ALTERNATIVE EDGE COMPUTING ARCHITECTURES FOR MANUFACTURING USE CASES

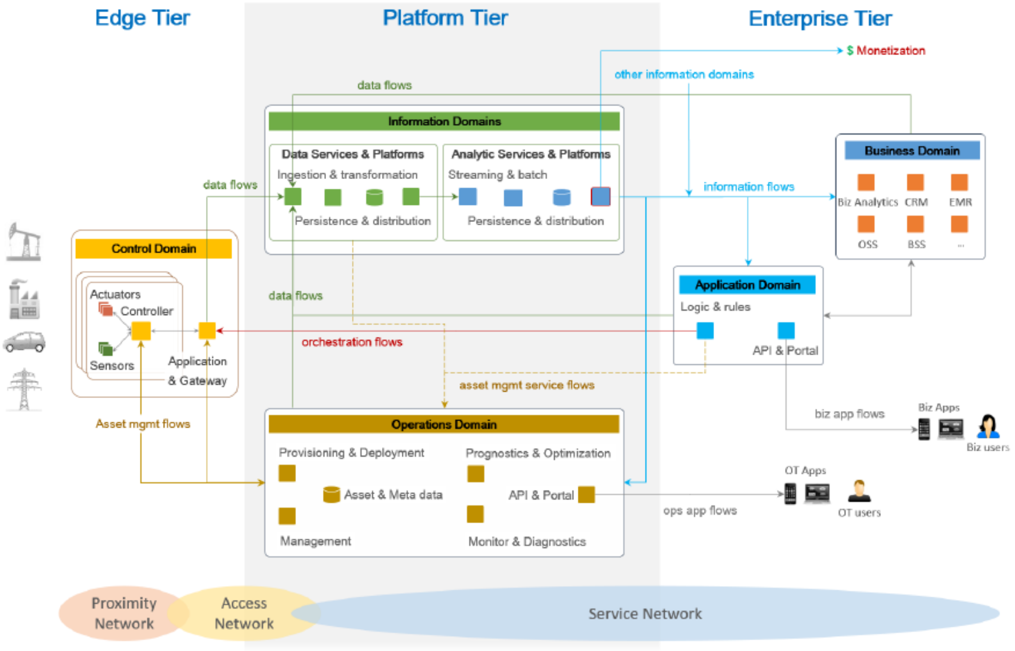
John Soldatos, Intrasoft International

IoT and Edge computing: Manufacturing, On-Line, April 27th, 2021

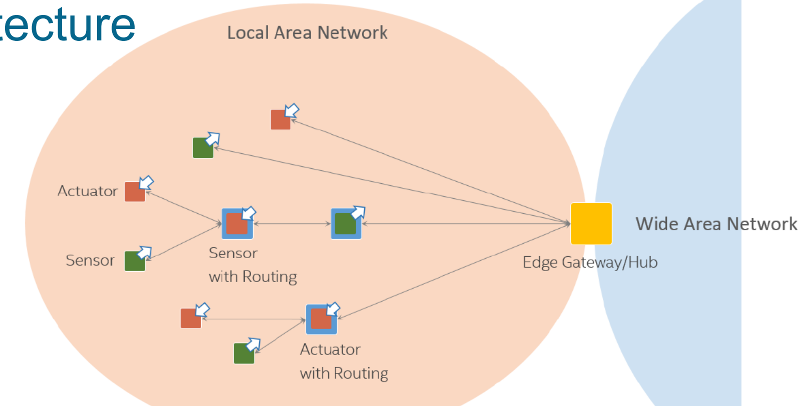
EDGE COMPUTING FOR INDUSTRIAL USE CASES: WHEN CLOUD IS NOT ENOUGH

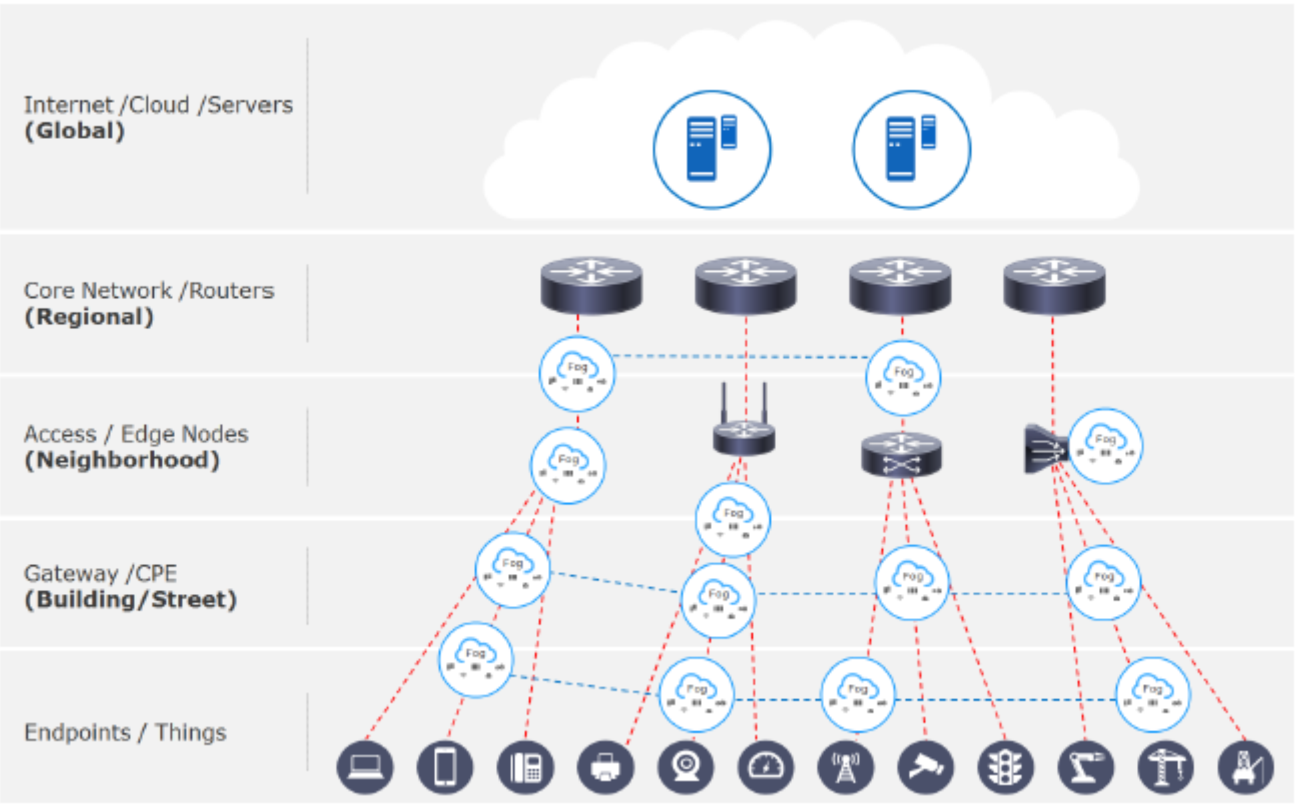
- Rationale for Edge Computing in Industrial Use Cases:
  - Latency & Real-Time Field Operations (e.g., Real-Time Actuation and Control)
  - Energy Efficiency (e.g., Sustainable Manufacturing)
  - Data Privacy and Protection (e.g., Industrial Data)
- Different Edge Computing Approaches:
  - Edge Computing with Local Clouds
  - Fog Computing
  - FarEdge Approaches (e.g., Embedded Machine Learning)
  - Federated Machine Learning
  - Decentralization based on Distributed Ledger Technologies

EDGE COMPUTING VS. STANDARD INDUSTRIAL ARCHITECTURES (SOURCE: HTTPS://WWW.IICONSORTIUM.ORG/)



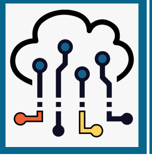
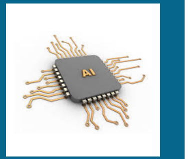
Industrial Internet Consortium Reference Architecture





OpenFog Reference Architecture

CLOUD VS. EDGE VS. FAREDGE

FEATURES	CLOUD (e.g., IOT/Cloud Integration (WAN)) 	EDGE (e.g., Local Clouds, Fog Computing) 	FarEdge (e.g.,AIoT, Embedded Devices, Microcontollers) 
Data Points Availability	High	Medium	Low
Energy Efficiency	Low	Medium-to-High	Very High
Privacy	Low-Medium	Medium-to-High	High
Real-Time Opportunities	Low	Medium-to-High	Very High

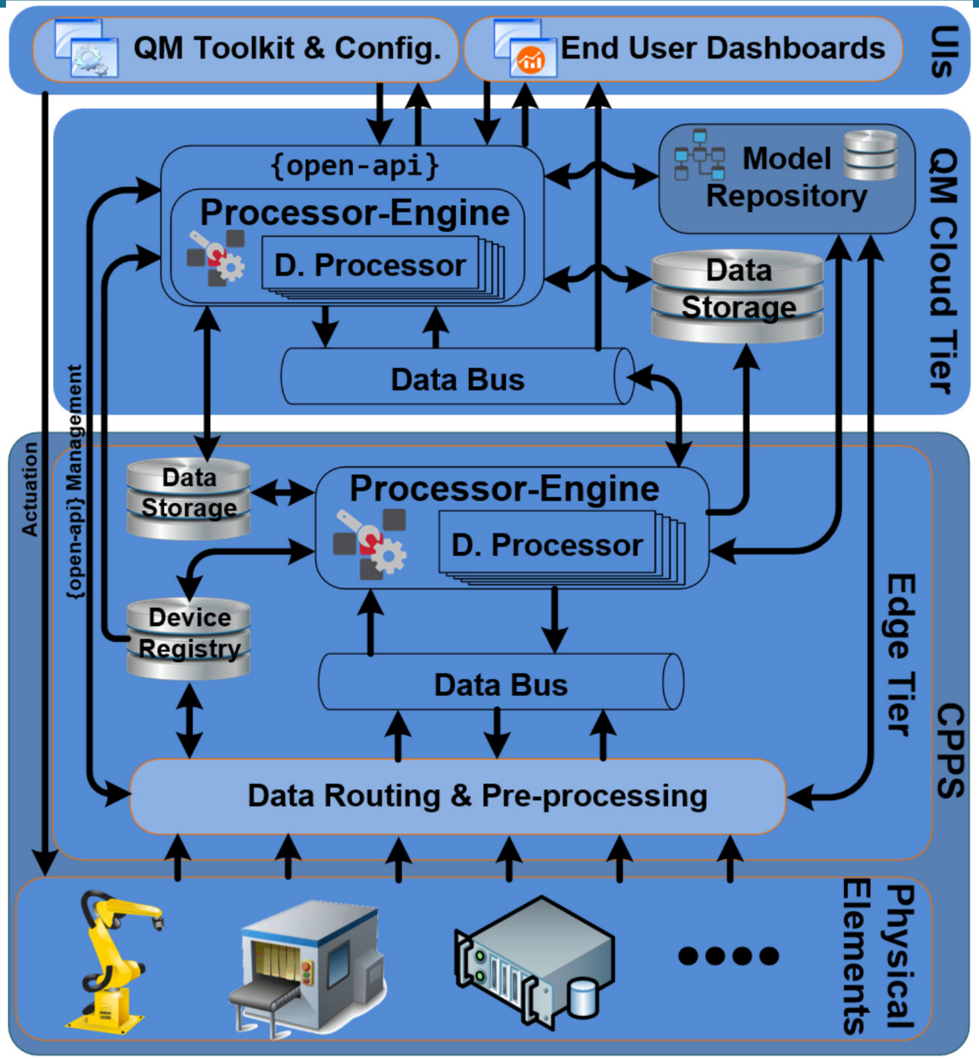
CLOUD VS. EDGE VS. FAREDGE

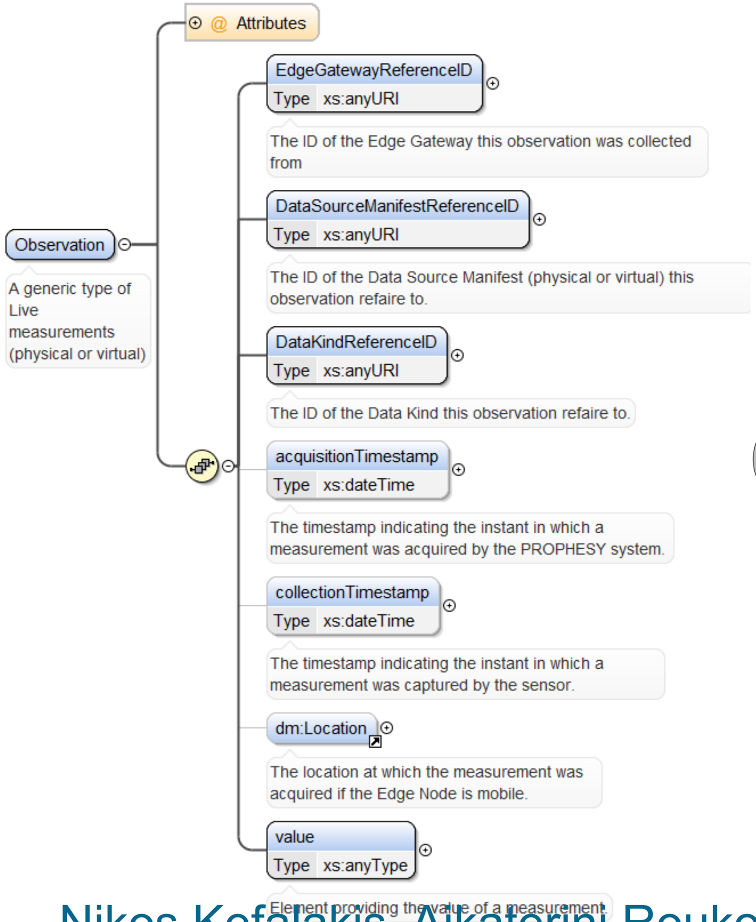
Transfer Learning

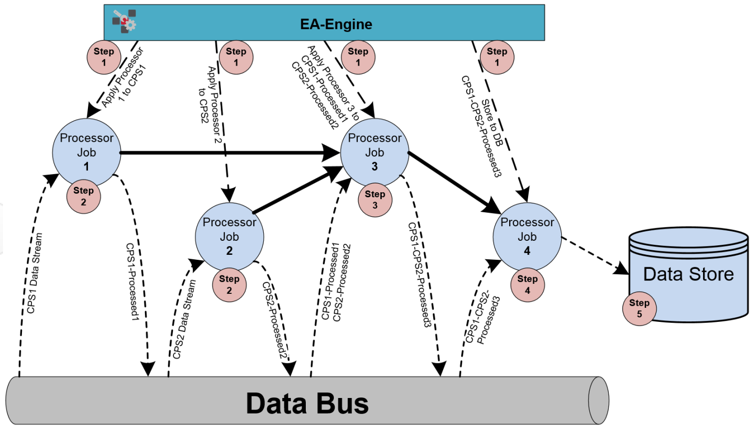
INDUSTRY USE CASE	CLOUD	EDGE	FarEdge
Asset Management & Predictive Maintenance	RUL Calculation at Cloud	RUL Calculation at Edge Cluster or Edge Devices	Fault Detection Inside the Machinery
Quality Management & Zero Defect Manufacturing (ZDM)	Quality Inspection – Defect Prediction	Defect Prediction & Near Real-Time Control	Defect Detection & Real-Time Control
Value Proposition	ML Model Accuracy	Speed vs. Accuracy Balance	Speed and Power Efficiency

Predictive, Preventive, and Reactive Strategies to Asset Management & Quality Management

INTRASOFT'S EDGE COMPUTING PLATFORM (DATACROP) FOR QUALITY MANAGEMENT







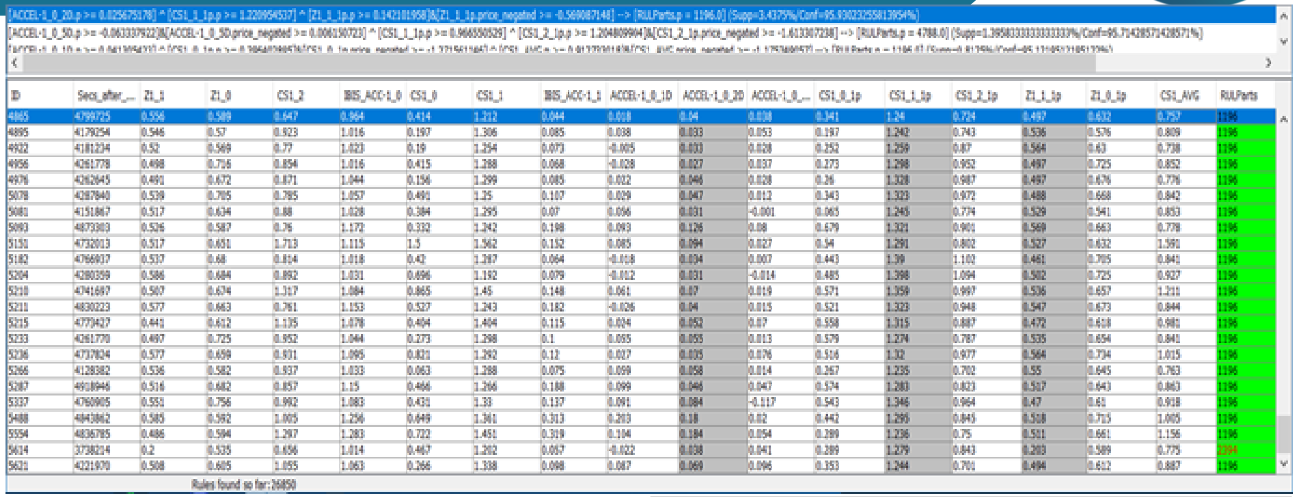
Processing Jobs are of three types:

- Pre-processing
- Storage
- Analytics (e.g., ML, calculation)

Nikos Kefalakis, Aikaterini Roukounaki, John Soldatos: Configurable Distributed Data Management for the Internet of Things. Inf. 10(12): 360 (2019)

ML Framework Integration over DataCrop - QARMA

- Different ML Algorithms run over DataCrop
  - Recurrent Neural Networks (RNN)
  - Long Short-Term Memory Networks (LSTM)
  - Attention-based Networks
- QARMA4Industry:
  - Rules Mining Approach
  - Identify Rules that hold on data and quantify them
  - Used in H2020 QU4LITY Project



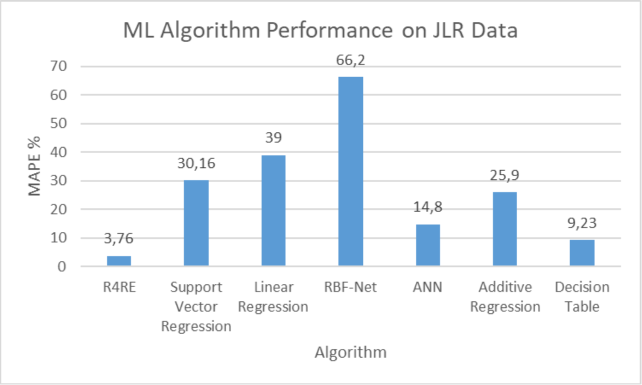
[ACCEL-1_0_20.p >= 0.025675178] ^ [CS1_1_1p.p >= 1.220954537] ^ [Z1_1_1p.p >= 0.142101958]&[Z1_1_1p.price_negated >= -0.569087148] --> [RULParts.p = 1196.0] (Supp=3.4375%/Conf=95.93023255813954%)

[ACCEL-1_0_50.p >= -0.063337922]&[ACCEL-1_0_50.price_negated >= 0.006150723] ^ [CS1_1_1p.p >= 0.966550529] ^ [CS1_2_1p.p >= 1.204809904]&[CS1_2_1p.price_negated >= -1.613307238] --> [RULParts.p = 4788.0] (Supp=1.3958333333333333%/Conf=95.71428571428571%)

ID	Secs_after_...	Z1_1	Z1_0	CS1_2	IBIS_ACC-1_0	CS1_0	CS1_1	IBIS_ACC-1_1	ACCEL-1_0_10	ACCEL-1_0_20	ACCEL-1_0_...	CS1_0_1p	CS1_1_1p	CS1_2_1p	Z1_1_1p	Z1_0_1p	CS1_AVG	RULParts
4865	4799725	0.556	0.589	0.647	0.964	0.414	1.212	0.044	0.018	0.04	0.038	0.341	1.24	0.724	0.497	0.632	0.757	1196
4895	4179254	0.546	0.57	0.923	1.016	0.197	1.306	0.085	0.038	0.033	0.053	0.197	1.242	0.743	0.536	0.576	0.809	1196
4922	4181234	0.52	0.569	0.77	1.023	0.19	1.254	0.073	-0.005	0.033	0.028	0.252	1.259	0.87	0.564	0.63	0.738	1196
4956	4261778	0.498	0.716	0.854	1.016	0.415	1.288	0.068	-0.028	0.027	0.037	0.273	1.298	0.952	0.497	0.725	0.852	1196
4976	4262645	0.491	0.672	0.871	1.044	0.156	1.299	0.085	0.022	0.046	0.028	0.26	1.328	0.987	0.497	0.676	0.776	1196
5078	4287840	0.539	0.705	0.785	1.057	0.491	1.25	0.107	0.029	0.047	0.012	0.343	1.323	0.972	0.488	0.668	0.842	1196
5081	4151867	0.517	0.634	0.88	1.028	0.384	1.295	0.07	0.056	0.031	-0.001	0.065	1.245	0.774	0.529	0.541	0.853	1196
5093	4873303	0.526	0.587	0.76	1.172	0.332	1.242	0.198	0.093	0.126	0.08	0.679	1.321	0.901	0.569	0.663	0.778	1196
5151	4732013	0.517	0.651	1.713	1.115	1.5	1.562	0.152	0.085	0.094	0.027	0.54	1.291	0.802	0.527	0.632	1.591	1196
5182	4766937	0.537	0.68	0.814	1.018	0.42	1.287	0.064	-0.018	0.034	0.007	0.443	1.39	1.102	0.461	0.705	0.841	1196
5204	4280359	0.586	0.684	0.892	1.031	0.696	1.192	0.079	-0.012	0.031	-0.014	0.485	1.398	1.094	0.502	0.725	0.927	1196
5210	4741697	0.507	0.674	1.317	1.084	0.865	1.45	0.148	0.061	0.07	0.019	0.571	1.359	0.997	0.536	0.657	1.211	1196
5211	4830223	0.577	0.663	0.761	1.153	0.527	1.243	0.182	-0.026	0.04	0.015	0.521	1.323	0.948	0.547	0.673	0.844	1196
5215	4773427	0.441	0.612	1.135	1.078	0.404	1.404	0.115	0.024	0.052	0.07	0.558	1.315	0.887	0.472	0.618	0.981	1196
5233	4261770	0.497	0.725	0.952	1.044	0.273	1.298	0.1	0.055	0.055	0.013	0.579	1.274	0.787	0.535	0.654	0.841	1196
5236	4737824	0.577	0.659	0.931	1.095	0.821	1.292	0.12	0.027	0.035	0.076	0.516	1.32	0.977	0.564	0.734	1.015	1196
5266	4128382	0.536	0.582	0.937	1.033	0.063	1.288	0.075	0.059	0.058	0.014	0.267	1.235	0.702	0.55	0.645	0.763	1196
5287	4918946	0.516	0.682	0.857	1.15	0.466	1.266	0.188	0.099	0.046	0.047	0.574	1.283	0.823	0.517	0.643	0.863	1196
5337	4760905	0.551	0.756	0.992	1.083	0.431	1.33	0.137	0.091	0.084	-0.117	0.543	1.346	0.964	0.47	0.61	0.918	1196
5488	4843862	0.585	0.592	1.005	1.256	0.649	1.361	0.313	0.203	0.18	0.02	0.442	1.295	0.845	0.518	0.715	1.005	1196
5554	4836785	0.486	0.594	1.297	1.283	0.722	1.451	0.319	0.104	0.184	0.054	0.299	1.236	0.75	0.511	0.661	1.156	1196
5614	3738214	0.2	0.535	0.656	1.014	0.467	1.202	0.057	-0.022	0.038	0.041	0.289	1.279	0.843	0.203	0.589	0.775	2294
5621	4221970	0.508	0.605	1.055	1.063	0.266	1.338	0.098	0.087	0.069	0.096	0.353	1.244	0.701	0.494	0.612	0.887	1196

Rules found so far: 26850

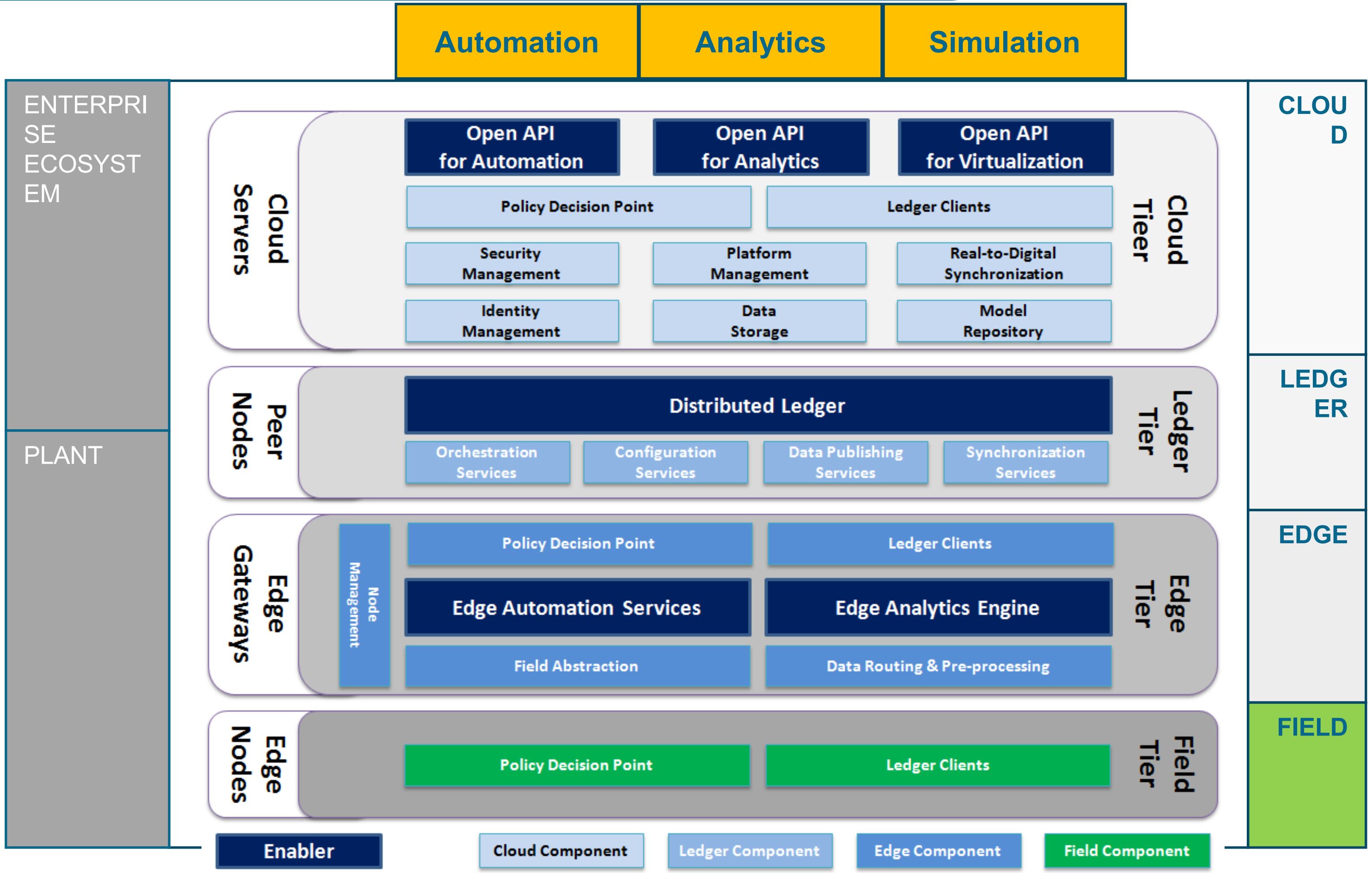
QARMA4Industry outperforms popular algorithms



Ioannis T. Christou, Nikos Kefalakis, Andreas Zalonis, John Soldatos, Raimund Bröchler, End-to-End Industrial IoT Platform for Actionable Predictive Maintenance, IFAC-PapersOnLine, Volume 53, Issue 3, 2020, Pages 173-178, ISSN 2405-8963,

H2020 FAR-EDGE : Distributed Ledger Technologies for Orchestrating & Configuring Processes at the Edge

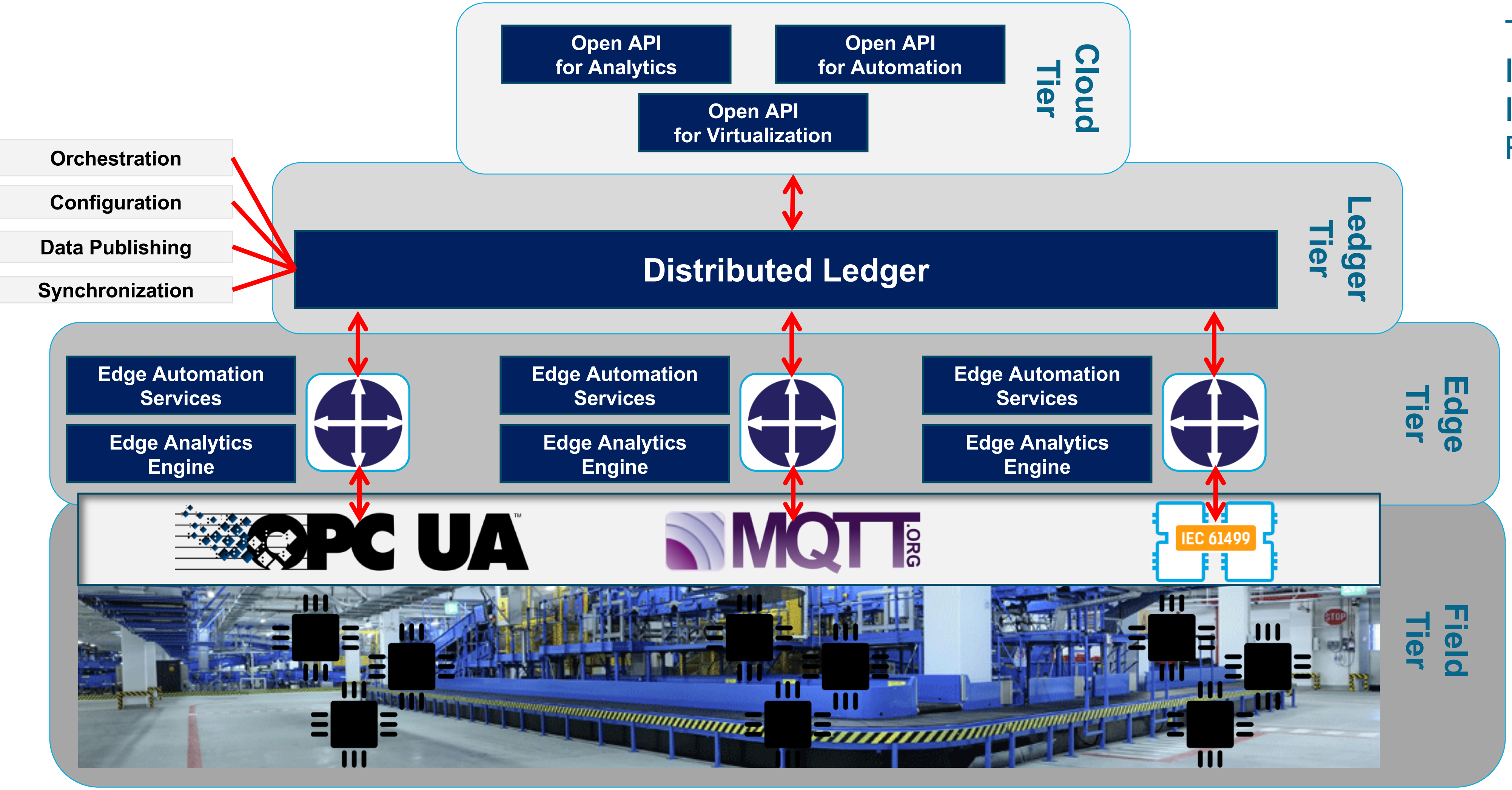
- Edge Computing Functions:
  - Edge Automation & Edge Analytics
- Edge Automation:
  - Low-overhead, low-latency connectivity
  - Two way interactions
- Edge Analytics:
  - Real-time analytics
  - One-way data savvy operations



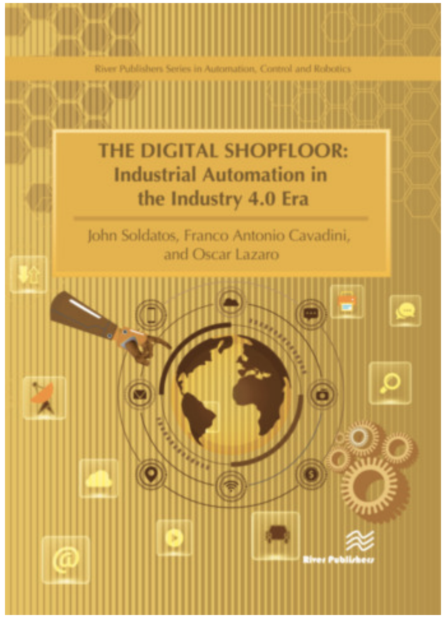
Mauro Isaja, John Soldatos:
Distributed ledger technology for decentralization of manufacturing processes. ICPS 2018: 696-701

DLT Technologies for Edge Computing Functions

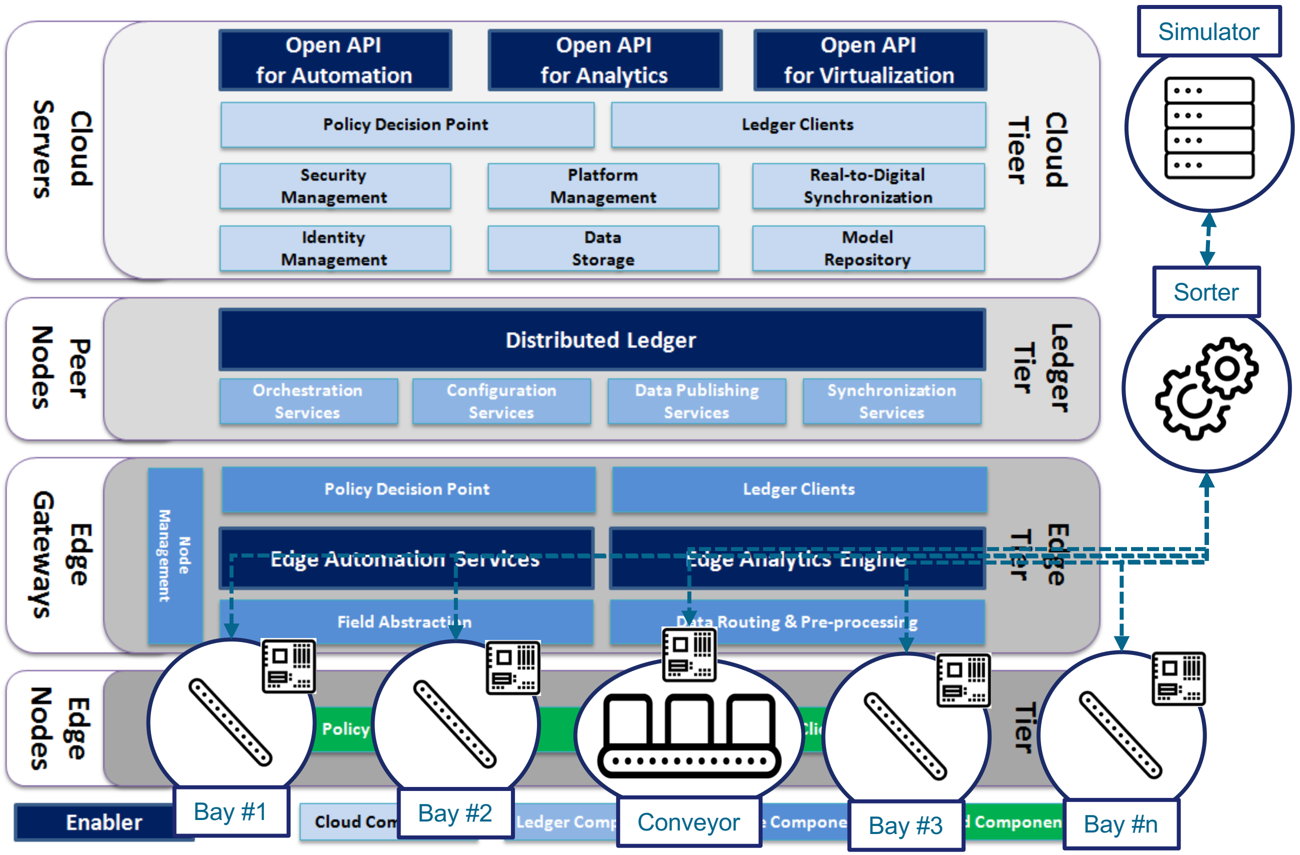
(see: www.Edge4Industry.eu)

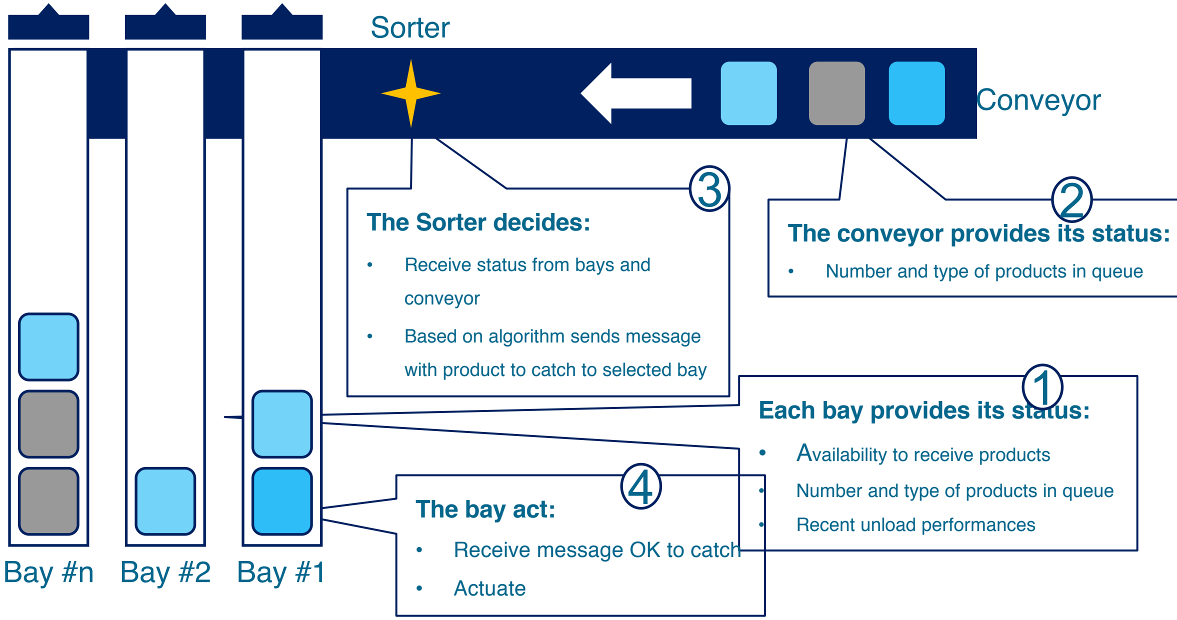


The Digital Shopfloor: Industrial Automation in the Industry 4.0 Era, RiverPublishers 2019



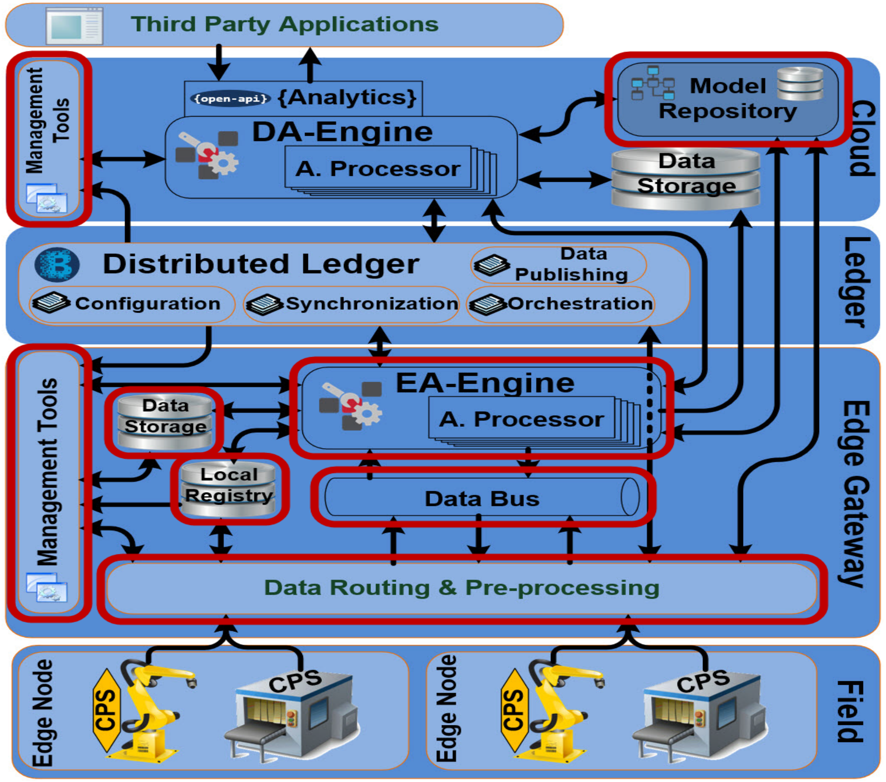
Edge Simulation Use Case (WhiteAppliances Factory) (source: FAR-EDGE Project)





Edge Analytics Use Case: Real Time Quality Control Statistics in a Wheel Alignment Station (source: FAR-EDGE Project)

- Benefits:
  - Improved accuracy of the assembly times as the influence of operator experience, variation in product quality of the inbound parts etc. are taken into account.
  - Productivity increase by automating engineering tasks to manage the theoretical time studies.



CONCLUSIONS

- Alternative Edge Computing Approaches in Industrial Environments
- No Silver Bullet: Selection Depends on Requirements:
  - Latency / Real-Time Concerns
  - Power Efficiency
  - Privacy
  - Decentralization
  - Security & Robustness
  - Federated Learning (not addressed in this presentation)
- An “Edge Operating System” should take into account relevant trade-offs
- Zero Defects Manufacturing Approach Combines Reactive, Preventive and Predictive Strategies
- Infrastructures like GAIA-X can boost a modular approach

THANK YOU FOR YOUR ATTENTION

eu-iot.eu

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