eWoT: A Semantic Interoperability Approach for Heterogeneous IoT Ecosystems Based on the Web of Things

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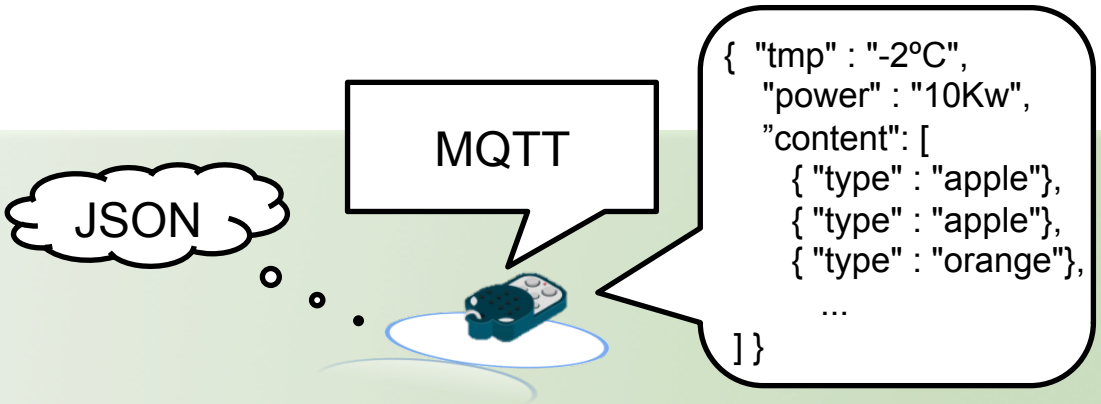
17/06/2020

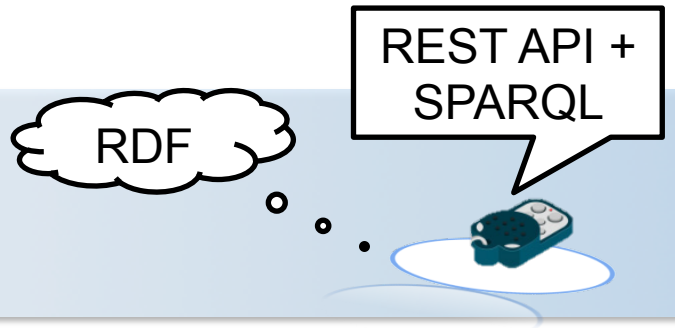
Enabling semantic interoperability for IoT infrastructures

Heterogeneity:
- Heterogeneus APIs
- Heterogeneus Formats
- Heterogeneus Models



Enabling semantic interoperability for IoT infrastructures

Syntactic Interoperability:
- **Homogeneus APIs**
- **Homogeneus Format**
- Heterogeneus Models



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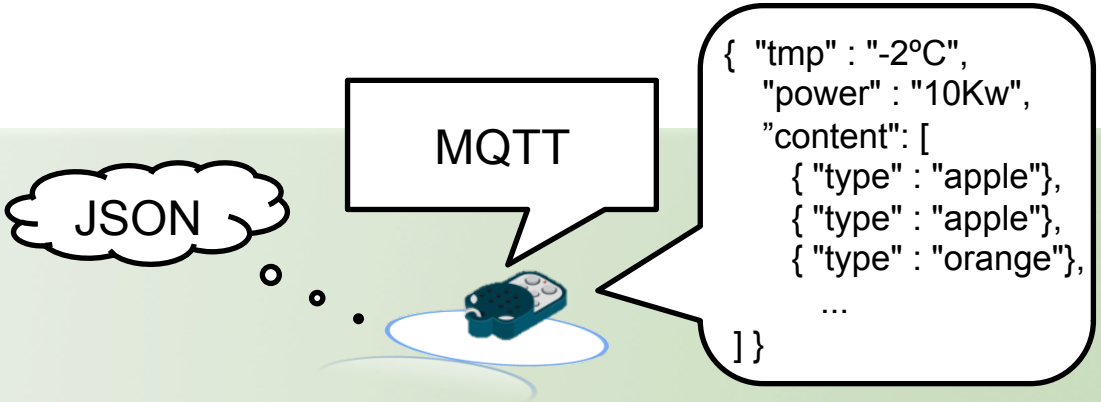

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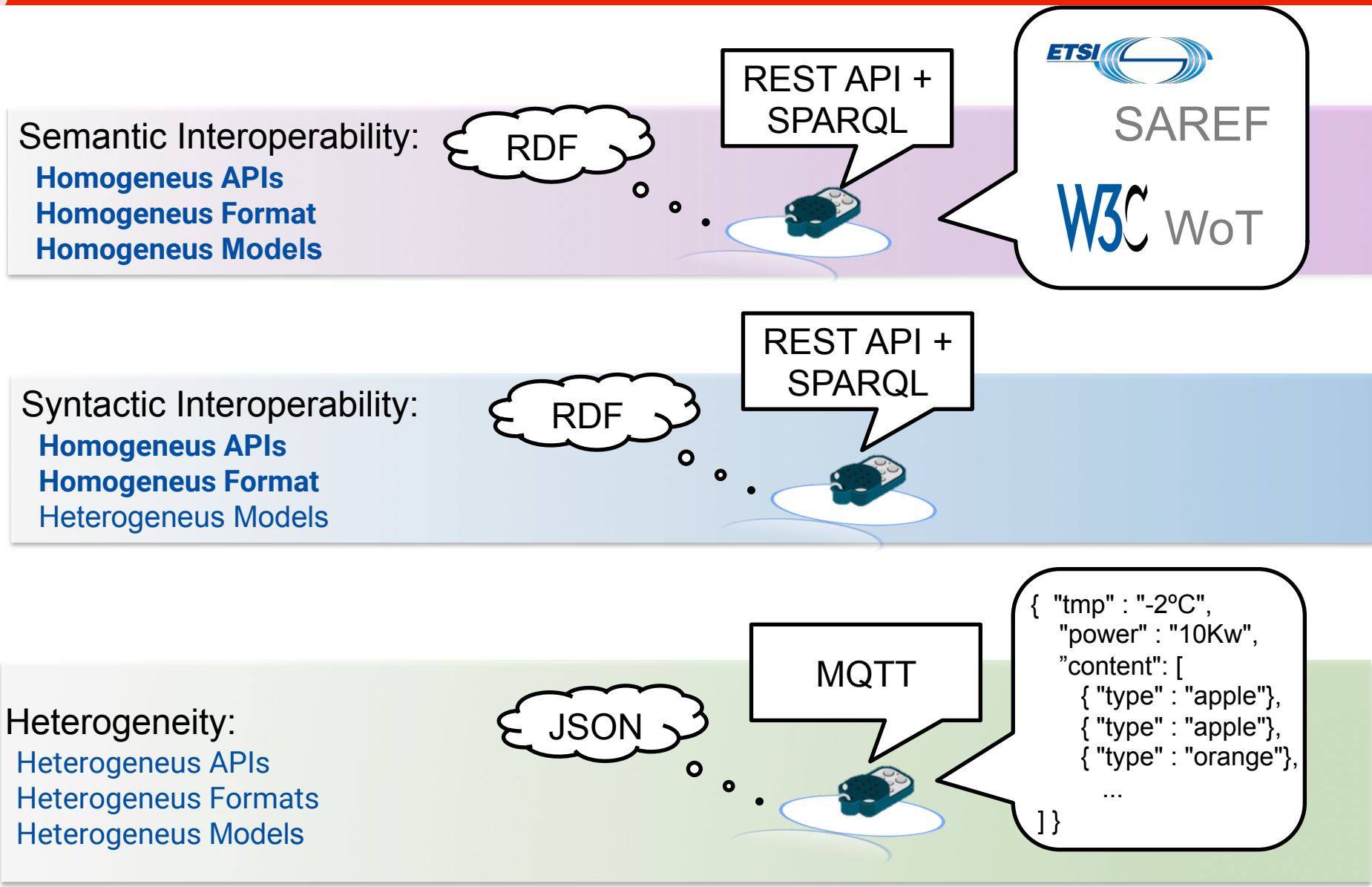
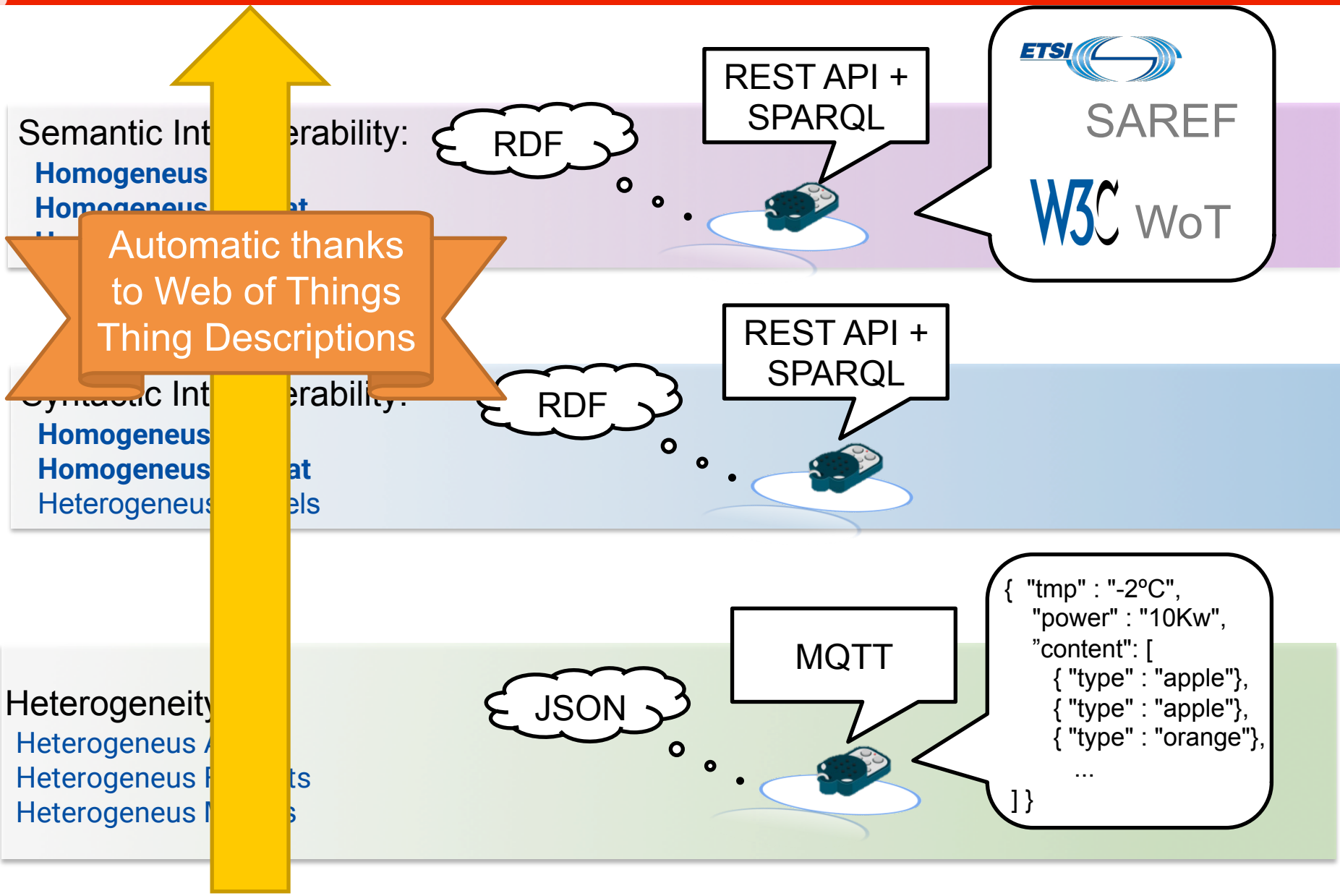
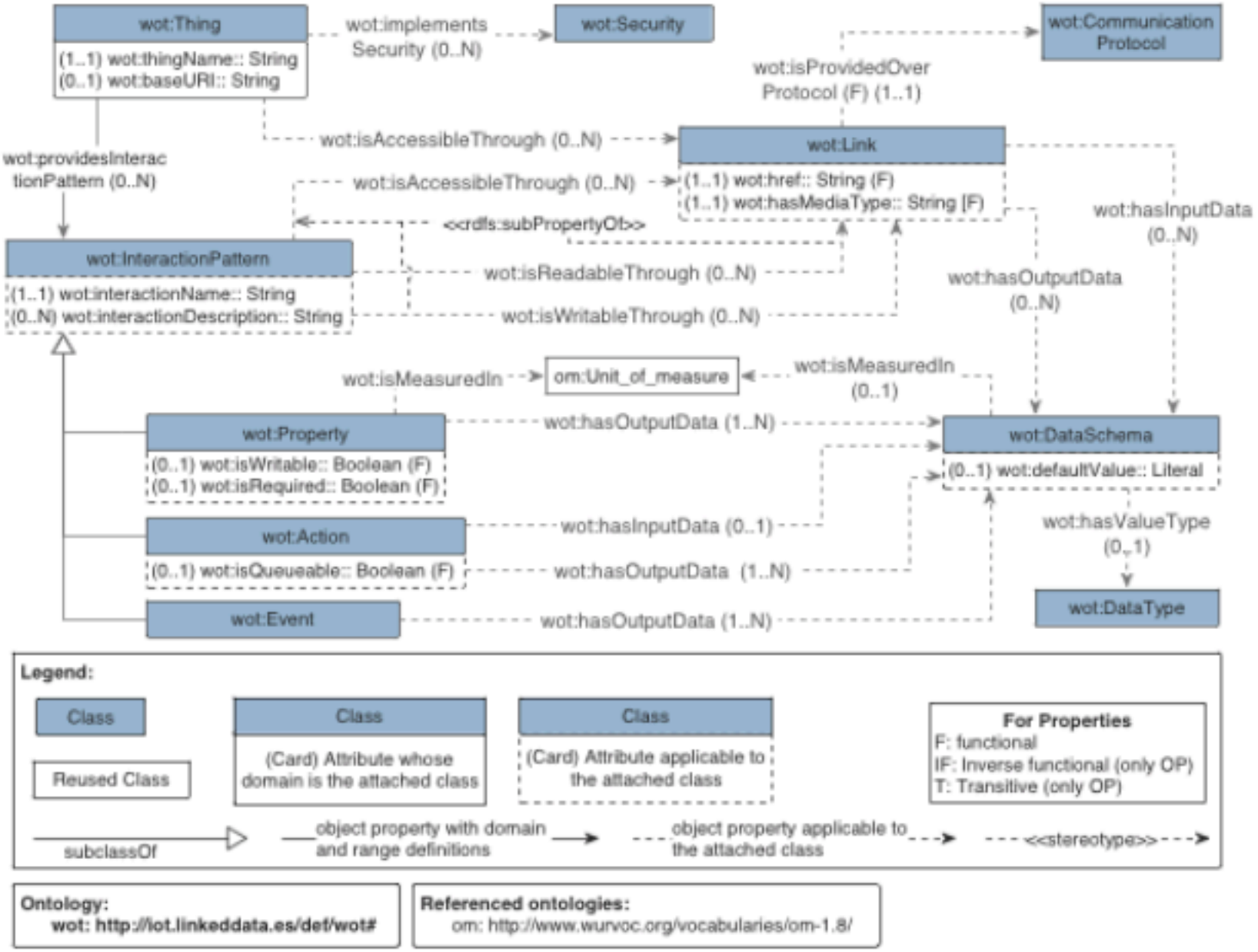


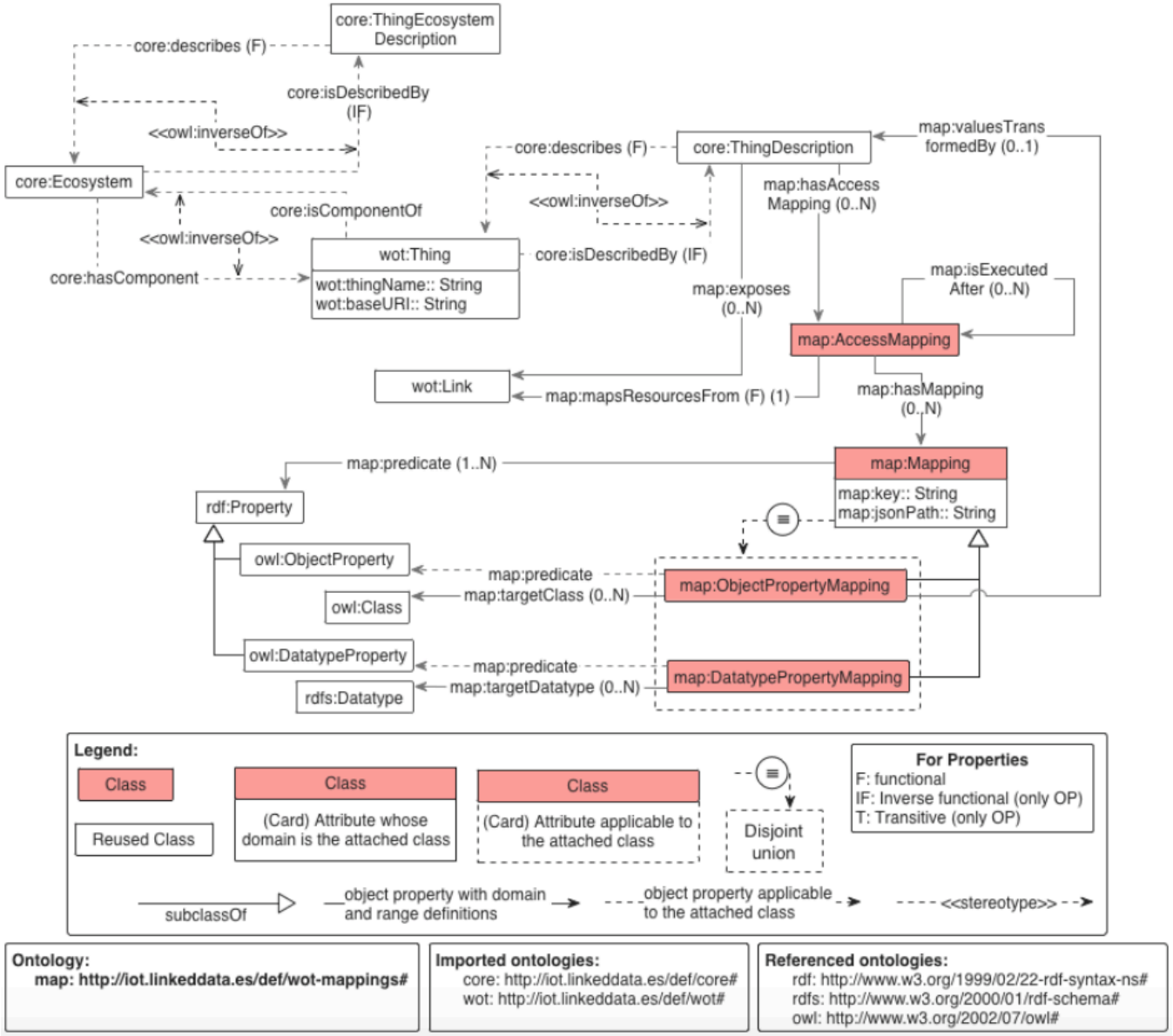
Enabling semantic interoperability for IoT infrastructures



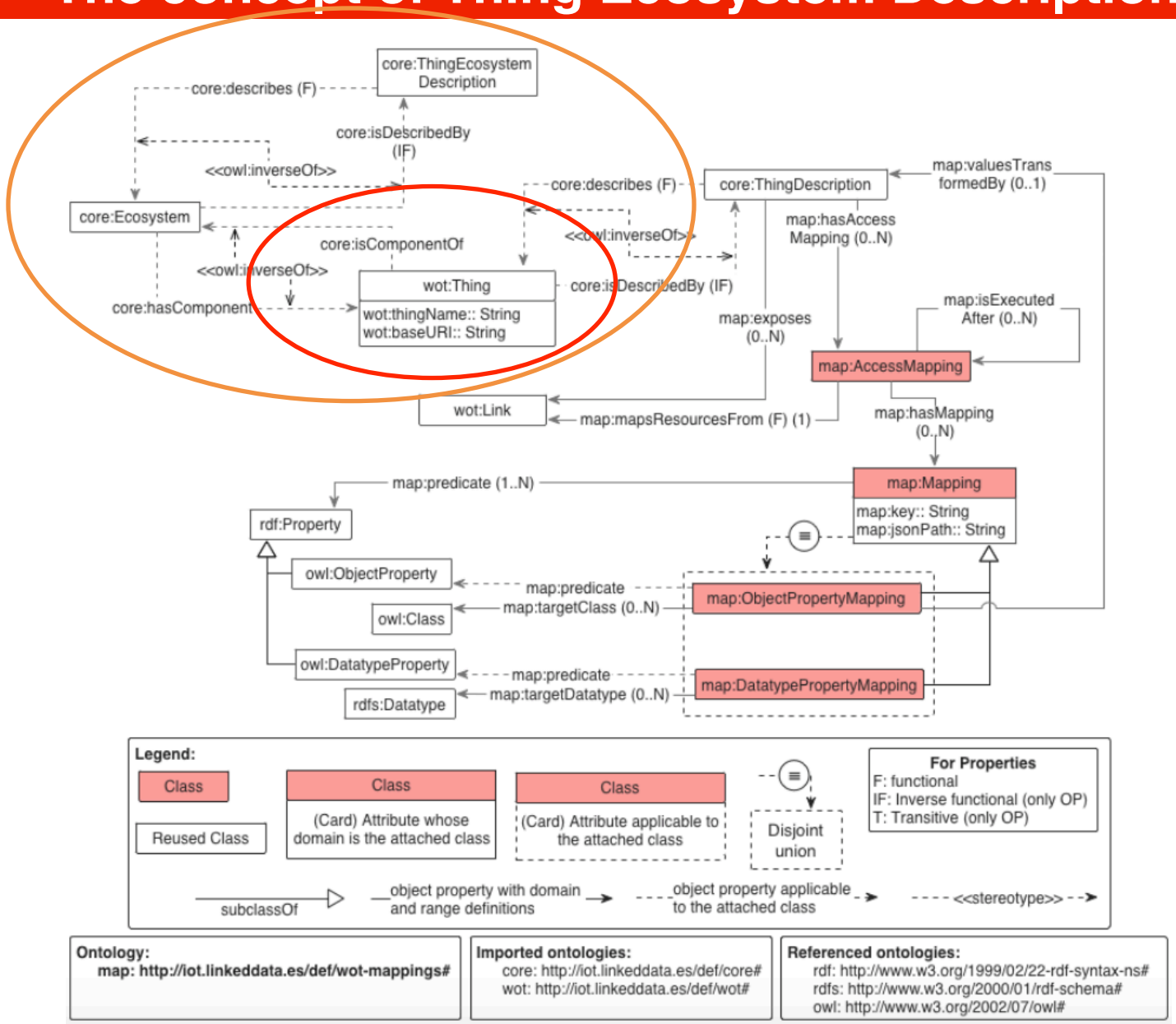
WoT Thing Description (TD)



WoT-Mappings (WoT-M)



The concept of Thing Ecosystem Description (TED)



The concept of Thing Ecosystem Description (TED)

- TED:
  - Contains several sensors descriptions
    - WoT TD (access)
    - WoT-M (translate)
    - Contextual-data
      - Location
      - City
      - Country
      - Owner
      - ….

- Web Service (API) client
  - Enables Semantic Interoperability for IoT Ecosystems

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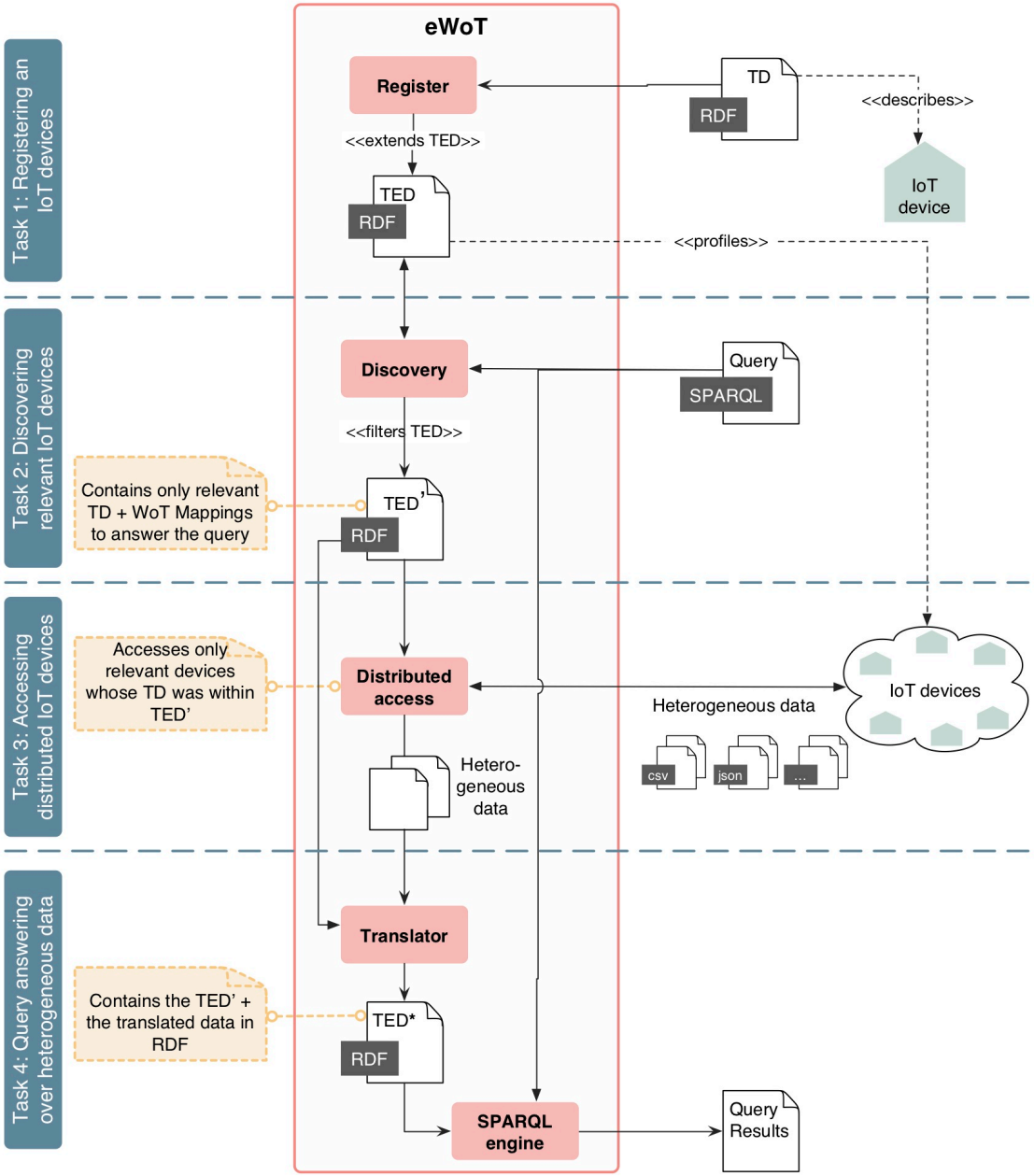
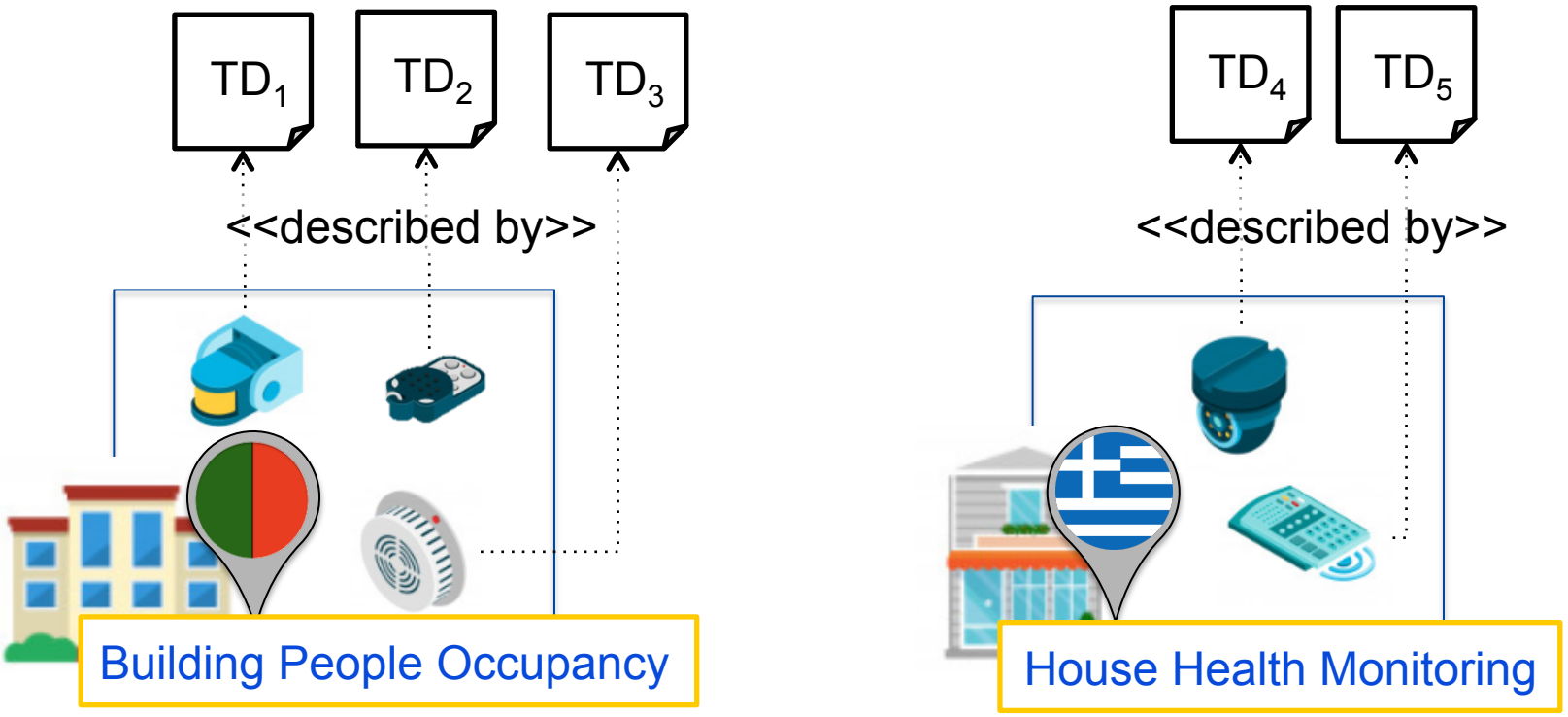
  - Enables Semantic Interoperability for IoT Ecosystems
  - Based on the Web of Things
  - Integration performed by means of Mappings
    - No further code needs to be developed
  - Tasks implemented:
    - Registering new Thing Description
    - Discover relevant Thing Descriptions for a given SPARQL query
    - Distributed access to heterogeneous IoT infrastructures
      - Translation on the fly of their data
    - Solves SPARQL queries using data allocated in the Thing Descriptions, or coming from the IoT infrastructures.

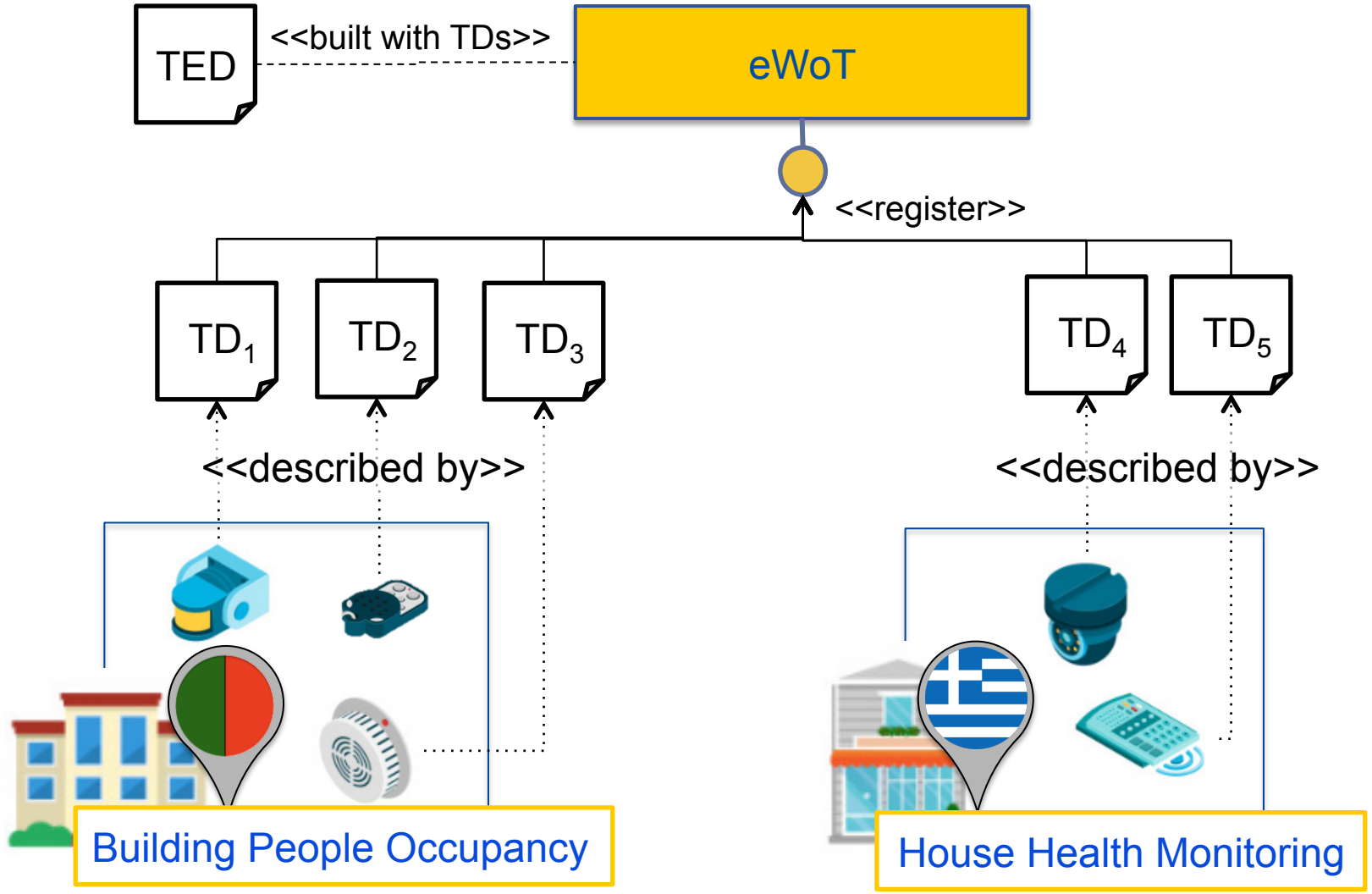
The eWoT architecture



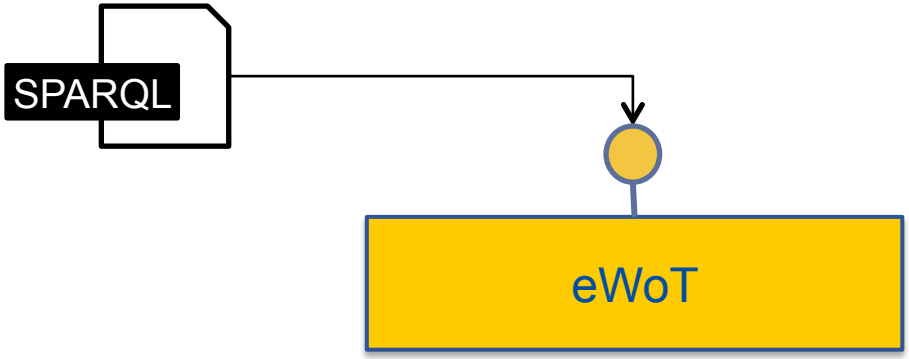
Semantic interoperable ecosystems: registering



Semantic interoperable ecosystems: registering



What is the occupancy given by known sensors in a room?



Enabling semantic interoperability: discovery + distributed access

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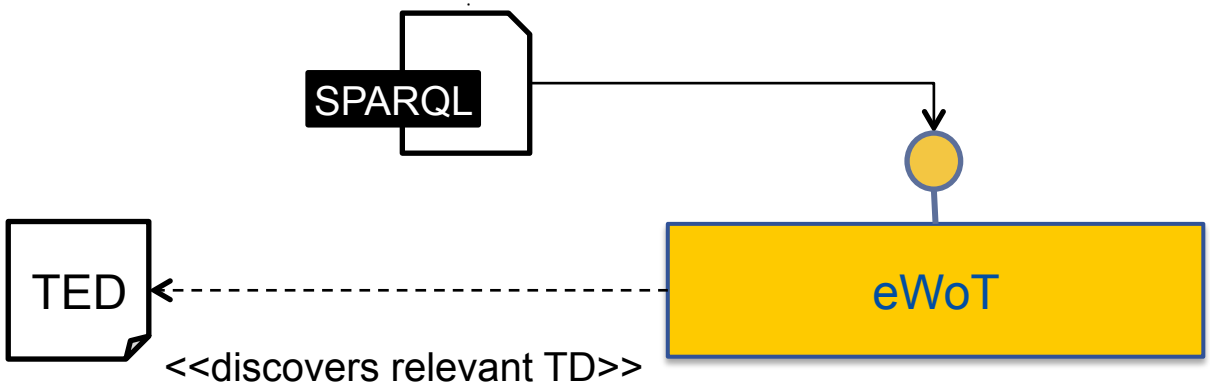
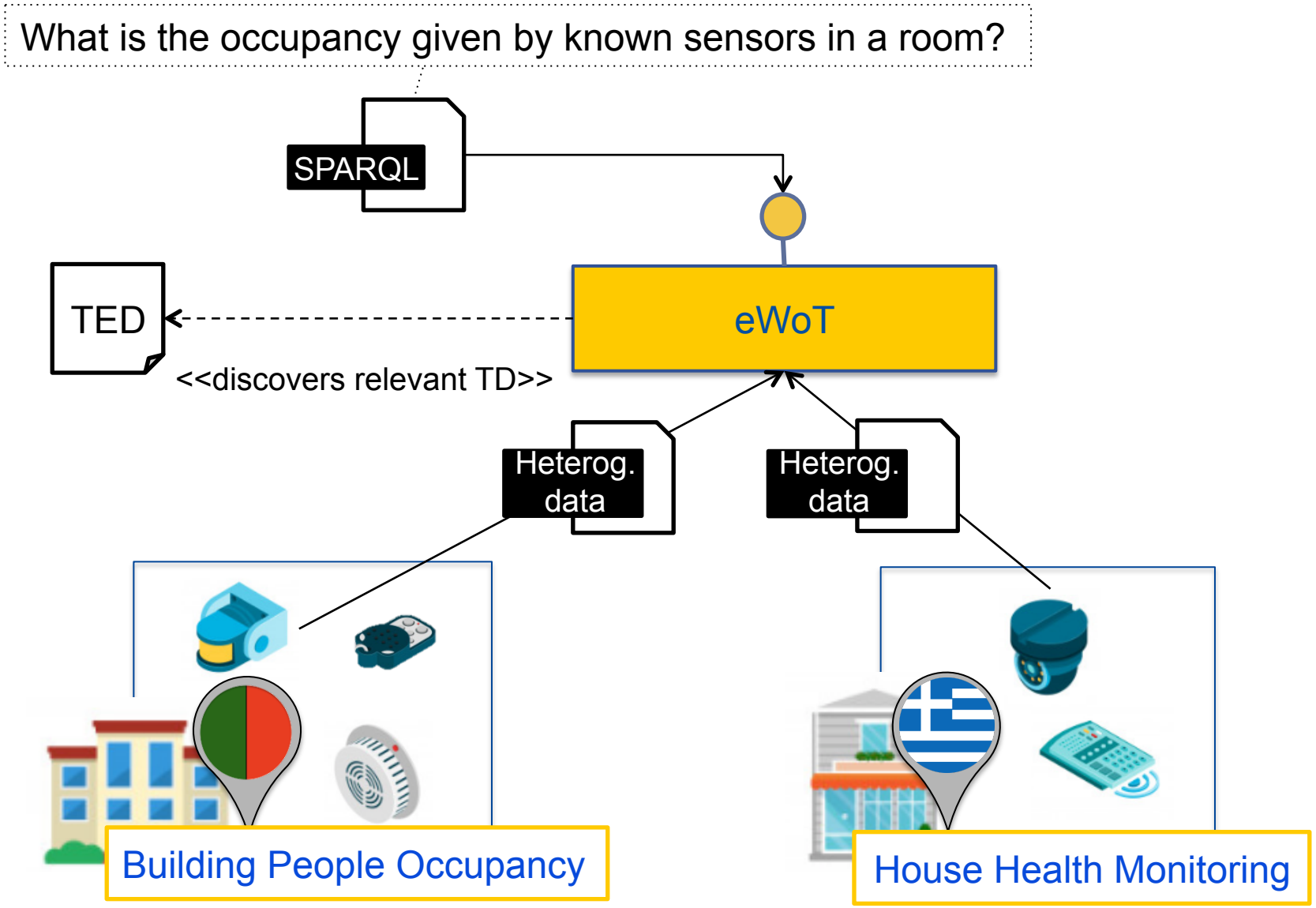
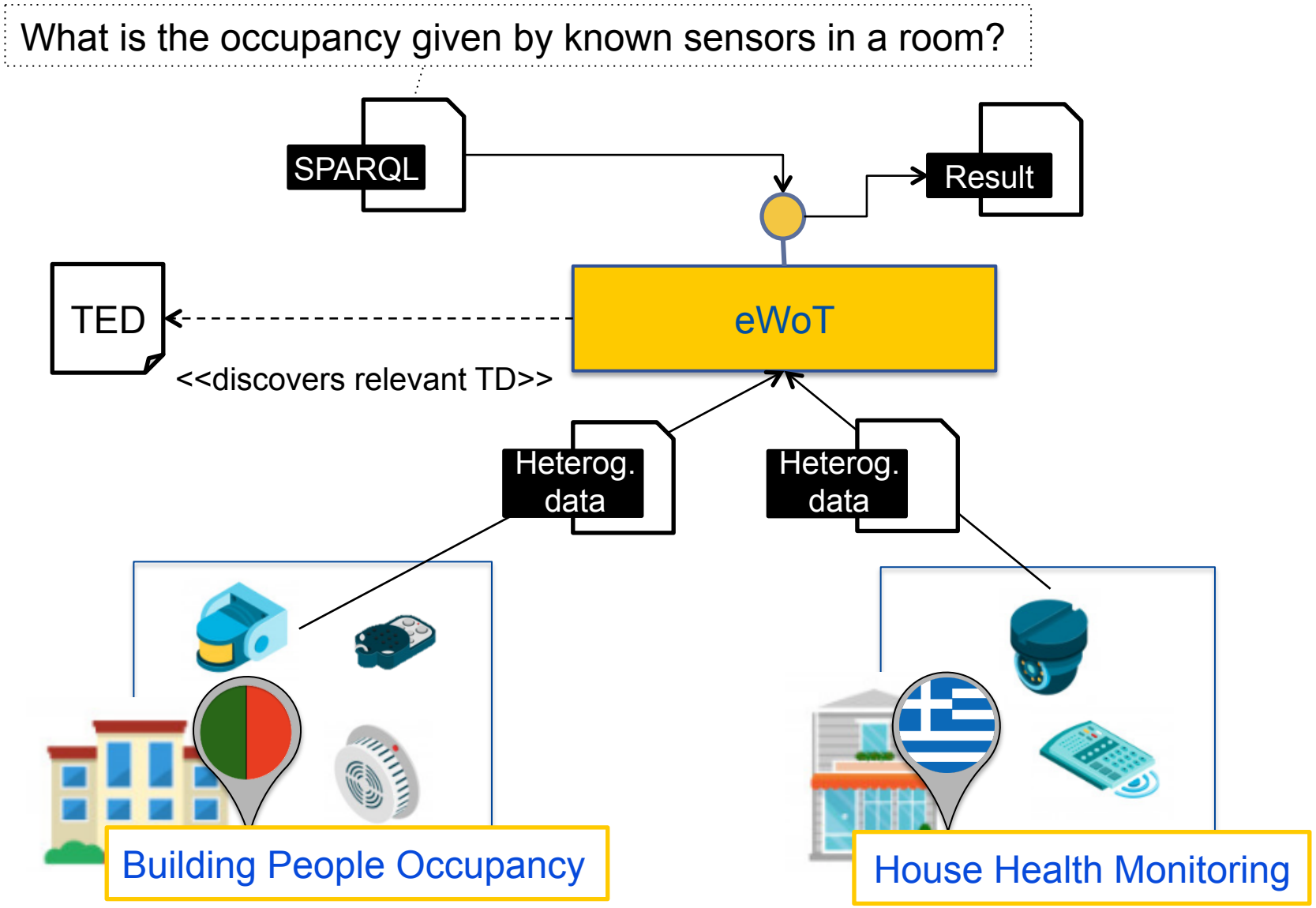
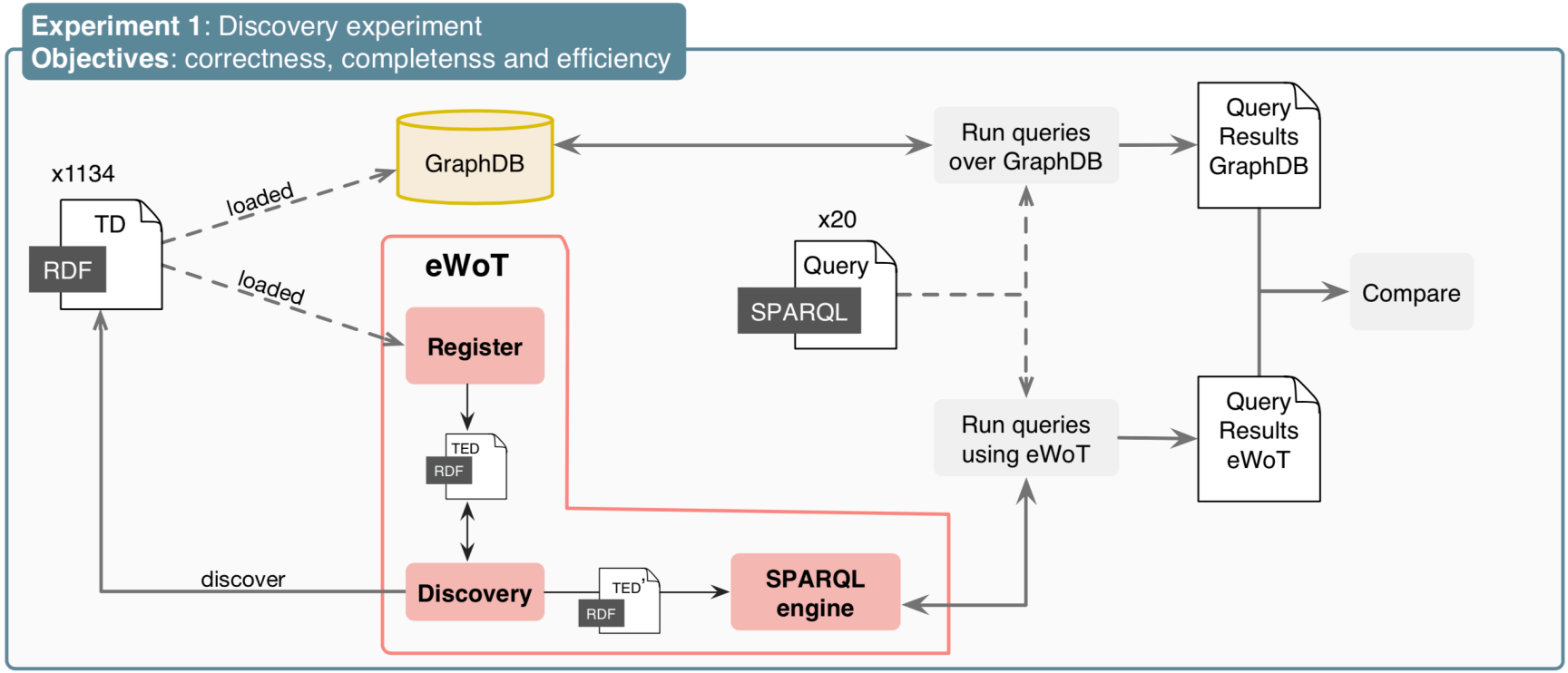


Enabling semantic interoperability: discovery + distributed access




What is the occupancy given by known sensors in a room?
SPARQL
Result
TED
eWoT
<<discovers relevant TD>>
Heterog. data
Heterog. data
Building People Occupancy
House Health Monitoring

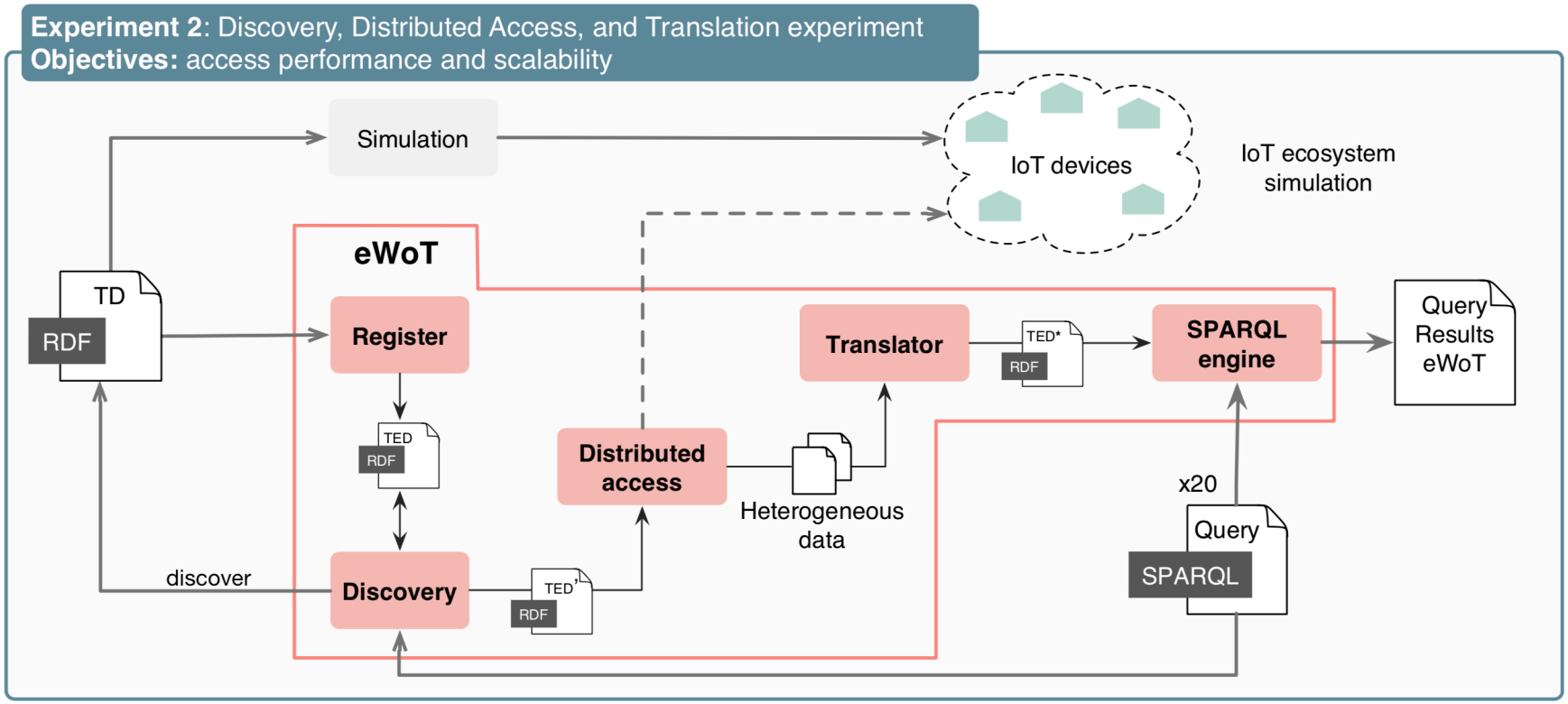

Experiments



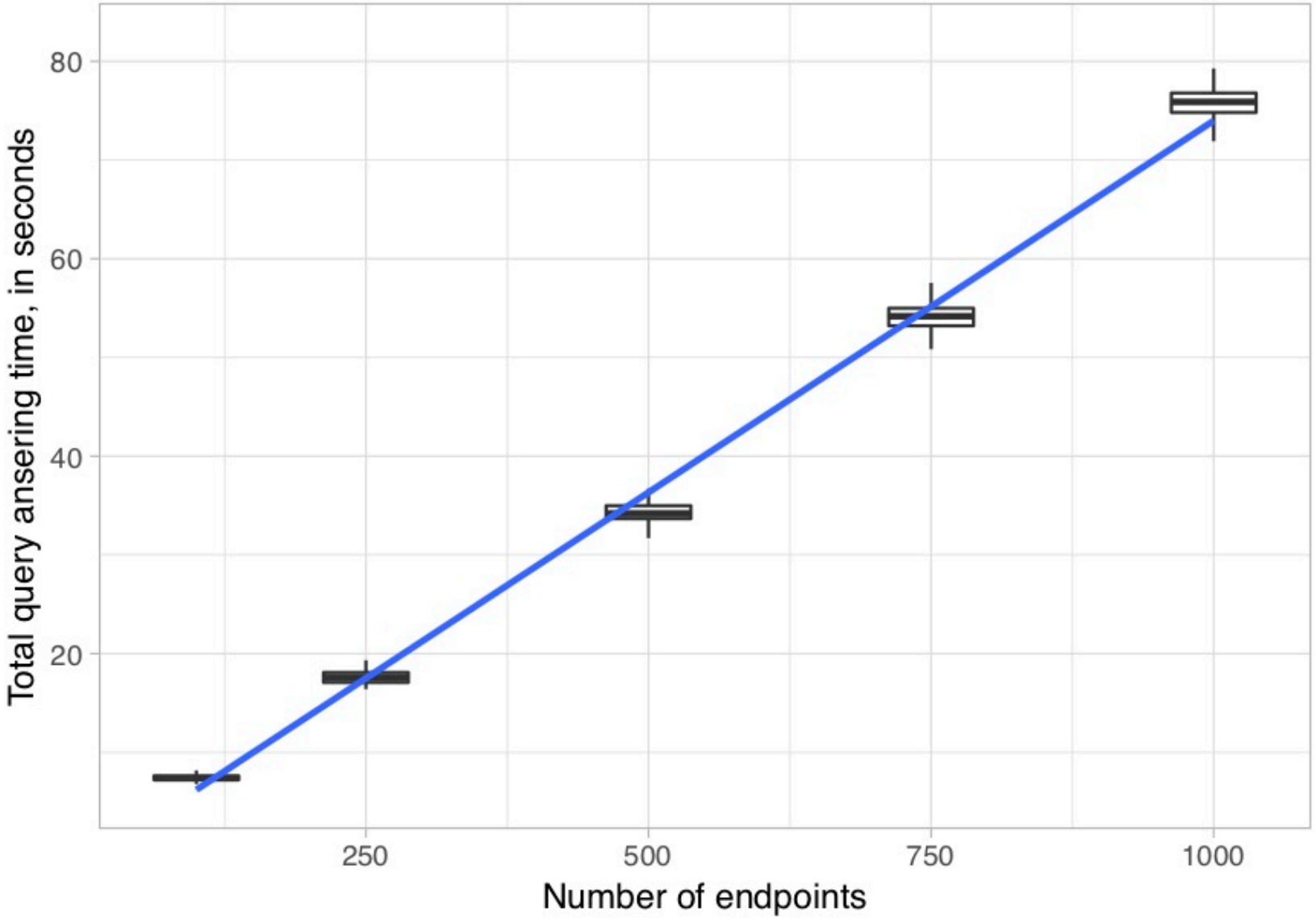
1.300 TDs stored in the GraphDB

Experiment 1 - Results

	GraphDB		eWoT	
Query	Answer size	Avg Time (s)	Answer size	Avg Time (s)
Linear 1	1520	0.08	1520	0.13
Linear 2	8832	0.09	8832	0.10
Linear 3	9120	0.10	9120	0.11
Linear 4	9120	0.16	9120	0.17
Star 1	4566	0.11	4566	0.11
Star 2	3603	0.06	3603	0.06
Star 3	5202	0.07	5202	0.07
Star 4	800000	24.78	800000	25.78
Tree 1	39258	0.48	39258	0.57
Tree 2	506529	10.23	506529	9.24
Tree 3	506529	15.48	506529	20.98
Tree 4	800000	35.4	800000	37.89
Cycle 1	259	0.02	259	0.02
Cycle 2	1150	0.10	1150	0.09
Complex 1	852042	25.68	852042	28.73
Complex 2	317040	7.15	317040	13.89
Complex 3	217500	11.80	217500	11.32
Complex 4	215700	6.46	215700	10.84
Complex 5	215700	11.20	215700	10.32
Complex 6	215700	12.12	215700	15.23


Experiment 2: Discovery, Distributed Access, and Translation experiment
Objectives: access performance and scalability
Simulation
IoT devices
IoT ecosystem simulation
eWoT
TD
RDF
Register
TED
RDF
Distributed access
Heterogeneous data
Translator
TED*
RDF
SPARQL engine
Query Results eWoT
x20
Query
SPARQL
discover
Discovery
TED'
RDF

Experiment 2 - Results



Experiment 2 - Results

	Query answering time in %									
	100 Endpoints		250 Endpoints		500 Endpoints		750 Endpoints		1000 Endpoints	
Query type	Discovery (%)	Access (%)	Discovery (%)	Access (%)	Discovery (%)	Access (%)	Discovery (%)	Access (%)	Discovery (%)	Access (%)
Complex 1	0.93	0.07	0.94	0.06	0.96	0.04	0.95	0.05	0.96	0.04
Complex 2	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Complex 3	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Complex 4	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Complex 5	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Complex 6	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Complex 7	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Complex 8	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Linear 1	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.95	0.05
Linear 2	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Linear 3	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Linear 4	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Star 1	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Star 2	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Star 3	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Star 4	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Tree 1	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
Tree 2	0.95	0.05	0.96	0.04	0.96	0.04	0.96	0.04	0.96	0.04
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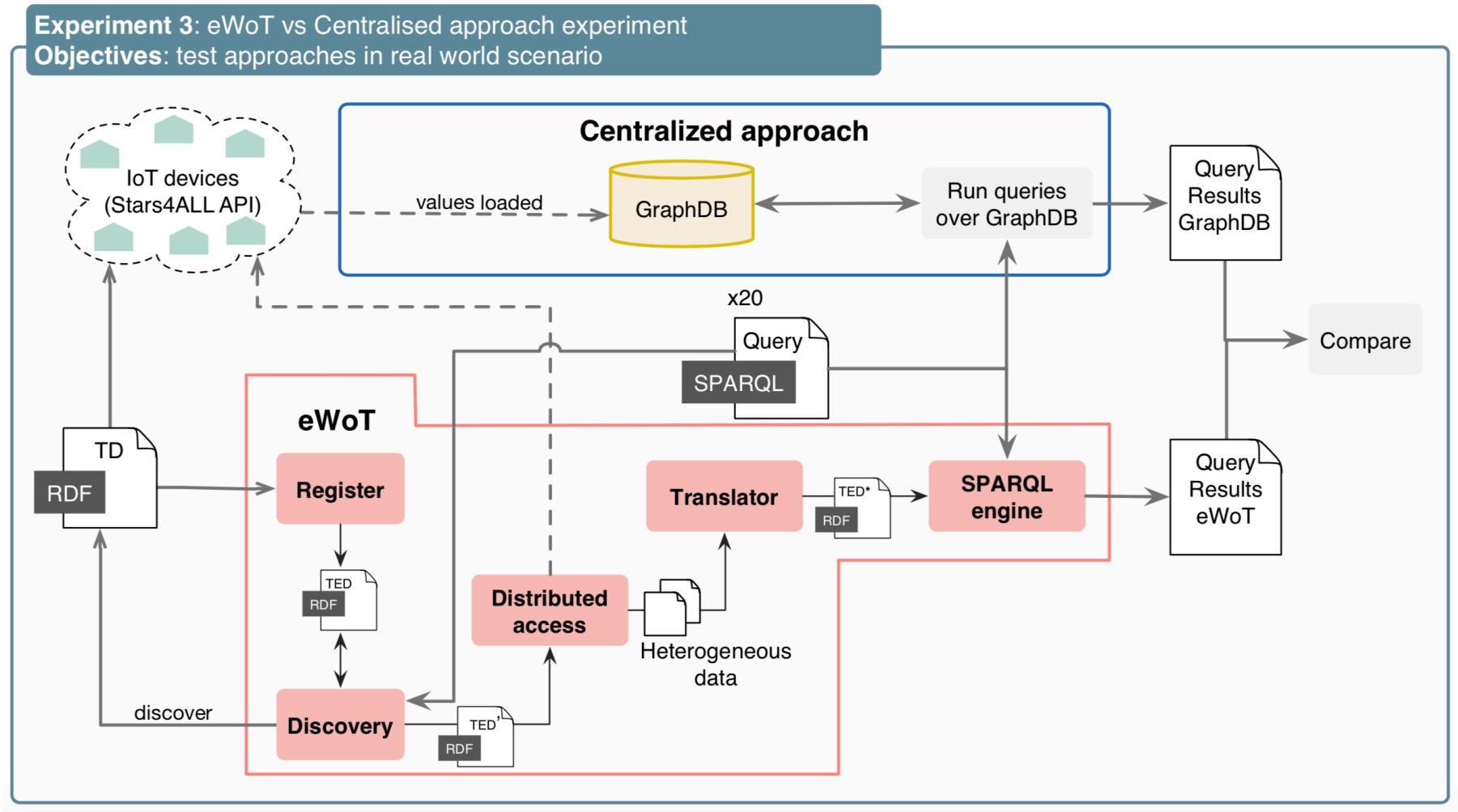
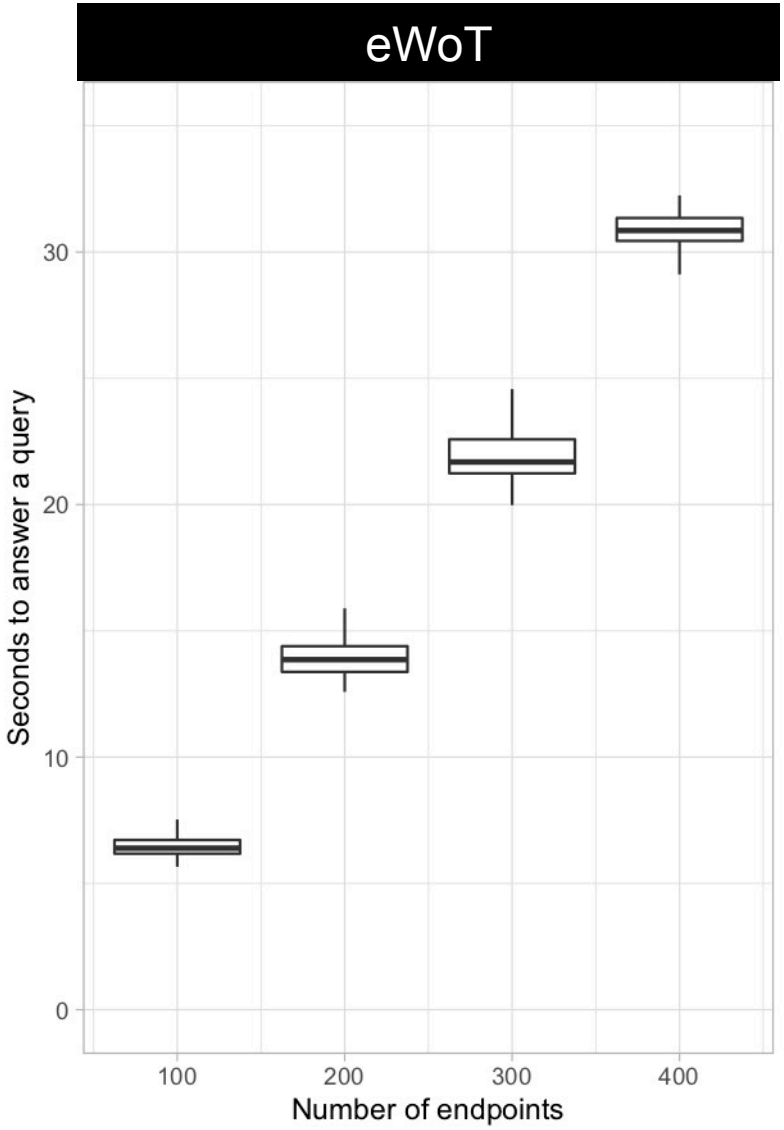
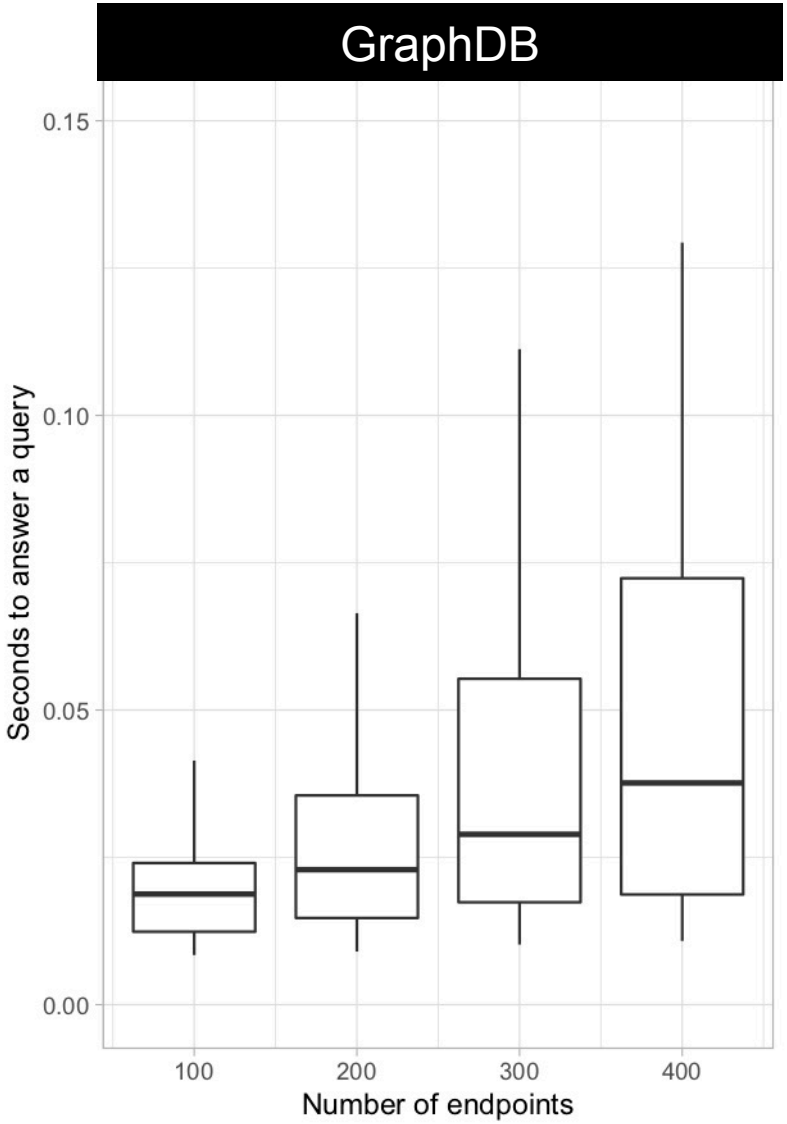

Experiment 3: eWoT vs Centralised approach experiment
Objectives: test approaches in real world scenario
IoT devices (Stars4ALL API)
Centralized approach
values loaded
GraphDB
Run queries over GraphDB
Query Results GraphDB
x20
Query
SPARQL
Compare
eWoT
TD
RDF
Register
Translator
TED*
RDF
SPARQL engine
Query Results eWoT
TED
RDF
Distributed access
Heterogeneous data
discover
Discovery
TED'
RDF

Experiment 3 - Results





Conclusions: eWoT

- eWoT enables semantic interoperable ecosystems
  - Based on the Web of Things
    - Extended with the WoT-Mappings
  - Integration of IoT infrastructures requires only the registration of their Thing Descriptions
  - Offers a SPARQL endpoint to transparently query a set of heterogeneous IoT infrastructures

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- eWoT enables semantic interoperable ecosystems
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  - Integration of IoT infrastructures requires only the registration of their Thing Descriptions
  - Offers a SPARQL endpoint to transparently query a set of heterogeneous IoT infrastructures
- Experimental results:
  - Show that eWoT is competitive
  - Show that there is room to improve the discovery algorithm
- Available at:
  - https://github.com/oeg-upm/eWoT

Current ~~Future~~ research directions

- Implement mappings to translate from RDF to heterogeneous sources
- Improve discovery algorithm to cope with larger scenarios

- European Project VICINITY H2020

- Partially re-used in the European Project DELTA H20230

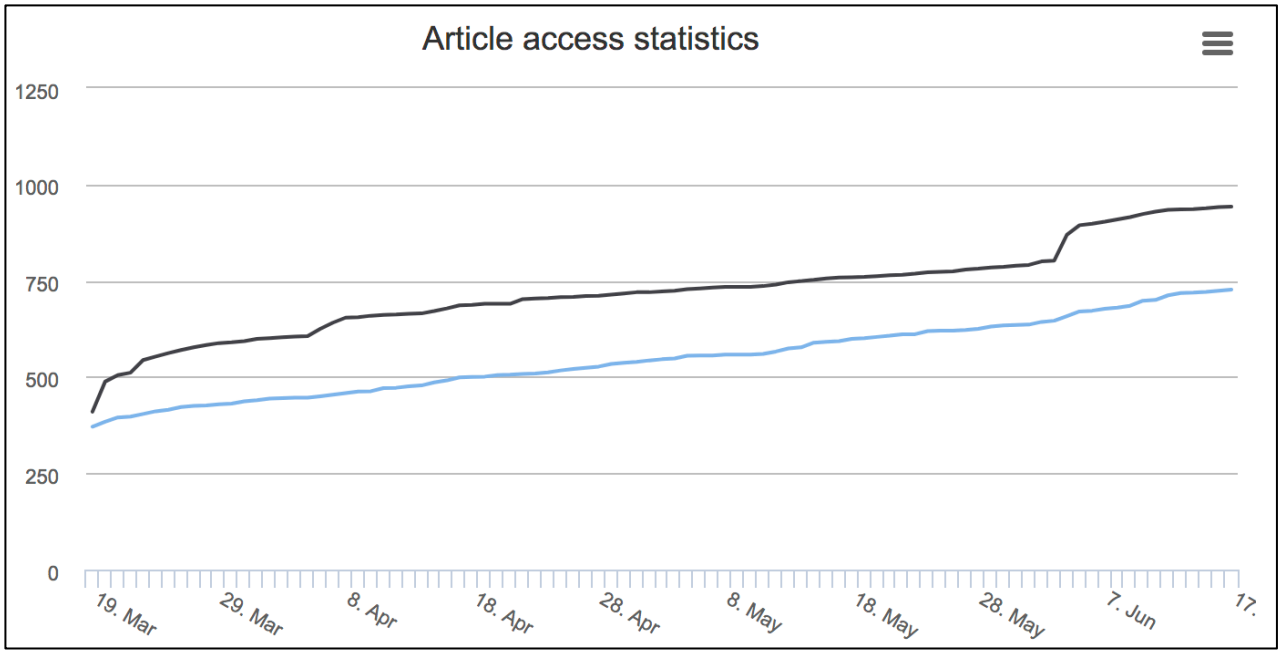
eWoT history (papers)

- CIMMINO, Andrea, et al. Towards Semantic Interoperability in WoT Ecosystems. Second W3C Workshop on the Web of Things. 2019

- CIMMINO, Andrea, et al. VICINITY: IoT Semantic Interoperability Based on the Web of Things. En 2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS). IEEE, 2019. p. 241-247.

- CIMMINO, Andrea, et al. A Generic Semantic Interoperability approach based on the Web of Things. ETSI IoT Workshop & Showcases. 2019

- https://doi.org/10.3390/s20030822
- Sensors:
  - Impact Factor: 3.031
  - JCR category rank: 15/61 (Q1) in ‘Instruments & Instrumentation’, 23/84 (Q2) in ‘Chemistry, Analytical’ and 12/26 (Q2) in the ‘Electrochemistry’



Most Notable Articles (January–March 2020)

Physical Sensors
Fused-Deposition-Material 3D-Printing Procedure and Algorithm Avoiding Use of Any Supports
Gianluca Barile et al.

Physical Sensors
Inertial Sensor-Based Lower Limb Joint Kinematics: A Methodological Systematic Review
Ive Weygers et al.

Remote Sensors
An Assessment of Surface Water Detection Methods for Water Resource Management in the Nigerien Sahel
Kelsey Herndon et al.

Intelligent Sensors
eWoT: A Semantic Interoperability Approach for Heterogeneous IoT Ecosystems Based on the Web of Things
Andrea Cimmino et al.

Physical Sensors
Design and Realization of an Efficient Large-Area Event-Driven E-Skin
Florian Bergner et al.

Remote Sensors
Wind Profiling in the Lower Atmosphere from Wind-Induced Perturbations to Multirotor UAS
Javier González-Rocha et al.

eWoT as reseach seed for discovery in standardisation groups

- **W3C Web of Thing:**
  - Discovery working group
  - eWoT discovery algorithm as main contribution
  - Potentially, WoT-Mapping as secondary contributions

- **Specialist Task Force 589:**
  - Semantic Discovery and Query in oneM2M
  - Bringing the whole eWoT approach as contribution
  - Improving current OneM2M semantic discovery with the eWoT discovery algorithm

Q&A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TEŞEKKÜR EDERIM
KÖSZÖNÖM
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