THE NORTHERNMOST UNIVERSITY
of Technology in Scandinavia

Interoperability
the Enabler of Production Automation

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Supported by
Productive4.0 and Arrowhead Tools projects
ECSEL-JU grant 737459 and 826452

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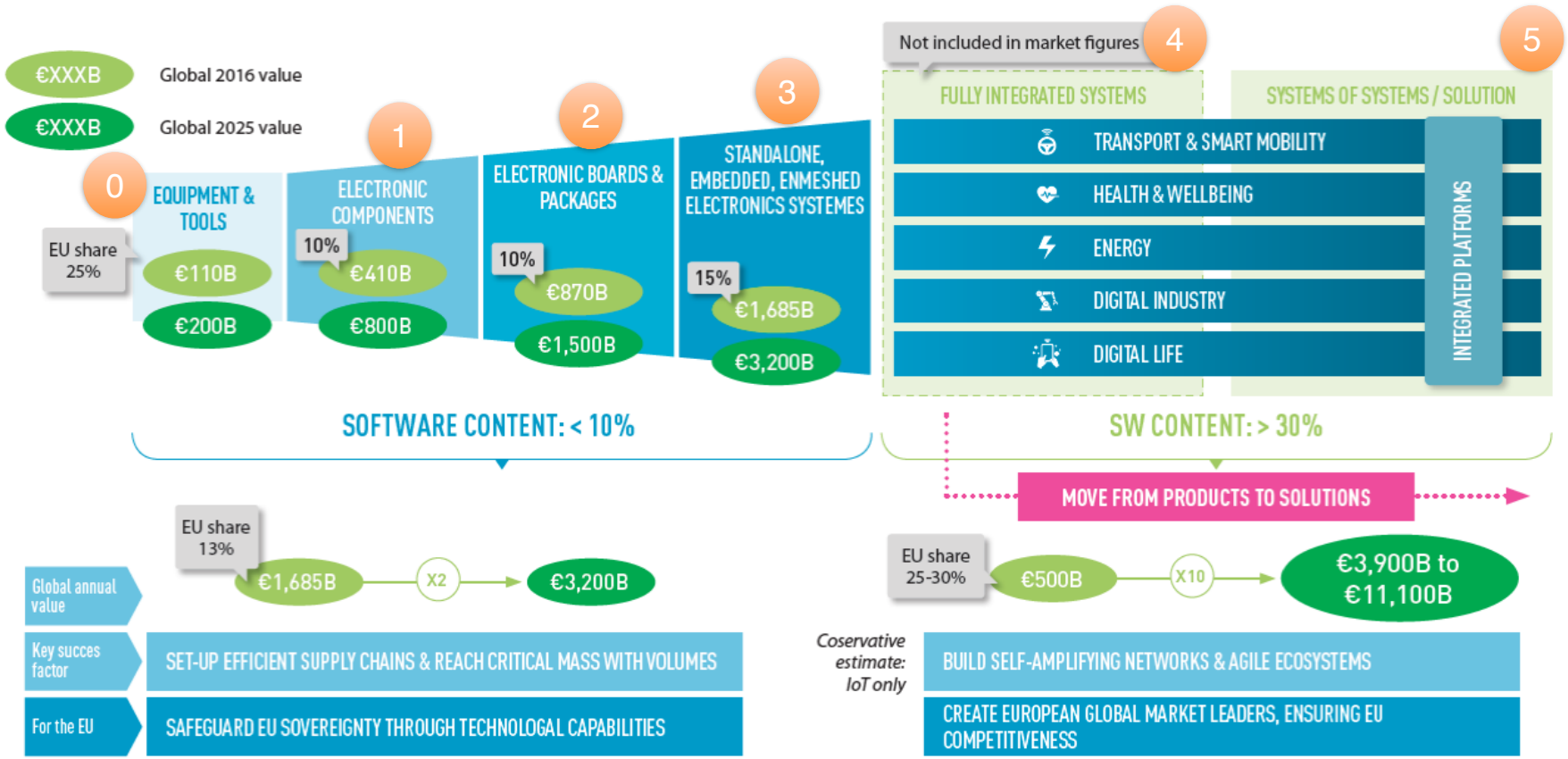
Value is shifting across the CPS value chain (1/2)
Today value is concentrated at 75% upstream

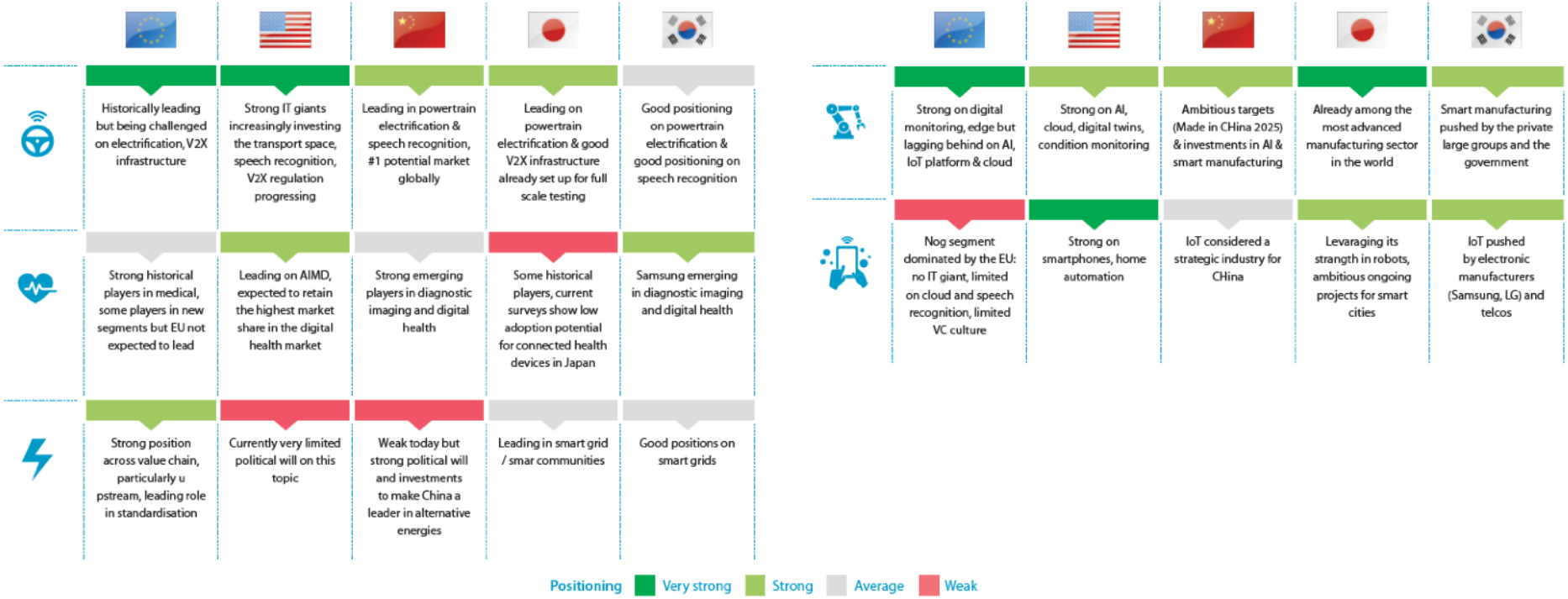
advancy



Note: rounded figures. (1): 2025 estimate value potential for the Internet of Things, not the full potential for ECS end-applications.
Source: Decision, IDC, MGI, Advancy research & analysis

Region strengths & weaknesses per application

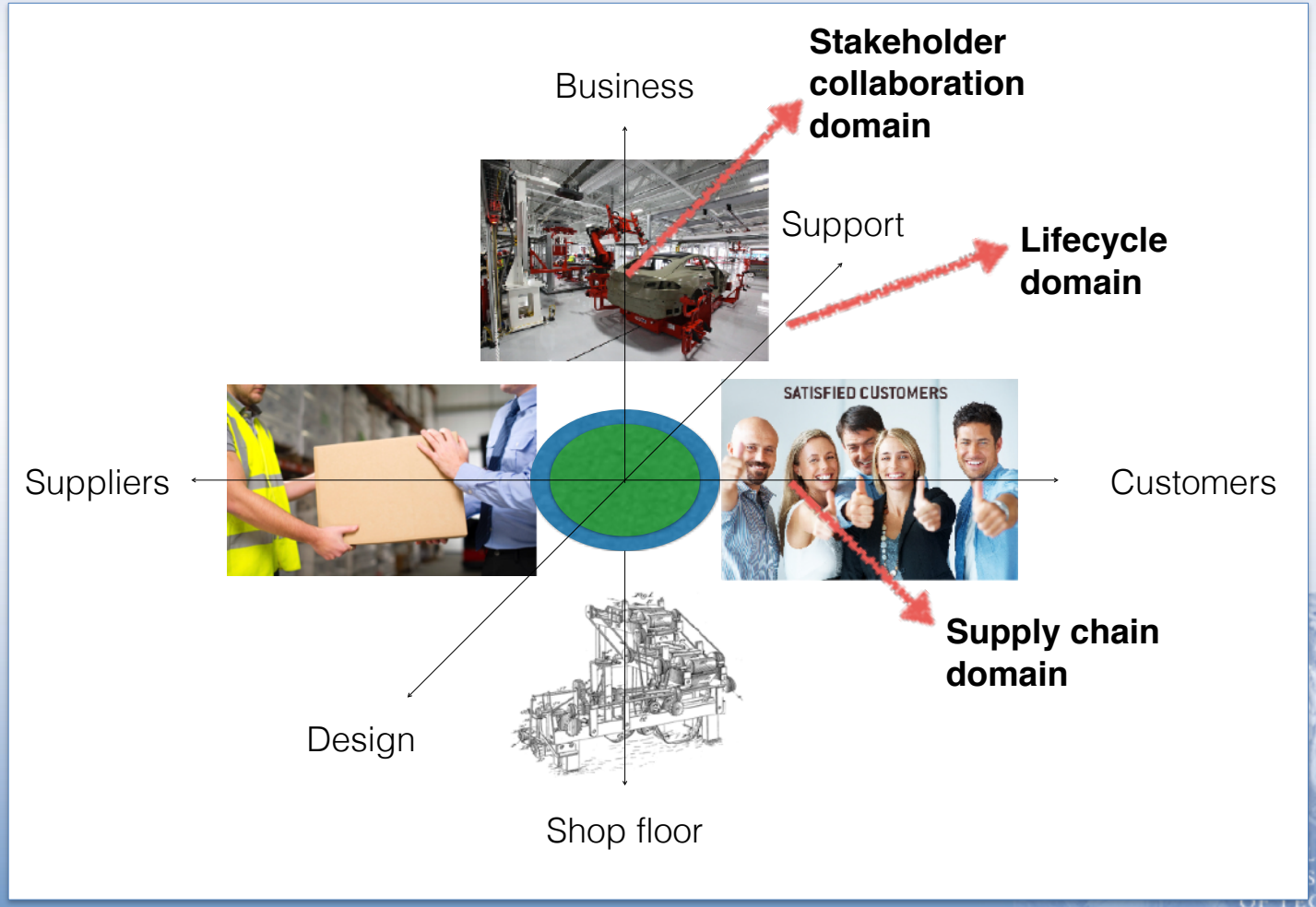
advancy



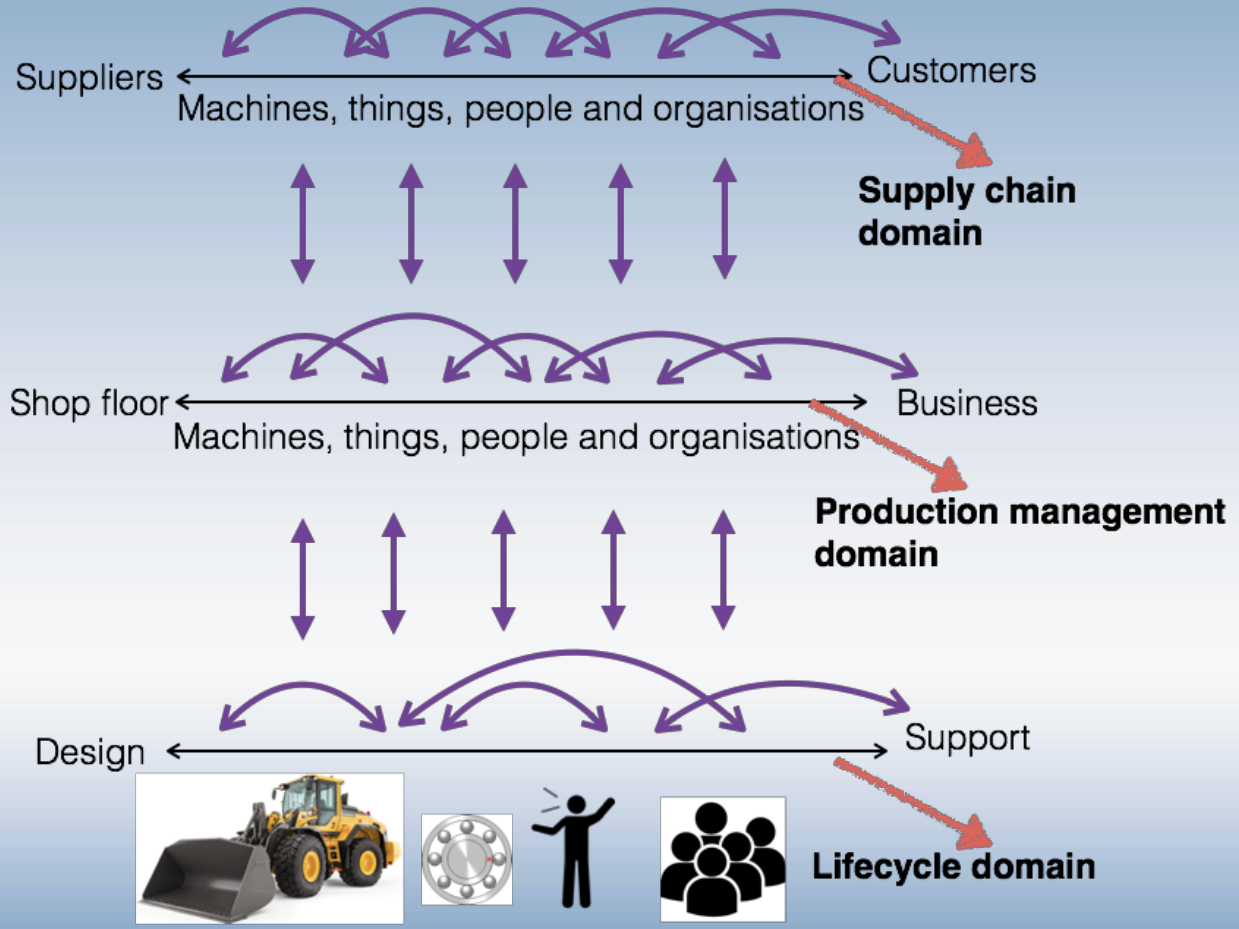
Source: ECS-SRA 2018, Advancy research & analysis

Figure 12: *International benchmarks by application*

From enterprise to multi stakeholder operation

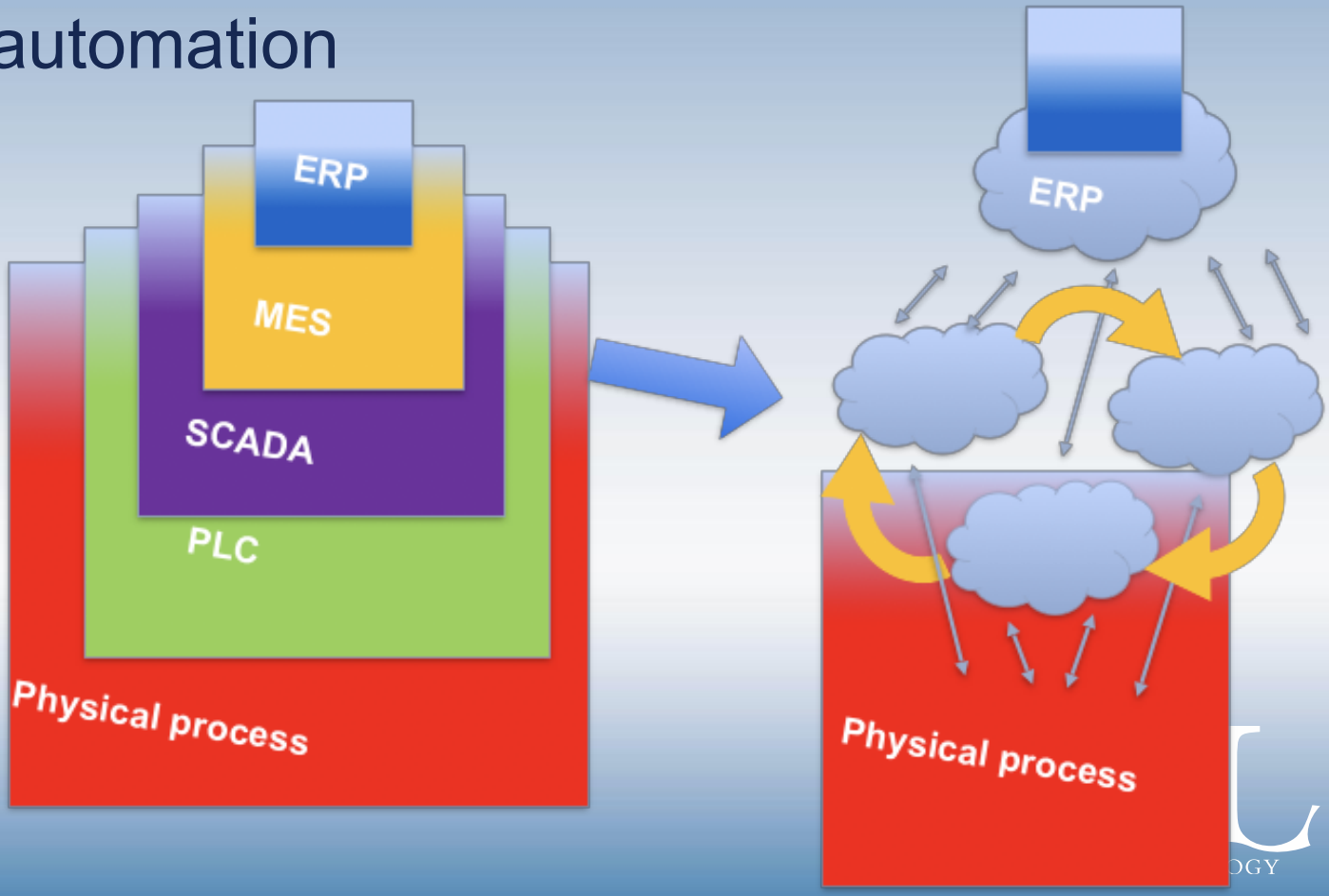


Information feedback enables improvements



Distribution and run-time dynamics

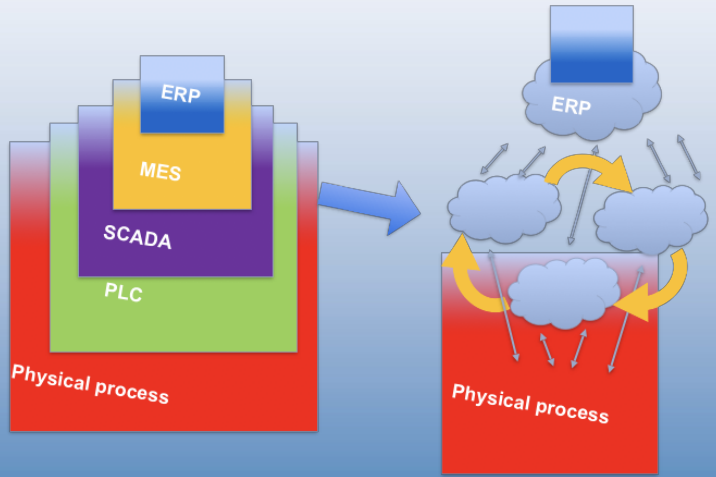
- ✓ Flexible production
- Flexible automation

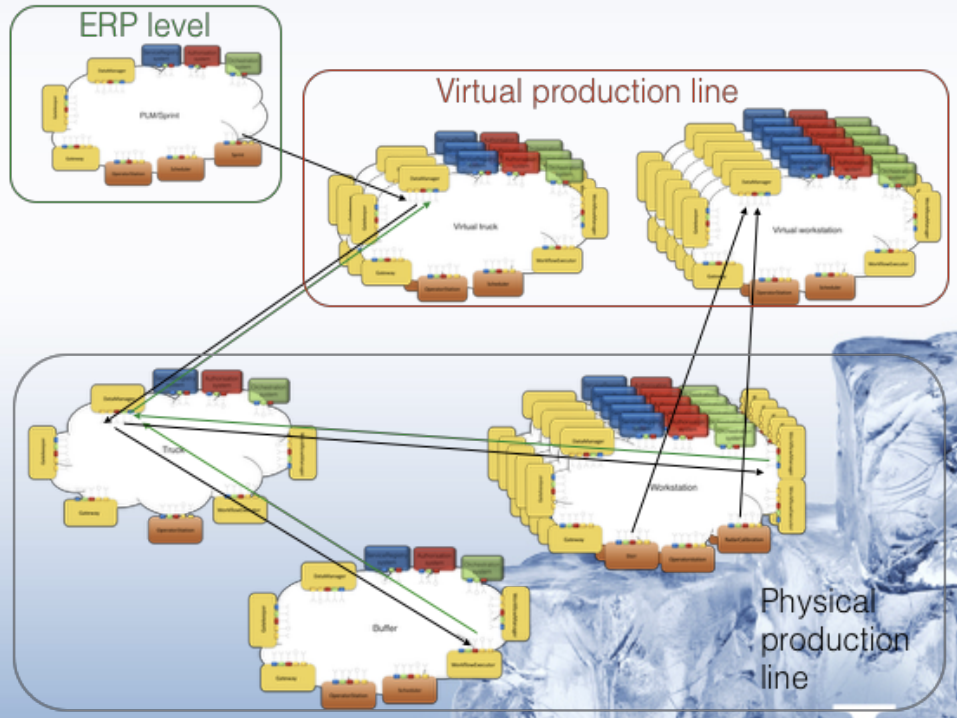


Distribution and run-time dynamics

Flexible automation

Decentralised and virtualised production system





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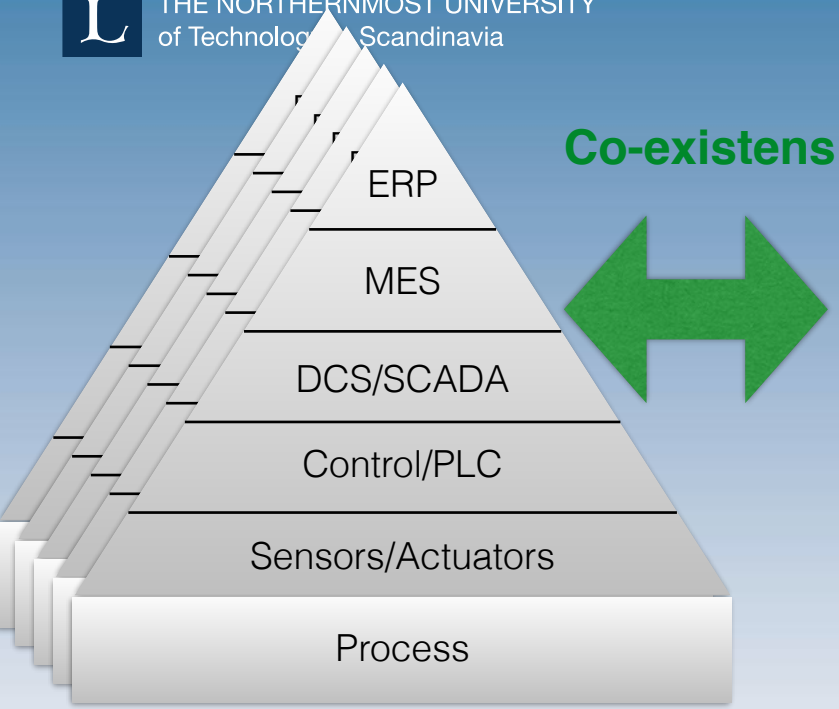
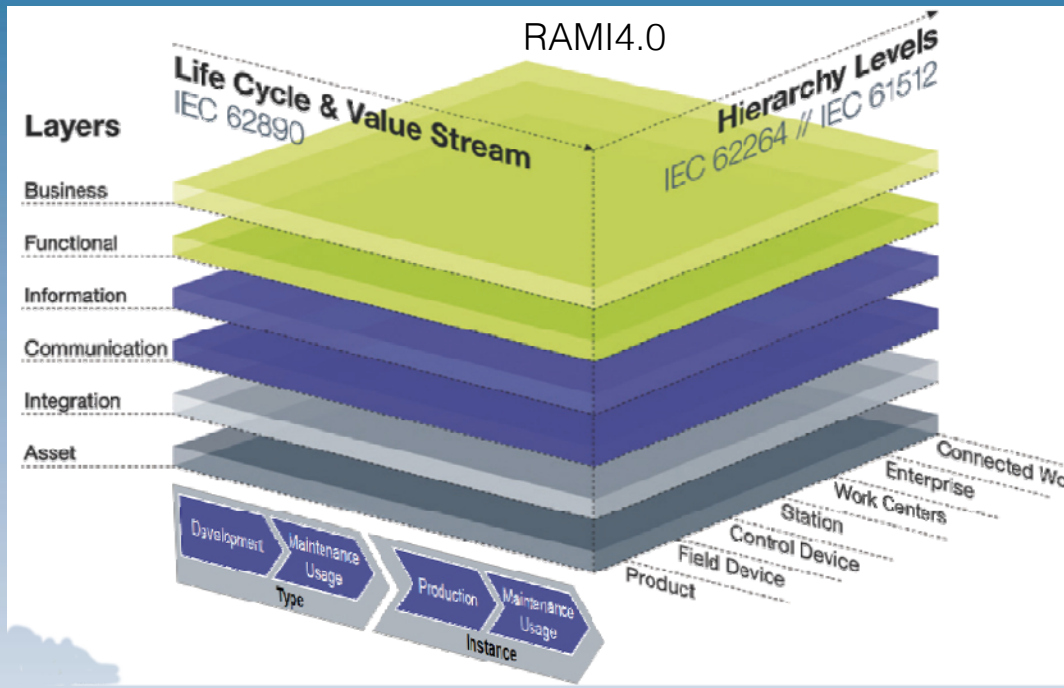
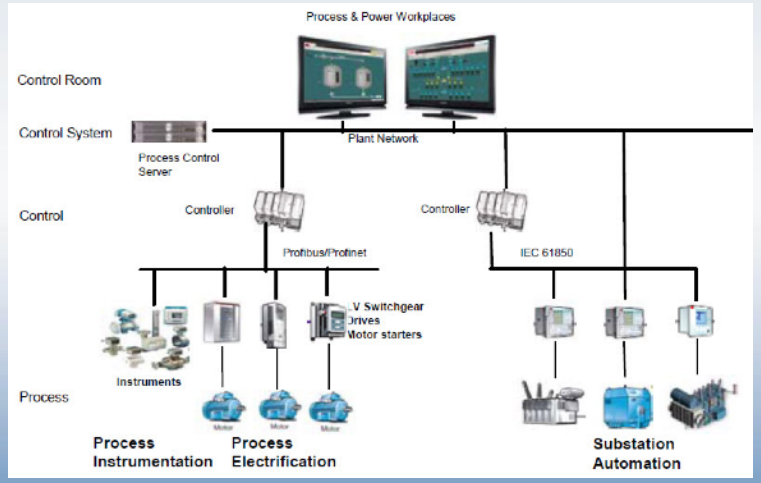
of Technolog Scandinavia



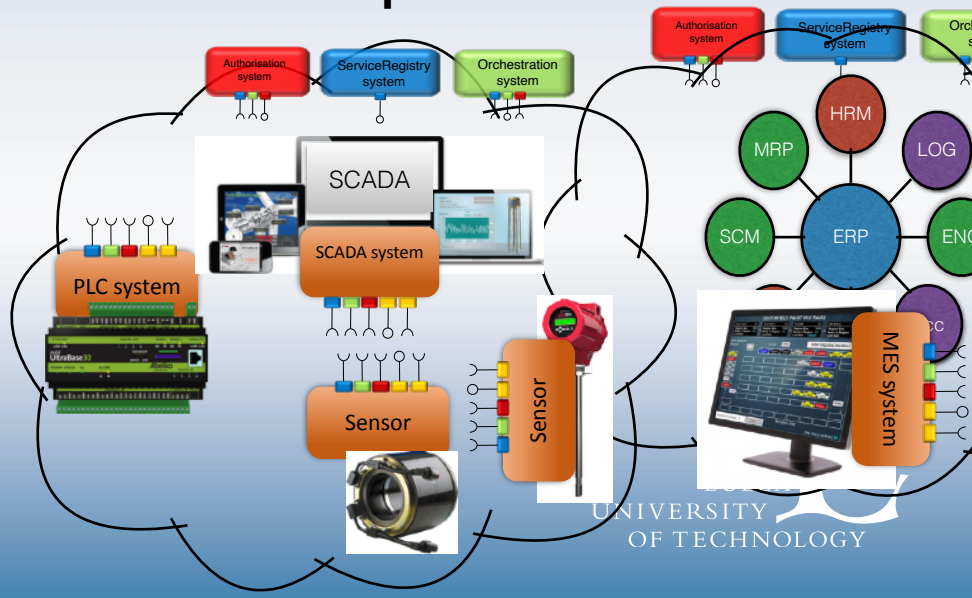
Co-existens

RAMI4.0





Local automation cloud implementation



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Interoperability between what

- Sensors, actuators, controllers
- Machines
- Tools; Analysis, Optimisation
- Groups
- Organisations
- Management: Operational, security, safety, …
- Engineering: Tools, Engineering procedures, ..

Automation engineering tools chain an Example

- LindbäcksBygg
  - Vertex - building CAD tool
  - Speaks BIM XML
- ABB Robot Studio
  - Speaks proprietary semantics

ARROWHEAD TOOLS

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Translation by hand
Two engineers full time

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Interoperability

SoS interoperability: technology enabling instant and seamless understanding of data/ information exchanged within and between networked and distributed systems.

Interoperability

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Protocols

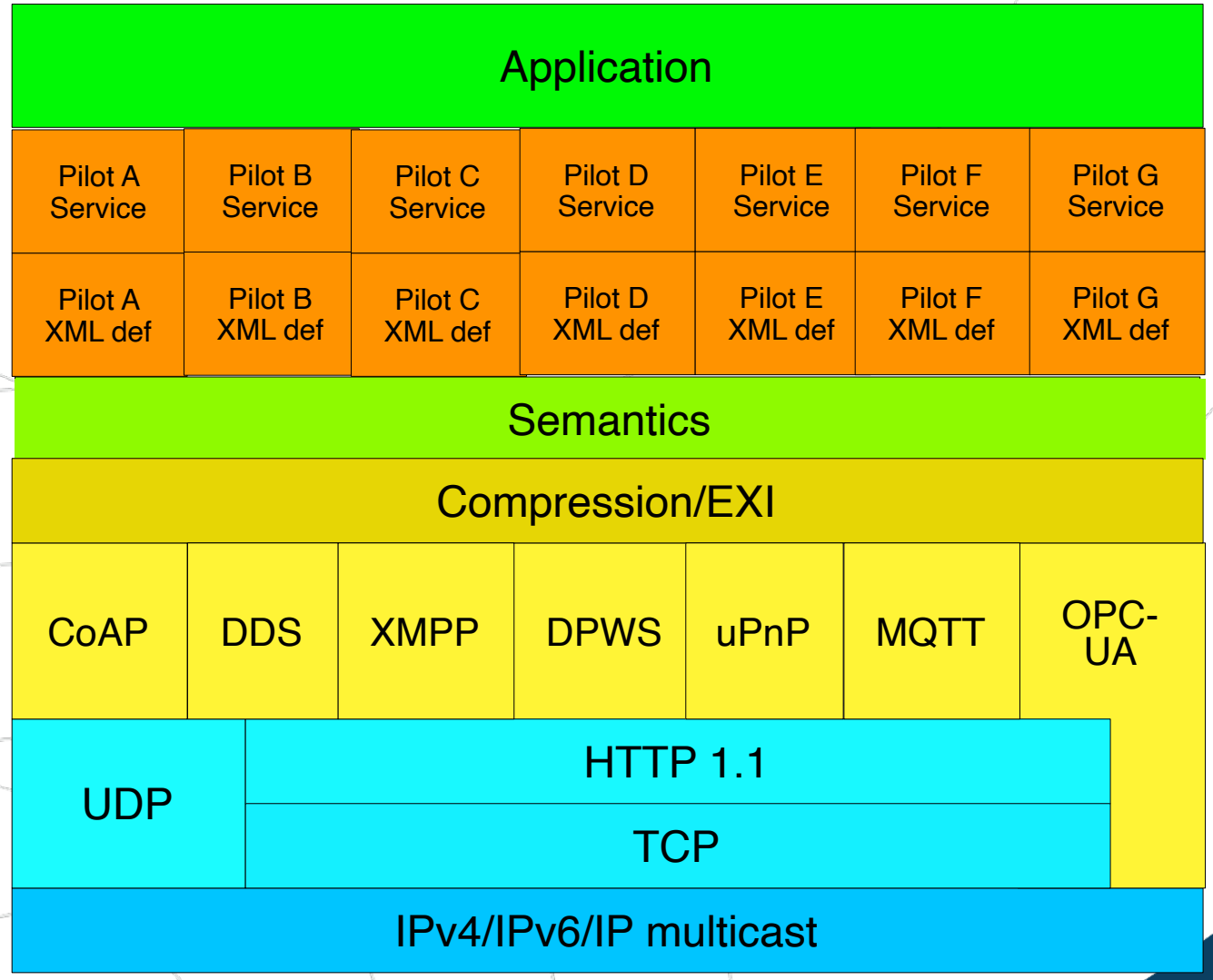
Encoding

Compression

Security

Data semantics

Service Oriented Protocols - Interoperability?



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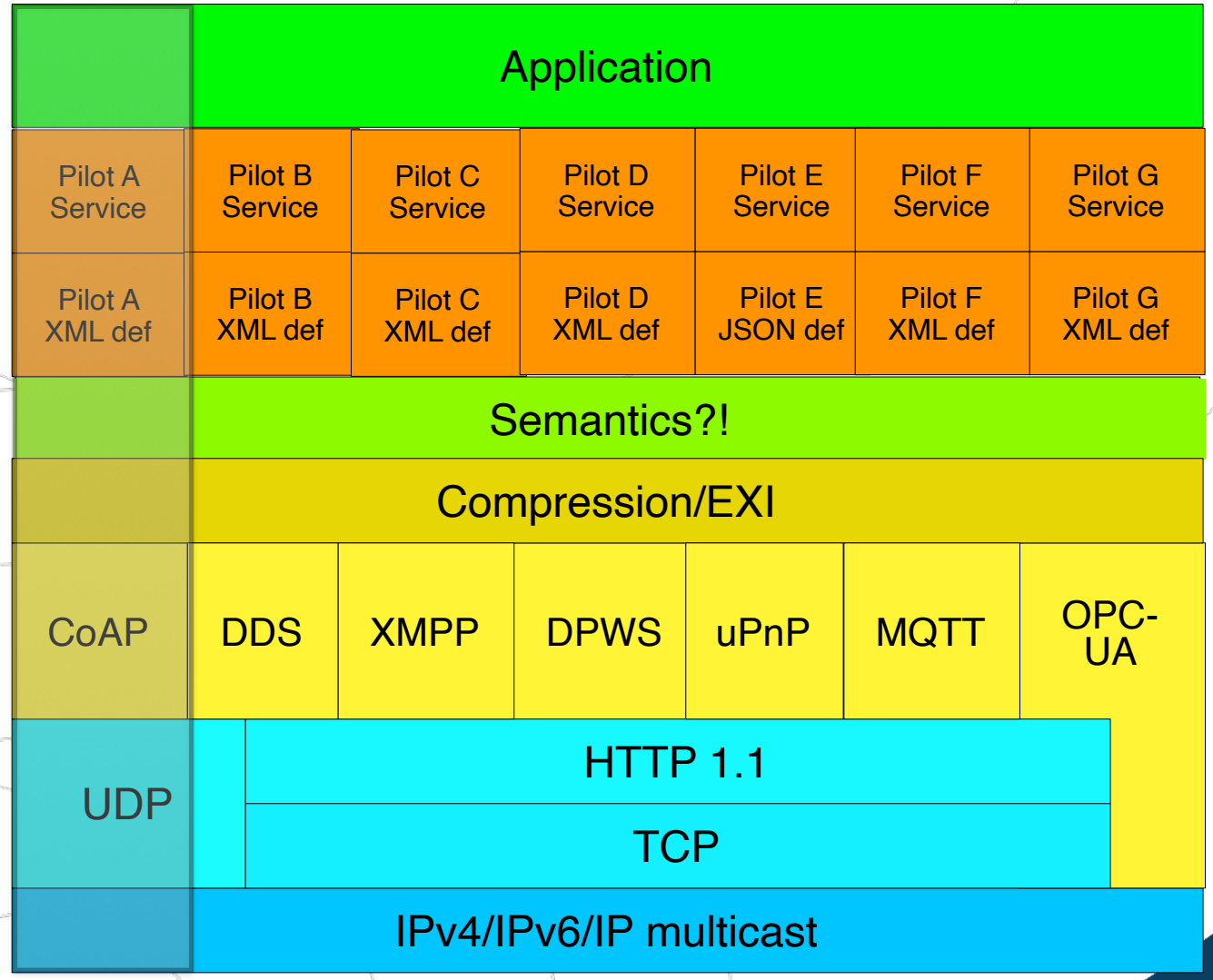
Service Oriented Protocols - Interoperability?



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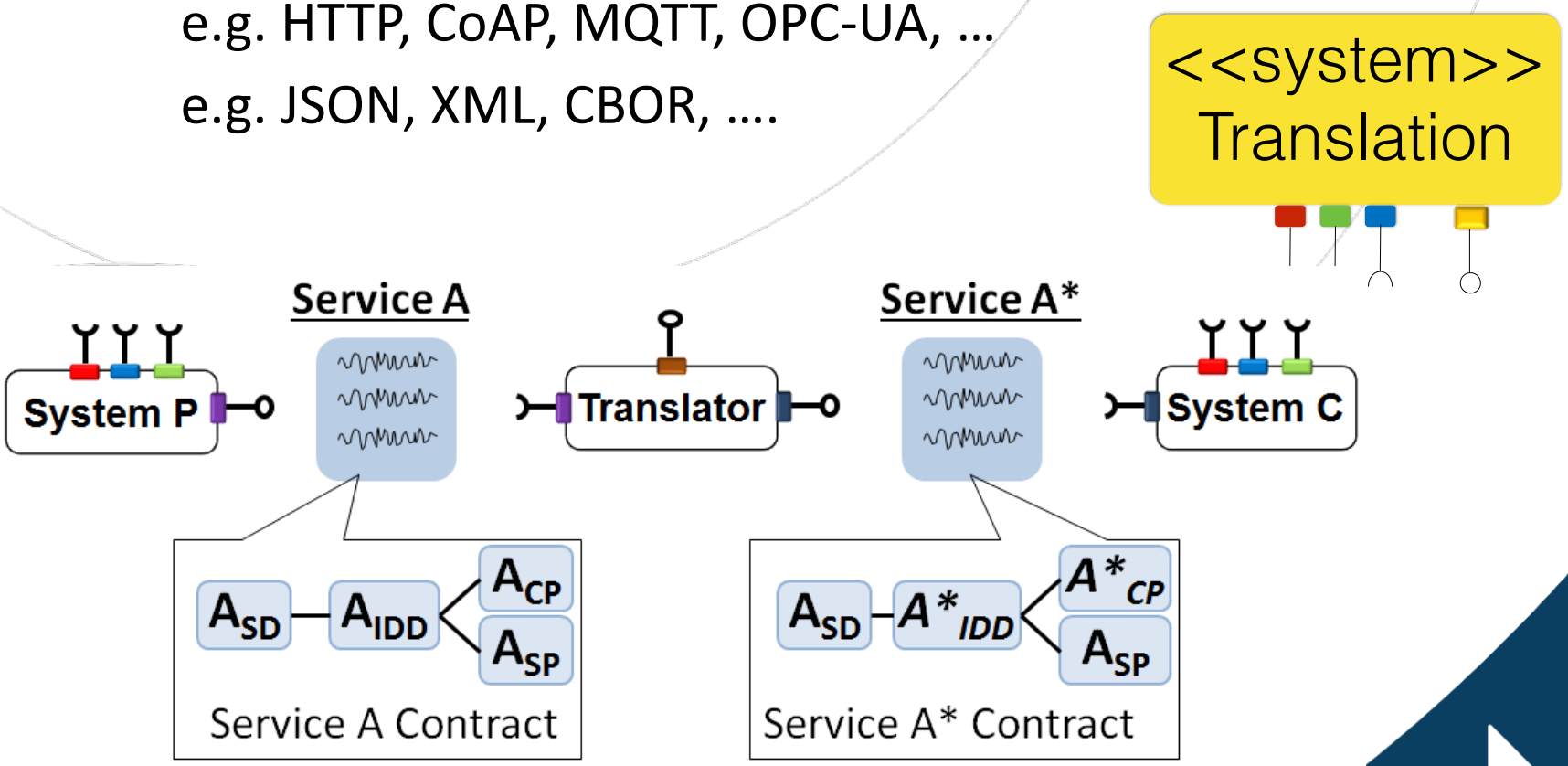
Interoperability based on translation

Translation between different protocols and encoding

e.g. HTTP, CoAP, MQTT, OPC-UA, …

e.g. JSON, XML, CBOR, ….



H. Derhamy, J. Eliasson and J. Delsing, "IoT Interoperability—On-Demand and Low Latency Transparent Multiprotocol Translator," in IEEE Internet of Things Journal, vol. 4, no. 5, pp. 1754-1763, Oct. 2017.

ARROWHEAD

Interoperability

- SoS interoperability: technology enabling instant and seamless understanding of data/information exchanged within and between networked and distributed systems.

✓Protocols

✓Encoding

✓Compression

- Security
- Data semantics

ARROWHEAD TOOLS

Security interoperability

- Authentication
- Authorisation
- Data encryption

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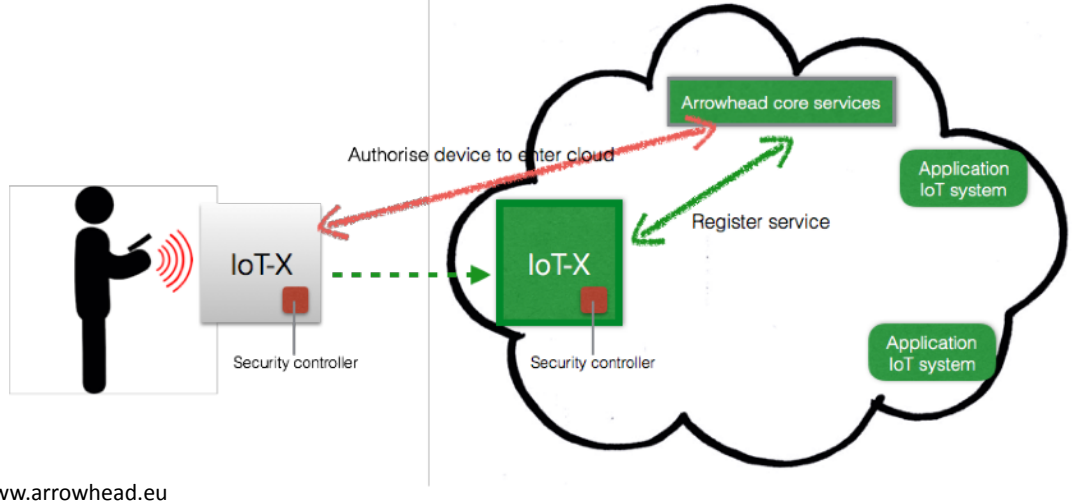
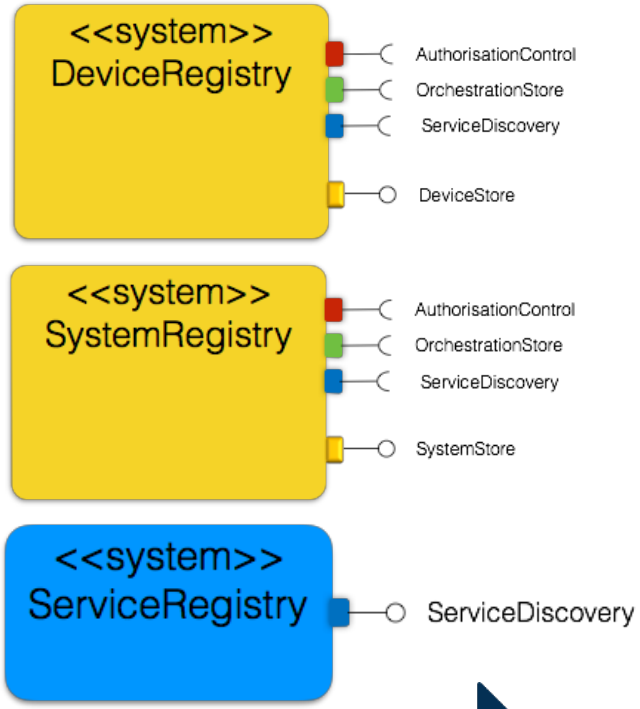
Authentication

Need chain of trust from HW to Services

- HW certificates
- SW certificates
- Registries for HW, SW, Services

- On-boarding procedures





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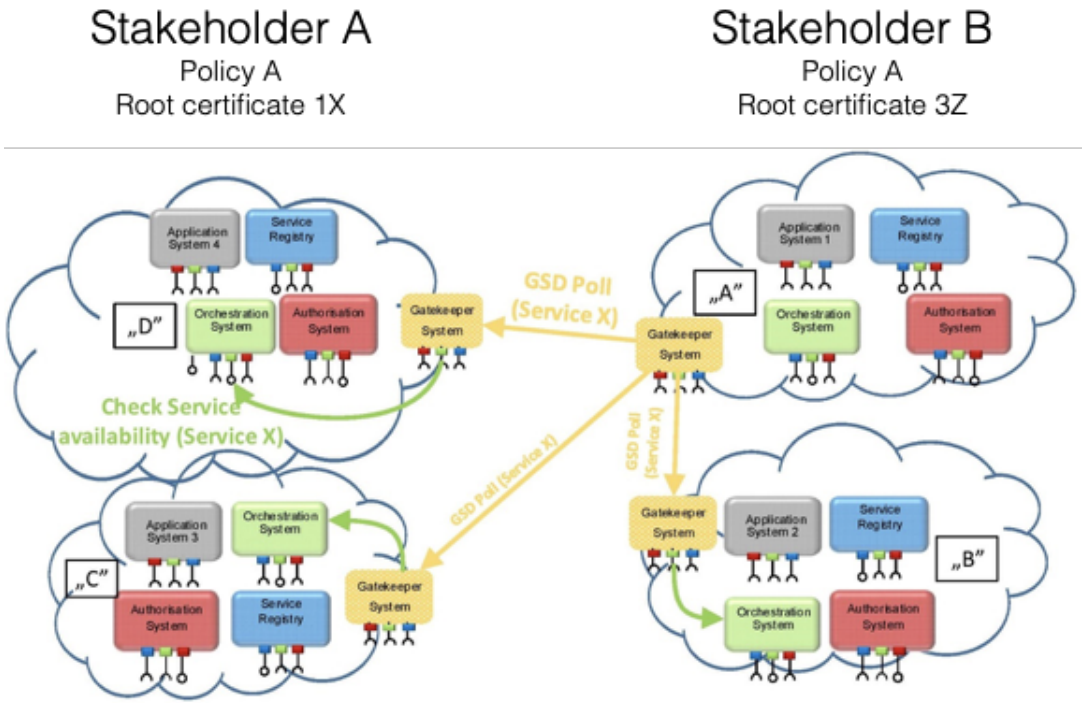
A. Bicaku, S. Maksuti, C. Hegedűs, M. Tauber, J. Delsing and J. Eliasson, "Interacting with the arrowhead local cloud: On-boarding procedure," 2018 IEEE Industrial Cyber-Physical Systems (ICPS), St. Petersburg, 2018, pp. 743-748.

ARROWHEAD TOOLS

Authorisation

- Management issue
  - How to describe authorisation policies?
  - Type of certificates, root certificates,
- **Which authorisation policy languages will an Authorisation system understand**



ARROWHEAD TOOLS

Data encryption

- Many algorithms, e.g.
  - Triple Data Encryption Standard (TripleDES)
  - Blowfish Encryption Algorithm
  - Twofish Encryption Algorithm
  - Advanced Encryption Standard (AES)
  - IDEA Encryption Algorithm
  - MD5 Encryption Algorithm
  - HMAC Encryption Algorithm
  - RSA Security

ARROWHEAD TOOLS

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  - RSA Security

- **Which algorithms does a consumer system have code for**

Data semantics interoperability

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ARROWHEAD TOOLS

Data semantics interoperability

Semantics translation problem

CPS A message

```
[
        {“n”: “OO_temp_sensor”,
         “t”:  318350,
         “u”: “K”,
         “v”: 294.05}
]
```

CPS B message

```
[
        {“bn”: “temp_sensor”, “bt”: 318350},
        {“u”: “Cel”, “v”: 20.9},
        {“u”: “Lon”, “v”: “1”},
        {“u”: “Lat”, “v”: “-1”}
]
```

ARROWHEAD TOOLS

Data semantics interoperability

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]
```

Same ontology
Same data
Do not look the same!!

ARROWHEAD TOOLS

Interoperability strategies

Standards - do like me and we are interoperable!?

- Asset descriptions
  - ISO 15926
  - ISO 10303 (AP 223)
  - Asset administration shell DIN ….
- Sensor data
  - SenML (RFC 8428) developed by OMA
  - SensorML (OGC standard)

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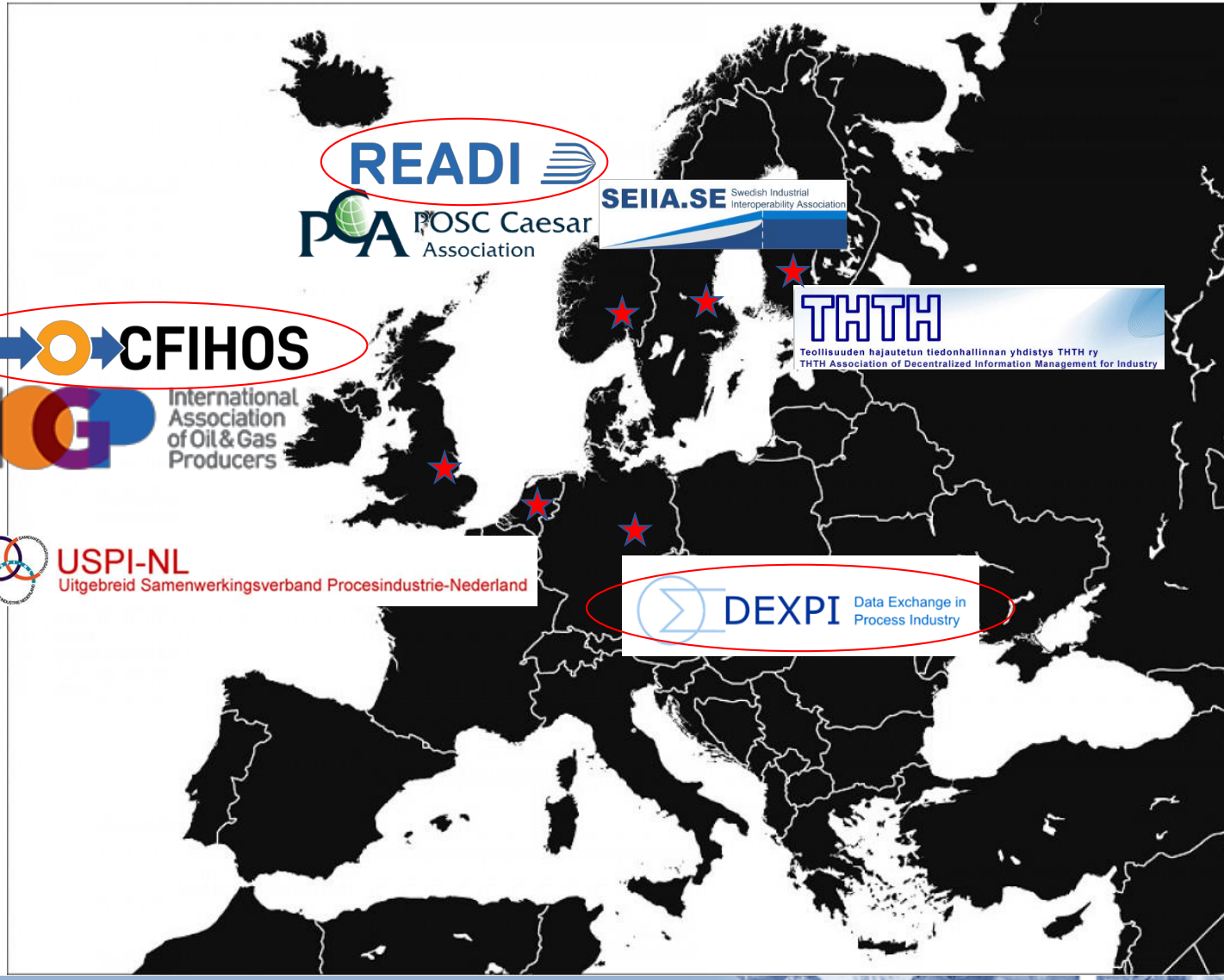
ISO 15926



Changing How the World Builds

MIMOSA

ENA

Interoperability strategies

Ontology based approaches

Semantic web approach (SO 15926)

Semantic annotations of XSD files, the meta-data, that describe the exchanged XML messages.

R. Campos-Rebelo, F. Moutinho, L. Paiva and P. Maló, "Annotation Rules for XML Schemas with Grouped Semantic Annotations," IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society, Lisbon, Portugal, 2019, pp. 5469-5474.

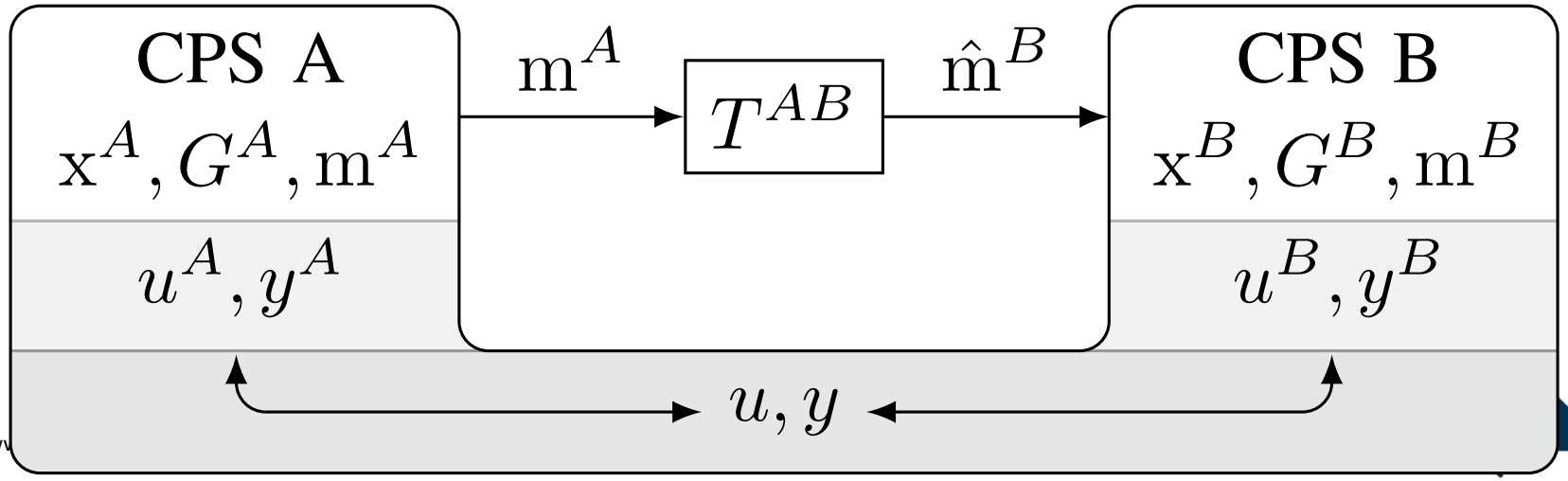
ARROWHEAD TOOLS

Interoperability strategies

Machine learning approach

- Model of communicating cyber-physical systems (CPS) with different data representations and semantic definitions that interact in a physical environment (gray) and service-oriented architecture (white) via messages m translated by a function T^{AB}

.



J. Nilsson, F. Sandin and J. Delsing, "Interoperability and machine-to-machine translation model with mappings to machine learning tasks," 2019 IEEE 17th International Conference on Industrial Informatics (INDIN), Helsinki, Finland, 2019, pp. 284-289.

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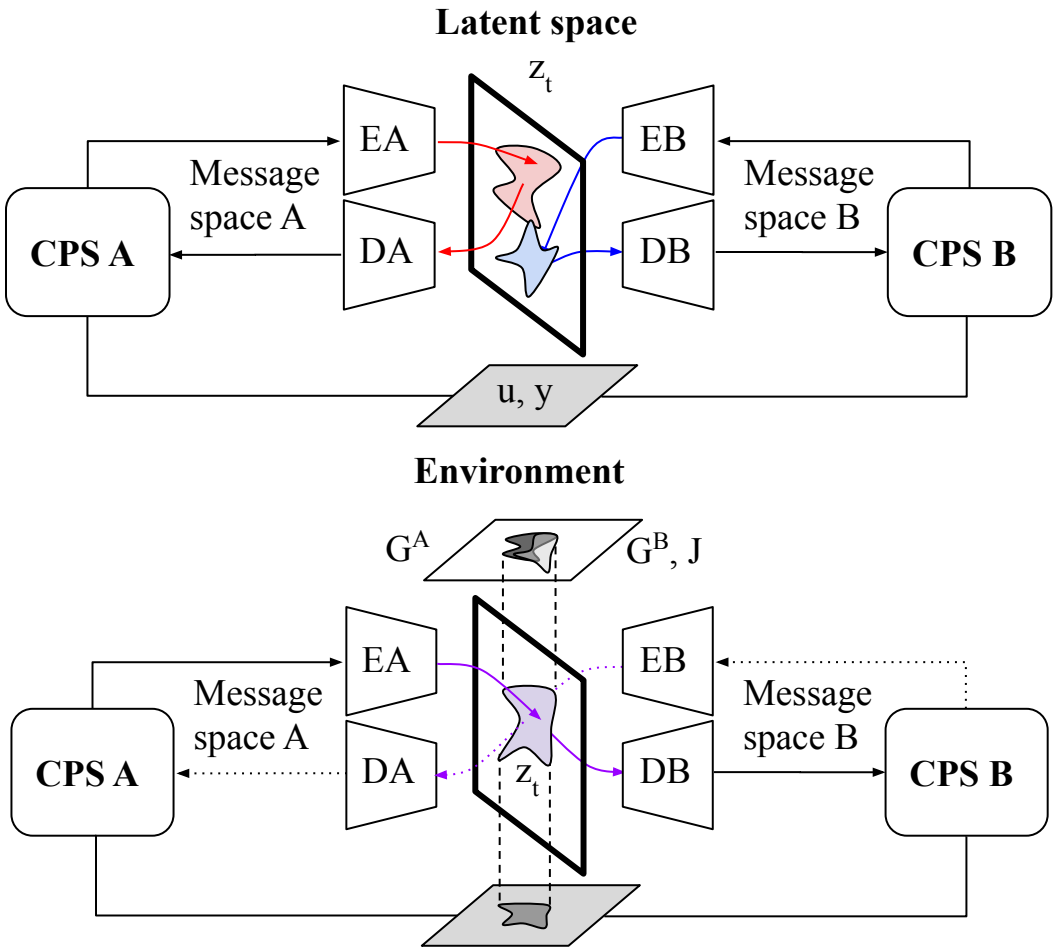
Data semantics translation approach



Nilsson, J. (2019). System of Systems Interoperability Machine Learning Model (Licentiate dissertation). Luleå University of Technology. Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:ltu:diva-76229

ARROWHEAD TOOLS

Tool data semantics interoperability

Semantics translation results

TABLE I: Tested models and their results.

Model	Kind	Strategy	Size	Accuracy		Error	
				Max	Mean	Min	Mean
0	non-shared	2	1-layer	0.70	0.44	0.57	4.0
1	non-shared	2	2-layer	0.73	0.38	0.50	4.9
2	non-shared	1	1-layer	0.66	0.39	0.48	6.7
3	non-shared	1	2-layer	0.74	0.34	0.71	12.0
4	shared	2	2-layer	0.70	0.34	0.54	15.0
5	shared	3	2-layer	0.75	0.41	0.43	2.7
6	shared	1	2-layer	0.69	0.33	0.53	12.0
7	supervised	–	1-layer	1.0	1.0	0.16	0.17
8	supervised	–	2-layer	1.0	0.99	0.16	0.19

Interoperability considerations

New standards are created

Standards are updated - 5-15 years

Technology life times and update and upgrade cycles

- Mechanical life time - 20-100 years
- Automation/IT HW life time - 10 years

Semantics/ontologies

- New once invented every hour

ARROWHEAD TOOLS

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Semantics/ontologies

- New once invented every hour

Automation/IT SW lifetime - ….. months to a few years?!

ARROWHEAD TOOLS

Interoperability engineering

- Design time
  - Write a situation specific and dedicated translator
  - Make use of general translator

- Run time??
  - What can be automated and made autonomous?
    - Can service contract mismatches be identified?
    - Can we inject protocol and encoding translation?
    - Can we inject missing consumer capabilities?
    - Can we inject servitisation of legacy API?

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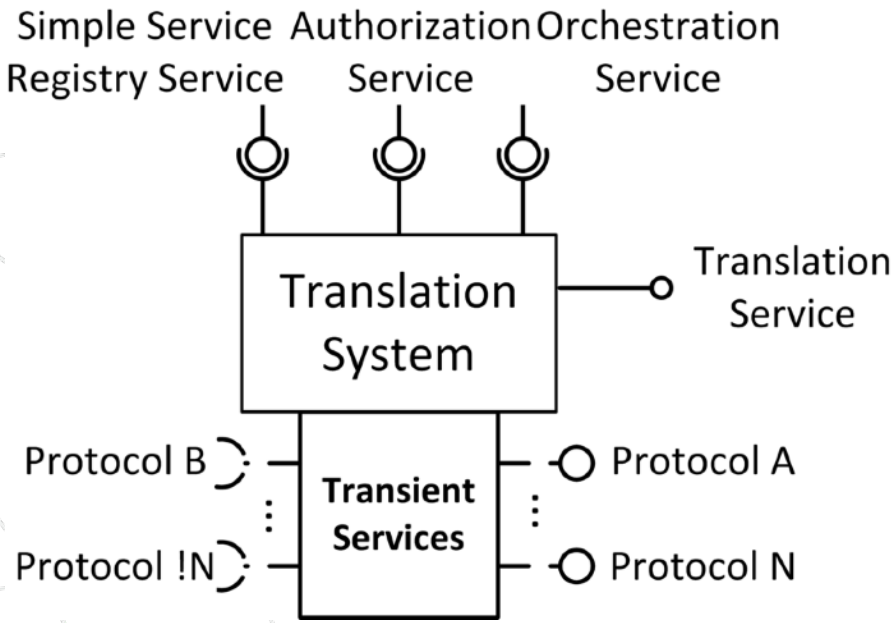
Dynamic instantiation of translation

- Instantiation of translator based on needs:
  - Protocol
  - Encoding
  - Semantics



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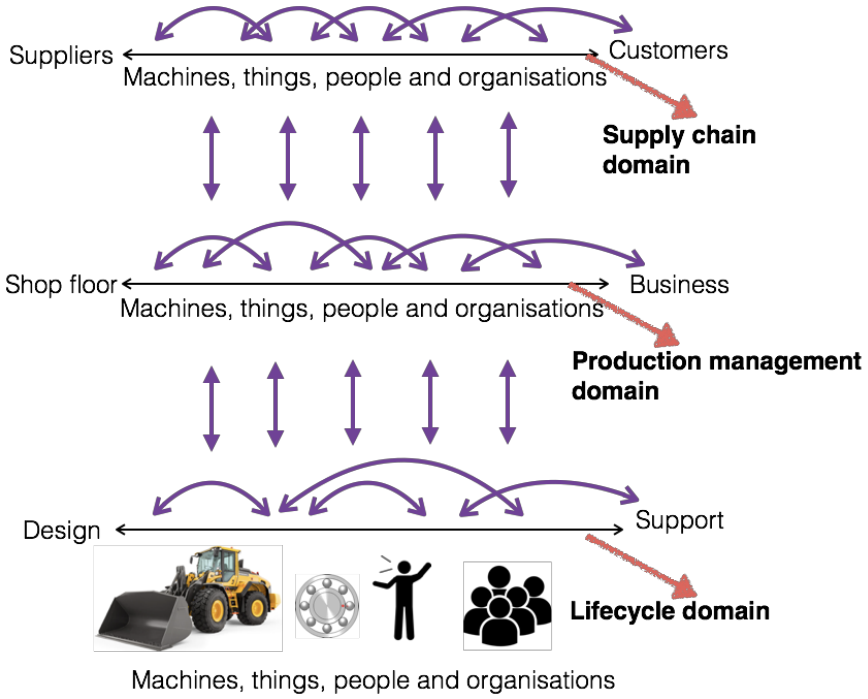
Emerging interoperability issues

- Outcome-based business models

- Micro service transactions
- **<u>Currency</u> interoperability** at the edge



ARROWHEAD TOOLS

IoT-SoS Architectures & Platforms

Features	Arrowhead	AUTOSAR	BaSyx	FIWARE	IoTivity	LWM2M	OCF
Key principles	SOA, Local Automation Clouds	Runtime, Electronic Control Unit (ECU)	Variability of production processes	Context awareness	Device-to-device communication	M2M, Constrained networks	Resource Oriented REST, Certification
Real-time	Yes	Yes	No	No	Yes (IoTivityConstrained)	No	No
Run-time	Dynamic orchestration and authorization, monitoring, and dynamic automation	Runtime Environment layer (RTE)	Runtime environment	Monitoring, dynamic service selection and verification	No	No	No
Distribution	Distributed	Centralize	Centralize	Centralize	Centralize	Centralize	Centralize
Open Source	Yes	No	Yes	Yes	Yes	Yes	No
Resource accessibility	High	Low	Very low	High	Medium	Medium	Low
Supporters	Arrowhead	AUTOSAR	Basys 4.0	FIWARE Foundation	Open Connectivity Foundation	OMA SpecWorks	Open Connectivity Foundation
Message patterns	Req/Repl, Pub/sub	Req/Repl, Pub/sub	Req/Repl,	Req/Repl, Pub/sub	Req/Repl, Pub/sub	Req/Repl	Req/Repl
Transport protocols	TCP, UDP, DTLS/TLS	TCP, UDP, TLS	TCP	TCP, UDP, DTLS/TLS	TCP, UDP, DTLS/TLS	TCP, UDP, DTLS/TLS, SMS	TCP, UDP, DTLS/TLS, BLE
Communication protocols	HTTP, CoAP, MQTT, OPC-UA	HTTP	HTTP, OPC-UA	HTTP, RTPS	HTTP, CoAP	CoAP	HTTP, CoAP
3rd party and Legacy systems adaptability	Yes	Yes	Yes	Yes	No	No	No
Security Manager	Authentication, Authorization and Accounting Core System	Crypto Service Manager, Secure Onboard Communication	--	Identity Manager Enabler	Secure Resource Manager	OSCORE	Secure Resource Manager
Standardization	Use of existing standards	AUTOSAR standards	Use of existing standards	FIWARE NGSI	OCF standards	Use of existing standards	OCF standards

ARROWHEAD TOOLS

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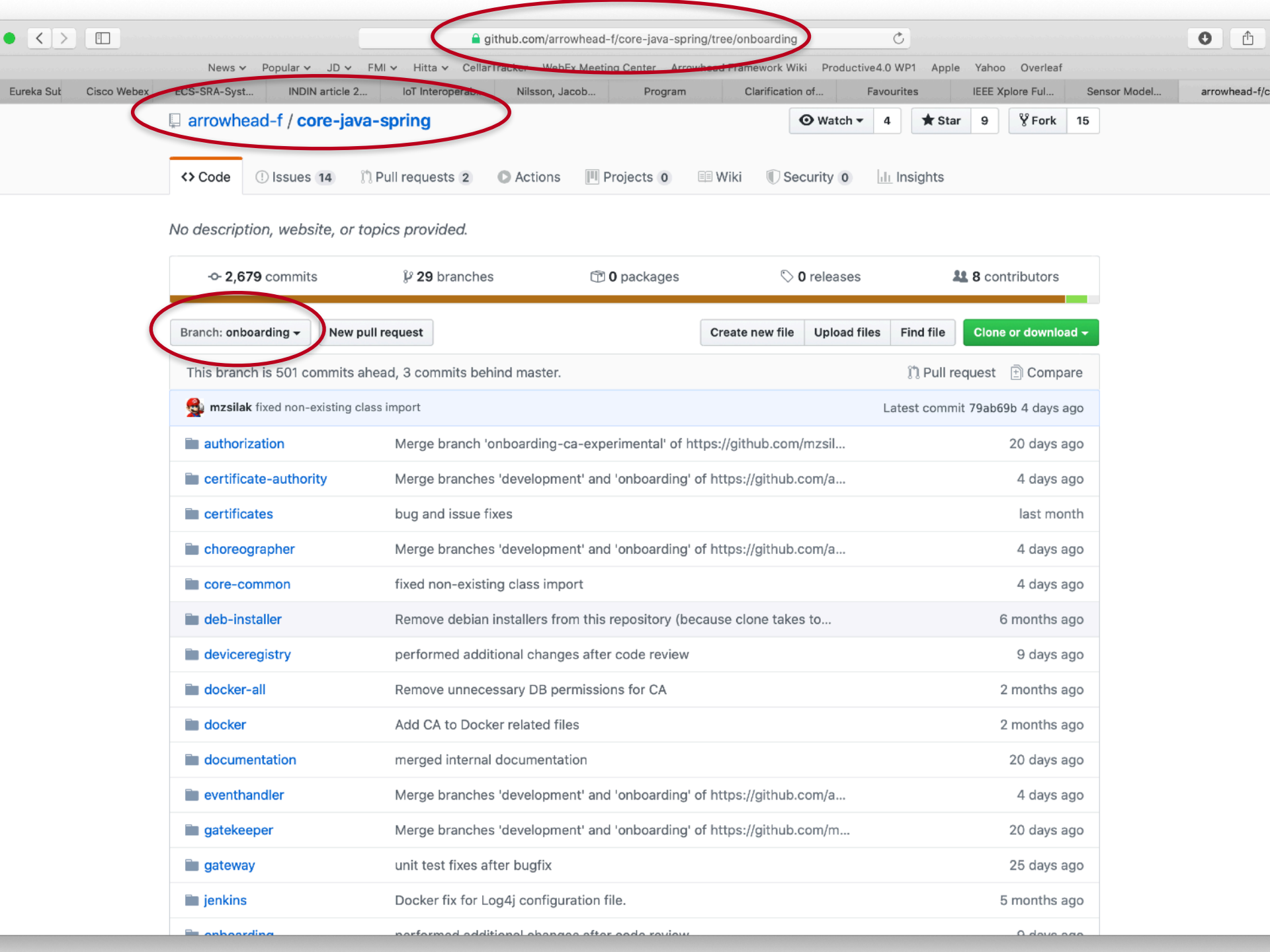
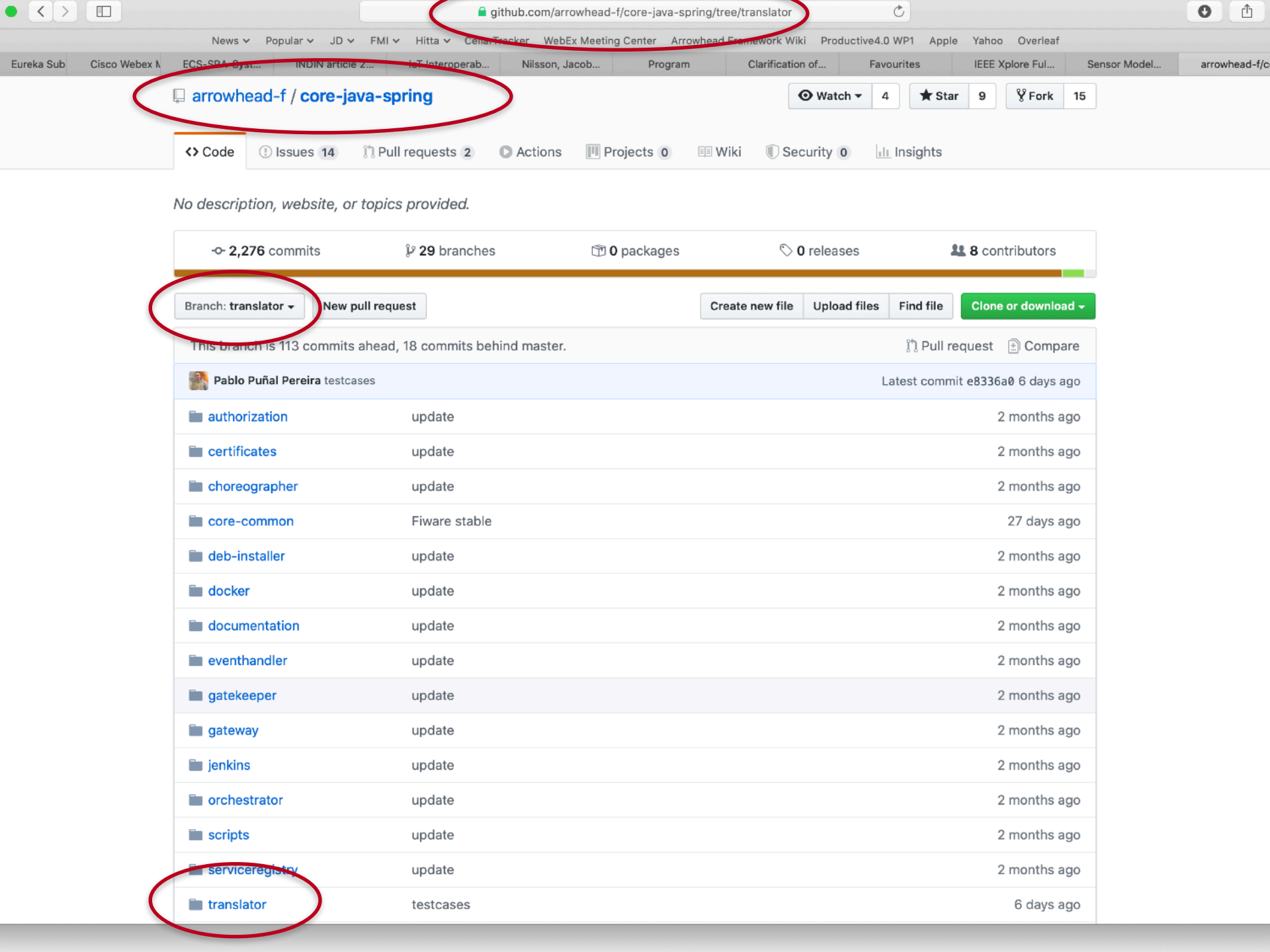

github.com/arrowhead-f/core-java-spring/tree/onboarding
arrowhead-f / core-java-spring
Watch 4
Star 9
Fork 15
Code
Issues 14
Pull requests 2
Actions
Projects 0
Wiki
Security 0
Insights
No description, website, or topics provided.
2,679 commits
29 branches
0 packages
0 releases
8 contributors
Branch: onboarding
New pull request
Create new file
Upload files
Find file
Clone or download
This branch is 501 commits ahead, 3 commits behind master.
Pull request
Compare
mzsilak fixed non-existing class import
Latest commit 79ab69b 4 days ago
authorization Merge branch 'onboarding-ca-experimental' of https://github.com/mzsil... 20 days ago
certificate-authority Merge branches 'development' and 'onboarding' of https://github.com/a... 4 days ago
certificates bug and issue fixes last month
choreographer Merge branches 'development' and 'onboarding' of https://github.com/a... 4 days ago
core-common fixed non-existing class import 4 days ago
deb-installer Remove debian installers from this repository (because clone takes to... 6 months ago
deviceregistry performed additional changes after code review 9 days ago
docker-all Remove unnecessary DB permissions for CA 2 months ago
docker Add CA to Docker related files 2 months ago
documentation merged internal documentation 20 days ago
eventhandler Merge branches 'development' and 'onboarding' of https://github.com/a... 4 days ago
gatekeeper Merge branches 'development' and 'onboarding' of https://github.com/m... 20 days ago
gateway unit test fixes after bugfix 25 days ago
jenkins Docker fix for Log4j configuration file. 5 months ago


github.com/arrowhead-f/core-java-spring/tree/translator
arrowhead-f / core-java-spring
Watch 4
Star 9
Fork 15
Code
Issues 14
Pull requests 2
Actions
Projects 0
Wiki
Security 0
Insights
No description, website, or topics provided.
2,276 commits
29 branches
0 packages
0 releases
8 contributors
Branch: translator
New pull request
Create new file
Upload files
Find file
Clone or download
This branch is 113 commits ahead, 18 commits behind master.
Pull request
Compare
Pablo Puñal Pereira testcases
Latest commit e8336a0 6 days ago
authorization update 2 months ago
certificates update 2 months ago
choreographer update 2 months ago
core-common Fiware stable 27 days ago
deb-installer update 2 months ago
docker update 2 months ago
documentation update 2 months ago
eventhandler update 2 months ago
gatekeeper update 2 months ago
gateway update 2 months ago
jenkins update 2 months ago
orchestrator update 2 months ago
scripts update 2 months ago
serviceregistry update 2 months ago
translator testcases 6 days ago

Conclusions

- Non-interoperability is a cost driver in production automation
- Interoperable engineering tools and support is necessary
- Autonomous interoperability instantiation can become a huge cost saver

Thanks for listening

jerker.delsing@ltu.se