

A Distributed Scalable Approach for Rule Processing: Computing in the Fog for the SWoT

Nicolas Seydoux^{1,2} Khalil Drira¹ Nathalie Hernandez²
Thierry Monteil¹

LAAS-CNRS,
Université de Toulouse, CNRS, INSA, Toulouse, France

IRIT,
Univ. Toulouse Jean Jaurès, Toulouse, France

Contact: {nicolas.seydoux}@laas.fr

From IoT to SWoT

IoT

- Multiple application domains (e.g. domotics, smart city, e-health...)
- Hardware, communication and software heterogeneity

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Semantic Web

- Native human and machine understandability
- Interoperability based on shared conceptualizations [?]

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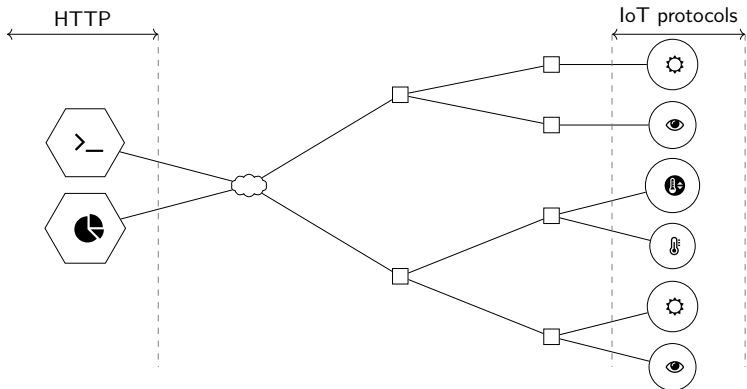
- ### Semantic Web requirements
- Resource-consuming processing and formats
 - Limited scalability

From IoT to SWoT

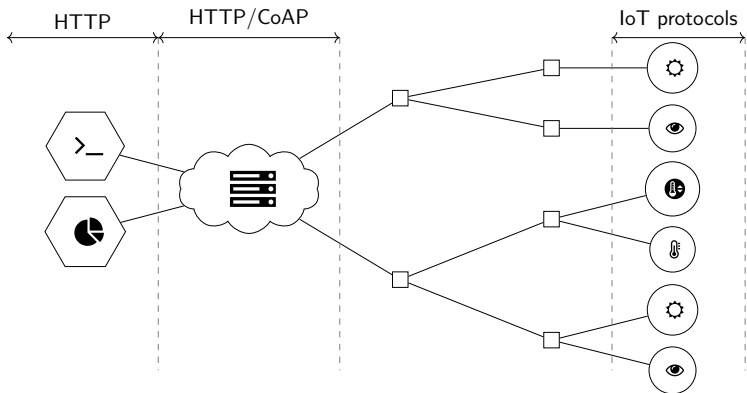
Semantic Web of Things (SWoT)

- Incepted early [Berners-Lee et al., 2001]
- Coming together recently [Scioscia and Ruta, 2009]

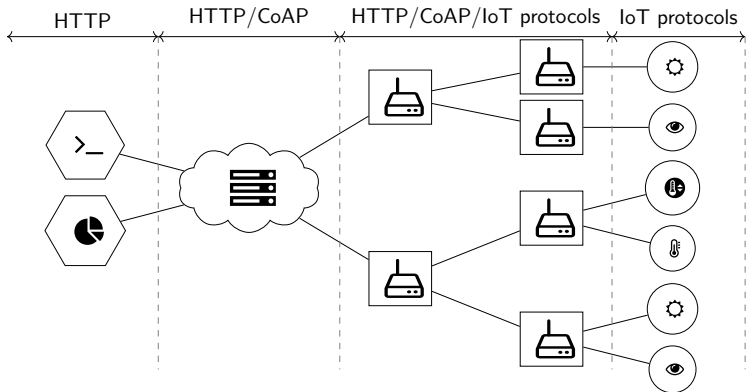
SWoT architecture



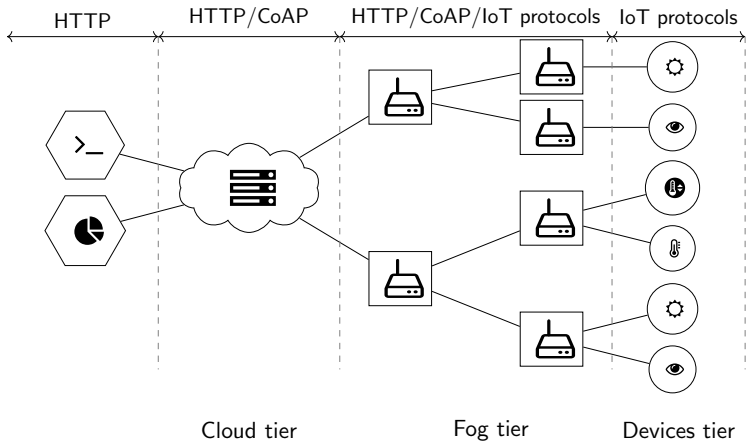
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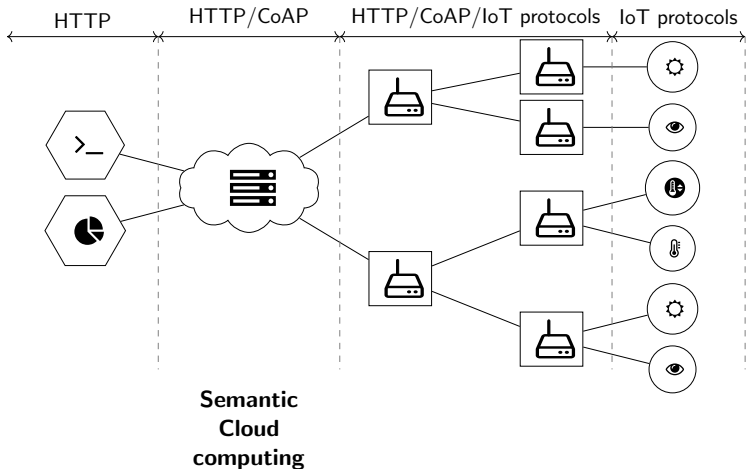
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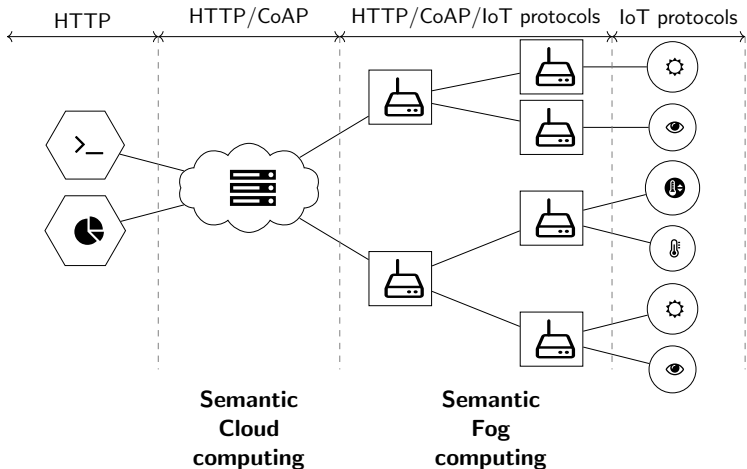
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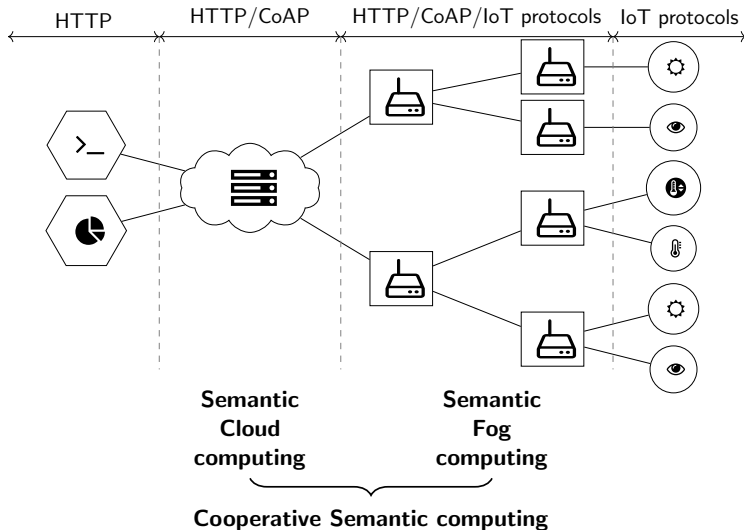
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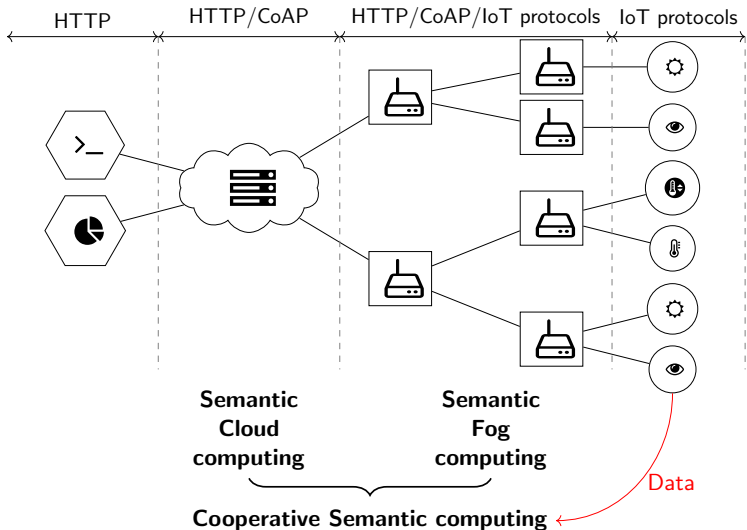
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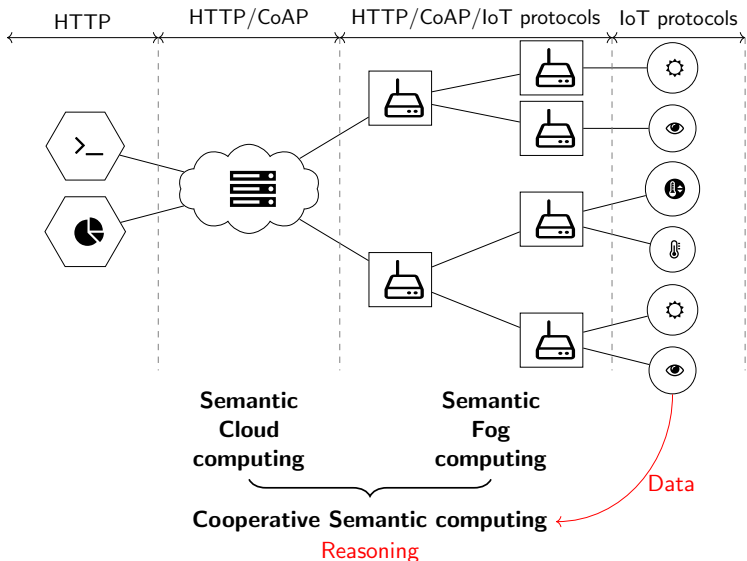
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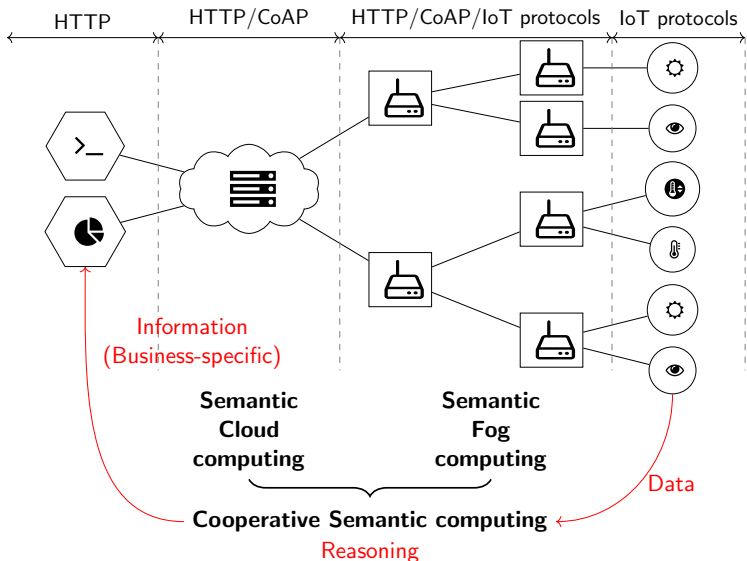
SWoT architecture



SWoT architecture



SWoT architecture



Issues tackled in this contribution

Enabling distributed reasoning through deduction representation

- Rules are self-contained expressions of deductive mechanisms
- Rules may be exchanged among nodes to propagate reasoning

Dynamically decentralizing computation

- Computation should be shared between Cloud and Fog nodes
- Nodes should be able to make propagation deduction locally

Rule management

Reusing rules

- Linked Open Rules [Khandelwal et al., 2011]
- S-LOR [Gyrard et al., 2017]

Rule formats

- SWRL [Horrocks et al., 2004] and SPIN [Knublauch et al., 2011]
- RIF [Kifer and Boley, 2013]
- SHACL [Knublauch and Kontokostas, 2017] and its extensions

Where are rules processed ?

On Cloud nodes

- Studies such as [Wang et al., 2018] or [Gyrard et al., 2017] store and process the rules on Cloud nodes
- Latency and scalability issues of such approaches are studied in [Maarala et al., 2017]

On Fog nodes

- Studies such as [Desai et al., 2014] or [Kaed et al., 2018] propose to deploy rules on Fog nodes
- Such approaches focus on individual optimizations, and not on dynamic deployment

Contribution: EDR_T

Dynamically distributing rule-based reasoning

- Based on SHACL rules
- Associated to a propagation algorithm
- Peer-to-peer rule propagation
- Local decisions based on proxying

EDR_T, bringing computation closer to sensors

- Propagates rules as close to sensors as possible
- Considers produced and consumed data types

Assumptions about the rules

Nature of the rules

- Application-level logic is captured in **production rules**
- Rules capture patterns in a node's KB
- In particular, rules consume properties of features of interest (temperature, luminosity) to produce high-level symptoms

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Restrictions on rules considered

- Compliant with LOR principles
- Aggregation rules are excluded
- Only stratified rule set are considered

Rule representation

Office discomfort (R_d): If someone is in an office where the luminosity and the temperature are too low, this office is uncomfortable.

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$$R_d: \text{person} \text{ eye} \text{ thermometer} \rightarrow \text{flag}$$

$$r_x : \underbrace{\Gamma_1 \wedge \dots \wedge \Gamma_n}_{\text{body}} \rightarrow \underbrace{\Delta_1 \wedge \dots \wedge \Delta_m}_{\text{head}}$$

Rule representation

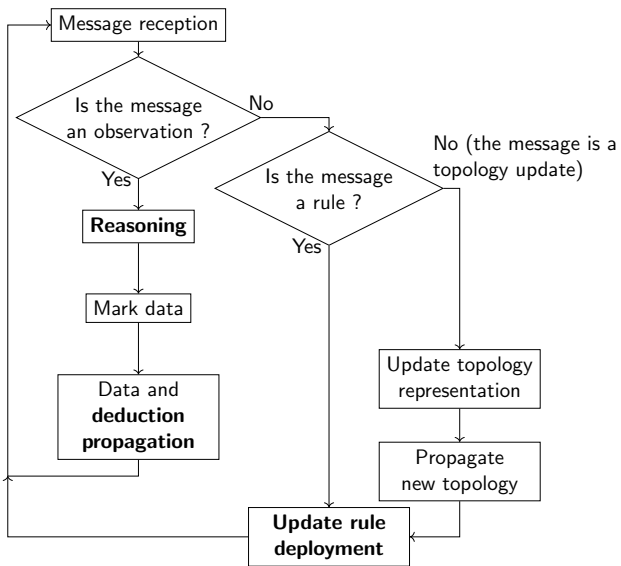
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$$\text{body}_t(r_x) = \{\Gamma_1, \dots, \Gamma_n\} \quad \text{head}_t(r_x) = \{\Delta_1, \dots, \Delta_m\}$$

Propagation algorithm



ADREAM, an example of smart building

- Over **6500 sensors** in the building



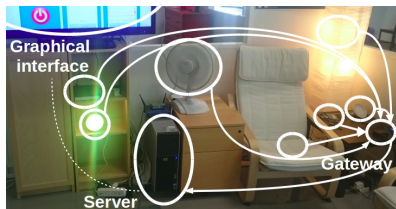
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ADREAM, an example of smart building

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













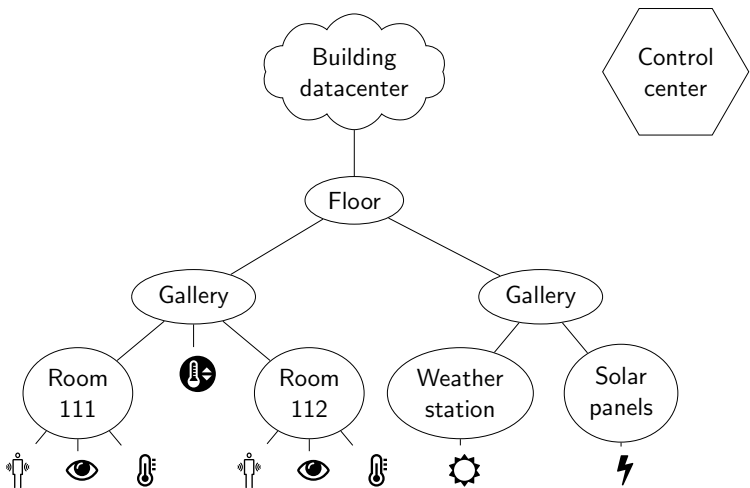
Illustrative use case

Smart building management

- Event detection in the building
- Notifications to the control center

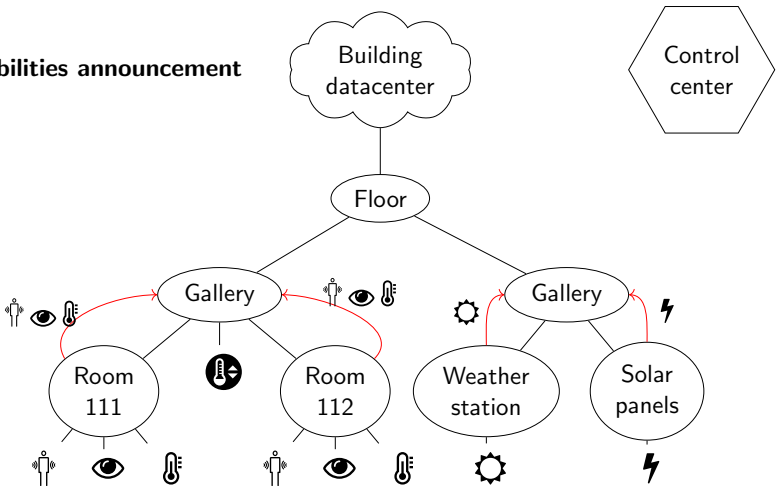
Rule examples

- Office discomfort (R_d):    → 
- Abnormal production (R_p):   → 
- HVAC malfunction (R_h):   → 

EDR_T by the example

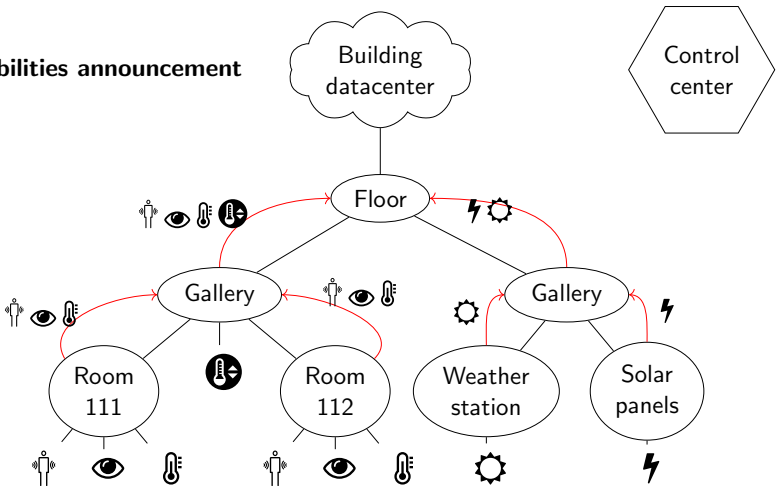
EDR_T by the example

Capabilities announcement



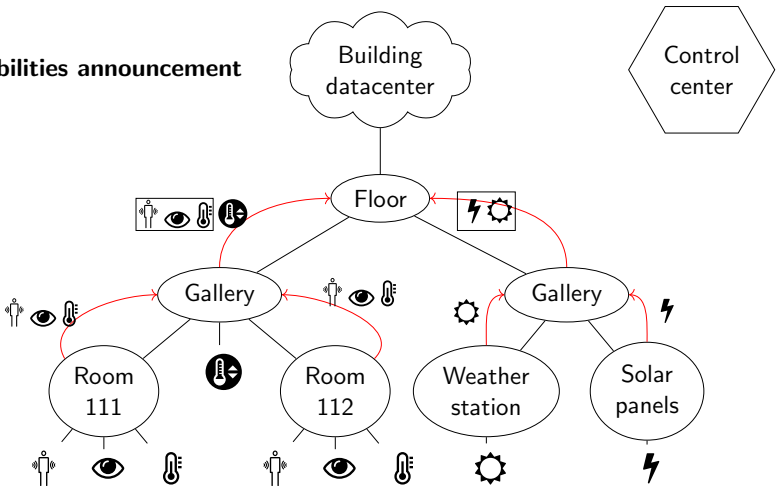
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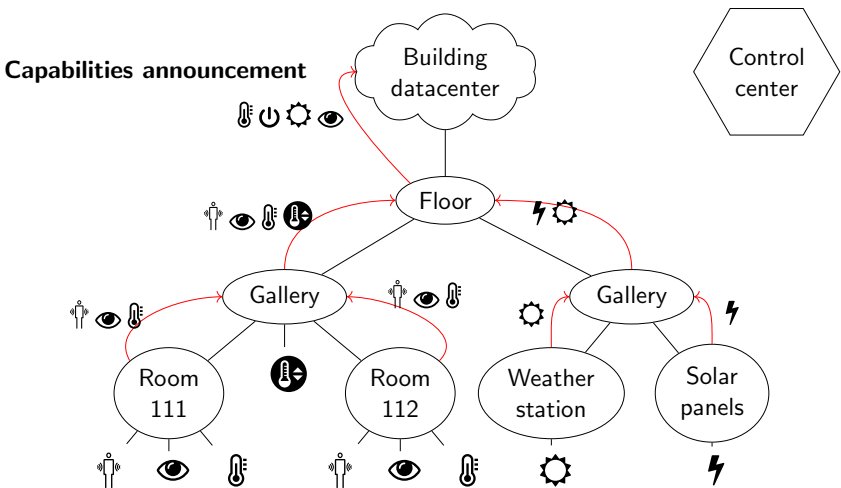


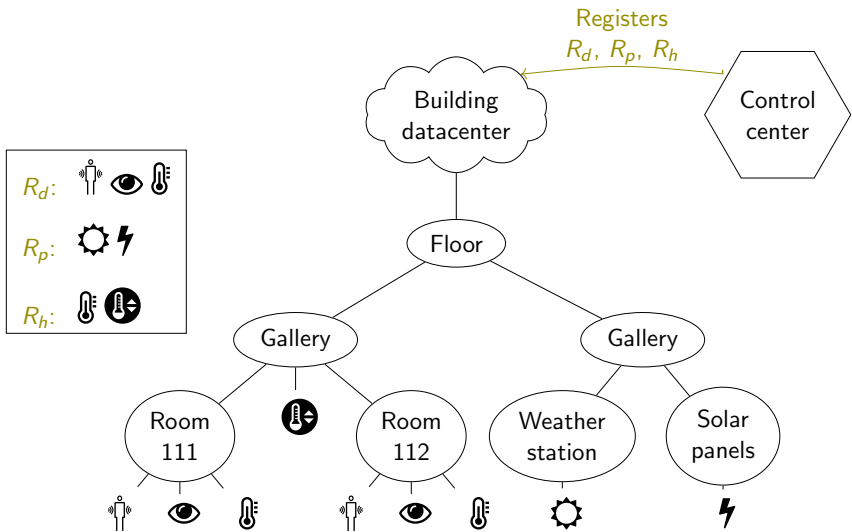
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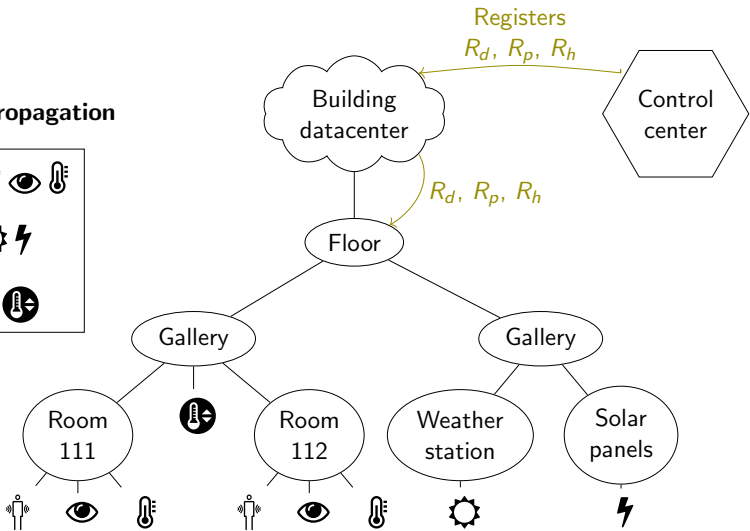
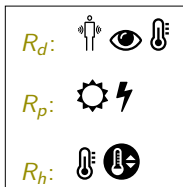
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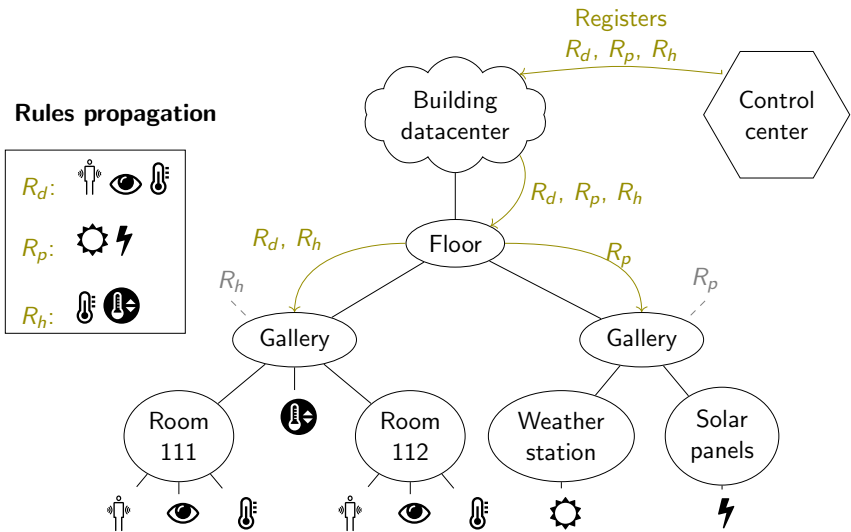


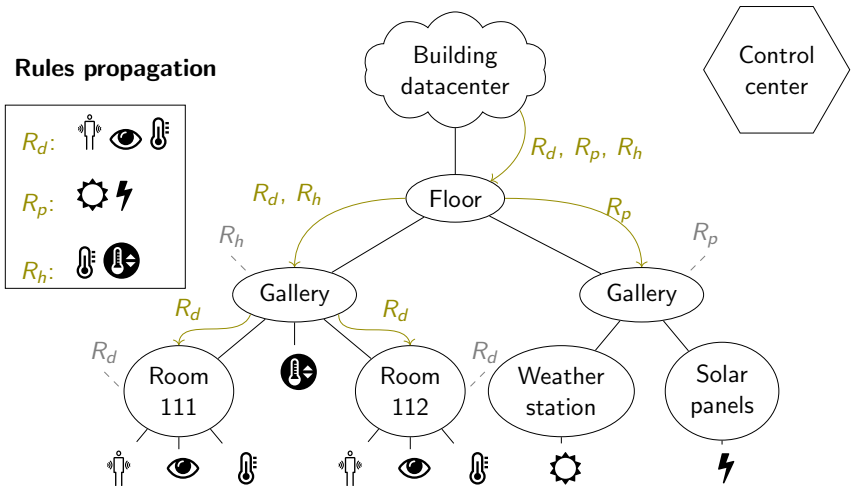
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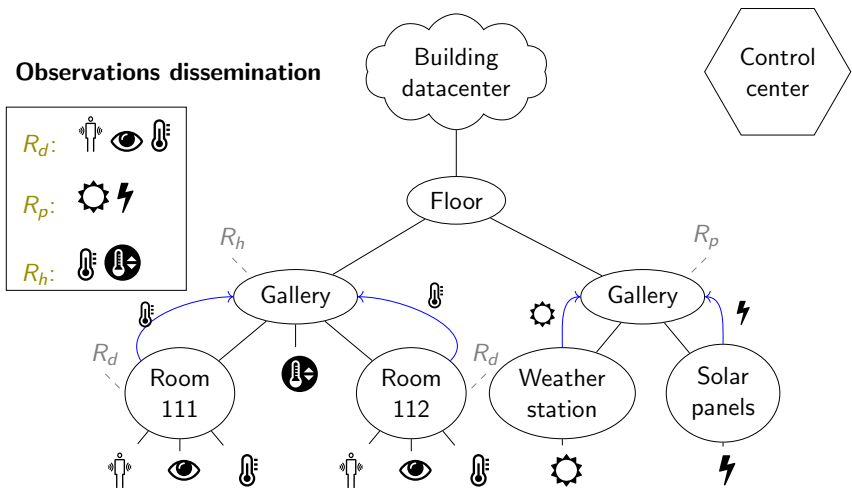
EDR_T by the example

Rules propagation



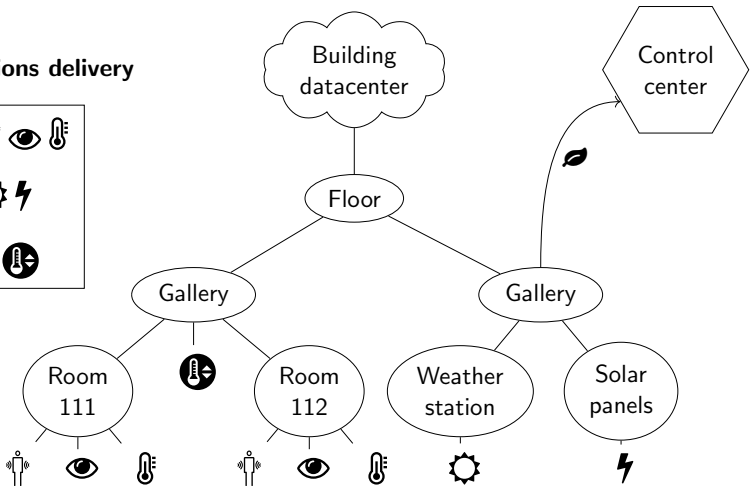
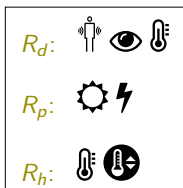
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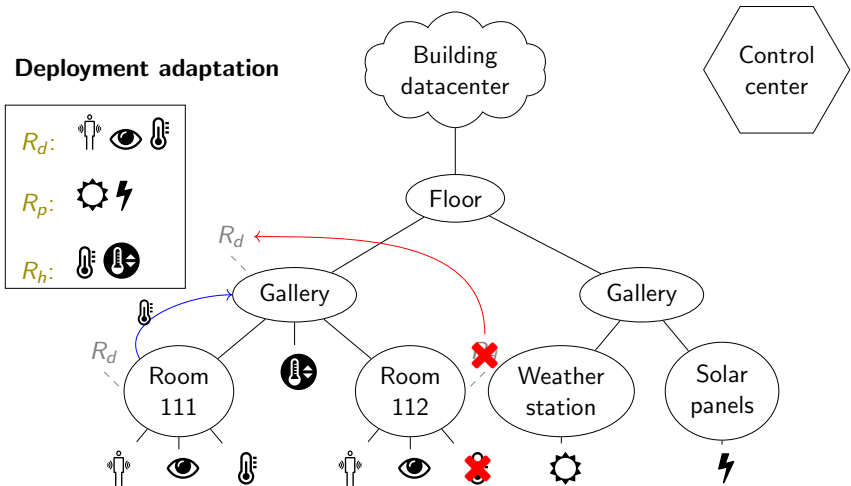
EDR_T by the example

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Deductions delivery



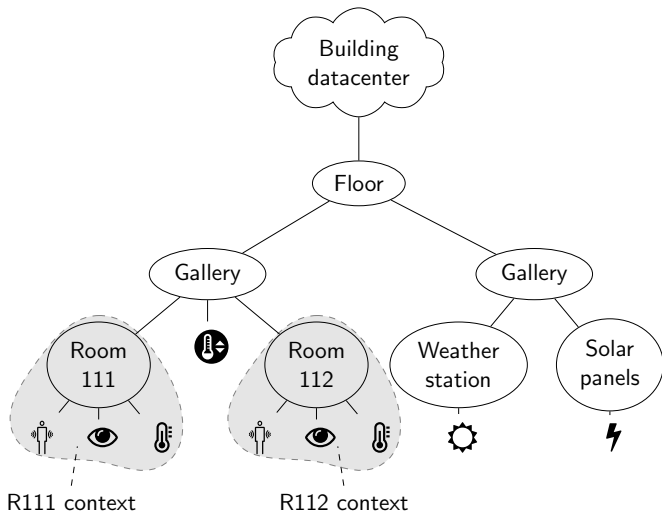
EDR_T by the example

Assumptions made on the topology

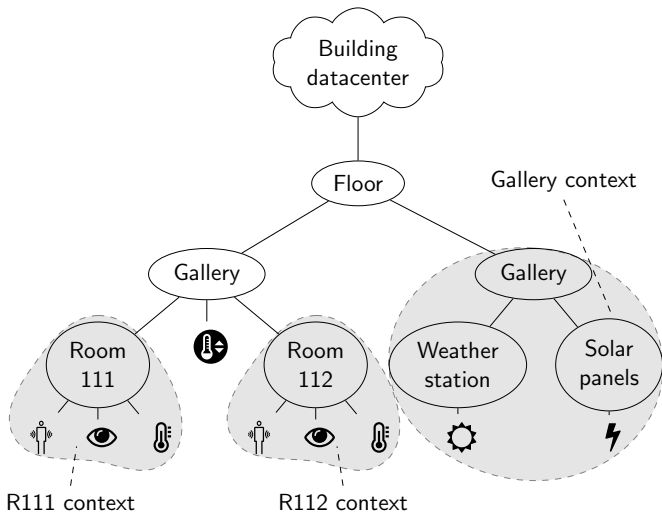
A typical IoT architecture is...

- ...hierarchical
- ...not neutral with respect to the data collected

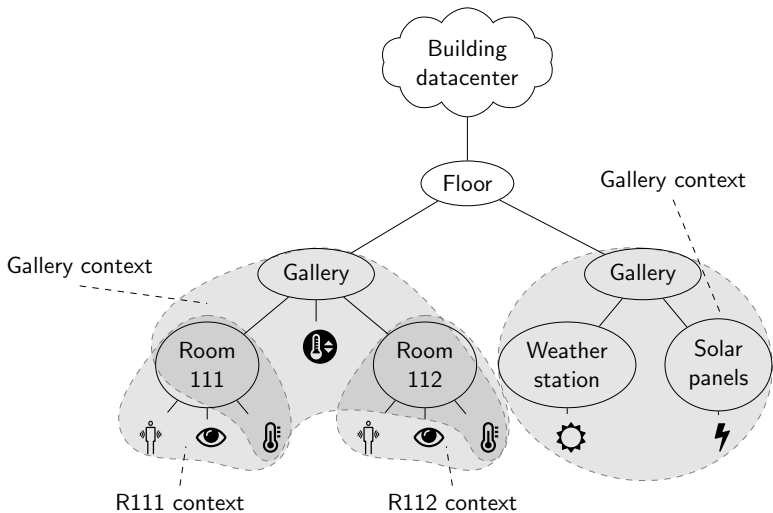
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Evaluation

Measured parameter

Delivery delay, interval between observation and deduction reception by the application

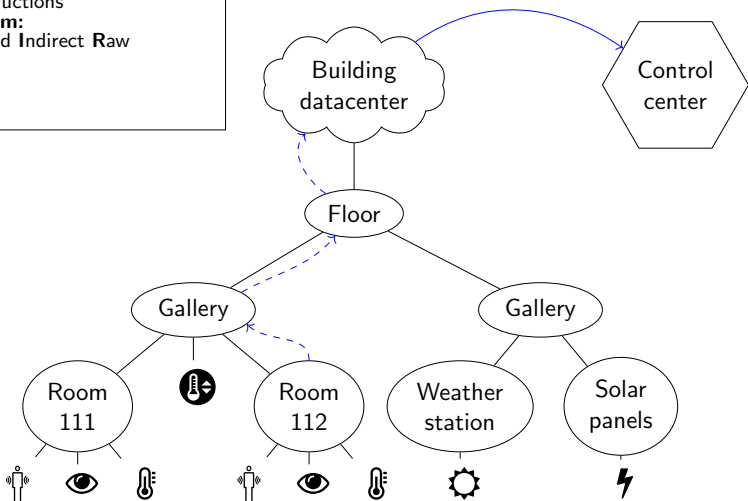
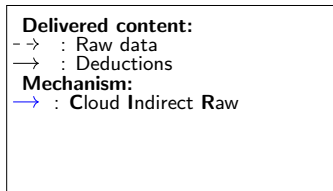
Experimentations

- Scalability
- Distribution

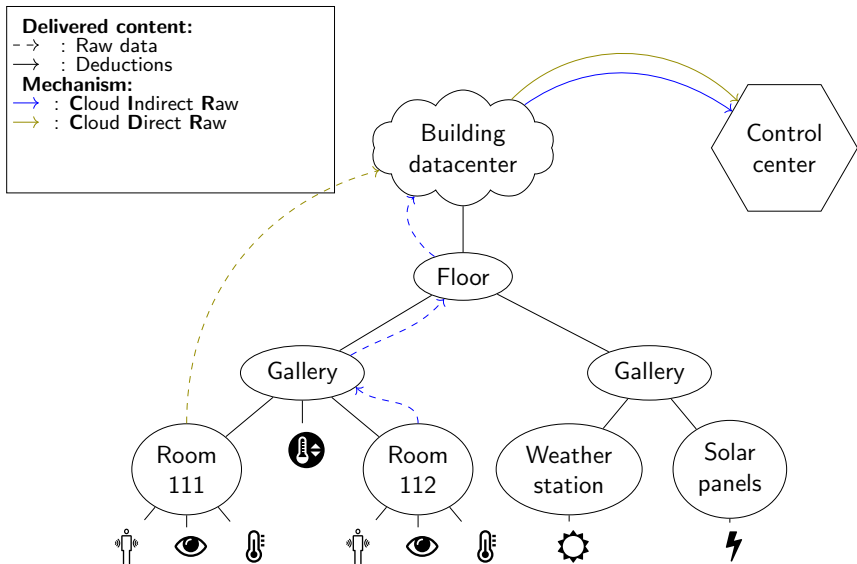
Defining an baseline and its variations

- Comparing centralized and decentralized reasoning
- Nuancing the evaluation

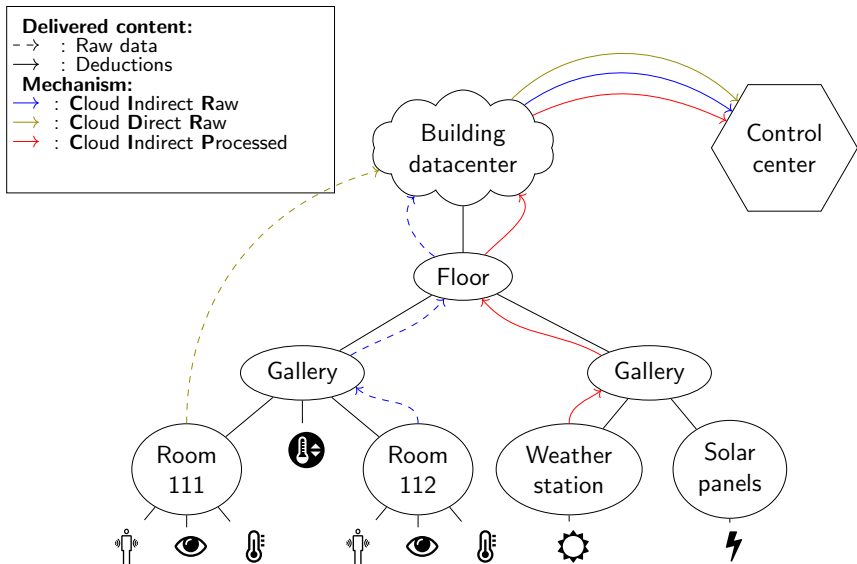
Comparing delivery mechanisms



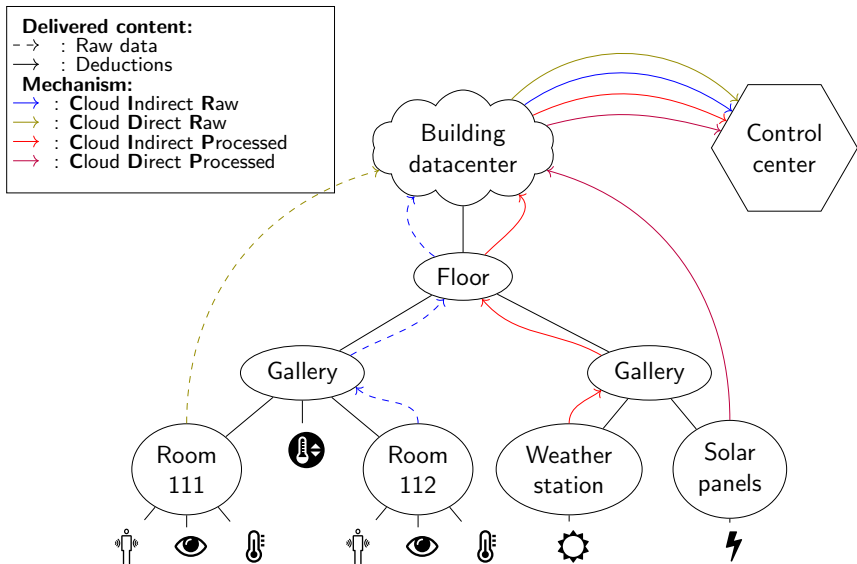
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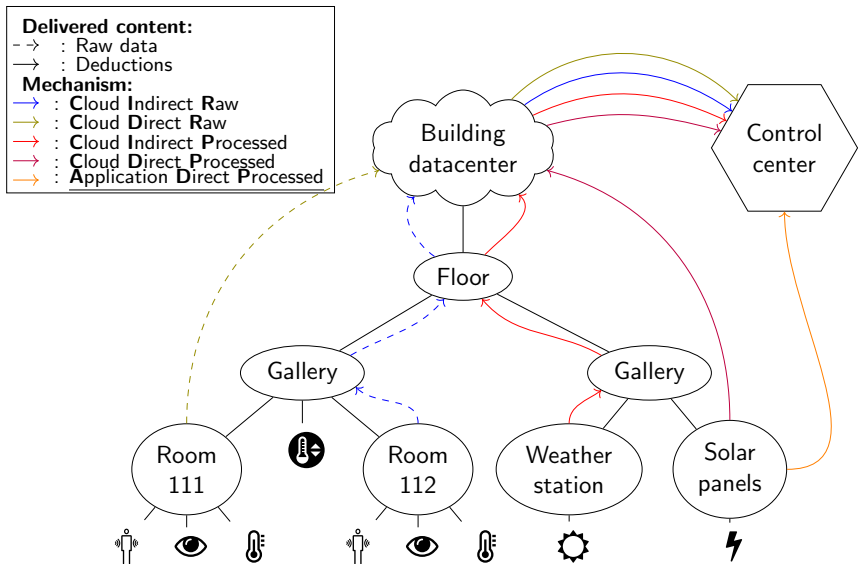
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Comparing delivery mechanisms

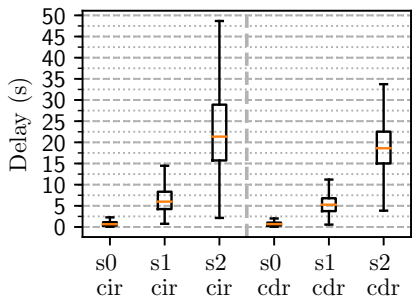


Comparing delivery mechanisms

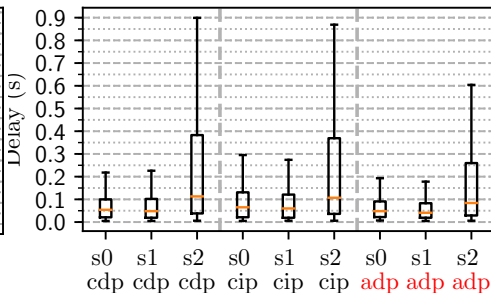


Scalability of the proposed approach

Topology	s0	s1	s2
Nodes	31	61	91

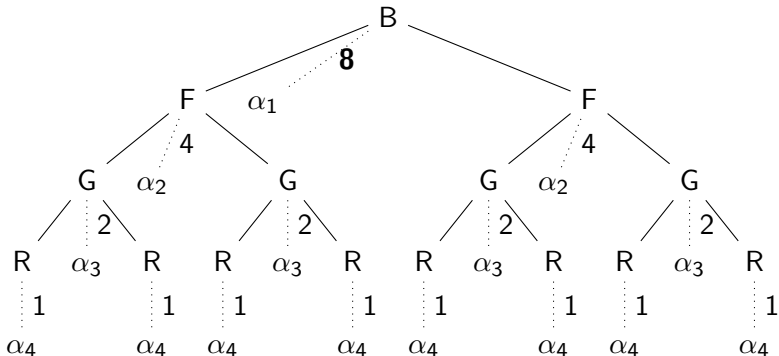


Centralized reasoning

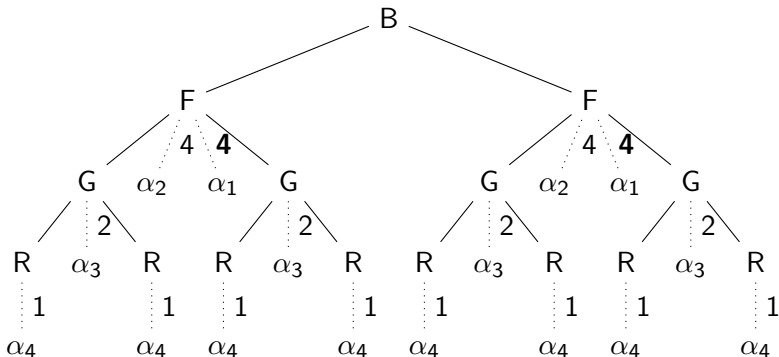


Distributed reasoning

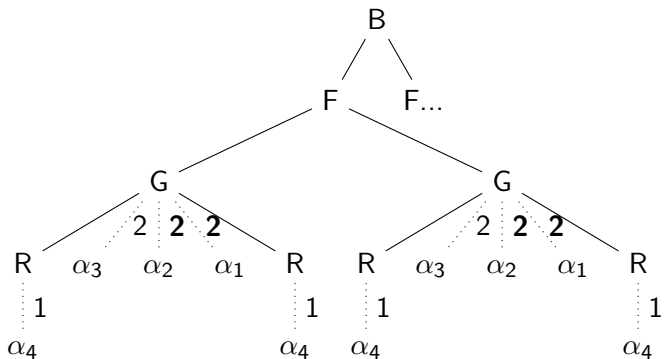
Distribution experimentations



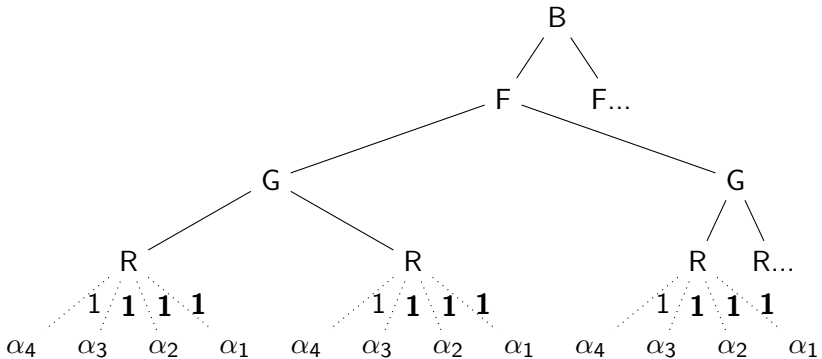
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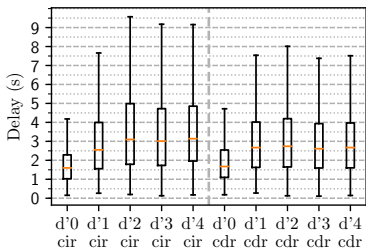


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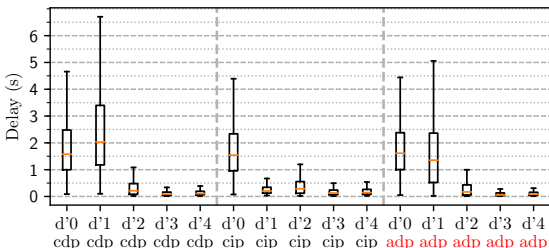


Validation of the hypothesis

	R1	R2	R3	R4	R5	R6	R7
d'0	0	0	0	0	0	0	0
d'1	0	1	0	1	1	0	0
d'2	1	1	0	1	1	0	0
d'3	1	1	0	3	3	1	3
d'4	3	2	2	3	3	2	3



Centralized reasoning



Distributed reasoning

Conclusion and perspectives

Contribution

- EDR_T, an approach to dynamic distribution of rule-based reasoning
- Support for the scalability and the increased performances for distributed reasoning

Conclusion

Cooperative semantic computing enables the development of a constraint-aware SWoT

Evolution of the contribution

Generalization of the approach

- EDR_T is actually a refinement of EDR, a generic approach
- EDR is based on modular rules, where the transfer condition are captured (instead of hard-coded)
- The announcement of capabilities is based on a dedicated vocabulary

Future work

Further extensions of EDR

- Other strategies for EDR: node capabilities, privacy
- Perform evaluations in a real-world deployment

A vocabulary to implement strategies

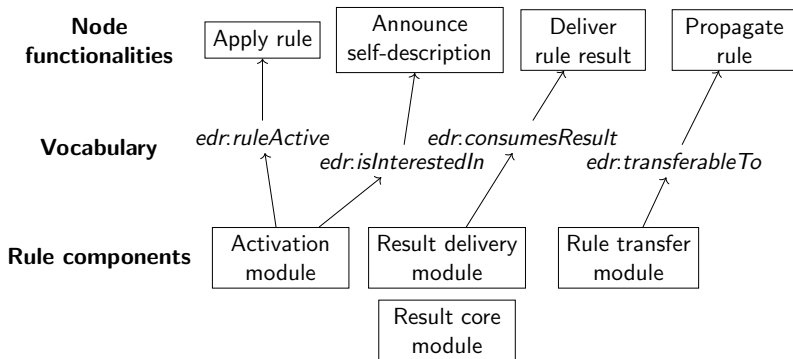



Image credit

- : Power by i cons from the Noun Project
- Miscellaneous icons from FontAwesome



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