



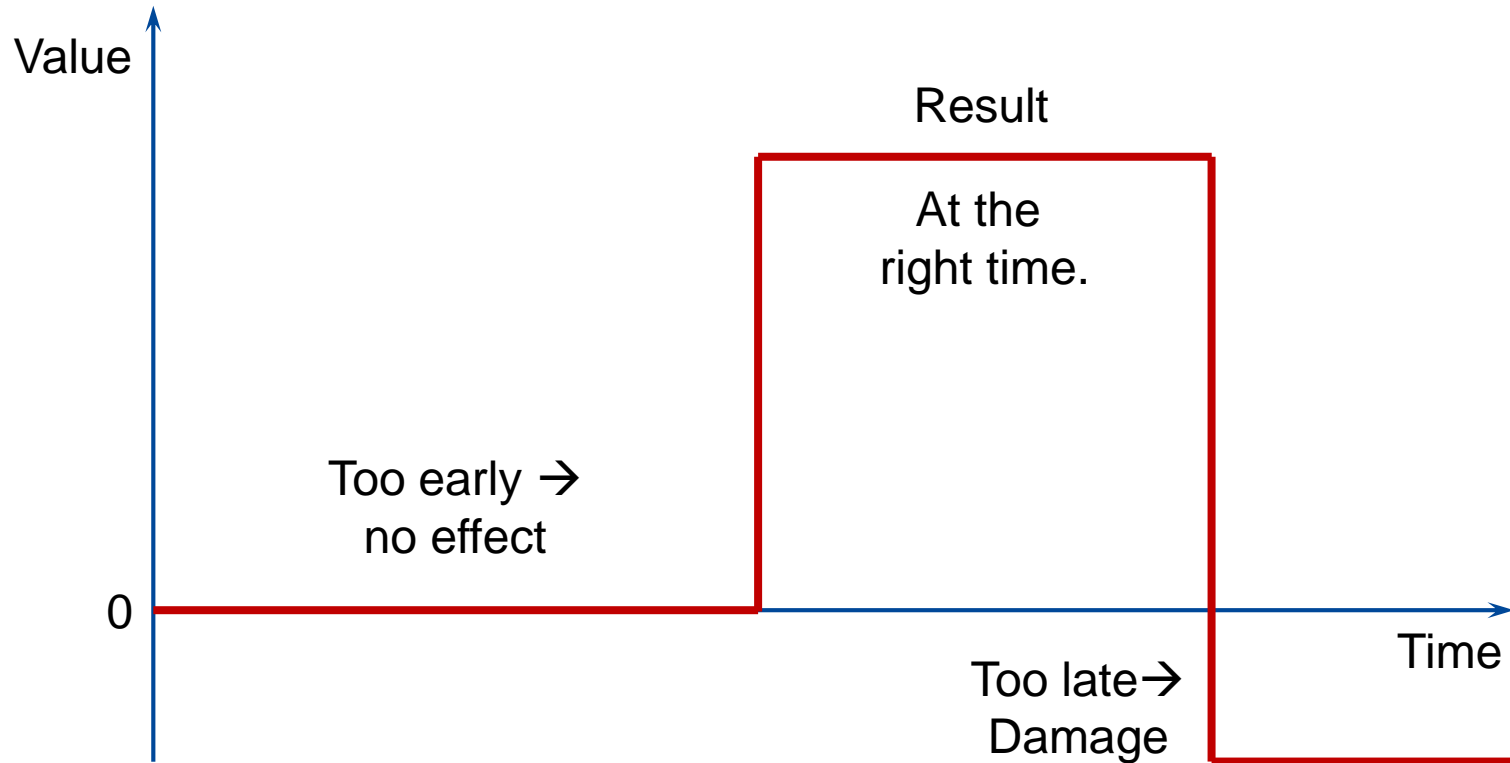
Realtime Communication for Cyber-Physical Systems

NEidl / Projekt CSI

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What is Realtime (Echtzeit)?



Not necessarily fast, but **predictable!**
→ Do the **right thing** at the **right time**.

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

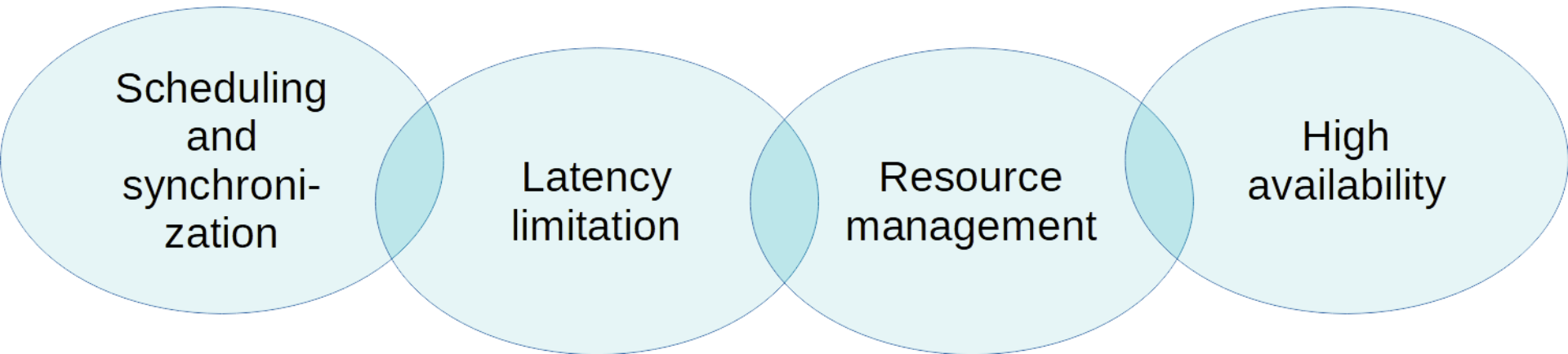


Industry robots made by Kuka

Flexible communication in case of task changes.

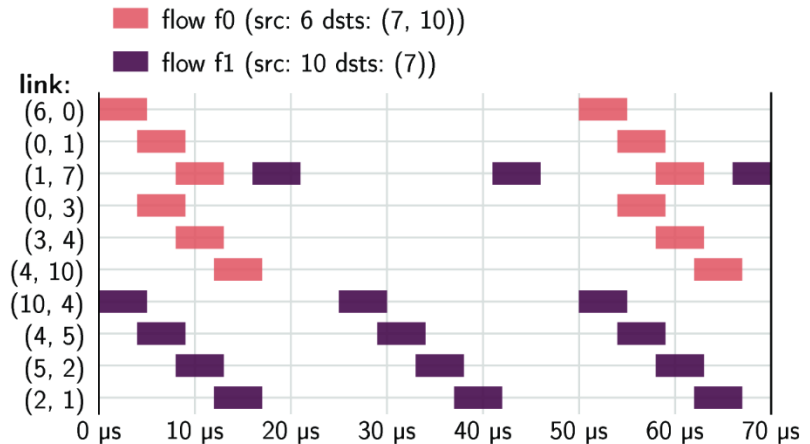
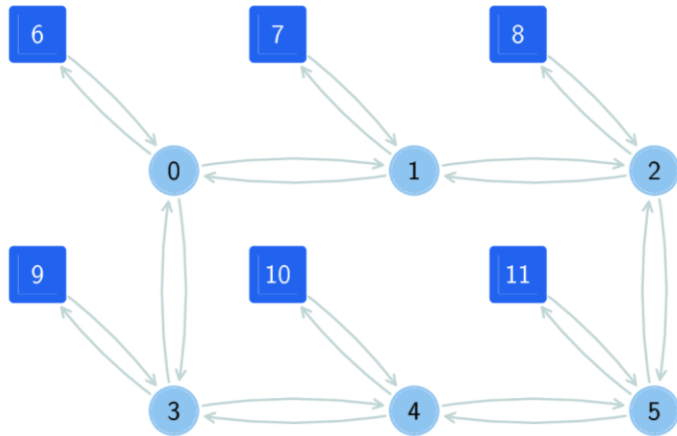
Realtime Ethernet: Time-Sensitive Networking

- > Wired communication according to IEEE 802.1Q
- > Extension of Ethernet
- > Adaptation to ISO/OSI layer 2 (data link layer)
- > Modular principle



- > TSN networks must be configured: we need scheduling for this!

Communication Schedule



> Streams

- > From node 6 to nodes 7 and 10 (multicast)
- > From node 10 to node 7

> Schedule

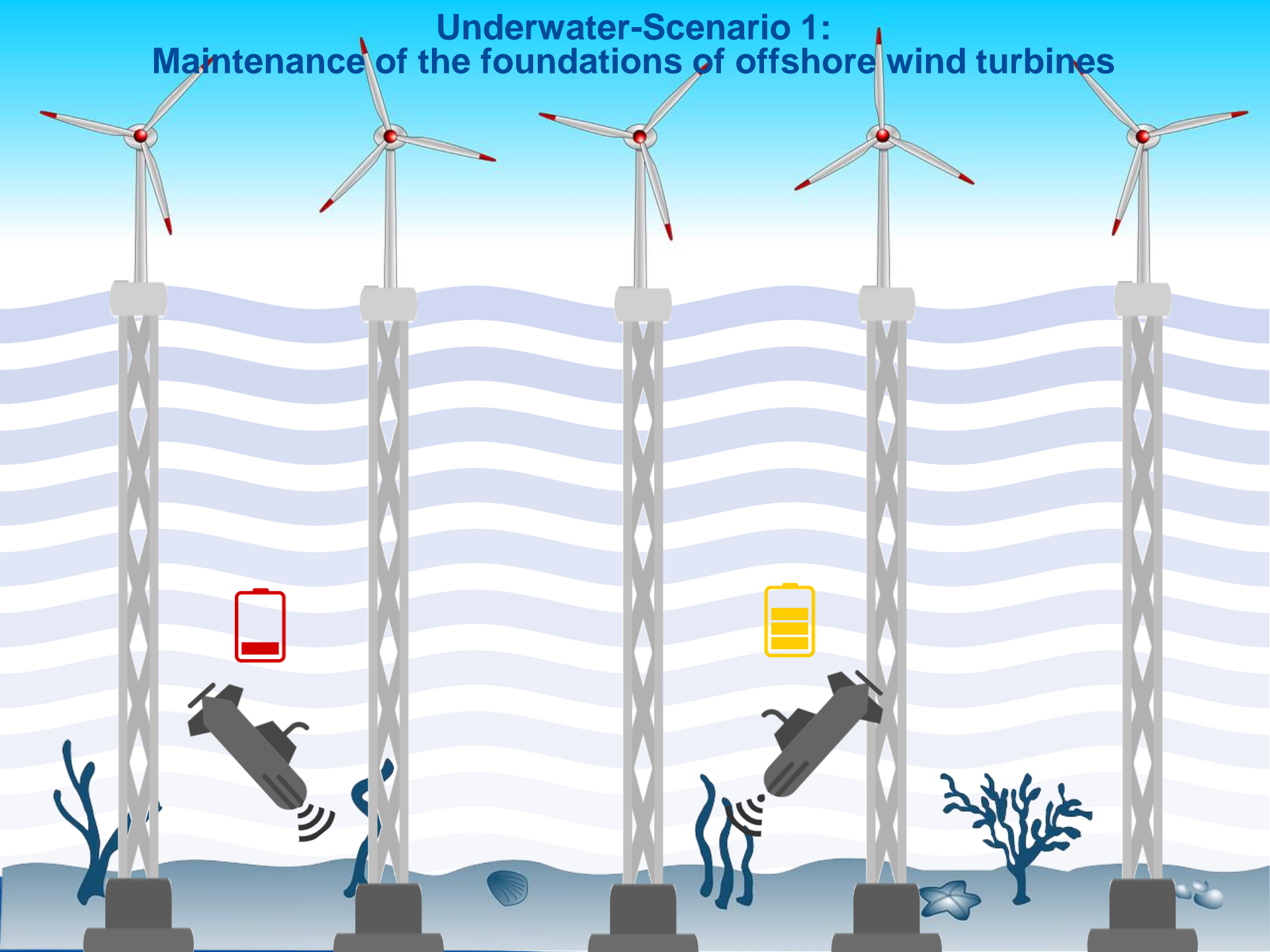
- > Determines exactly when which packet is sent over which link
- > Has to be always without conflicts \rightarrow provable correct
- > Needs to be adapted whenever communication pattern changes
- > Additional traffic of lesser importance is possible

Wireless Communication

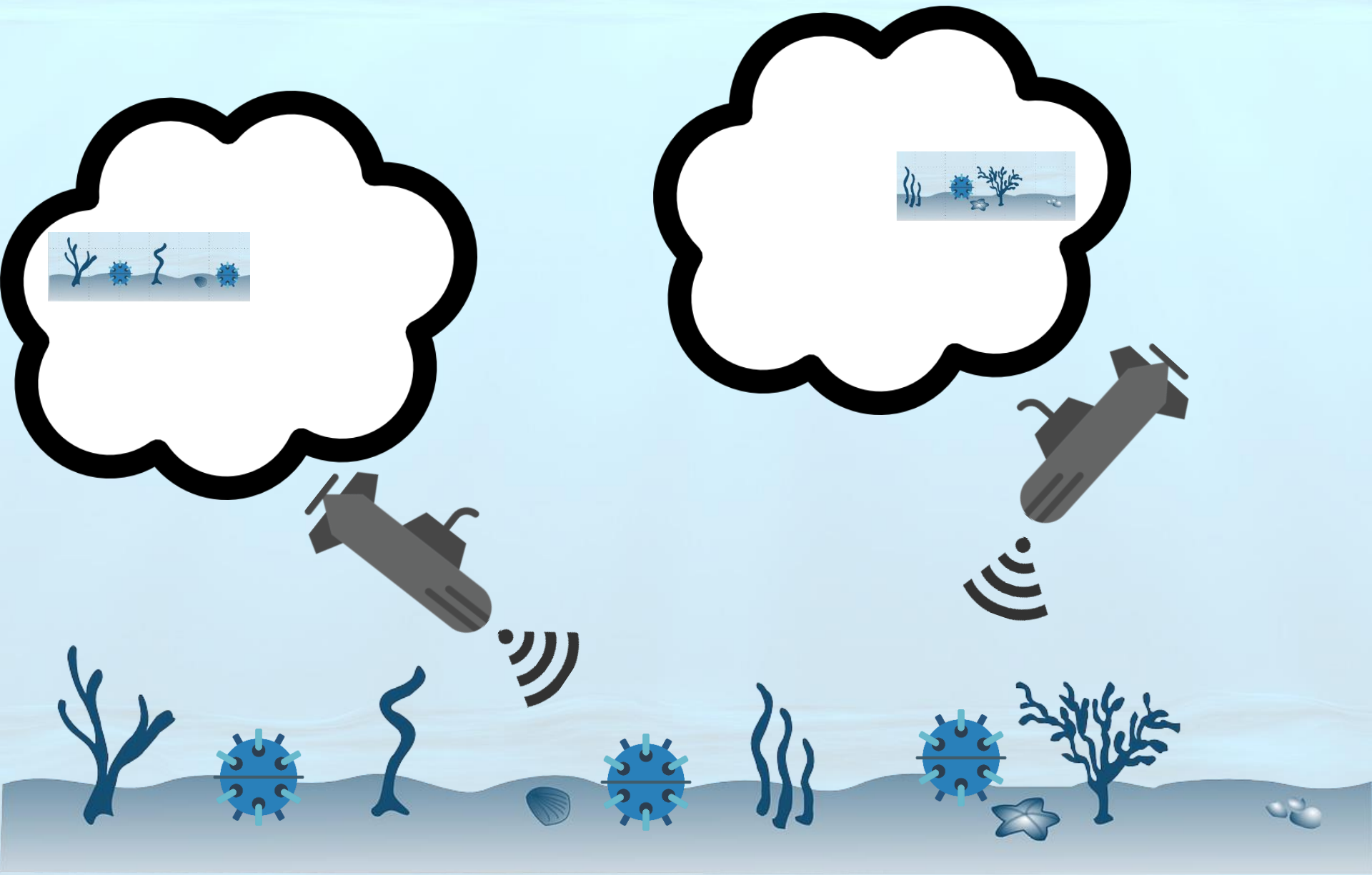
- > Communication diversity in CPS
 - > Combination of wired stability and wireless flexibility to meet various application requirements
- > 5G as a key factor
 - > Ultra-low-latency and highly reliable wireless communication for mobile and dynamic CPS applications
- > Challenges posed by 5G
 - > Security risks, interoperability issues and energy efficiency as key topics for integration in CPS



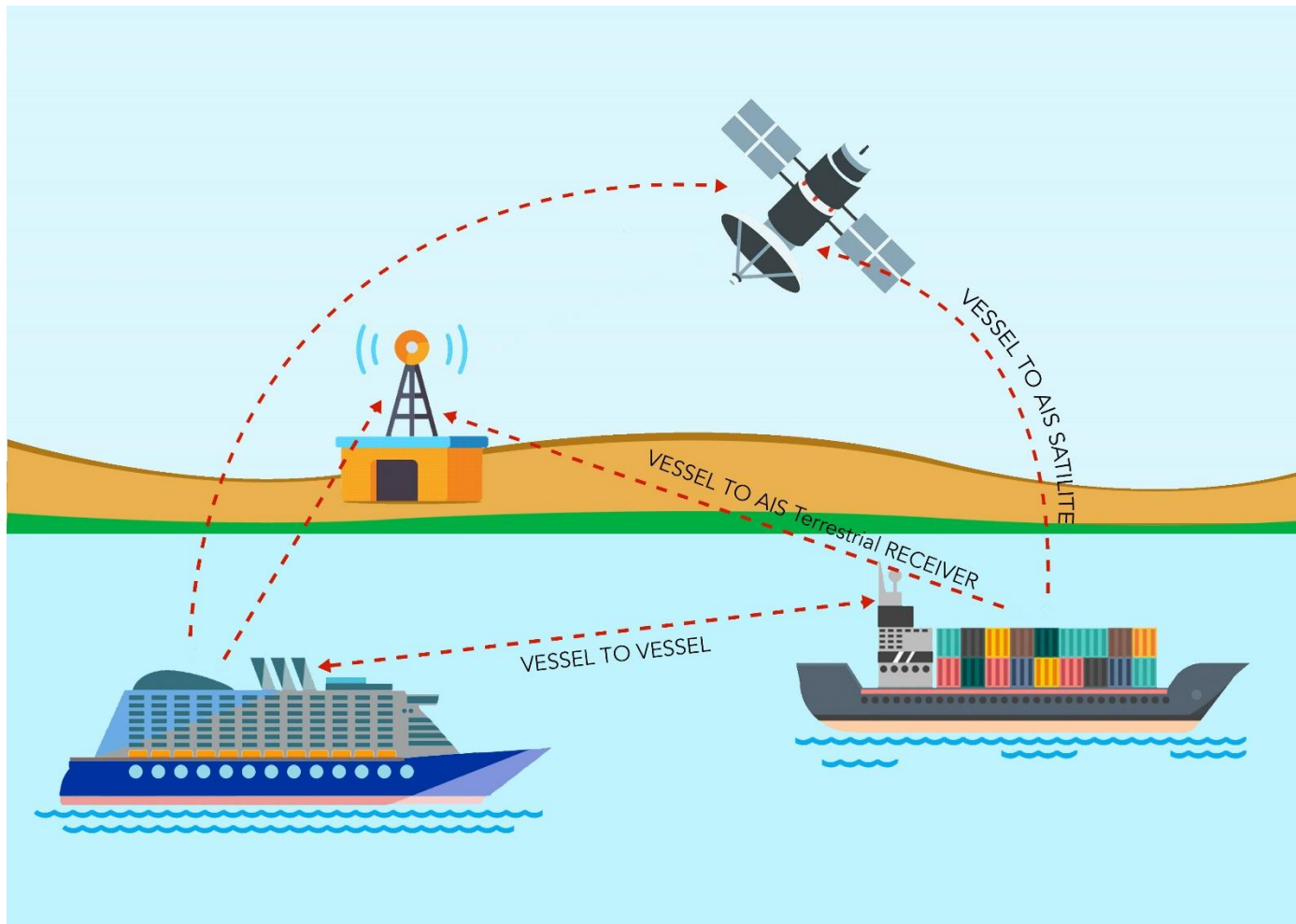
Underwater-Scenario 1: Maintenance of the foundations of offshore wind turbines



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



Automatic Identification System (AIS)



Radio system to exchange navigation and ship data.

Projects and Collaborations

- > Realtime publish/subscribe communication
 - > Part of a DFG project
 - > 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: TSN Standards in OMNeT++

- > OMNeT++ framework INET includes simulation models for TSN standards
- > INET offers various TSN showcases to demonstrate the functionality of these standards
- > Task TSN.1: Showcases
 - > Commissioning of a showcase
 - > Reproduction of the showcase in your own use case
 - > Integration of missing TSN features into the simulation models if necessary
- > Task TSN.2: Tutorial
 - > Design a tutorial for a scientific conference
 - > Theoretical explanation and practical demonstration of a TSN standard

Tasks: 5G Communication in OMNeT++

- > Simu5G: Simulator for 5G NR and LTE/LTE-A networks, integrated in OMNeT++ and INET
- > Functions: Simulation of the data plane in 5G RAN and core network with FDD/TDD, heterogeneous gNBs, D2D communication and dual connectivity
- > Task 5G.1: Showcases
 - > Commissioning of Simu5G
 - > Analysis and testing of Simu5G
 - > Development of own showcases

Tasks: Autonomous Vehicles in OMNeT++

- > Use of an OMNeT++ simulation model for autonomous vehicles (AVs)
- > Simulation model has a modular structure and can be easily adapted
- > Task AV.1: Energy model
 - > Commissioning of the simulation model in OMNeT++
 - > Analysis of various energy models and consumption curves
 - > Integration of an energy model
- > Task AV.2: Cooperative missions
 - > Formation of several AUVs
 - > Mapping of the seabed
 - > Cooperative hunting

Tasks: AIS Data Processing and Analysis

- > AIS data processing pipeline
 - > Decoding of AIS messages
 - > Check for completeness and transmission errors
 - > Elimination of duplicate messages
- > Storage and retrieval of AIS data
 - > Compact storage format vs. fast retrieval
 - > Fast processing of common queries
- > Data analysis
 - > Plausibility check
 - > Identification of suspicious behavior
- > Programming in Java and/or Python
 - > Deployment of relevant middleware platforms

Organizational Matters

- > Weekly meeting on **Thursdays** at **11:00 am** in **R 201 (AE22)**
- > Up to two teams
 - > Team A: TSN, 5G, and AUVs (Peter)
(probably more fine-grained distribution of tasks)
 - > Team B: TSN Linux Host (Helge)
- > 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

> Enrolment in respective Stud.IP course

1.  23848 Lecture: Recent Development in Computer Science (NEdl) : AVA
2.  23897 Integrierte Lehrveranstaltung: Project CSI : AVA

> Questions via email to Peter Danielis and Helge Parzyjegl

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