

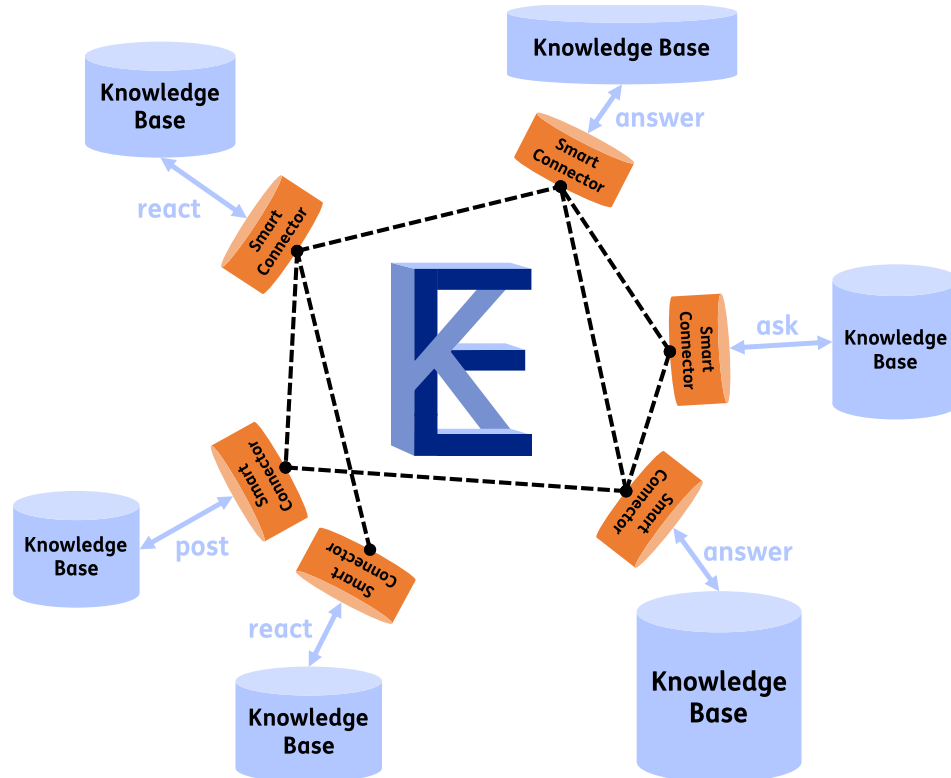
Knowledge Engine

Simplifying knowledge exchange with semantics

Sophie Lathouwers & Barry Nouwt

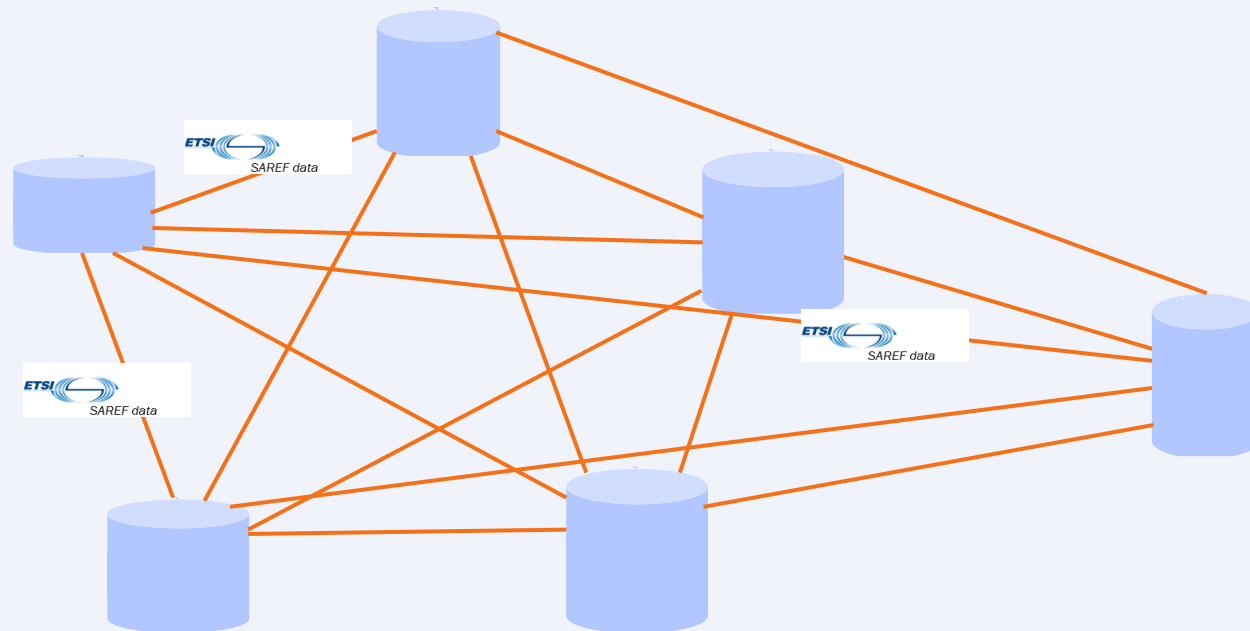
TNO innovation
for life

Content



- Challenge
- How does the Knowledge Engine work?
- Reasoning
- Knowledge Engine in the Dutch pilot
- When to use the Knowledge Engine
- Summary & Questions

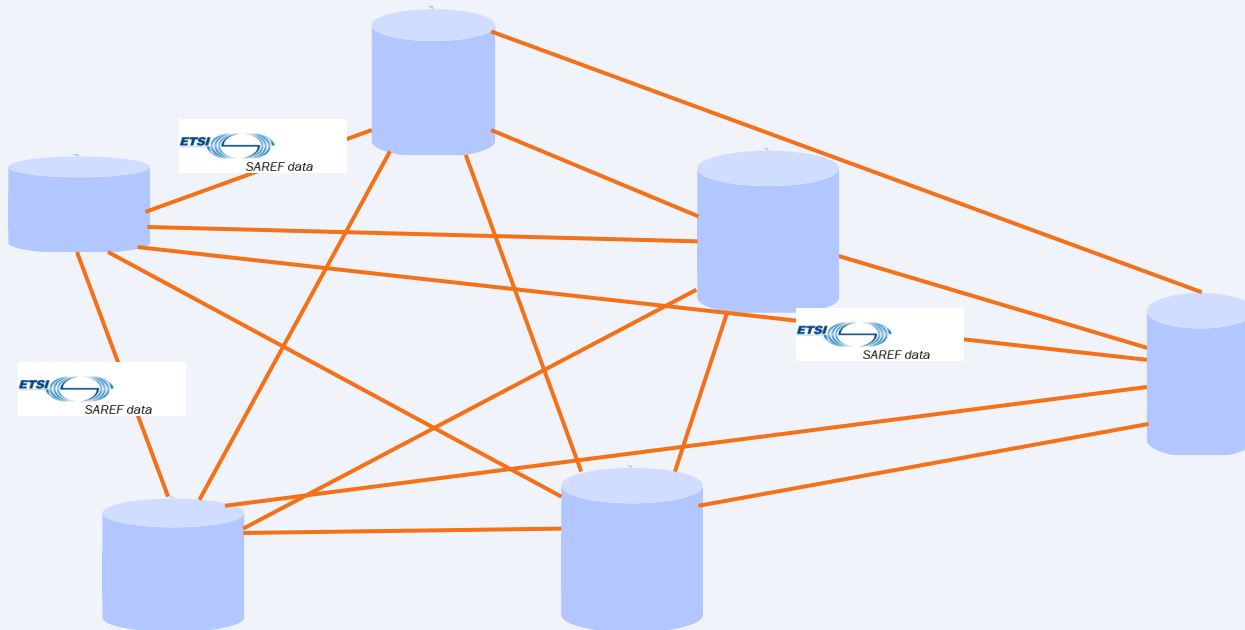
Challenge: exchanging knowledge



Example situation:

- 45 data producers x 28 variables, resulting in **1260** elements to monitor

Challenge: exchanging knowledge

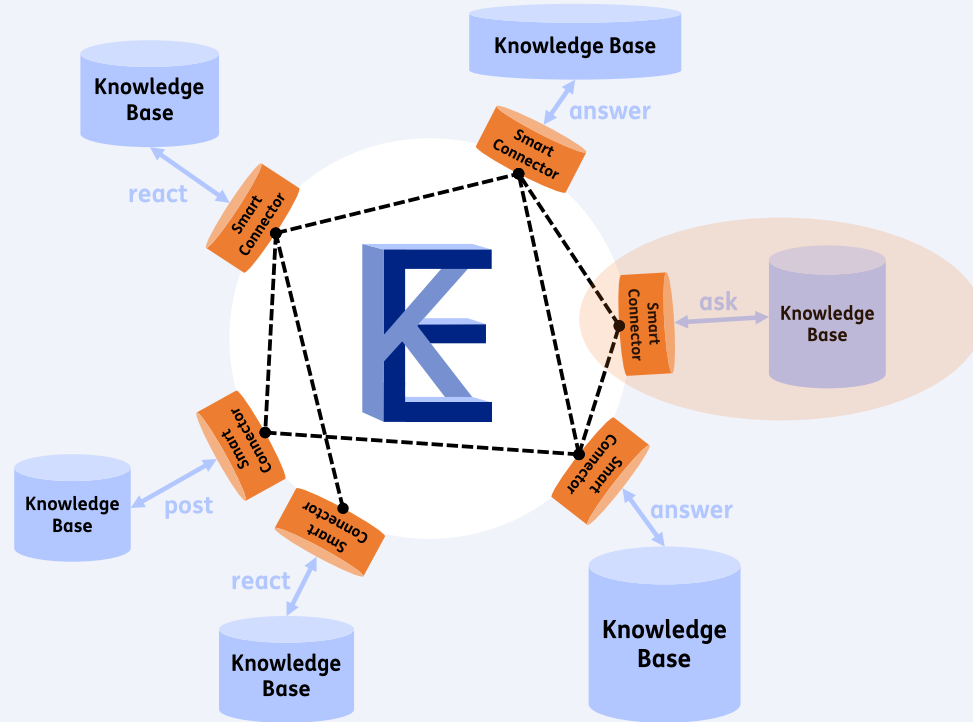


Difficulties:

- Many elements to monitor
- Need new connection for each new data source
- Data is not semantically interoperable
 - E.g. one writes “2-3-2025” and another “2nd of March 2025”, this complicates development

Intelligent knowledge exchange with the KE

How does it work?



- **Joining the network**
 - Shared domain language, ontology
 - Which data do you want to receive?
 - Which data do you want to send?
 - ASK – ANSWER, POST – REACT
- **Sharing data**
 - Knowledge Engine knows which data sources are relevant for you
 - Combines data from various sources
- **No central data store**
 - Data stays at the source
- **Open ecosystem**



Interaction types

ASK:
Which devices are linked
in the network?

ANSWER:
Currently the following
devices are linked: Solar
Panel 1, Smart meter A
and EV Charger 2

POST:
Smart meter A has
measured a new value:
22 °C

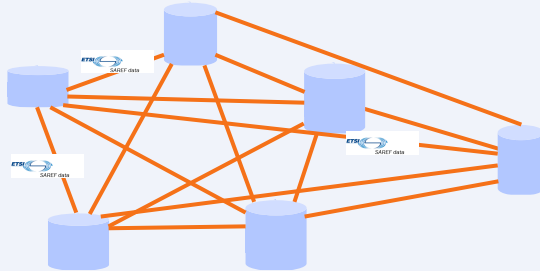
REACT:
Then I'll turn off the
heating element

Interaction types

Different use cases will require different interactions

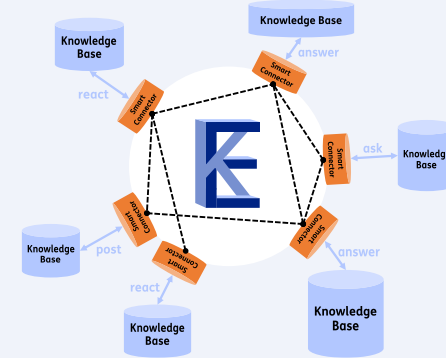
- Ask-Answer for ...
 - When you want to get the current status of a device
 - If a user asks a question in a dashboard
- Post-React for ...
 - Given a new temperature measurement, you want to turn on the air conditioning
 - Given a new measurement, the anomaly detector should determine whether this measurement is an anomaly

Solution: Knowledge Engine



Typical solution:

- Many elements to monitor
- Need new connection for each new data source
- Data is not semantically interoperable,
 - e.g. One source writes “3-2-2025” and the other “2 March 2025”



Data exchange with the Knowledge Engine:

- Only need to monitor a single connection
- No need for a new connection for new data sources
- Data is transformed to make it semantically interoperable
 - This also makes it easy to combine information from multiple sources

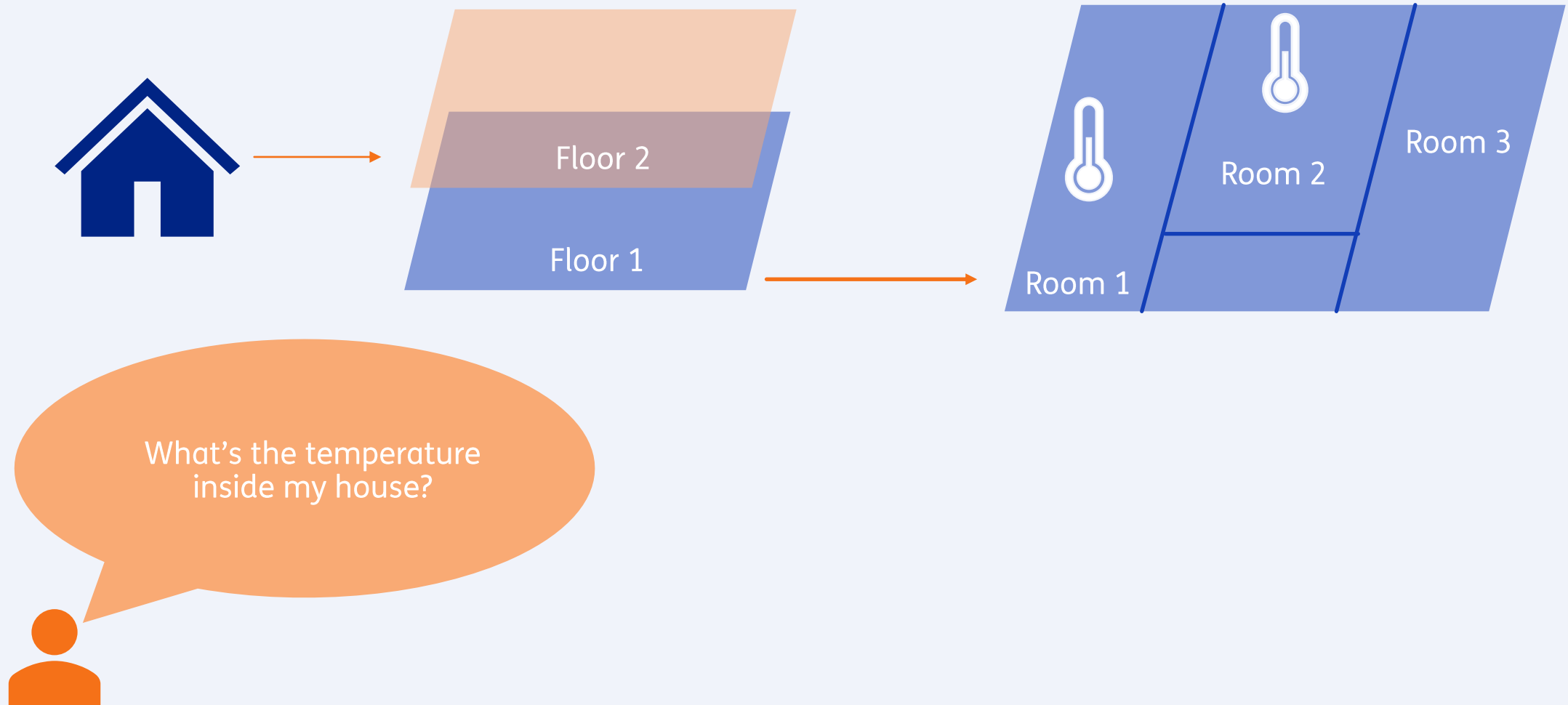
Reasoning: When do you need reasoning?

To answer complex queries,
e.g. combining information
from multiple sources

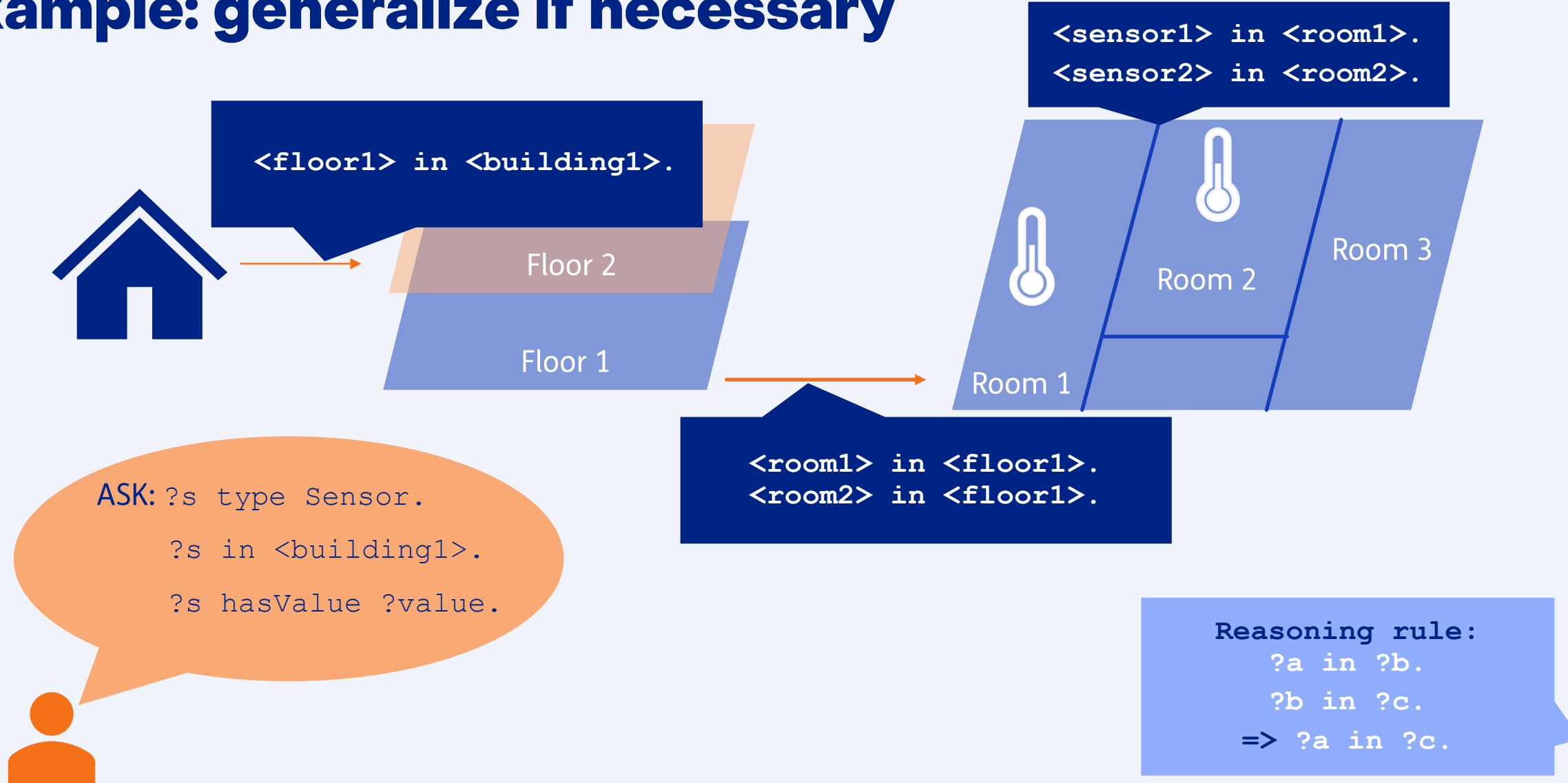
To incorporate domain
knowledge when answering
queries

Infer new facts from the
existing data

Example: generalize if necessary



Example: generalize if necessary



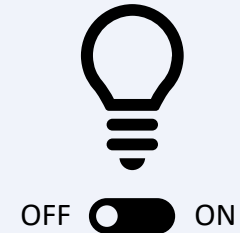
Example: incompatability

```
?l rdf:type ex:OnOffLamp .  
?l ex:isOn ?o .
```

App KB
- post KI

```
?l rdf:type ex:OnOffLamp .  
?l ex:isOn ?o .
```

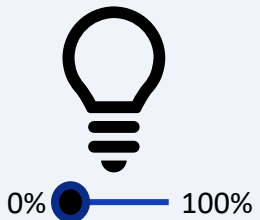
Lamp1 KB
- react KI



```
?l rdf:type ex:DimmableLamp .  
?l ex:hasBrightness ?b .
```

Lamp2 KB
- react KI

```
?s rdf:type ex:OnOffLamp .  
?s ex:isOn "true" .  
=>  
?s rdf:type ex:DimmableLamp .  
?s ex:hasBrightness "100" .
```



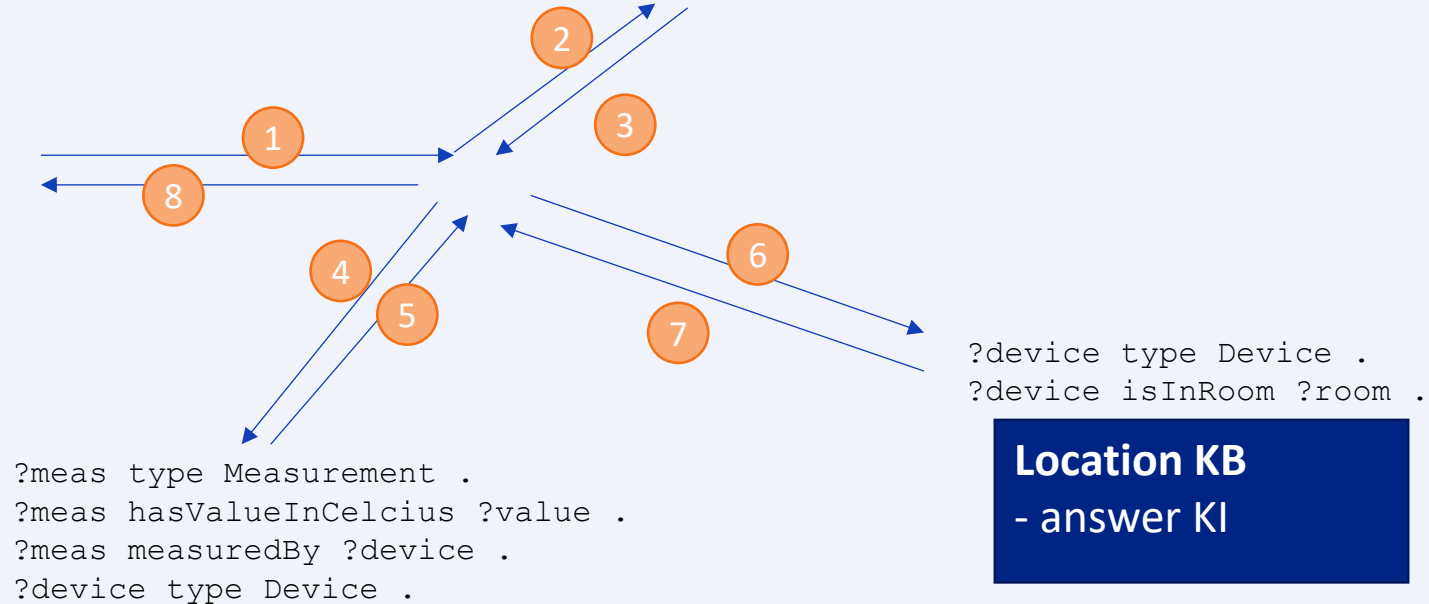
Example: dynamically combine Knowledge Bases

```
?m type Measurement .  
?m hasValueInCelcius ?val .  
?m measuredBy ?d .  
?d type Device .  
?d isInRoom ?r .
```

App KB
- ask KI

```
?mm type Measurement .  
?mm hasValueInCelcius ?v .  
?mm measuredBy ?dev .  
?dev type Device .  
?dev isInRoom ?rm .
```

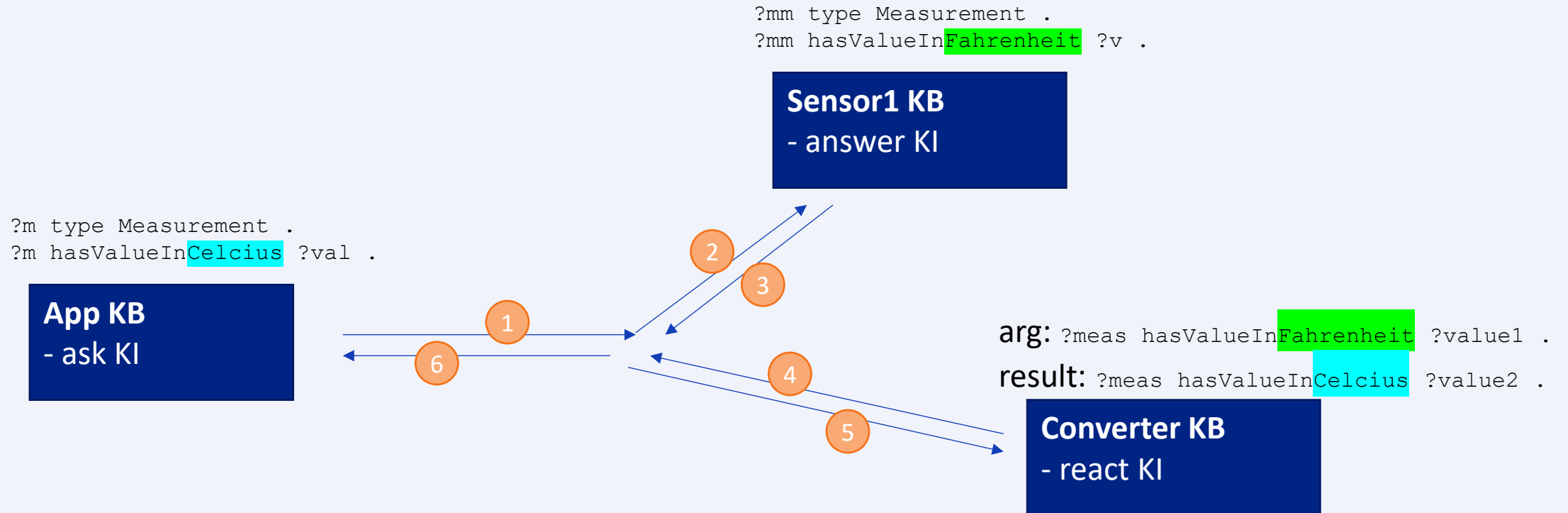
Sensor1 KB
- answer KI



Sensor2 KB
- answer KI

Location KB
- answer KI

Example: automatic conversion



Use cases



interconnect

- 50 European partners
- 11 countries
- 7 large pilots

www.interconnectproject.eu



HEDGE-IoT

- 42 partners
- 13 European countries
- 6 pilots

www.hedgeiot.eu



Safety & Security

- Command & Control (C&C)



PLOUTOS

- More than 30 European partners
- Sustainable agrifood chain

www.plutos-h2020.eu



TEAM
DUURZAAM INSTALLEREN

- More than 30 European partners
- Energy transition
- Heatpumps

www.teamduurzaaminstalleren.nl



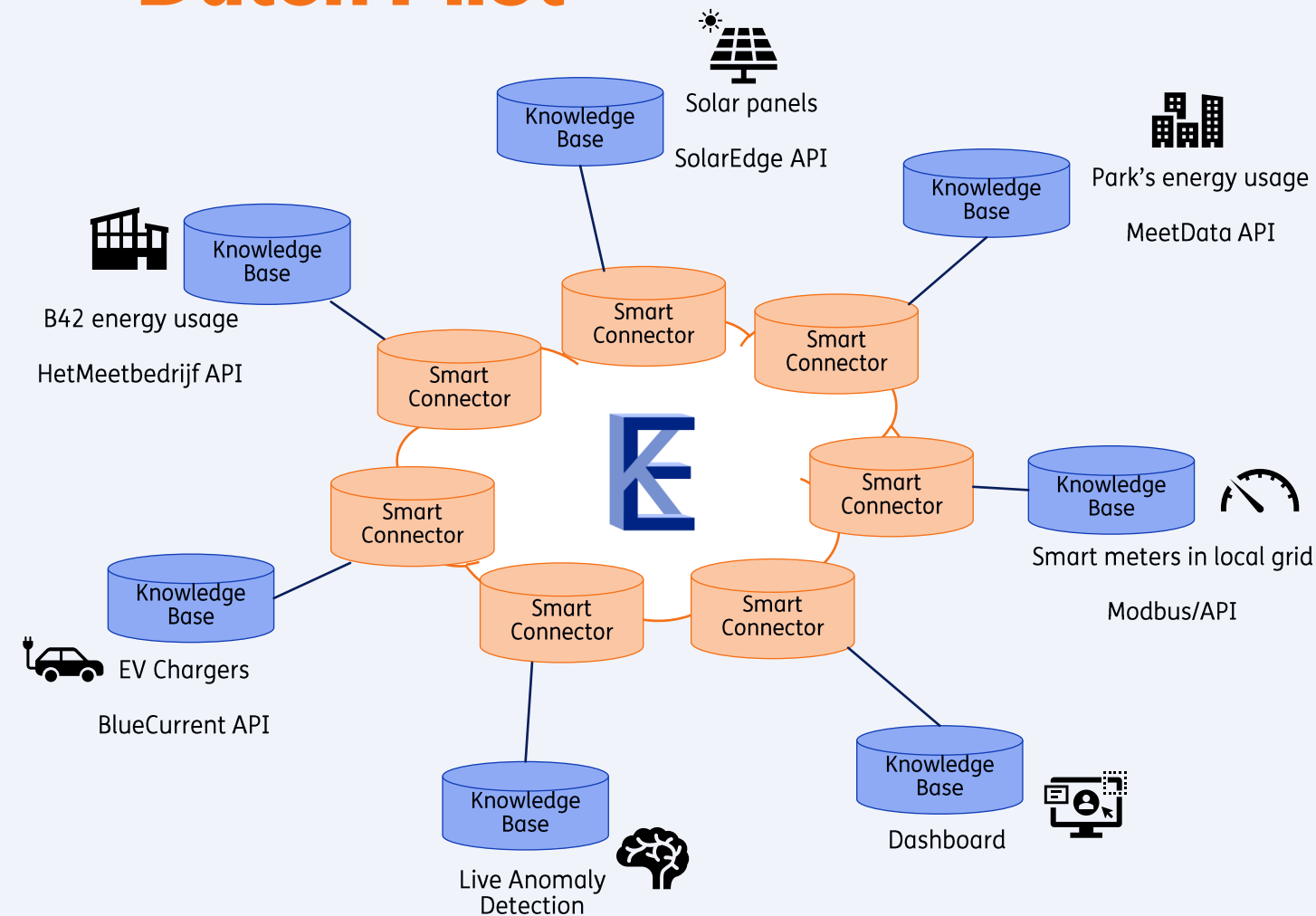
MAGPIE
SMART GREEN PORTS

- Smart green ports
- Data spaces

www.magpie-ports.eu



Knowledge Engine in the Dutch Pilot



- Reduce peak energy consumption
- SAREF, SAREF4ENER, Units of Measure(OM)
- Running on 3 separate servers that are located across the Netherlands

Using the KE

ASK interaction (give me all devices in the network of Arnhems Buiten):

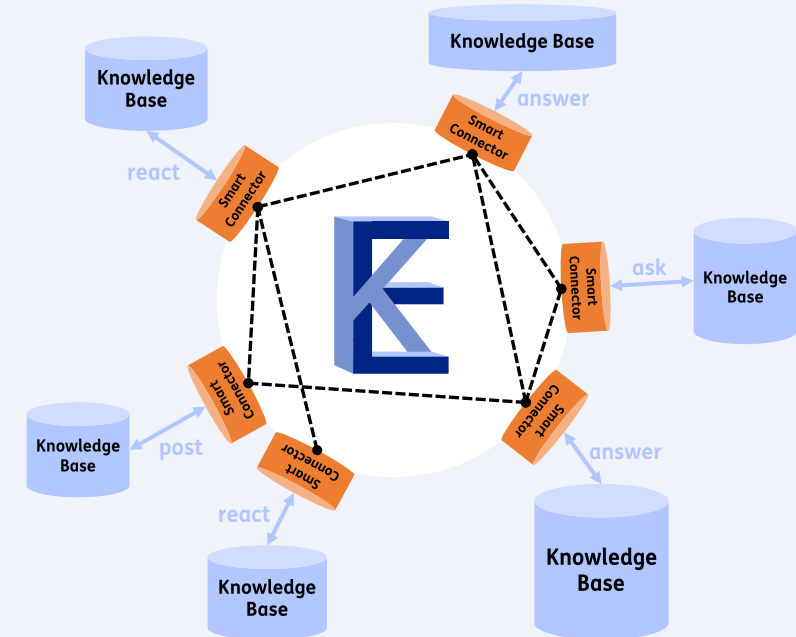
```
?device rdf:type saref:Device .  
?device rdfs:label ?label .  
?device saref:observes ?prop .  
?prop rdf:type saref:Property .  
?prop rdfs:label ?propLabel .
```

Example of data:

```
?device = <https://tno.nl/energy/data/hedgeiot/meter/12345>  
?label = "Arnhems Buiten, Solar Panel 1"  
?prop = <http://qudt.org/vocab/quantitykind/Energy>  
?propLabel = "Energy"
```

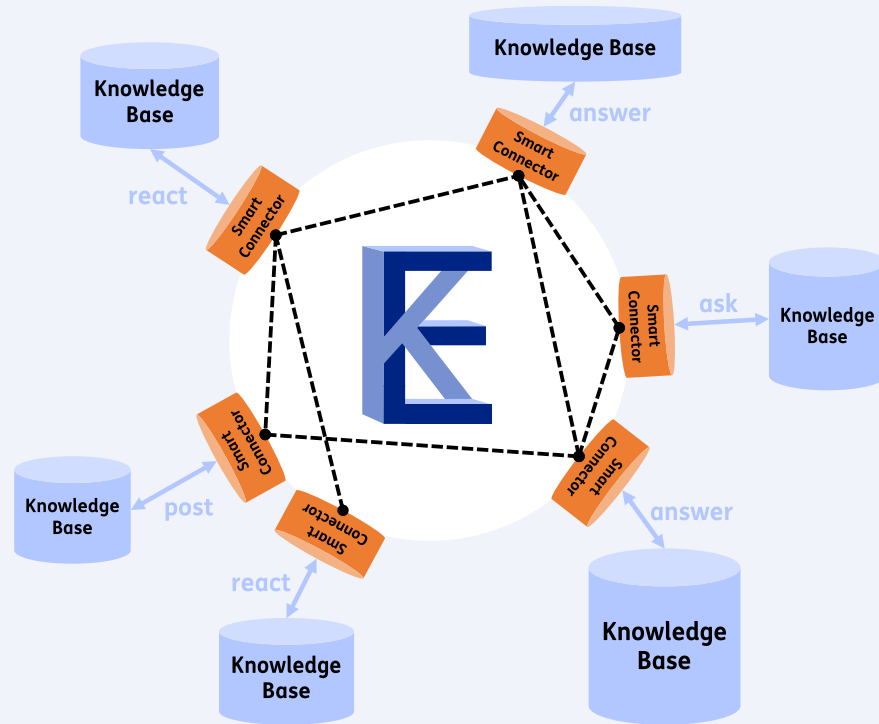
When to use the Knowledge Engine

- No central data storage or central server
 - Data should be kept at the source locations
- Distributed network
 - E.g. multiple companies that share information
- Different types of data sources (API, sensors, Modbus, ...)
- Multiple interaction formats: querying, publish-subscribe
- Want to do intelligent data exchange
 - E.g. combining data from multiple sources and/or domain specific knowledge
- Dynamic networks
 - Knowledge bases come and go over time
- Want to build an open ecosystem
- When you need advanced semantic interoperability



Intelligent knowledge exchange with the KE

The power of the Knowledge Engine



- Efficient access
 - Only connect to network, not to all parties
 - No vendor lock-in
- Little maintenance
 - No additional work for new data sources
- Intelligent
 - Complex questions
 - Reasoning
- Secure
 - Data stays at the source
 - You decide **what** data to share and with **whom**.



Questions?

- Open source at: <https://github.com/TNO/knowledge-engine>
- More information? See our webpage www.knowledge-engine.eu
- Or contact me via e-mail: sophie.lathouwers@tno.nl

Knowledge Engine team



Barry Nouwt
Lead architect



Jack Verhoosel
Architect/consultant



Klaas A. de Graaf
Scientist



Kit Buurman
Project leader



David de Best
Developer



Sophie Lathouwers
Developer