
KubeCon
CloudNativeCon
North America 2022
BUILDING FOR THE ROAD AHEAD
DETROIT 2022
TiKV
TiKV
HELM

BUILDING FOR THE ROAD AHEAD

DETROIT 2022

Energizing the Manufacturing Industry with Kubernetes and Cloud Native

Marcel Wagner, Intel

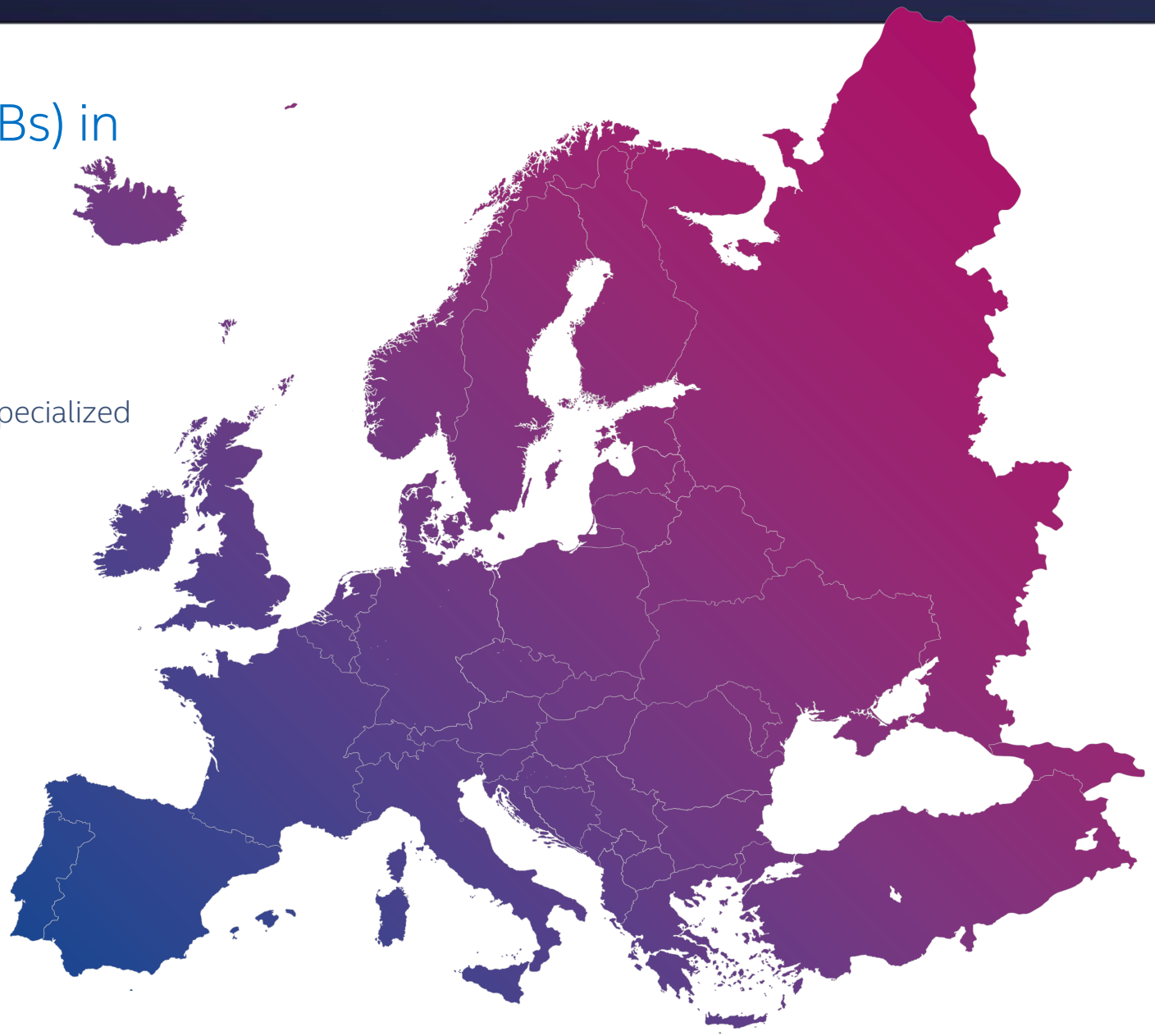
Agenda

- Context & Motivation: Why Cloud Native in Industrial
- Semantic Web Standards in a Nutshell
- Cloud Native Architecture of IndustryFusion® Project
- Semantic SQL K8s Operator
- Demo
- Conclusion
- Q & A

Small & Medium Businesses in European Manufacturing

Small & Medium Businesses (SMBs) in Europe

- Definition: Less than 250 employees
- 99%[+] of industry are SMBs
- 53%[+] of Industrial value add is created by SMBs
- Often family-owned, tech. market leaders & highly specialized



Challenges in Industrial

- Still at the beginning of the Industry 4.0 journey
- Heterogeneous machine landscape
  - Not a unified environment from a single machine builder
  - Large “legacy” of old machines
- No common open digitization platform
- Worry to lose control over own data

[+]Source: https://www.ifm-bonn.org/

IndustryFusion* Foundation (IFF) – Self Empowerment of SMBs

- Founded by 60 manufacturers and stakeholders in the metal processing industry in Germany
- Focus: Metal sheet processing, cutting, welding, de-burring
- Aligned with Platform Industry 4.0
- Ownership of base platform
- Semantics based use-case and machine definition
- Open source (Apache 2.0)
- Cloud Native from shopfloor to Cloud

- https://www.industry-fusion.com/
- https://github.com/IndustryFusion

Image Source: Provided by IndustryFusion Foundation

Reference Use Case: „Smartness“ for OpEx

Legacy: Cutting System + Air Filter hardwired

- Safety regulations demands air filtering
- Hard-wire is reliable and safe, yet non-economical!

Opportunity: Knowledge-based “smart” filtering

- Strength of filter COULD be dependent on dimensions of workpiece
  - Use knowledge about the workpiece: material, thickness…
  - Control the strength of filtering – save operation energy
  - Retain the filtered air – save heating energy
  - Reduce hazard level of filter cartridges – save disposal cost

Image Source: Provided by IndustryFusion Foundation

Domain Expert Cooperation and Safety are Biggest Challenge to Create Value

Image Source: Provided by IndustryFusion Foundation

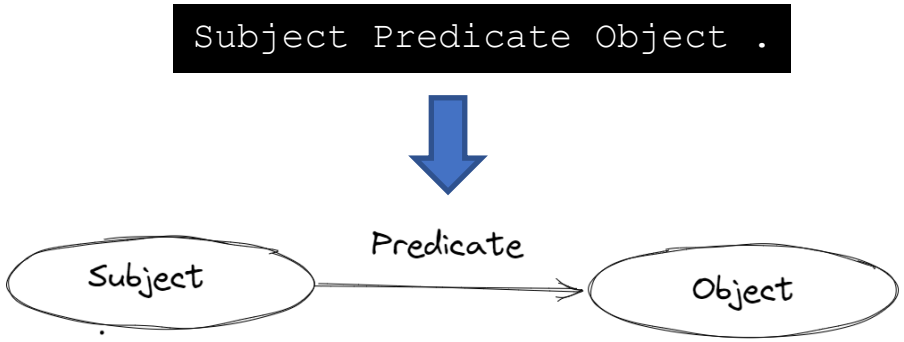
Challenges

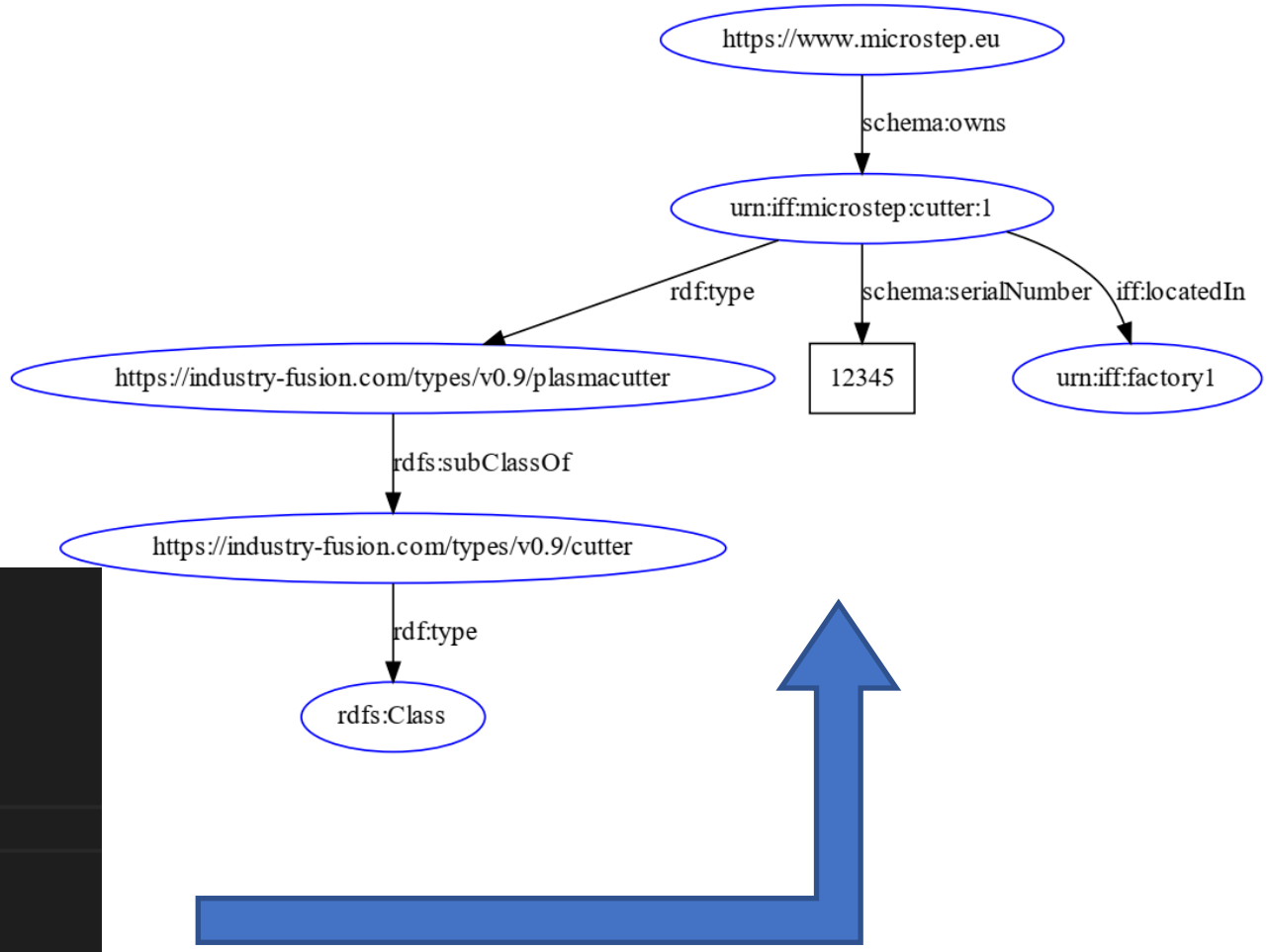
- Safety recertification might be needed dependent on required changes
- Domain experts have no formal common language to express system improvements
- Use-cases are going across domains, e.g. knowledge on machines, processes, buildings, material and environment need to be combined
- The expected ROI for only one use case with specific machines is not high enough to justify additional Infrastructure and Interfaces

Solution

- Such a system must go beyond simple “metrics collection” and dashboards
- Semantic Web standards allow to
  - add context and relationships to domains to create “ontologies”
  - relate ontologies from different domains
  - assess smart safety requirements from formal description
  - collaborate on use-cases development in a community

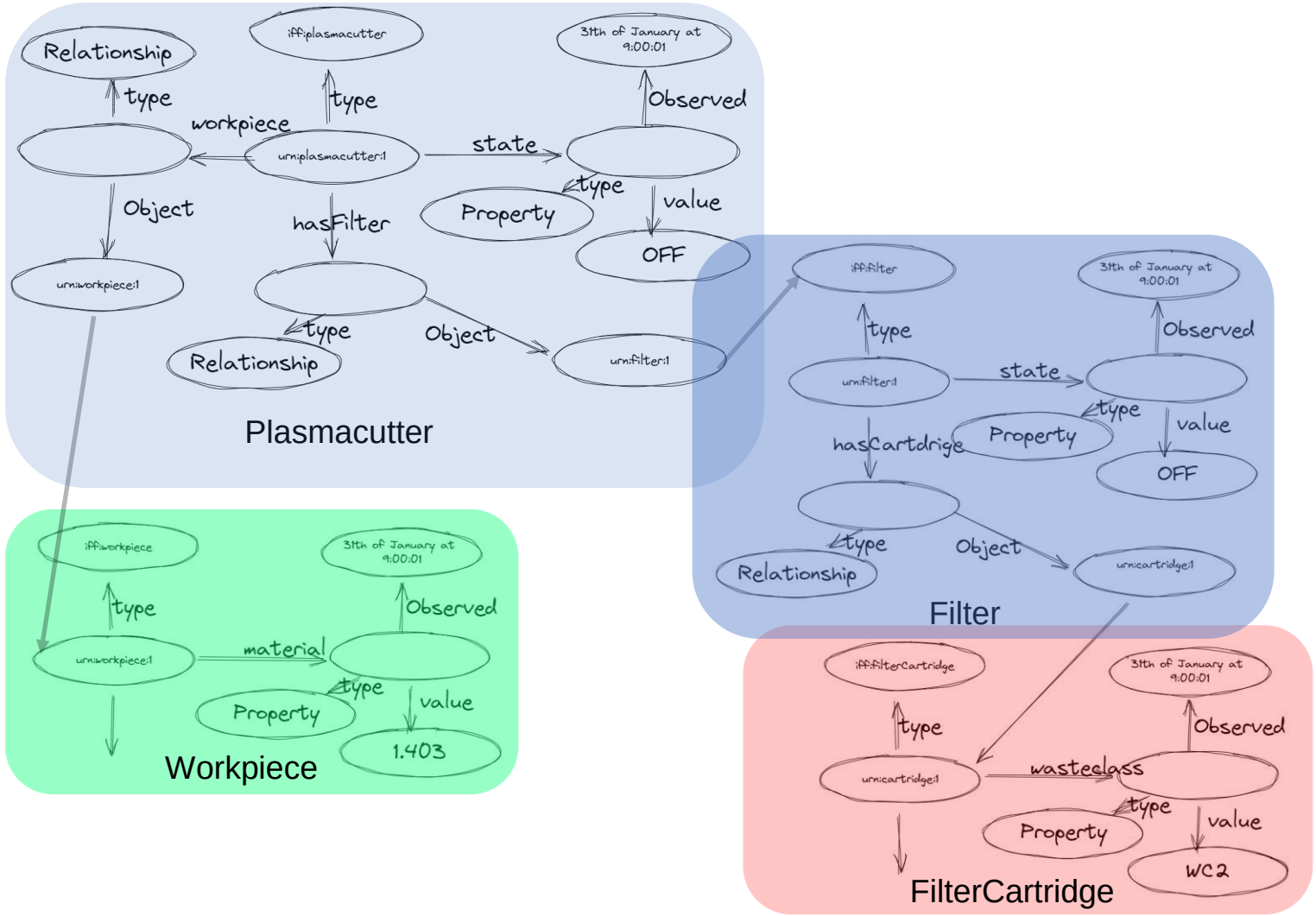
Semantic Web in a Nutshell: Resource Description Framework (RDF)





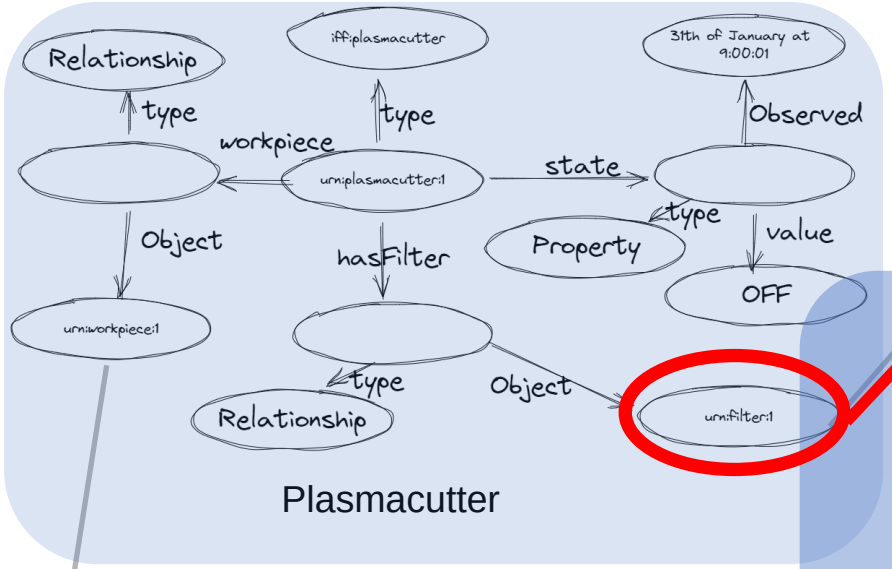

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix iff: <https://industry-fusion.com/types/v0.9/> .
@prefix schema: <http://schema.org> .

iff:cutter rdf:type rdfs:Class .
iff:plasmacutter rdfs:subClassOf iff:cutter .
<urn:iff:microstep:cutter:1> rdf:type iff:plasmacutter .
<urn:iff:microstep:cutter:1> schema:serialNumber "12345" .
<urn:iff:microstep:cutter:1> iff:locatedIn <urn:iff:factory1> .
<https://www.microstep.eu> schema:owns <urn:iff:microstep:cutter:1> .
```

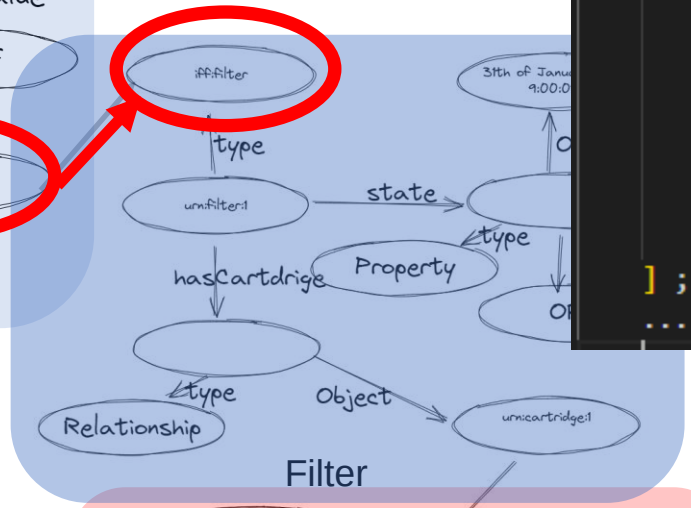
Entities of the Semantic Web: JSON-LD

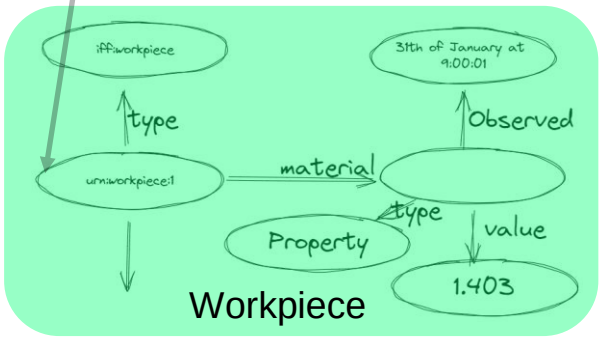


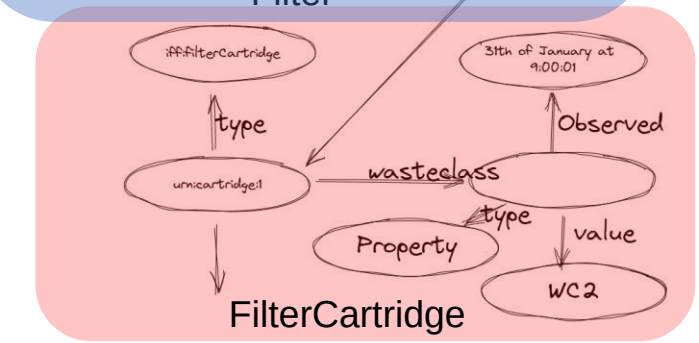

```
{
    "@context": "https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld",
    "id": "urn:plasmacutter:1",
    "type": "https://industry-fusion.com/types/v0.9/plasmacutter",
    "https://industry-fusion.com/types/v0.9/state": {
      "type": "Property",
      "value": {
        "@id": "https://industry-fusion.com/types/v0.9/state_ON"
      }
    },
    "https://industry-fusion.com/types/v0.9/hasWorkpiece": {
      "type": "Relationship",
      "object": "urn:workpiece:1"
    },
    "https://industry-fusion.com/types/v0.9/hasFilter": {
      "type": "Relationship",
      "object": "urn:filter:1"
    }
},
{
    "@context": ["https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld",
                 { "xsd": "http://www.w3.org/2001/XMLSchema#"}
    ],
    "id": "urn:filter:1",
    "type": "https://industry-fusion.com/types/v0.9/filter",
    "https://industry-fusion.com/types/v0.9/state": {
    "type": "Property",
    "value": {
        "@id": "https://industry-fusion.com/types/v0.9/state_ON"
    }
    },
    "https://industry-fusion.com/types/v0.9/strength": {
    "type": "Property",
    "value": {
      "@value": "1",
      "@type": "xsd:integer"
    }
    },
    "https://industry-fusion.com/types/v0.9/hasCartridge": {
    "type": "Relationship",
    "object": "urn:filterCartridge:1"
    }
},
```

Validation of the Semantic Web: Shapes Constraint Language (SHACL)







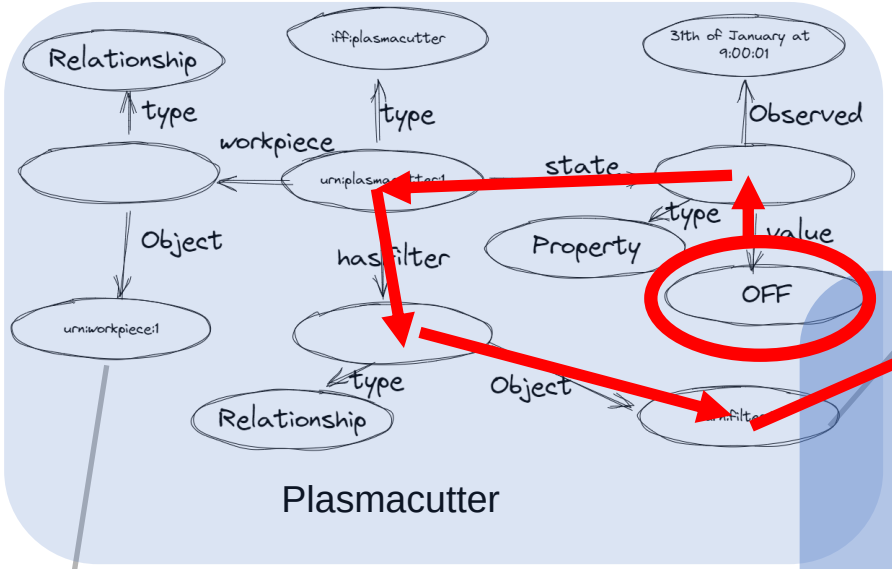


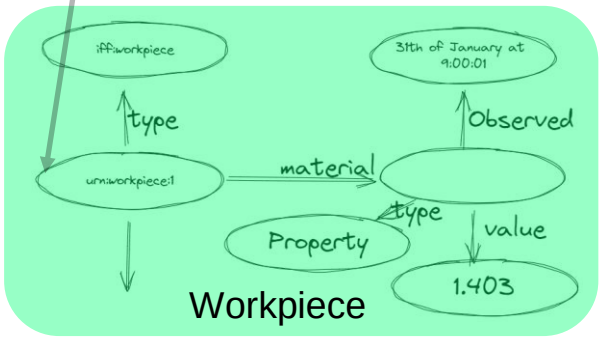

```
iff:CutterShape
    a sh:NodeShape ;
    sh:targetClass iff:cutter ;
    ...
    sh:property [
        sh:path <https://industry-fusion.com/types/v0.9/hasFilter> ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:severity iff:severityCritical ;

        sh:property [
            sh:path <https://uri.etsi.org/ngsi-ld/hasObject> ;
            sh:class iff:filter ;
        ] ;
    ] ;
    ...
```

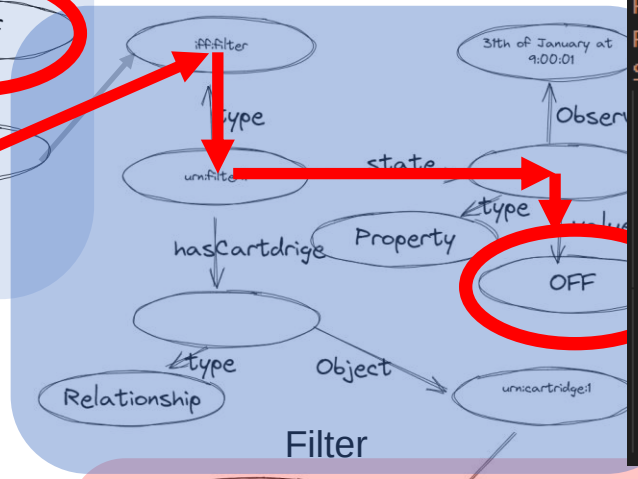
Validates

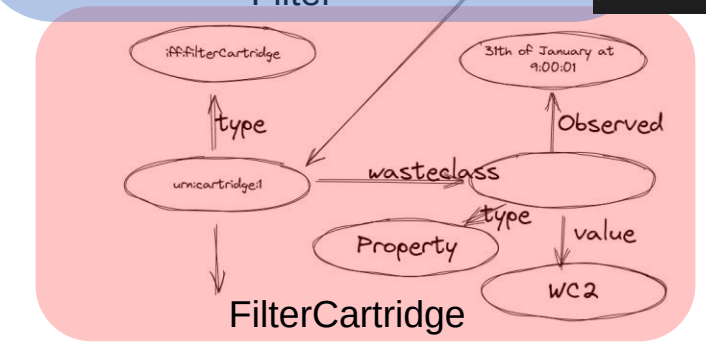
- Every entity of type ‘cutter’
- Whether there are exactly 1 ‘filter’ relationship from cutter
- Whether the linked filter is of type ‘filter’

Validation of the Semantic Web: Shapes Constraint Language (SHACL)







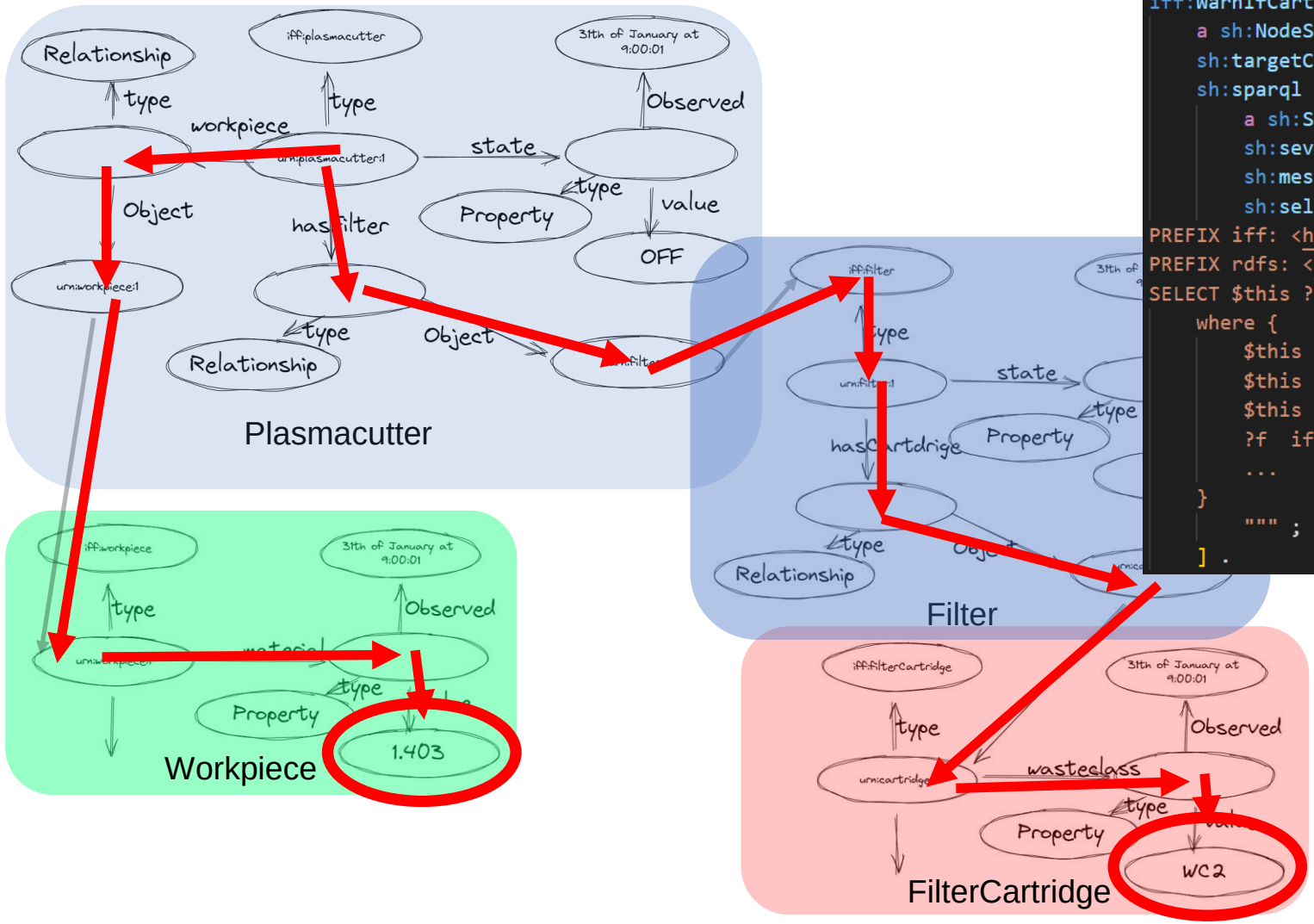



```
iff:StateOnCutter
    a sh:NodeShape ;
    sh:targetClass iff:cutter ;
    sh:sparql [
        a sh:SPARQLConstraints;
        sh:severity iff:severityCritical ;
        sh:message "Cutter running without running filter" ;
        sh:select """
PREFIX iff: <https://industry-fusion.com/types/v0.9/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT $this ?v1 ?f ?v2
    where {
        $this a iff:cutter .
        $this  iff:state [<https://uri.etsi.org/ngsi-ld/hasValue> ?v1 ] .
        $this  iff:hasFilter [ <https://uri.etsi.org/ngsi-ld/hasObject> ?f ] .
        ?f  iff:state [ <https://uri.etsi.org/ngsi-ld/hasValue> ?v2 ] .
        FILTER(?v1 = <https://industry-fusion.com/types/v0.9/state_ON> &&
            ?v2 != <https://industry-fusion.com/types/v0.9/state_ON>)

    }
        """ ;
    ] .
```

Validates

- Every Entity of type ‘cutter’
- If cutter is running, whether linked filter runs, too

Validation of the Semantic Web: Shapes Constraint Language (SHACL)




```
iff:WarnIfCartridgeClassChanges
    a sh:NodeShape ;
    sh:targetClass iff:cutter ;
    sh:sparql [
        a sh:SPARQLConstraints;
        sh:severity iff:severityCritical ;
        sh:message "Cutter running without running filter" ;
        sh:select """
PREFIX iff: <https://industry-fusion.com/types/v0.9/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT $this ?v1 ?f ?v2
    where {
        $this a iff:cutter .
        $this  iff:hasFilter [ <https://uri.etsi.org/ngsi-ld/hasObject> ?f ] .
        $this  iff:hasWorkpiece [ <https://uri.etsi.org/ngsi-ld/hasObject> ?w ] .
        ?f  iff:hasCartridge [ <https://uri.etsi.org/ngsi-ld/hasObject> ?c ] .
        ...
    }
        """ ;
    ] .
```

Validates

- If material type of workpiece is changing the hazard level in the cartridge wasteclass

Semantic Web Summary

Resource Description Framework (RDF)

- Define Knowledge-Graphs (KG) and contexts

JSON-LD

- Serializing RDF in a human readable way
- Grouping of RDF data entities

SHACL

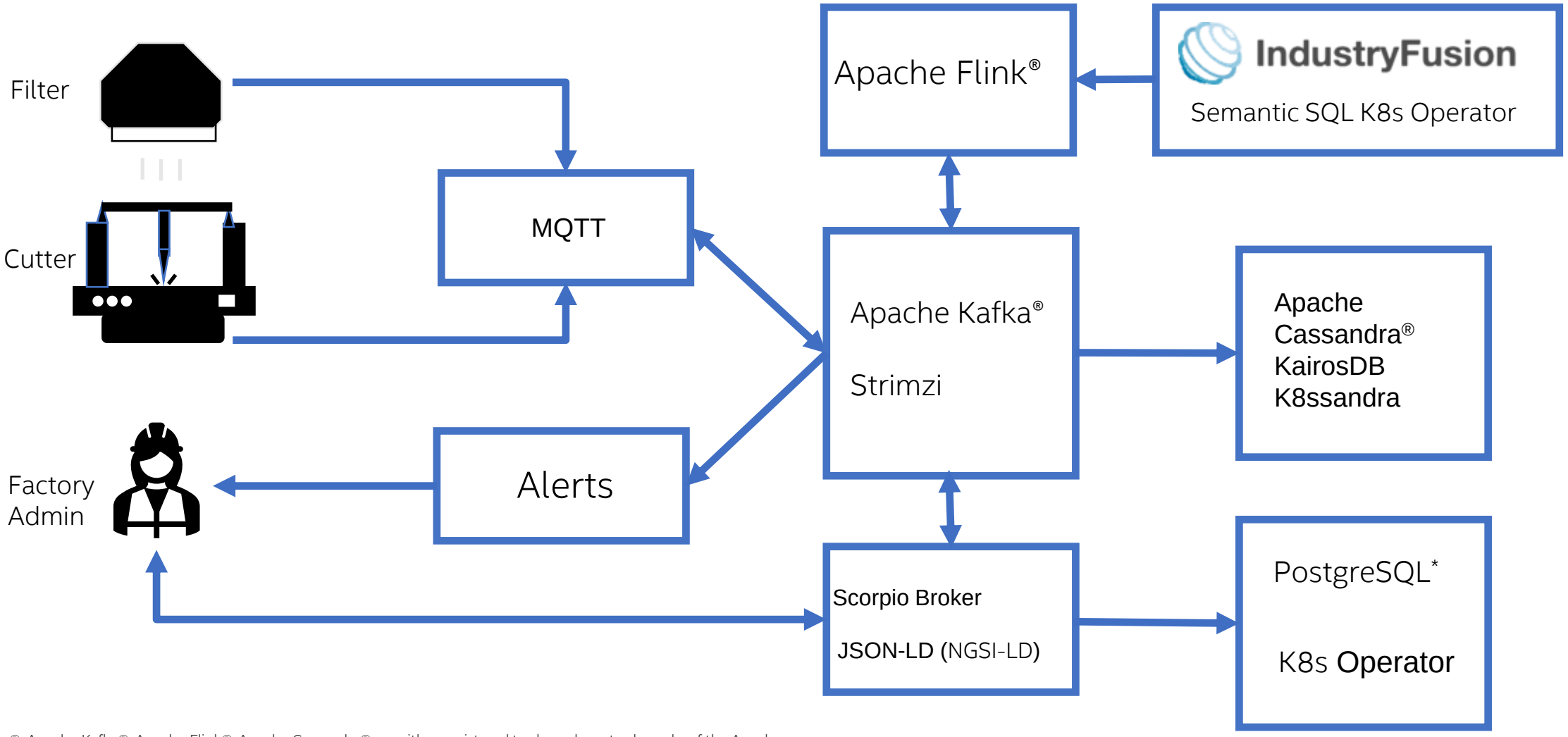
- Define Constraints on KG's and entities
- Define Constraints between Entities
- Allows to change and update the Graph

=>Standardized and expressive way to define use-cases and safety constraints - collaboratively and domain specific.

Motivation for Selected Architecture

- Requirements
  - This is a streaming analytics problem
    - Align 100,000s events per second with your graphs
    - Check for every single event the defined constraints
  - Knowledge Graphs can be huge (especially when used for inferring facts)
  - This is a declarative system (we specify the desired and critical states)
  - This must be calculated in low-latency
  - IFF wants to prefer general vs. specific solution and prefer solutions with broad communities
- Decisions
  - Graph vs. Relational => StreamingSQL
  - Scalability, stateful data processing, low latency => Apache Flink & Apache Kafka
  - Must be Cloud Native: K8s and operators where possible and feasible

IndustryFusion Architectural Overview



Semantic SQL K8s Operator: Declarative Data Processing Generated from SHACL

SHACL

```
iff:CutterShape
    a sh:NodeShape ;
    sh:targetClass iff:cutter ;
    ...
    sh:property [
        sh:path <https://industry-fusion.com/types/v0.9/hasFilter> ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:severity iff:severityCritical ;

        sh:property [
            sh:path <https://uri.etsi.org/ngsi-ld/hasObject> ;
            sh:class iff:filter ;
        ] ;
    ] ;
    ...
```

SQL DDL

alerts Table

```
CREATE table alerts (
            resource STRING,
            event STRING,
            severity STRING,…
) WITH (
            'connector'='kafka',
            'topic'='alerts',…
);
```

cutter Table

```
CREATE table cutter (
            `iff:state`STRING,
            `iff:hasFilter` STRING,
            `iff:hasWorkpiece` STRING,…
) WITH (
            'connector'='kafka',
            'topic'='cutter',…
);
```

filter Table

```
CREATE table filter (
            `iff:state`STRING,
            `iff:hasCartridge` STRING,
            `iff:strength` STRING,…
) WITH (
            'connector'='kafka',
            'topic'='filter',…
);
```

SQL DML

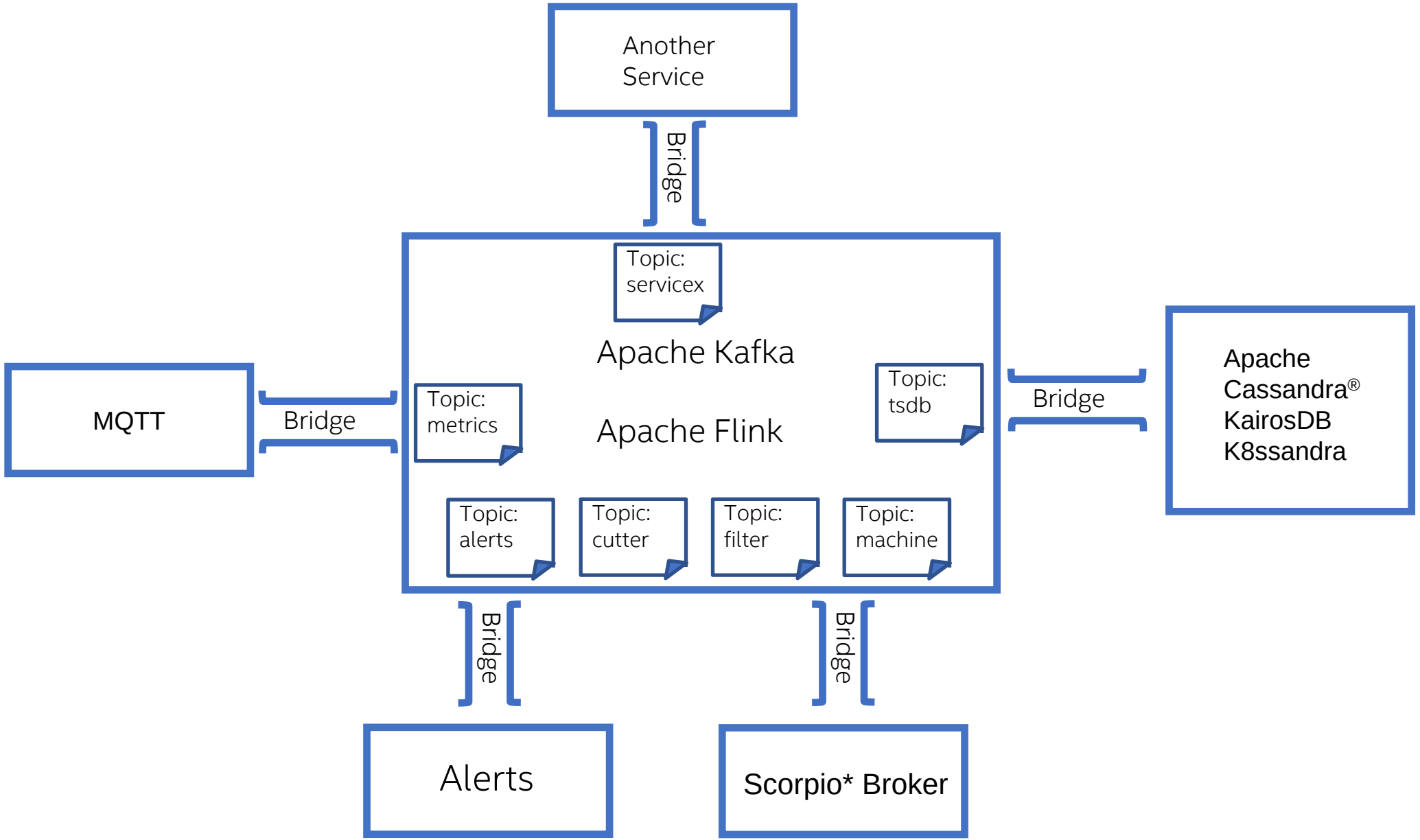
SQL Constraint Check

```
SELECT
            `iff:state`,
            `iff:strength`
FROM cutter WHERE
`iff:state` = 'iff:state_ON'
AND `iff:strength` > 0.5;
```

SQL "action" triggered by inserting

```
INSERT INTO alerts
SELECT
'urn:filter:1' AS `resource`,
'SHACL check' AS 'event',
… FROM (subquery);
```

Everything is a topic … and a relational table



IndustryFusion Semantic SQL K8s Operator: CRDs to Manage Tables and SQL Execution

Create Streaming SQL Table/Kafka Topic

```yaml
apiVersion: industry-fusion.com/v1alpha2
kind: BeamSqlTable
metadata:
  name: alerts
  spec:
    name: alerts
    connector: kafka
    fields:
    - 'resource': STRING
    - 'event': STRING
    - 'severity': STRING
    - …
    kafka:
     topic: kafka-topic
     properties:
       bootstrap.servers: my-cluster-kafka-bootstrap:9092
     scan.startup.mode: earliest-offset
```

Create Streaming SQL instruction sets

```yaml
apiVersion: industry-fusion.com/v1alpha2
kind: BeamSqlStatementSet
metadata:
  name: mystatements
  spec:
    sqlstatements:
    - |
      INSERT INTO alerts SELECT ...;
    - |
      SQL statement 2;
      ...
    - |
      SQL statement n;
```

DEMO

Kubernets and Industrial SMBs – Does it Fit?

- K8s helps to unify operations from Cloud to Edge
  - Applicable to large amount of typical Edge Operation
  - Exception: Deterministic Real-Time (RT) and Functional Safety (FuSa) => Future work needed
- At the beginning, people are questioning the approach: “Do I really need cloud native? I have only few gateways.”
  - But then: What is the alternative? Working with very specific edge solution with uncertain future?
  - Make your own math about expected data and how to handle it – surprise, it is huge.
- The machine builders without own IT department are facing challenges to understand K8s properly
  - But there is IT help needed anyway, not really K8s specific problem
  - The impressive amount of documentation, examples, tutorials and courses is helping to build trust in K8s
- The line between Operational Technology(OT)/IT is blurring, especially new college graduates are much more familiar to K8s concepts and how to apply to OT

Conclusion, Future Work & Call to Action

- Semantic Web Standards enable to
  - collaborate domain specific,
  - across domains,
  - assess safety issues,
  - validate data model in real-time, and
  - link data in real-time
- The IFF Digital Process Twin is using SHACL specifications to derive validation and processing rules.
- Cloud native helps to provide the operational excellence, scale and redunancy needed for reliable operations in the factory
- K8s Operators have been used where available: PostgreSQL, Cassandra*, Apache Kafka*, Apache Flink*, Keycloak*, MinIO*,
- IndustryFusion provides a Semantic SQL K8s operator with respective CRDs to manage StreamingSQL based validation and operation on Semantic Data Models with very low latency
- Future Work:
  - Improve tooling for semantic modelling and domain collaboration between SMBs
  - Explore more „static“ K8s use for real-time and safety
  - Make Semantic Web and Knowledge Graphs part of Safety Certification Process
- Checkout the project and give us feedback:
  - https://github.com/IndustryFusion/DigitalTwin

KubeCon | CloudNativeCon
North America 2022

BUILDING FOR THE ROAD AHEAD

DETROIT 2022

Please scan the QR Code above to
leave feedback on this session

Legal Notices and Disclaimers