An Ontology-based Approach for IoT Data Processing using Semantic Rules

Ahmed Bali, Mahmud Al-Osta and Gherbi Abdelouahed

Ecole de technologie supérieure (ETS), Montreal, Canada

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Plan

Research Context

- Internet of Things (IoT) applications.
  Heterogeneous devices including sensors that sense the environment and send the collected data to the cloud through the gateway.
- Massive amount of Heterogeneous data.

Research Issues

IoT constraints :

- Resources constraints of the IoT Devices.
- Bandwidth limitation of the gateways communication networks.
- The communication cost of the data.
- The cost associated with data storage and processing at the cloud level.

Objectives

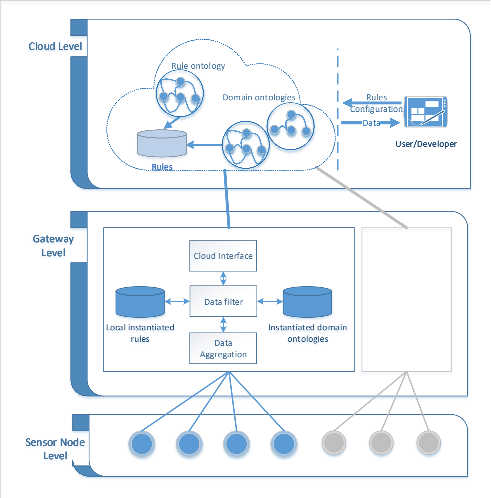
- Support the processing of heterogeneous data ⇒ (semantic) annotation.
- Support the reuse and sharing of knowledge.
- Support the data processing at the resource constrained devices.
- Minimise the transferred data to the cloud.
- Minimise data storage and processing cost at the cloud.

Solution Highlights

- Edge computing.
- Annotation of data based on the semantic techniques such as ontologies and standard languages (RDF, RDF(S) and OWL).
- Use of the (semantic) rules notion.
- Use of the notion of Platform Independent Model (PIM) and Platform Specific Model (PSM) as well as the metamodel.

Plan

Overall Architecture



Storage and monotoring data.
PIM:

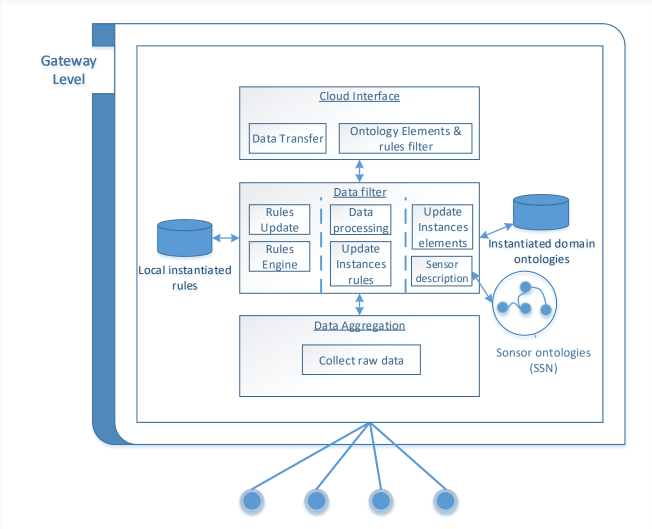
- Domain ontologies.
- Rule ontology and rules.

Processing and filtering data.
PSM:

- Data as instances of domain knowledge.
- Instantiation of rules.

Collecting data.

Gateway Level Architecture



Plan

Knowledge and Data Modeling

Table: Modeling Levels

Level	Object	Semantic tool
Metamodel	Representation languages Rule metamodel	RDF, RDF(S), OWL Rule Ontology
PIM	Domain Knowledge concepts, rules...	Domain ontologies Feltering rules
PSM	Data specific rules	Instances of domain ontologies Instances of rules

Platform Independent Model (PIM)-Domain Ontologies

Definitions

Domain Ontologies

The ontology which semantically describes a domain of knowledge defines the concepts of the domain and the different relations between them.

Languages

To support the machine processing, the ontologies should be coded in standard formats and languages such as RDF (S) and OWL.

Platform Independent Model (PIM)-Domain Ontologies

Example

```
<?xml version=1.0?>
<rdf:RDF
   xmlns:owl ="http://www.w3.org/2002/07/owl#"
   xmlns:rdf ="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
   xmlns:xsd ="http://www.w3.org/2001/XMLSchema#">
   <owl:Ontology rdf:about="Gaz"/>
   <owl:Class rdf:ID="CO">
      <rdfs:comment>Carbon monoxide</rdfs:comment>
      <rdfs:subClassOf rdf:resource="#oxide"/>
   </owl:Class>
   <owl:DatatypeProperty rdf:ID="hasValue">
      <rdfs:domain rdf:resource="#CO"/>
      <rdfs:range rdf:resource="&xsd;positiveInteger"/>
   </owl:DatatypeProperty>
   <owl:Class rdf:ID="Ci2"/>
   ...
   <owl:Class rdf:ID="Gas">
      <owl:unionOf rdf:parseType="collection">
      <owl:Class rdf:about="#CO"/>
      <owl:Class rdf:about="#Ci2"/>
      ...
   </owl:Class>
   <owl:DatatypeProperty rdf:ID="measureUnit">
      <rdfs:domain rdf:resource="#Gas"/>
     <rdfs:range rdf:resource="&xsd;string"/>
   </owl:DatatypeProperty>
    ...
</rdf:RDF>
```

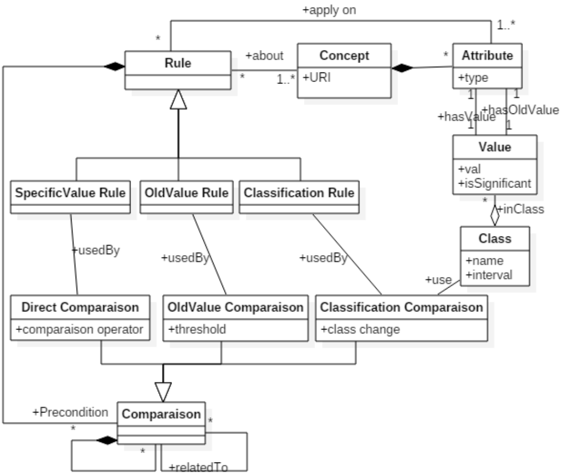
Platform Independent Model (PIM)-Rules

Rules Categories

1. Rules based on a specific data value:
   IF(Temperature.hasValue>= 20) THEN Significatif(Temperature.hasValue)
2. Rules based on the old data value:
   IF(T.hasValue != T.oldValue) THEN Significatif(T.hasValue)
3. Rules based on the classification of data values:
   IF(CO.hasValue< 50) THEN (CO.inClass=Safe)
   IF(CO.hasValue>= 50)&(CO.hasValue< 1200) THEN (CO.inClass=Unsafe)

Platform Independent Model (PIM)-Rules

Rules metamodel



Platform Independent Model (PIM)-Rules

Rules Ontology

```
<rdf:RDF
   xmlns:owl ="http://www.w3.org/2002/07/owl#"
   ....>
   <owl:Ontology rdf:about="Filtering Rule model"/>
   <owl:Class rdf:ID="Rule"/>
   <owl:Class rdf:ID="DirectValue Rule">
      <rdfs:subClassOf rdf:resource="#Rule"/>
   </owl:Class>
   ...
   <owl:Class rdf:ID="Classification Rule">
      <rdfs:subClassOf rdf:resource="#Rule"/>
   </owl:Class>
   <owl:Class rdf:ID="Concept"/>
   <owl:ObjectProperty rdf:ID="about">
      <rdfs:domain rdf:resource="#Rule"/>
      <rdfs:range rdf:resource="#Concept"/>
   </owl:ObjectProperty>
   <owl:DatatypeProperty rdf:ID="OntologyURL">
      <rdfs:domain rdf:resource="#Concept"/>
      <rdfs:range rdf:resource="&xsd;anyURI"/>
   </owl:DatatypeProperty>
   <owl:Class rdf:ID="Attribute"/>
   <owl:ObjectProperty rdf:ID="hasAttribut">
```

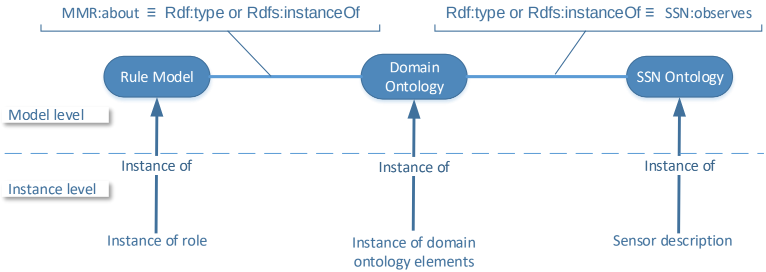
Platform Independent Model (PIM)-Rules

Rules Model

```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:GasO="http://localhost/GasOntology#"
  xmlns:MMR="http://localhost/MetaModelRules\#">
  <MMR:Class rdf:ID="Safe">
    <MMR:minLimit rdf:datatype="&xsd;nonNegativeInteger">0</MMR:minLimit>
    <MMR:maxLimit rdf:datatype="&xsd;positiveInteger">50</MMR:maxLimit>
  </MMR:Class>
  <MMR:Class rdf:ID="UnSafe">
    <MMR:minLimit rdf:datatype="&xsd;positiveInteger">50</MMR:minLimit>
    <MMR:maxLimit rdf:datatype="&xsd;positiveInteger">1200</MMR:maxLimit>
  </MMR:Class>
  <MMR:Value rdf:ID="oldValue"/>
  <MMR:Value rdf:ID="currentValue"/>
  <MMR:Attribute rdf:ID="attribut">
    <MMR:hasOldValue rdf:resource="#oldValue"/>
    <MMR:hasValue rdf:resource="#currentValue"/>
  </MMR:Attribute>
  <MMR:Concept rdf:ID="CO">
    <MMT:hasAttribut rdf:resource="#attribut"/>
  </MMR:Concept>
  <MMR:ClassificationRule rdf:ID="CRuleCO1">
    <MMR:about rdf:resource="#CO"/>
    <MMR:applyOn rdf:resource="#attribut"/>
  </MMR:ClassificationRule>
  <MMR:ClassificationComparaison rdf:ID="ClassificationComp">
    <MMR:usedBy rdf:resource="#CRuleCO1"/>
    <MMR:use rdf:resource="#Safe"/>
     ...
  </MMR:ClassificationComparaison>
  ...
</rdf:RDF>
```

Platform Specific Model (PSM)

Models Mapping



Platform Specific Model (PSM)

Instantiation of Domain Knowledge

```
<rdf:RDF
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:GasO="http://localhost/GasOntology#">

   <rdf:Description rdf:ID="CO_inst1">
      <rdf:type rdf:ressource="GasO:CO"/>
      <GasO:MeasureUnit rdf:datatype="&xsd;string">PPM</GasO:MeasureUnit>
      <GasO:hasValue rdf:datatype="&xsd;positiveInteger">60</GasO:hasValue>
   </rdf:Description>
   ...
</rdf:RDF>
```

An instance of the CO concept (CO_inst1) having a value of 60 PPM.

Platform Independent Model (PSM)

Instantiation of Rules

```
<rdf:RDF
   xmlns:rdf=\textquotedblleft http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:GasO="http://localhost/GasOntology#"
   xmlns:MMR="http://localhost/MetaModelRules#">
   ...
   <MMR:Value rdf:ID=\textquotedblleft oldValue\textquotedblright>
      <MMR:val rdf:datatype="&xsd;positiveInteger">40</MMR:val>
      <MMR:inClass rdf:resource="#Safe"/>
   </MMR:Value>

   <MMR:Value rdf:ID="currentValue">
      <MMR:val rdf:datatype="\&xsd;positiveInteger">60</MMR:val>
      <MMR:inClass rdf:resource="#UnSafe"/>
      <MMR:isSignificant rdf:datatype="&xsd;boolean">true</MMR:isSignificant>
   </MMR:Value>
   ...
   <MMR:ClassificationComparaison rdf:ID="ClassificationComp">
      <MMR:usedBy rdf:resource="#CRuleC01"/>
      ...
      <MMR:classChanged rdf:datatype="&xsd;boolean">true</MMR:classChanged>
   </MMR: ClassificationComparaison>
   ...
</rdf:RDF>
```

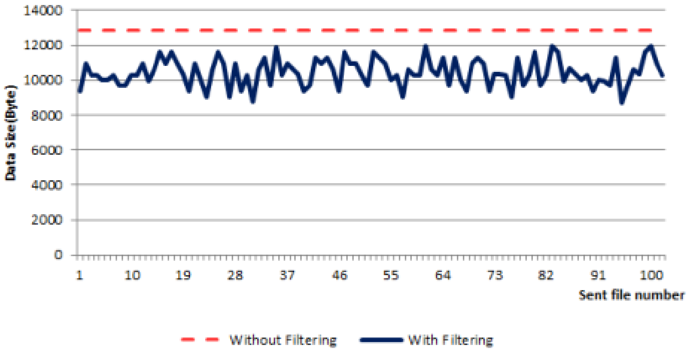
Plan

Implementation

- The prototype implemented in Java using JDK 1.8.
- The ontologies, their instances, and the rules are coded using the semantic languages (RDF, RDF(s) and OWL) using the API Jena 2.12.1.
- For our test setup, we used a Raspberry pi3 model B having a Quad-core 1.2 GHz Cortex-A53 CPU, 1 GB RAM, and 16 GB SD card.
- We created set of virtual electrochemical sensors (60 sensors) for gas detection such as CO, NH3, and NO2. These sensors are configured to periodically (after each 1 ms) send data to the implemented prototype.

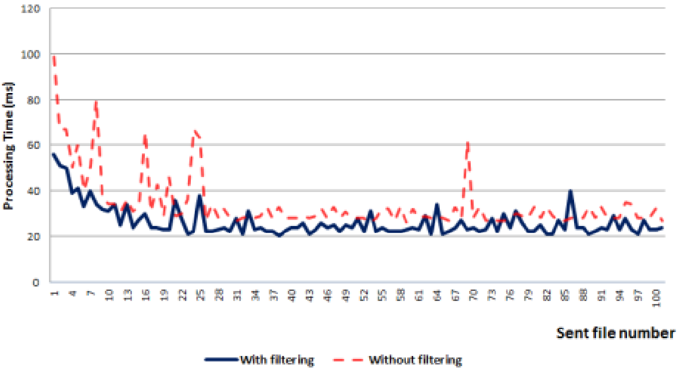
Evaluation

Communicated Data Size



Evaluation

Processing Time



Plan

Conclusion

Data heterogenity semantic modeling based on domain ontologies and standard languages.

Data amount semantic rules to select only the significant data.

Knowledge sharing and ruse PIM and PSM.

Evaluation The efficient of our approach in term of reduce of data size and the improvement of data processing.

Conclusion

Future work

- Enrich our meta-model rule to support other aspects such as security, performance and maintenance.
- Studying the load balancing issue to manage the distribution of edge computing tasks based on resources available at the gateway level.

Questions

Thank you