Large Scale Time Synchronization of Measurement Signals in the Experimental Wind Farm WiValdi

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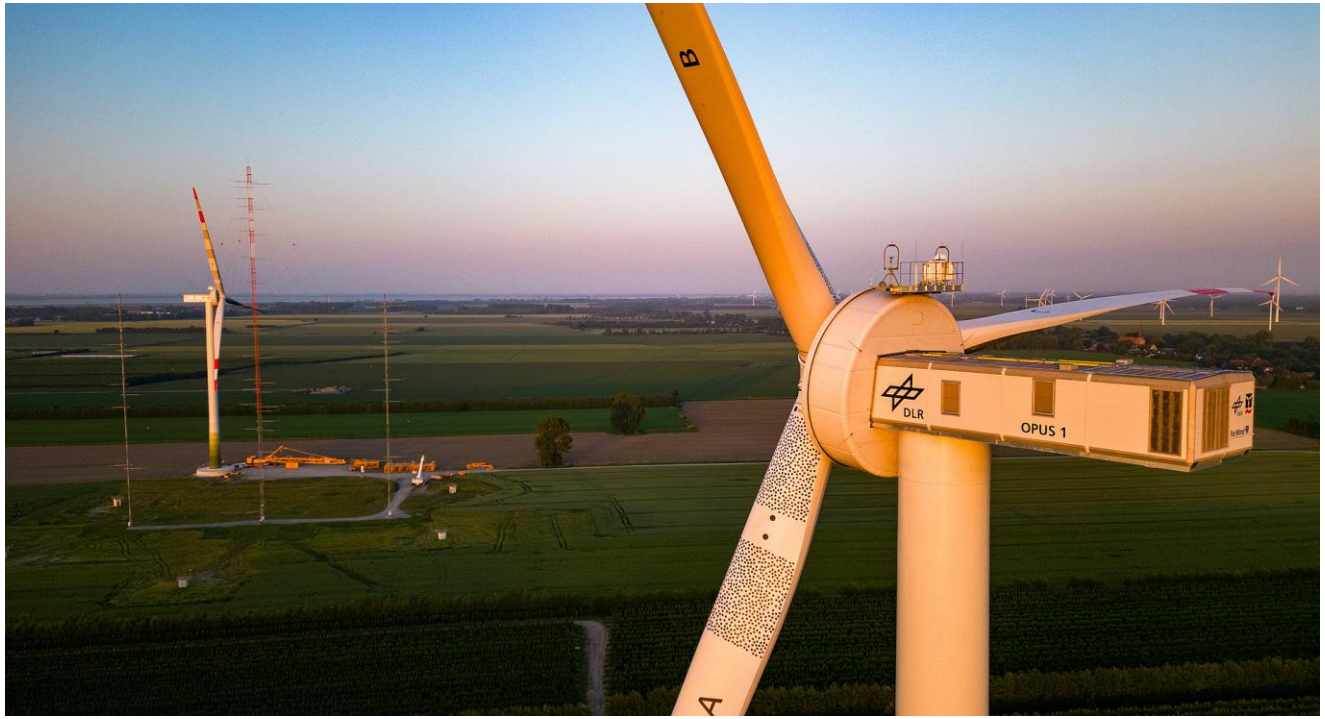
Research Alliance Wind Energy

DLR

Research Wind Farm WiValdi
Background

- Two state-of-the-art commercial wind turbines (150m height) in northern Germany
- Four meteorological masts
- Control center with grandmaster clock
- Central Data Management System for all experimental sensors



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https://windenergy-researchfarm.com/

Research Wind Farm WiValdi
Turbine Setup

- Turbine type: 4.2MW Enercon E-115 EP3
- Next Generation Control System
- Access to turbine controller data
- Wake-flow examination

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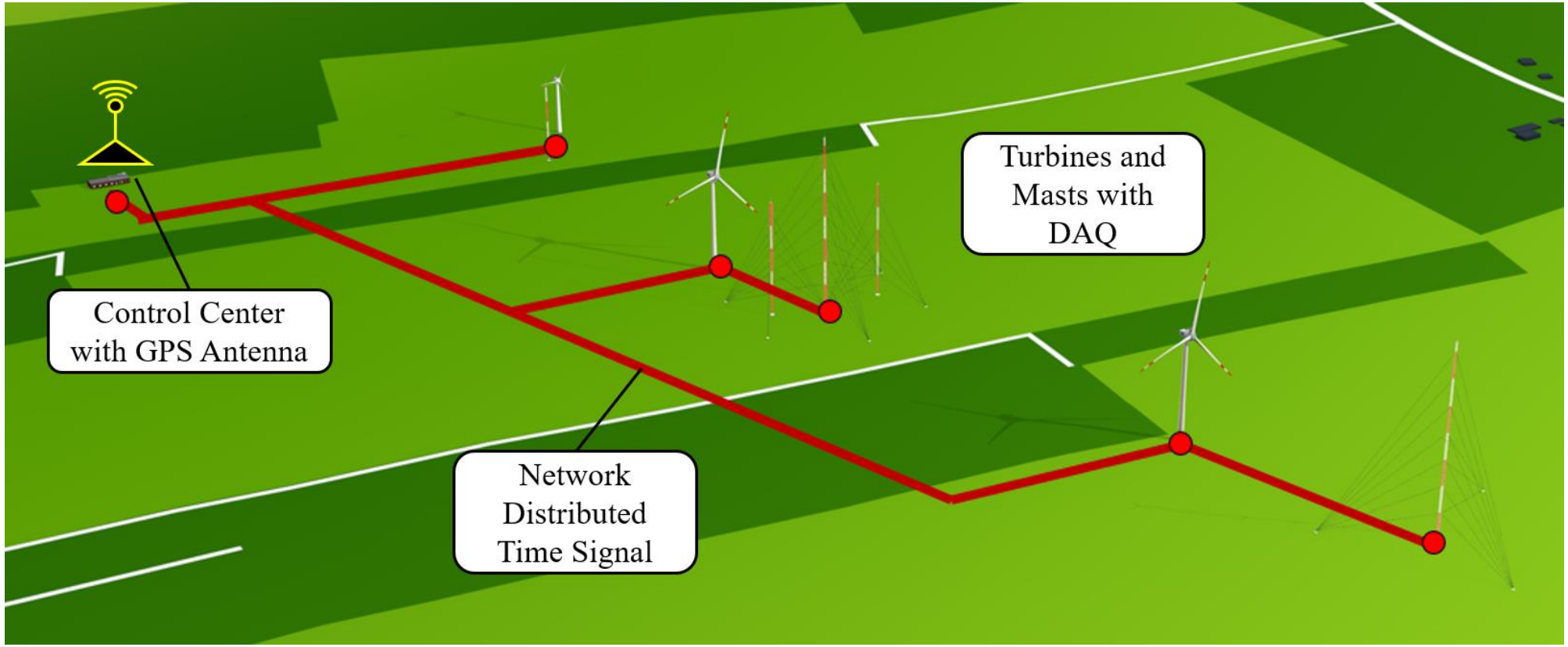
Research Wind Farm WiValdi
Research Setup

- Sensing equipment installed in all sections of the turbines and the meteorological masts
- Accurate record of all sensor data:
  - Near real-time data availability and minimal coverage losses
  - Highly synchronized time-stamps, with low delay

Implementation

- Precision Time Protocol v2: Difference of <50 ns between device clocks
- Optical network connections, where feasible

Data Infrastructure
Experimental System



- Experimental devices controlled from Control Center server hub
- Decentralized data collection with DAQs in all wind farm components

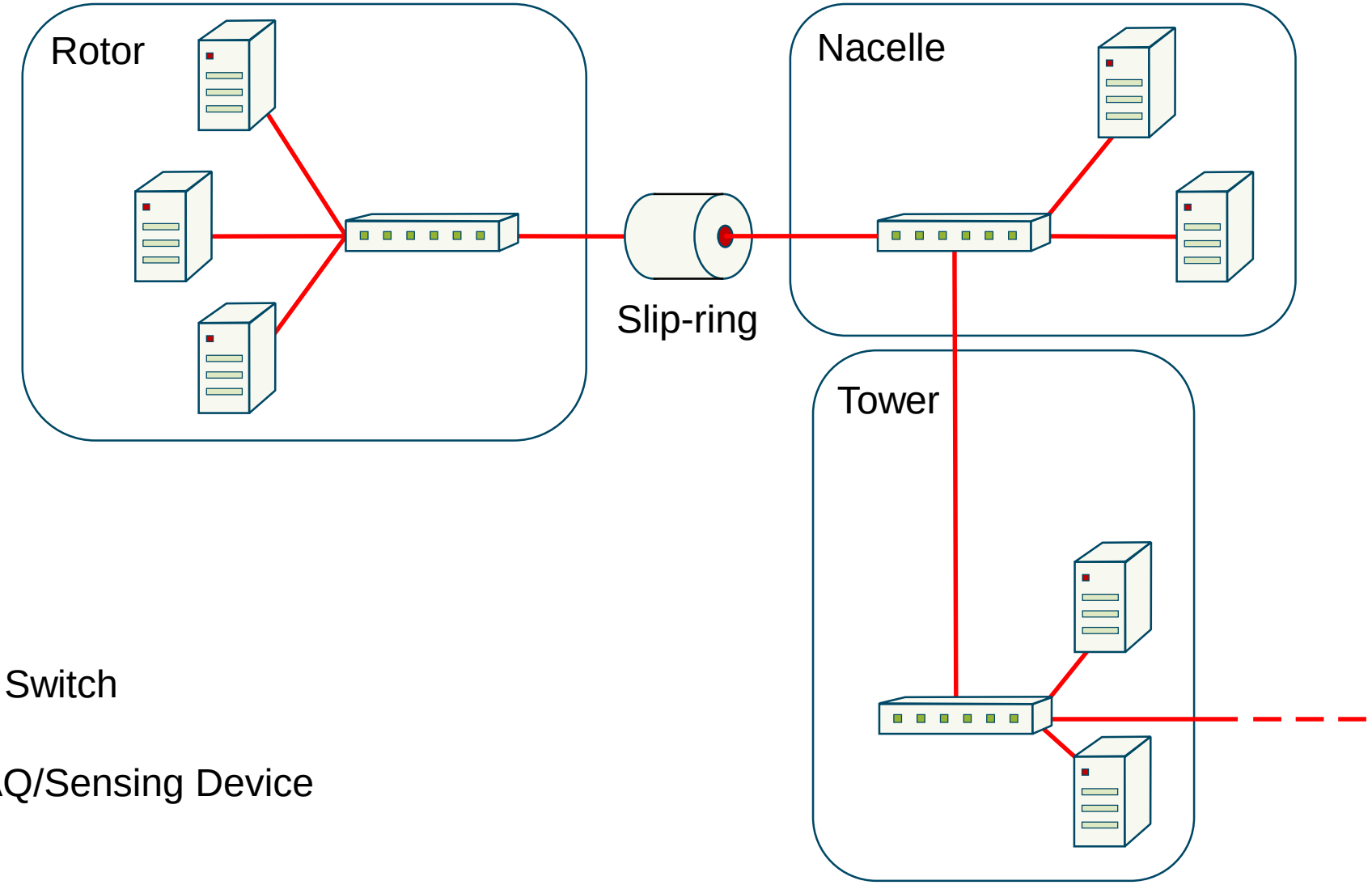
Data Infrastructure
Network Design

Research system design process:

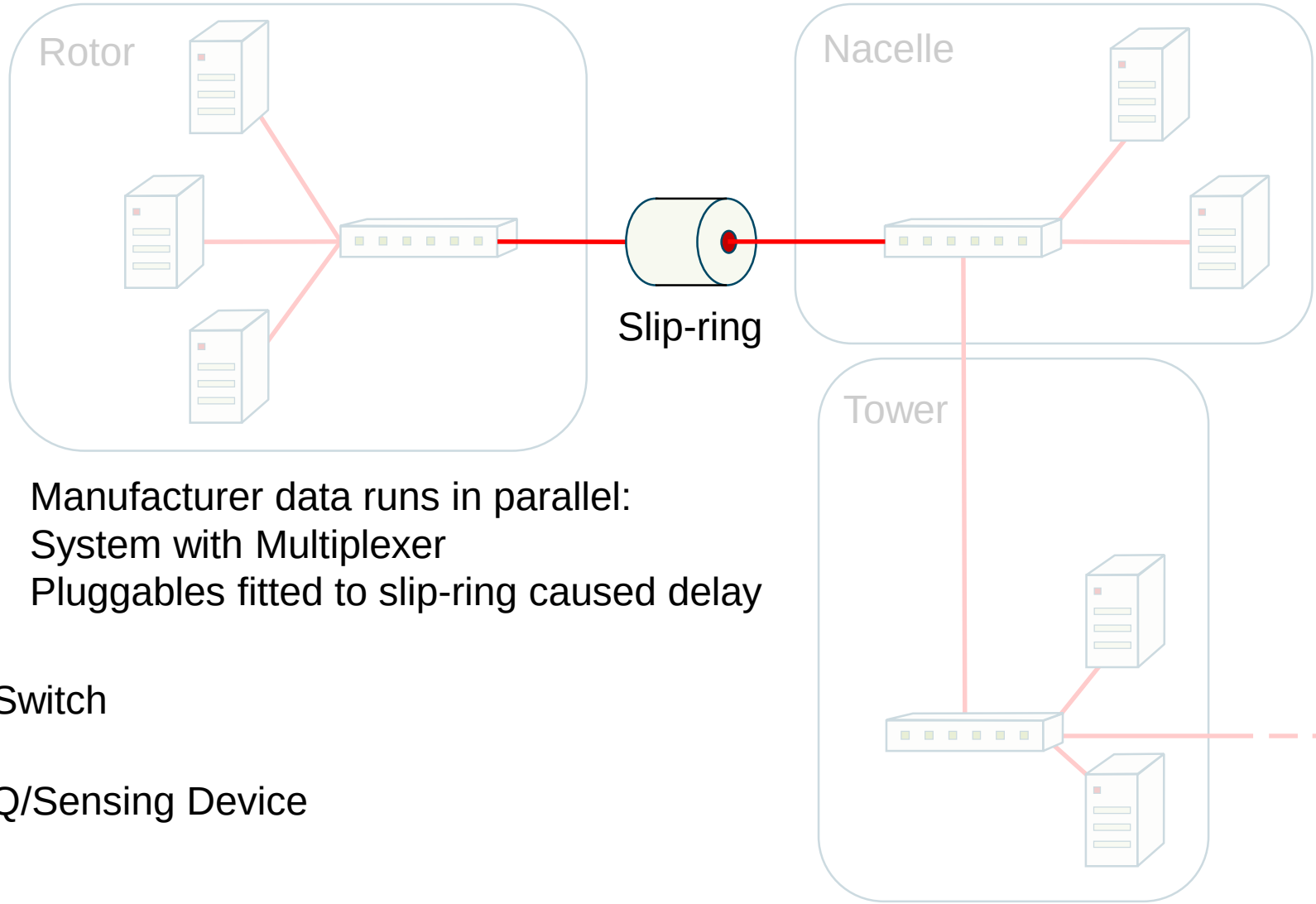
Consequences:

- Fragile elements within the network, due to research requirements
- Sensing equipment was selected first, network had to be designed around this
- Compatibility with time protocol was secondary requirement

Data Infrastructure
Implementation: Wind Turbine



Data Infrastructure
Implementation Issues: Examples

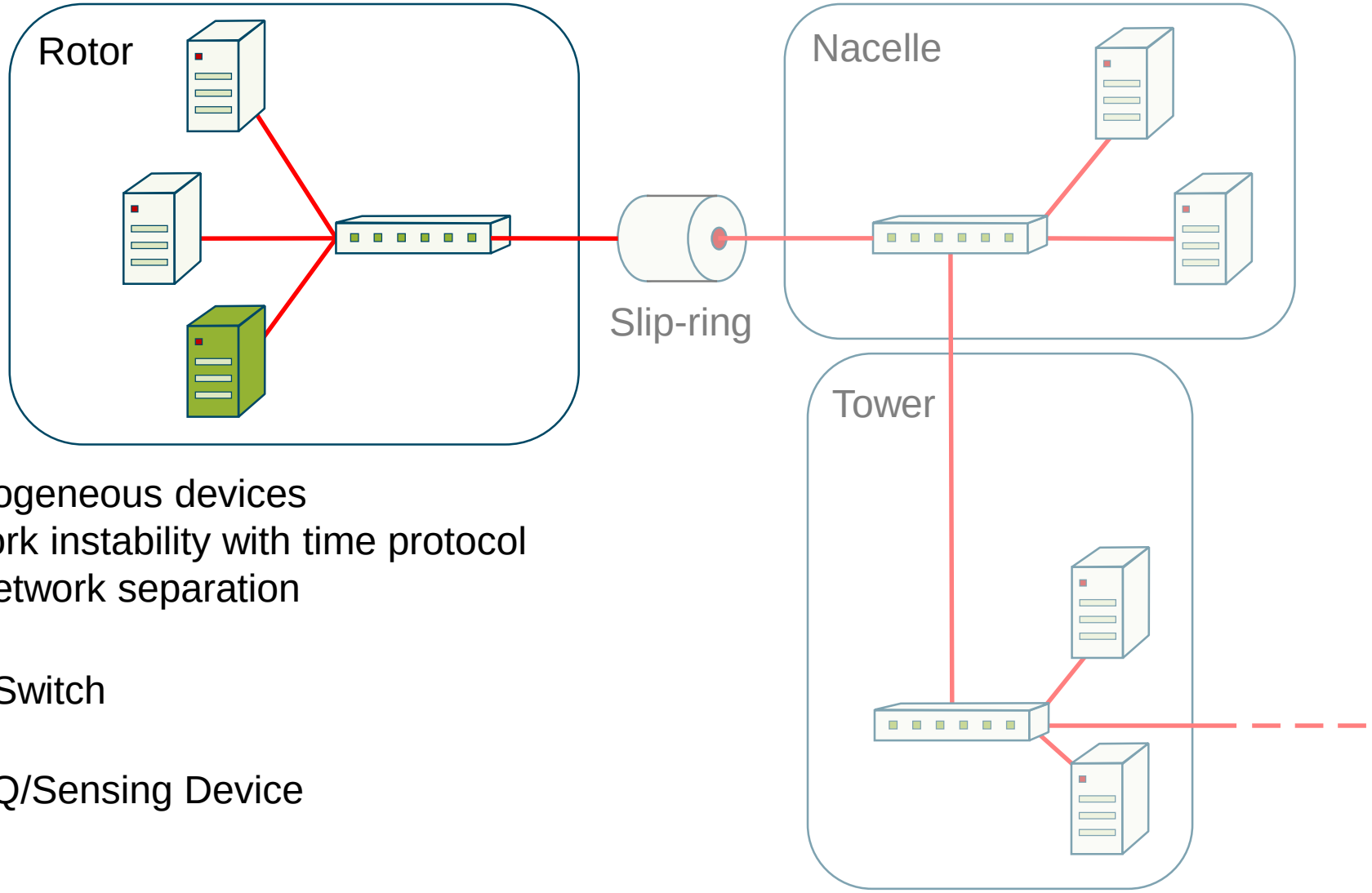


- Manufacturer data runs in parallel:
  System with Multiplexer
- Pluggables fitted to slip-ring caused delay


: Switch


: DAQ/Sensing Device

Data Infrastructure
Implementation Issues: Examples

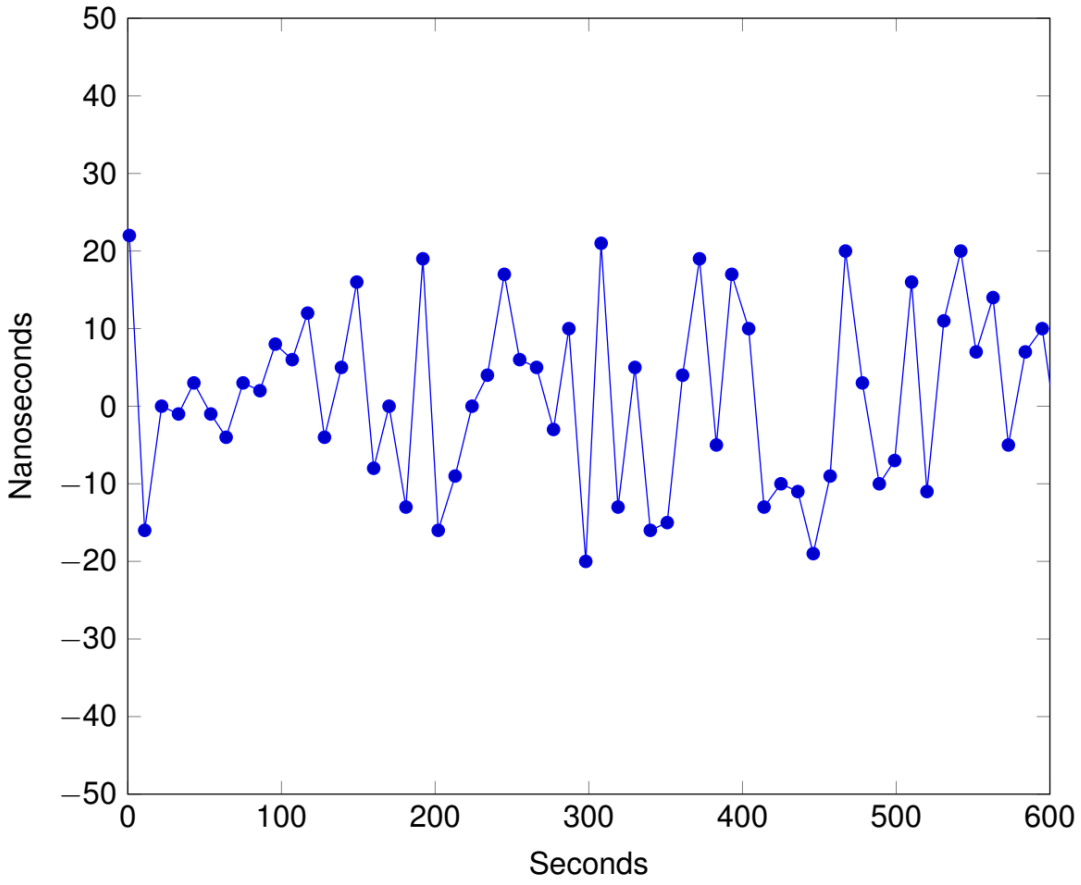


- Heterogeneous devices
- Network instability with time protocol
- Fix: network separation

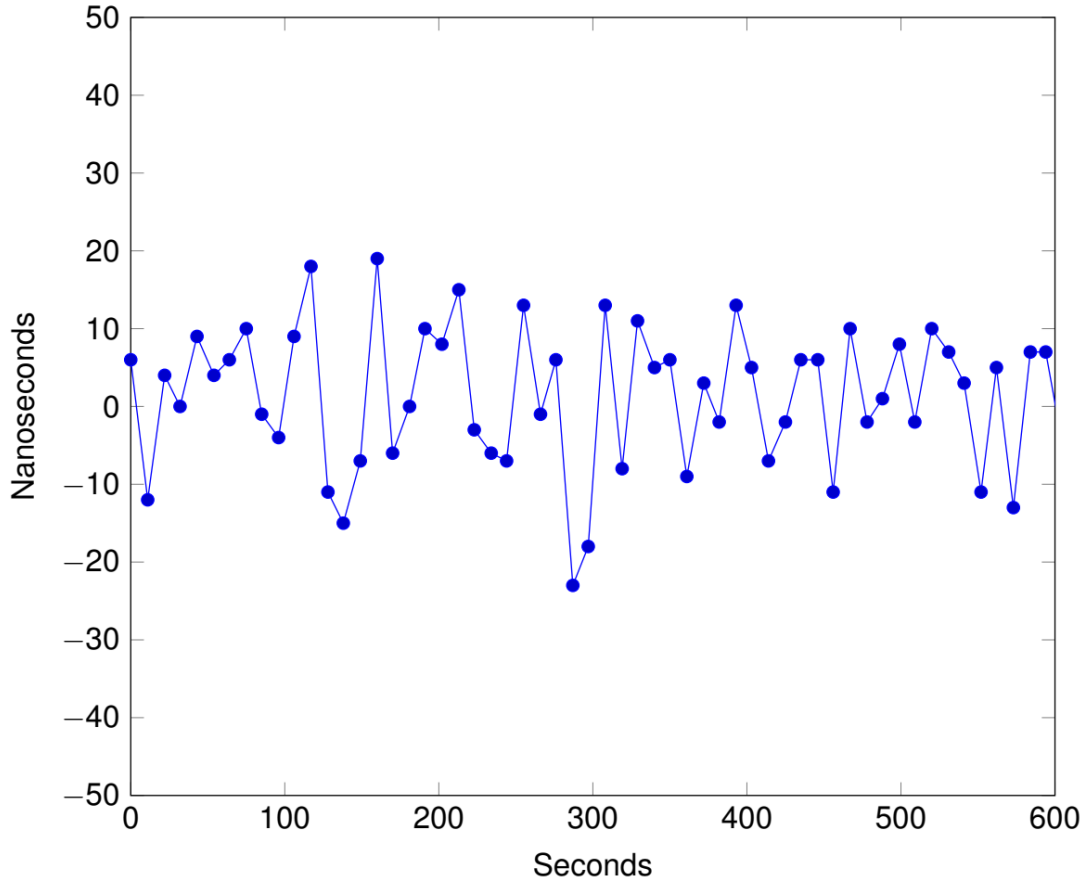
: Switch

: DAQ/Sensing Device

Time Synchronization
Switches: Time Synchronization Discrepancy



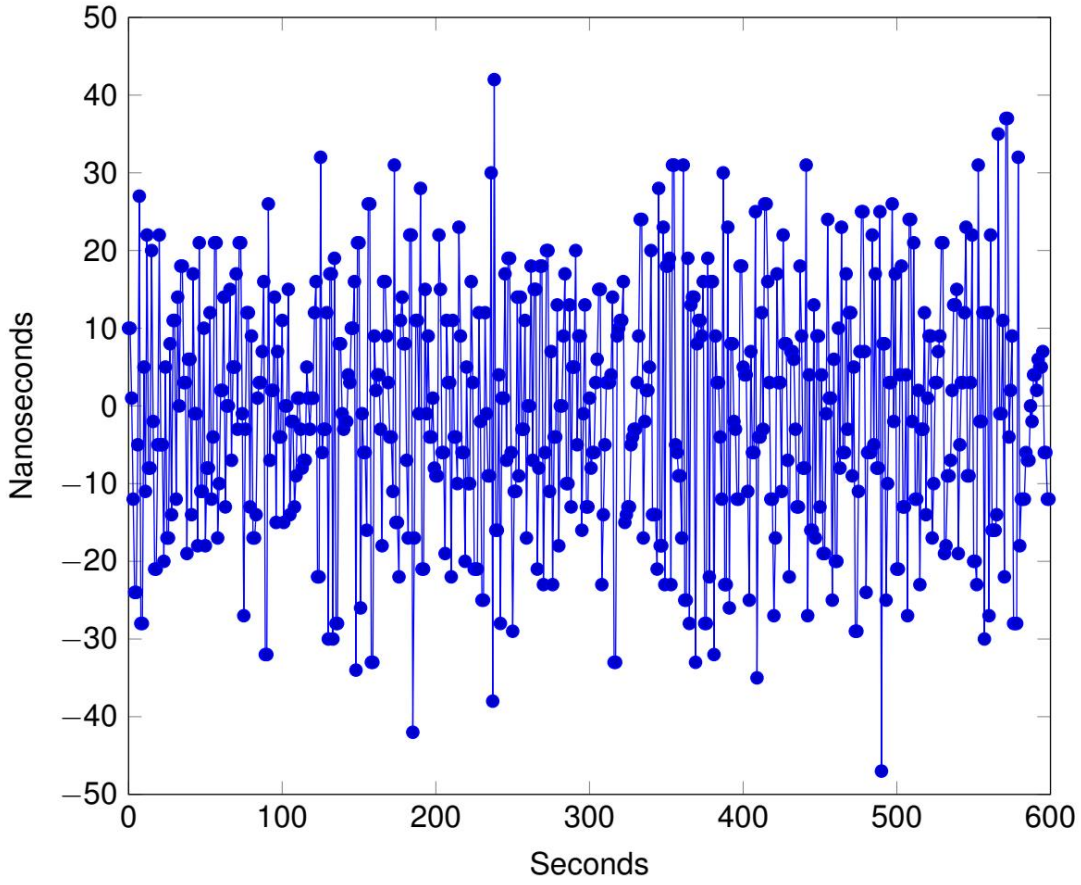
WT1 Nacelle Switch



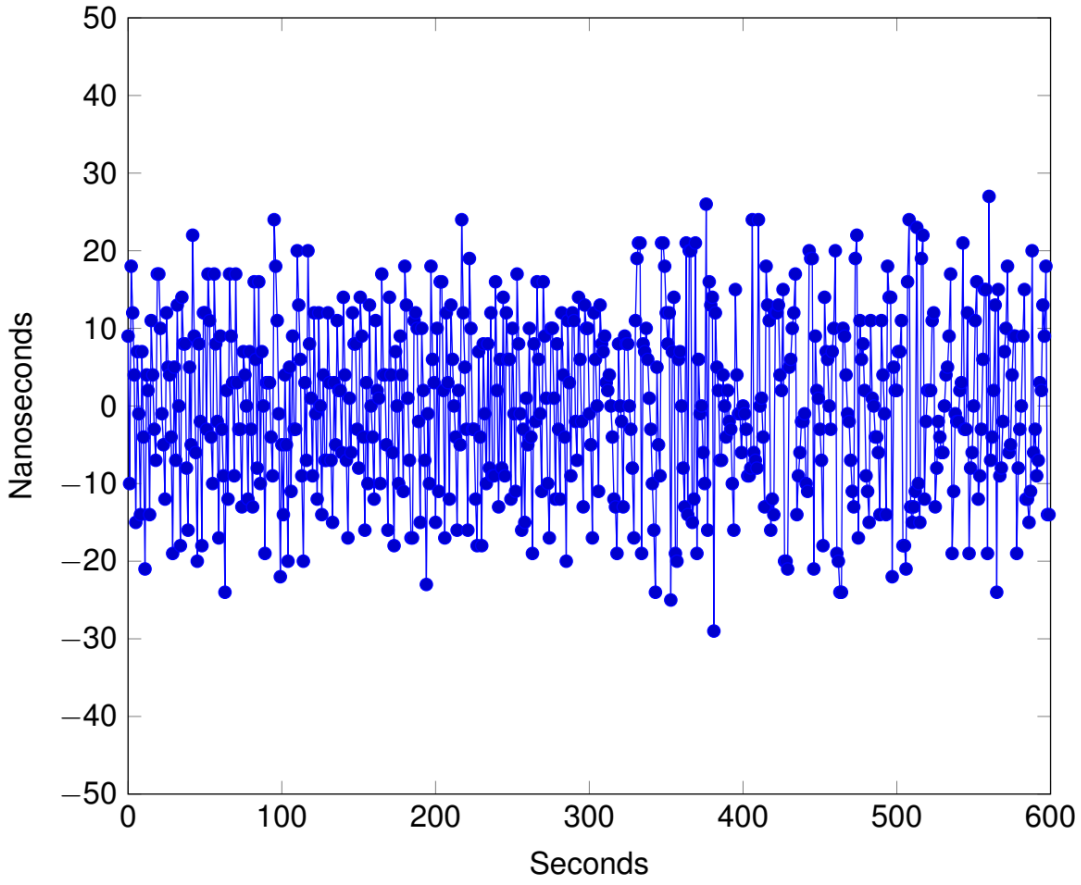
Meas. Mast Switch

Time Synchronization

Network Devices: Time Synchronization Discrepancy



WT1 Tower DAQ



Meas. Mast DAQ

Conclusion

- A highly accurate time protocol (PTPv2) was set up for the wind farm WiValdi.
- Heterogeneous network devices and research requirement priorities caused issues in testing and operation.
- First look at time signal discrepancy; in-depth analysis to follow.

References (for full titles, see Abstract):

[1] Berg and Robertson, 1998; [2] Polonelli, et al., 2023; [3] Shankarkumar, et al., 2017; [4] Wildmann, et al., 2022

Acknowledgements

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