MASCHINENBAU UND VERFAHRENSTECHNIK

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Interactive Optimization for the Energy Efficient Operation of Fresh Water Distribution Systems

10th INTERNATIONAL CIRCULAR ECONOMY CONFERENCE

SAM

LEHRSTUHL FÜR STRÖMUNGSMECHANIK UND STRÖMUNGSMASCHINEN

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Water JPI

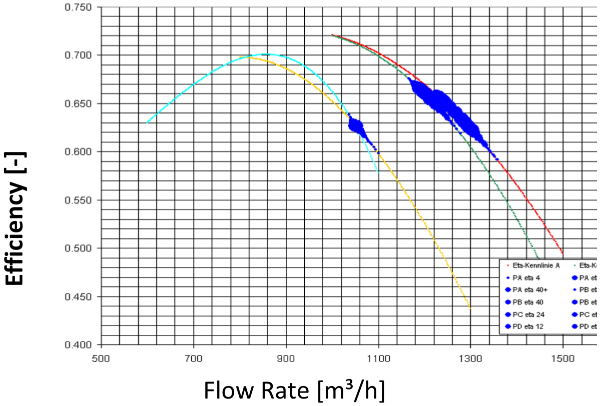
2017 JOINT CALL

Contents

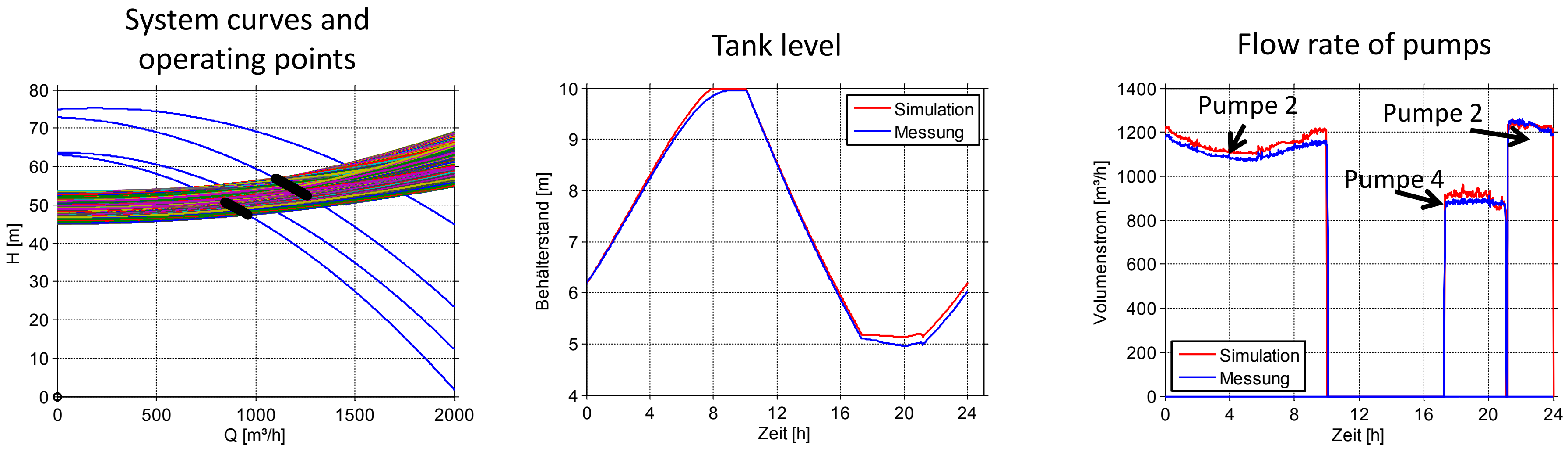
- Motivation
- Presentation of two research projects at SAM
    1. H2Opt - Interactive decision support for operation and energy management of water systems based on multi-objective optimization methods
    2. IoT.H2O - IoT for Supervision and Control of Water Systems

Motivation

- Today, very efficient pumps are available on the market
- Pumps are very often not operated efficiently. Grundfoss:
  - 10% of worldwide electricity consumption is used for driving pumps
  - 2/3 of all pumps are not operated efficiently
  - Savings up to 60% are possible
- To ensure that pumps are operated efficiently
  - Monitoring tools have to be established
  - Operating data has to be visualized
  - Models for simulating pump operation in real systems have to be developed

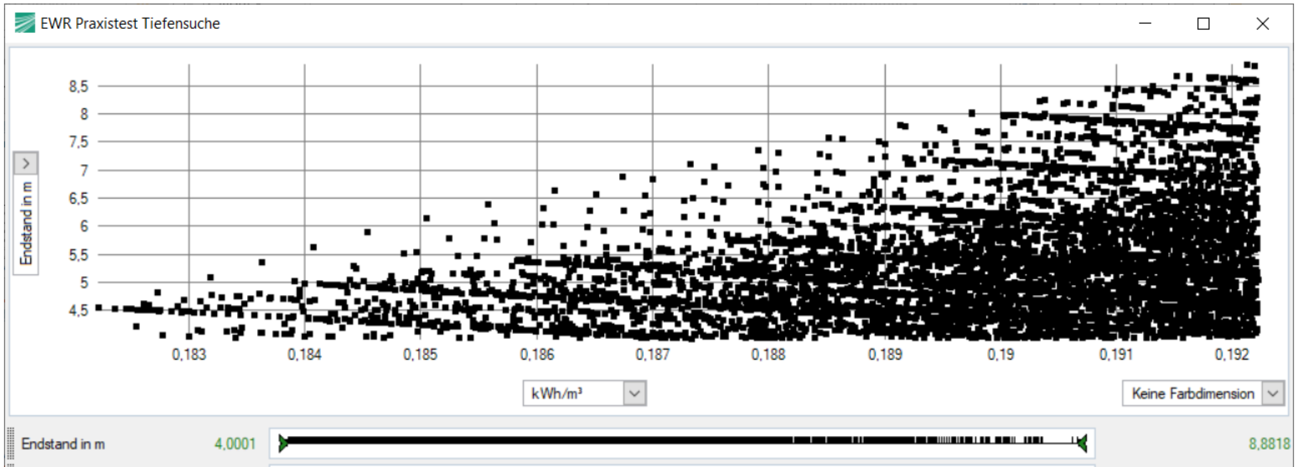


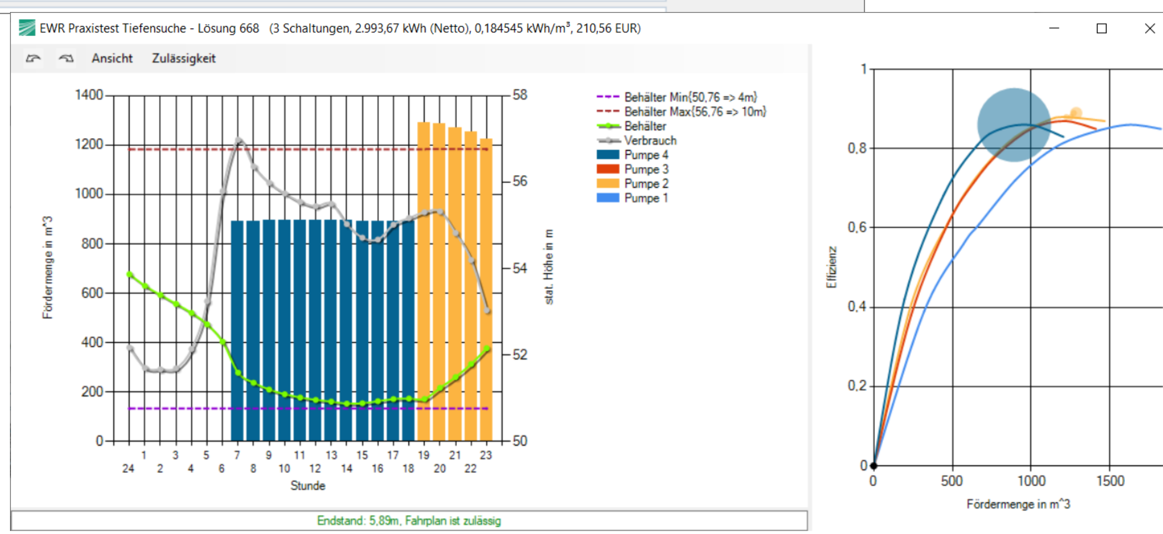
H2Opt: Hydraulic models for pump operation – Digital Twin



- Very good agreement between simulation and experiment
- Max. deviation Q_{Pump} ~4%, Tank level < 1%

H2Opt: Optimization of pump scheduling





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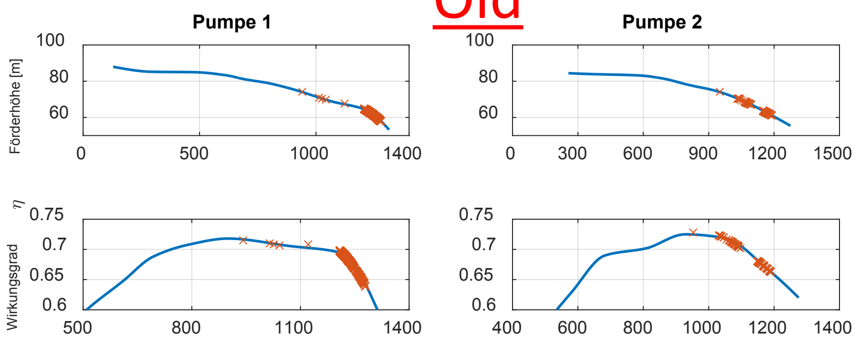
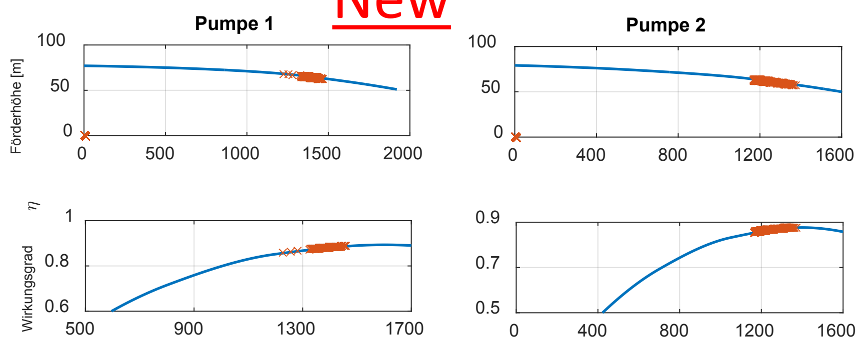
Selection of new pumps for a water utiliy in Worms, Germany

Old



New



- Efficiency degradation due to wear
- Pumps are operated at off-design conditions

- High efficiency
- Operating points close to BEP

➡ Energy savings of approx. 370.000 kWh/Year

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Selection of well pumps for a water utility in Kaiserslautern, Germany

	Neu			Neu			Neu			Neu			Neu		
	Brunnen G			Bunnen S 1			Brunnen S 2			Brunnen H			Brunnen S 4		
Förderhöhe, m	11,00			65,00			57,00			10,00			75,00		
Fördermenge, l/s	24,00			24,00			40,00			22,00			15,00		
Fördermenge, m³/h	86,40			86,40			144,00			79,20			54,00		
Fördermenge jährlich, m³/a	100.000,00			500.000,00			700.000,00			100.000,00			300.000,00		
Laufzeit jährlich, h/a	1.157,41			5.787,04			4.861,11			1.262,63			5.555,56		
Bieter	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Motorleistung, kW	5,50	5,50	7,50	37,00	45,00	26,00	37,00	45,00	37,00	4,00	5,50	7,50	22,00	26,00	26,00
Kabelquerschnitt	4 x 4²	4 x 2,5²	4 x 6²	4 x 16²	4 x 10²	4 x 10²	4 x 16²	4 x 10²	2 x 2 x 10²	4 x 4²	4 x 2,5²	4 x 4²	4 x 16²	4 x 16²	4 x 25²
Gesamtwirkungsgrad															
aufgenommene Leistun, kW															16,04
spez. Energiebedarf, kWh/m³															0,297
Energiebedarf jährlich, kWh/a															89.106
Energiekosten, EUR/kWh															0,30 €
Energiekosten jährlich, EUR/a															26.731,67 €
Beobachtungszeitraum, a															10
Energiekosten für Beobachtungszeitraum, EUR															267.316,67 €
Montagekosten															1.500,00 €
Kosten E-Technik															15.000,00 €
Preis Pumpe															7.561,27 €
Gesamtpreis															**291.377,94 €**
Laufrad/Anmerkung															

- Energy savings up to 75% are possible!
- Continuous monitoring of operating data is necessary

	Bestand	Bestand	Bestand	Bestand	Bestand
	Brunnen G	Brunnen S 1	Brunnen S 2	Brunnen H	Brunnen S 4
spez. Energiebedarf, kWh/m³	0,153	0,287	0,328	0,179	0,57
Energiebedarf järlich	15.300,00	143.500,00	229.600,00	17.900,00	171.000,00
Energiekosten, EUR/kWh	0,30 €	0,30 €	0,30 €	0,30 €	0,30 €
Energiekosten jährlich, EUR/a	4.590,00 €	43.050,00 €	68.880,00 €	5.370,00 €	51.300,00 €
Beobachtungszeitraum, a	10	10	10	10	10
Energiekosten für Beobachtungszeitraum, EUR	45.900,00 €	430.500,00 €	688.800,00 €	53.700,00 €	513.000,00 €
Einsparung Energiekosten	67,19%	12,97%	33,18%	74,61%	47,89%
Gewinn über 10 Jahre (Energiekosten für Beobachtungszeitraum (Bestand) - Gesamtpreis (neu)	**9.586,90 €**	**30.224,65 €**	**199.765,00 €**	**18.876,37 €**	**221.622,06 €**
Empfehlung	**Pumpe erneuern**	**Pumpe erneuern**	**Pumpe erneuern**	**Pumpe erneuern**	**Pumpe erneuern**

IoT.H2O – Supervision and Control of water systems

- How to get the data?
- SCADA (Supervisory Control and Data Acquisition) systems are used for data acquisition, process control and visualization of water systems
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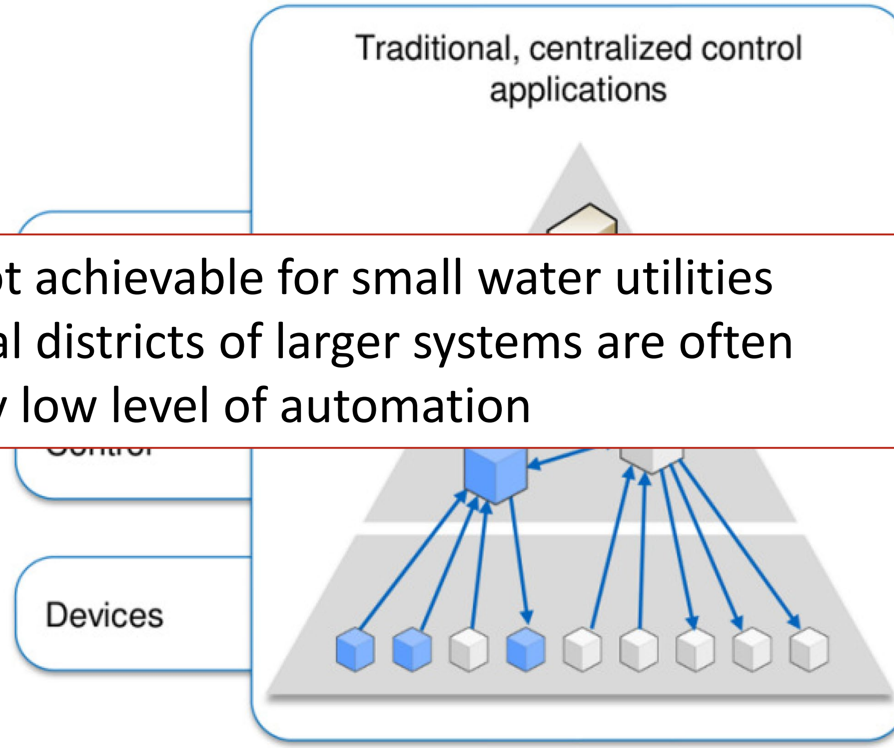
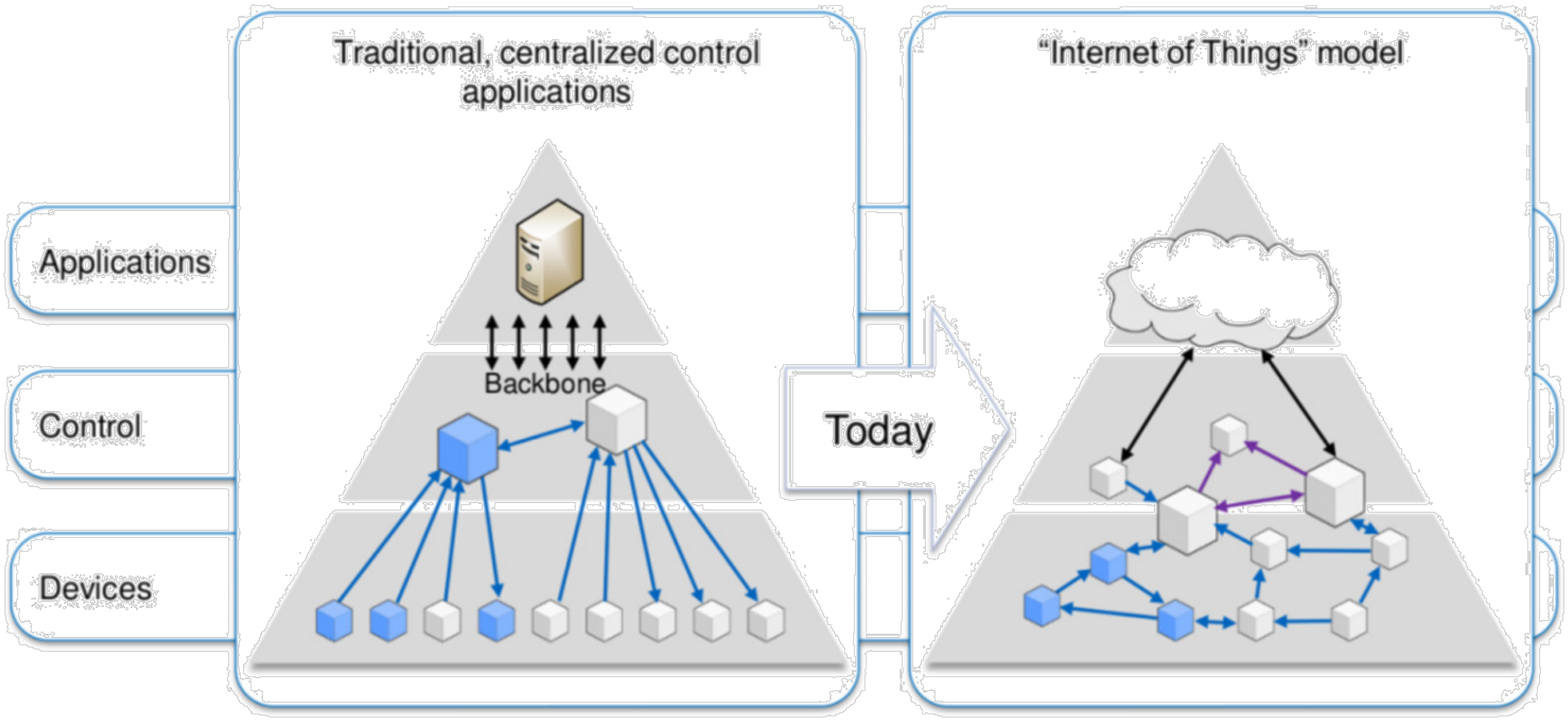
- number of measuring devices are limited
- significant parts of the network remain “invisible”
- long term observation and big data analysis not possible



SCADA systems are very often not achievable for small water utilities
Small water systems or peripheral districts of larger systems are often operated manually or with a very low level of automation

IoT.H2O – SCADA vs. Internet of Things model



IoT: decentralized interconnected field devices : additional sensors can „easily" be added

[Picture from EU Research project rtSOA] rtSOA - A Data Driven, Real Time Service Oriented Architecture for Industrial Manufacturing. Cited from: Vermesan, Ovidiu; Friess, Peter: Internet of Things Strategic Research and Innovation Agenda. In: Internet of Things – From Research and Innovation to Market Deployment. River Publishers Series in Communication.

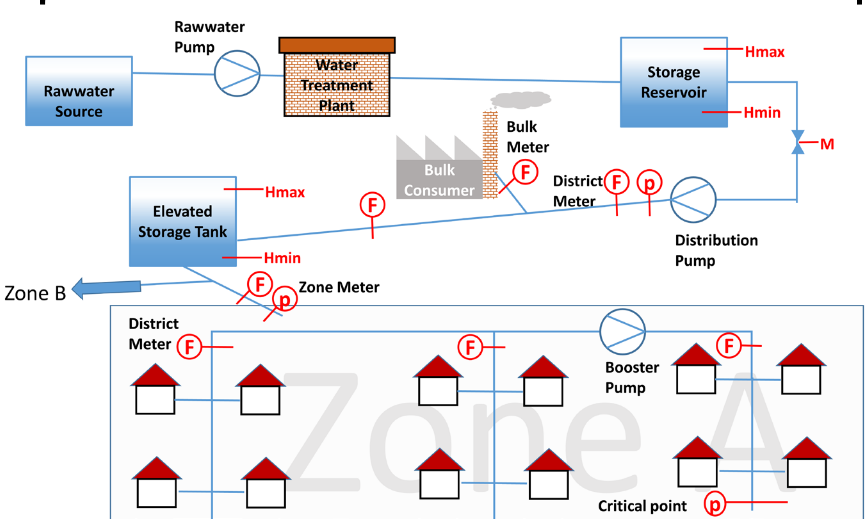
Objectives – IoT for supervision and control of water systems

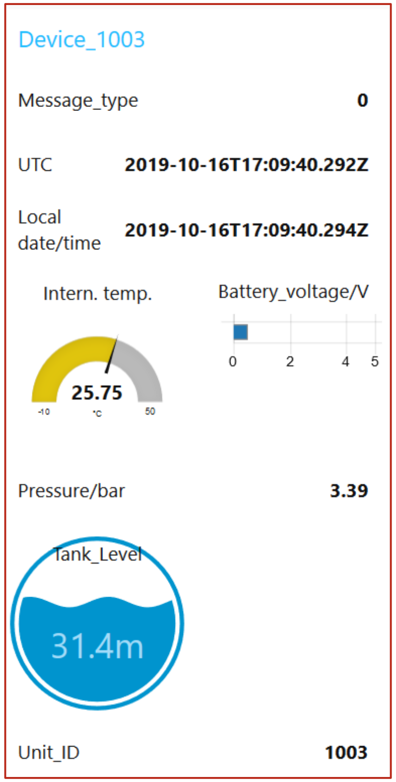
- Explore the potential of the Internet of Things (IoT) model for monitoring and operating small water utilities
- low-cost hard- and software
- manufacturer independent computer platforms
- sensors and actuators with digital interfaces
- free or open-source visualization technologies
- digital hydraulic water system modelling
- digital twin technology for prototyping and testing and as an operational support tool

➡ Cheap but powerful control and supervision system for water utilities

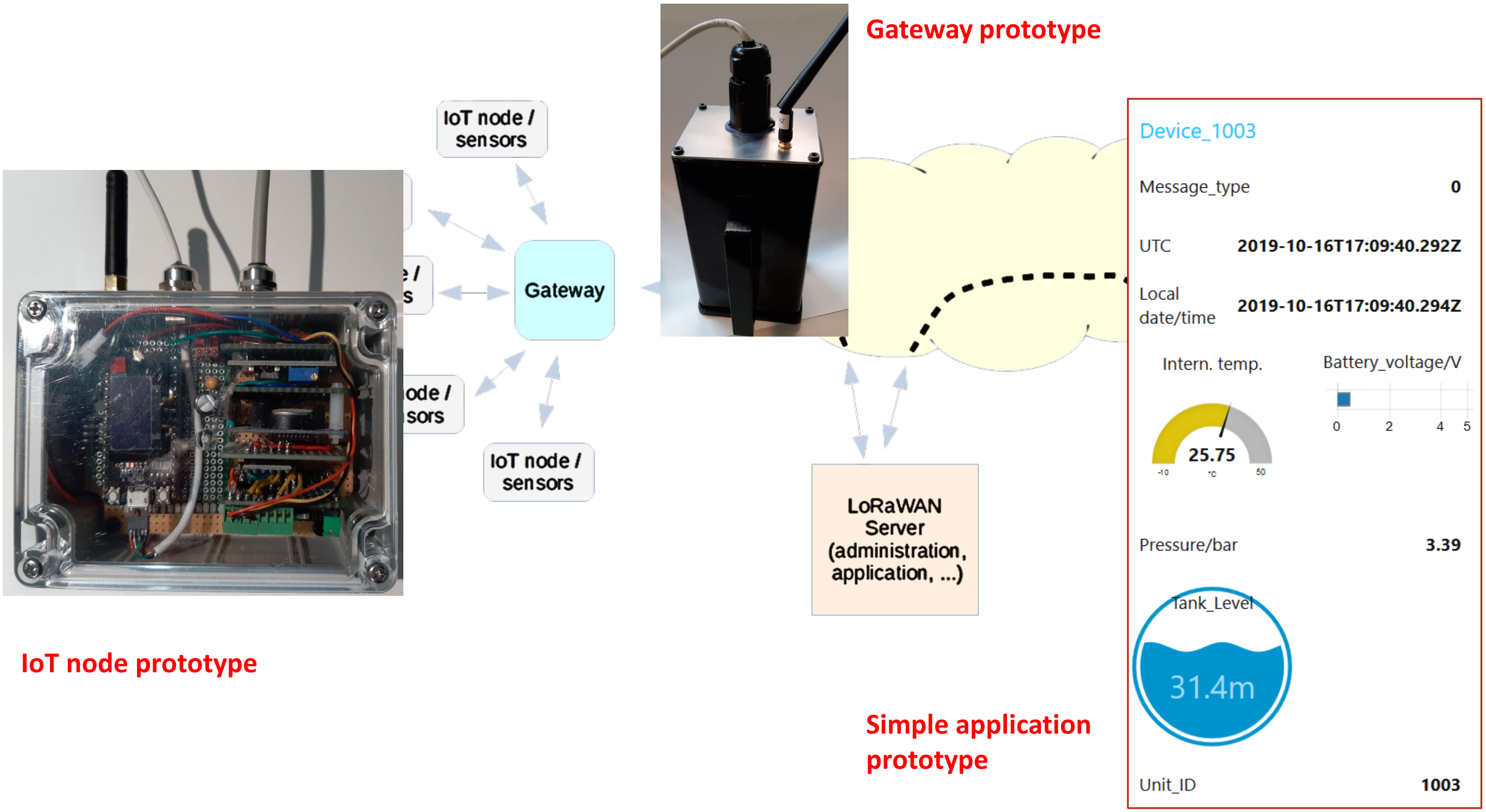
IoT.H2O water system

Field layer (Devices / Gateways) | Network layer | Application layer





IoT.H2O approach based on LoRaWAN



Gateway prototype

IoT node prototype

Simple application prototype

Consortium – H2Opt

- Technical University of Kaiserslautern (Germany), Institute for Fluid Mechanics and Fluid Machinery (SAM)
- Fraunhofer-Institut für Techno- und Wirtschaftsmathematik, Kaiserslautern
- EWR Netz GmbH, Worms
- Obermeyer Planen + Beraten GmbH, Standort Kaiserslautern
- SWK Stadtwerke Kaiserslautern Versorgungs-AG

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Consortium – IoT.H2O

- Technical University of Kaiserslautern (Germany), Institute for Fluid Mechanics and Fluid Machinery (SAM)
- Dr. Krätzig Ingenieurgesellschaft mbH (KI), Aachen, Germany
- Federal University of Minas Gerais, Brazil (CPH), Centro de Pesquisas Hidráulicas e Recursos Hídricos
- Liege University, Research group Hydraulics in Environmental and Civil Engineering (HECE), Belgium
- Institut national des sciences appliquées de Rouen, LITIS LAB, MIND Group, France