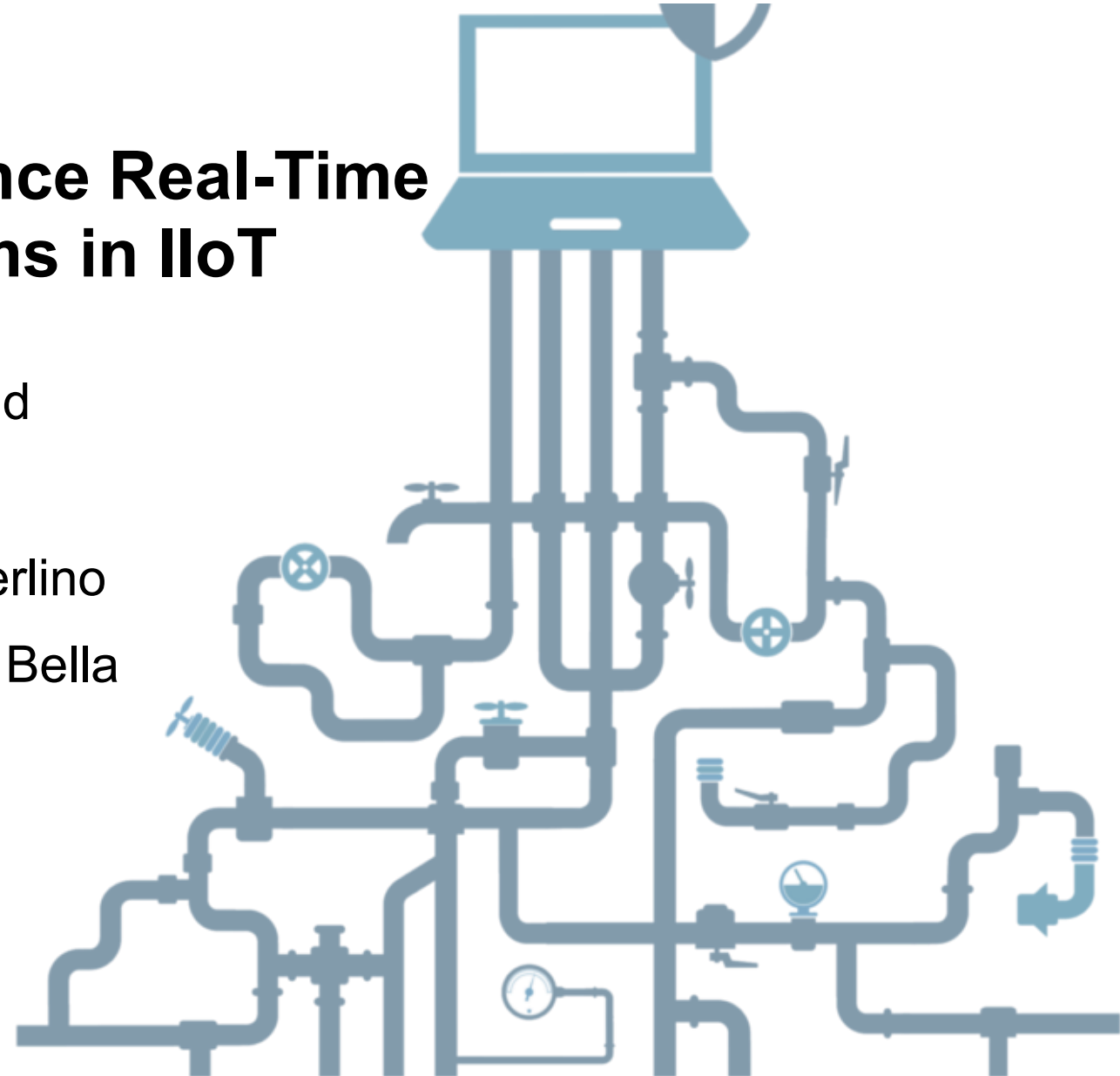


# Enabling Real-Time Operations in IIoT

and

Merlino

Bella

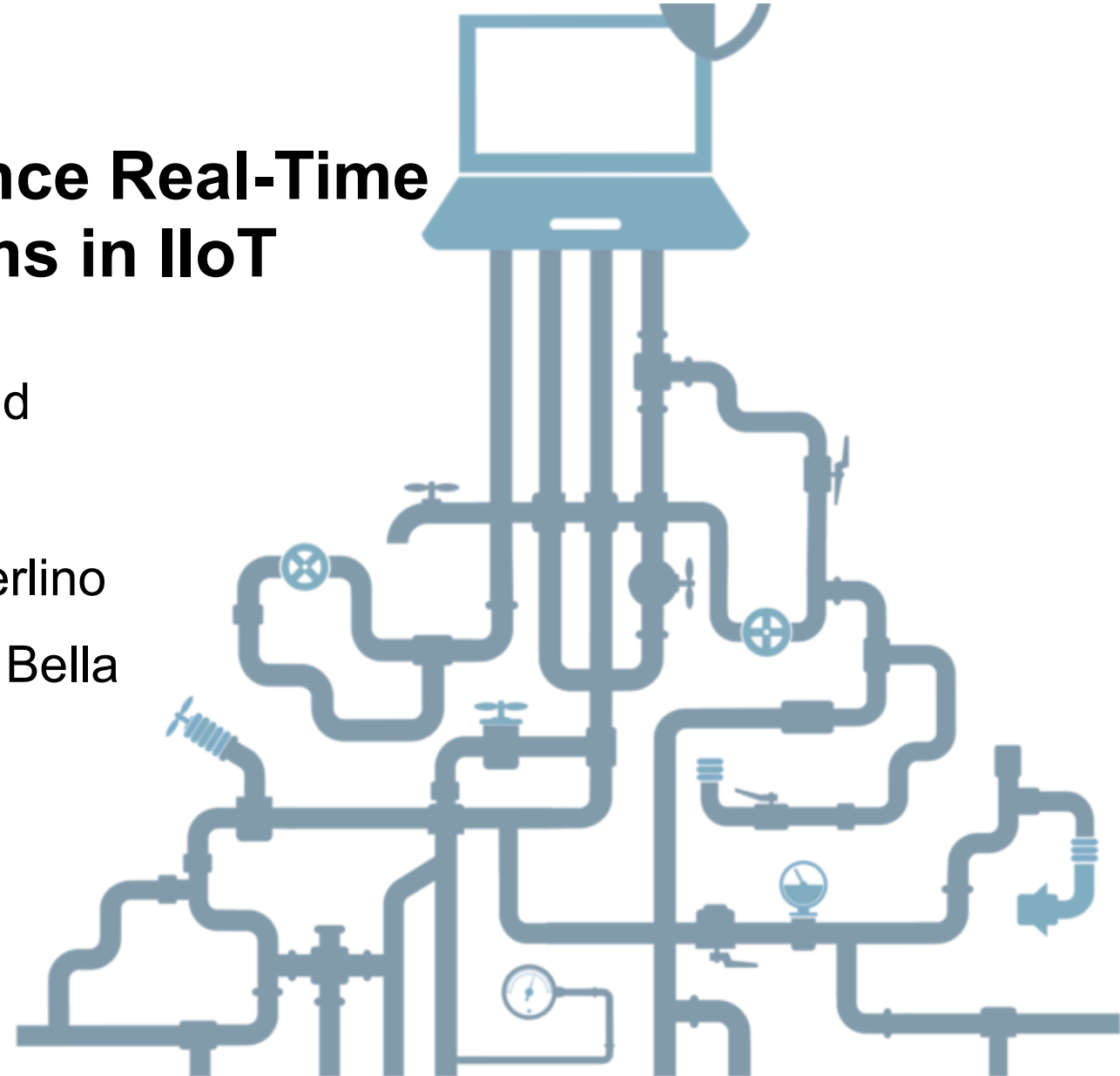
A stylized blue illustration of a complex industrial piping system. At the top center is a laptop icon. Below it, a dense network of pipes, valves, and gauges is depicted. The pipes are represented by thick blue lines, while valves and gauges are smaller circular icons with internal details. The overall shape of the piping system is roughly triangular, expanding outwards from the laptop. The background is white, and the text 'Enabling Real-Time Operations in IIoT' is on the left side, with 'and', 'Merlino', and 'Bella' below it.

# Enabling Real-Time Operations in IIoT

and

Berlino

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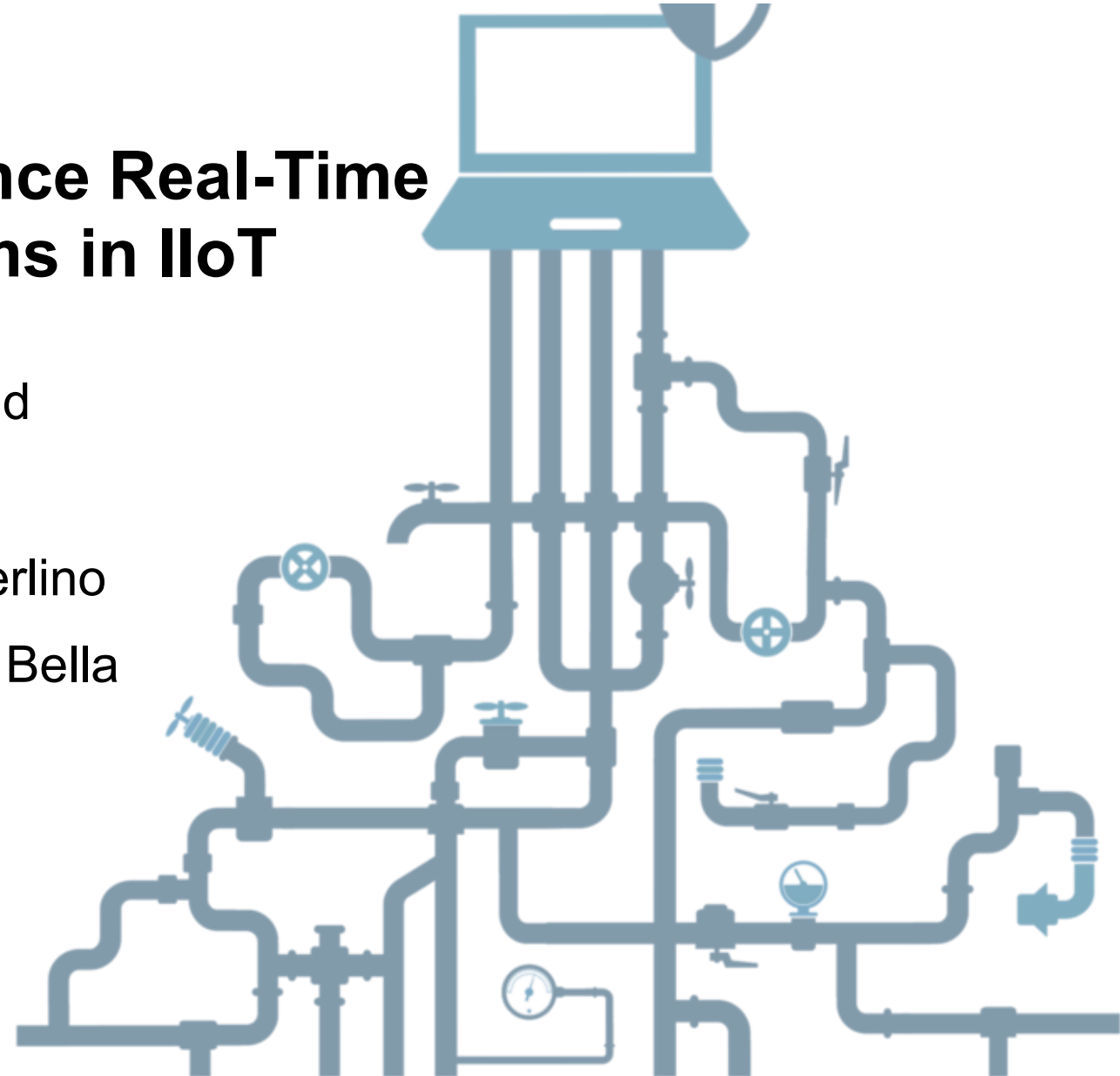
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# Enabling Real-Time Analytics in IIoT

and

Berlino

Bella

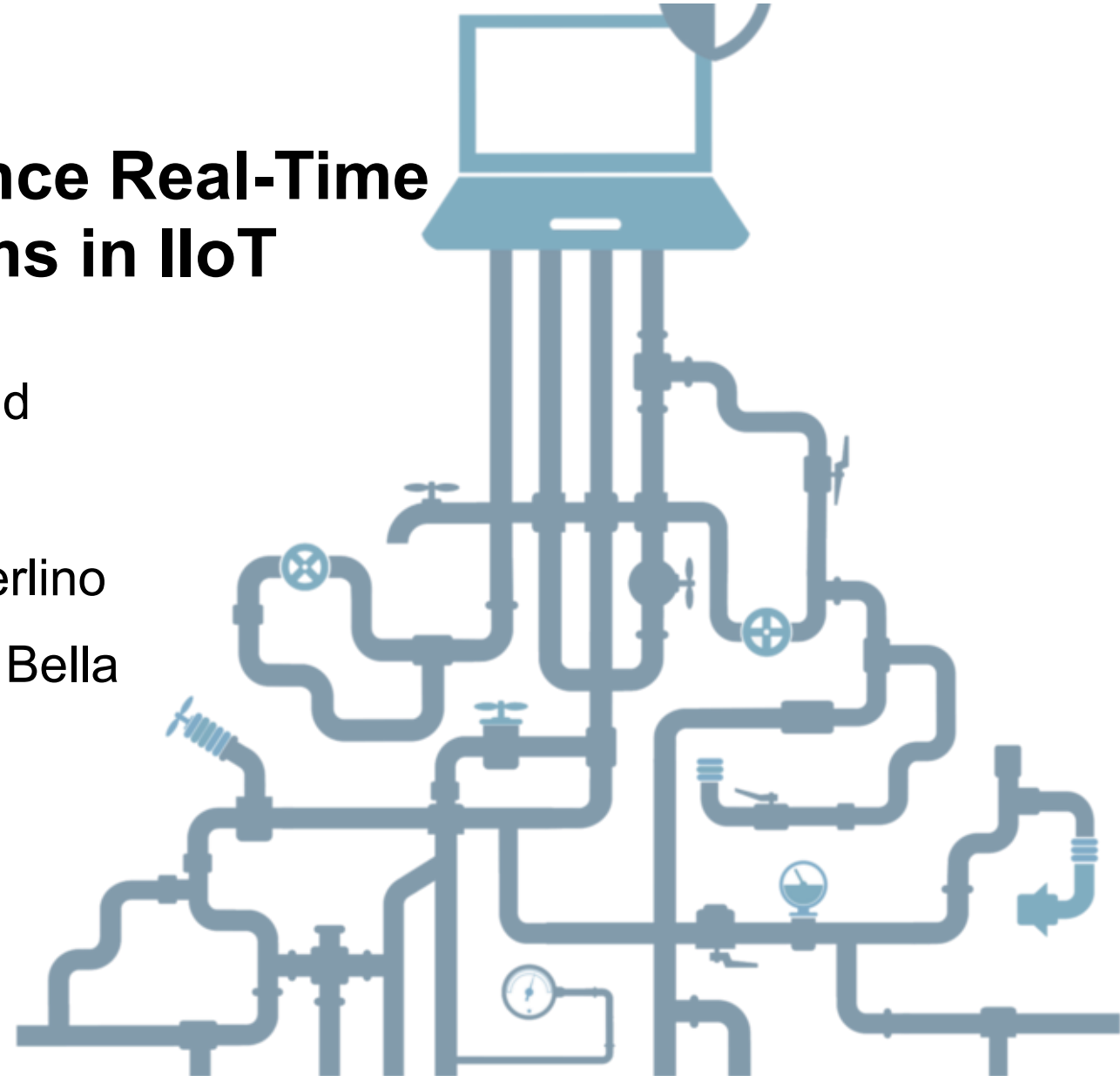
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# Enabling Real-Time Operations in IIoT

and

Berlino

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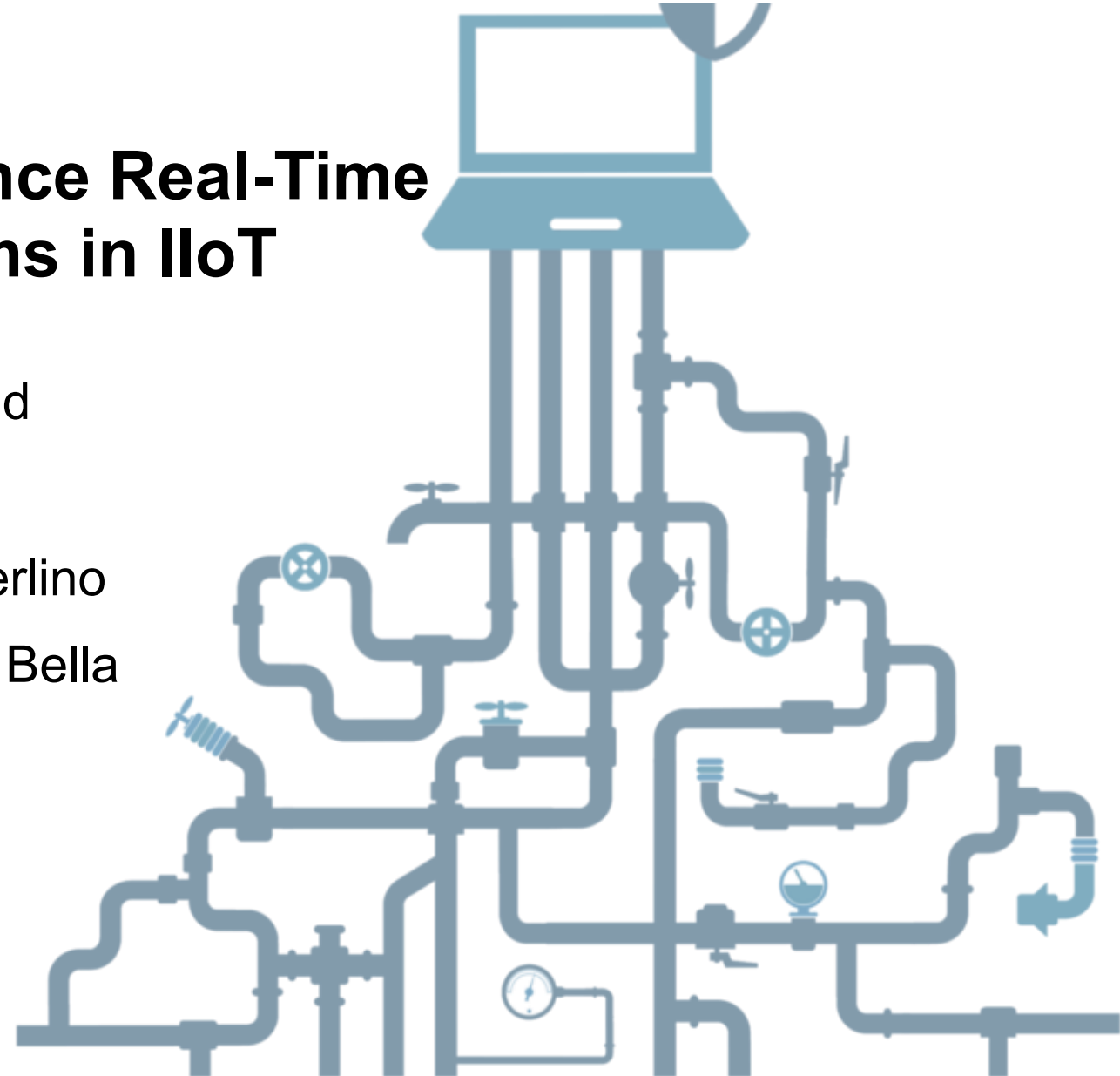
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and

Berlino

Bella

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# Why do modern industrial systems fail after deployment?

- x Timing violations
- x Network delays and jitter
- x Lack of coordination between control and communication
- x Centralized solutions don't scale

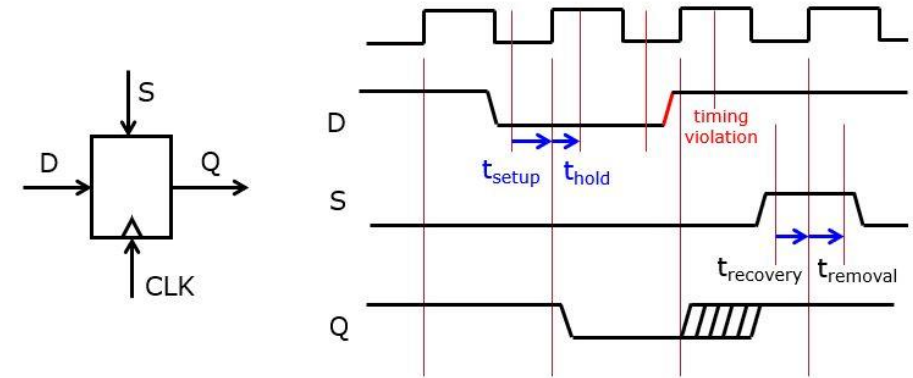


Fig1. Timing violations

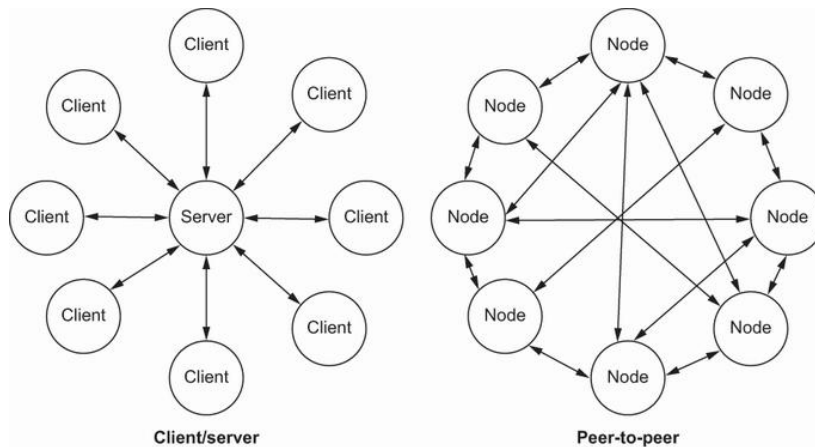


Fig3. Centralized VS. Distributed systems

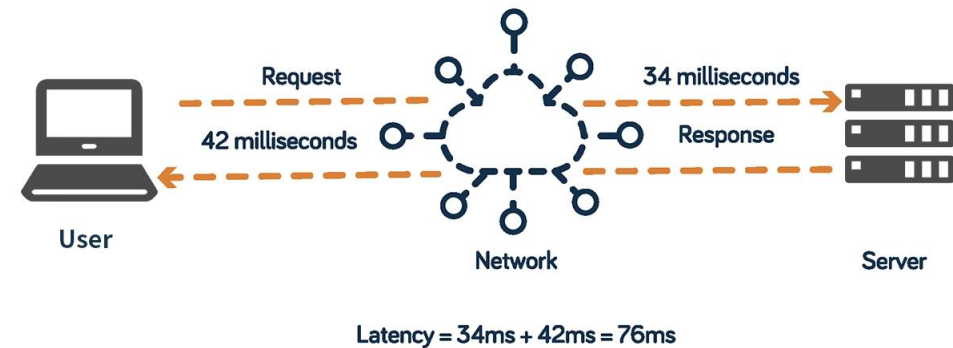


Fig2. Latency example in the network

## System Examples:

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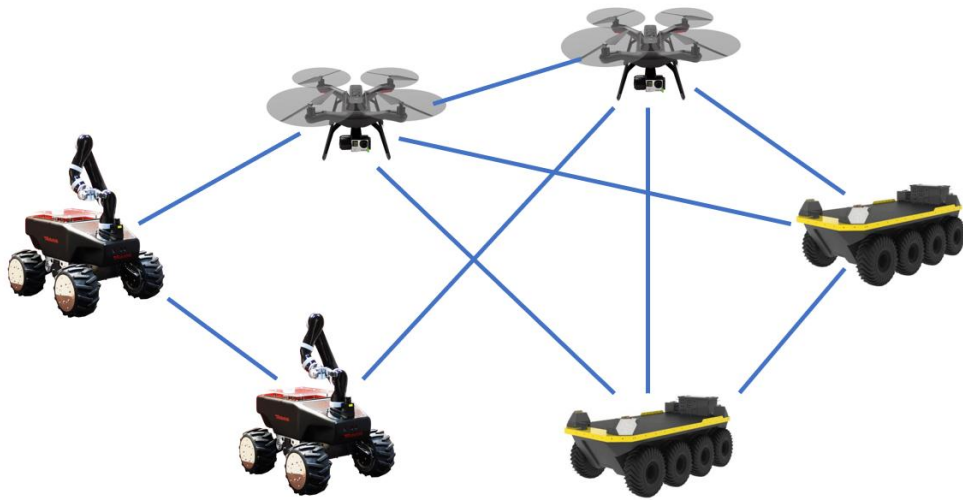


Fig4. IoT in Networked robots

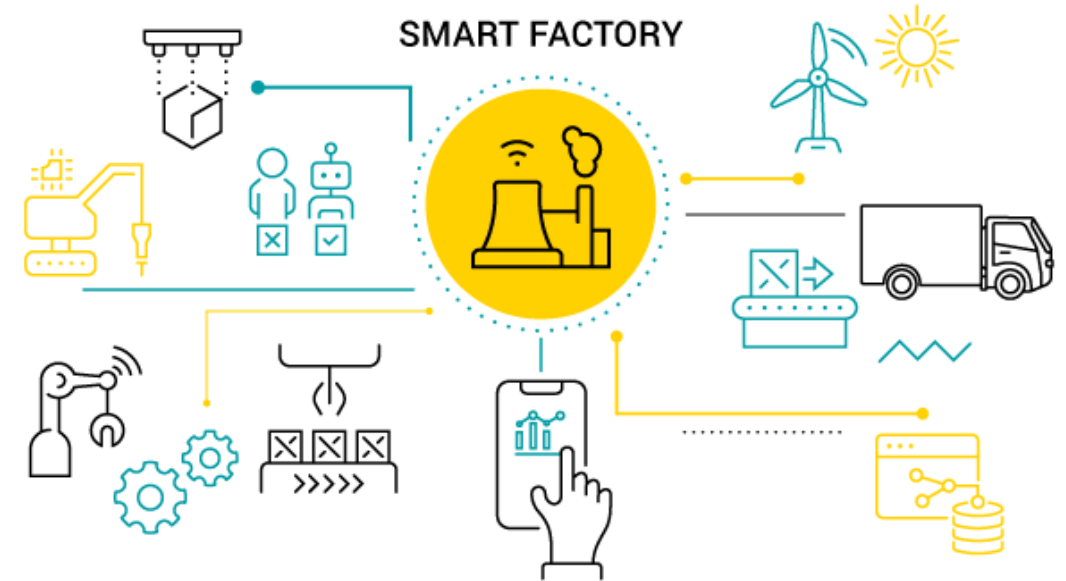


Fig5. IoT in Smart Factories, IIoT

# Digital Twin: a safe and realistic experimentation space

- Runs with real timing constraints
- Includes control logic
- Models communication and network effects
- Can run before or in parallel with the real system

**“But what kind of control are we talking about?”**

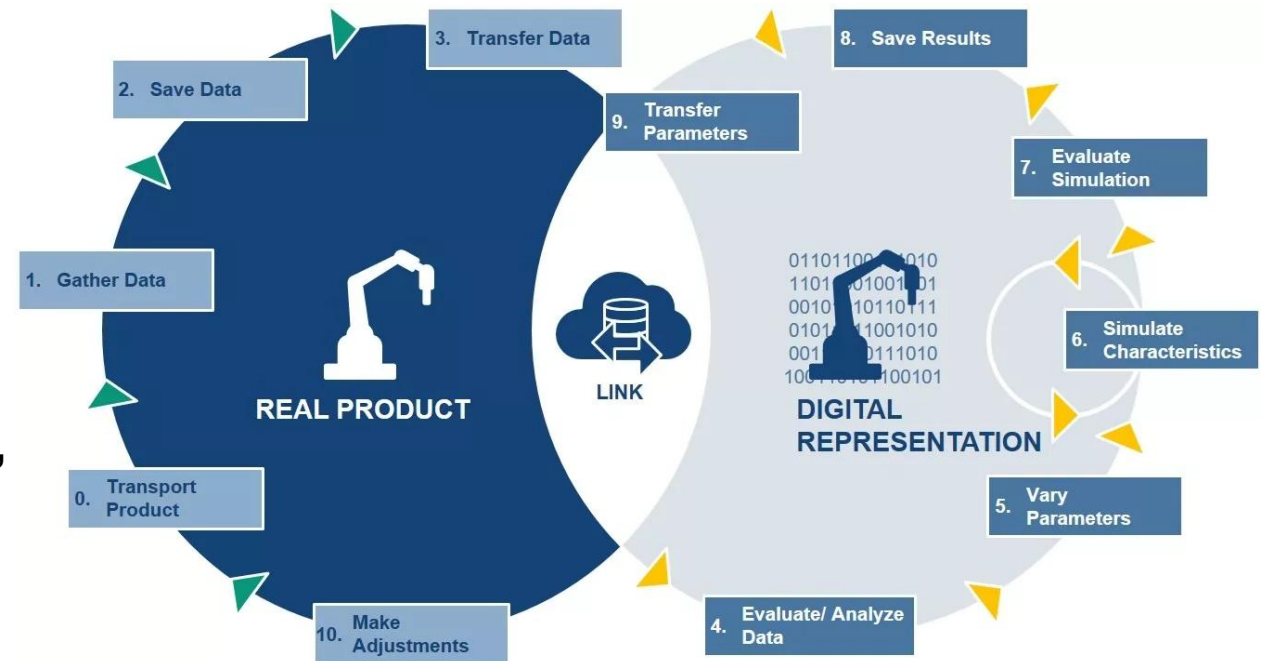


Fig6. Digital Twin workflow

## When control is distributed and time matters?

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- .Multiple controllers
- .Each controls a local subsystem
- .They communicate over a network

**“These controllers must not only make correct decisions, but make them on time.”**

- .Distributed MPC
- .Coordination mechanisms
- .Local autonomy + global objectives

**“A correct decision made too late is still a failure”**

# From models to realistic validation

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## Theoretical side

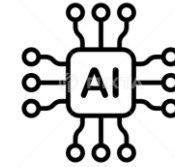
- .Control models
- .Performance and stability analysis
- .Real-time constraints

## Experimental side

- .Digital twin implementation
- .Middleware-level experimentation
- .Network and timing emulation

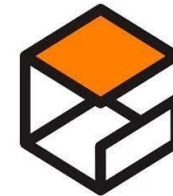


kubernetes

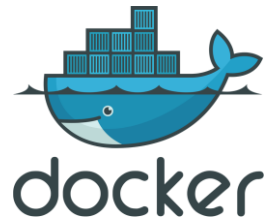


TensorFlow

ROS 2™



GAZEBO



kafka



## Why this research matters

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- ✓ **Safer system design**
- ✓ **Faster development and validation**
- ✓ **Better scalability of distributed control**
- ✓ **Reduced deployment risks in IIoT systems**

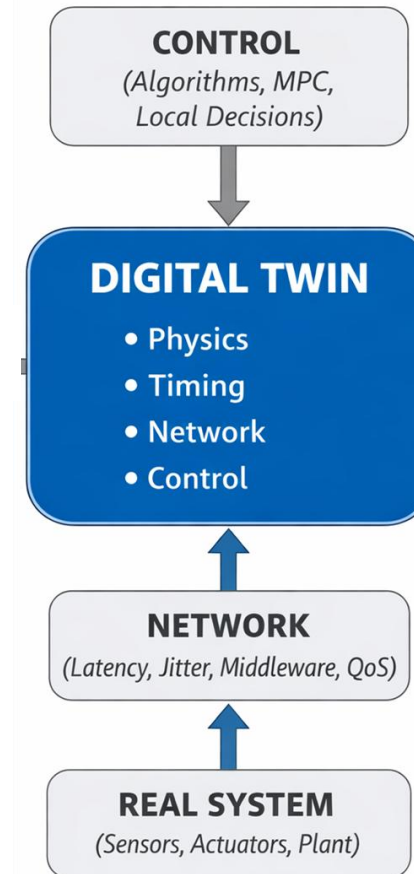


Fig7. High-performance IIoT architecture

**Thank you for your attention!**