DISTRIBUTED INTELLIGENCE FOR CLOUD-BASED INDUSTRIAL APPLICATIONS: A VISION INSPECTION USE CASE

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Fraunhofer HHI

OUTLINE

- Edge Cloud for Industrial Applications
- Vision Inspection Use-case
- Distributed Intelligence
  - Centralized Edge Cloud for Distributed Production Sites
  - Distributed ML for Communication-efficient and Privacy-Preserving Model Training
- Summary

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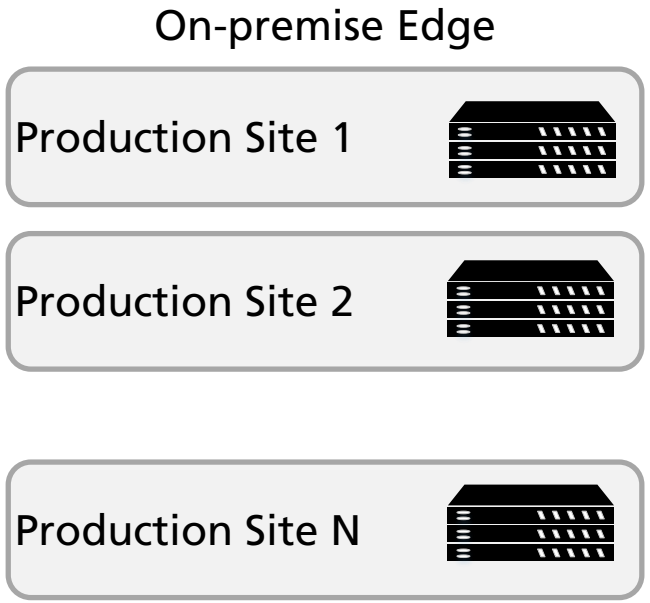
Edge Clouds for Industrial Applications

- **Private On-Premise Edge Clouds** are becoming increasingly important for real-time, secure, robust and low-latency communication in production sites.
  - a proven means for larger manufacturing companies
  - SMEs cannot afford such infrastructures due to the high acquisition costs



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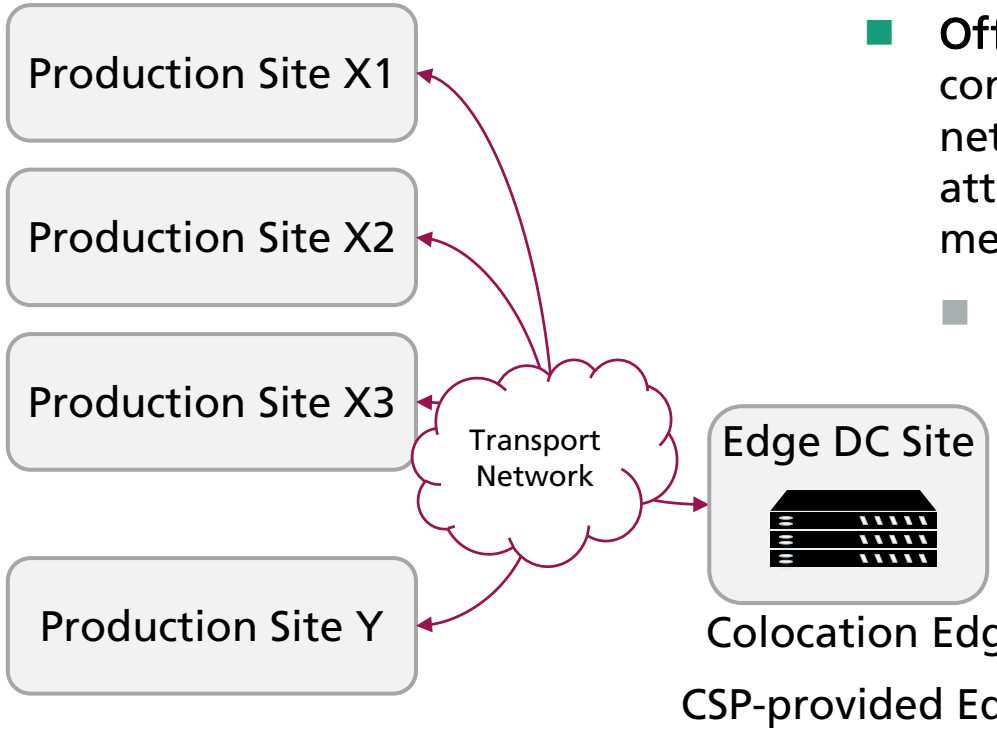
Edge Clouds for Industrial Applications



- **Off-Premise Private/Public Edge Cloud** connected via a real-time communication network offers new, economically highly attractive possibilities, especially for small and medium-sized manufacturing companies.
  - for real-time support of distributed, urban production sites, **a real-time, low-latency, broadband fibre optic infrastructure is required.**

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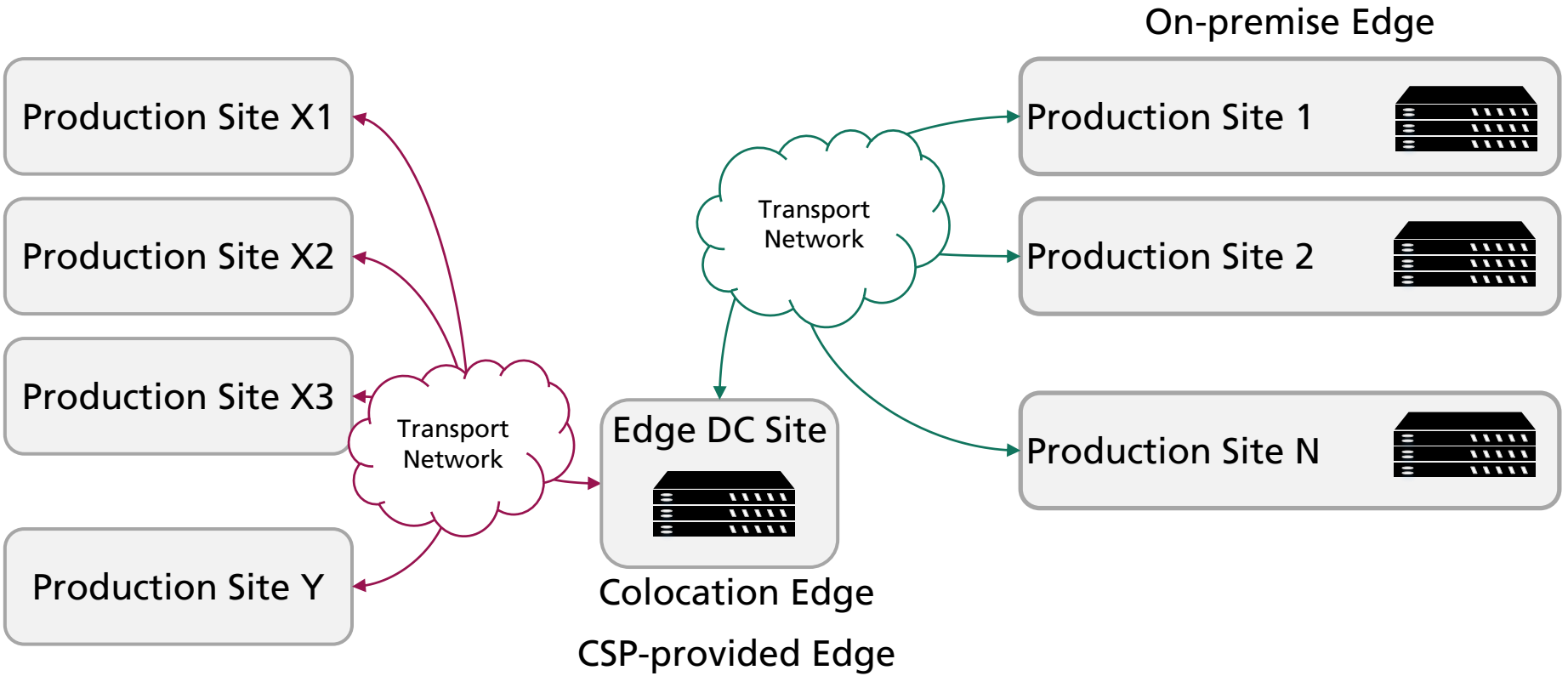

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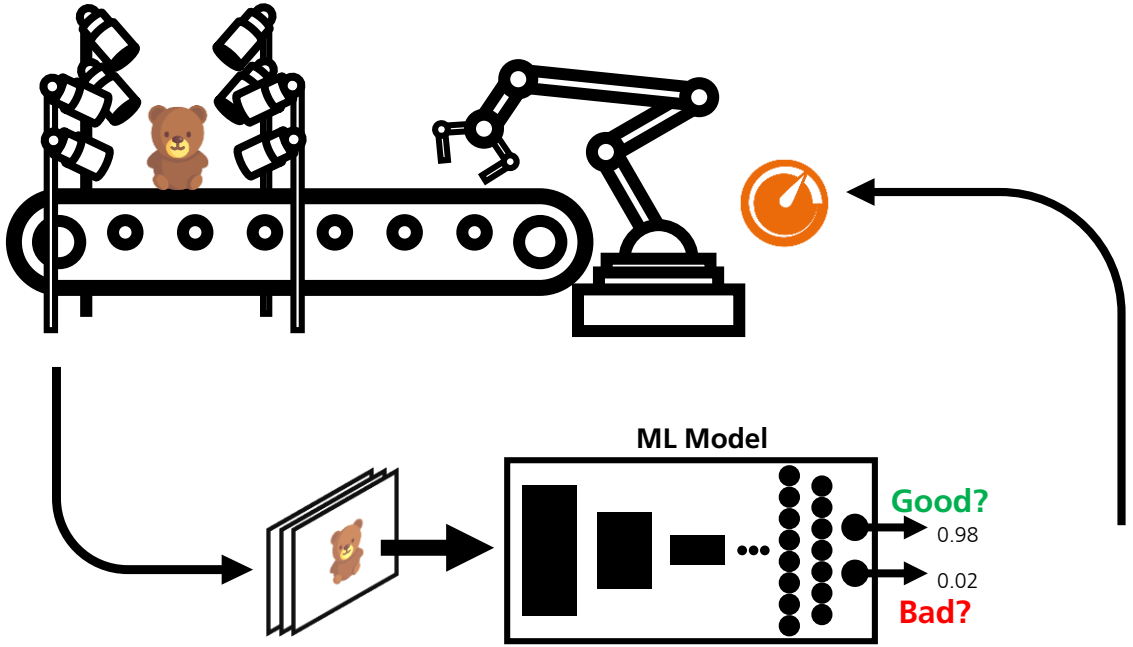
Vision Inspection Use-case

Sorting-out Defected Items Using Industrial Cameras and Robot Arms

- Industrial-grade video cameras monitor produced objects
- The video streams are processed by AI-assisted video analytics to assess the quality of the produced parts
- automatic quality control measures are taken on the factory shop floor, such as e.g. controlling robotic actors to handle defect parts.



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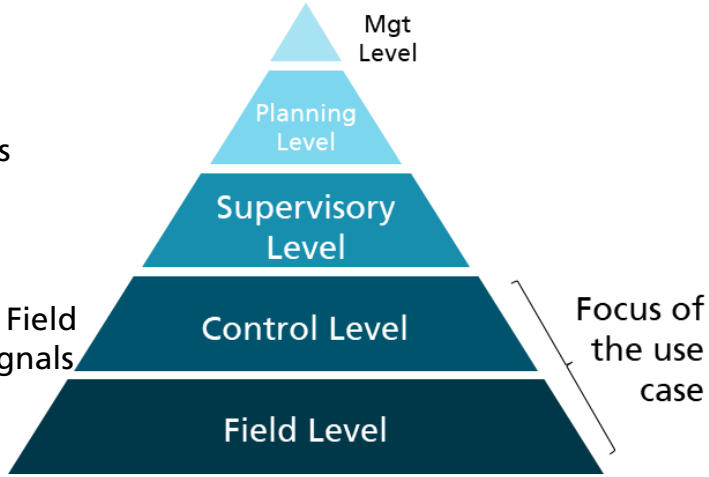
Industrial Automation: Vision Inspection Use-case

The Role of Edge Clouds

- Field Level
  - physical manufacturing equipment on the factory shop floor such as motors, actuators, video cameras and other sensors.
- Control Level
  - receives sensor and monitoring information from the devices in the Field Level. Based on that information, decisions are taken and control signals for the devices in the Field Level are generated, e.g. by using Programmable Logic Controllers (PLC).



- The current trend is towards virtualization of control functions in the form of virtual PLCs (vPLC) running in **edge/cloud environments**.
- vPLCs alleviates the need for costly and often proprietary solutions for local PLCs on the shop floor, where cooling, power consumption, space and environmental effects are critical issues.

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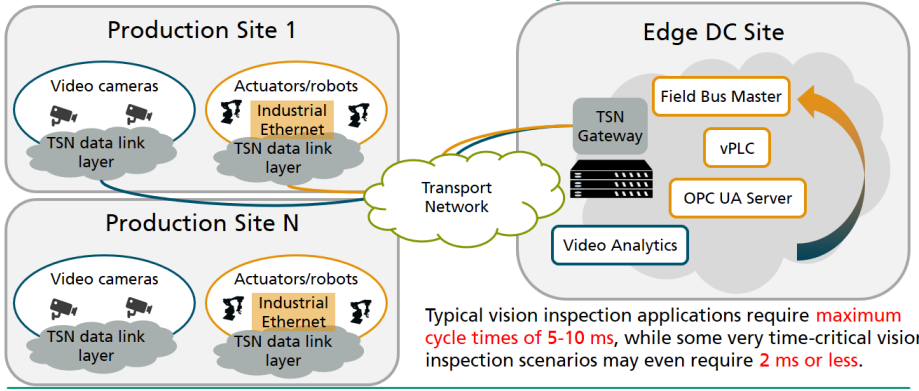
Distributed Intelligence

Off-Premise Edge Cloud for Distributed Production Sites

A critical metric is the minimum achievable cycle time.



Typical vision inspection applications require maximum cycle times of 5-10 ms, while some very time-critical vision inspection scenarios may even require 2 ms or less.

a real-time, low-latency, broadband fiber optic infrastructure is required

Distributed ML for Communication-efficient and Privacy-Preserving Model Training

to prevent transporting large and sensitive data from production sites to a central location

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Off-Premise Edge Cloud for Distributed Production Sites

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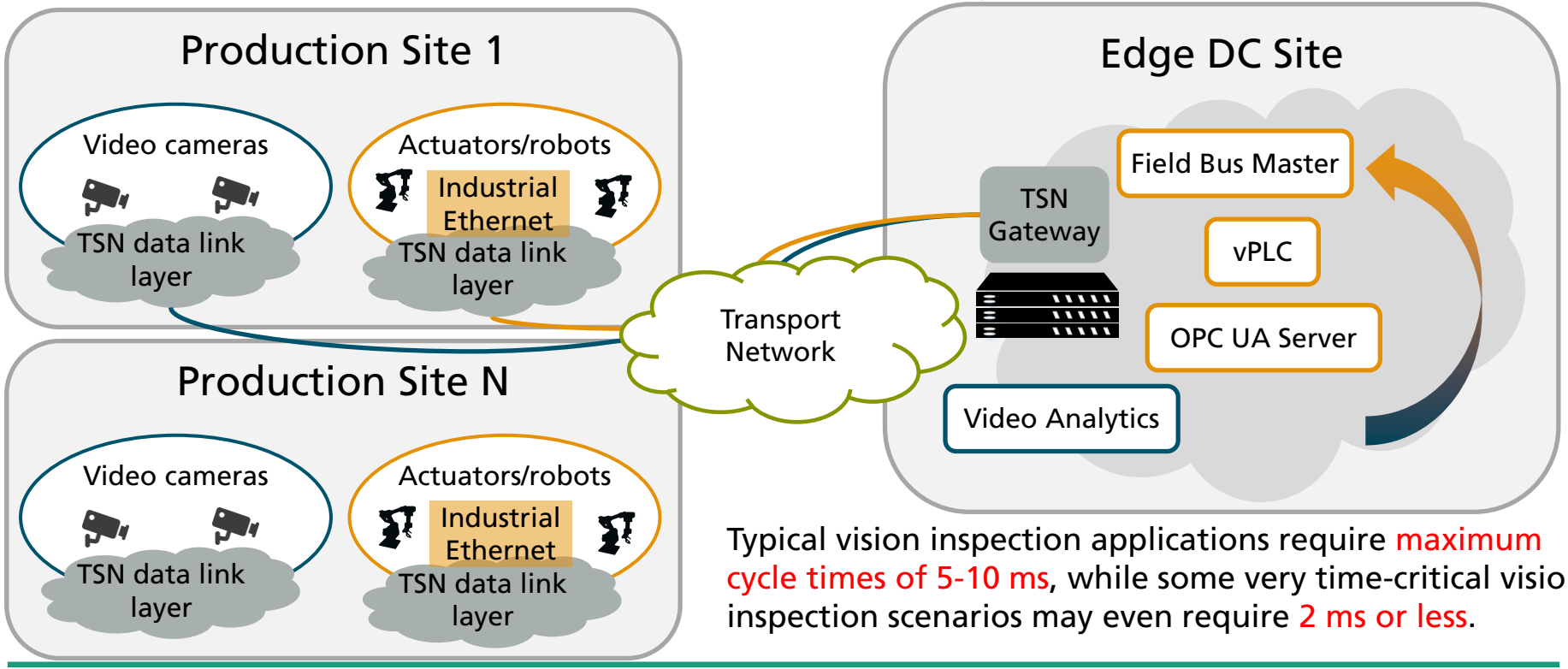

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Off-Premise Edge Cloud for Distributed Production Sites

Bandwidth Requirements for Vision Inspection Use-case

- Current industrial cameras provide resolutions above 1 Megapixel and support **GigE Vision** and/or **USB3 Vision** interfaces.
  - allow precise synchronization and/or real-time operation of multi-camera systems,
  - provide power supply to the cameras, e.g. based on PoE in case of GiGE Vision.
- Typical state-of-the-art cameras are able to completely saturate the bandwidth of the interfaces, i.e. **1 Gb/s in case of GigE Vision** and **5 Gb/s in case of USB3 Vision**.
- The number of cameras per vision inspection station ranges between one and four.
  - the aggregated data rate per vision inspection station **typically ranges between 1 Gb/s and 20 Gb/s**.
- The upstream data rates towards the off-premise edge lead to a highly asymmetric traffic profile for this use case, since the control signals transported in the downstream direction require a comparably negligible data rate.

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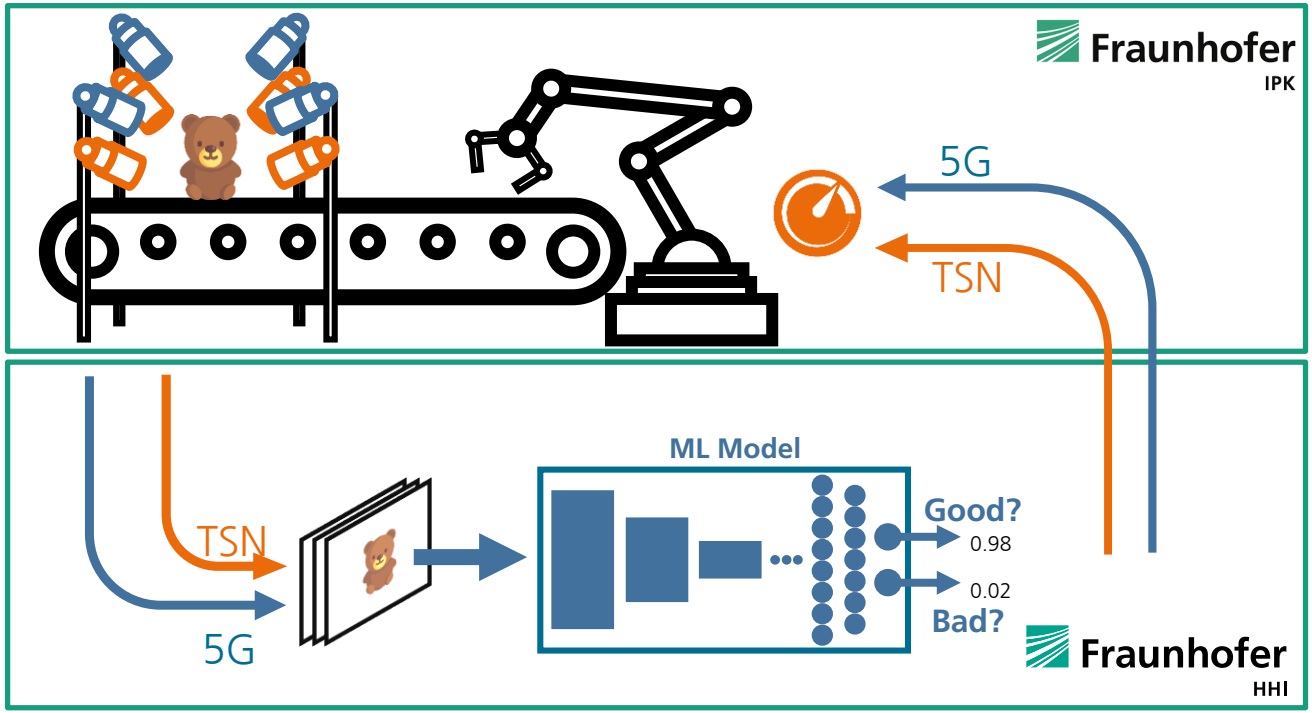
Off-Premise Edge Cloud for Distributed Production Sites

Vision Inspection PoC - Berlin Center for Digital Transformation



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Berlin Center for Digital Transformation

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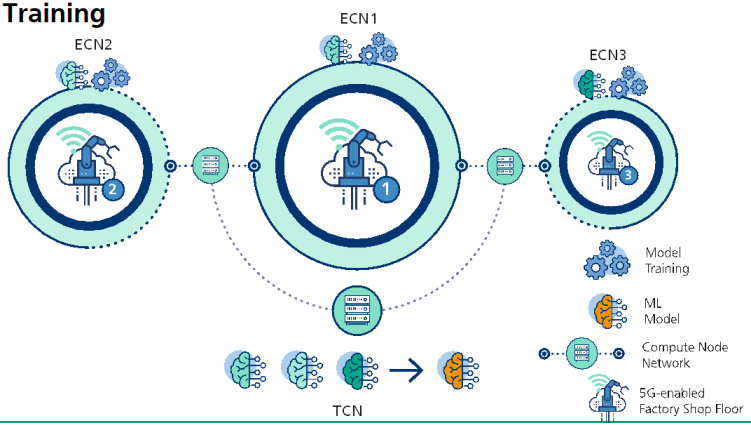

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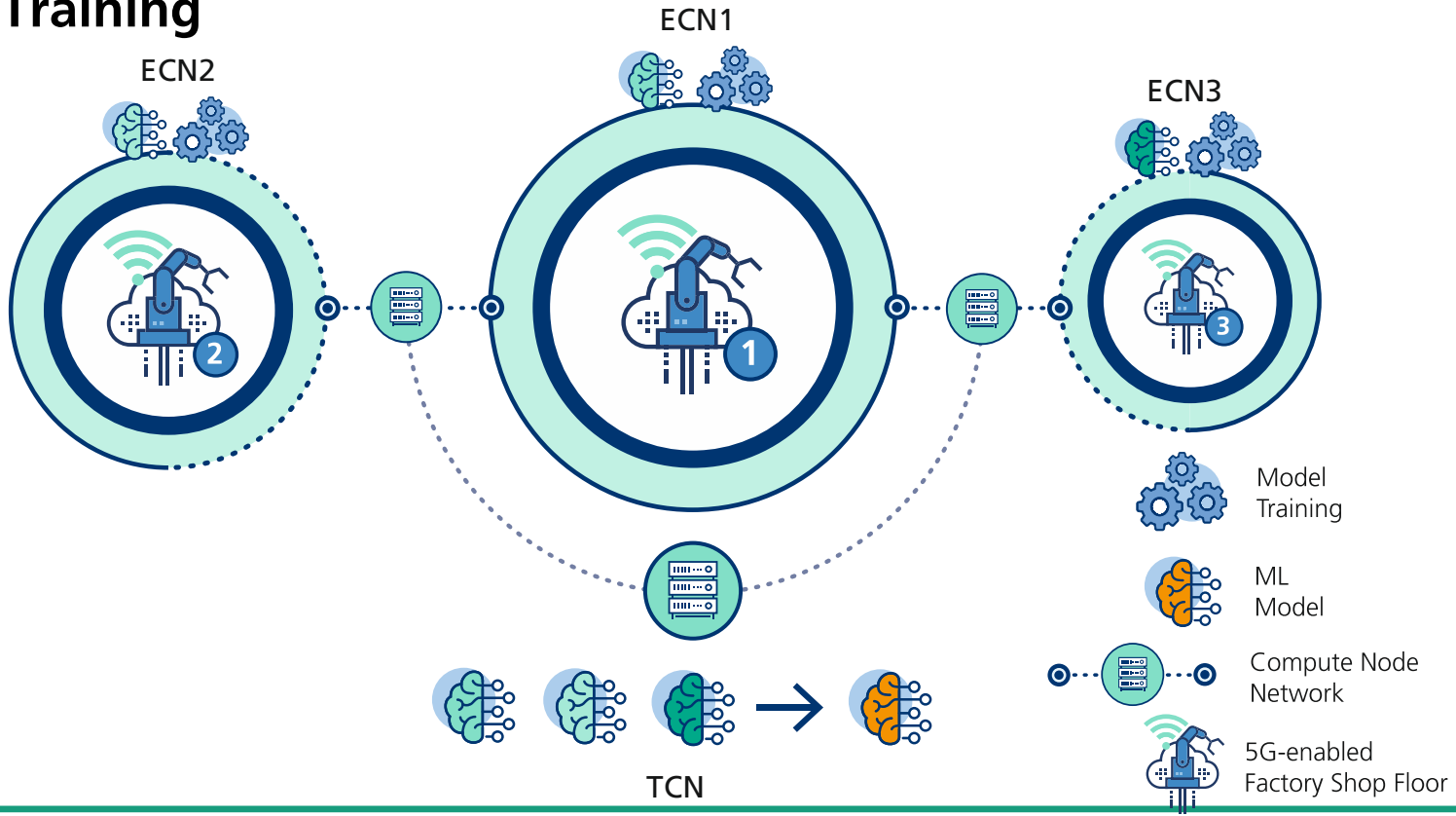

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DLFi – The Distributed Learning Framework

Modular, Pluggable, and Cloud Native

- We define Distributed Learning (or Federated Learning) as the procedure of *training a global ML model using data hosted on a set of geo-distributed edge nodes*. These edge nodes are assumed to have computing resources.
- DLFi comprises of two main components:
  - Training Coordinator Node (**TCN**)
  - Edge Contributor Node (**ECN**)
- DLFi
  - reduces the amount of transported data,
  - protects the privacy of data owners,
  - supports different downstream tasks,
    - *Vision inspection, predictive maintenance, QoT estimation, etc.*
  - supports GPU-based acceleration.

[ref] https://www.hhi.fraunhofer.de/dlfi

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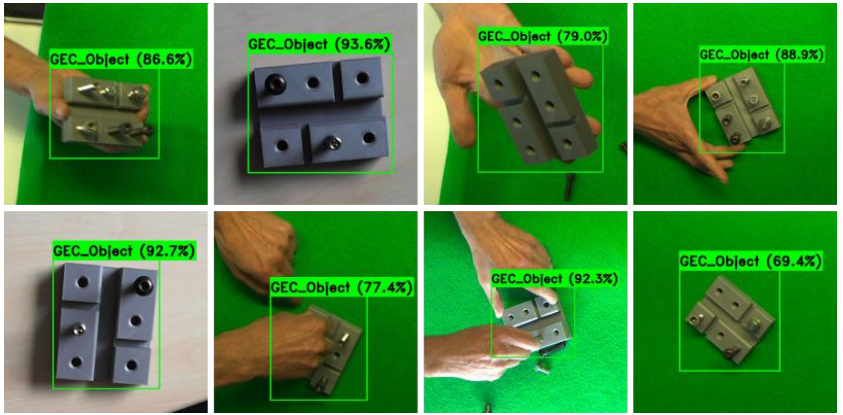
PoC of DLFi for Visual Inspection Use-cases

Visual Inspection in Factories with Geo-distributed Manufacturing Sites

- Scenario: Production lines in factories located at multiple geo-distributed sites
- A commercial grade Video Analytics package (developed by the Video and Imaging Technologies Department at HHI)
- DLFi enables this package to train/validate its model on training/validation data available on different sites



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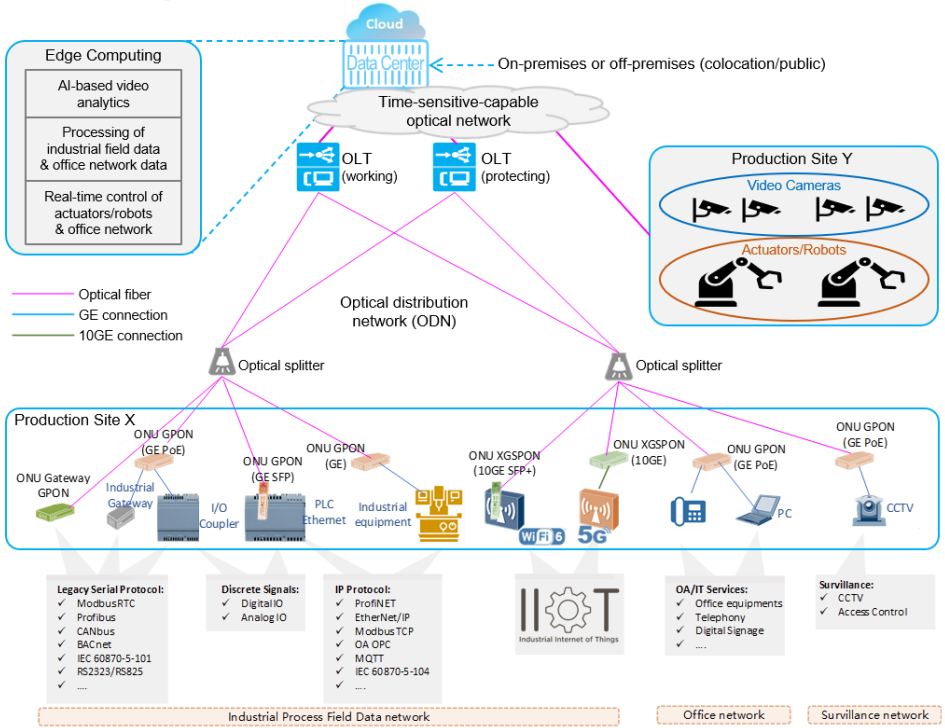
Fiber Optic Infrastructure Is A Must!

Time Sensitive Capable Optical Network for Cloud-based Industrial Applications



[ref] L. Pesando, et al., "Service-Enabling Architecture and Application of the 5th Generation Fixed Network (F5G)," submitted to IEEE Communication Magazine, June 2021.

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