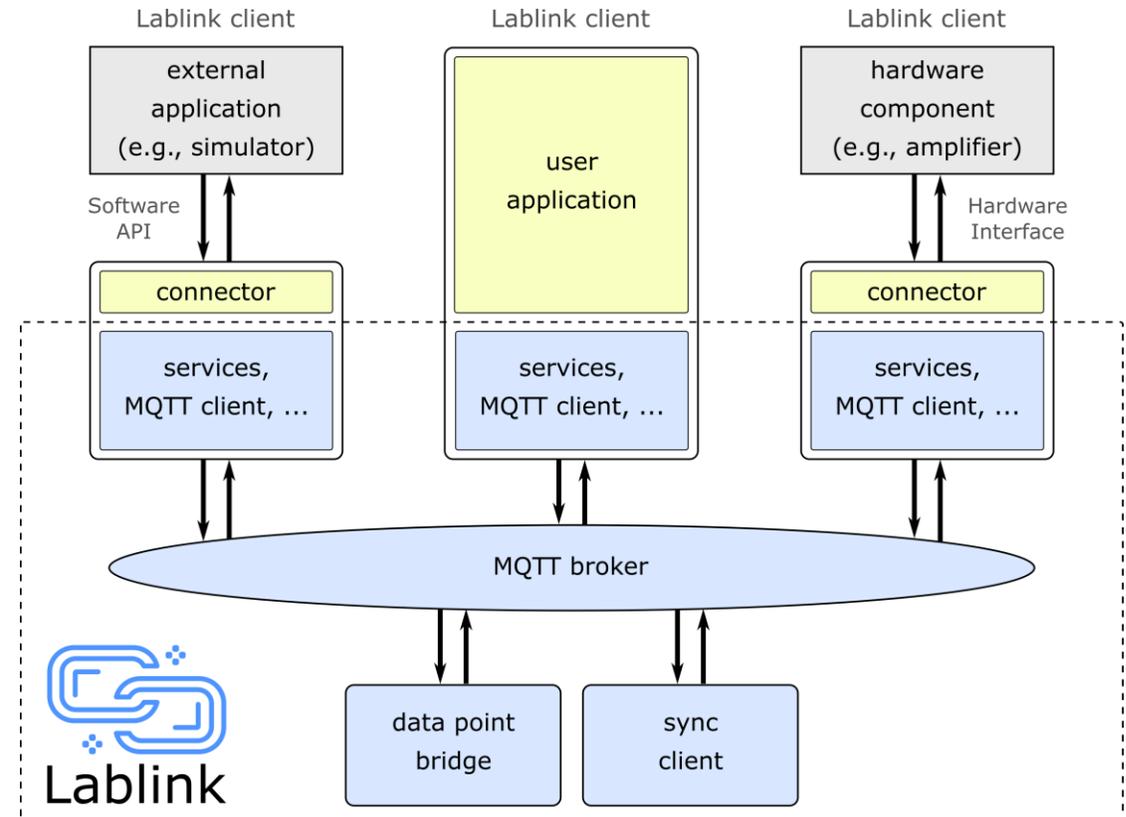
Digitalization solutions

- modular concept offers a large number of coupling options for digitization solutions
- REST API used for the prototype



Lablink middleware

- enabling technology behind the DigitalEnergyTestbed prototype
- open-source middleware for management of and data transfer between distributed clients
- dedicated clients for accessing hardware (e.g., lab equipment) and software (e.g., simulation tools)
- relies on MQTT for messaging between clients over standard TCP/IP connections
- auxiliary tools for logging, data visualization, client synchronization etc.



Lablink clients based on open standards

- **OPC UA client**

- OPC Unified Architecture (OPC UA) used for communication with DH substation test stand



- **FMU simulator client**

- Functional Mock-up Interface (FMI) for connecting to simulation tools



- **Redis client**

- OPAL-RT real-time simulator synchronized with Redis database
- synchronization rate can be adapted (in general well below time resolution of real-time simulation)



- **ERIGrid 2.0 Universal API client**

- API for REST-based communication



Lablink resources



Documentation: <https://ait-lablink.readthedocs.io>



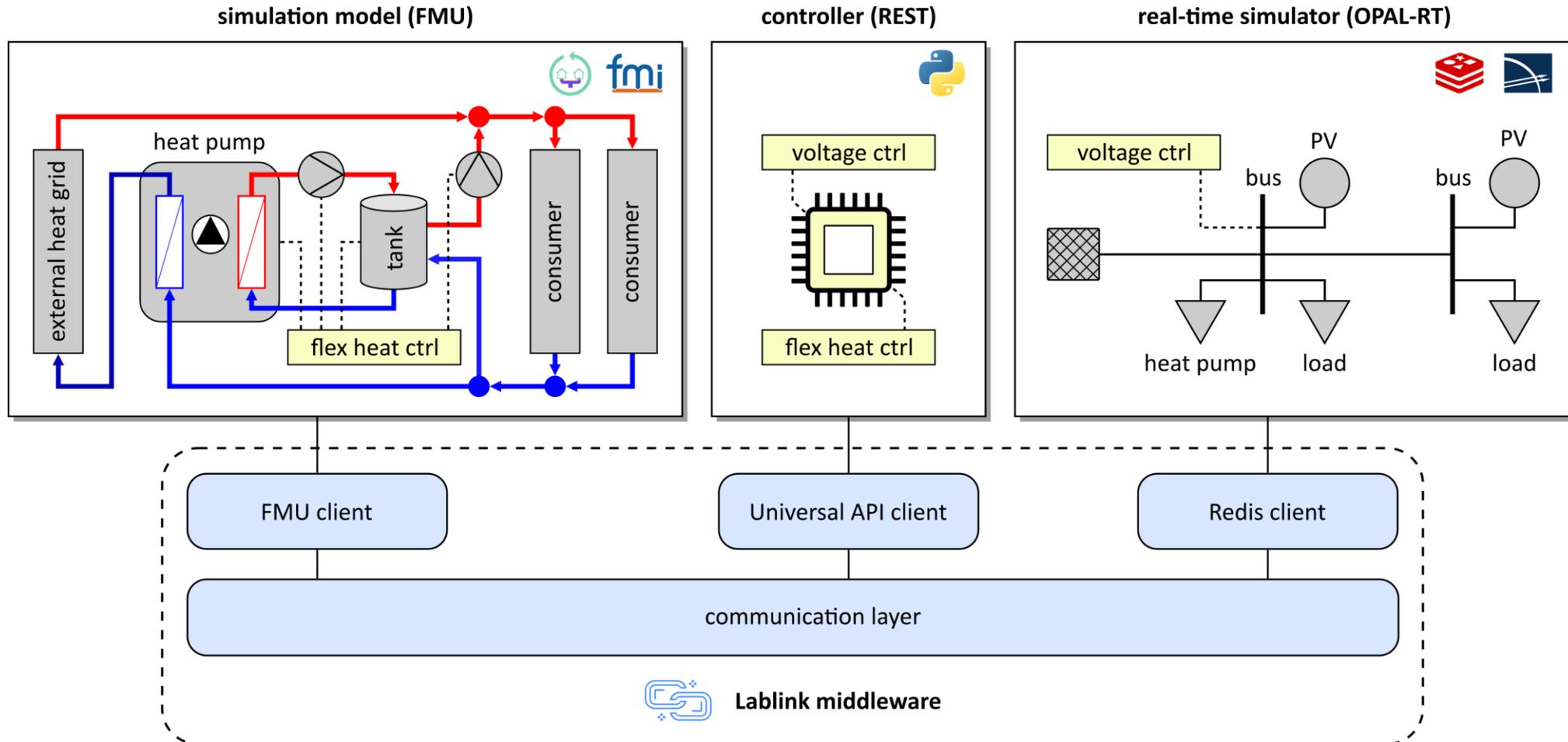
Source code: <https://github.com/ait-lablink>



Try it out yourself – example study with a digital twin:
<https://github.com/AIT-IES/detb-lablink-example>



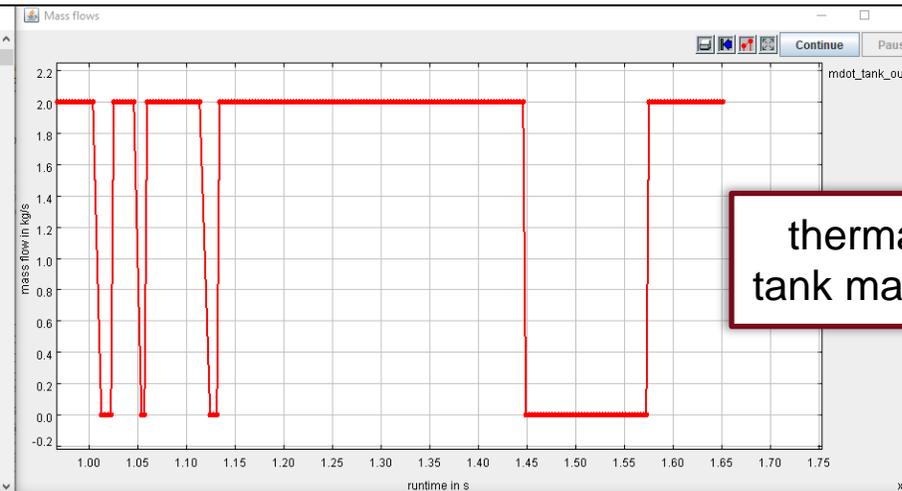
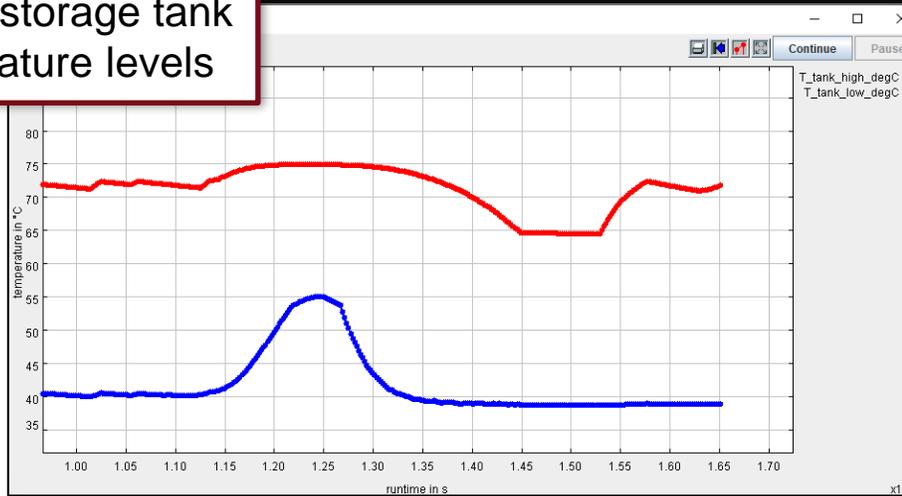
Test Case 2: Coordinated control of P2H in multi-energy network



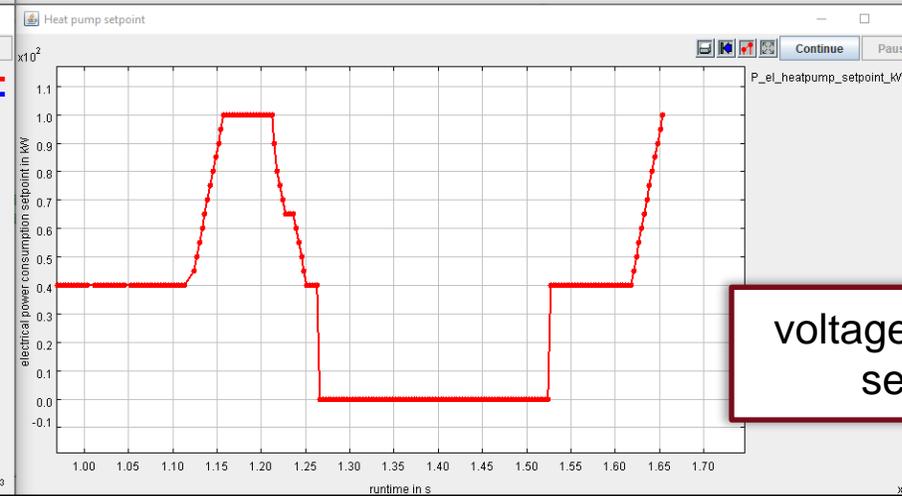
Test Case 2: Results

```
Thermal Network Sim - C:\Development\detb\detb-multi-energy-network\setup\2_run_testbed\sim-thermal-network.cmd  
AIT LABLINK  
AIT Lablink [0.0.2]  
Copyright © 2020 AIT Austrian Institute of Technology GmbH.  
Distributed under the terms of the Modified BSD License.  
Visit https://ait-lablink.readthedocs.io/ for more information.  
  
Welcome to the AIT Lablink Client Shell!  
Please type your commands below.  
You can enter ?l to list the available commands.  
llclient> ls  
Name      DataType      State  
mdot_tank_out Double 0.0  
P_el_heatpump_setpoint_kW Double 0.0  
T_tank_high_degC Double 74.94000472665977  
T_tank_low_degC Double 49.9429423662412  
P_el_heatpump_MW Double 0.09572843142687355  
Found 5 registered service(s).
```

thermal storage tank temperature levels



thermal storage tank mass flow rate



voltage controller setpoint

Conclusions and future work

- **DigitalEnergyTestbed prototype**
 - proof-of-concept implementation of an open testbed for IES applications
 - enables the deployment of cross-domain test applications in a real-time environment
 - uses a combination of laboratory equipment and simulation models
- **Open testbed**
 - implemented with open-source software
 - all interfaces of the testbed rely on open standards



Thank you!

Edmund Widl

April 20, 2023

