Experiences Modeling an OPC UA / DDS Gateway in AADL in the Context of Fog Computing

Based on: „Modelling protocol gateways for cyber-physical systems using Architecture Analysis & Design Language" [3].
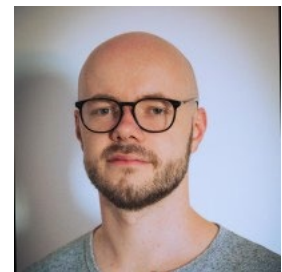
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ADEPT Workshop 2022

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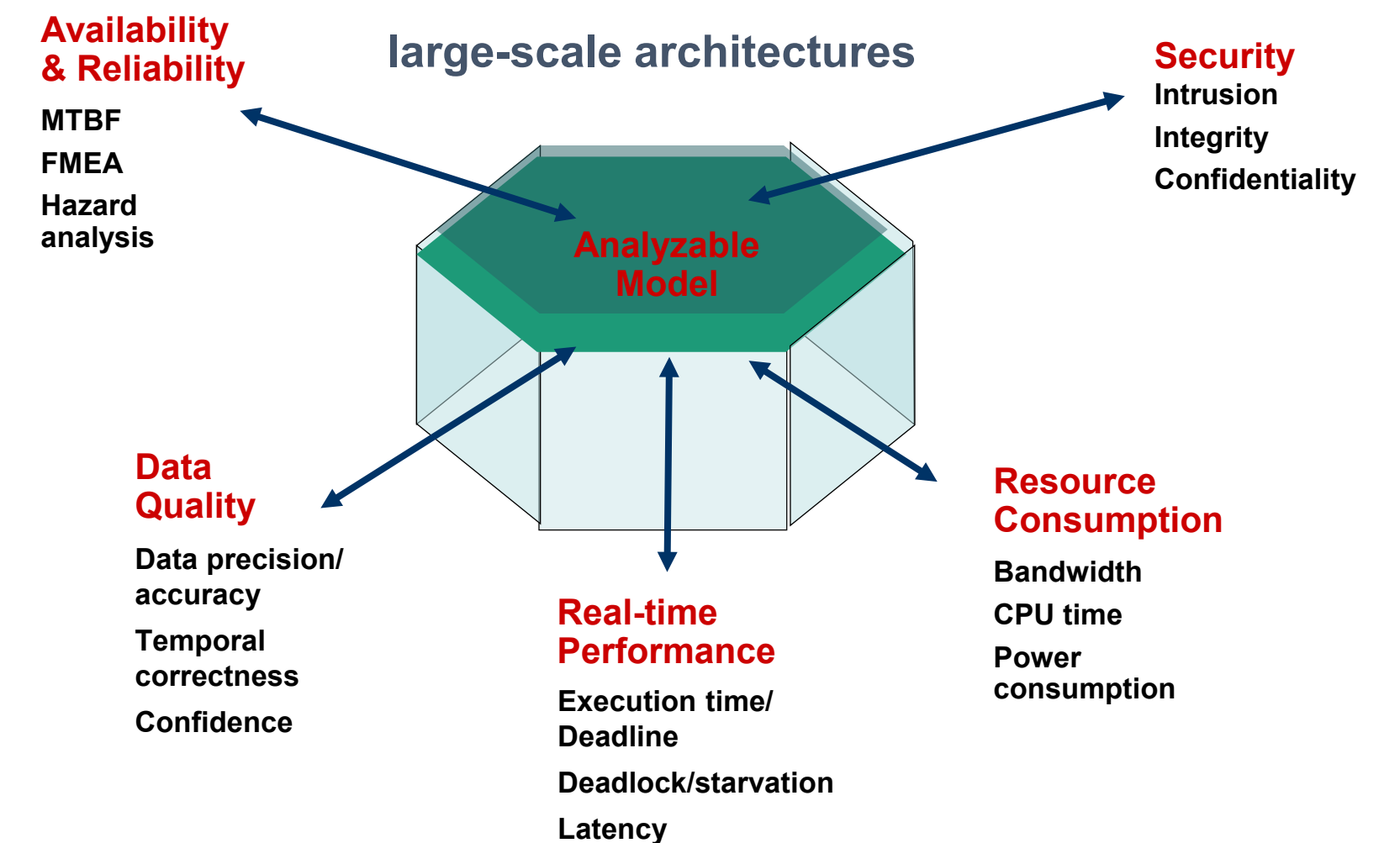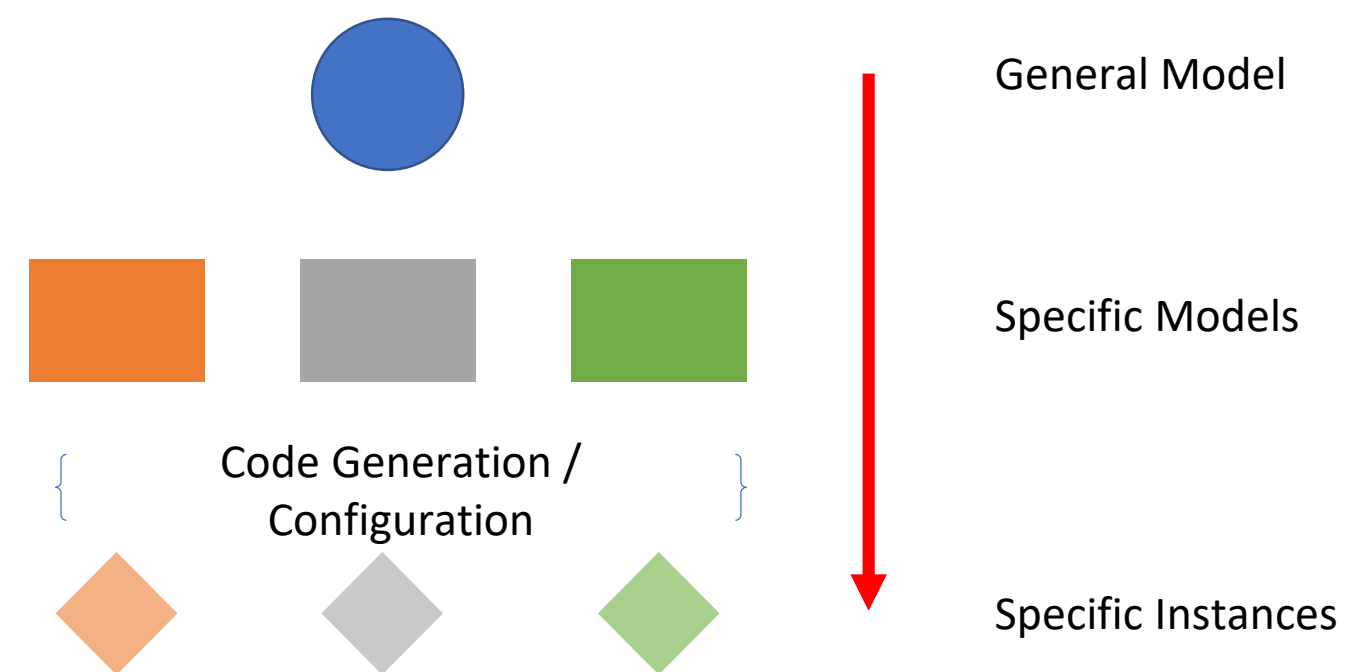FORA—Fog Computing for Robotics and Industrial Automation.

- European Union's Horizon 2020, Marie Skłodowska-Curie PhD School

- 15 PhD Students.

- Finished Dec. 2021

- The aim was to develop a Fog Computing Platform (FCP)

- Hardware, Software and Tools

- The platform is modelled in AADL.

  - https://git.auto.tuwien.ac.at/fora

- As described in [1].
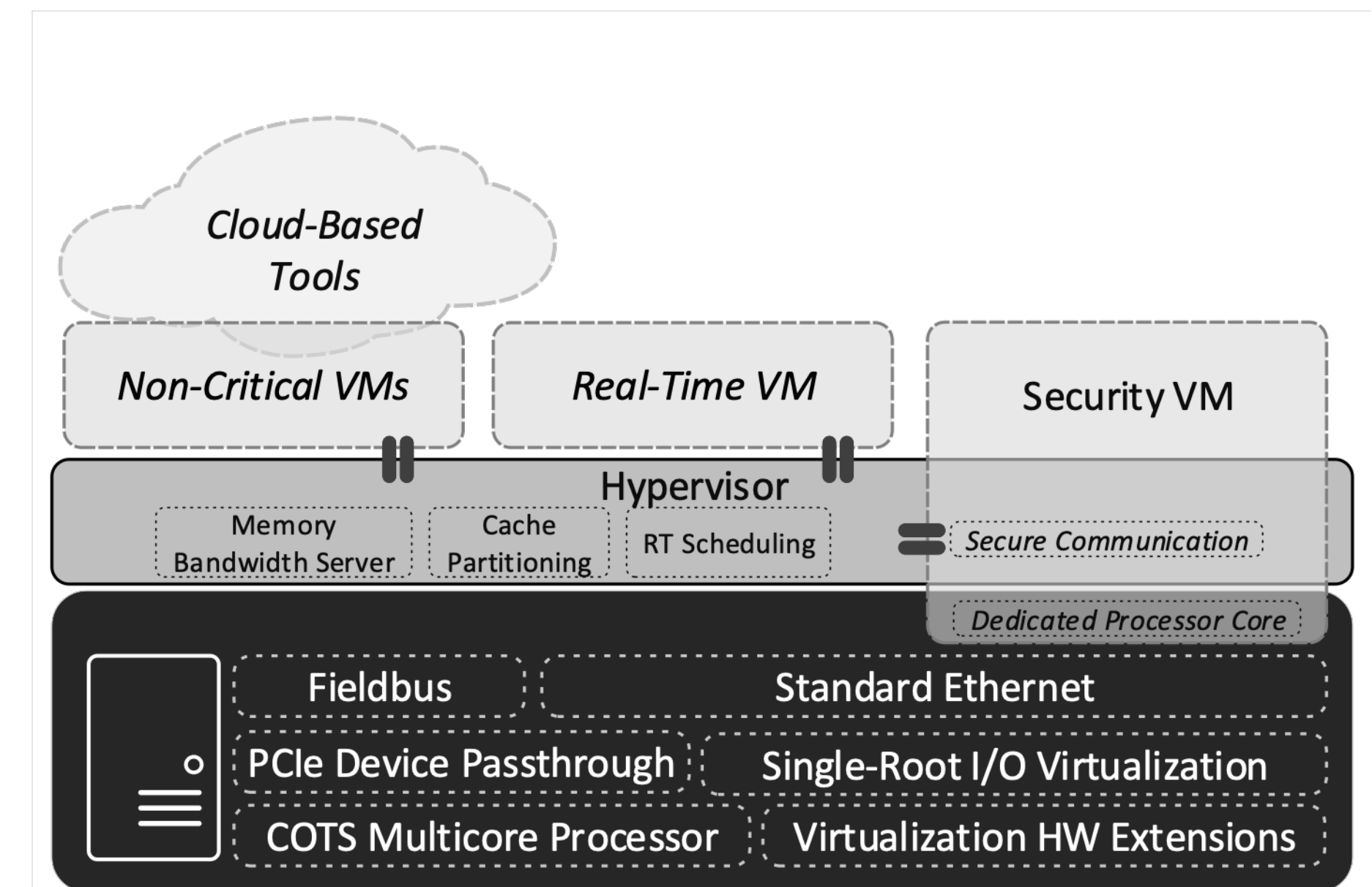
Fog Computing Platform (FCP)

Motivation for the Gateway and why AADL

- Connect Legacy protocols in industrial automation.

- Various instances (Gateways), protocols, and hardware sometimes.

- Exploring the capabilities of AADL.

- Code generation and other tools

- Open Source AADL Tool (OSATE), and for code generation, the Ocarina tool suite.

General Model

Specific Models

Code Generation /
Configuration

Specific Instances

large-scale architectures

Availability & Reliability
MTBF
FMEA
Hazard analysis

Security
Intrusion
Integrity
Confidentiality

Analyzable Model

Data Quality
Data precision/ accuracy
Temporal correctness
Confidence

Real-time Performance
Execution time/ Deadline
Deadlock/starvation
Latency

Resource Consumption
Bandwidth
CPU time
Power consumption

OPC UA / DDS Gateway (Study object)

- OMG specification of a bi-directional gateway as the foundation.

  - A structured instruction on how to build a gateway.

  - Provides conformance points to check the built gateway.

- OPC Unified Architecture: Server-Client based middleware and a possible standard for Industry 4.0.

- Data Distribution Service (DDS): Publish/Subscribe middleware with advanced capabilities.

- We also implemented a prototype to test the capabilities in a later study.

General Structure of the AADL System Model
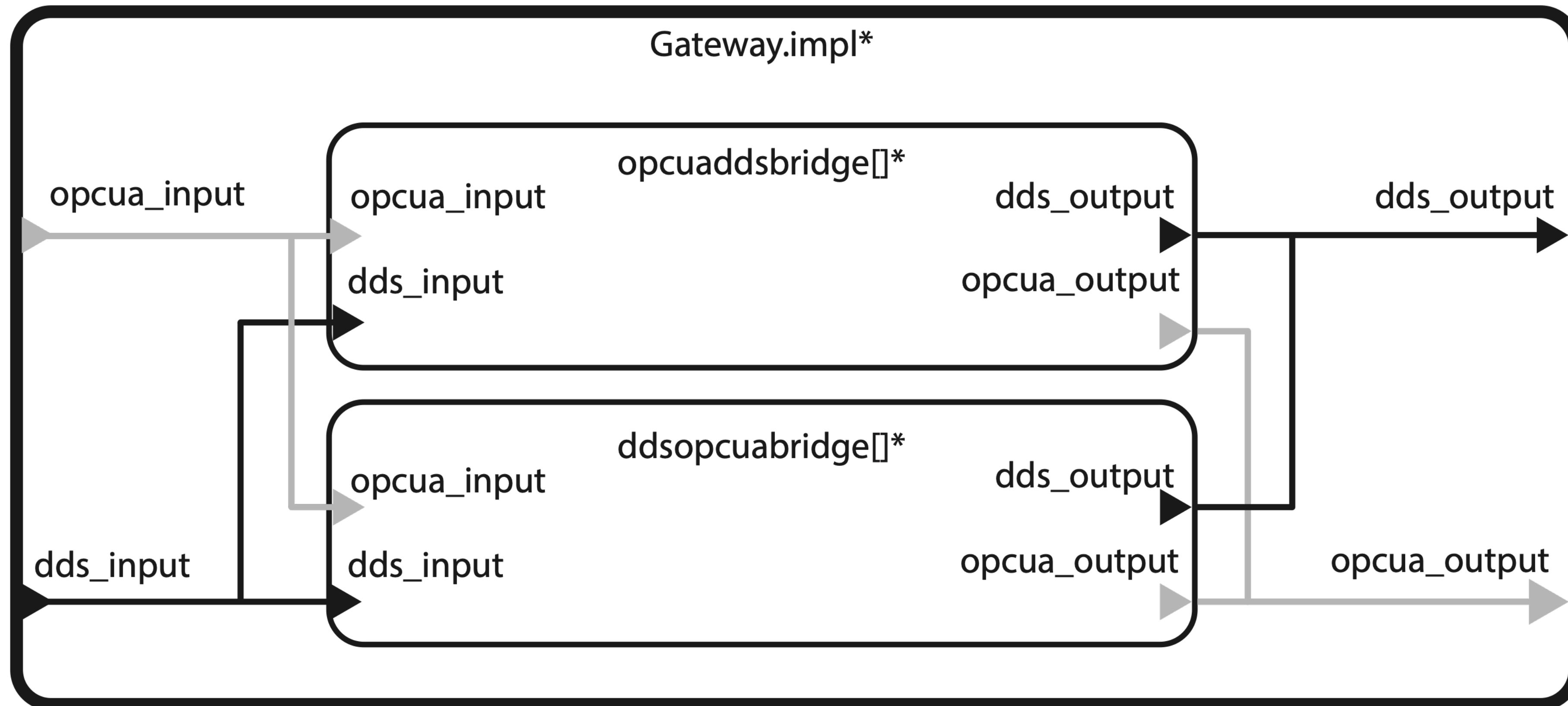
The two bridges (Conformance Points)

OPC UA / DDS

- Basic: Requires the implementation of the System and Service Set mappings.

- Complete: the full adherence to the Subscription Model.

DDS / OPC UA

- Basic: Requires the DDS Type System and the DDS Global Data Space Mapping.

- Complete: Adds a sub-clause demanding the reading of historical data from instance nodes.
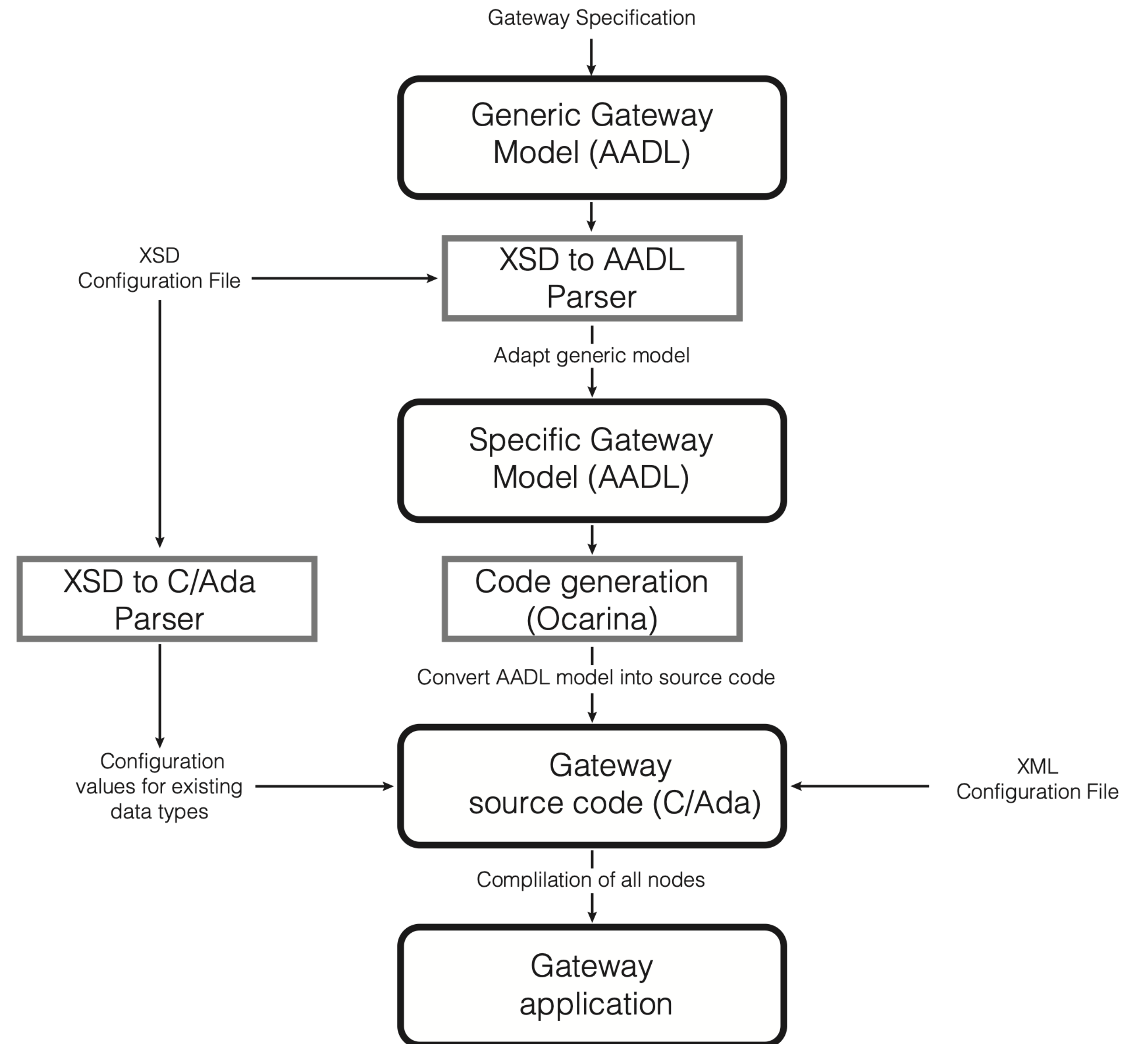
Results compared to related work

- Our findings mirror experiences made by other researchers that used AADL for modelling embedded systems in the avionics domain [38, 40]

- As described by Delanote et al. [7], problems with modelling software layers could not be identified.

- However, implementing the OMG-specified hybrid data types is challenging as the required information is only available during the compilation of the final instance.

Addressing Configuration and Code Generation

General Model

Specific Models

Code Generation / Configuration

Specific Instances

Gateway Specification

Generic Gateway Model (AADL)

XSD Configuration File → **XSD to AADL Parser**

Adapt generic model

Specific Gateway Model (AADL)

XSD to C/Ada Parser

Code generation (Ocarina)

Convert AADL model into source code

Configuration values for existing data types →

Gateway source code (C/Ada) ← XML Configuration File

Compilation of all nodes

Gateway application

Discussion and Challenges

- Due to an internal issue in the Ocarina toolchain, compiling the complex data type mappings was impossible.

- The problem occurs during the transformation of the AADL code to C programming language, a problem other authors did not experience [21].

- Identifying the issue in Ocarina was difficult, and it was necessary to continue the trials with a reduced gateway model with fixed mappings.

Discussion and Challenges

- An adjusted instance of the generated gateway provided the foundation for a study to assess the gateway's capacities to transport automation data from OT to an IT environment [9].

- The XSD and XML files require considerable formulation effort due to the complexity of the internal gateway mappings.

- This finding initiated the development of an external configurator to ease the creation process for the configuration files. The configurator and the gateway instance are part of a recent study [10].

Conclusion

- Explored the modelling capabilities of AADL.

- The created model of the OPC UA / DDS gateway complies with the specification.

  - https://git.auto.tuwien.ac.at/fora/aadl_opcuaddsgateway

- Proposed a code generation process to create specific gateway instances.

- Presented the problems in the AADL toolchain for code generation.

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General Feedback

- Limited reference/learning material

- „Hard to get started. "

- Tooling is challenging to handle.

- „Straightforward for simple problems, the more complex not clear how to model particular things. Try and error approach."

- Additional tools are challenging to use if still working.

- Some tools are not open source available.

Inquires and Questions

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Publications

- [1] P. Pop, B. Zarrin, M. Barzegaran, S. Schulte, S. Punnekkat, J. Ruh, and W. Steiner, "The FORA fog computing platform for industrial IoT," Information Systems, vol. 98, p. 101727, 2021.

- [2] P. Denzler, J. Ruh, M. Kadar, C. Avasalcai, and W. Kastner, "Towards Consolidating Industrial Use Cases on a Common Fog Computing Platform," in 2020 25th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), vol. 1, pp. 172–179, 2020.

- [3] P. Denzler, D. Scheuchenstuhl, D. Ramsauer, and W. Kastner, "Modelling protocol gateways for cyber-physical systems using Architecture Analysis & Design Language," Procedia CIRP, vol. 104, pp. 1339–1344, 2021. 54th CIRP CMS 2021 - Towards Digitalized Manufacturing 4.0.

- [4] P. Denzler, D. Ramsauer, and W. Kastner, "Tunnelling and Mirroring Operational Technology Data with IP-based Middlewares," in 2021 22nd IEEE International Conference on Industrial Technology (ICIT), vol. 1, pp. 1205–1210, 2021.

- [5] P. Denzler, D. Ramsauer, T. Preindl, and W. Kastner, "Communication and container reconfiguration for cyber- physical production systems," in 2021 26th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), pp. 1–8, 2021.