TOWARDS SEMANTIC MODEL EXTENSIBILITY

IN INTEROPERABLE IOT DATA EXCHANGE PLATFORMS

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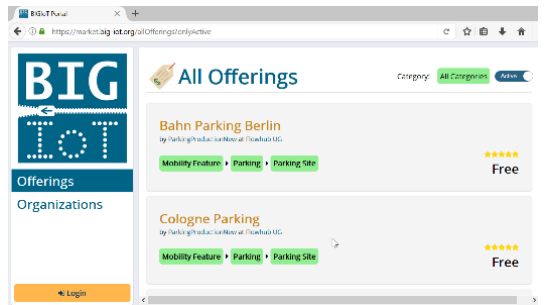
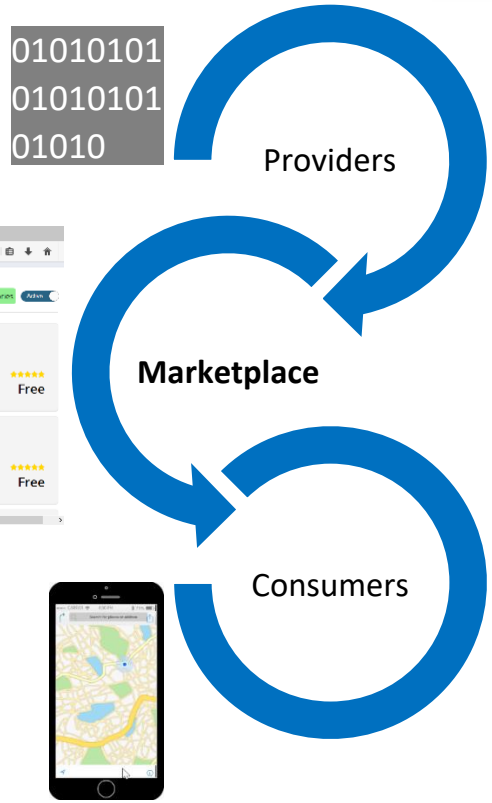
Overview

- Context and motivation
  - Data marketplaces ● Interoperability in IoT
- Problem statement
  - Extensibility ● Ontologies ● Challenges
- Solution
  - Modeling patterns ● Annotation graphs
  - Dynamic form generation
- Benefits of the approach





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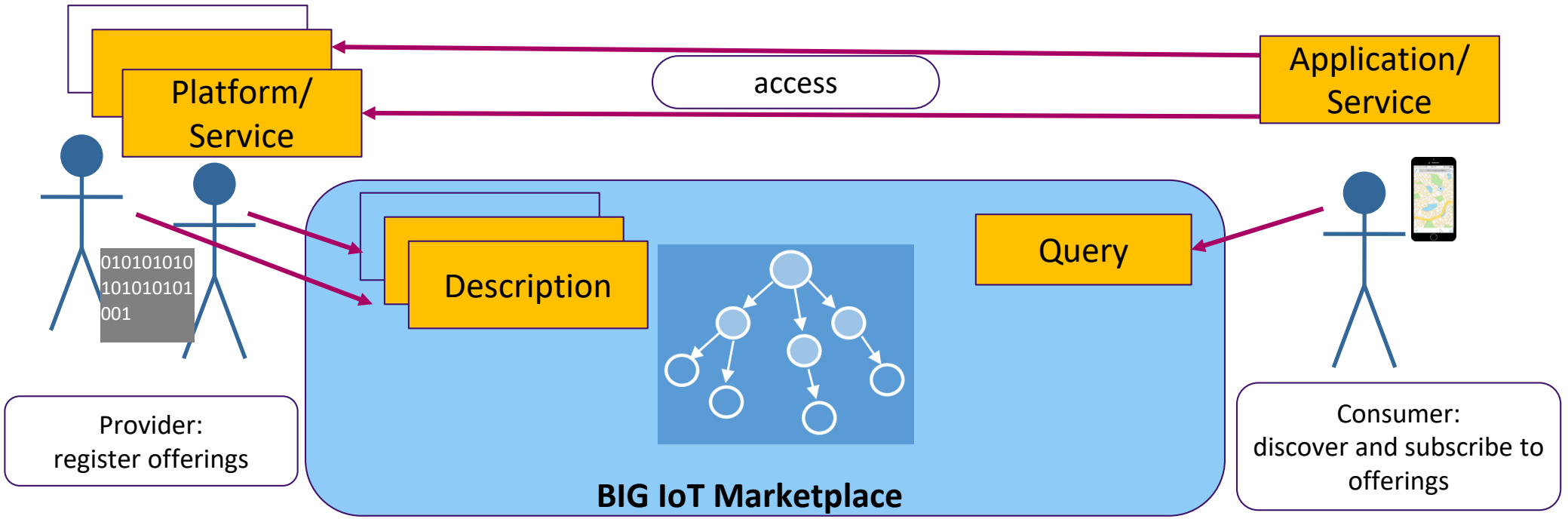
CONTEXT

Context and Motivation

Data Marketplace

"Digital marketplaces are platforms that connect providers and consumers of data sets and data streams, ensuring high quality, consistency, and security."*



* J. Deichmann et al. Creating a Successful Internet of Things Data Marketplace. McKinsey Quarterly 10/2016.

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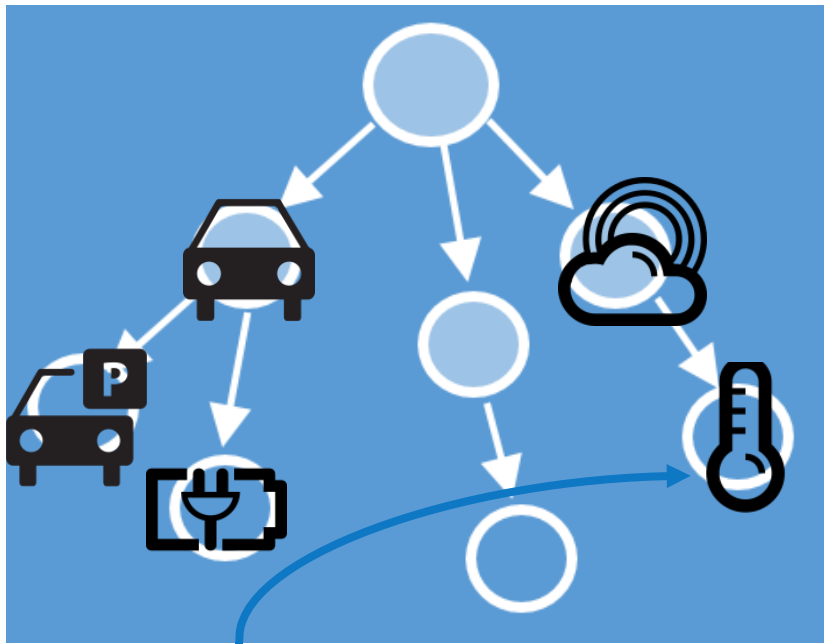
Context and Motivation

Semantic Models and Categorization

Two-fold purpose of the models:

- Categorize offerings


```
[ ⊟
  { ⊟
    "latitude":48.2517561098094,
    "longitude":11.637541693635,
    "freeSpots":67,
    "dt":1485789600
  }
]
```


```
[ ⊟
  { ⊟
    "city_id":12345,
    "temp":268.987,
    "temp_min":268.987,
    "temp_max":268.987
  }
]
```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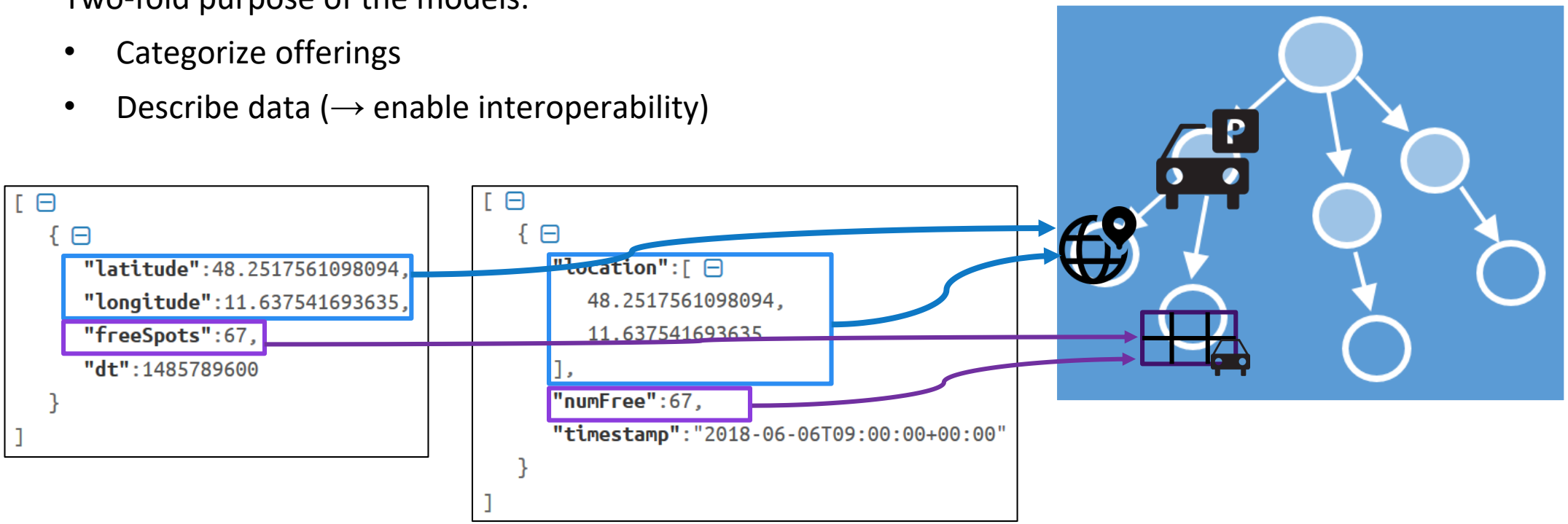
Context and Motivation

Semantic Models and Interoperability

Two-fold purpose of the models:

- Categorize offerings
- Describe data (→ enable interoperability)



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Context and Motivation
Ontology, Knowledge Graph

- Ontology
  - “formal, explicit specification of a shared conceptualization” *,
  - “formalized vocabularies of terms, often covering a specific domain and shared by a community of users. They specify the definitions of terms by describing their relationships with other terms in the ontology” **.
- Knowledge graph
  - graph-structured knowledge base in RDF (Resource Description Framework) format.
- Both models (= ontologies) and offering descriptions/queries are stored in an RDF triple store as a knowledge graph.

* R. Studer et al. Knowledge Engineering: Principles and Methods. Data & Knowledge Engineering, 25(1–2) (1998): 161–198.
** W3C OWL Working Group. OWL 2 Web Ontology Language Document Overview. 2009.

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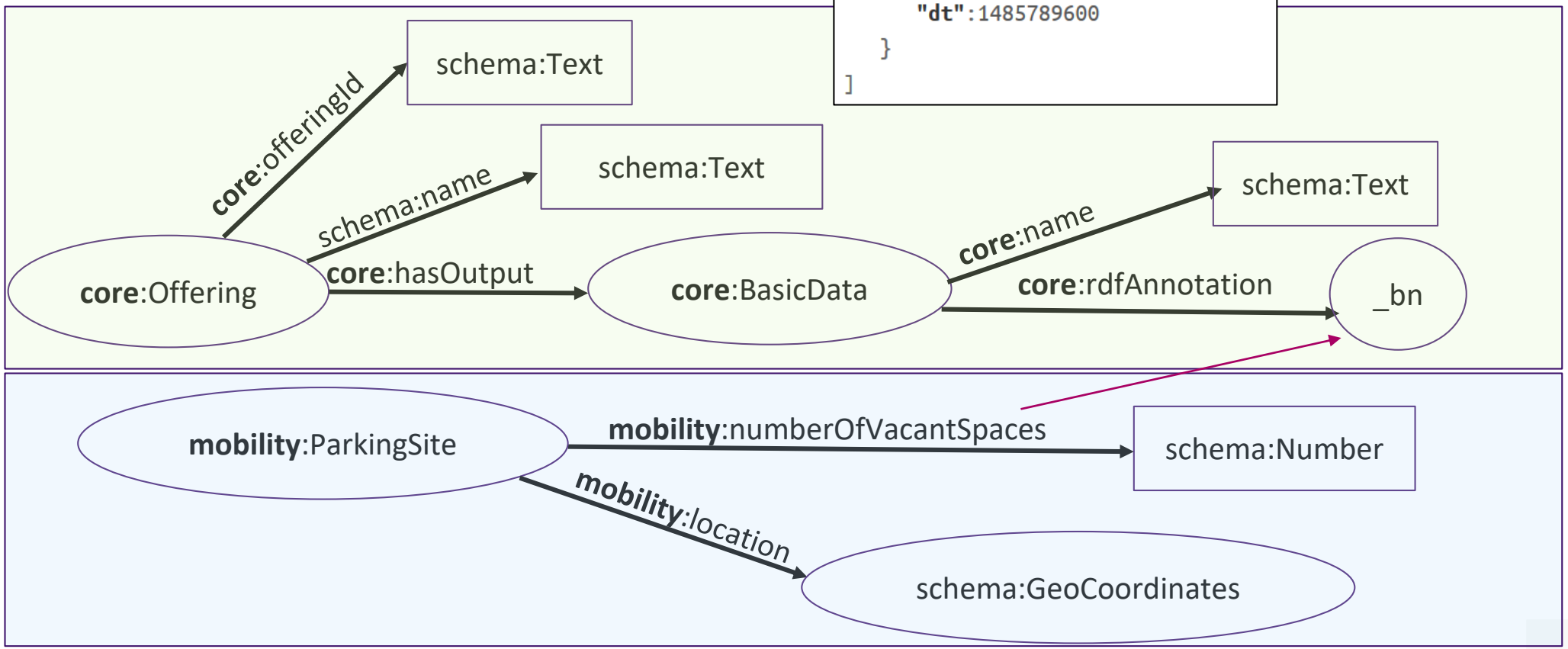
Context and Motivation

Modeling: Example (simplified)


```
[ ⊟
  { ⊟
    "latitude":48.2517561098094,
    "longitude":11.637541693635,
    "freeSpots":67,
    "dt":1485789600
  }
]
```

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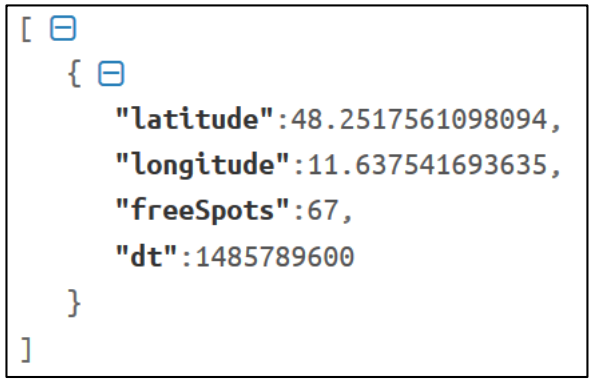
Context and Motivation

Offering Description



```
[ ⊖
  { ⊖
      "latitude":48.2517561098094,
      "longitude":11.637541693635,
      "freeSpots":67,
      "dt":1485789600
  }
]
```

```
{
  providerId: "Parking_Provider"
  name:       "ParkingSite_Information"
  category:   "bigiot:Parking"
  subcategory:                    "bigiot:ParkingSite"

  outputData: [
              {name: "longitude",   rdfAnnotation: "schema:longitude"}
              {name: "latitude",    rdfAnnotation: "schema:latitude"}
              {name: "freeSpots",   rdfAnnotation: "mobility:numberOfVacantSpaces"}
              {name: "dt",          rdfAnnotation: "dbp:Unix-time"}
              ]
  endpoints: { uri: "http://bigiot/access/parkinginfo", type: "HTTP_GET"}

  licenseType: "OPEN_DATA_LICENSE"

  price:  { money: {amount: 0.002000, currency: "EUR"}, accountingModel: "PER_ACCESS"}
}
```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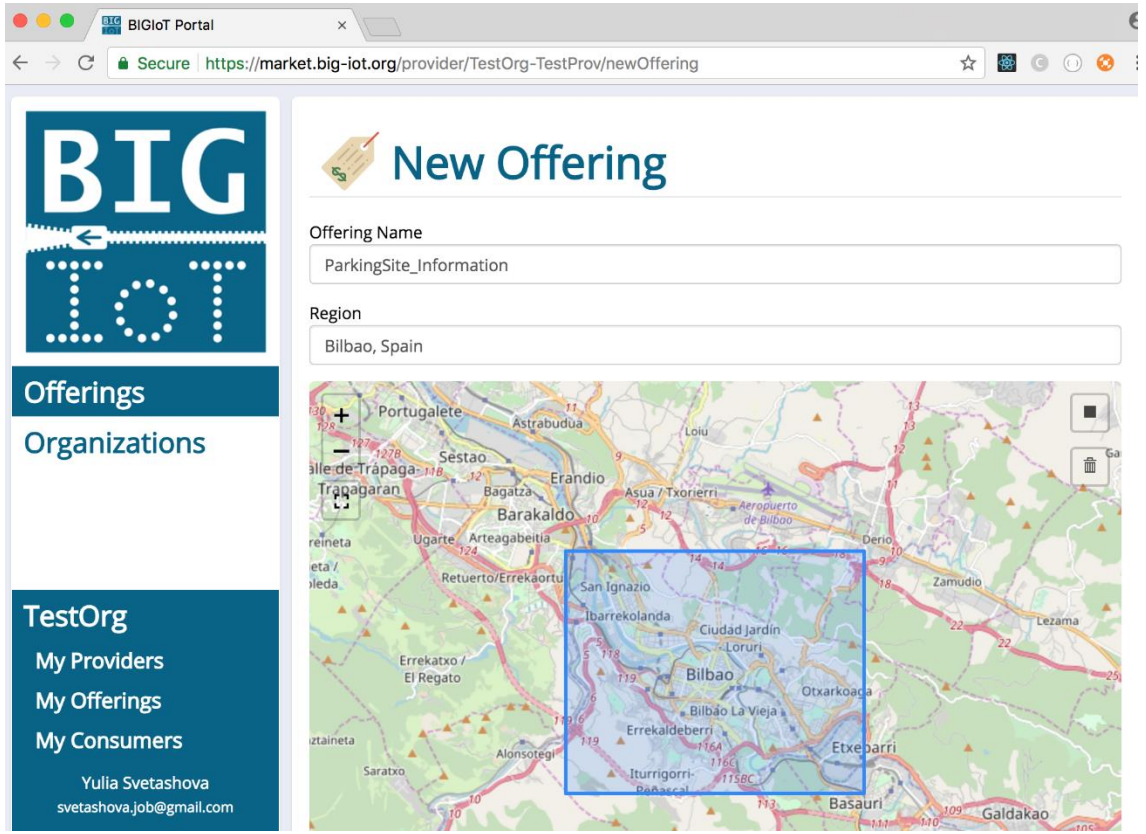
PROBLEM

Problem Statement

Offering Creation


```
[ ⊖
  { ⊖
      "address":"Plaza de Pío Baroja, 48001 Bilbao",
      "freeSpots":50,
      "totalSpots":100
  }
]
```

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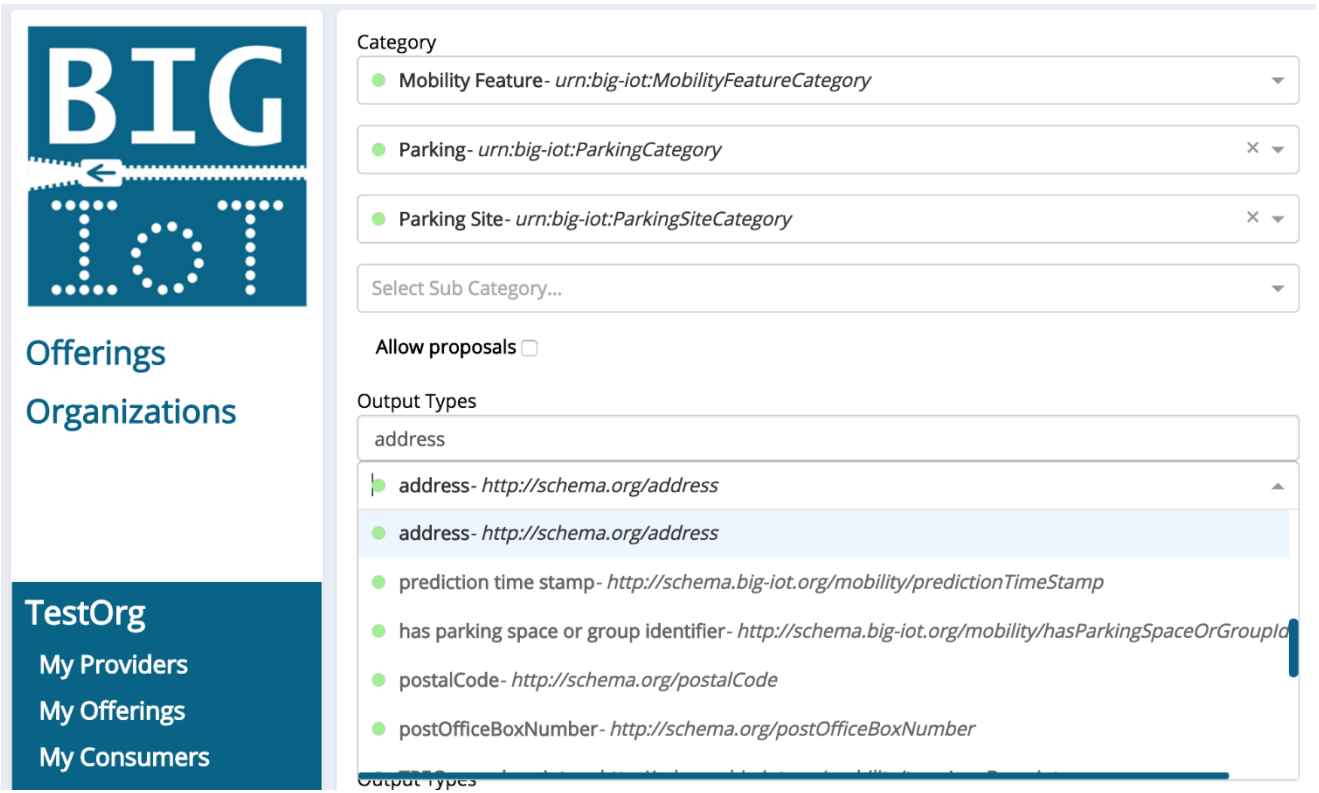
BOSCH

Problem Statement

Specifying the Output




```
[
  {
    "address":"Plaza de Pío Baroja, 48001 Bilbao",
    "freeSpots":50,
    "totalSpots":100
  }
]
```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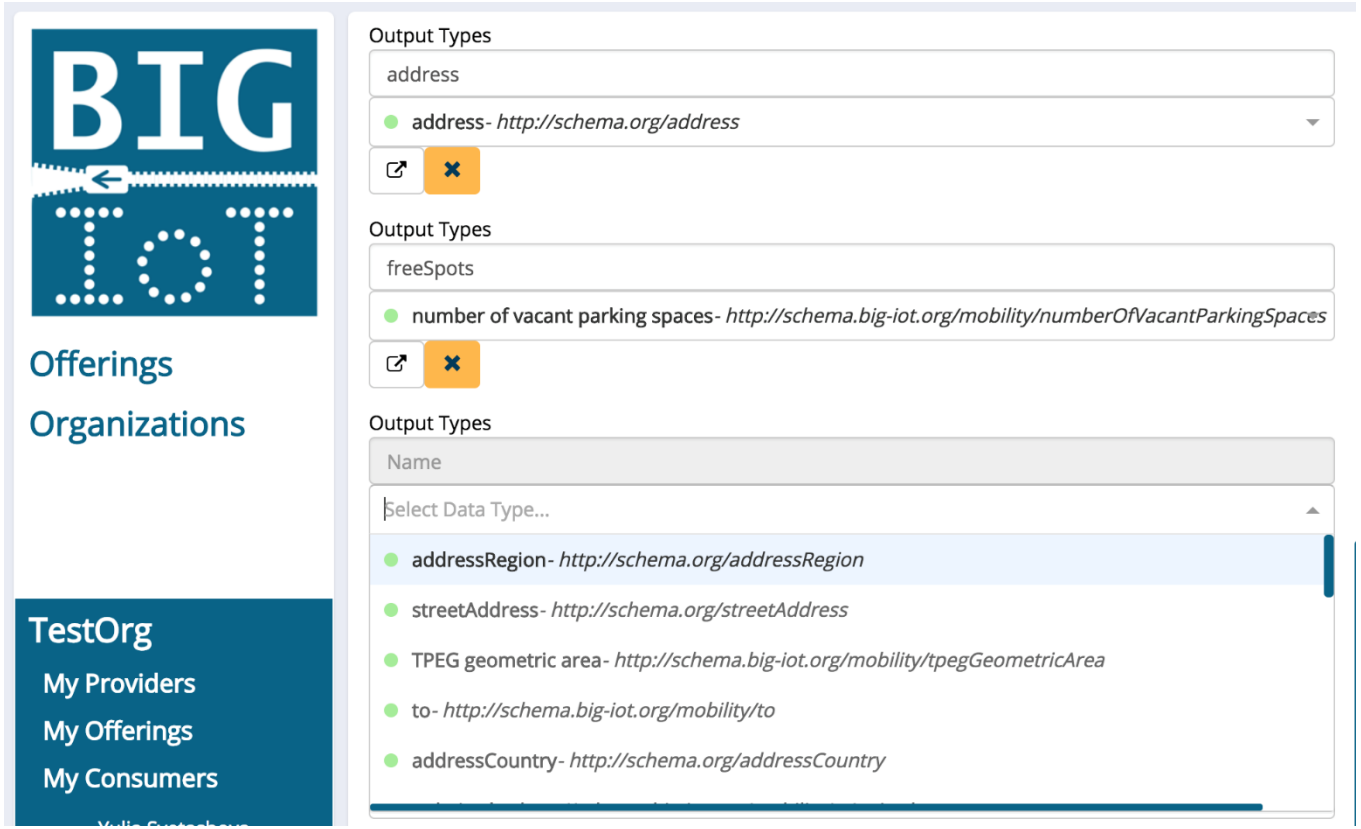
Problem Statement

Missing Model Elements




```
[
  {
    "address":"Plaza de Pío Baroja, 48001 Bilbao",
    "freeSpots":50,
    "totalSpots":100
  }
]
```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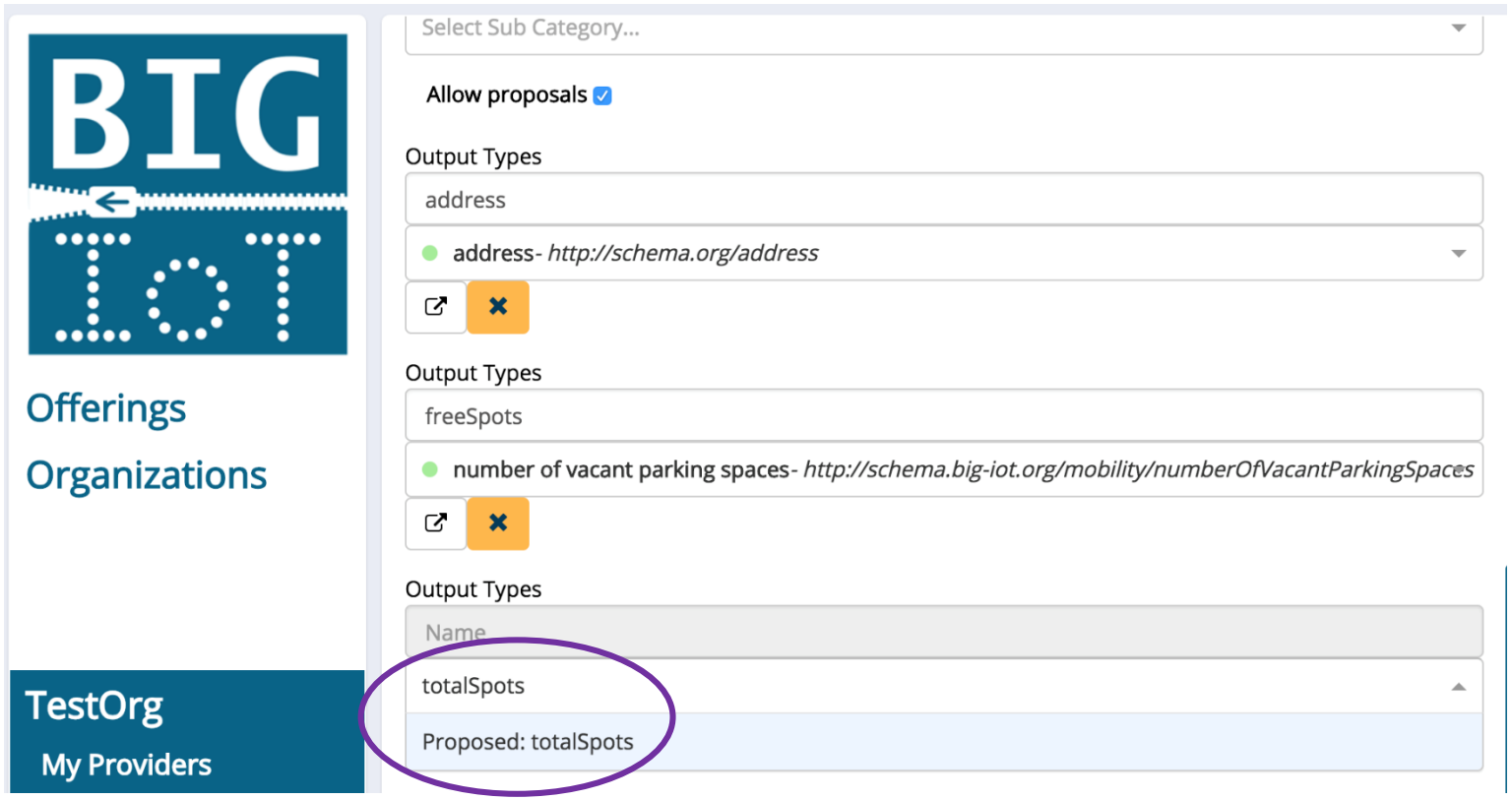
Problem Statement

Missing Concept



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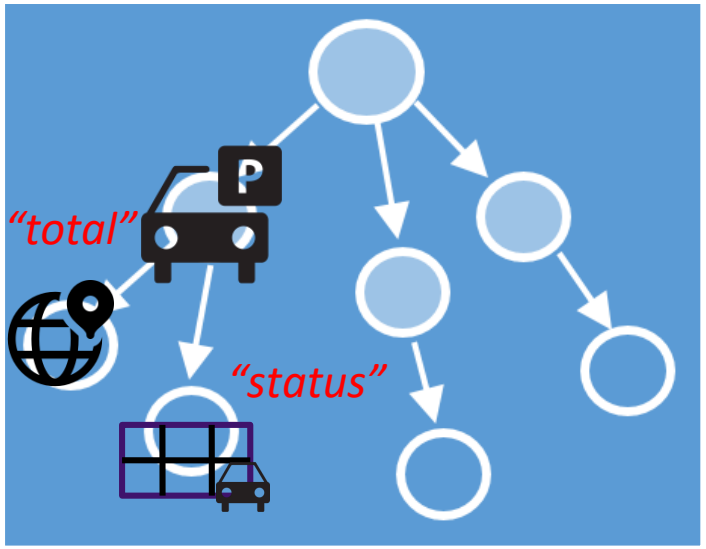
BOSCH

Problem Statement
Challenges

- A new, suggested concept is not machine-understandable:
  - it lacks a precise characterization of its
    - meaning,
    - returned value type,
    - unit of measurement (for sensor data);
  - it has no links to other model elements;
  - it can reflect a very different approach to the modeling of the phenomenon.
- The suggested concept can be ambiguous or a duplicate, and further communication with a data provider might be needed to incorporate it into the model.
- Scalability of the approach need to be ensured.



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APPROACH

BOSCH

Approach
Modeling Patterns

Initial broad categorization of a model element and a set of prototypical relations in the enclosing model.


```
[
  {
    "latitude":48.2517561098094,
    "longitude":11.637541693635,
    "freeSpots":67,
    "dt":1485789600
  }
]
```


spatial

sensor

temporal

Cf.: “ontology design patterns” [Gangemy, Presutti 2009], [Jupp et al. 2012],
“geo-ontology design patterns” [Janowicz 2012], “ontology alignment design patters” [Scharffe 2014].

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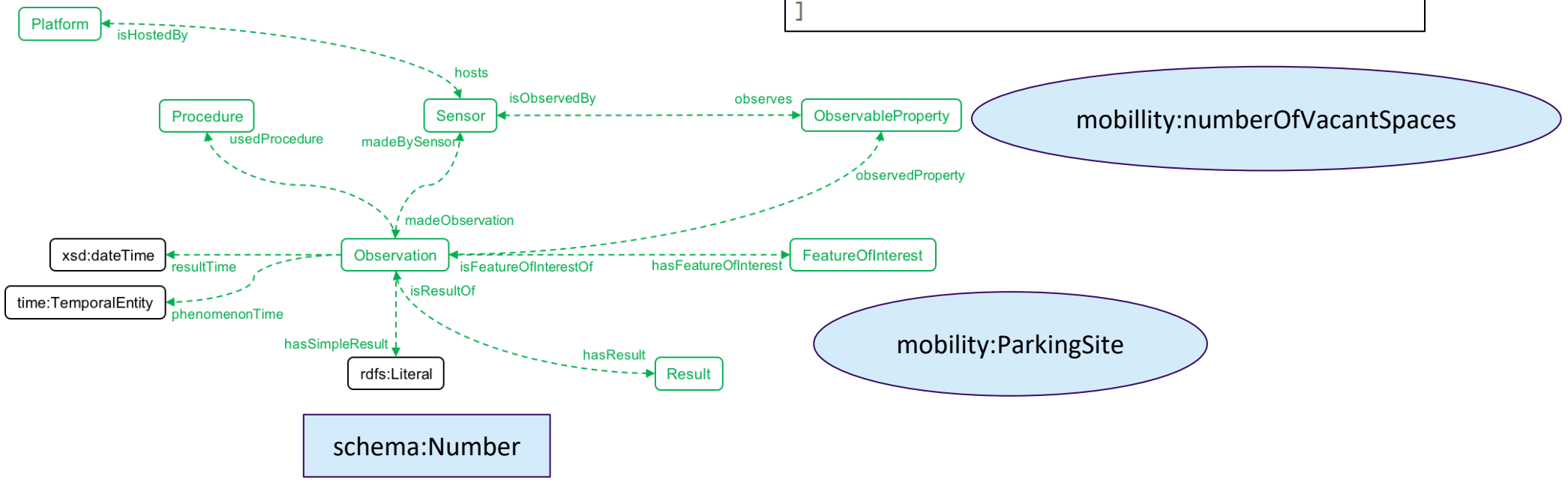
Approach

Sensor Pattern - I, SOSA


```
[
  {
    "address":"Plaza de Pío Baroja, 48001 Bilbao",
    "freeSpots":50,
    "totalSpots":100
  }
]
```


Sensor, Observation, Sample, and Actuator design pattern*



* A. Haller at al., Semantic Sensor Network Ontology. W3C Recommendation. W3C. https://www.w3.org/TR/vocab-ssn/.

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Approach

Pattern ⟶ Annotation Graph

```
sosa:Observation
        sosa:hasFeatureOfInterest sosa:FeatureOfInterest;
        sosa:observedProperty sosa:ObservableProperty;
        sosa:hasResult sosa:Result [
                rdf:type qudt:QuantityValue;
                qudt:numericValue dtype:numericUnion;
                qudt:unit qudt:Unit ] .
```


```
[
  {
    "address":"Plaza de Pío Baroja, 48001 Bilbao",
    "freeSpots":50,
    "totalSpots":100
  }
]
```


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Approach

Annotation Graph ⟶ User Interface Forms


```
[ ⊟
  { ⊟
    "address":"Plaza de Pío Baroja, 48001 Bilbao",
    "freeSpots":50,
    "totalSpots":100
  }
]
```


<Output/Parking_Info/03>
sosa:hasFeatureOfInterest ***?Feature*** .

<Output/Parking_Info/03>
sosa:observedProperty ***?Property*** .

<Output/Parking_Info/03>
sosa:hasResult [rdf:type ***?Type***] .

Select pattern

*Does the proposed output data relate to a **Parking Site**?*

*Which property of a **Parking Site** is being measured?*

TotalNumberOfSpaces

Is it a numeric value?

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Approach

Structured Annotations

proposed:TotalNumberOfSpaces

rdf:typeof ssn:Property, sosa:ObservableProperty;

ssn:isPropertyOf mobility:ParkingSite .

→ *Mobility model*

<Output/Parking/03>

core:rdfAnnotation [

sosa:hasFeatureOfInterest mobility:ParkingSite;

sosa:observedProperty **proposed:TotalNumberOfSpaces** ;

sosa:hasSimpleResult rdfs:Literal];

core:name “totalSpots” .

→ *Offerings’ metadata graph*

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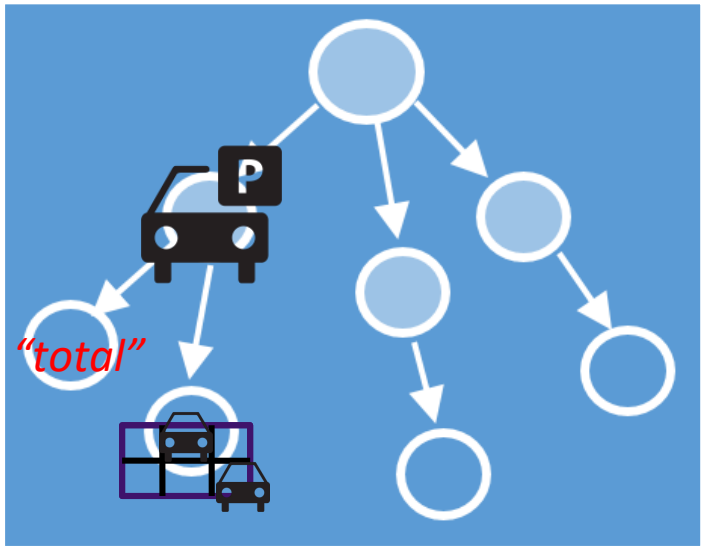
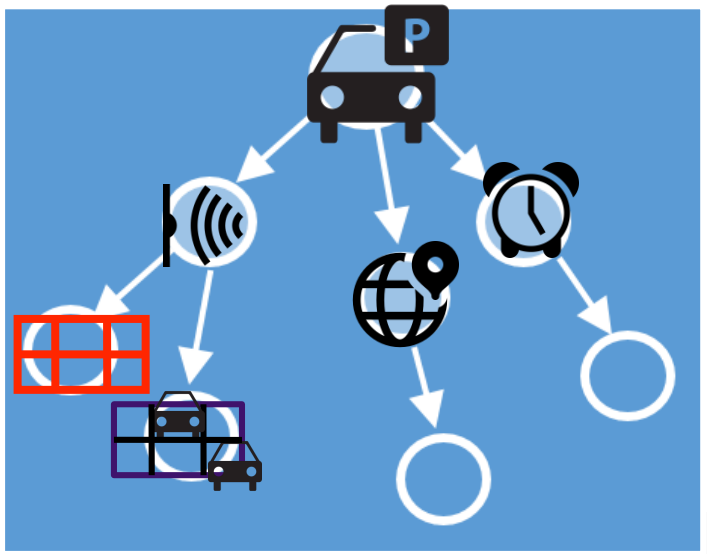
BENEFITS

Benefits

- The approach
  - assures a more coherent and less ambiguous description of a proposed concept;
  - allows to contextualize a concept: to place it closely to the semantically related concepts;
  - reduces the risk of concept duplication and unconventional naming.
- The resulting structured descriptions
  - are machine-processable and partially machine-understandable;
  - can be shared with others as linked data;
  - are easier understood by data consumers and validated by ontology engineers.





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THANK YOU

Marketplace: https://market.big-iot.org
Project website: http://big-iot.eu
Semantic models:
http://schema.big-iot.org/core/docs/schemas.html
http://schema.big-iot.org/mobility/docs/schemas.html
http://schema.big-iot.org/environment/docs/schemas.html

Contact:
yulia.svetashova@de.bosch.com
Yulia Svetashova

Appendix I: Approach
Relations

W3C: Ontologies “specify the definitions of terms by describing their relationships with other terms”

J. F. Sowa: Ontology is a “tightly interconnected collection of signs”

F. De Saussure: syntagmatic (co-occurence) and paradigmatic (similarity) relations

sosa:FeatureOfInterest	sosa:ObservableProperty	schema:unitCode
schema:Car	mobility:speed	om:kilometre_per_hour
schema:Car	mobility:intakeMAP	qudt:KiloPascalAbsolute
schema:Car	mobility:intakeAirTemperature	om:DegreeCelsius
schema:City	environment:temperature	om:DegreeCelsius, om:DegreeFahrenheit
schema:City	environment:humidity	om:percent

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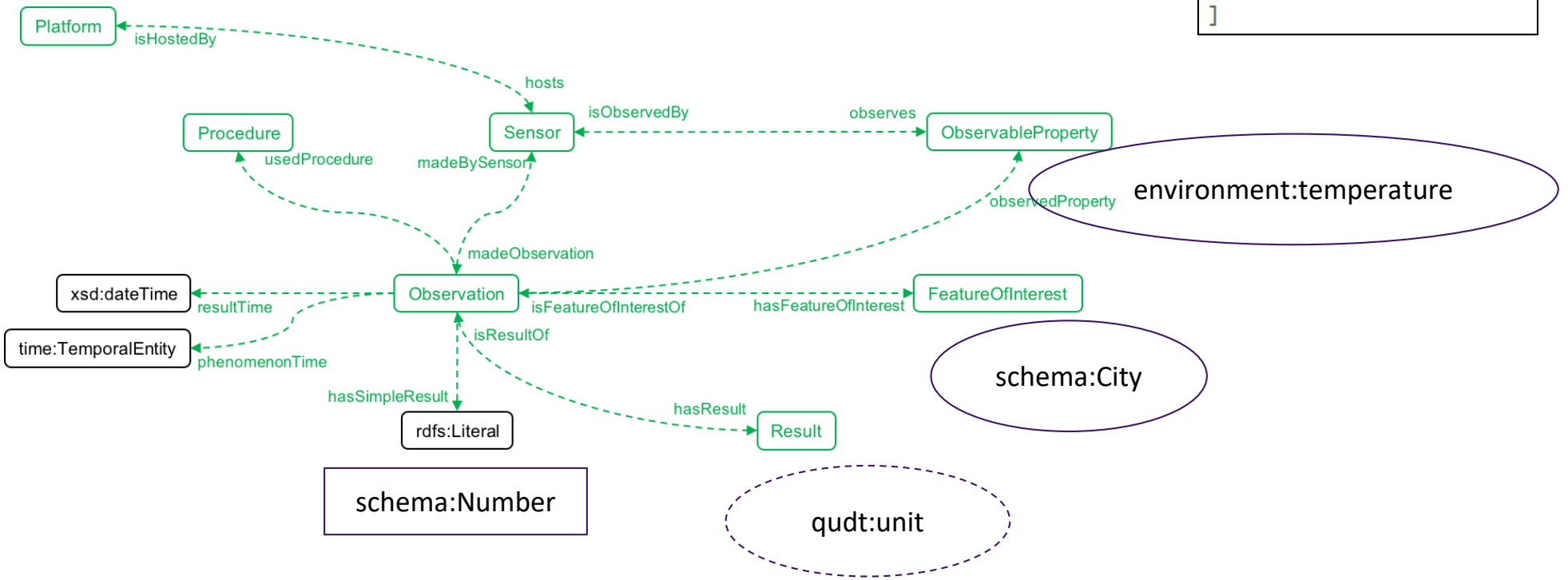
Appendix II: Approach
Sensor Pattern - II, SOSA


```
[ ⊟
  { ⊟
      "city_id":12345,
      "temp":268.987,
      "temp_min":268.987,
      "temp_max":268.987
  }
]
```

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