# Towards an interoperable IoT with a constraint-aware SWoT

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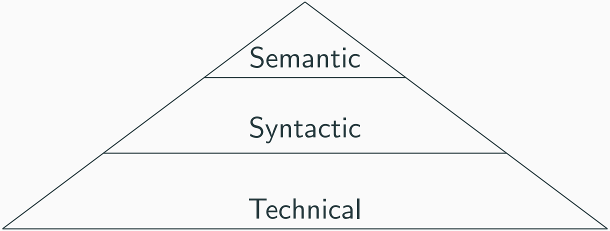
# Enabling interoperability with IoT ontologies

# Refining the notion of interoperability



# Finding ontologies online

## Ontology catalogue

- LOV
- LOV4IoT

## Standards, consortia and projects

- SSN/SOSA
- W3C WoT
- oneM2M BO
- SAREF and extensions
- IoT-Lite and M3
- iot.schema.org

# Designing a “good” IoT ontology

# Ontology engineering principles

## Ontology design process

The **NeOn** methodology:

- Identify requirements
- Identify existing resources
- Build ontology network

## Identifying requirements

- Functional requirements
- Conceptual requirements

# Functional requirements

**Reusability**

- **FR1**: the ontology is **compliant with LOV requirements**.
- **FR2**: The ontology is **modular**.
- **FR3**: The ontology is based on **Ontology Design Patterns**.
- **FR4**: The ontology is **aligned to upper ontologies**.
- **FR5**: the ontology **reuses existing resources**.

**Formalism**

The ontology used should **enable reasoning** and inference, while **remaining decidable** within reasonable time: **OWL-DL**.

# Functional requirements coverage

| | **FR1.1** Online | **FR1.2** LOV-compliant | **FR2** Modular | **FR3** ODP | **FR4** Upper ontologies | **FR5** External resources |
|---|---|---|---|---|---|---|
| **SSN (v1)** | ** | ** | * | ** | ** | * |
| **SOSA** | ** | ** | ** | (**) | ** | (**) |
| **WoT** | ** | * | | | | |
| **oneM2M** | ** | | | | | |
| **SAREF** | ** | ** | ** | | | * |
| **IoT-Lite** | ** | ** | * | | | ** |
| **FIESTA-IoT** | ** | * | ** | | ** | ** |
| **iot.schema.org** | * | | ** | | | * |
| **Hypercat** | ** | | | | | |
| **Spitfire** | * | ** | | | ** | ** |
| **OpenIoT** | * | | | | ** | ** |
| **MOFI** | * | * | ** | | | |
| **IoT.est** | ** | | | | ** | ** |
| **iot-ontology** | * | | | | ** | ** |
| **IoT-S** | ** | | * | (**) | (**) | ** |
| **SA** | * | | * | (**) | ** | ** |
| **STN** | ** | * | ** | | | |
| **SWOT-O** | ** | * | | | | |
| **SemIoT** | ** | * | ** | | ** | ** |
| **IoT-O** | ** | ** | ** | (**) | ** | ** |

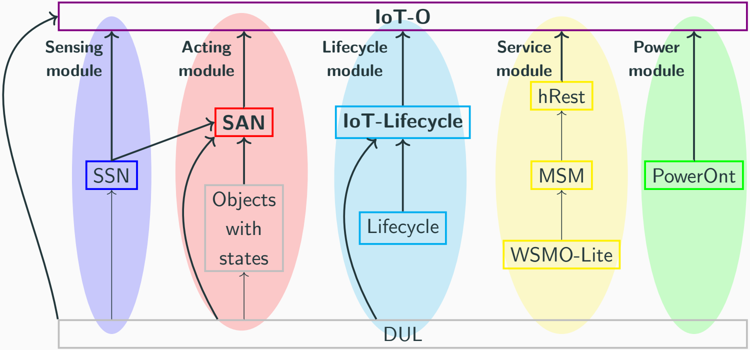
# Conceptual requirements

- **CR1**: **"Device"** (**CR1.1**) and **"software agent"** (**CR1.2**)
- **CR2**: **"Sensor"**(**CR2.1**), and **"observation"**(**CR2.2**)
- **CR3**: **"Actuator"**(**CR3.1**), and **"action"**(**CR3.2**)
- **CR4**: **"Service"**
- **CR5**: **"Energy"**
- **CR6**: **"Lifecycle"**

# Conceptual requirements coverage

| | **CR1.1** Device | **CR1.2** Software agent | **CR2.1** Sensor | **CR2.2** Observation | **CR3.1** Actuator | **C3.2** Action | **CR4** Service | **CR5** Energy | **CR6** Lifecycle |
|---|---|---|---|---|---|---|---|---|---|
| **SSN (v1)** | ** | | ** | ** | | | | * | * |
| **SOSA** | | | ** | ** | ** | ** | | | |
| **WoT** | * | * | | ** | | ** | ** | | * |
| **oneM2M** | ** | | | | | | ** | | |
| **SAREF** | ** | ** | * | | * | | ** | ** | * |
| **IoT-Lite** | (**) | | (**) | | * | | ** | | |
| **FIESTA-IoT** | (**) | | (**) | | (*) | | (**) | | |
| **iot.schema.org** | * | | * | ** | * | ** | | | |
| **Hypercat** | | | * | * | | | | | |
| **Spitfire** | (*) | | * | (*) | * | | | ** | |
| **OpenIoT** | (**) | | (**) | | | | (**) | (**) | * |
| **MOFI** | | | | ** | | | * | | * |
| **IoT.est** | (*) | | (*) | (*) | * | | (**) | * | (*) |
| **iot-ontology** | (**) | ** | (*) | (*) | * | * | ** | (*) | (*) |
| **IoT-S** | (*) | | (*) | (*) | | | (**) | (*) | (*) |
| **SA** | (**) | | (**) | (**) | * | | * | (**) | (**) |
| **STN** | * | * | | | | | | | |
| **SWOT-O** | (**) | | (**) | (**) | (**) | (**) | (**) | * | |
| **SemIoT** | (*) | | | | | | | | |
| **IoT-O** | (**) | * | (**) | (**) | (**) | (**) | (**) | (**) | (**) |

# IoT-O, a modular core-domain IoT ontology



# Evolutions of IoT-O

**Application-specific extensions**

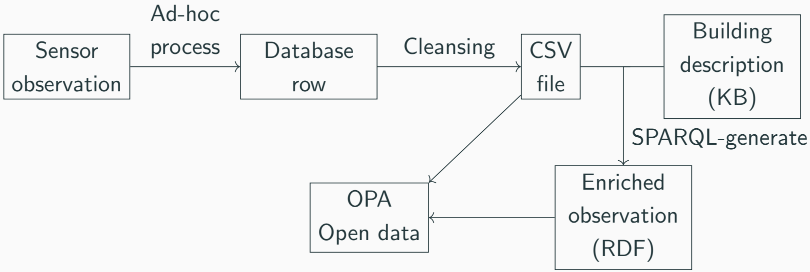
- Adream-core
- Adream-building
- Adream-apartment

**Alignments**

- SOSA
- FIESTA-IoT

# IoT-O use cases

# Enriching data for the OPA platform



# Publishing data for the FIESTA-IoT project

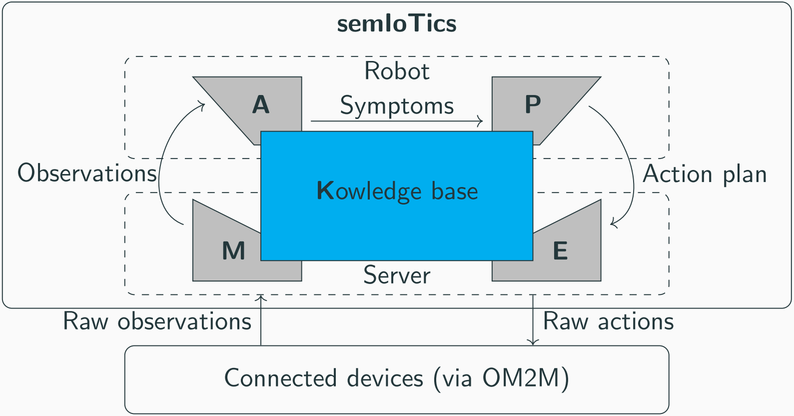
**FIESTA-IoT, federated data hub**

- Multiple testbeds
- Heterogeneous technologies
- One vocabulary for one interface

**Publishing OPA data**

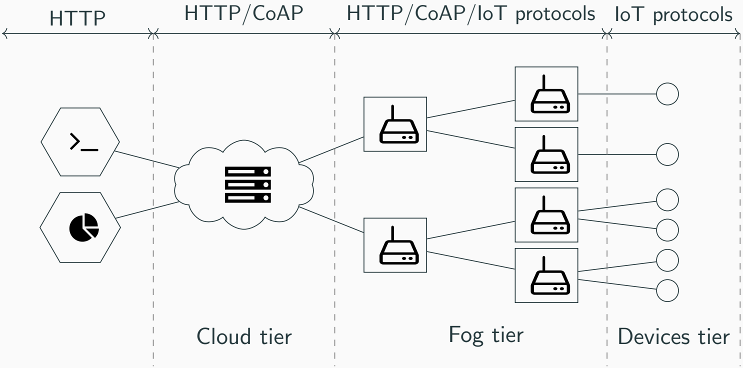
- Aligning IoT-O
- Using the alignment to transform data
- Daily publication

# semIoTics

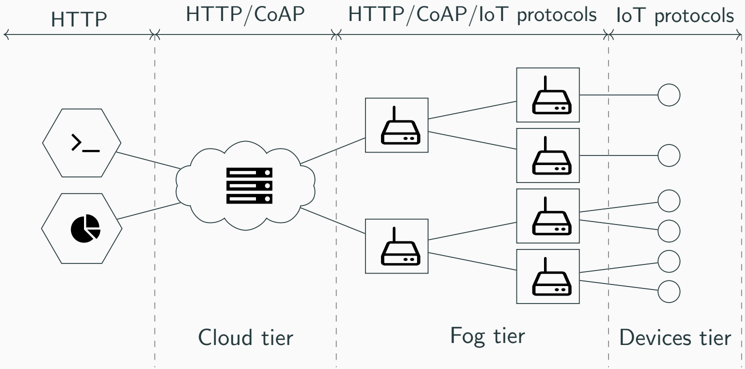

semIoTics
Robot
A
Symptoms
P
Observations
Kowledge base
Action plan
M
E
Server
Raw observations
Raw actions
Connected devices (via OM2M)

# SWoT architectural pattern

# Cloud-Fog-Device



# Cloud-Fog-Device




**Similar to**

- oneM2M
- W3C WoT

# Towards a constraint-aware SWoT

# Cloud& Fog computing

**Cloud computing**

- Centralized
- Powerful remote machines
- Stable

# Cloud& Fog computing

**Cloud computing**

- Centralized
- Powerful remote machines
- Stable

**Fog computing**

- Distributed
- Small local machines
- Dynamic

# Semantic Cloud& Fog computing

**Facing scalability issues**

- Semantic Web technologies do not scale well
- The IoT grows quickly

**Deploying on constrained devices**

- Semantic Fog computing
- Making local decisions

# EDR$_{\mathcal{T}}$, an approach for distributed reasoning

# $\text{EDR}_{\mathcal{T}}$ characteristics

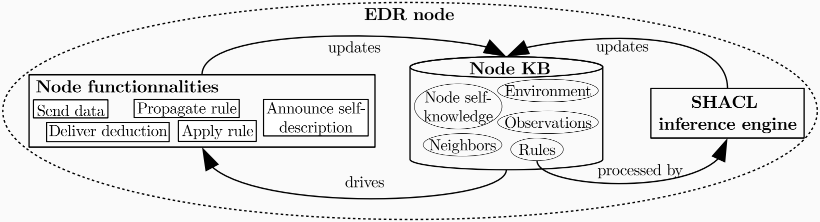
**EDR in general**

- Represent applicative needs with rules
- Exchange rules among Fog nodes
- Propagate Fog nodes knowledge to ensure local decision-making

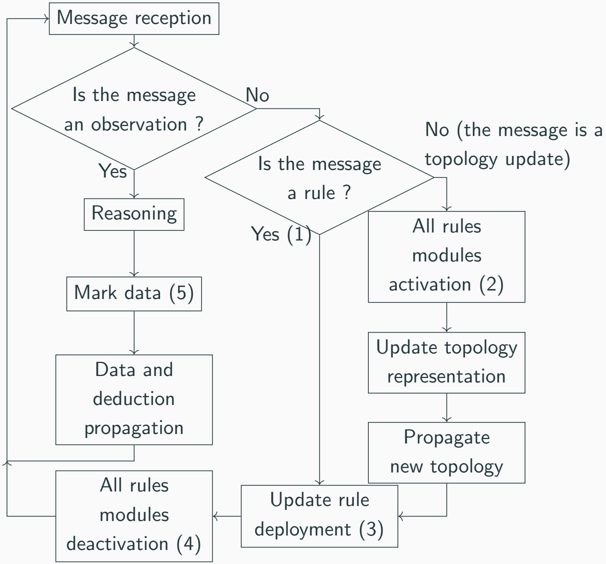
**$\text{EDR}_{\mathcal{T}}$ in particular**

- Bring computation close to devices
- Based on property types observed by devices

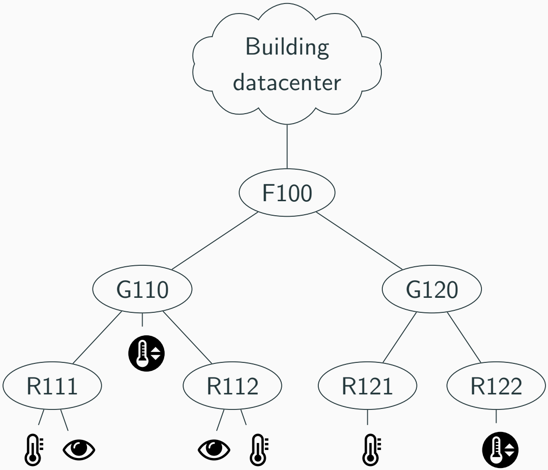
# Functional overview



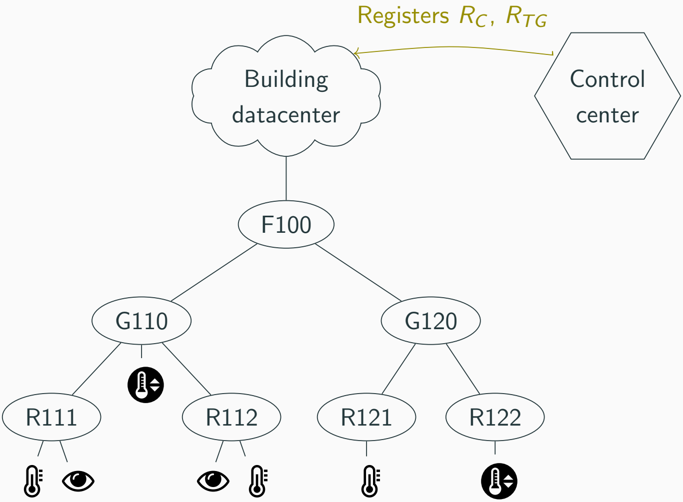
# EDR$_\mathcal{T}$ algorithm



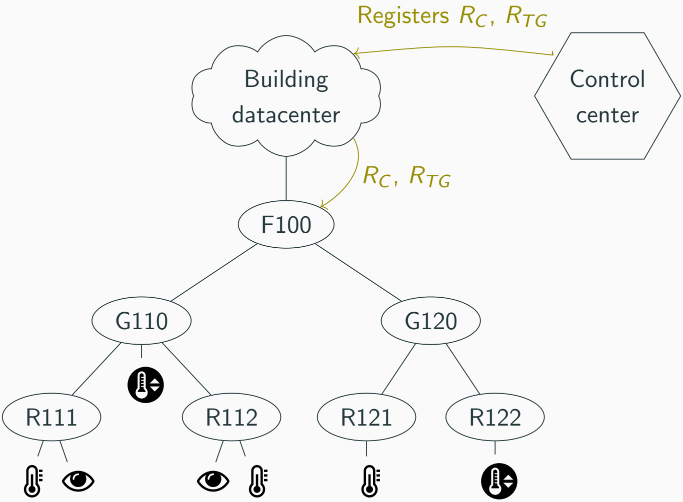
# EDR$_{\mathcal{T}}$ by the example



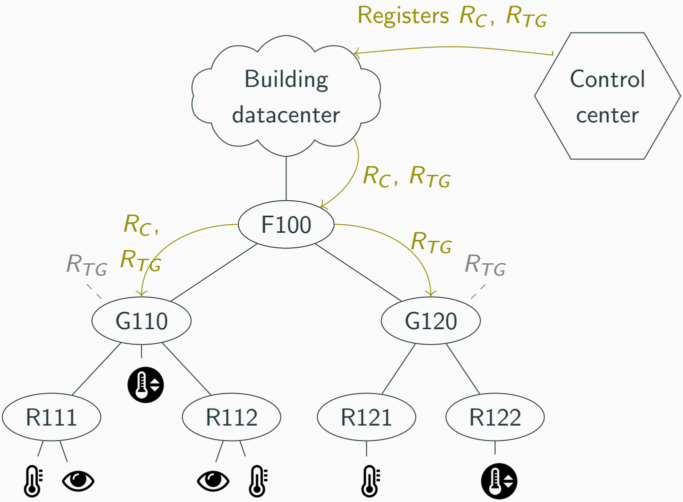
# EDR$_{\mathcal{T}}$ by the example



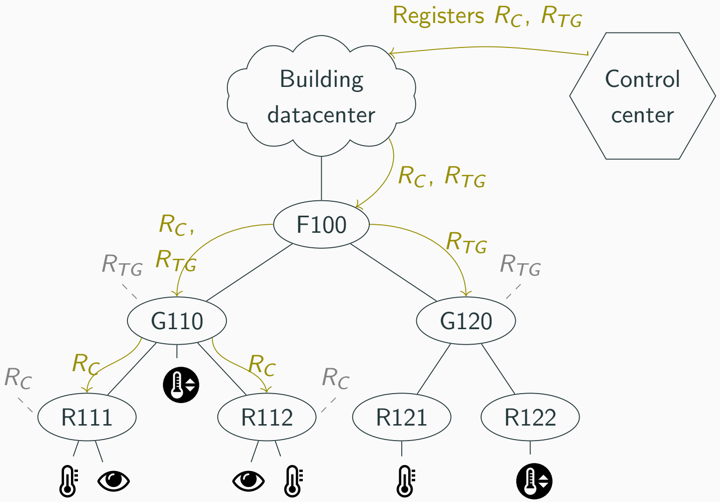
# EDR$_{\mathcal{T}}$ by the example



# $EDR_{\mathcal{T}}$ by the example



# $EDR_{\mathcal{T}}$ by the example



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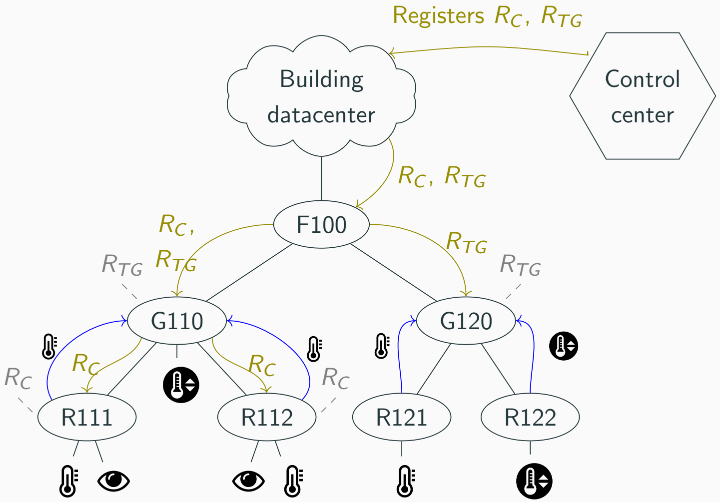
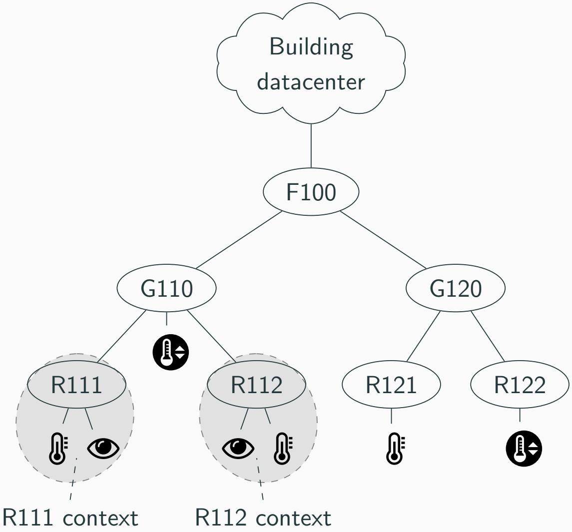
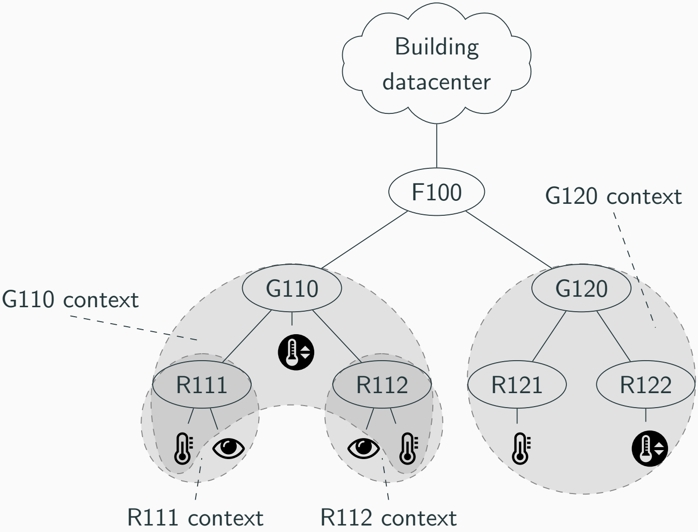


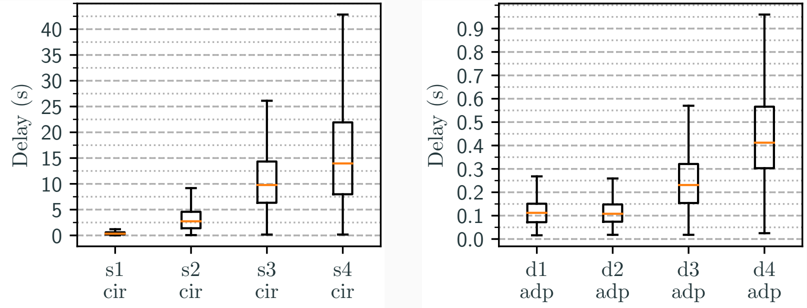
# Contextualizing properties with $EDR_{\mathcal{T}}$



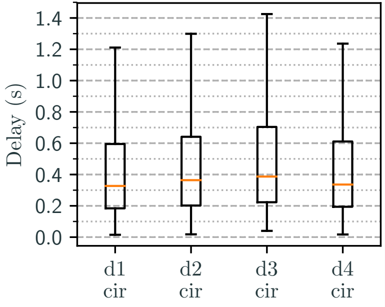
# Contextualizing properties with $EDR_{\mathcal{T}}$

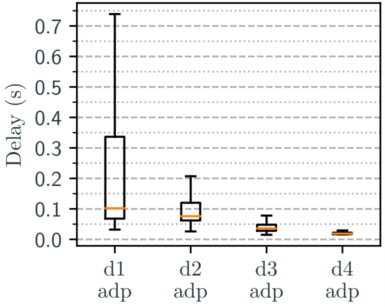


# Scalability of the proposed approach



# Performance of the proposed approach



# Conclusion and perspectives

## Conclusion

- Semantic Web technologies enable interoperability for the IoT
- Semantic Fog computing enable a constraint-aware

## Future work

- Consider node capabilites
- Privacy-aware deployment