Pushing the Semantic Web of Things to the Fog

Toward intereroperability and reasoning adapted to IoT constraints

Nicolas Seydoux, supervised by Khalil Drira, Nathalie Hernandez, Thierry Monteil

IRIT, LAAS-CNRS

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Agenda

Toward semantic interoperability for the IoT

- Context: Why do we need the SWoT ?
- Contribution: IoT-O and its usage

Toward scalability and dynamism for the SWoT

- Context: IoT resources constraints
- Moving reasoning to the Fog

The EDR algorithm (Emergent Distributed Reasoning)

Experimental results

Conclusion and future work

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IoT limitations

Heterogeneity in the IoT

- Multiple application domains
- Hardware, communication and software heterogeneity

IoT constrains

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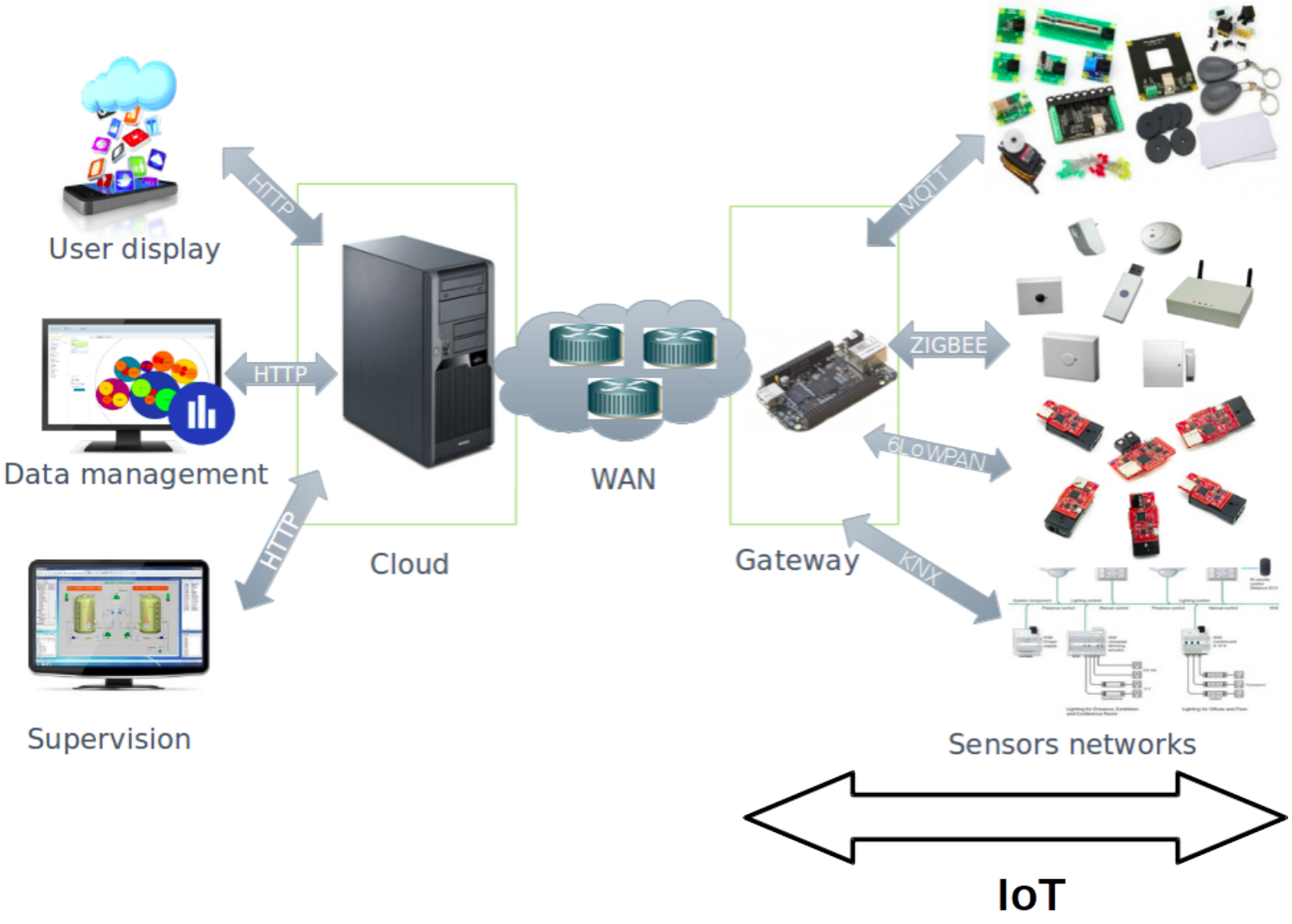
- Network topology is dynamic

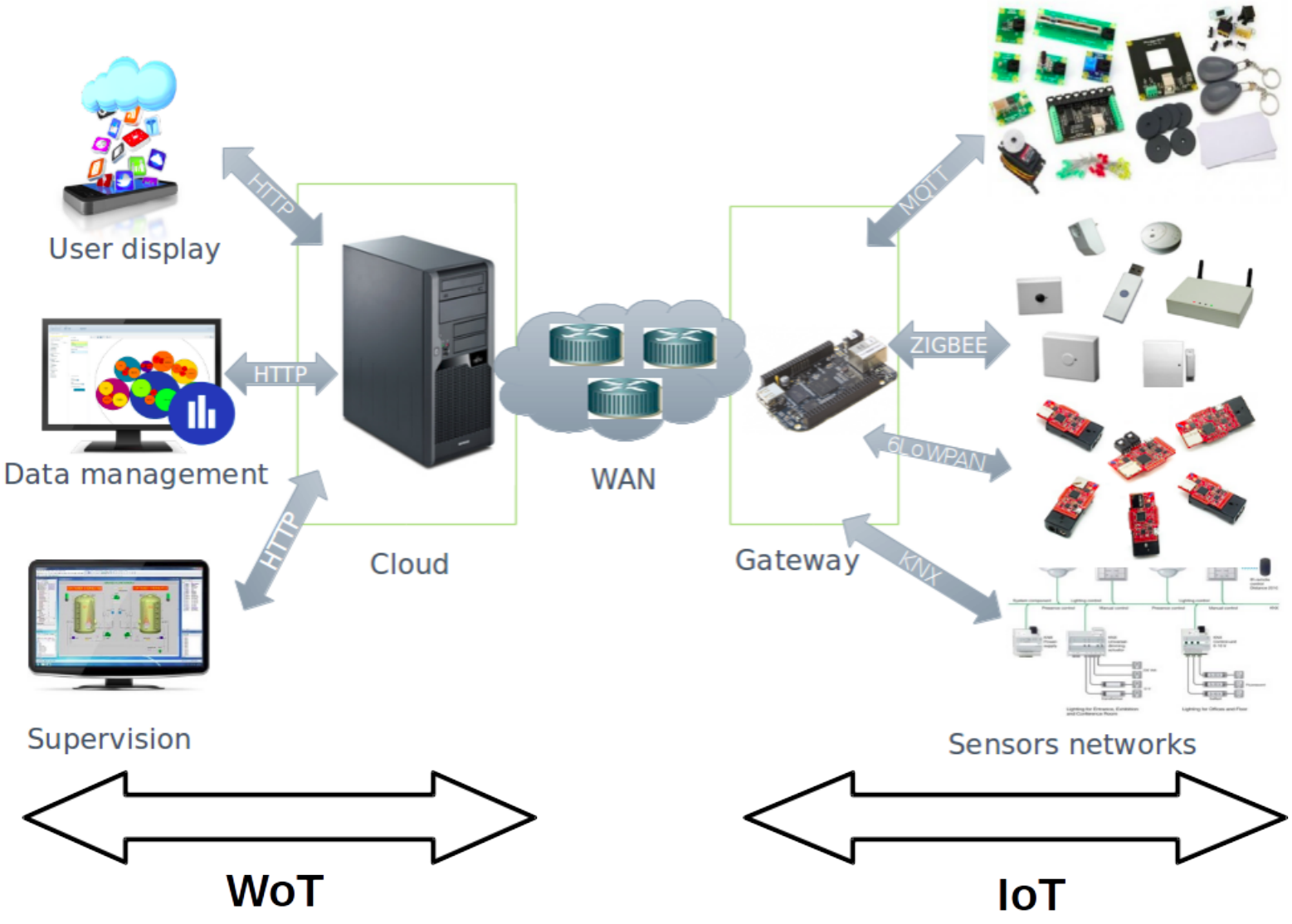
User-centricity

- Users can expect tailored deductions
- The IoT gathers sensitive data

Typical IoT deployment



Technical interoperability with the WoT



Putting the IoT on the web

Accessing IoT resources

- Web servers deployed on the Cloud or gateways
- Devices and/or data dereferencable

Protocols of the WoT

- HTTP
- CoAP

Semantic interoperability with the SWoT

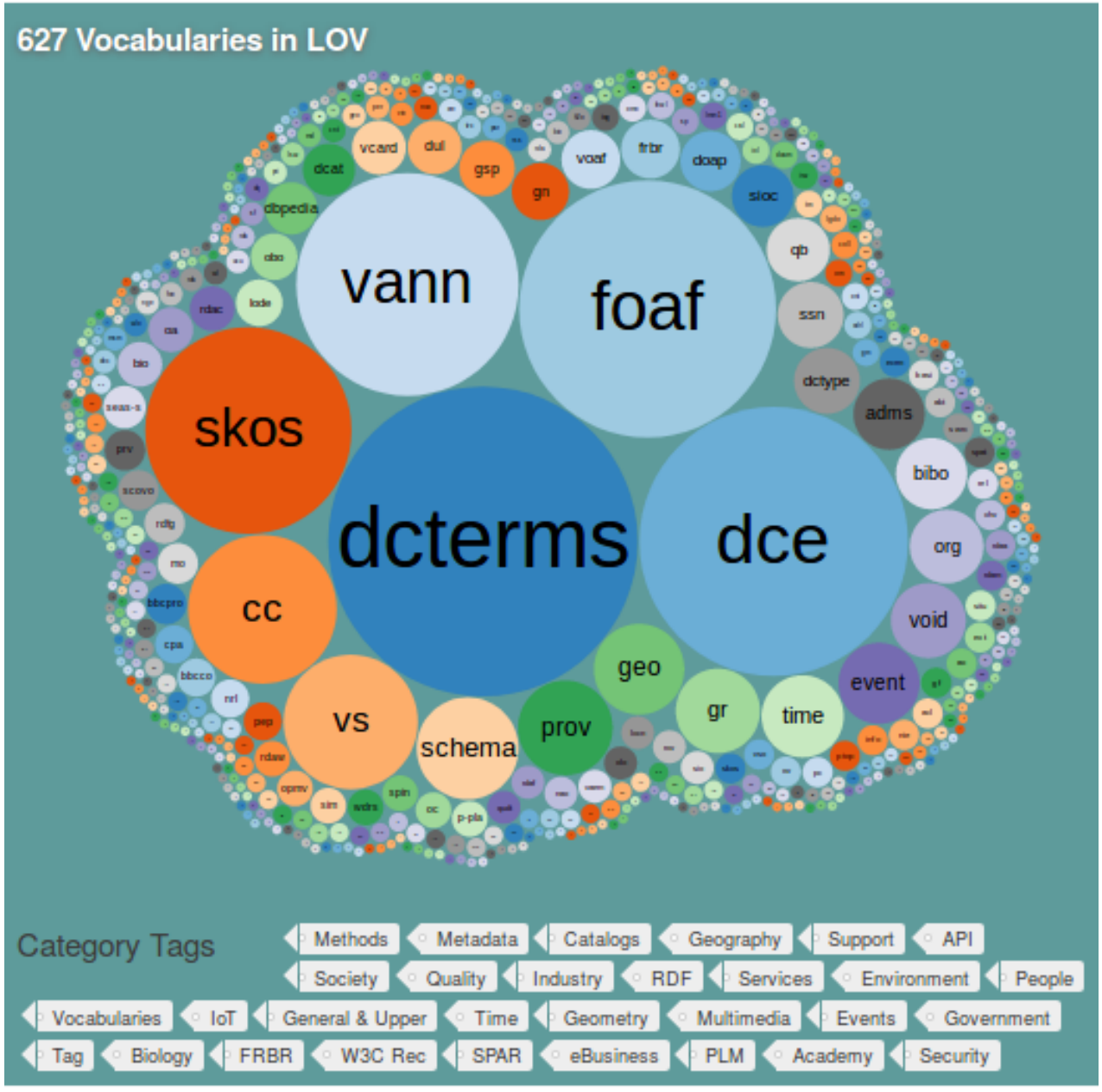
Describing devices and data

- IoT ontologies provide vocabularies for both devices (e.g. SOSA) and data (e.g. QUDT)
- The WoT can be used to enable IoT Linked Data

Reasoning for the IoT

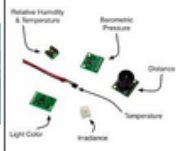
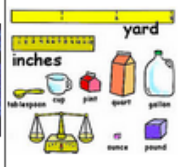
- Enabling devices and data sources discovery
- Making deductions to capture higher level symptoms

Ontology repository : the LOV



IoT ontologies repository : the LOV4IoT

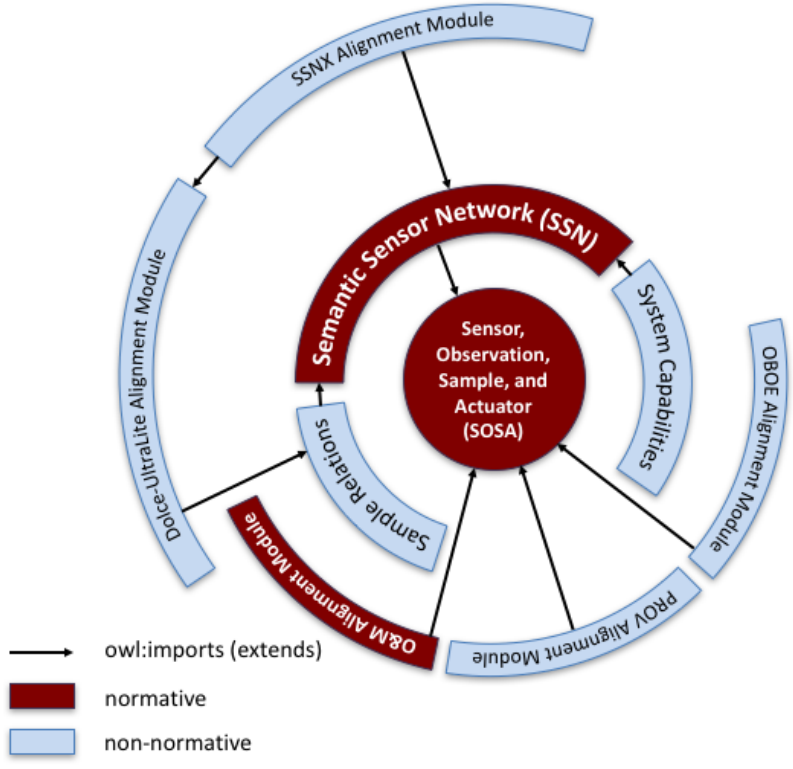
The LOV4IoT ontology catalogue references **391** ontology-based research projects for IoT and its applicative domains:

							
Nb onto: **46**	Nb onto: **27**	Nb onto: **11**	Nb onto: **23**	Nb onto: **57**	Nb onto: **62**	Nb onto: **15**	Nb onto: **30**
							
Nb onto: **35**	Nb onto: **24**	Nb onto: **18**	Nb onto: **6**	Nb onto: **16**	Nb onto: **14**	Nb onto: **30**	Nb onto: **7**
							
Nb onto: **6**	Nb onto: **7**	Nb onto: **32**	Nb onto: **5**	Nb onto: **5**			

Ontologies of the SWoT

Reference ontologies

- SAREF
- SSN/SOSA
- oneM2M
- M3-Lite



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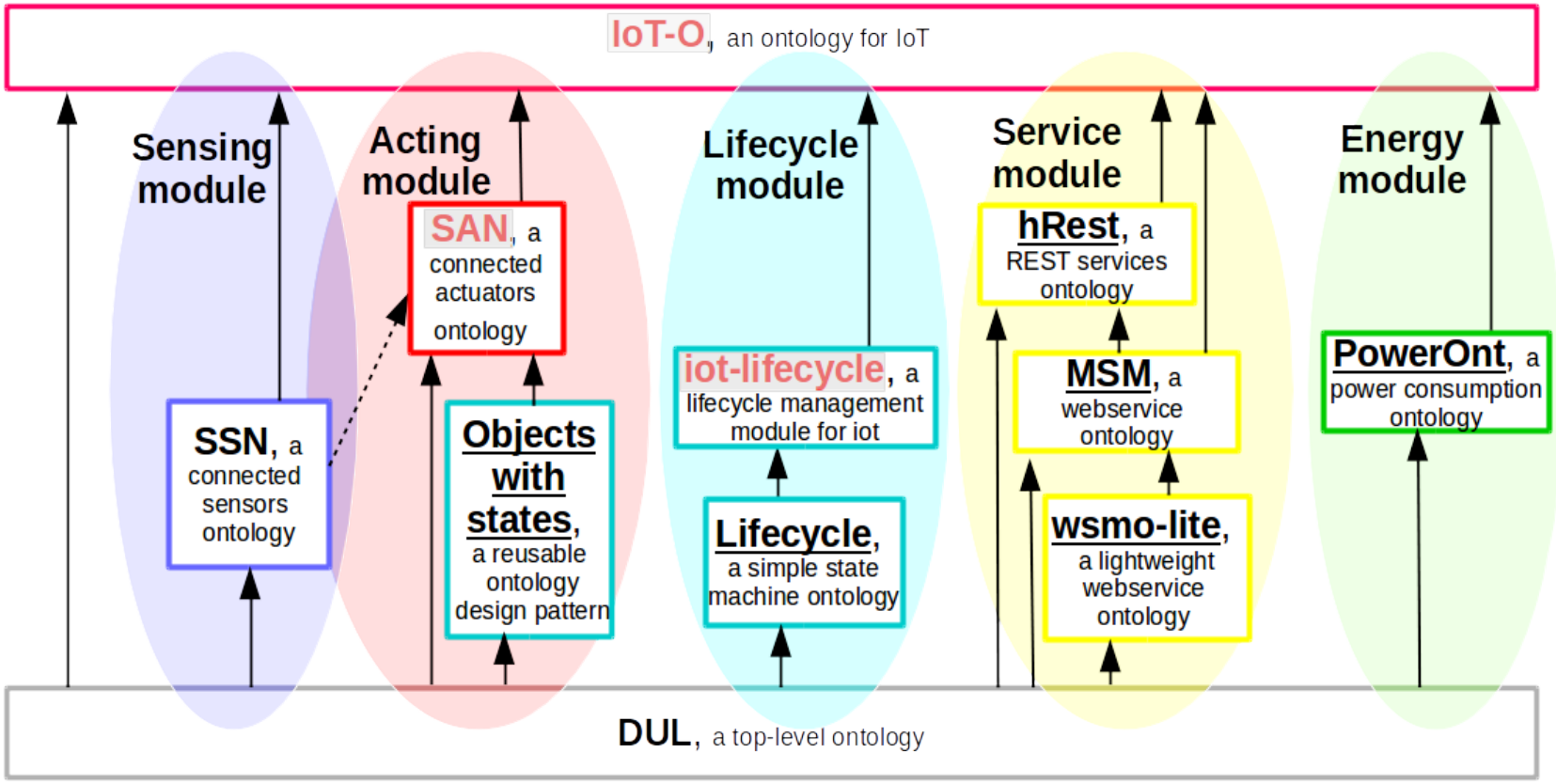
IoT-O

https://www.irit.fr/recherches/MELODI/ontologies/IoT-O



Seydoux, N., Drira, K., Hernandez, N., and Monteil, T. (2016). IoT-O, a core-domain IoT ontology to represent connected devices networks. In *EKAW*

The ADREAM building

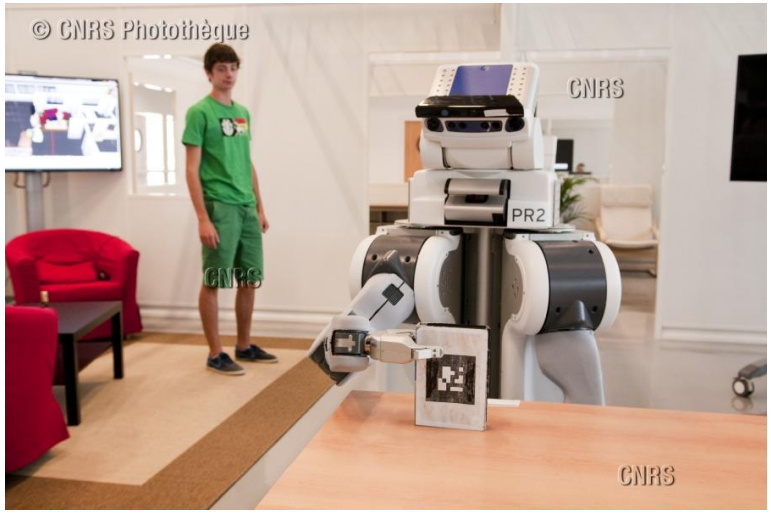
- Over **6500 sensors** in the building

The ADREAM building

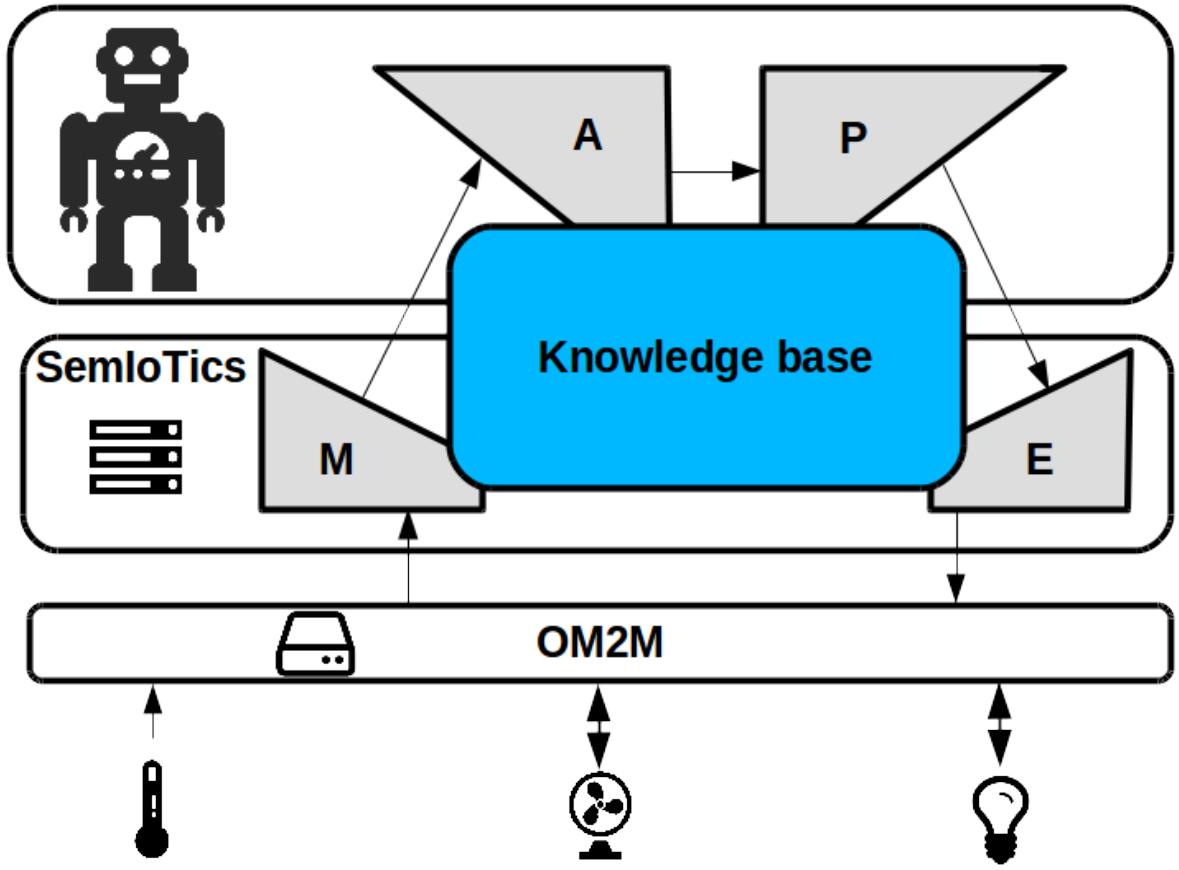
- Over **6500 sensors** in the building
- Small scale deployment in an **appartment**

The ADREAM building

- Over **6500 sensors** in the building
- Small scale deployment in an **appartment**
- A **shared** research platform

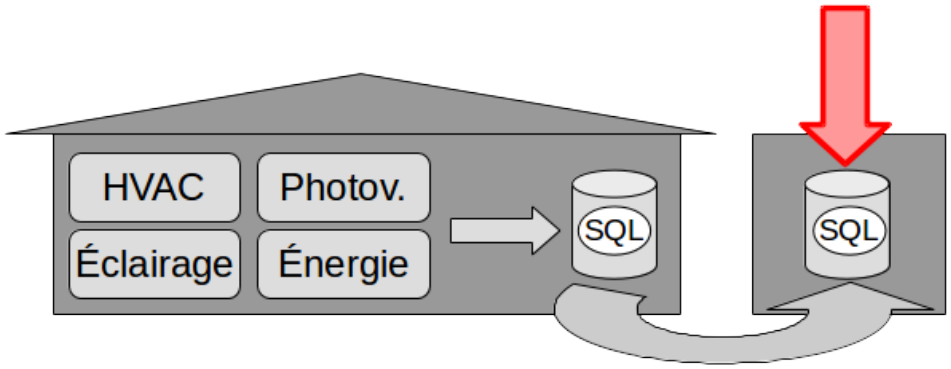


IoT-O in use : semIoTics



Aïssaoui, F., Garzone, G., and Seydoux, N. (2016). Providing interoperability for autonomic control of connected devices. In *InterIoT*, pages 1–7

IoT-O in use : Open Platform for Adream (OPA)



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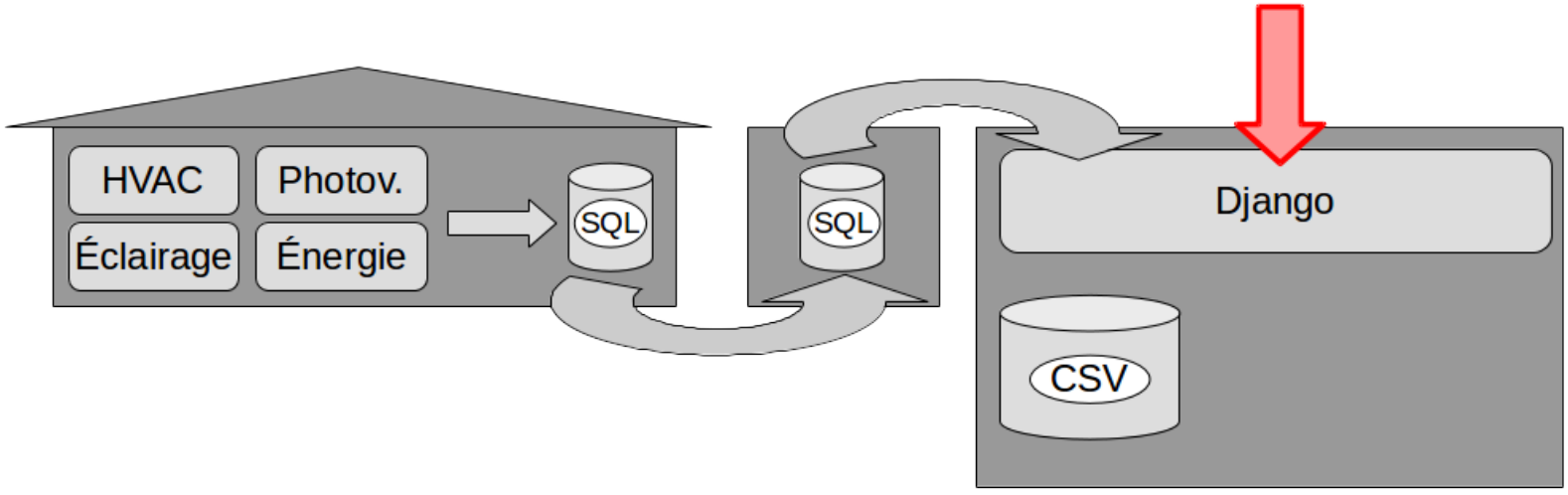

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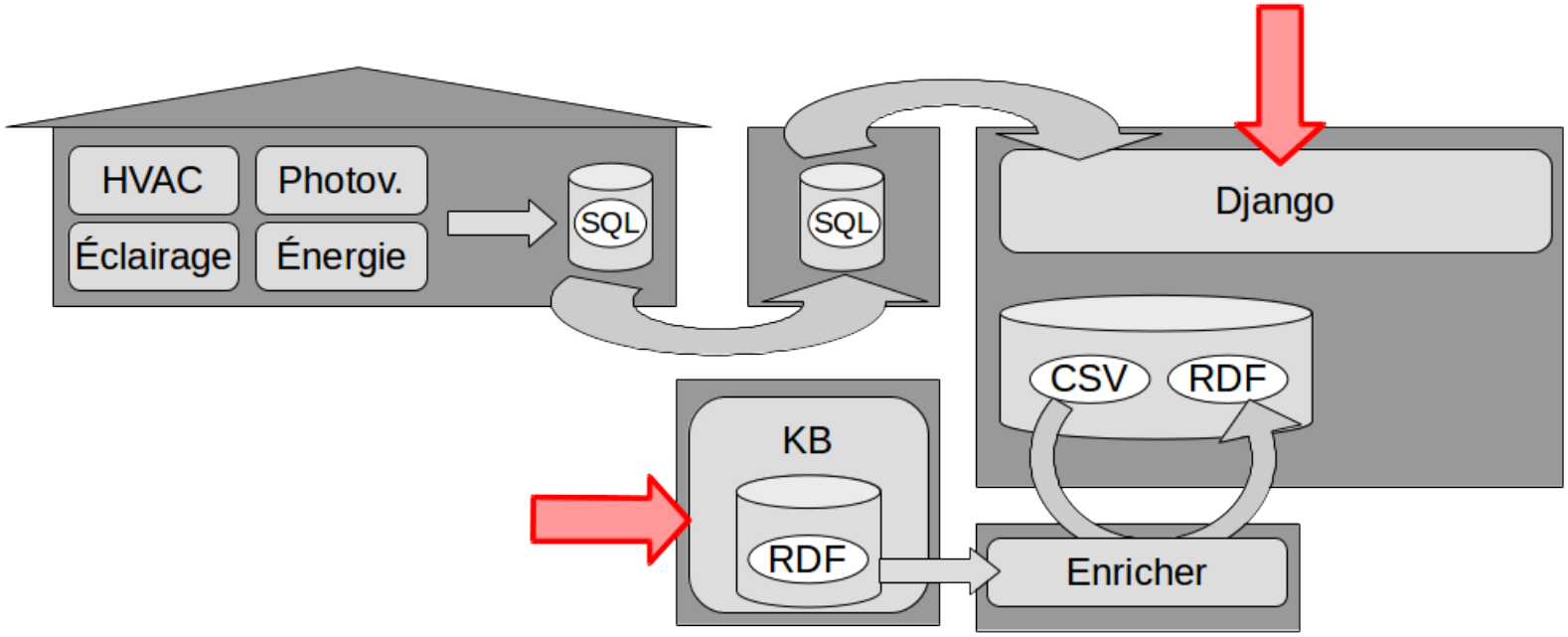
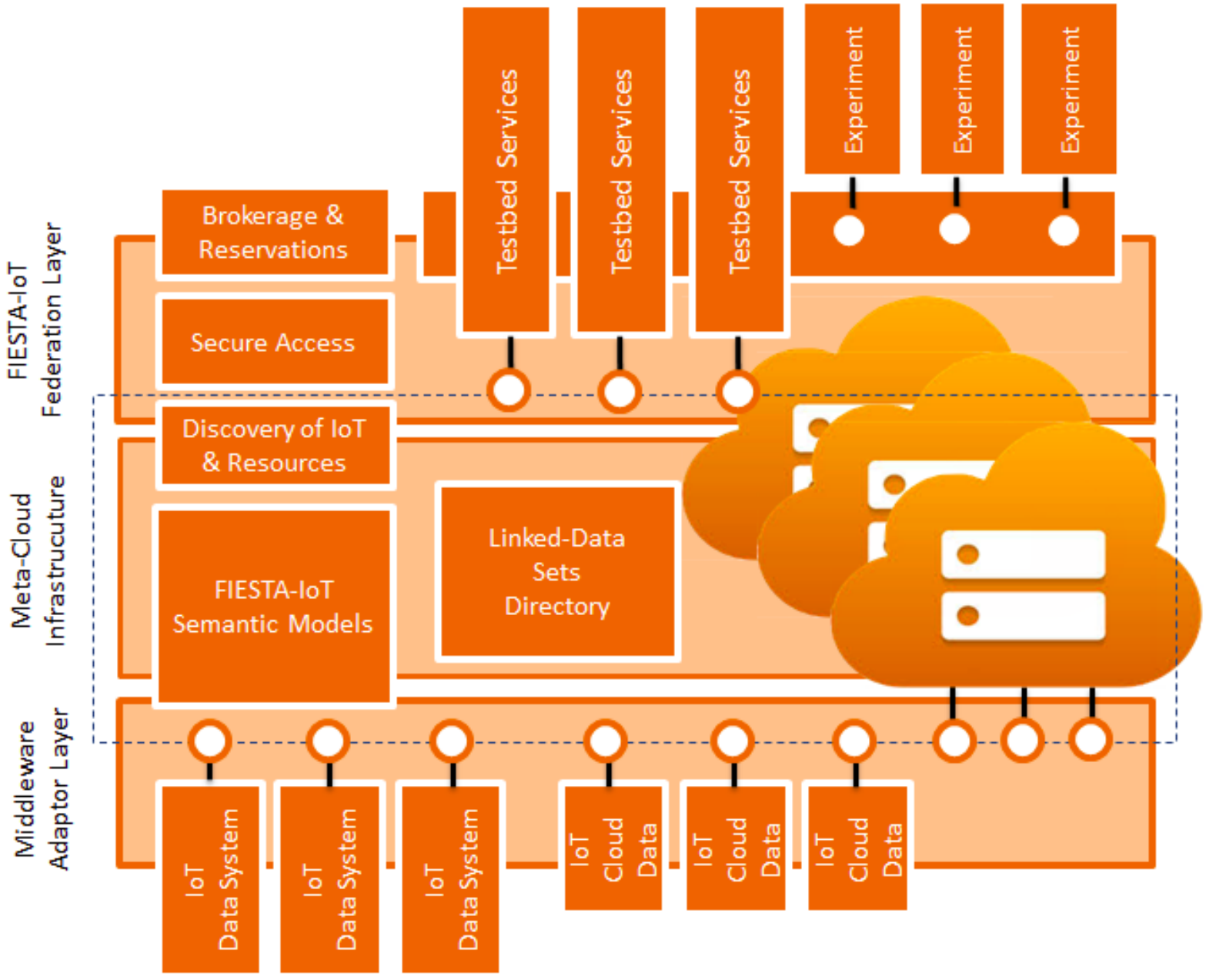
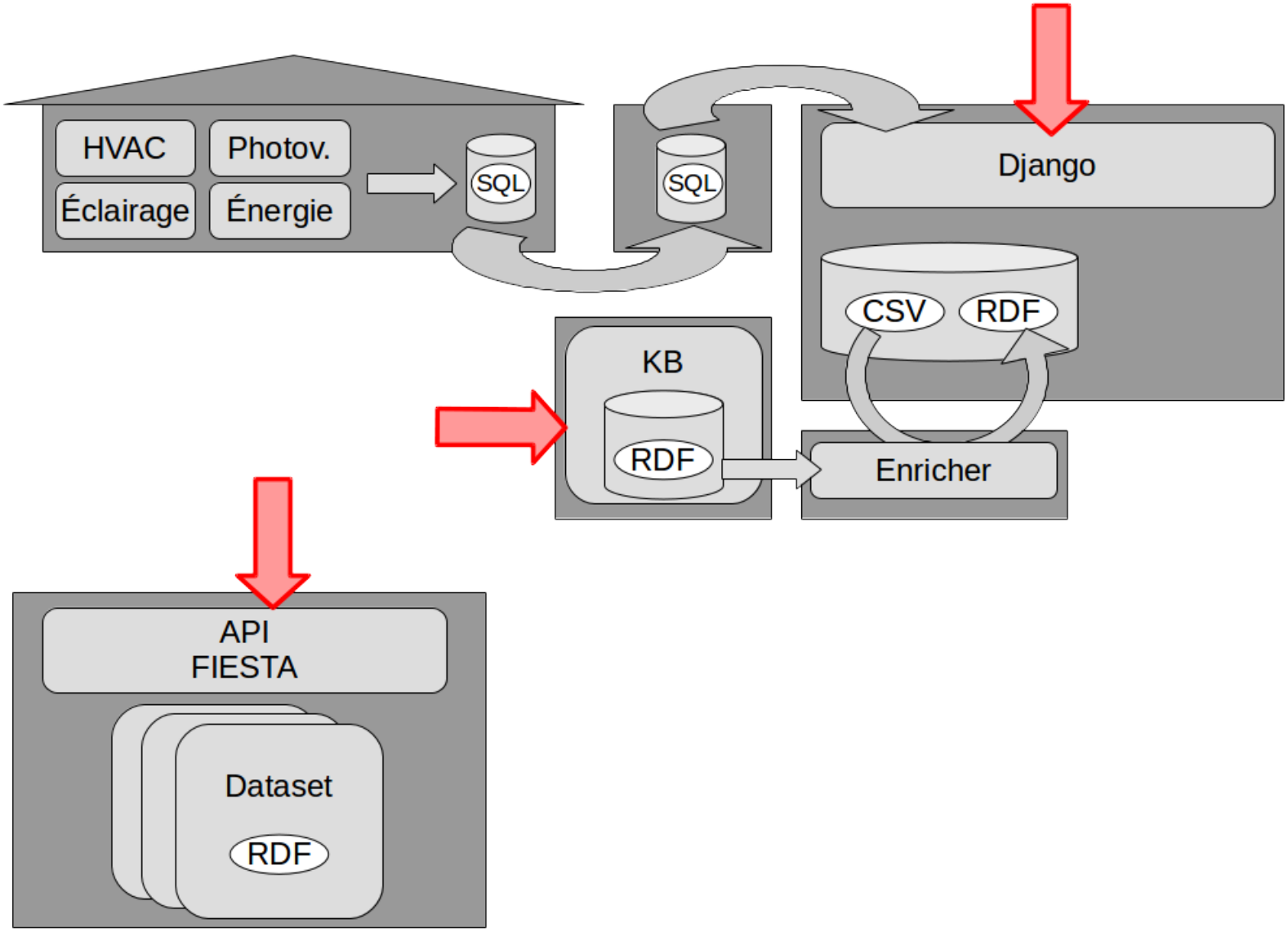


The FIESTA-IoT project



Alignment-enabled interoperability : FIESTA-IoT



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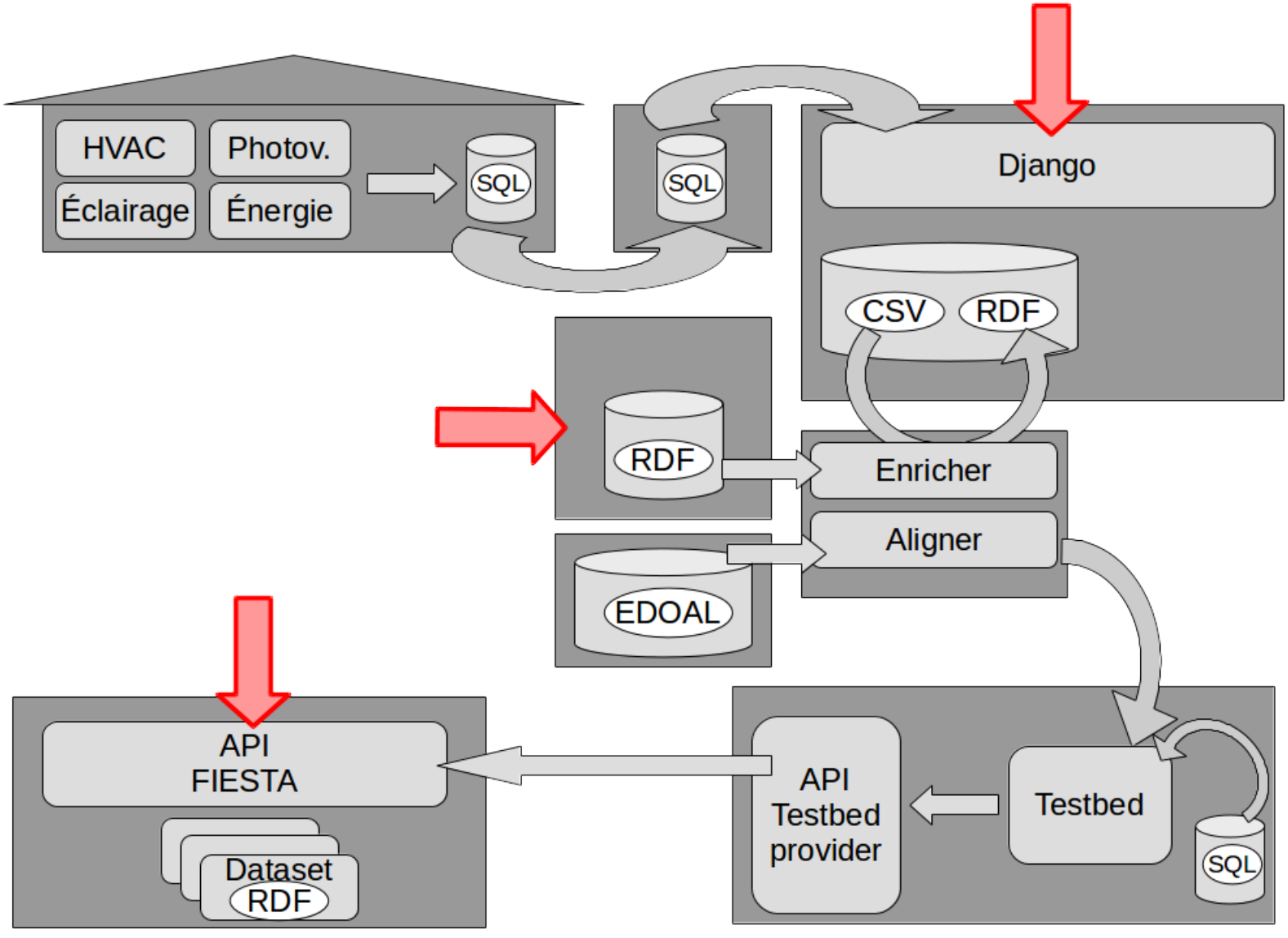

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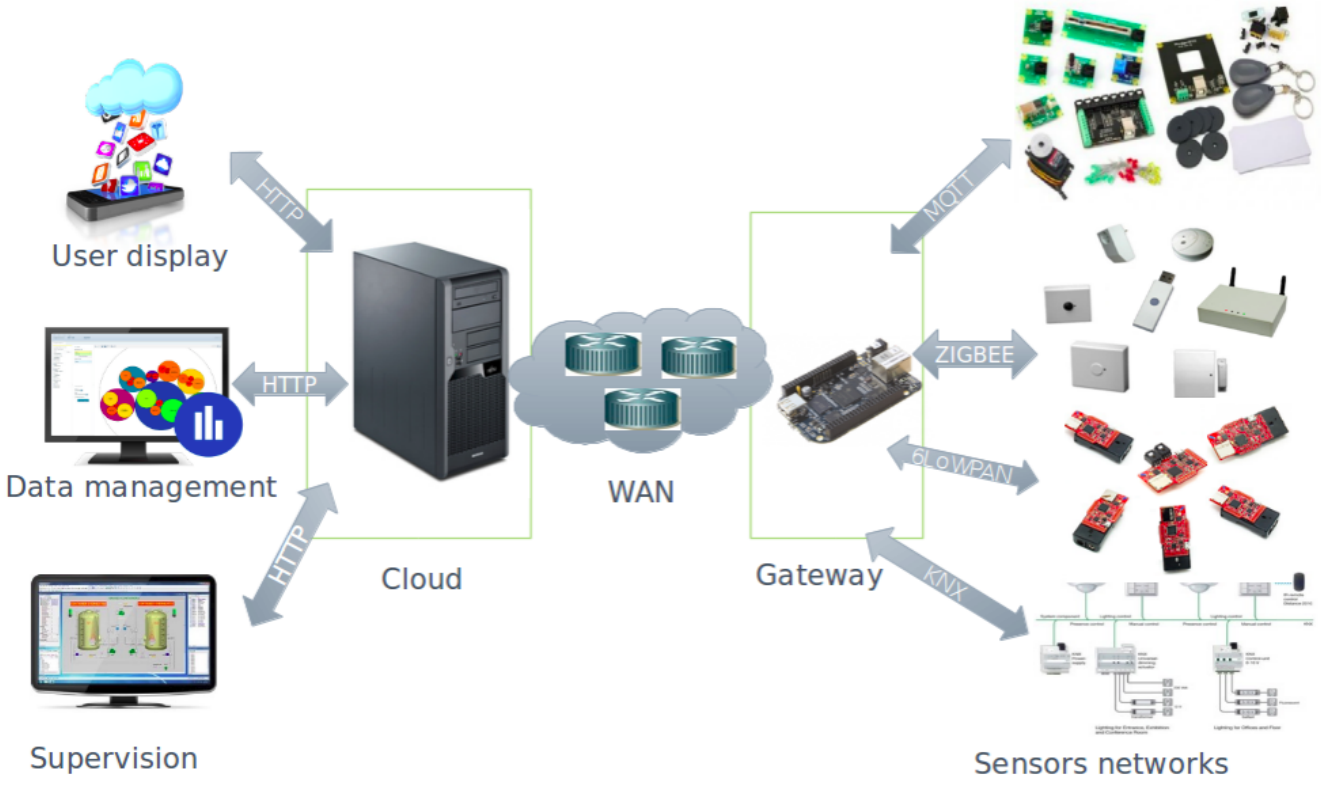
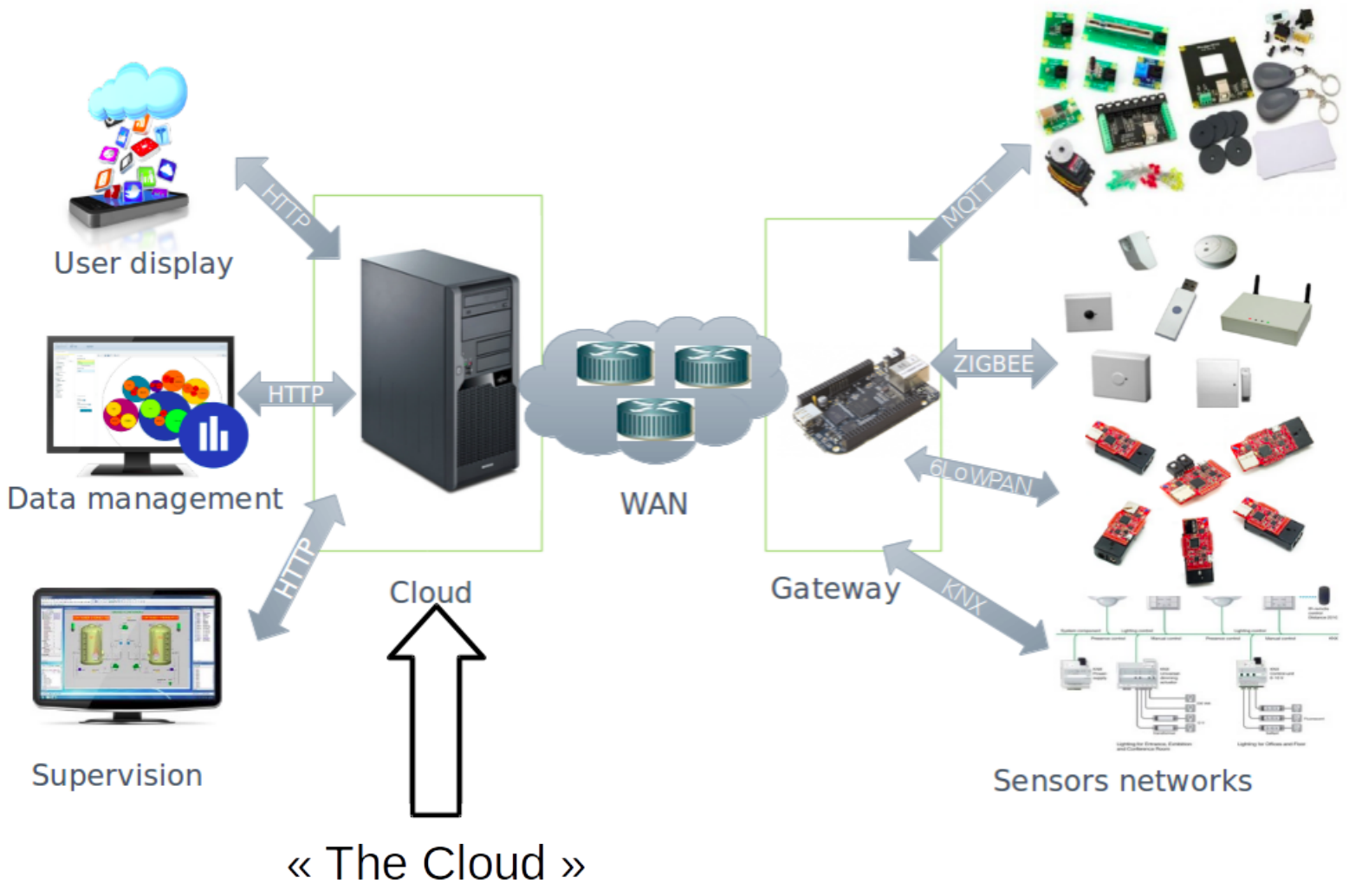
Large processing power in the Cloud



Applications are enabled by the Cloud

- Storage
- Processing
- Access control...

Reactive processing in the Fog



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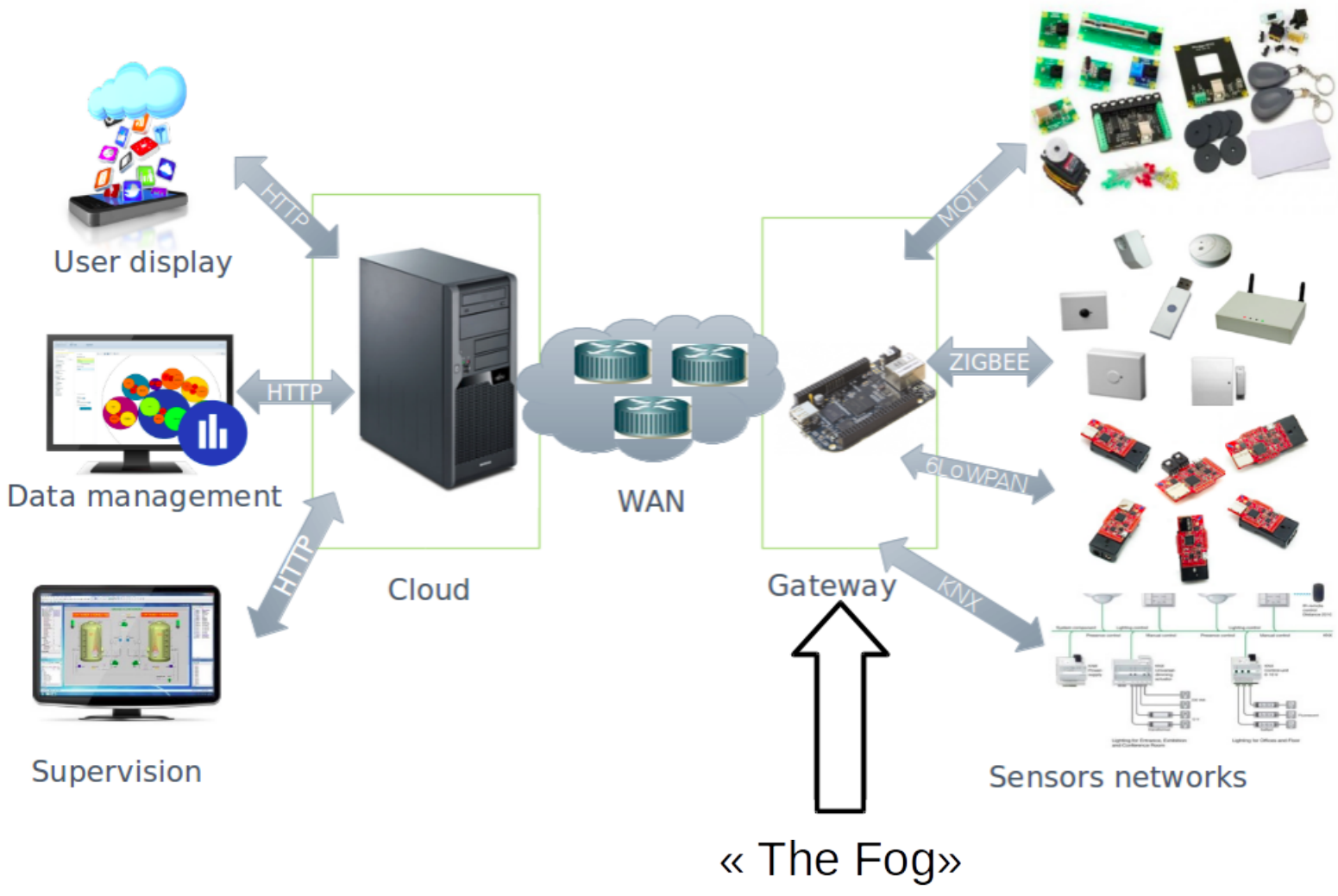
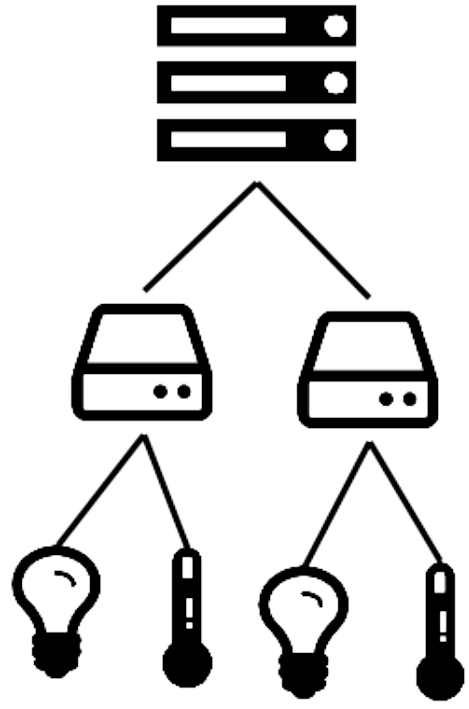


Fog characteristics

Fog and IoT are quite related

- Strongly distributed
- Potentielly mobile
- "Limited" calculation power
- The Fog is what connects the devices to the Cloud



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Rule-based reasoning

Capturing specific use cases

- Rules represent application-dedicated deductions mechanisms
- Rules can provide "behavioural interoperability"

From SWRL to SHACL

- SWRL allows the representation of rules that can be stored in an ontology
- SWRL evolved into SPIN, neither being W3C standards
- SHACL was adopted in 2017, to represent shapes and rules

Related work

Edge computing

- In [Taneja and Davy, 2017], applications component are distributed based on the resources they require

Rule-based reasoning

- LR[Khandelwal et al., 2011] and SLOR [Gyrard et al., 2017] model exchangeable rules
- [Maarala et al., 2017] measures the impact of distributed reasoning

In progress : Fog in the SWoT survey

- The fog is intrinsic to the IoT
- Before it was cool, the Fog was passive
- How is it used in the SWoT ?

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A scalable increase of responsiveness

Scalability through decentralization

- The IoT is growing[1]
- Centralization creates single points of failure

Enabling local decision making for responsivity

- Local decisions are quicker
- Making deductions closer to data source enables early notification

[1] https://internethealthreport.org/2018/spotlight-securing-the-internet-of-things/

Hypotheses

Network topology

- Nodes are organized hierarchically (3-tiers Cloud-Fog-Devices)
- Any reasoning node can communicate with the apps

Applications bursting

- Applications' business logic can be modelled with production rules
- These rules can be distributed

Intuition

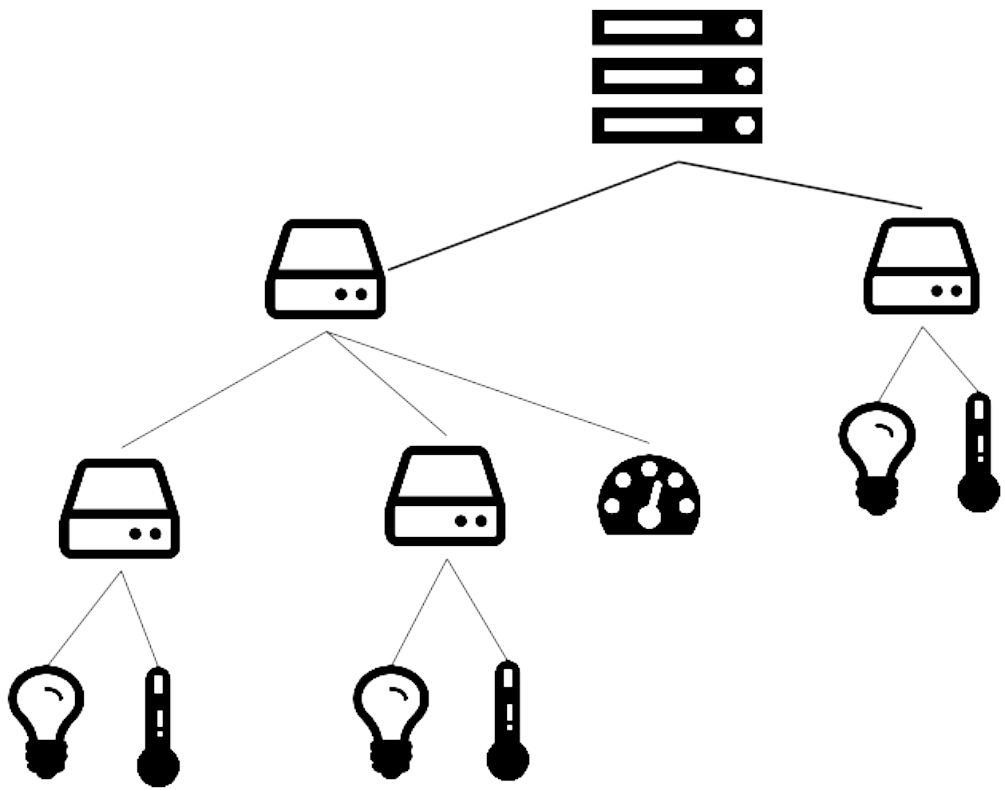
The closer, the better: moving to the Fog

- Reducing the distance and size of KB gives more reactivity [Maarala et al., 2017]
- The closer a gateway is to sensors, the less data it collects

Locality of decision

- Allowing nodes to make local decisions increases scalability

Illustrative use case



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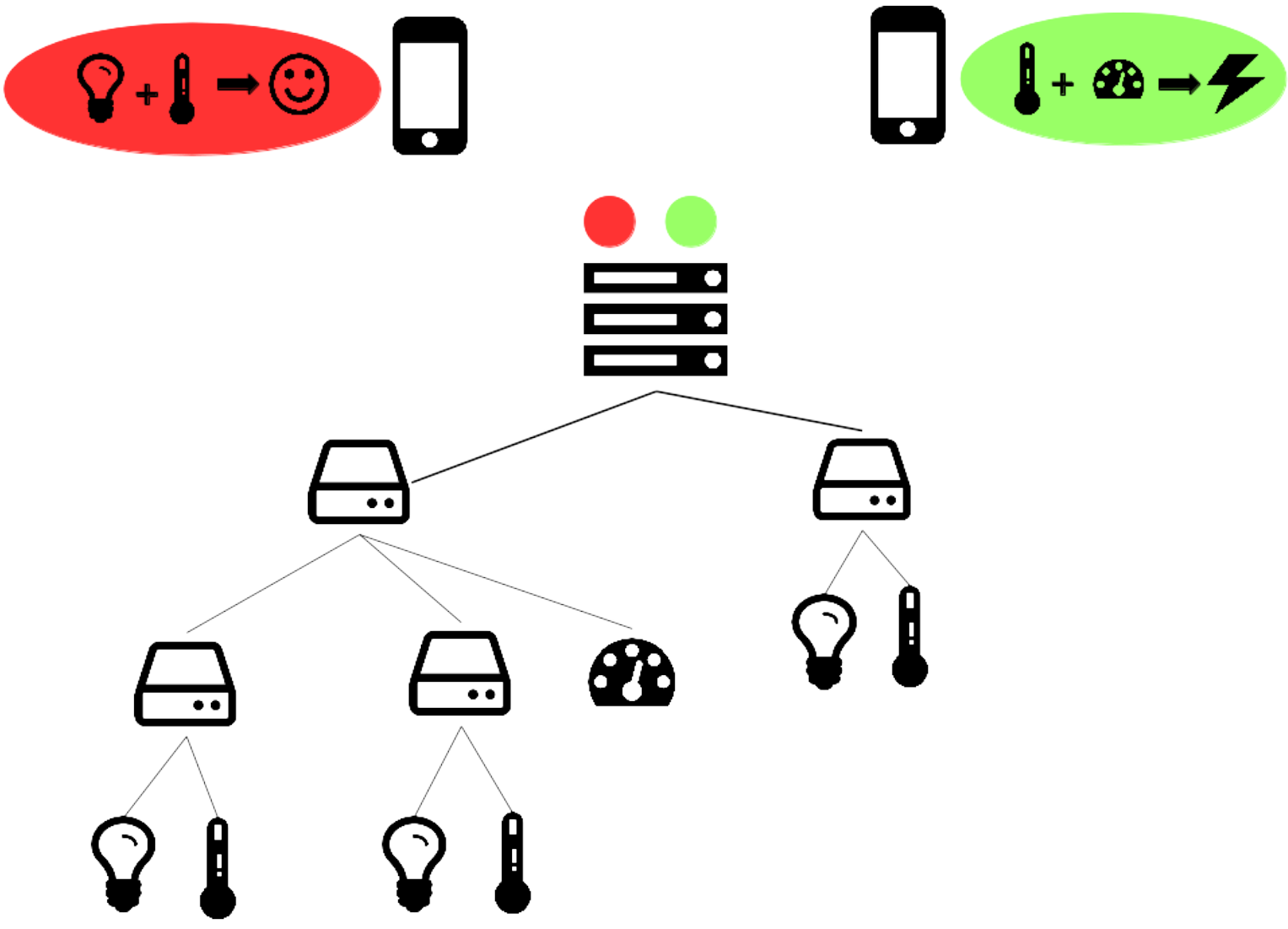

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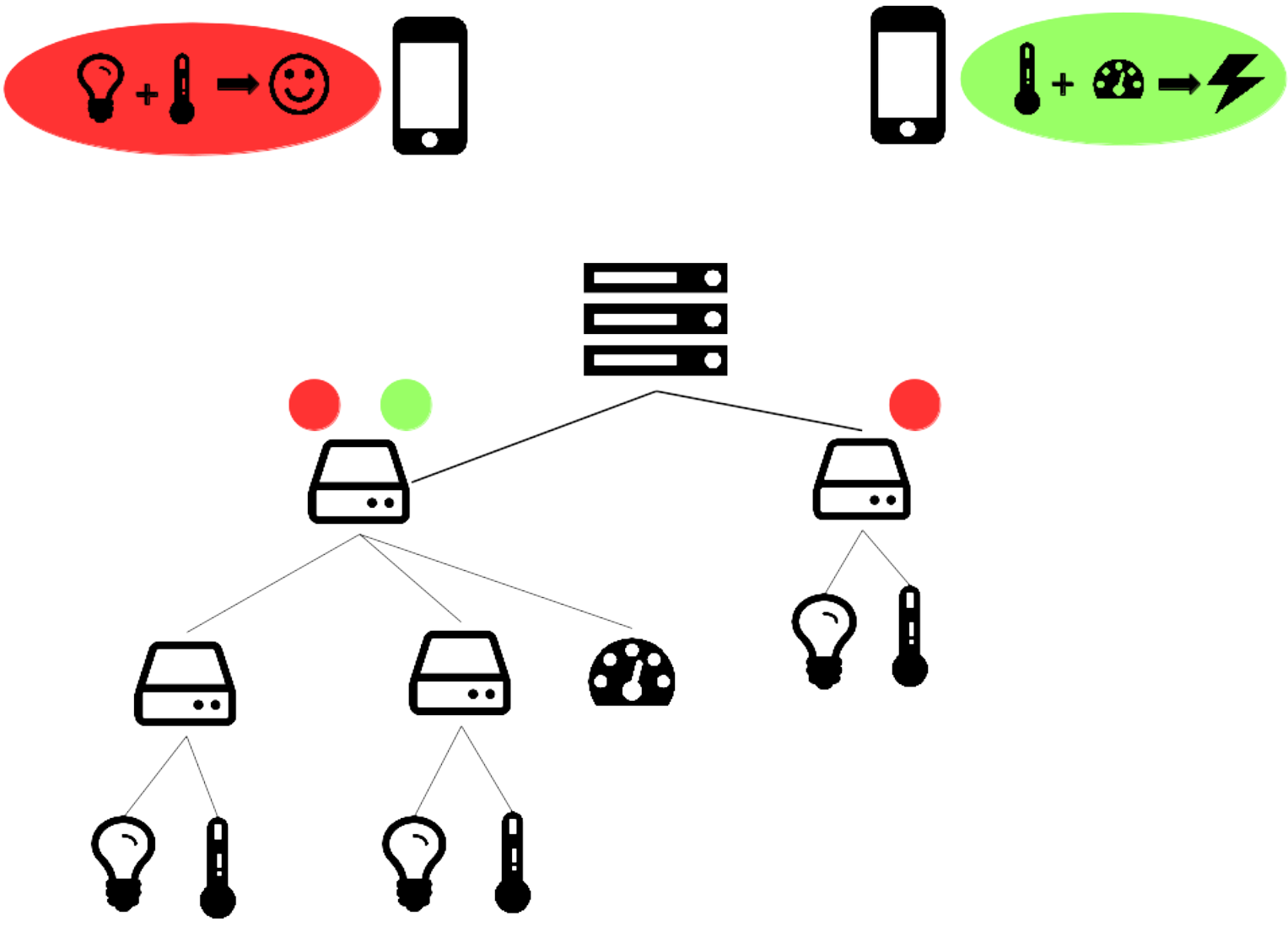

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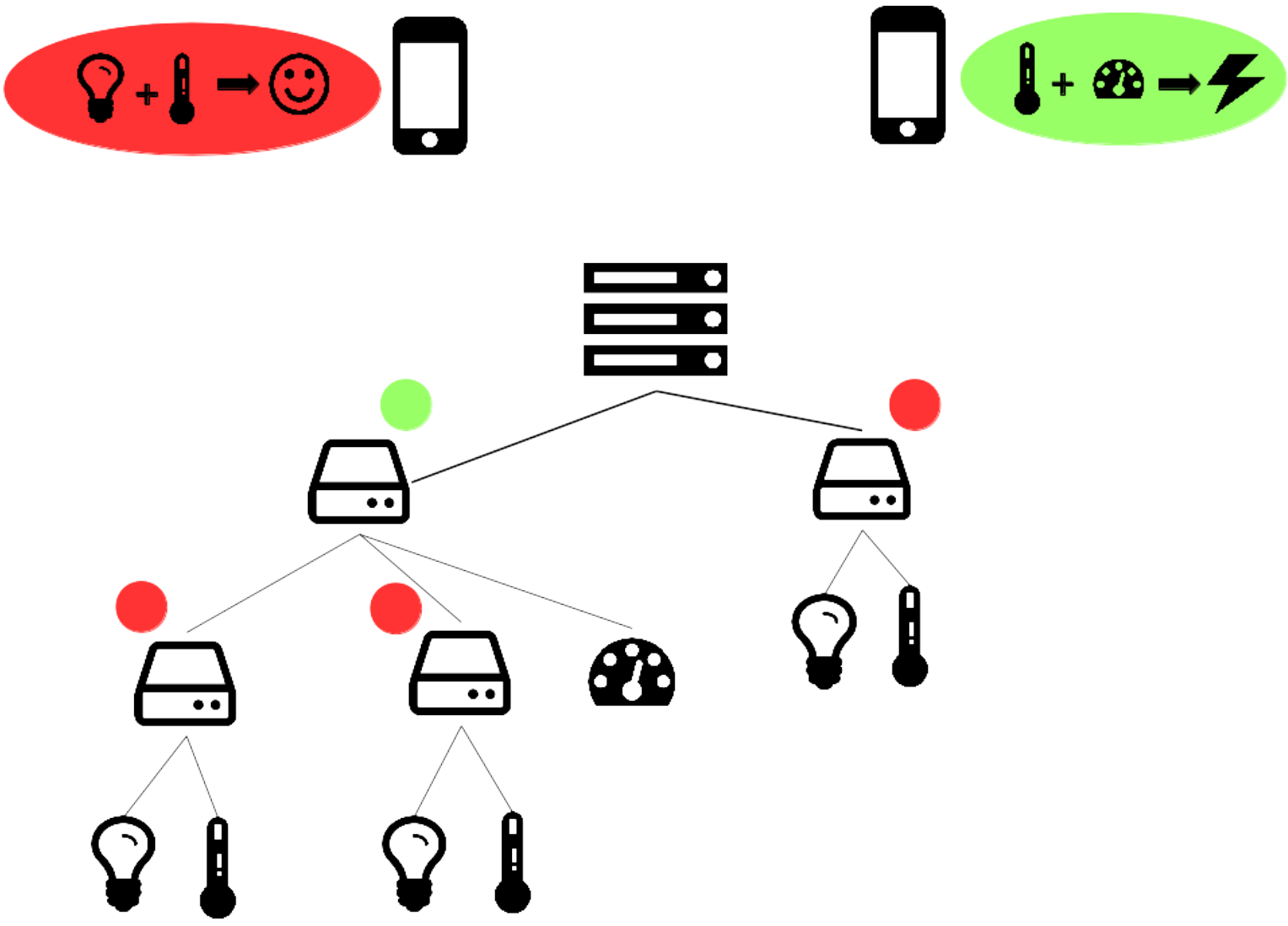

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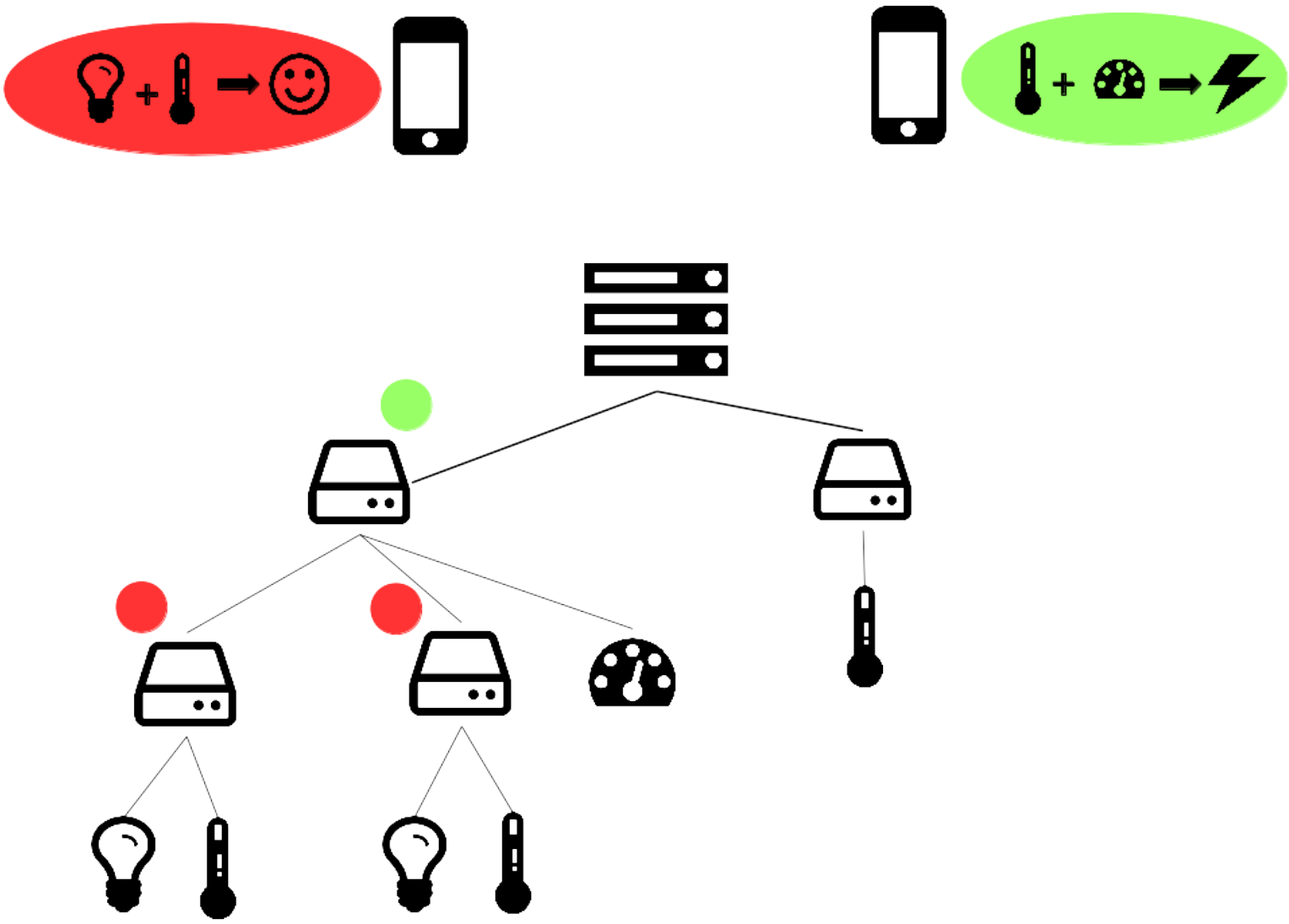

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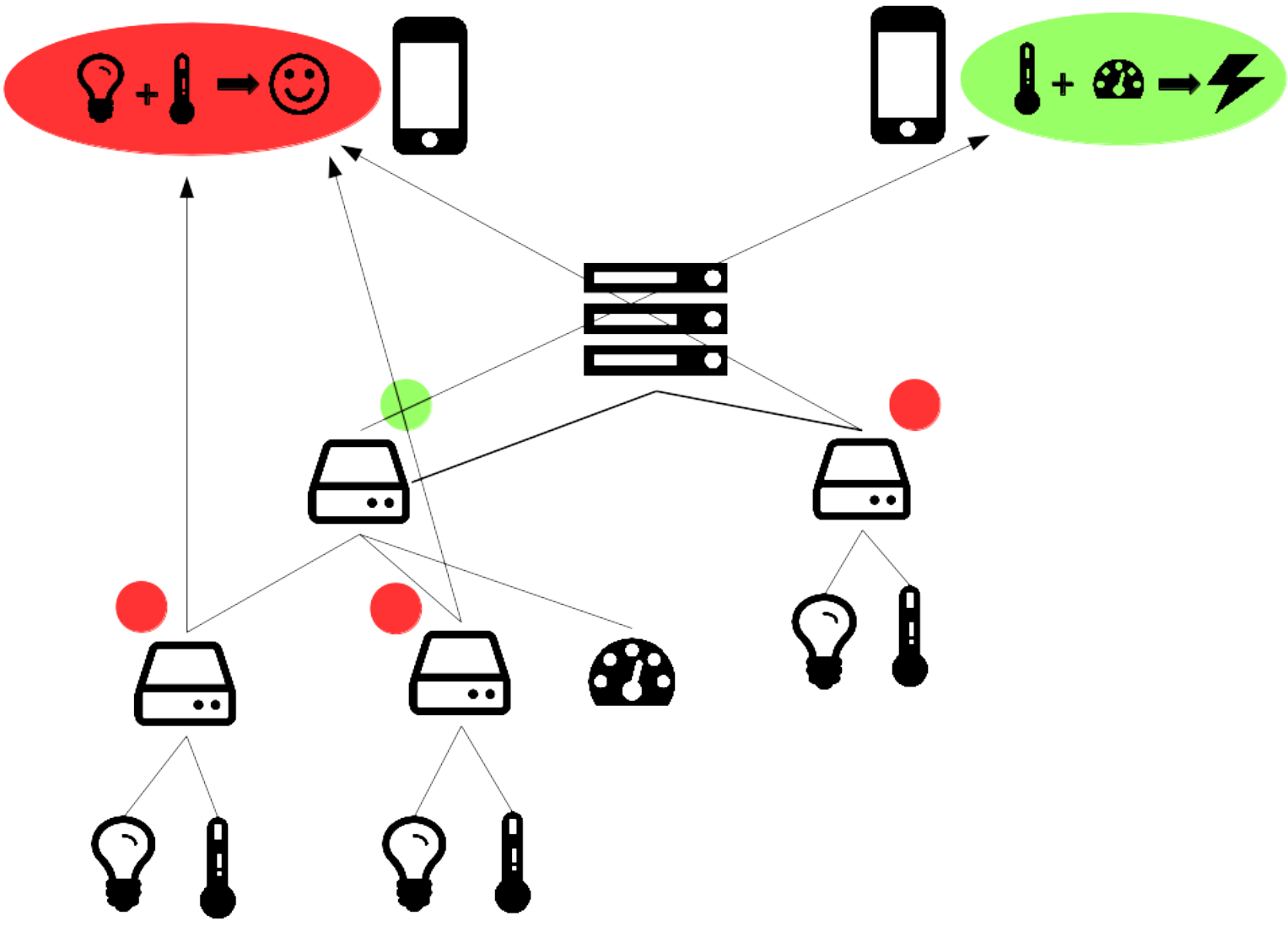

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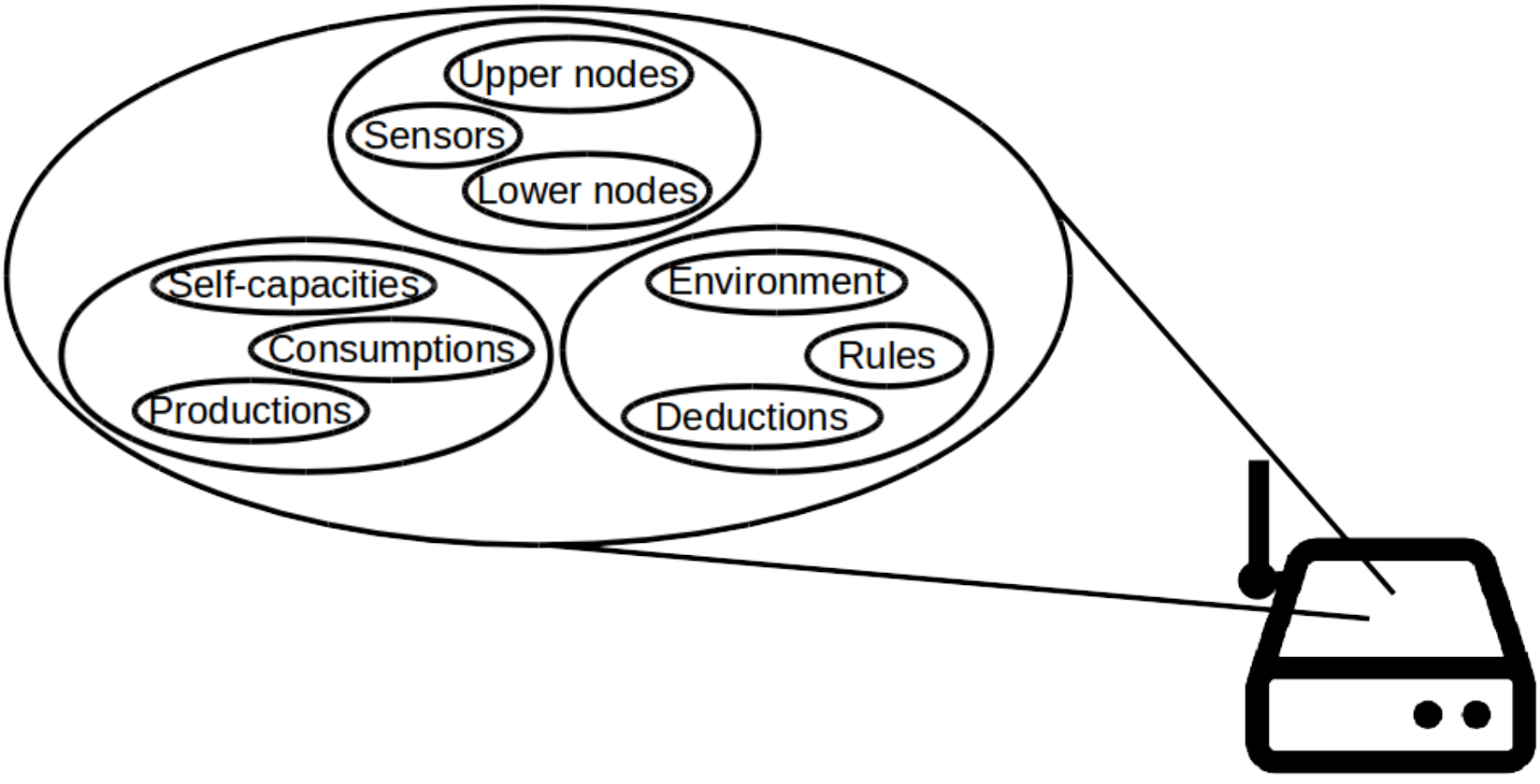
Nodes knowledge bases



An event-driven approach

Basing decisions on local knowledge

- Node transfer data and rules peer to peer
- Each node only knows its direct neighbors
- Proxying mechanism

Keeping a consistant topology representation

- Information is propagated on relevant events
- When does the topology evolve ?

Initialisation

What a node knows

- Self-knowledge
- Sensors and legacy devices to which it is connected
- Parent node in the hierarchy

What the node announces

Announces itself and its productions to its parent node

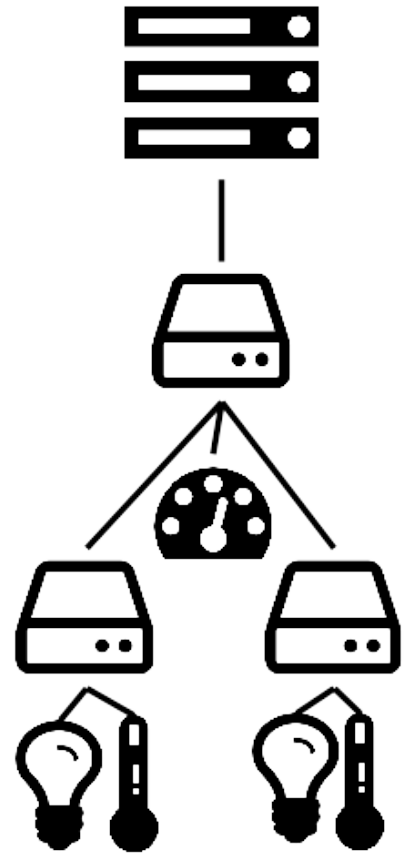
When the topology changes

When receiving announce from child

- Store new node information
- Proxy productions change to parent
- Reevaluate rule positioning

When receiving announce from parent

- Store new node information
- Proxy consumptions changes to children



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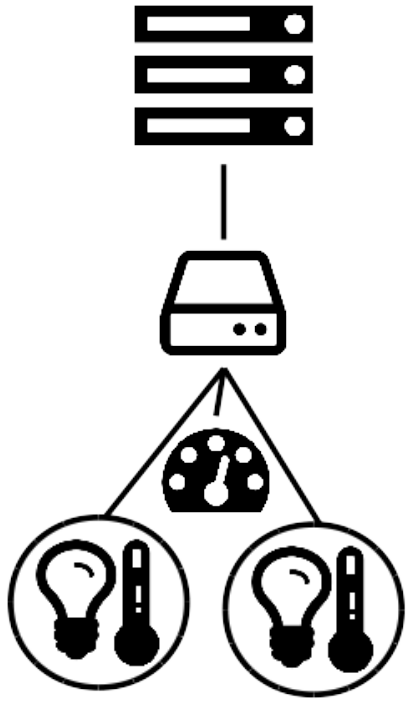

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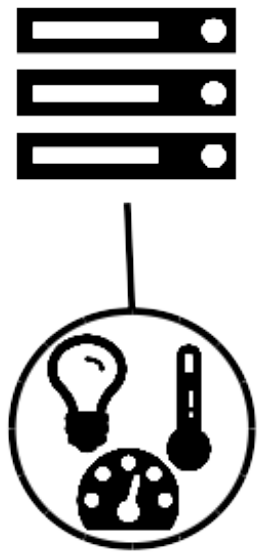

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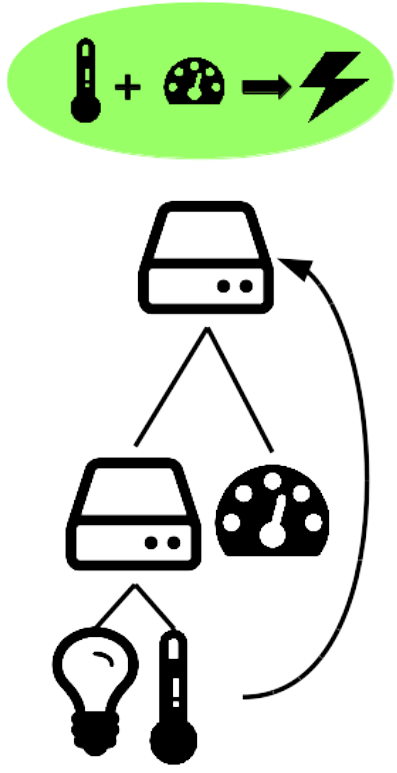


When receiving announce from parent

- Store new node information
- Proxy consumptions changes to children

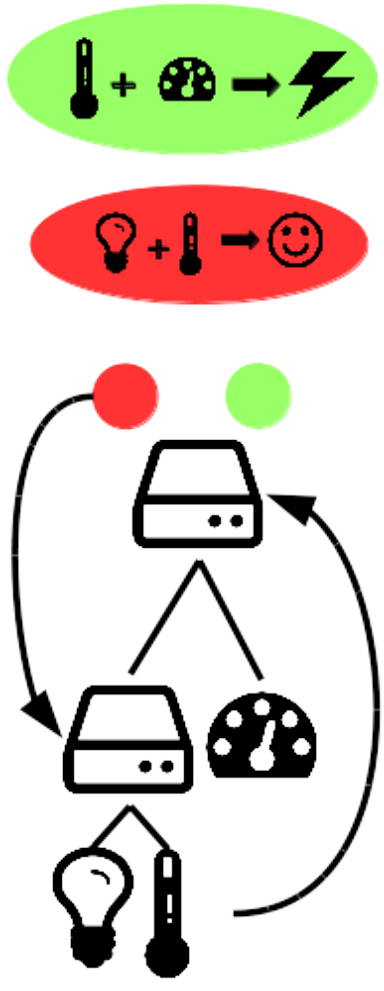
When receiving a new rule

Applying the rule

- Collecting observations from sensors
- Aggregating observations from children

Transferring the rule

- Transfer to children producing relevant observation types



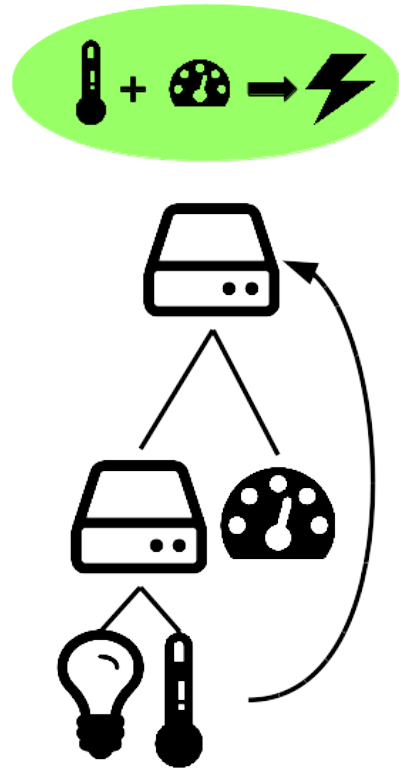
When receiving a new observation

Applying relevant rules

- Transferring deductions to originators and to consumers

Transferring the observation

- Transfer to children producing relevant observation types



Two implementations

Regular

- Rules are represented in SHACL
- Behaviour is code-based
- Reasoning is based on a regular SPARQL engine

SHACL

- Rules and conditions are represented in SHACL
- Coded behaviour is generic
- Reasoning is based on a SHACL engine

A SHACL EDR rule

Rule metadata

- Transferrability
- Applicability
- Result consumers

Rule core

- SPARQL CONSTRUCT
- Deduction mechanism

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Measured parameters

Deduction time

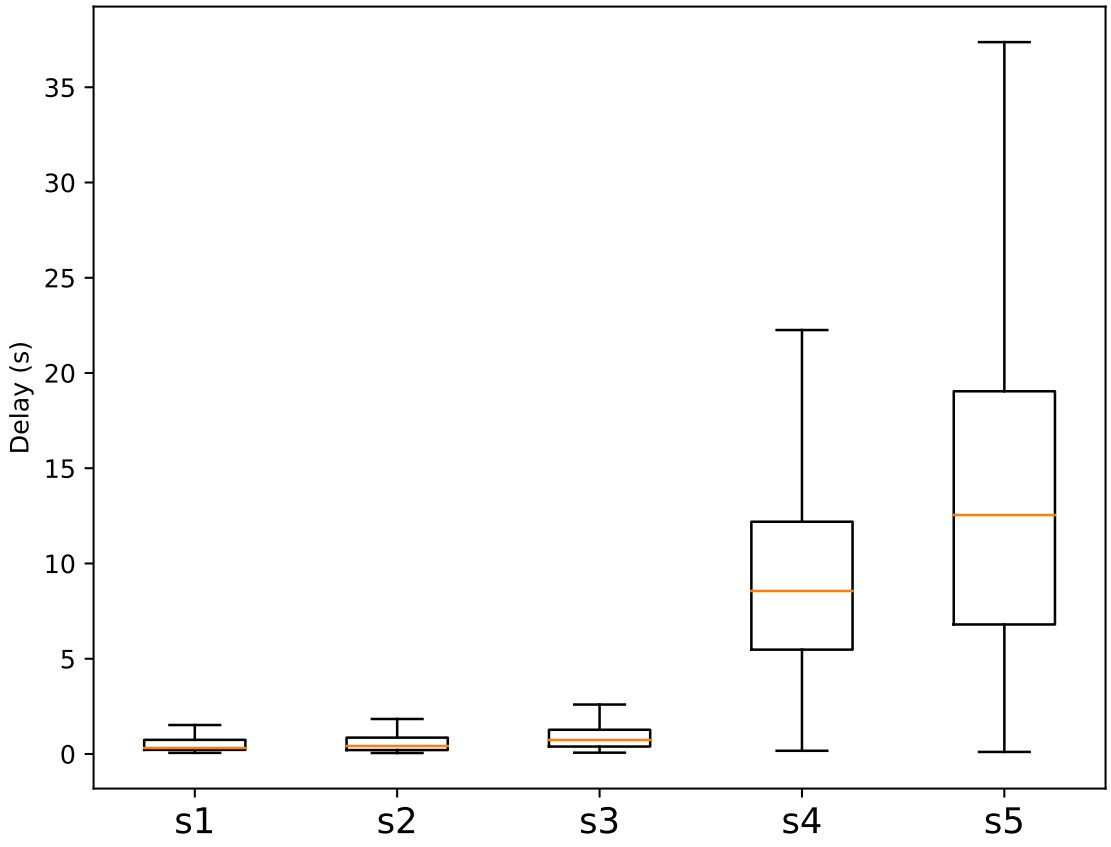
- Time between the last observation and the deduction

Modified parameters

- Scalability: Increase the number of nodes
- Distribution: Reduce the centrality of reasoning

Scalability evaluation

	Nodes
s1	17
s2	27
s3	41
s4	65
s5	78



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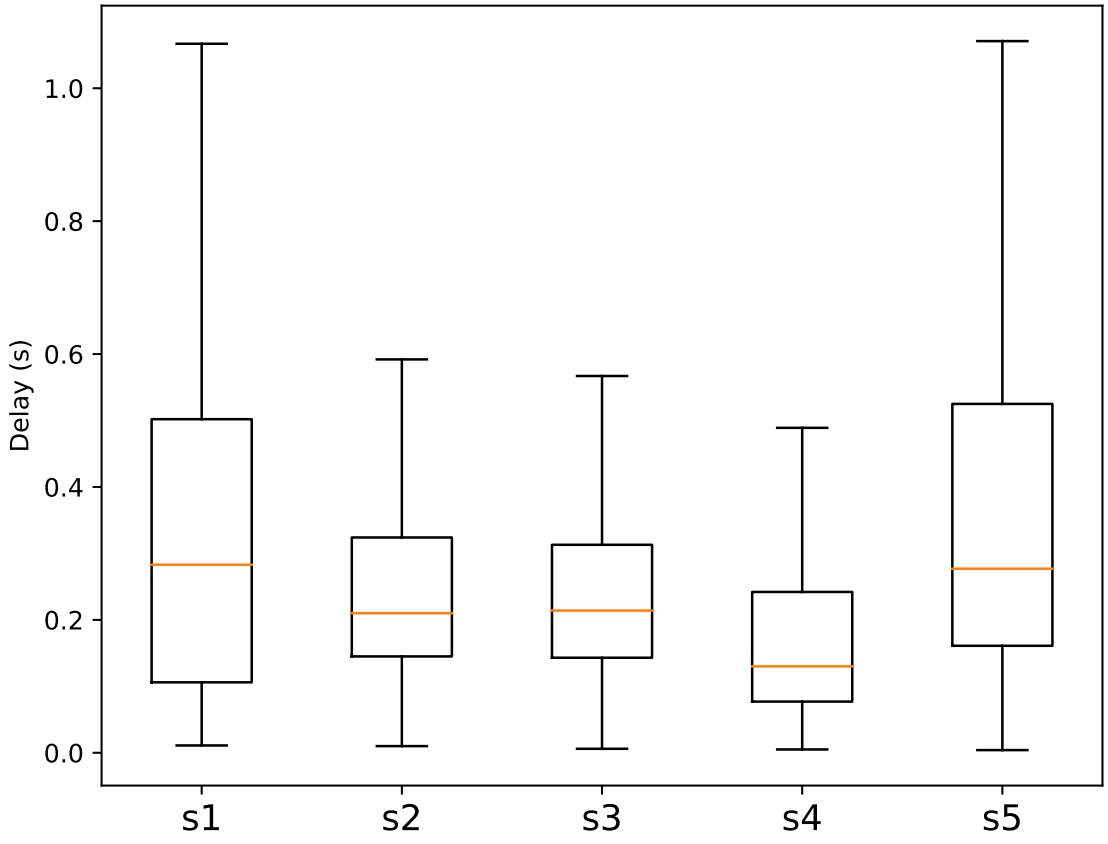
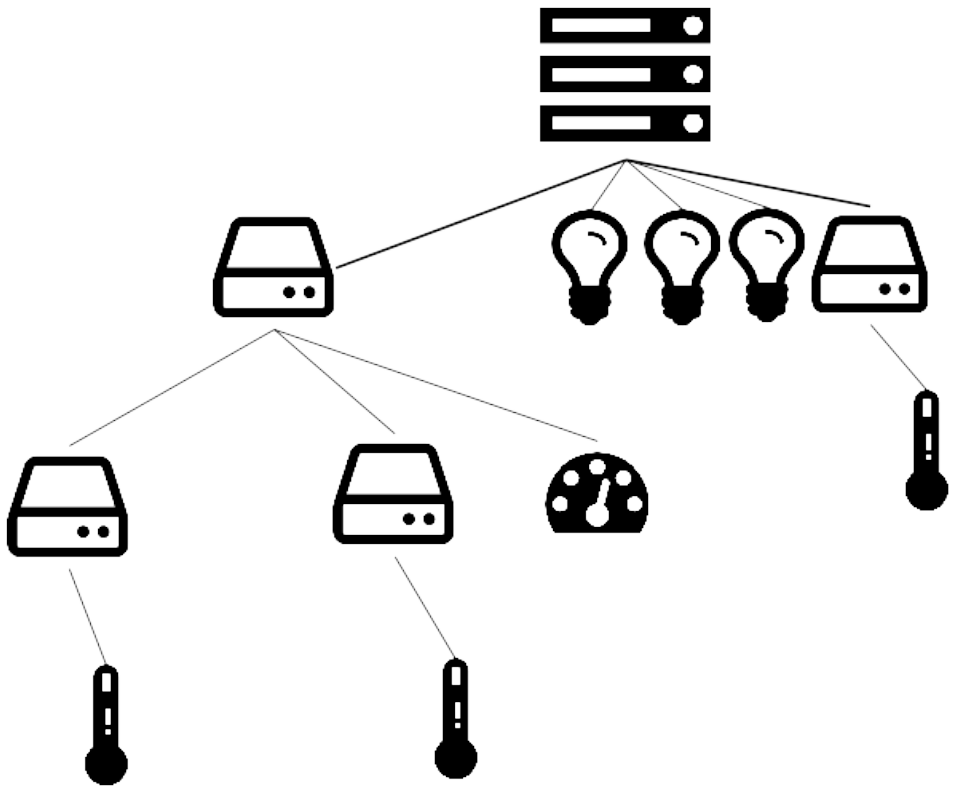


Distribution evaluation protocol



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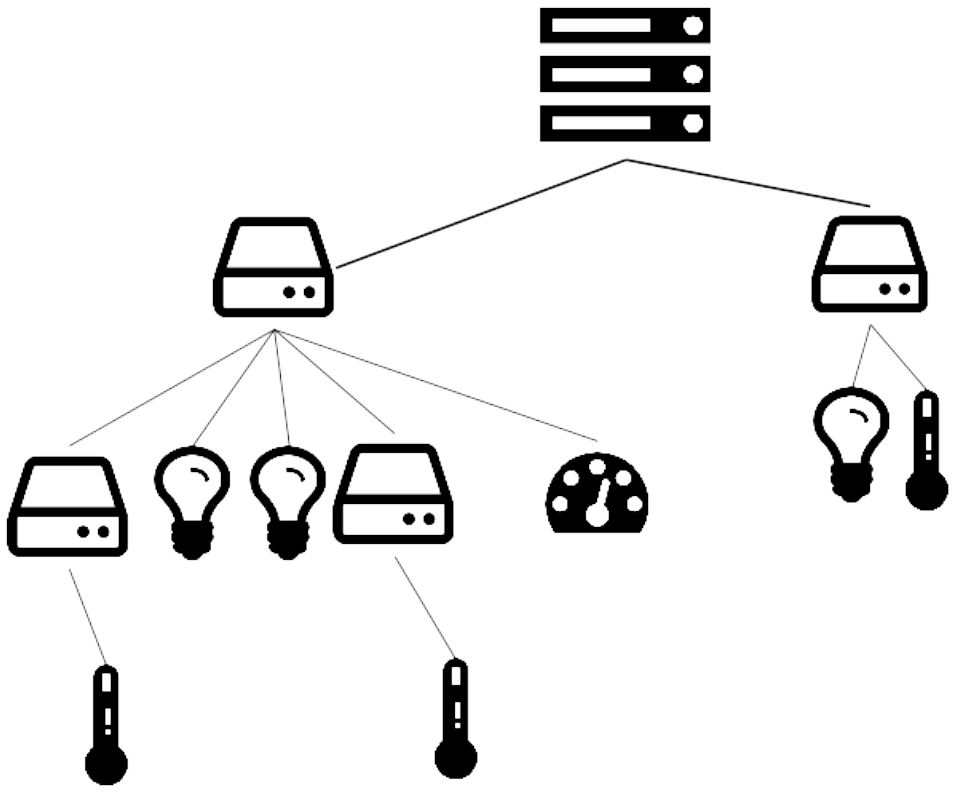

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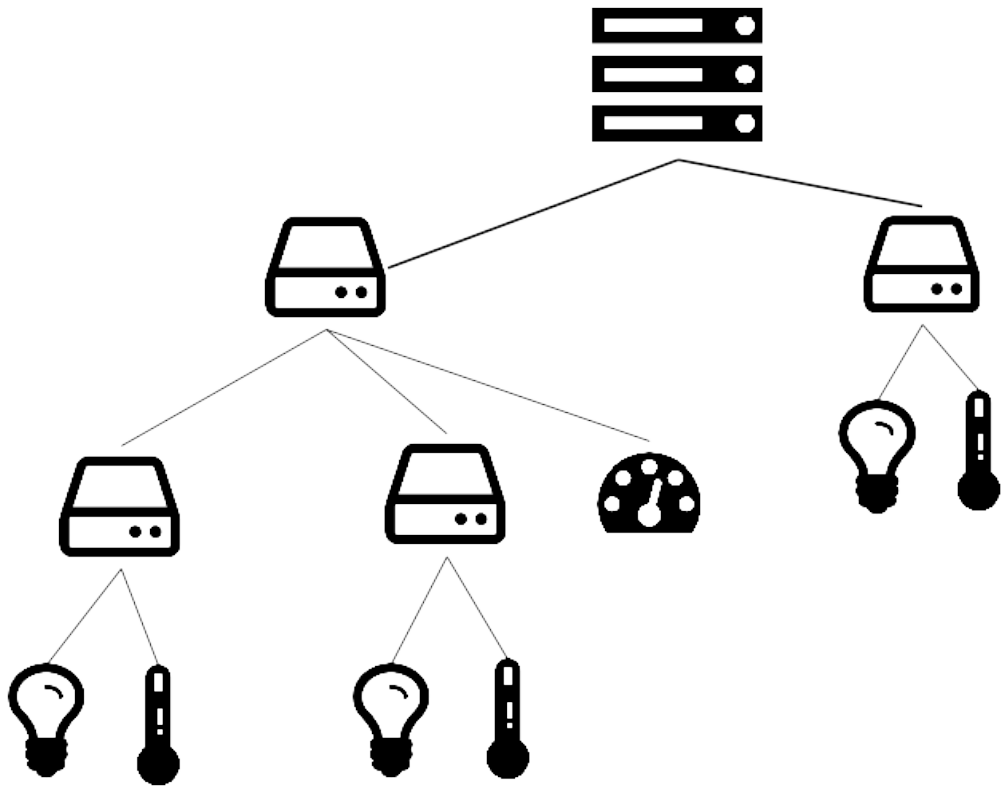
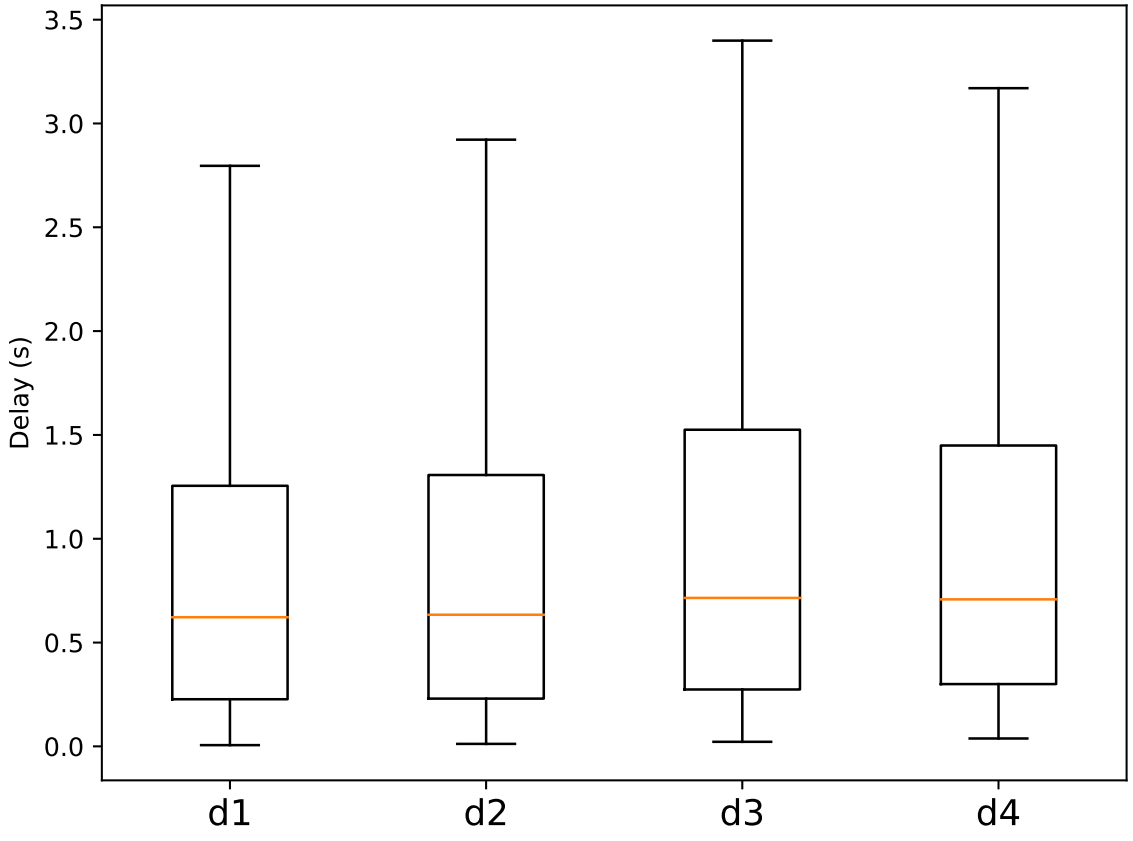


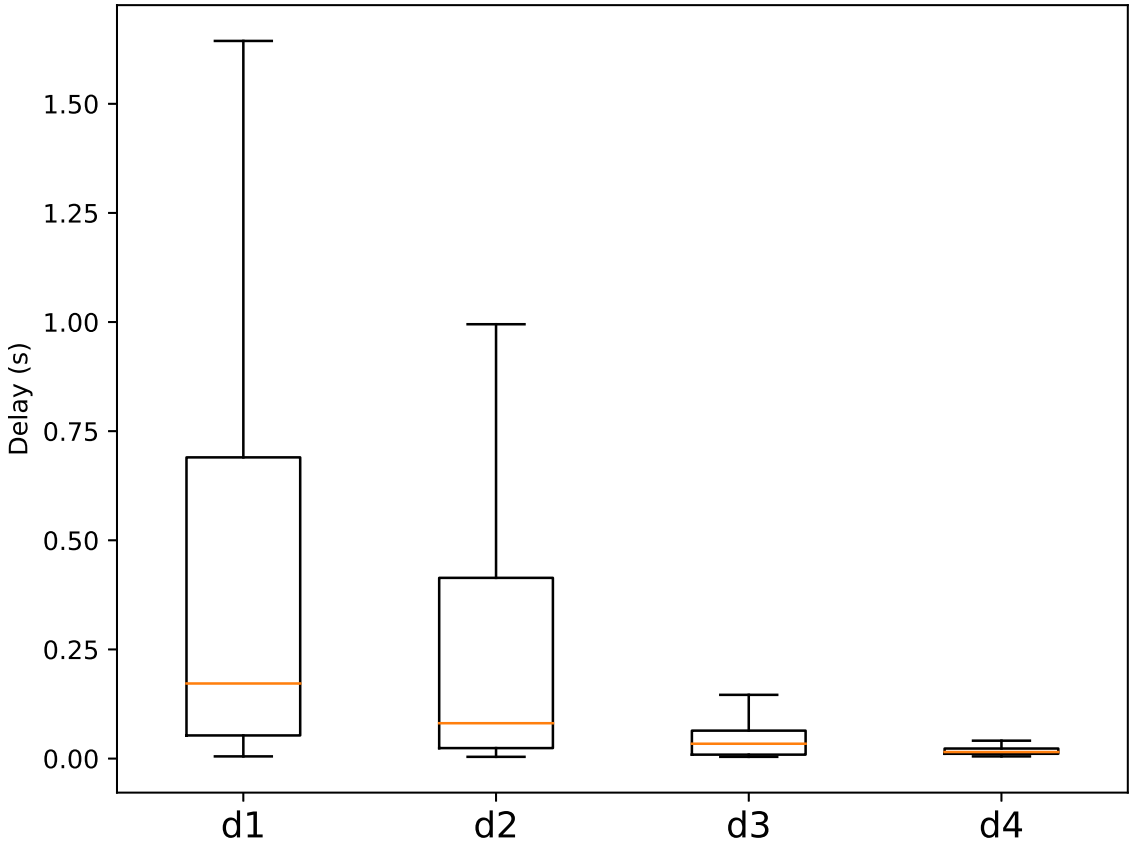
Distribution evaluation

Maximum depth	**r1**	**r2**	**r3**	**r4**
d1	1	2	3	4
d2	2	2	3	4
d3	3	3	3	4
d4	4	4	4	4



Distribution evaluation

Maximum depth	**r1**	**r2**	**r3**	**r4**
d1	1	2	3	4
d2	2	2	3	4
d3	3	3	3	4
d4	4	4	4	4



Agenda

Toward semantic interoperability for the IoT
- Context: Why do we need the SWoT ?
- Contribution: IoT-O and its usage

Toward scalability and dynamism for the SWoT
- Context: IoT resources constraints
- Moving reasoning to the Fog

The EDR algorithm (Emergent Distributed Reasoning)

Experimental results

Conclusion and future work

Conclusion

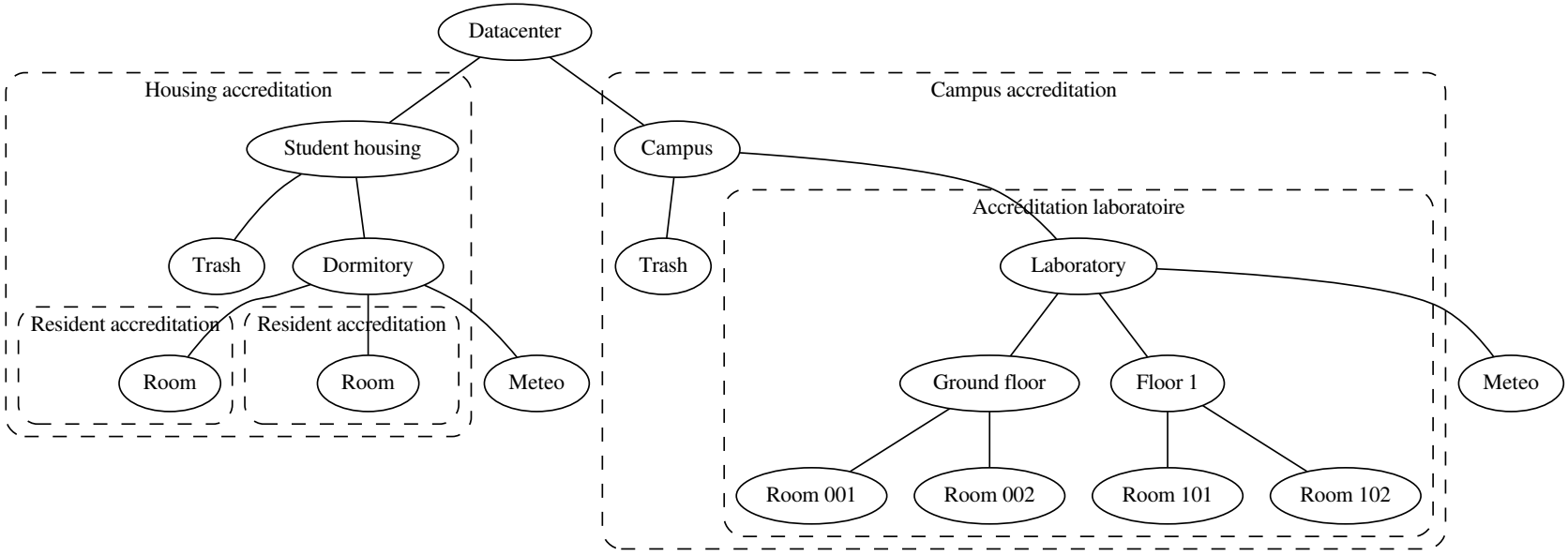
The SWoT is about interoperability...

- Standards are converging towards the SWoT
- The Semantic Web is a machine-interoperability providers

... and the Fog supports decentralization

- Distribution provides interoperability
- Many nodes are between IoT devices and the Cloud

Future work



Privacy

- Locality of reasoning supports privacy
- The rules are exchanged instead of data

Collaboration ground

- Fog-based processing
- Reasoning distribution
- Privacy
- SWoT applications in general