P5 presentation: Making sense of standards

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Contents

Introduction

- Increasing number of sensors
- Sensor web

- Allows better understanding and management of our environment

Understanding the sensor web

- **Sensor** Device to measure physical quantities and transforms them into electrical signals
- **Observation** Active acquisition of information from a primary source
- **Sensor Web** Group of interoperable web services which all comply with a specific set of sensor behaviours and interfaces specifications
- **Standard** Formulation, publication, and implementation of guidelines, rules, and specifications for common and repeated use, aimed at achieving optimum degree of order or uniformity in a given context, discipline, or field

Sensor data in the built environment

*Why important for **citizens**?*

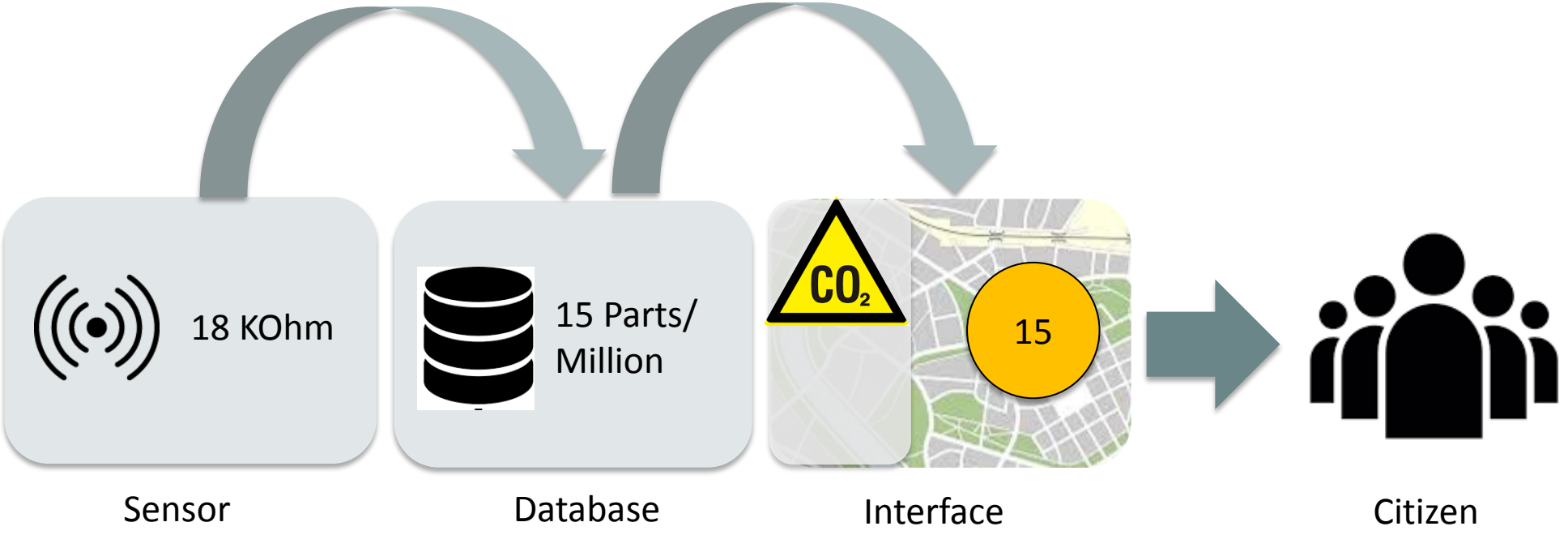
- Use and reuse of sensor data in applications
- Objective observation of phenomena
- Measure life quality

*Why important for **sensors maintainers**?*

- Updated technical sensor information
- More time efficient sensor maintenance
- Maintenance and configuration at distance

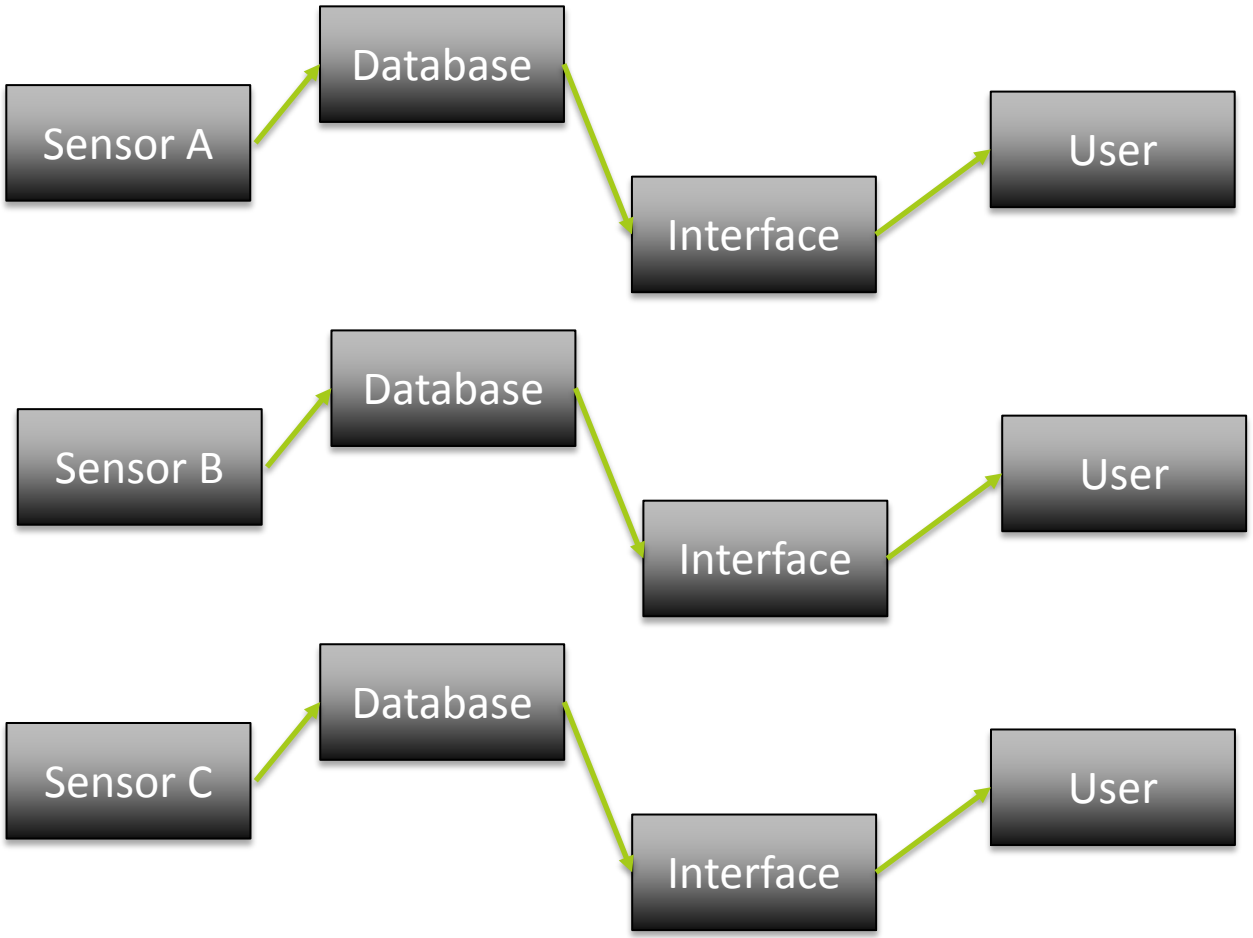
Understanding sensor data

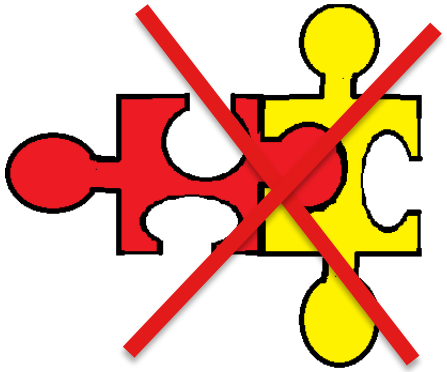
- Sensor data accessed in applications
- Transformation required:



Problem statement

- Current situation

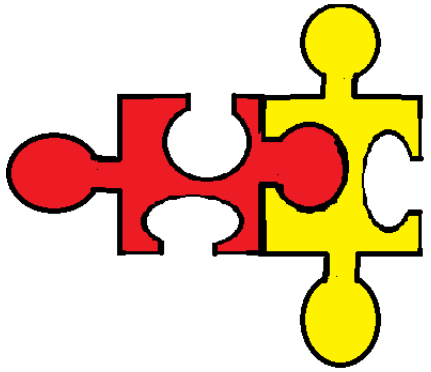




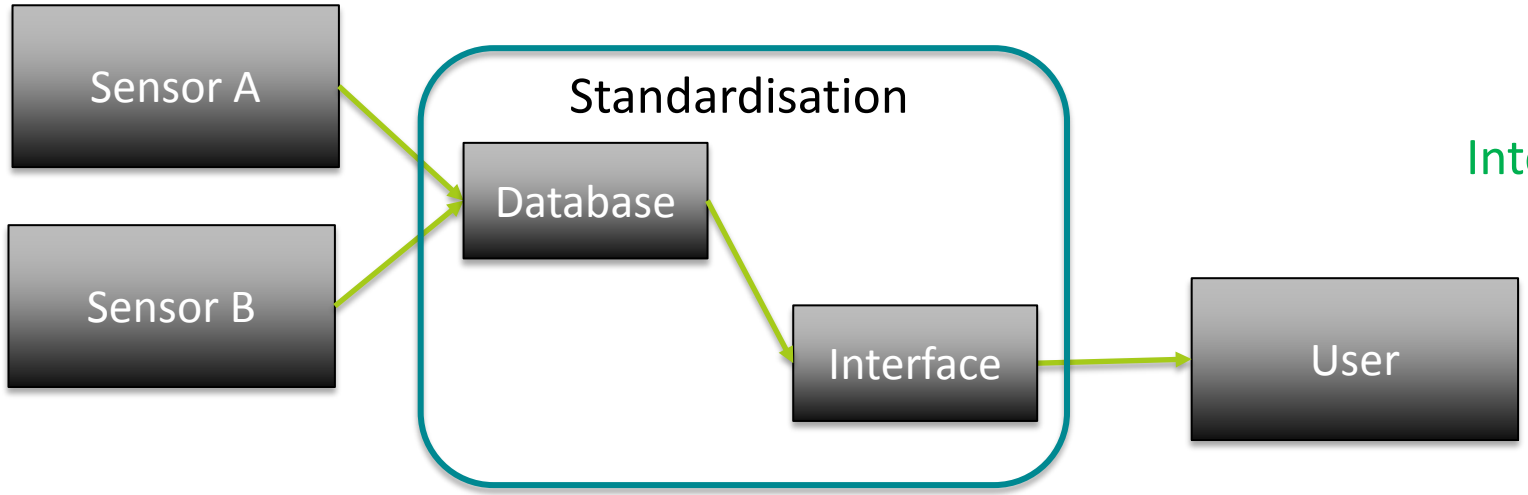
No Interoperability

Problem statement

- Ideal situation



Interoperability



Abundance of standards

- SensorML
- Sensor Alert Service
- Sensor Observation Service
- Observations & Measurements
- SemSos
- Generic Sensor Api
- Sensor Event service
- Semantic Sensor Network
- SensorThings API
- SensorML
- IEEE 1451
- Sensor Planning Service
- Pub/Sub

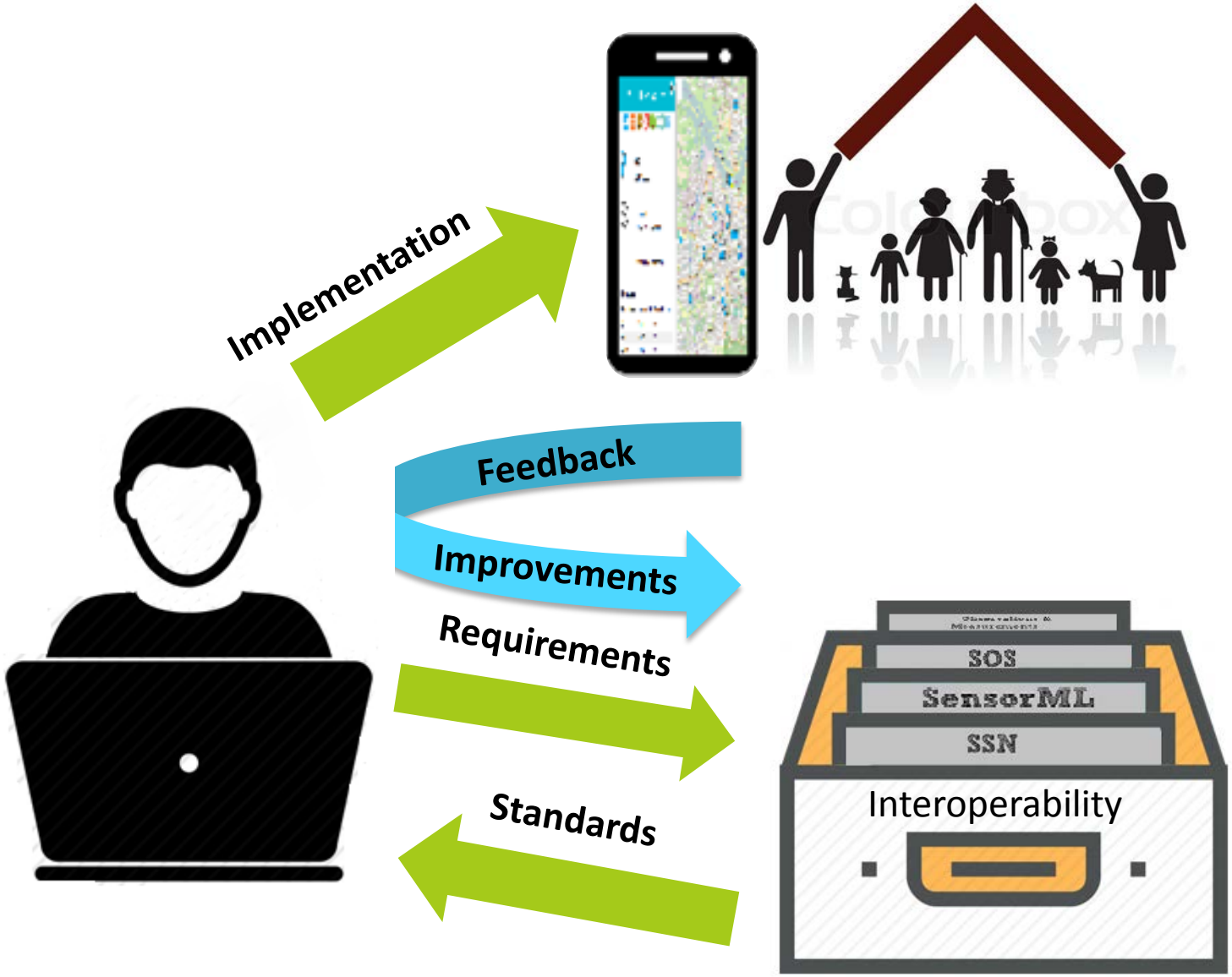
Research scope

- Create insight:
  - Define requirements
  - Research Sensor Web's technical capabilities
  - Create UML model
  - Order standards

Use case supported research

Towards interoperability between standards

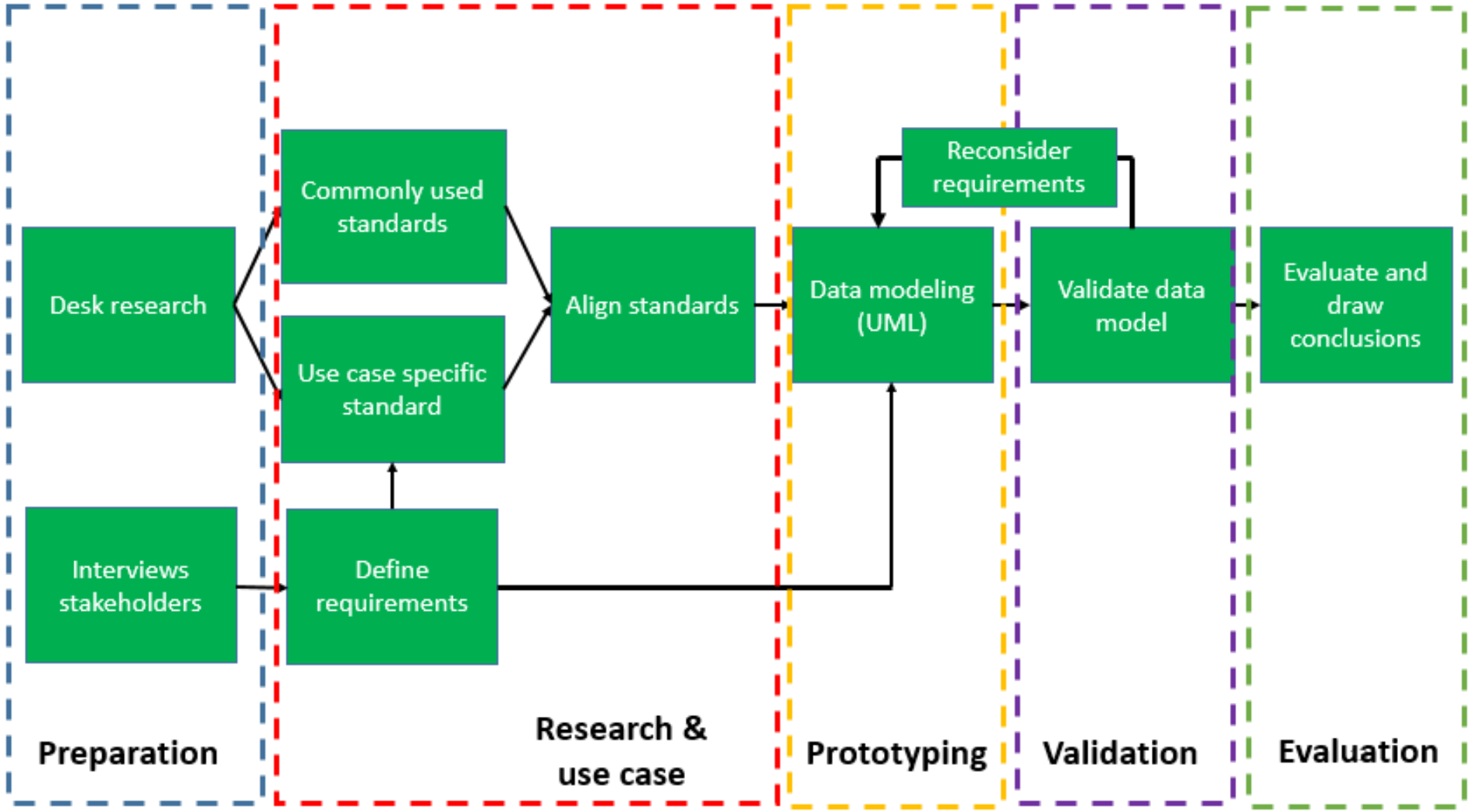
Research scope



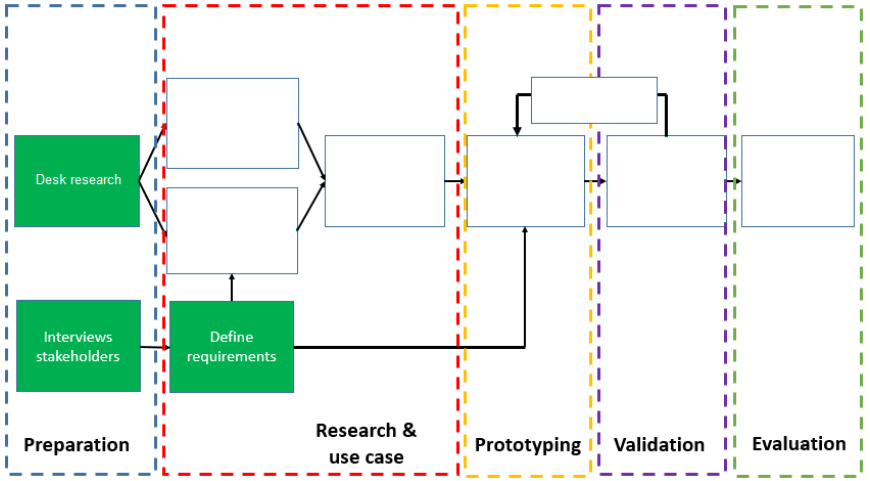
Research question

- To what extent is there an **alignment** of existing **sensor standards** for describing **observations** and **sensors**, and how can the standards be **harmonized** further?

Work flow

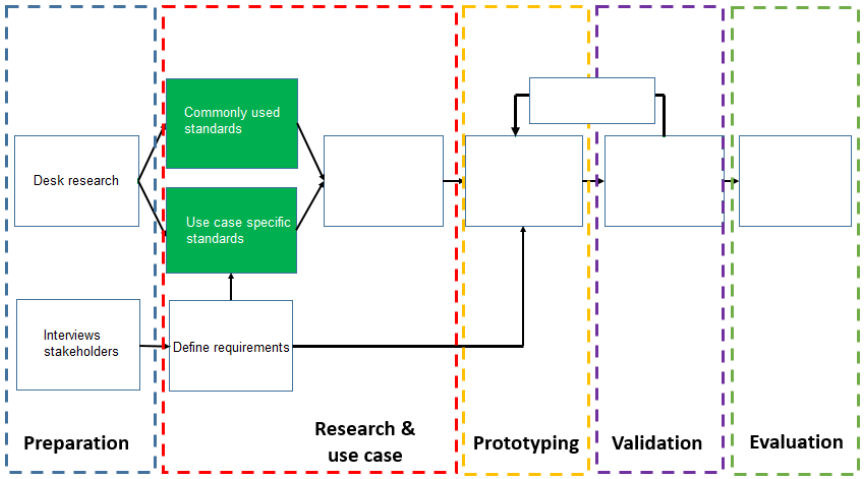


Preparation & research



- Desk research
  - Use cases
  - Technical capabilities standards
  - Data structure/ semantics
- Interviews
  - Demand citizens/ maintainers
  - Supply developers
  - Technical requirements

Commonly- & use case specific standards



Commonly:

- 5 Standards are compared
- Selected on:
  - Relevance for the use case
  - Frequency of hits on google

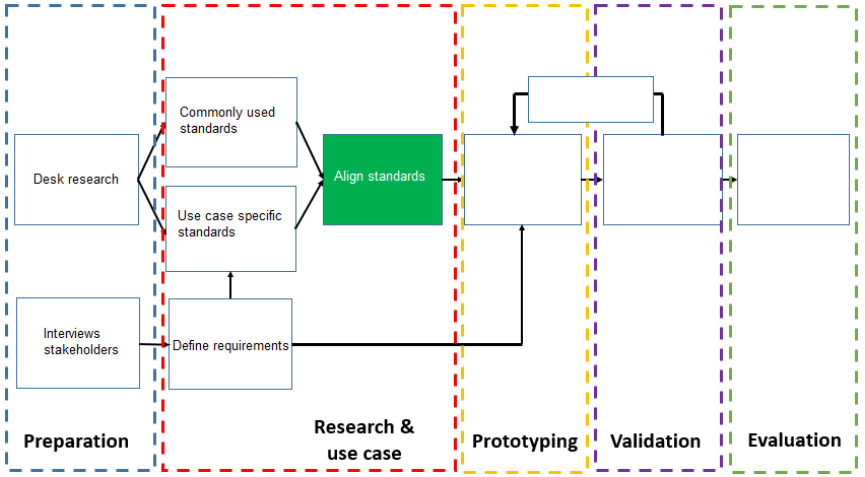
Use Case Specific:

- Depending on the Project Team

Alignment

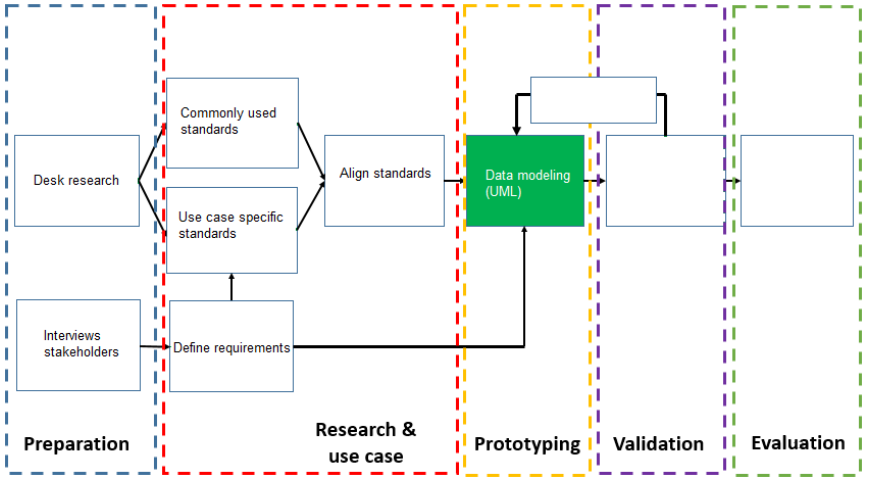
- Based on technical requirements

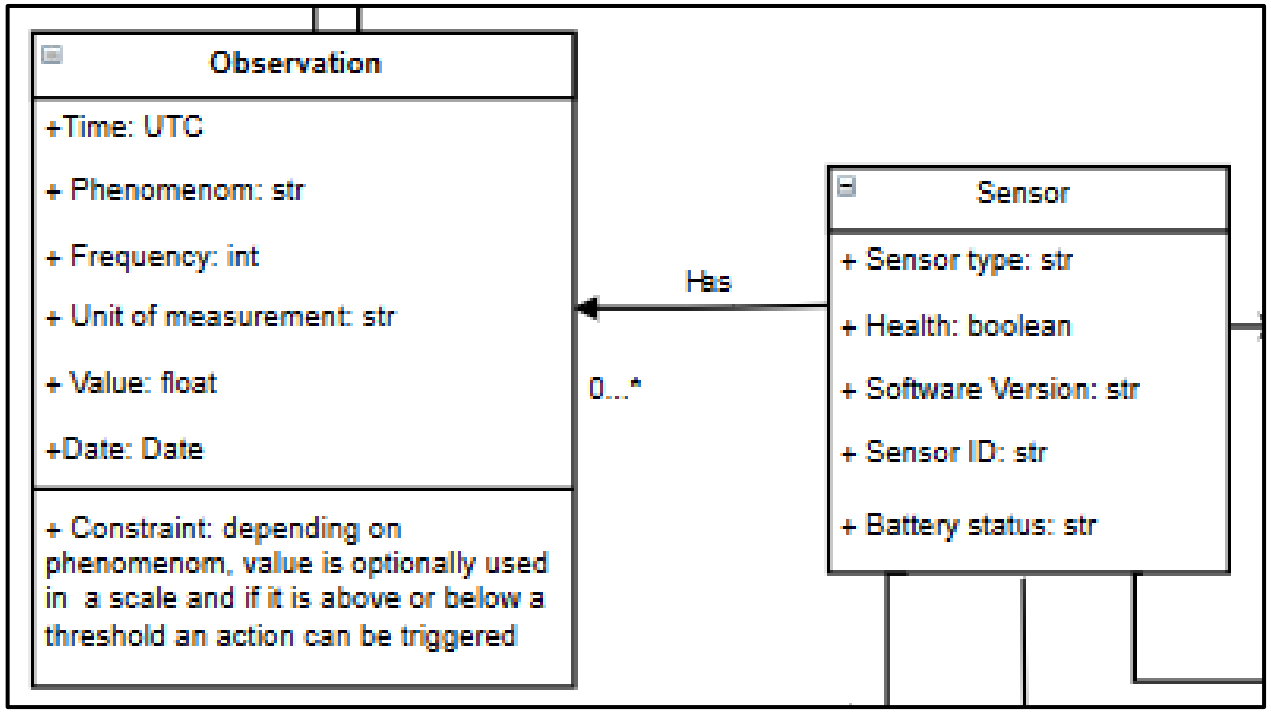
Requirements
Sensor data
View sensor data
download sensor data
Last value data
Time series data
Data requestable interval
Data requestable point in time
Sensor spatially dispersed in map
Clear units of measurements
Scales if required for measurement
Select sensor by clicking
Select sensor by geometry
Charts for sensor data
Metadata sensor
Battery status
Wifi status and network
Sensor health
Sensor name
Last maintenance
Frequency of measurement



UML model

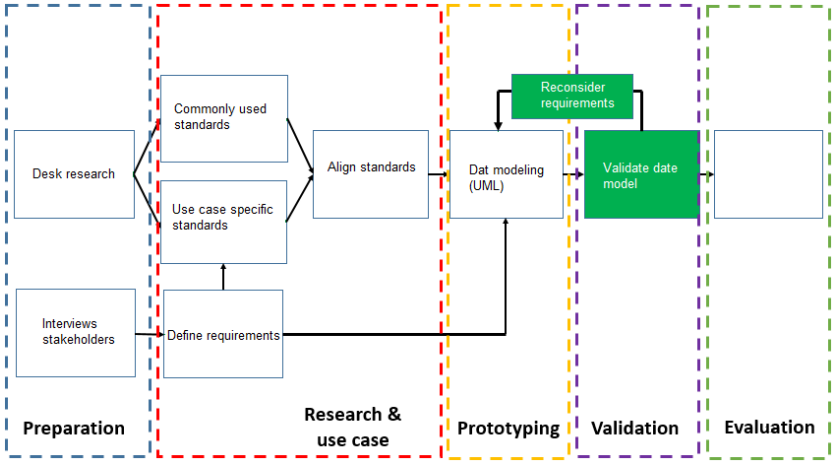
- Unified Modeling Language
- Structure diagram
- Basis for standards





Example from research

Validation of the UML model

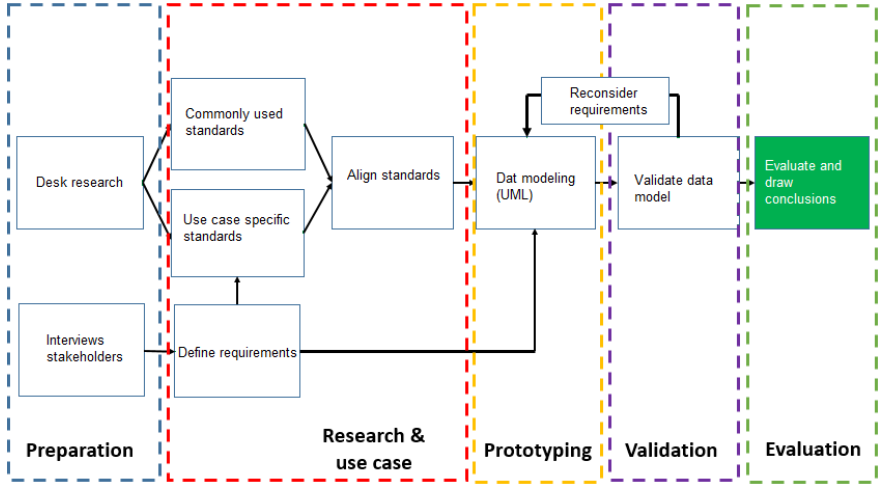


- Check the technical requirements in all available applications
  - One functioning sensor
  - One time frame
  - One indicator

If necessary: improve the data model

Evaluation of the use case

- Feedback for the Sensor Web, based on the use case

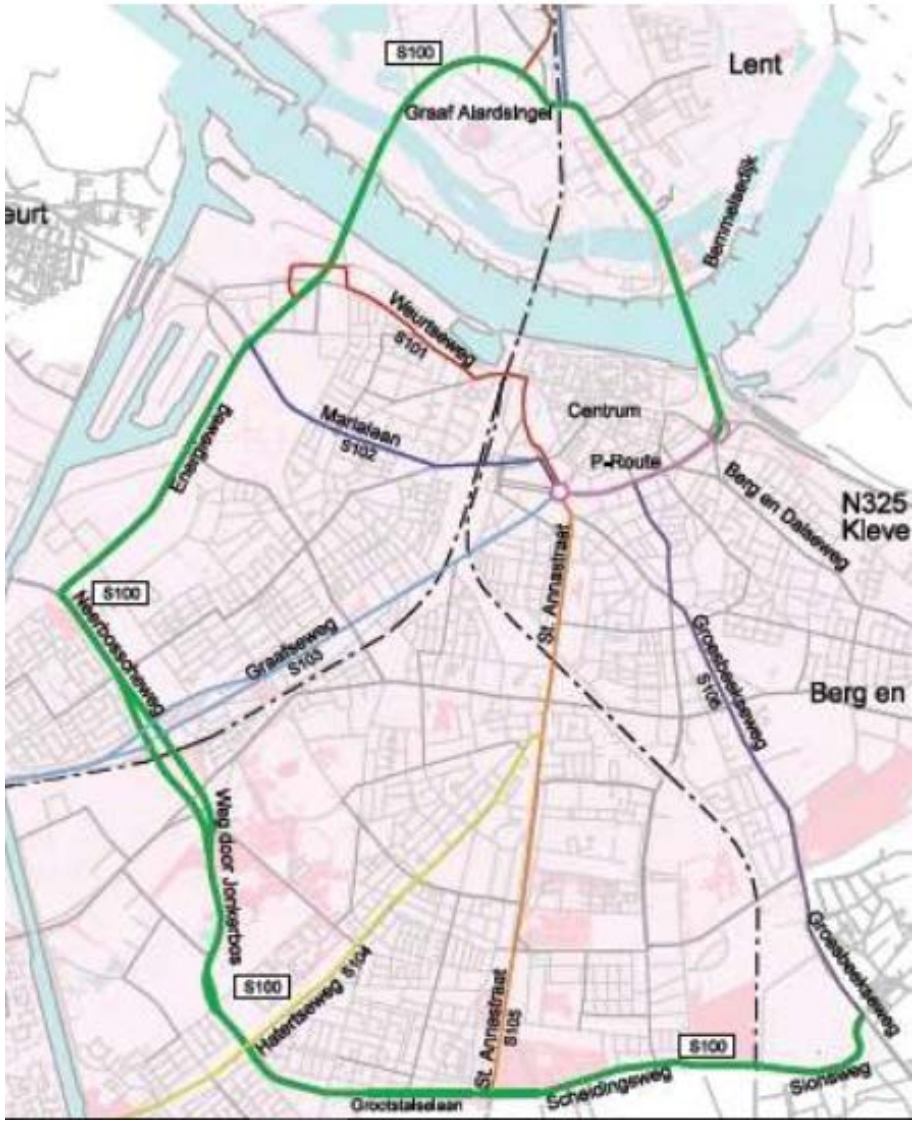


Use case

New road

Renovated bridge

Nijmegen



Source: Smart Emission project

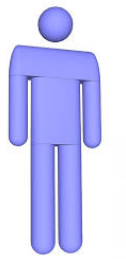
Use case

- Use case
  - Citizen participation
  - Create insight into environmental factors
  - **Wish to standardize the data flow**

  Current situation:
  - Three applications

  Towards:
  - One application

Use case specifications



Citizen

Location

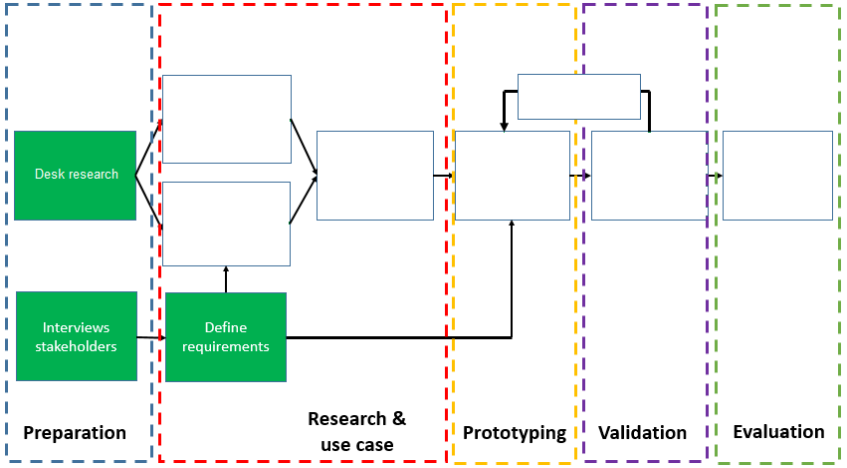
Question

Data acquisition

Visualisation

Interviews

- 3 interviews experts
  - Network Maintainer
  - Calibration expert
  - Data analyst
- 6 meetings citizens
- 4 project meetings data experts
- 5 project group meetings



Interviews

- Results:
  - Citizens
    - Clear calibrated observation data
    - No gaps in sensor data flow
    - Real time sensor data
    - Historical sensor data
  - Maintainers
    - Device information
    - Maintenance history

Source: Smart Emission project

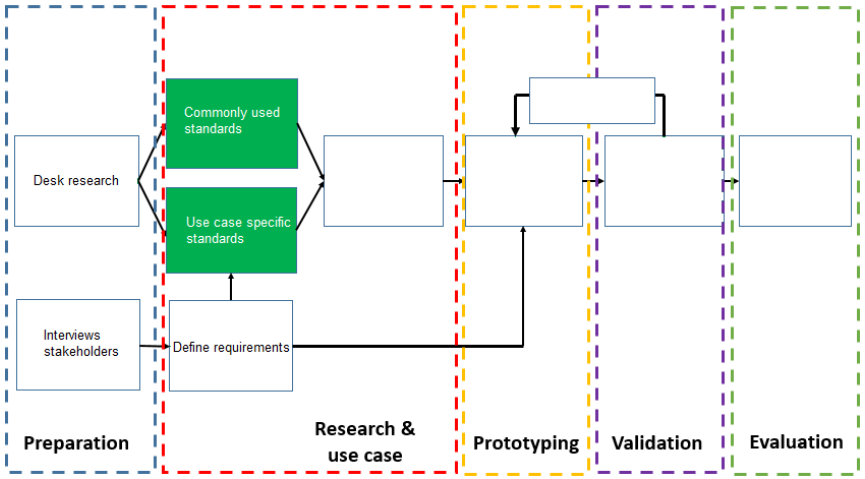
Technical requirements

Citizens

Maintainers of the network

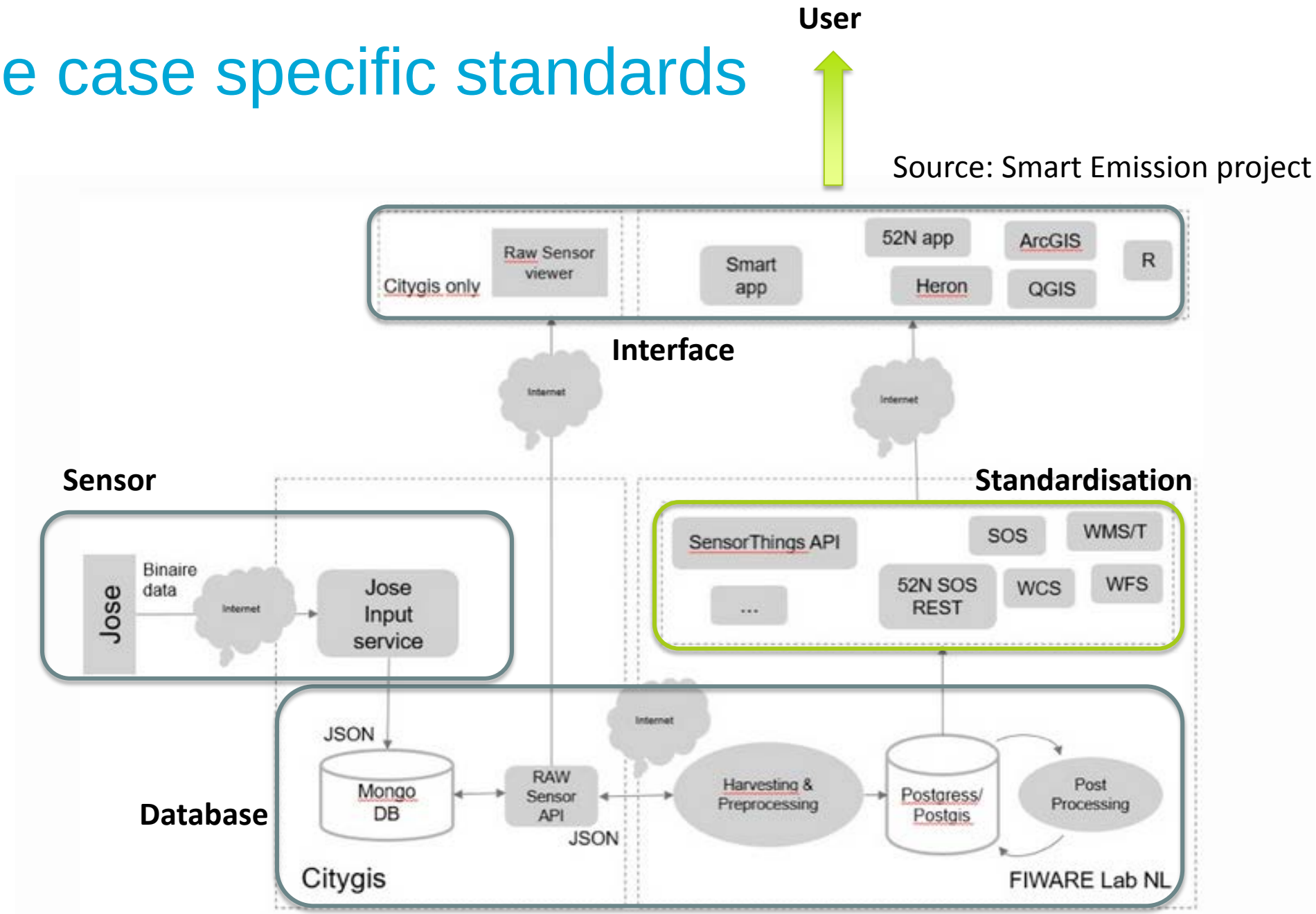
Requirements
Sensor data
View sensor data
download sensor data
Last value data
Time series data
Data requestable interval
Data requestable point in time
Sensor spatially dispersed in map
Clear units of measurements
Scales if required for measurement
Select sensor by clicking
Select sensor by geometry
Charts for sensor data
Metadata sensor
Battery status
Wifi status and network
Sensor health
Sensor name
Last maintenance
Frequency of measurement

Commonly used standards



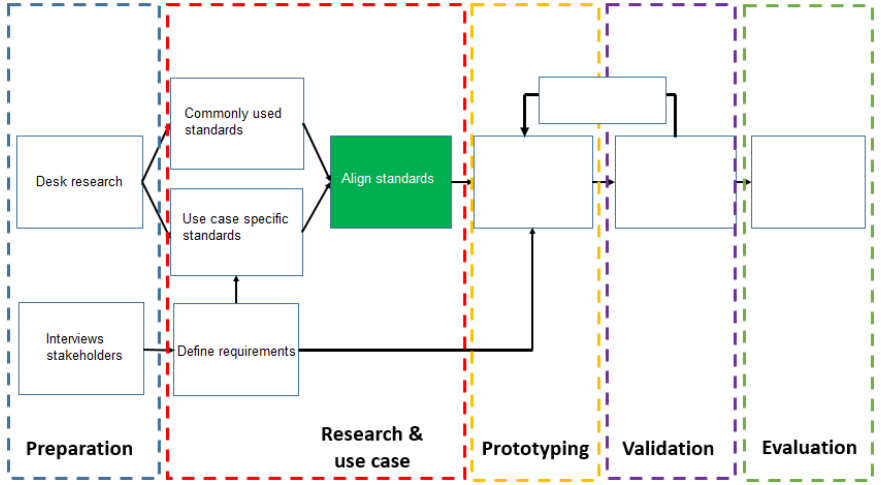
- *SensorML*
- *Observations and Measurements*
- *Sensor Observation Service*
- *Semantic Sensor Network*
- *SensorThings API*

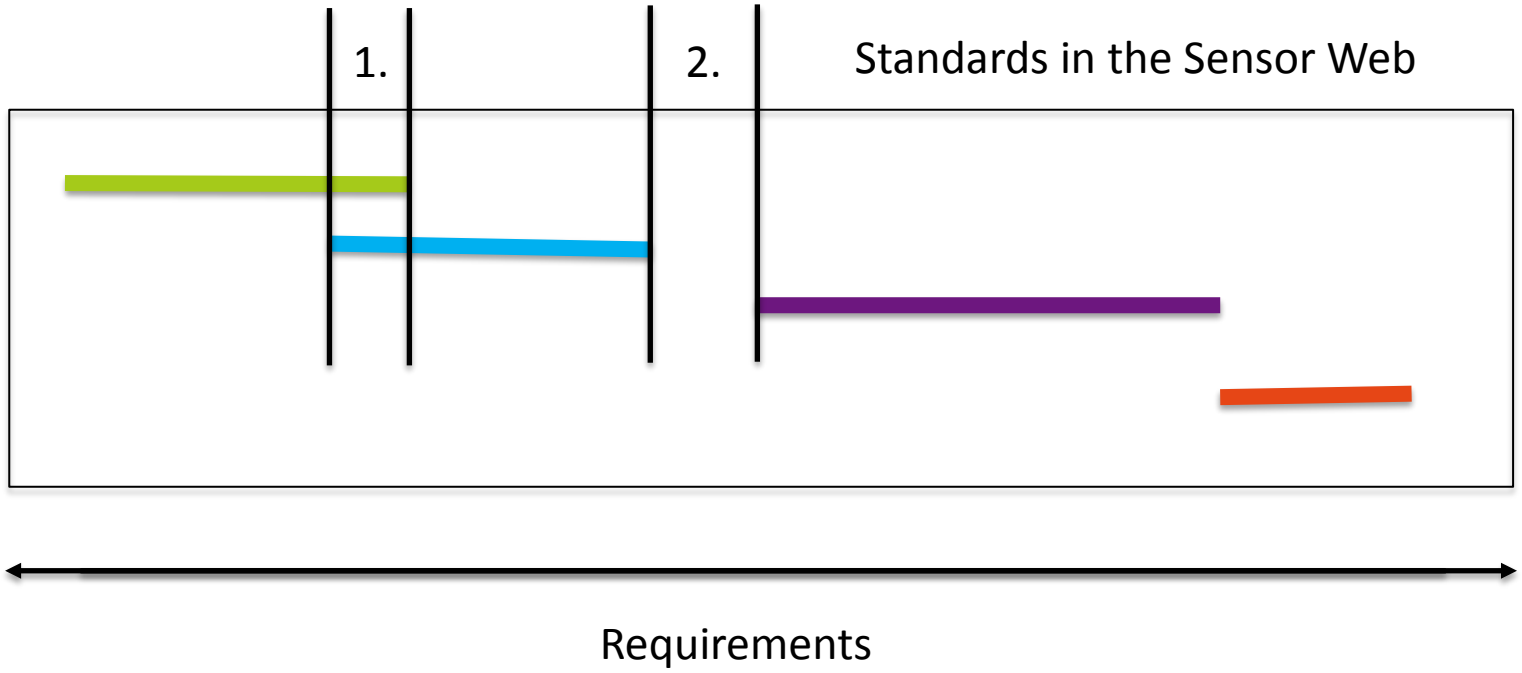
Use case specific standards



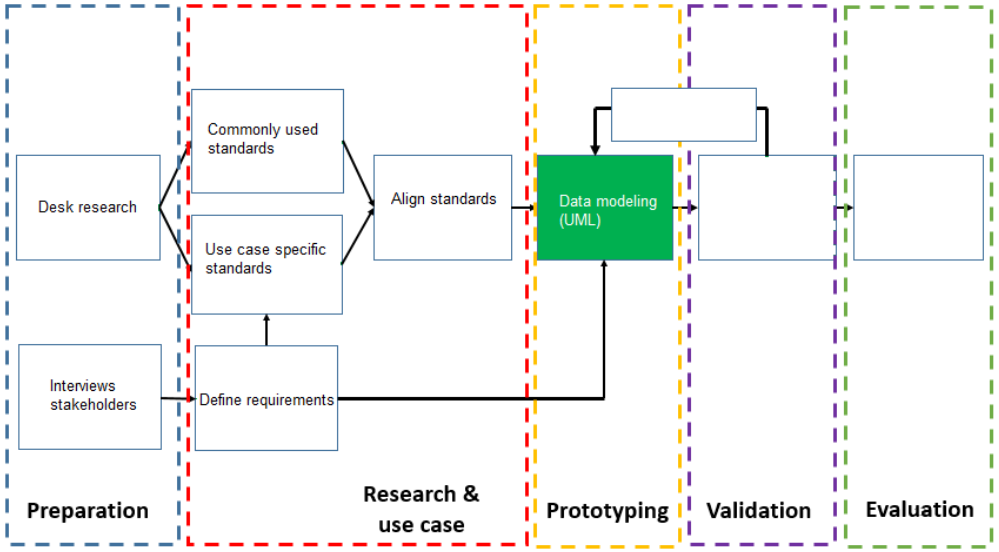
Alignment

- Some similarities, standards are created for specific goal





UML model

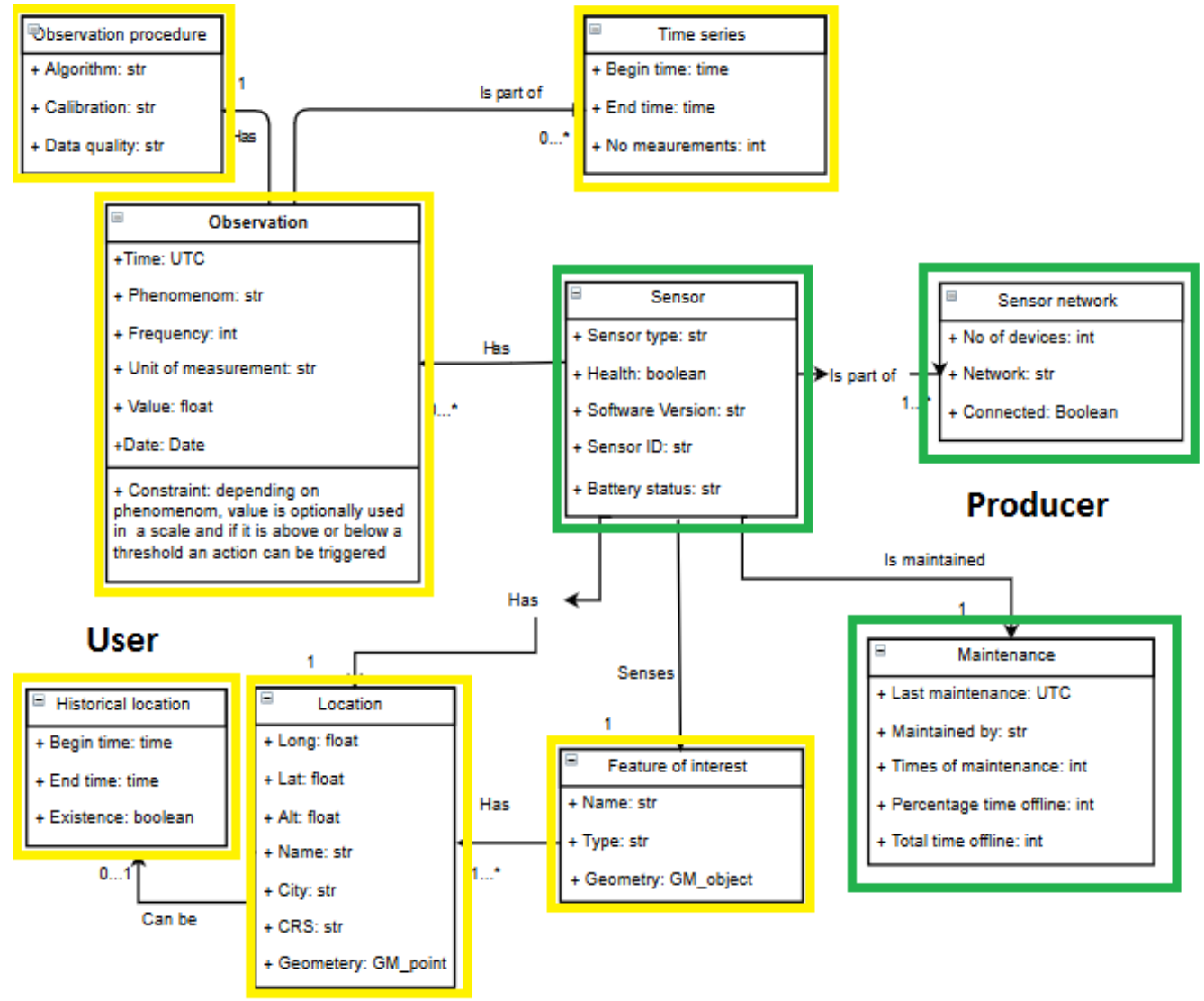


- UML model based on:
  - Harmonized sensor standards
  - Use case requirements
- To test the requirement on the applications
- To test if the possibilities of the standards are sufficiently used

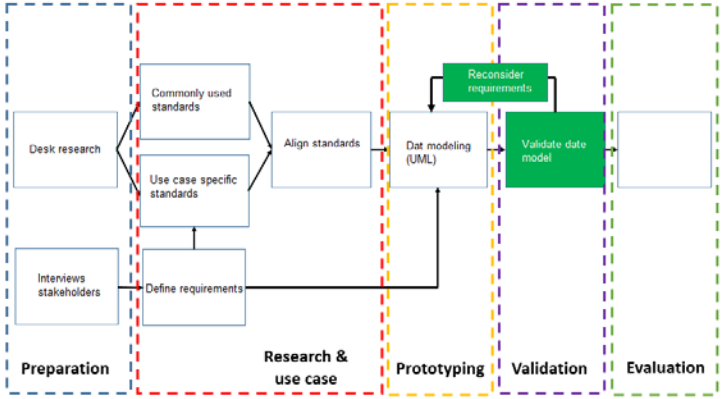
UML model

Observation data

Device data



Validation of the UML model



Value

Date, time

Longitude, latitude, altitude

Unit of measurement

Frequency

Sensor Health

Battery health

Sensor type

Last maintenance

Compatibility with platforms

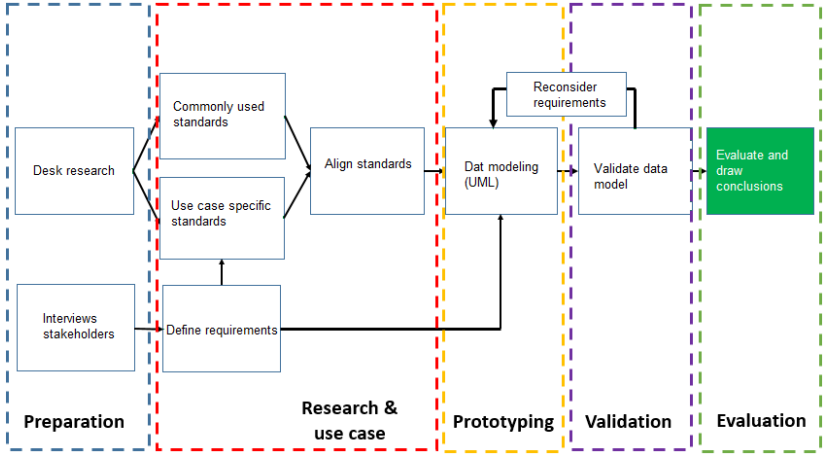
Validation of the UML model

Requirements	Fulfilled	Standard used
Sensor data		
View sensor data	✓	SOS, O&M
download sensor data	✓	SOS, WMS, WFS
Last value data	✓	SOS, O&M
Time series data	✓	WMS-Time
Data requestable interval	✓	WMS-Time
Data requestable point in time	x	x
Sensor spatially dispersed in map	✓	SOS
Clear units of measurements	✓	none
Scales if required for measurement	✓	none
Select sensor by clicking	✓	none
Select sensor by geometry	✓	none
Charts for sensor data	✓	SOS
Metadata sensor		
Battery status	x	x
Wifi status and network	x	x
Sensor health	x	x
Sensor name	✓	SOS
Last maintenance	x	x
Frequency of measurement	x	x

Validation of the UML model

- Requirements maintainer not fulfilled
- Half of the requirements met without standardization
- Sensor Observation Service mostly used for standardisation

Evaluation of the use case



- Geo & sensor standards used:

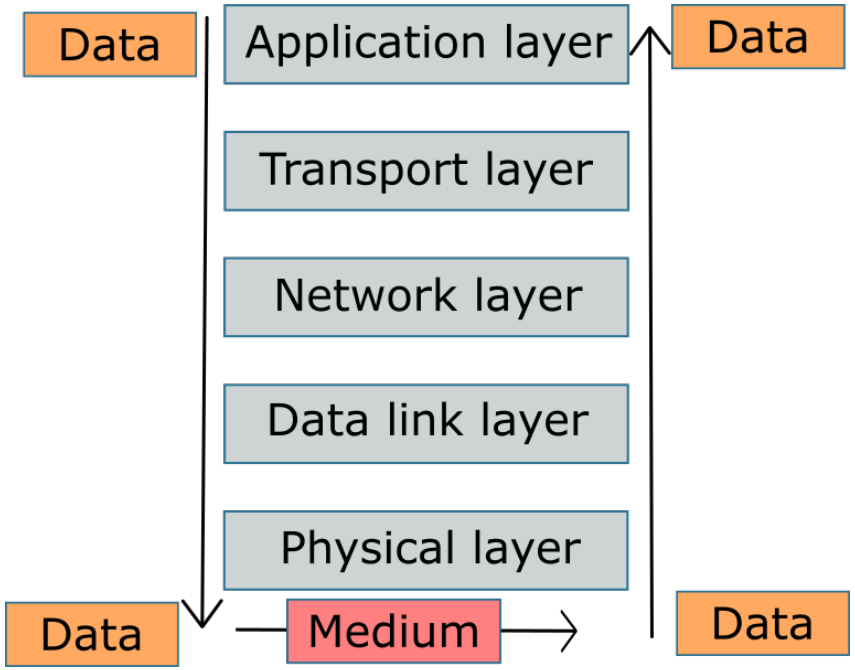
WMS, WFS, SOS

- Another standard planned: SensorThingsAPI
- Observation standards, no device standards
- Adding more semantics required
- Most of the requirements met
- Finding fitting standards is time consuming
- Several applications required
- **Ordering of standards is required**

Bringing order

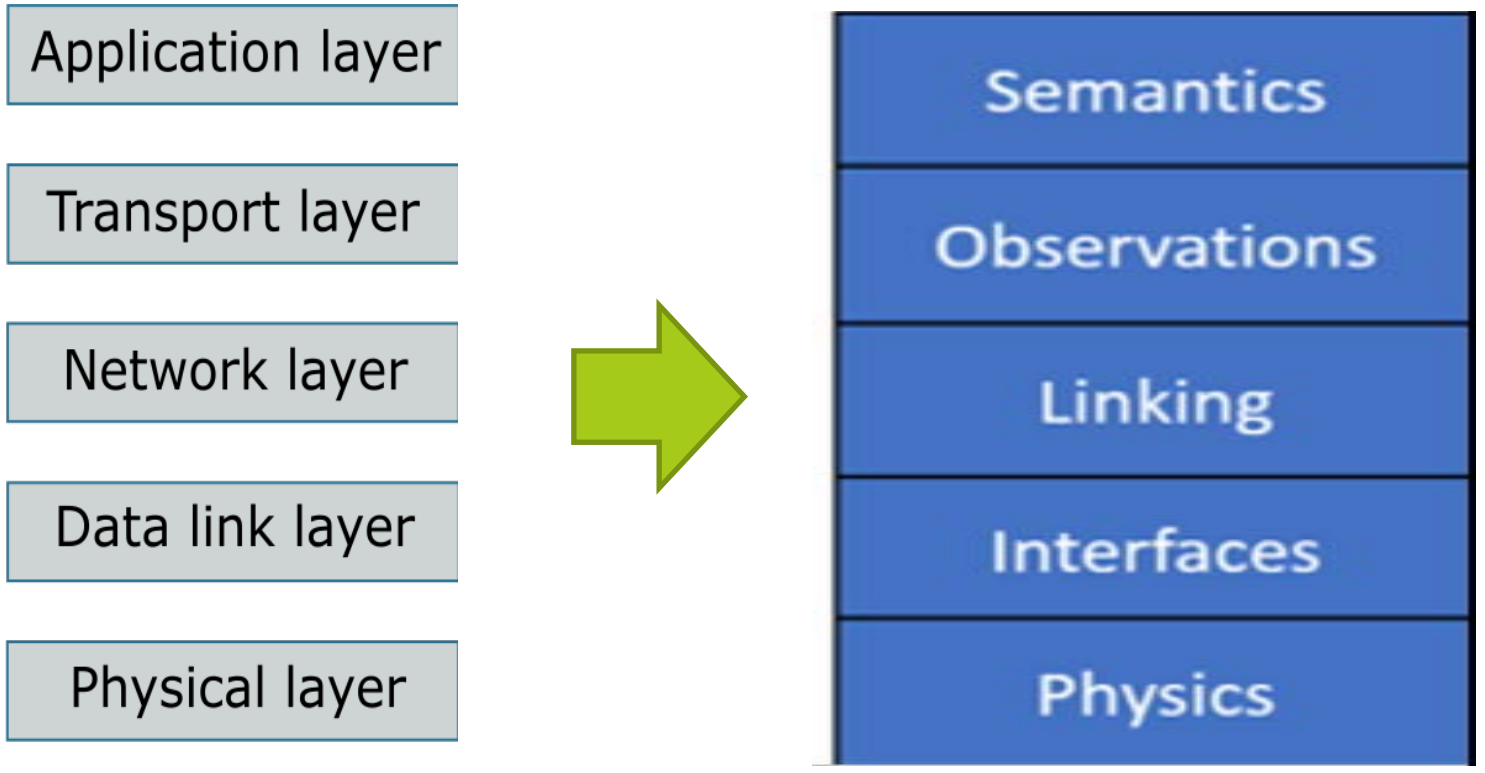
- Why ordering:
  - Inventory and ordering of standards
  - Developer can easier pick a standard
  - Standards can be better fine-tuned and adapted
- Adapting the Open System Interconnection (OSI) model

OSI model



- What does it contribute?
  - Used as a model for the Internet and Internet of Things standards

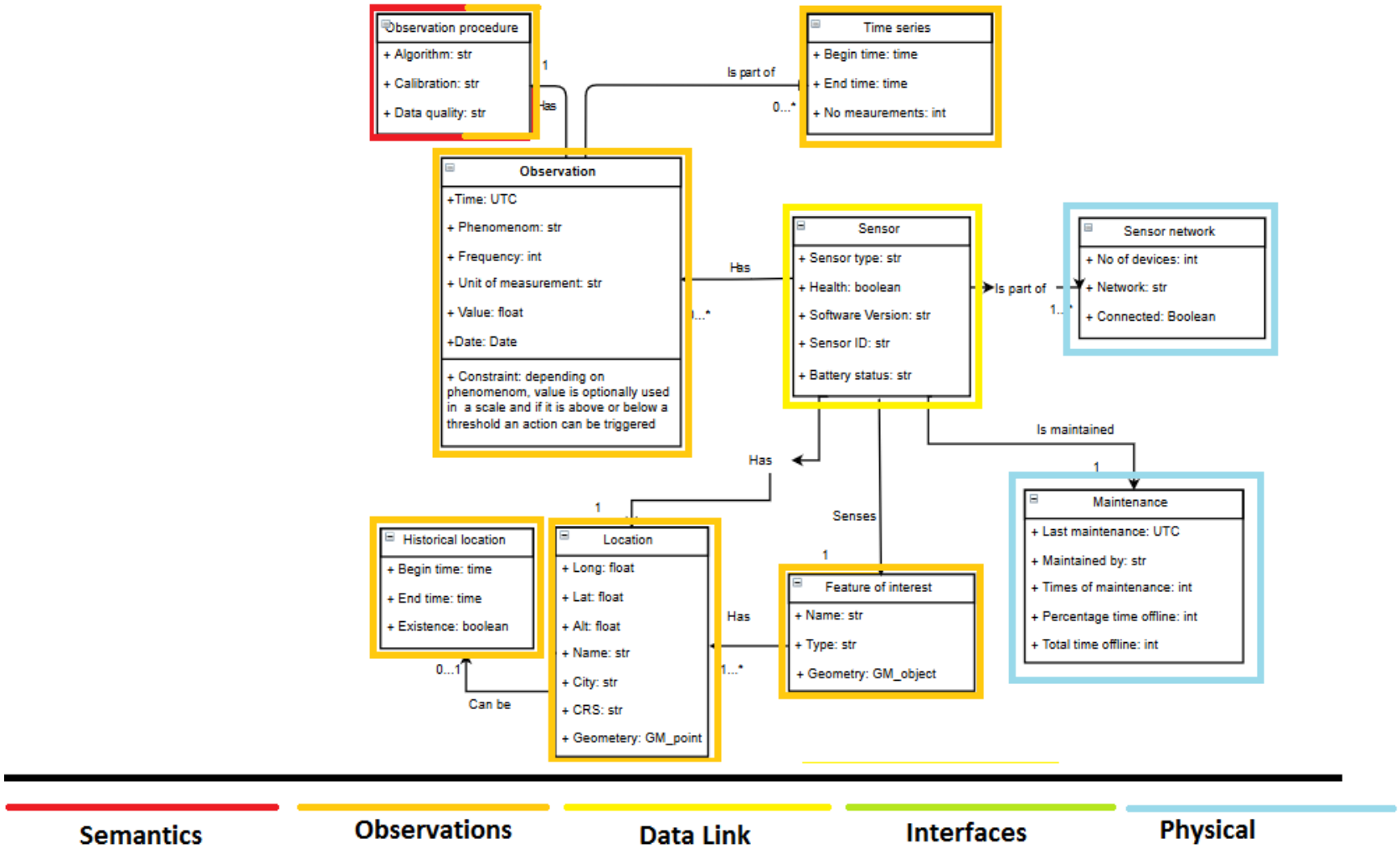
Adaption



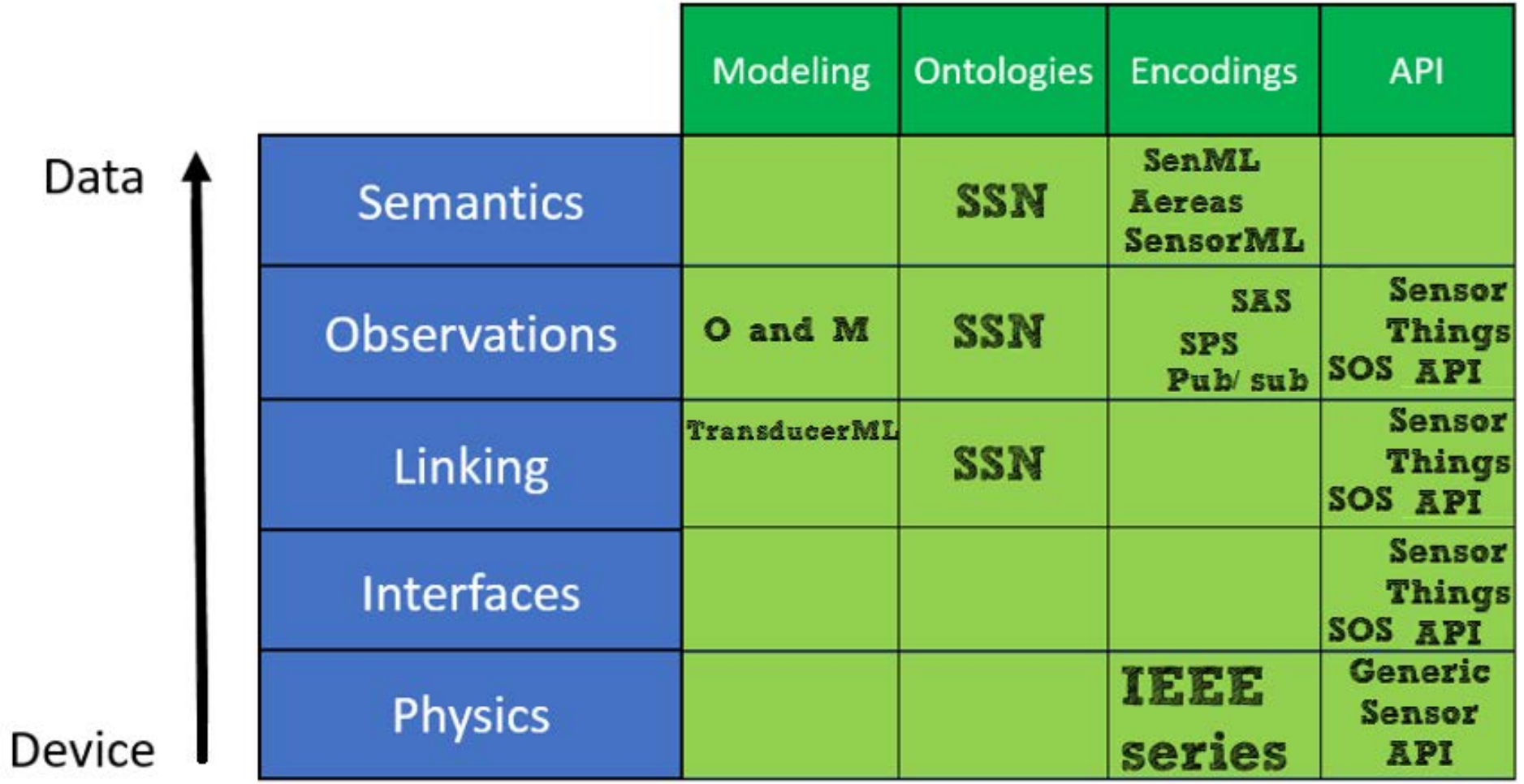
Original OSI-model

Adapted OSI-model

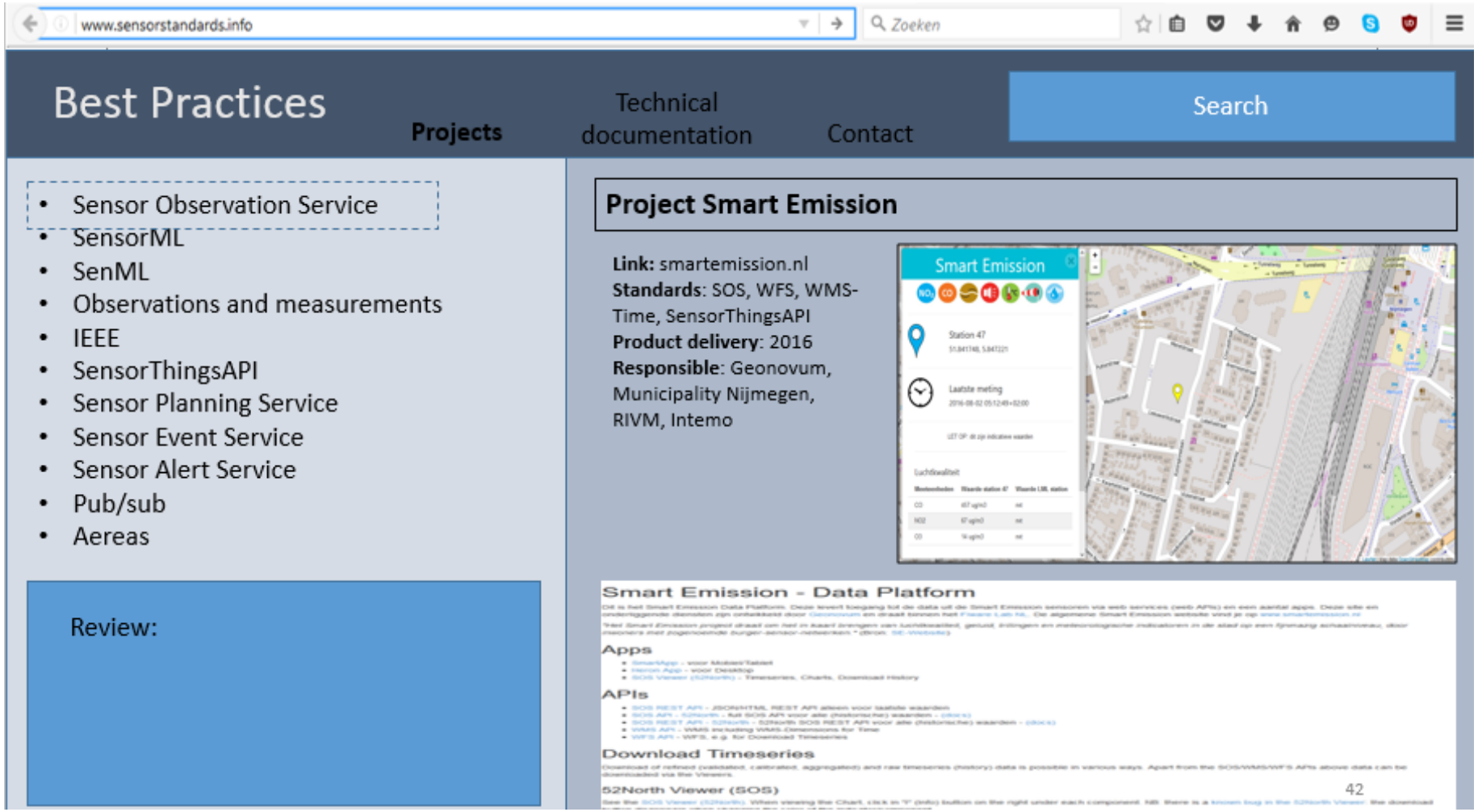
Layers in the data model



Adapted OSI model



Future of the Adapted OSI model



Future of the Adapted OSI model

- Maintenance required
- Cooperation stakeholders and standard organizations required
- One organization needs to be responsible

Conclusions

To what extent align existing **sensor standards** for describing both **observations** and **sensors?**

- Situation sensor web: rapid developments, a lot of standards, no overview.
- Standards not sufficiently harmonized
- Sensor standards focus on a small section in the sensor web.
- Sensors and observations should have both equal importance in UML models
- Having one universal standard for the sensor web currently limits the flexibility of the sensor web

Conclusions

What steps can be taken to **harmonize** standards in the **sensor web**?

- Collect the available standards
- Make an alignment
- Make a UML model based on the use case
- Remove duplications, fill gaps in the data model
- Validate the data model using use case requirements
- Order the standards in an ordering model
- Maintain the ordering model

Limitations

- One use case: air quality
- Standards can cover more than one layer
- The layer definitions are broadly defined
- Vague boundary geo-standard and sensor standard
- Process not automated yet

Future work

- Check if specifications are in other standards.
- Make an overview of possible implementations and best practices discoverable online
- Keep the model up-to-date
- More use cases need to be tested
- Involve sensor standard creators
- More use of Semantic sensor standards

Thank you for your attention!

Special thanks to

- Michel Grothe for help at geonovum,
- Wilko Quak and Bastiaan van Loenen at TU Delft

TU Delft

GEONOVUM

Link

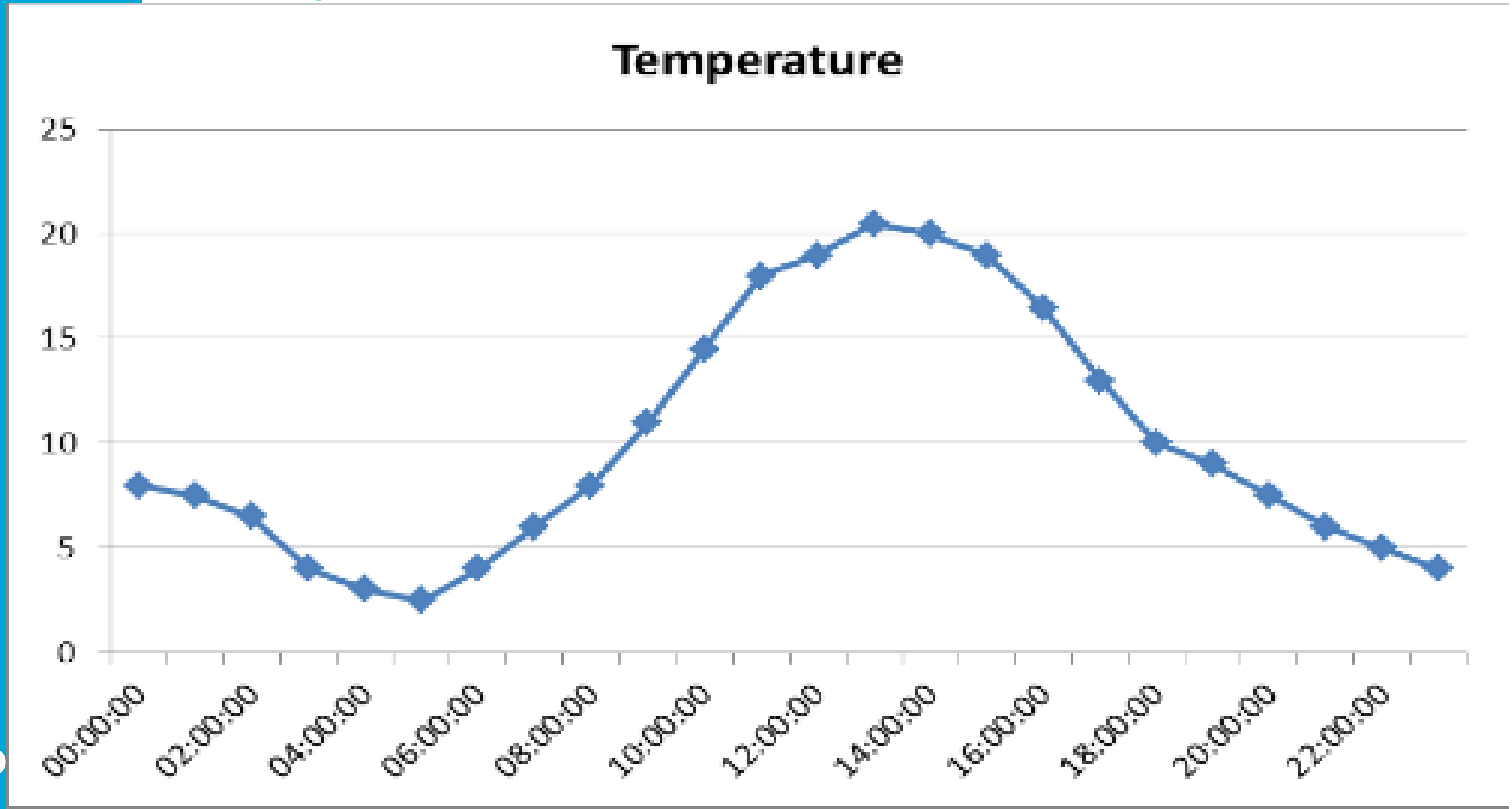
http://data.smartemission.nl/

Sensor

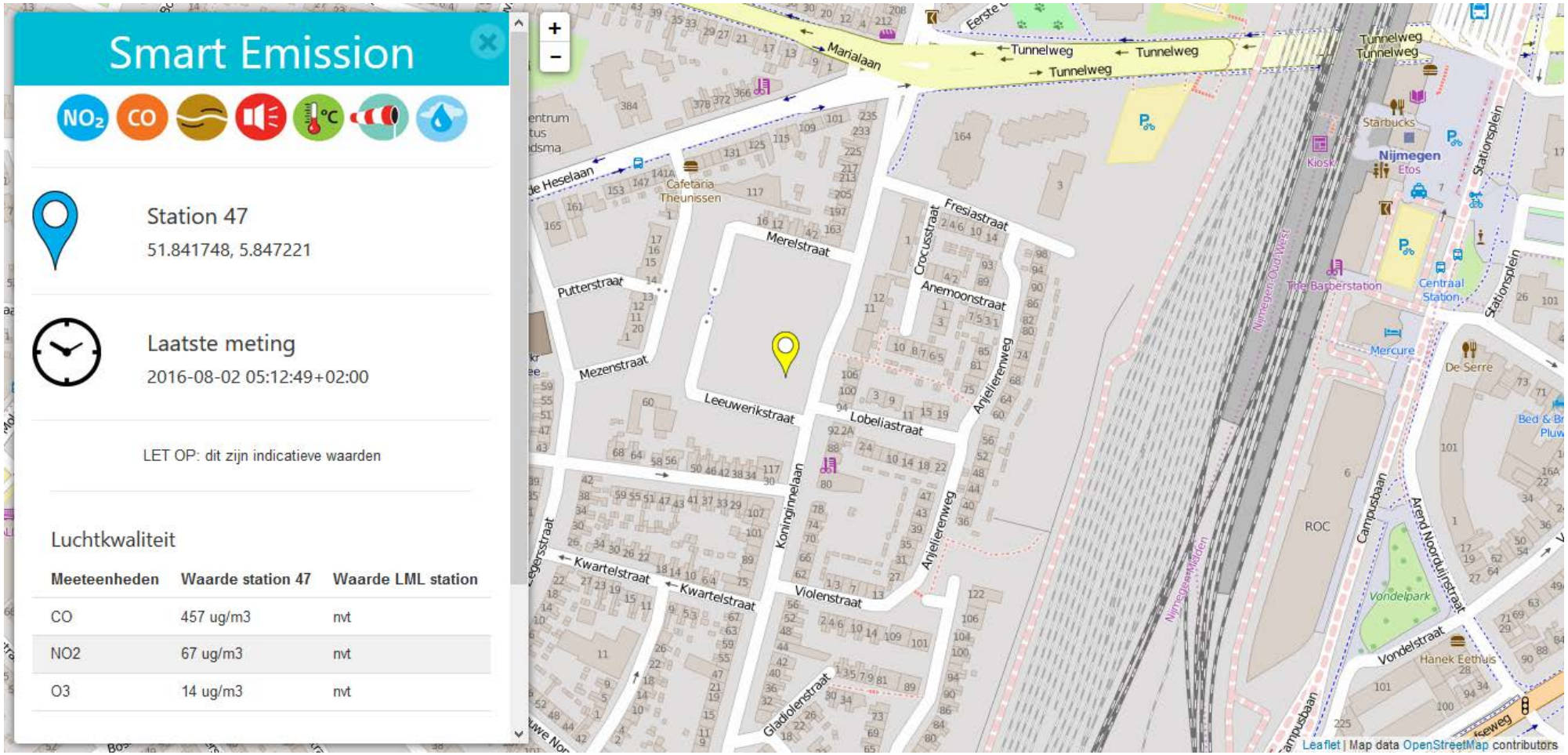
Source: Intemo

Temporal data

Source: Smart Emission project



Real time data



Source: Smart Emission project

```
11/13/2015 11:09:45,S.RtcTime,788771
11/13/2015 11:09:45,P.SessionUptime,331596
11/13/2015 11:09:45,P.BaseTimer,4
11/13/2015 11:09:45,P.ErrorStatus,0
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11/13/2015 11:09:46,S.36,0
11/13/2015 11:09:46,S.CO2,1116000
```

Raw Sensor Data

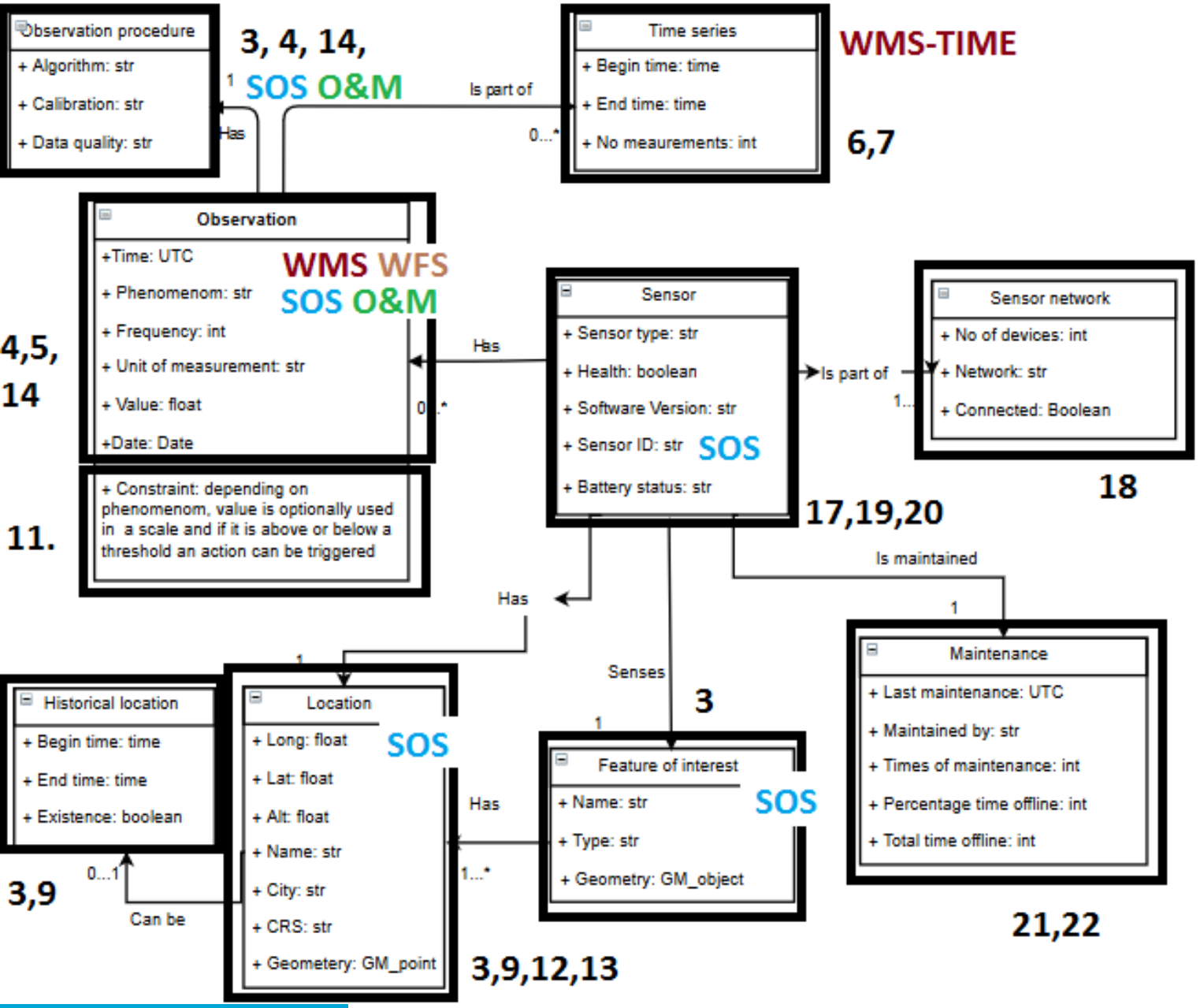
Standard	Observations & Measurements	SensorML	Sensor things API	Semantic sensor network	Sensor Observation service
Author	OGC	OGC	OGC	W3C	OGC
Architecture style	Resource Oriented Architecture	Service Orientated *Architecture*	Resource Oriented Architecture	Semantic Service Oriented Architecture	Service Oriented Architecture
encoding schema	XML, Json, OWL and Schematron for validation	Xml	REST, JSON, OASIS OData and URL	OWL	SensorML
Focus	XML implementation of schemas for observations, and for features	Restriction of sensor description, and sensor discovery	interconnects IoT devices, data, and applications over the Web	describes sensors, observations, and related concepts	Web service interface to query observations, sensor metadata, and representations of observed features.
Binding	SOAP	Sensor Markup Language	REST	OWL	SOAP, REST via extension
Insert new sensors and observations	Not Supported	Not Supported	HTTP POST	Not Supported	SOS specific interface: RegisterSensor() and InsertObservation()
Delete sensors	Not Supported	Not Supported	HTTP DELETE	Not Supported	SOS specific interface: DeleteSensor()
Updating Properties of Existing Sensors	Not Supported	Not Supported	HTTP PATCH and JSON PATCH	Not Supported	Not Supported
Deleting Existing Observations	Not Supported	Not Supported	HTTP DELETE	Not Supported	Not Supported
Pub/sub support	Not Supported	Not Supported	MQTT and SensorThings MQTT Extensior	Not Supported	Not Supported
Pagination	Not Supported	Not Supported	$top/$skip/$nextLink	Not Supported	Not Supported
Linked Data Suppor	Not Supported	Not Supported	JSON-LD	Not Supported	Not Supported
Usage	Core for other standards vb. Observation Data Model 2.0	IOOS® Sensor Observation Service,	resource-constrained device on top of the OpenIoT middleware	SPITFIRE FP7 project, 52North, emsorGrid4Env, xalted project	52north, PySOS, Deegree, MapServer
Geolocation	GML: point	Supported by CRS and Long lat alt	Every "thing" has a location	Does not describe location module Platform gives location	GML:Point
Meta data sensor	Earth Observation metadata	Uses Common Data Models	Metadata from sensor systems	Semantic meta data	Sensor meta data can be queried
limitation	No prototype yet with only UML More work on reference systems needed	Doesn't support describing workflows yet	Relatively new	Does not describe domain concepts time, locations, etc. Not easy to apply	Limitations are depending on the server Ex. 52North SOS does not scale very well
Strong point	Great observation model for other standards	Complementary role for CityGML and IndoorGML Everything is modelled as a process	easy to use interface to sensor values. simple resource based interface	powerful description framework of almost any kind of sensor observation	Implementation works for different servers

Detailed comparison standards

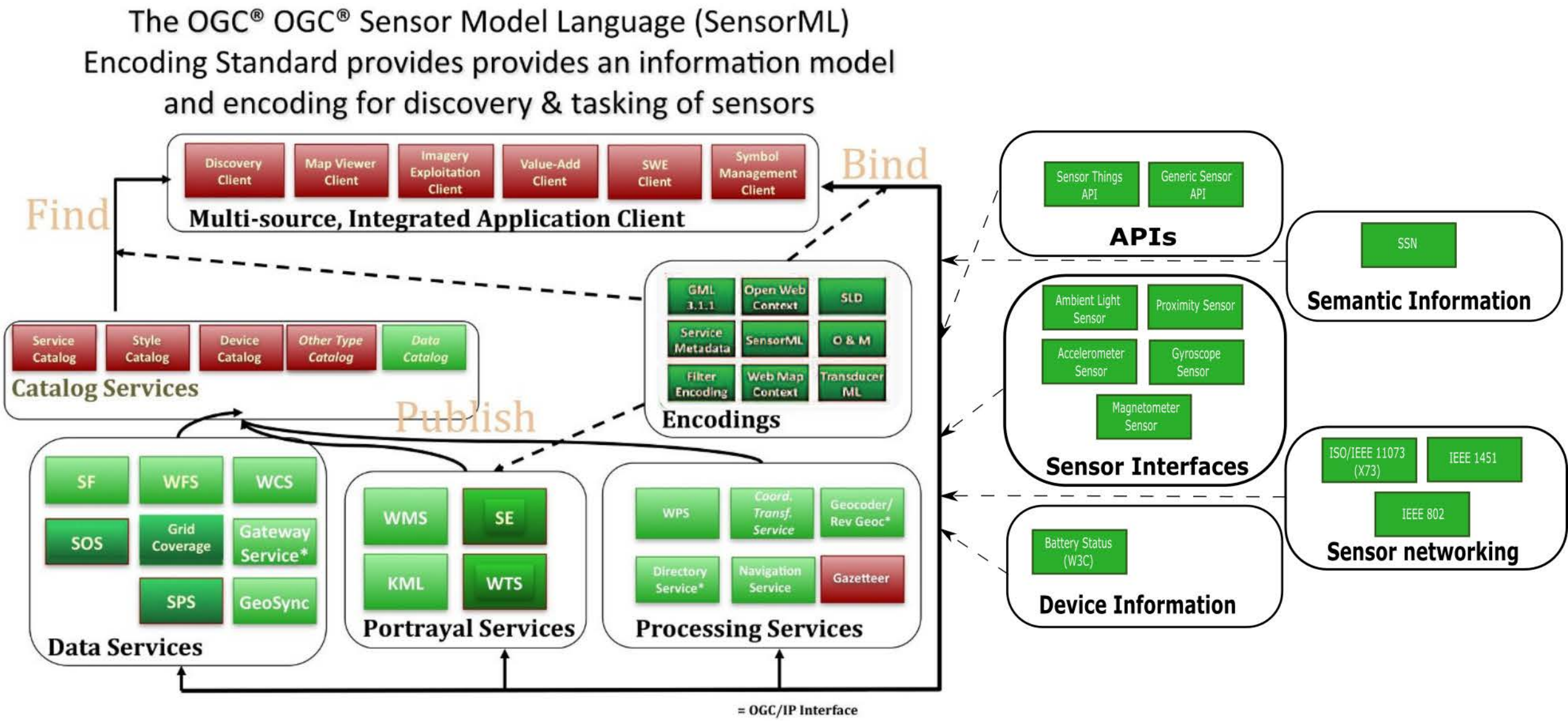
Standard	Observations & Measurements	SensorML	Sensor things API	Semantic sensor network	Sensor Observation service
Sensor data					
View sensor data	x	x	✓	x	✓
download sensor data	x	x	✓	x	✓
Last value data	✓	✓	✓	x	✓
Time series data	✓	✓	✓	x	✓
Data requestable interval	x	✓	✓	x	x
Data requestable point in time	x	✓	✓	x	✓
Sensor spatially dispersed in map	x	x	✓	x	✓
Clear units of measurements	x	✓	✓	x	✓
Scales if required for measurement	x	x	x	x	x
Select sensor by clicking	x	x	✓	x	✓
Select sensor by geometry	x	x	✓	x	✓
Charts for sensor data	x	x	✓	x	✓
Metadata sensor					
Battery status	x	✓	x	✓	x
Wifi status and network	x	x	x	x	x
Sensor health	x	x	x	✓	x
Sensor name	✓	✓	✓	✓	✓
Last maintenance	x	x	x	x	x
Frequency of measurement	x	x	x	✓	x
Comments	Used in combination with other standards	Used in combination with other standards	Still in development	Adds a semantic layer	

Assessment standards

TU Delft



2	**Sensor data**	
3	View sensor data	SOS, O&M
4	download sensor data	SOS, WMS, WFS
5	Last value data	SOS, O&M
6	Time series data	WMS-Time
7	Data requestable interval	WMS-Time
8	Data requestable point in time	x
9	Sensor spatially dispersed in map	SOS
10	Clear units of measurements	none
11	Scales if required for measurement	none
12	Select sensor by clicking	none
13	Select sensor by geometry	none
14	Charts for sensor data	SOS
15		
16	**Metadata sensor**	
17	Battery status	x
18	Wifi status and network	x
19	Sensor health	x
20	Sensor name	SOS
21	Last maintenance	x
22	Frequency of measurement	x

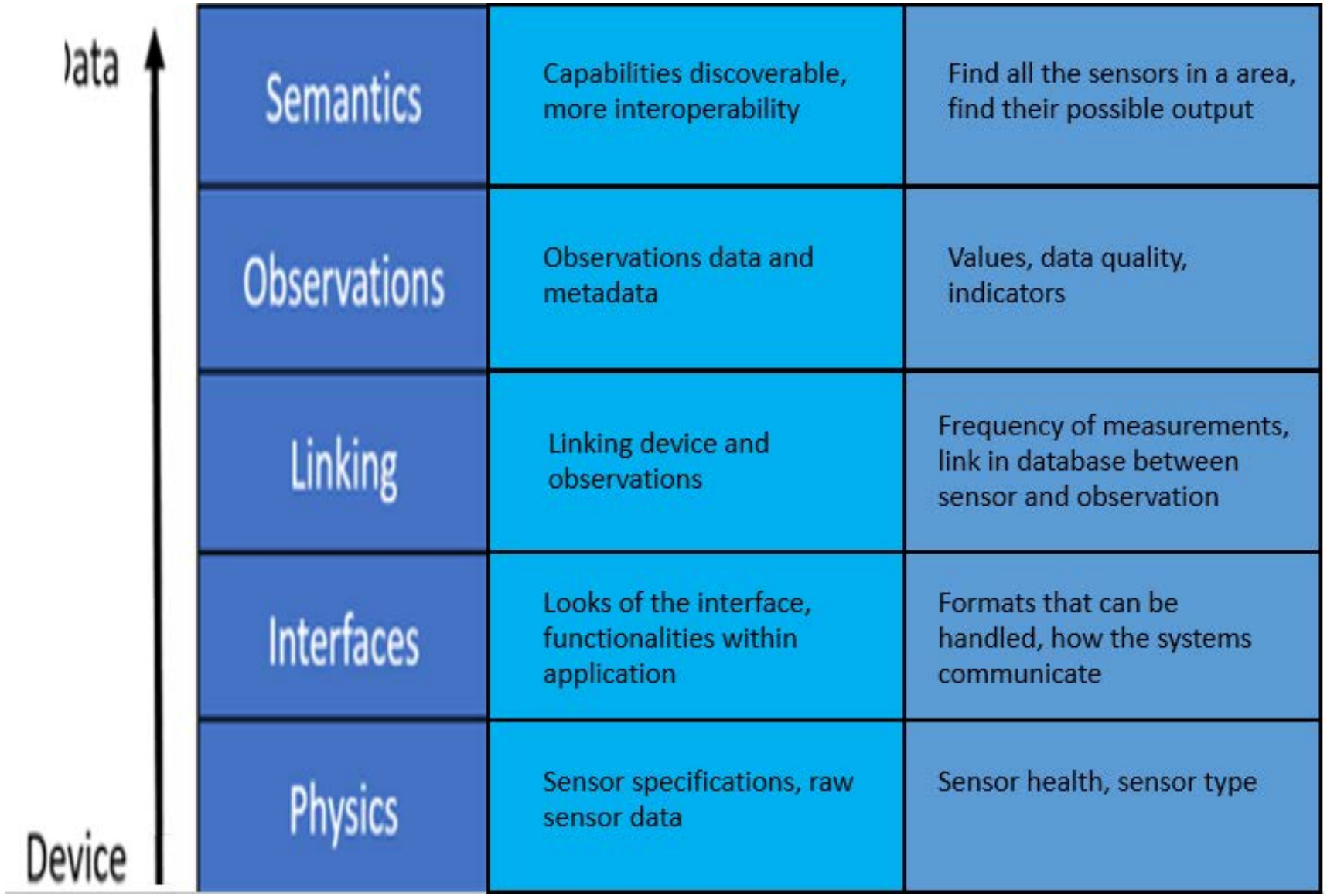


Source: OGC

OGC standards grouping

Semantics

- Semantics: spatial, temporal, and thematic semantic metadata
- Knoesis –Semantic sensor network
- Observation is an "act of measuring or otherwise determining the value of a property" and a measurement is a "set of operations having the object of determining the value of a quantity.”



Semantics	Capabilities discoverable, more interoperability	Find all the sensors in a area, find their possible output
Observations	Observations data and metadata	Values, data quality, indicators
Linking	Linking device and observations	Frequency of measurements, link in database between sensor and observation
Interfaces	Looks of the interface, functionalities within application	Formats that can be handled, how the systems communicate
Physics	Sensor specifications, raw sensor data	Sensor health, sensor type

Contents layers
Adapted OSI model

Sub questions

- What are the commonly used sensor standards?
- To what extent do commonly used sensor standards align?
- Which sensor standard or standards are used in the Smart Emission use case?
- What steps can be distinguished to align the use case standard to the commonly used sensor standards?