Universität Rostock

Traditio et Innovatio

# Realtime Publish/Subscribe for Cyber-Physical Systems

## KSWS AVA / Projekt AVA / NEidI VHR


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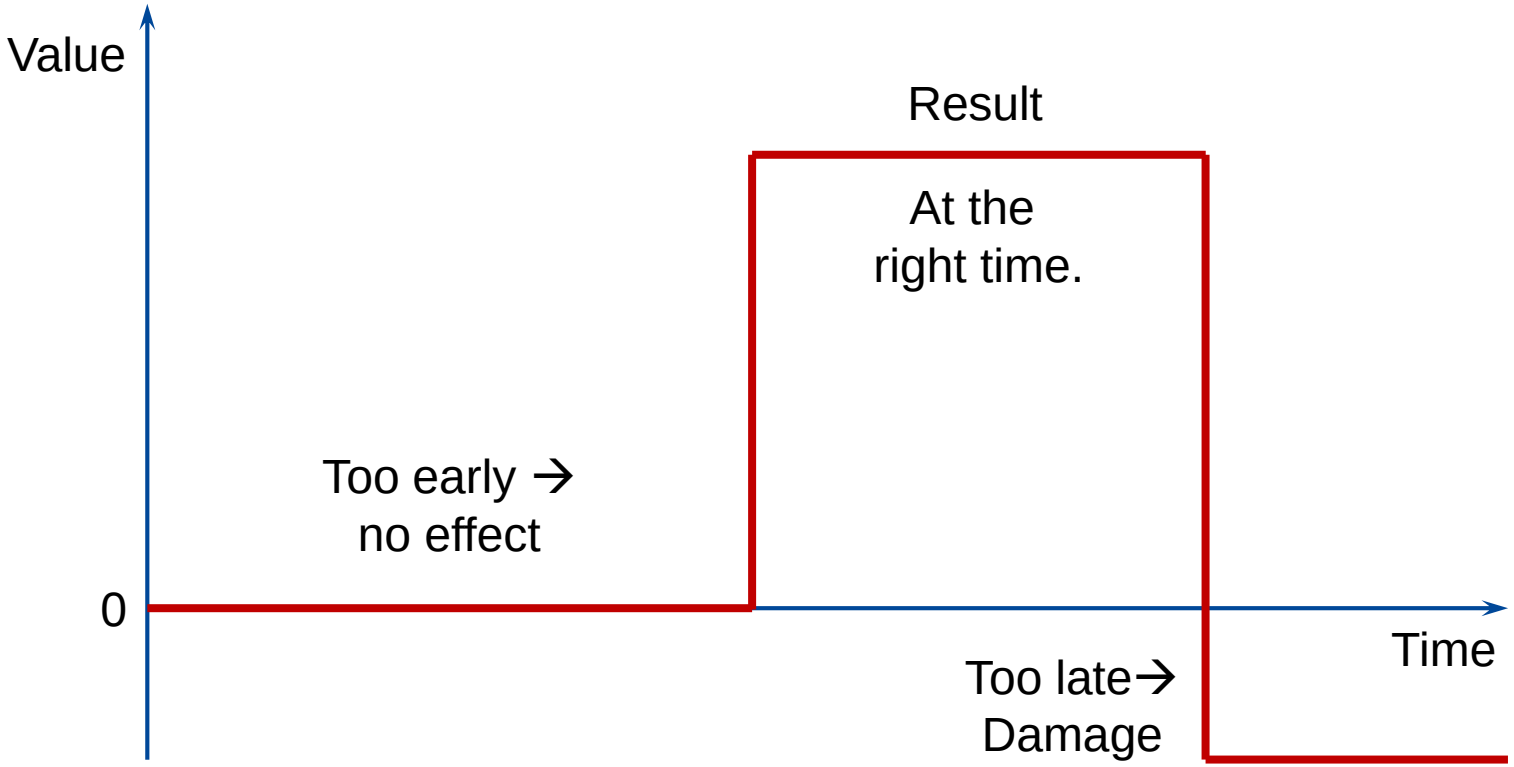
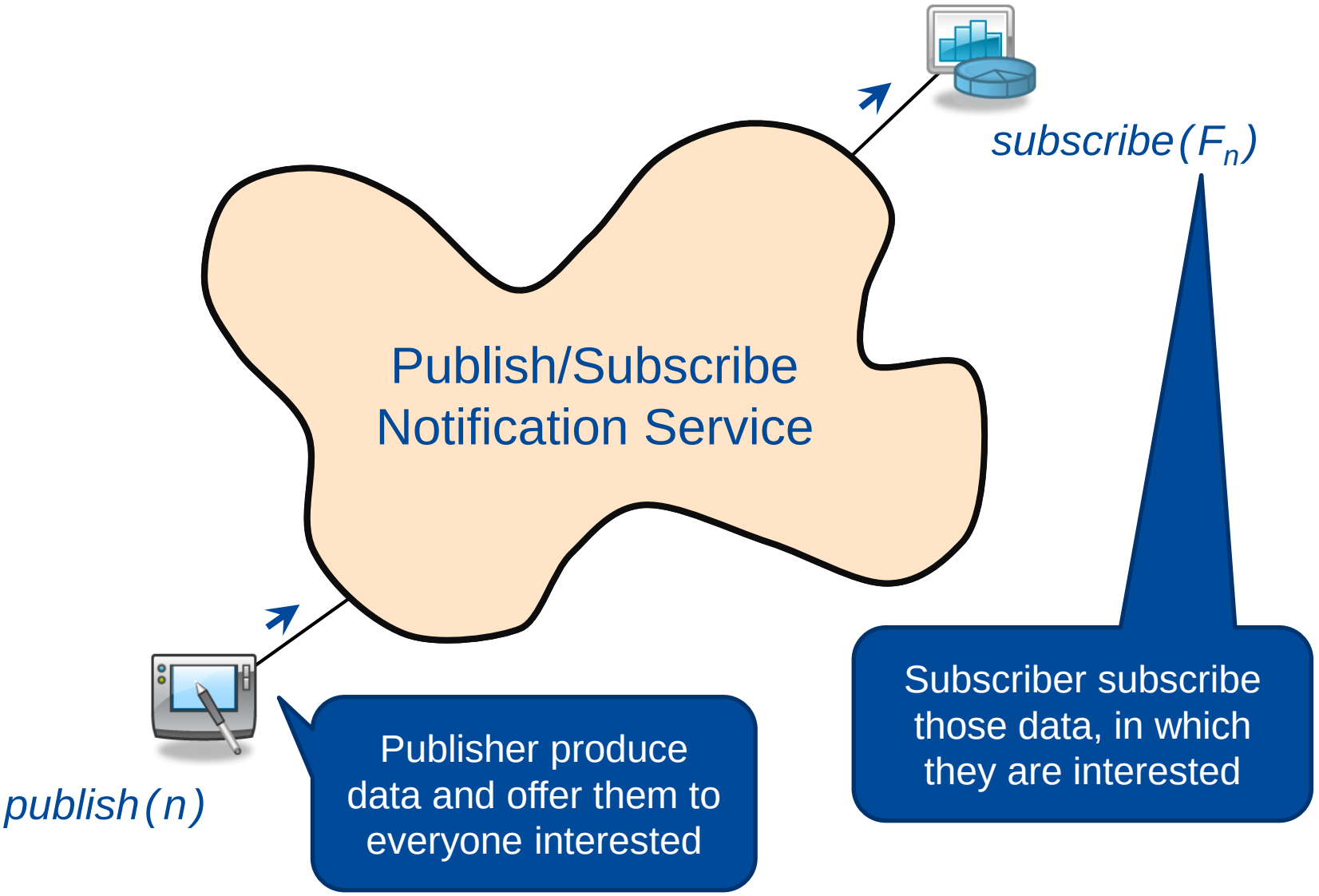
# What is Realtime (Echtzeit)?

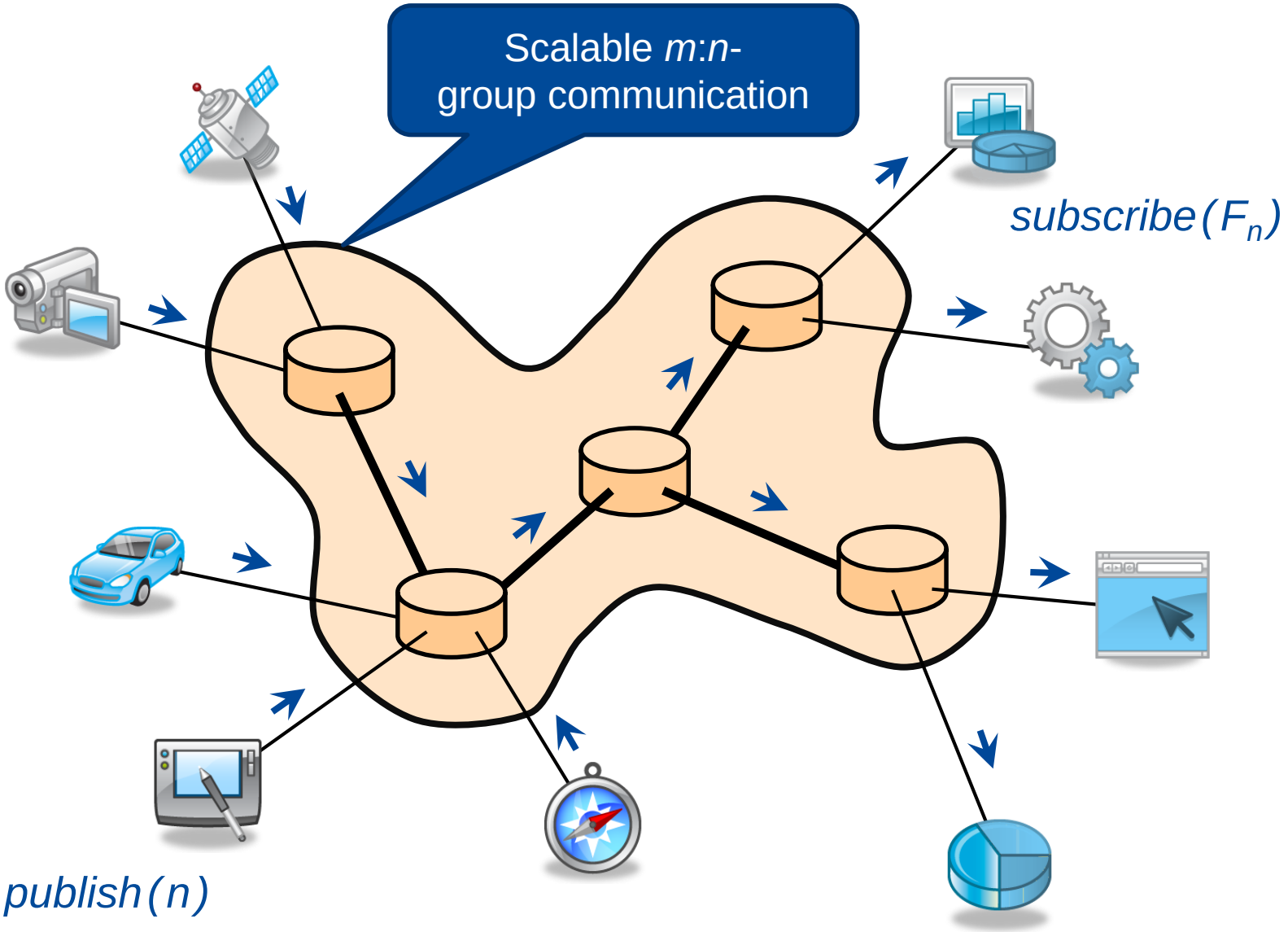



Not neccessarily fast, but predictable!

→ Do the right thing at the right time.

# What is Publish/Subscribe?




Scalable m:n-
group communication
subscribe(F_n)
publish(n)

# What are Cyber-Physical Systems?

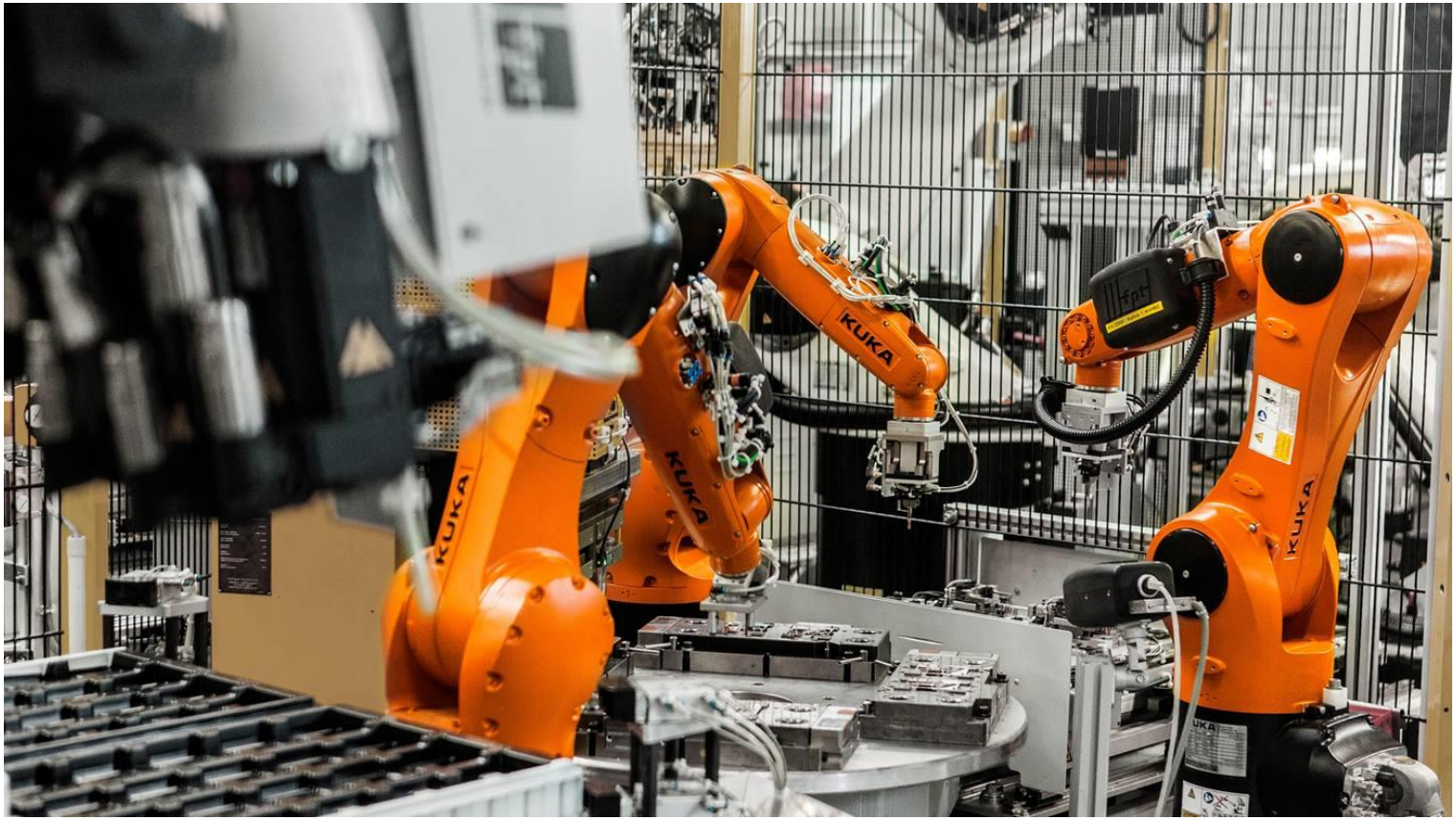
- Systems containing software components and mechanical or electronic parts that are interconnected via network
- Interact with the real, physical world
  → are subject to physical laws
  → have requirements w.r.t (real) time
- Examples
  - Industry robots
    - Production line in the smart factory
    - Reconfigurable production cell of a smart factory
  - Modern (autonomous) vehicles
    - Steer/fly by wire
    - Autopilots of any kind

# Industry Robots in a Smart Factory


Industry robots made by Kuka

Time-critical communication when handing over work pieces.

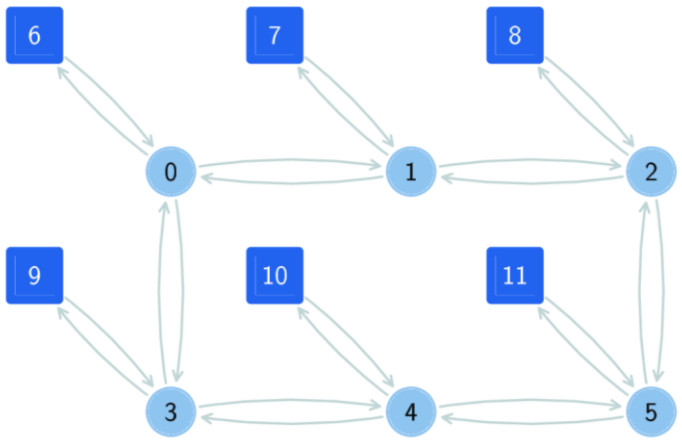
# Reconfigurable Production Cell

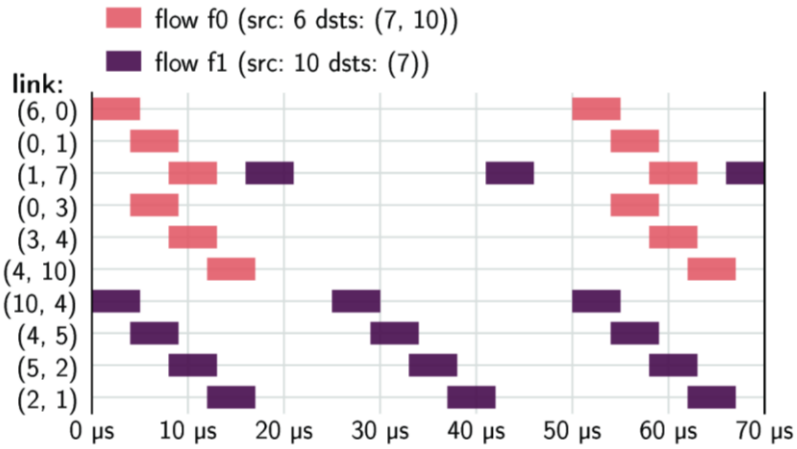



Industry robots made by Kuka

Flexible communication in case of task changes.

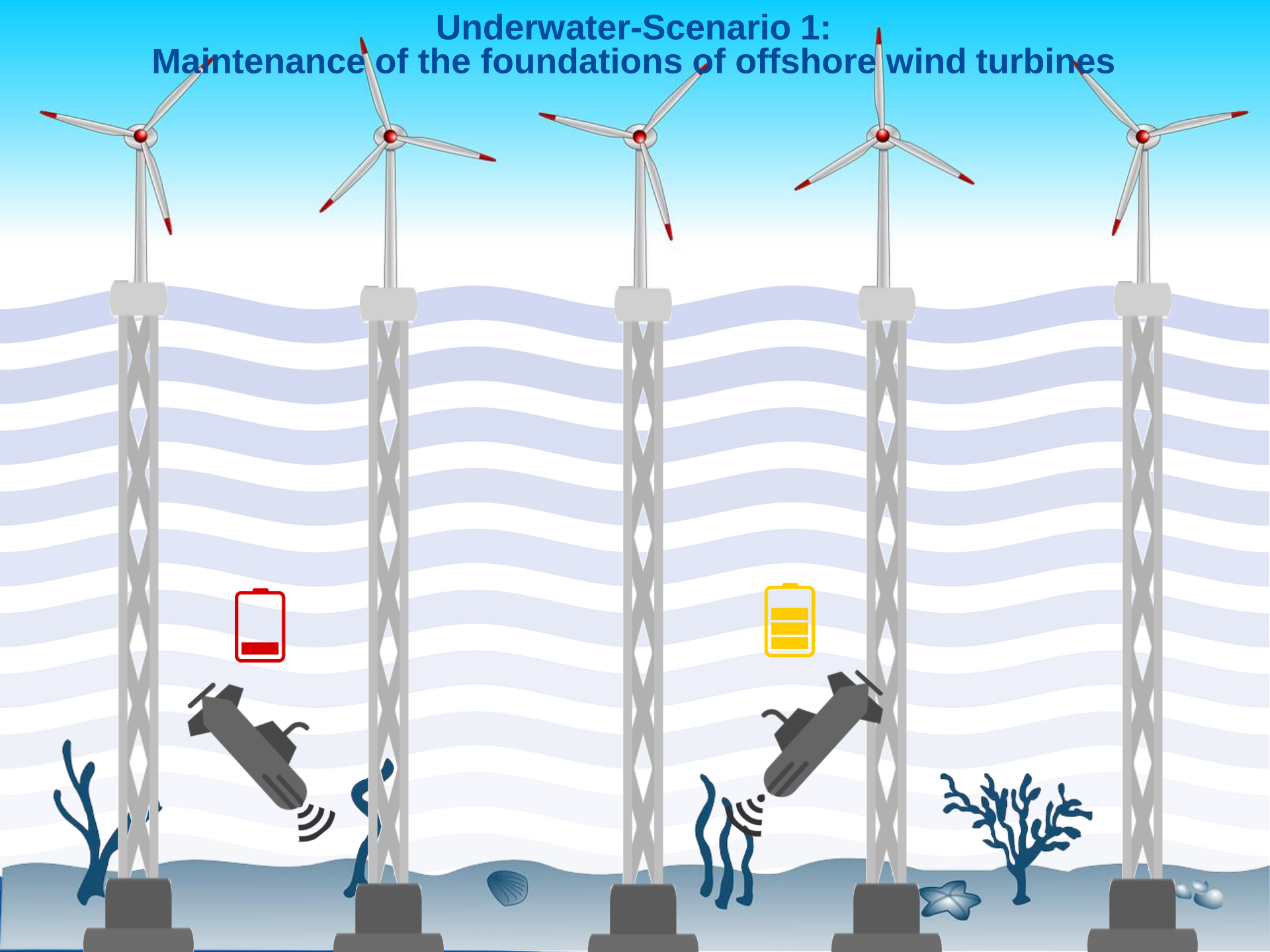
# Communication Schedule



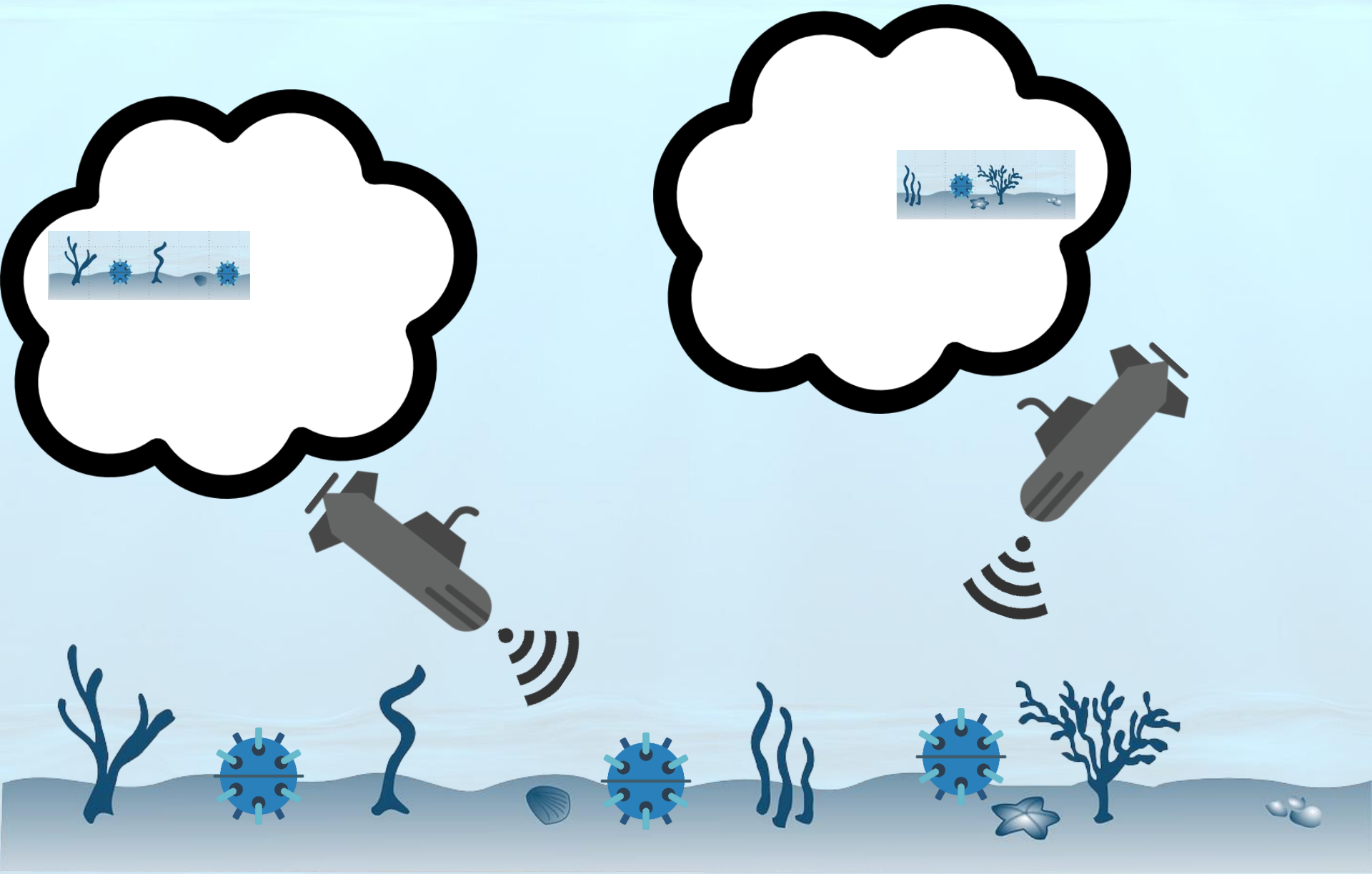




- Streams
  - From node 6 to nodes 7 and 10 (multicast)
  - From node 10 to node 7
- Schedule
  - Determines exactly when which packet is sent over which link
  - Has to be always without conflicts → provable correct
  - Needs to be adapted whenever communication pattern changes
  - Additional traffic of lesser importance is possible

# Underwater-Scenario 1:
# Maintenance of the foundations of offshore wind turbines



# Underwater-Scenario 2:
# Clearance of Unexploded Ordnance (UXO) from World War II



# Projects and Collaborations

- Realtime publish/subscribe communication
  - Part of a DFG project (VHR, AVA und IMD)
  - Planning of flexible communication patterns and reservation of required time slots on communication links
  - Formal models and methods for scheduling
  - Estimation of the worst case runtime for publishing and filtering (content-based if necessary) a notification
  - Application scenario within a smart factory
- Autonomous Underwater Vehicles (AUVs)
  - Cooperation with the Institute for the Protection of Maritime Infrastructures, Resilience Department of Maritime Systems, German Aerospace Center (DLR) Bremerhaven
  - Cooperative navigation of several AUVs
  - Limited Energy restricts movement and usage of sensors
  - Opportunistic communication via acoustic modems

# Tasks: Realtime Publish/Subscribe

- Simulation models for realtime communication (TSN standards)
  - TSN configuration (IEEE 802.1Qcc)
  - Time synchronization (IEEE 802.1AS)
  - Controlled timing (IEEE 802.1Qch)
  - Reliable communication (IEEE 802.1Qca, IEEE 802.1Qci)
- TSN controller (CUC and CNC)
  - Implementation of TSN configuration option (IEEE 802.1Qcc)
  - Based on Ryu framework for SDN controller
  - Integration of a trivial planning component
- Development and test platform for prototypes
  - Scripts for configuring TSN switches
  - Generators for test data
  - Management tools for different purposes

# Tasks: Realtime Communication Schedule

- Integer Linear Programming (ILP) model
  - Familiarize with formal modeling of optimization problems
  - Familiarize with programming an ILP solver (→ Python)
- Porting existing ILP model from Gurobi to CPLEX and PuLP
  - Document the steps for porting models
  - Evaluation of model complexity and solver runtime
- ILP models for flow migration
  - Development of new models to reschedule a part of an existing schedule
  - Migration of flows/streams to different time slots and/or different paths

# Tasks: Autonomous Underwater Vehicles

- Cooperative navigation of several AUVs
  - Implementation of motion models
  - Implementation of localization algorithms
- Energy consumption caused by motion and activated sensors
  - Implementation of models for energy consumption for movement and activated sensors
  - Implementation of models for energy consumption for image processing algorithms
- Opportunistic communication via acoustic modems
  - Implementation of realistic underwater communication
- Implementations using Simulator OMNeT++ and C++
  - Python for scripting and evaluation of simulation results

# Organizational Matters

- Up to three teams
  - Team A: Realtime publish/subscribe
    (probably more fine-grained distribution of tasks)
  - Team B: Realtime communication schedule (ILP)
    (only on Tuesdays 9-11)
  - Team C: Autonomous Underwater Vehicles (AUVs)
    (small team)
- Design methodology
  - Agile development
  - Three milestones w.r.t. design, implementation, documentation

Type and size/scale of tasks depends on number and interests of participants!

# Registration and Contact

- Enrolement in respective Stud.IP course

1. 23850 (Vorlesung) KSWS: Verteiltes Hochleistungsrechnen
2. 23848 (Vorlesung) Neueste Entwicklungen der Informatik (Verteiltes Hochleistungsrechnen)
3. 23851 (Projekt) Projekt: Verteiltes Hochleistungsrechnen

- Questions via email to Peter Danielis and Helge Parzyjegla
  - peter.danielis@uni-rostock.de
  - helge.parzyjegla@uni-rostock.de