Jean-Paul Calbimonte
University of Applied Sciences and Arts Western Switzerland HES-SO

Swarm Intelligence for Agents in Smart Edge Environments

Web Agents Community Group
★ W3C TPAC 2023, Seville, 11–15 September ★

Motivation

- smart devices, sensors, autonomous robots, drones: pervasiveness
- acquisition + actuation + complex processing
- dynamic changes in the number and type of devices

higher-level abstractions

self-organization of smart devices

collaborative distribution of tasks

swarm-inspired behavioral patterns

Challenges and open issues

- Heterogeneous agent knowledge
- Swarm-inspired models for smart edge agents?
- Social coordination of agents in a swarm environment
- Negotiation in the context of swarm agents

Challenges and open issues

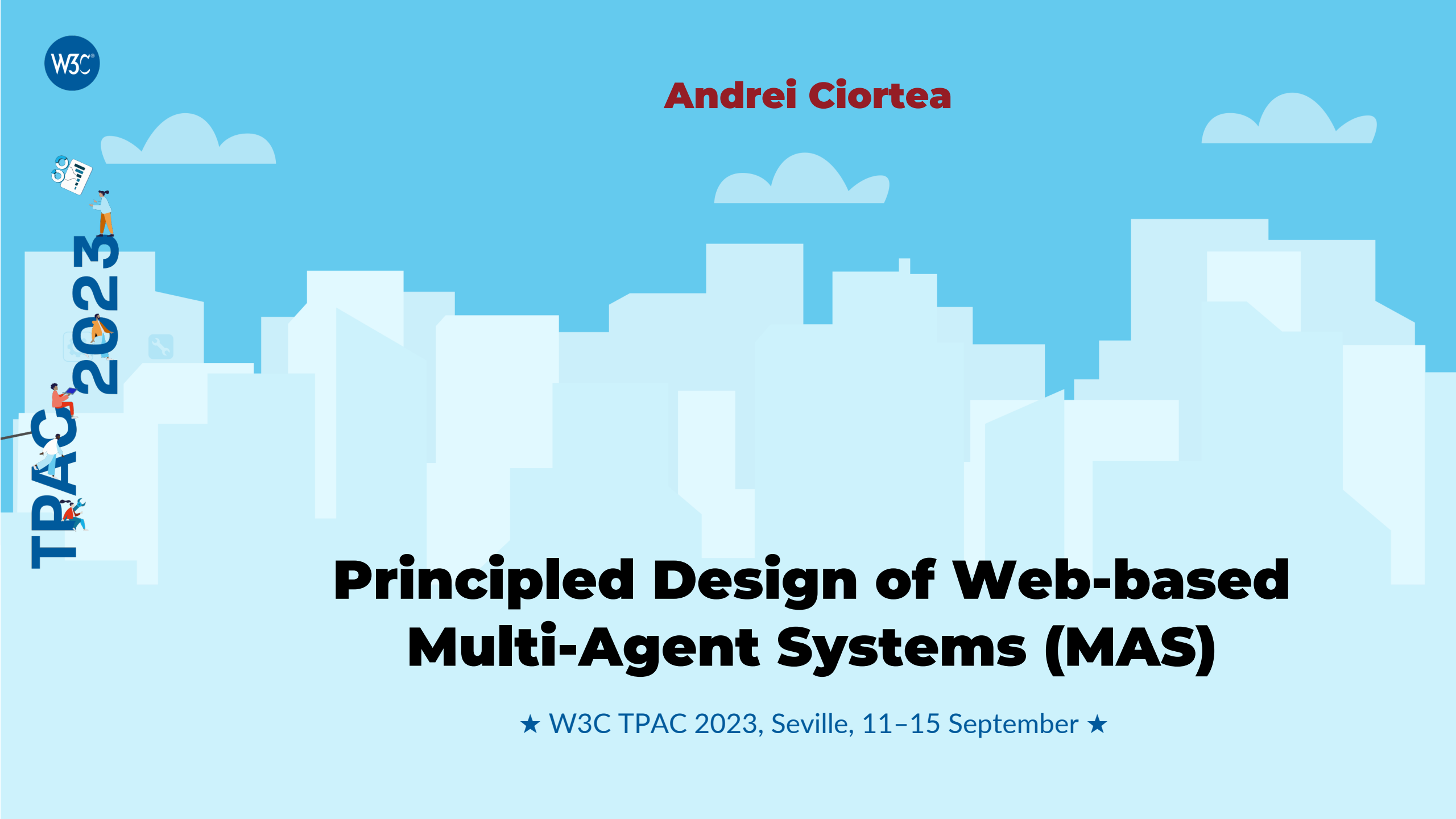
- risks of manipulation and mischievous behaviors
- integrity, confidence, and transparency mechanisms
- handle sensitive data, strict privacy constraints
- maintaining computation and processing goals

Opportunities

- Semantic representation of shared goals, organization patterns, and behaviors
- Implementation of low-code solutions: abstract the complexity of smart edge agents
- The Web: solid and standard foundations for interoperability, discovery, accessibility among swarms.
- Fully decentralized swarms of agents: self-organization approaches

Opportunities

- Domain-specific deployments: drive requirements and implementation, e.g.: automation, self-driving vehicles, robotics, domotics, eHealth
- Federated learning and decentralized processing adapted to run on swarm agents



Andrei Ciortea

Principled Design of Web-based Multi-Agent Systems (MAS)

★ W3C TPAC 2023, Seville, 11–15 September ★

Principled Design of Web-based MAS

Environment as a First-Class Abstraction

Asynchronous Interaction

Uniform Interaction

Situatedness and Embodiment

Decentralization

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Intelligent, rational behavior is innately linked to the environment an agent occupies

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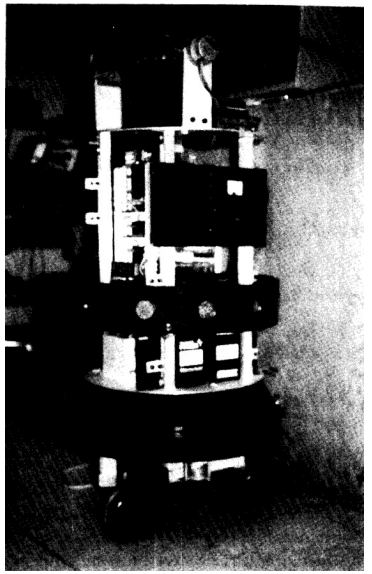

"The MIT AI Lab mobile robot"
[Brooks, 1985]

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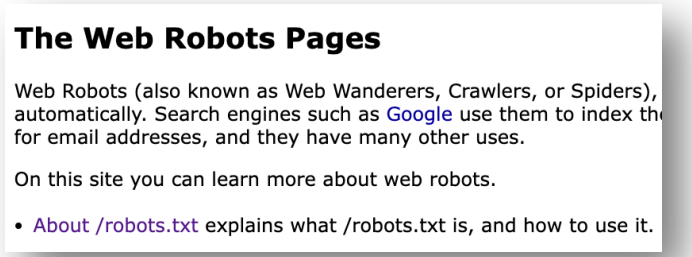
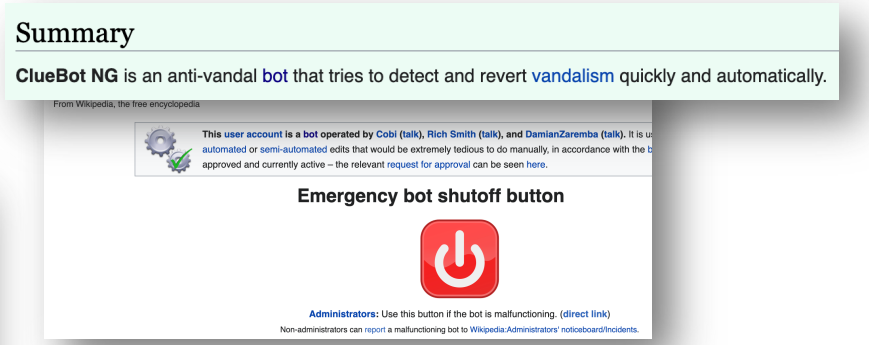


Robots Exclusion Protocol
https://www.robotstxt.org/



Wikipedia's Content Agents
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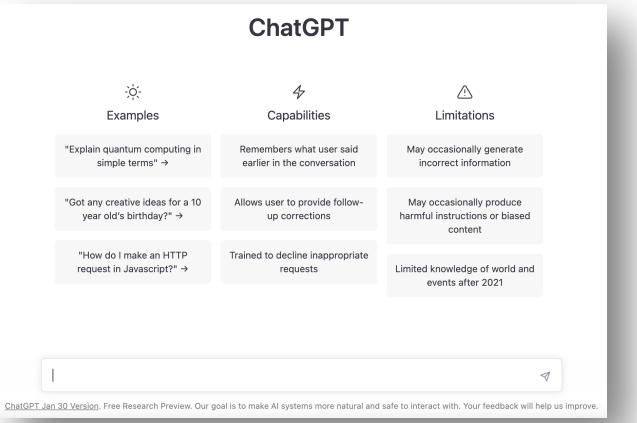

https://chat.openai.com/

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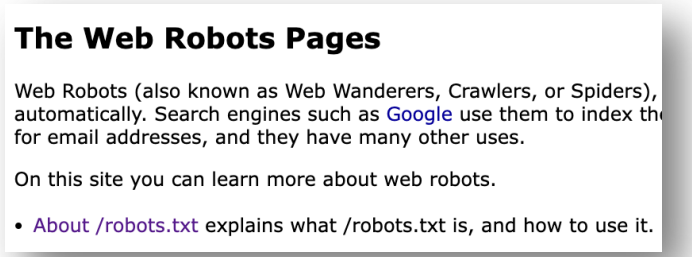
> **"Where are all the intelligent agents?"**
>
> — James Hendler, IEEE Intelligent Systems, 2007



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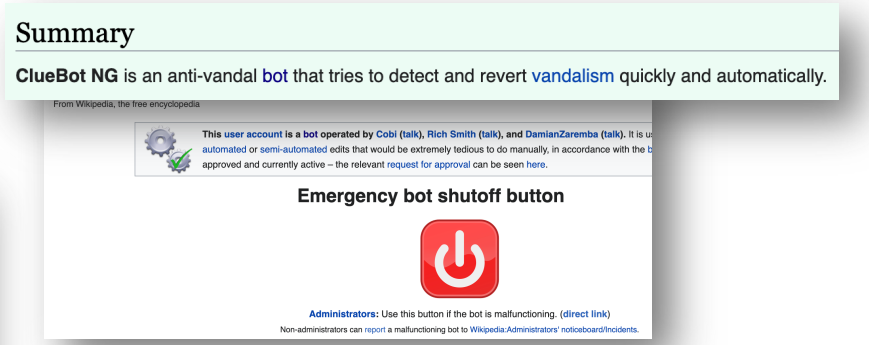

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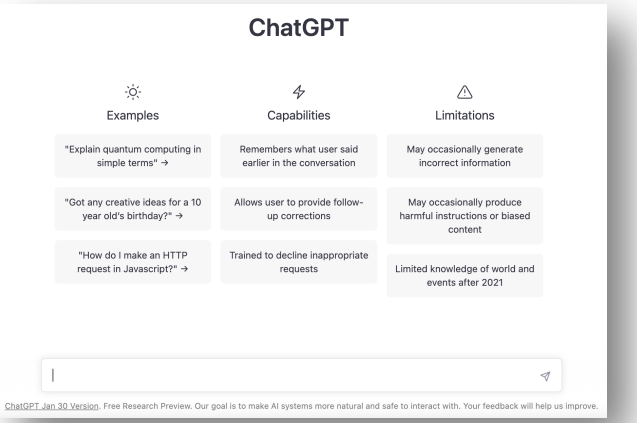

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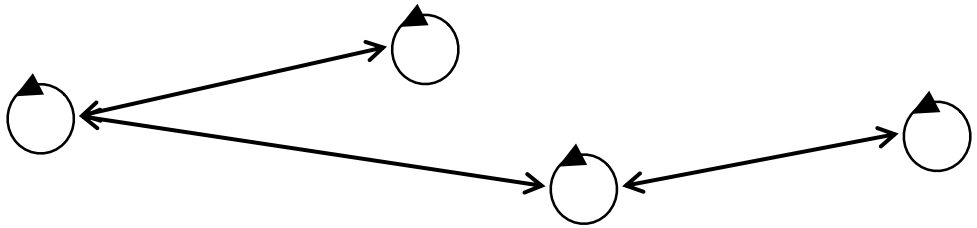
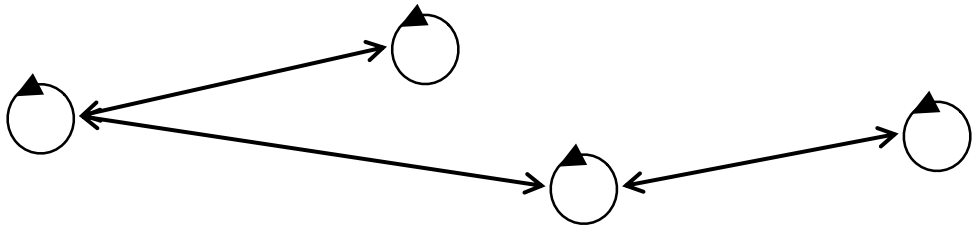


The Web as a **transport layer** for messages exchanged between agents

A. Ciortea, S. Mayer, F. Gandon, O. Boissier, A. Ricci, and A. Zimmermann, A Decade in Hindsight: The Missing Bridge Between Multi-Agent Systems and the World Wide Web, AAMAS 2019.

Web-based MAS without the Environment Dimension



The Web as a **transport layer** for messages exchanged between agents

MAS remain **outside** of the Web and are **misaligned** with the Web architecture.

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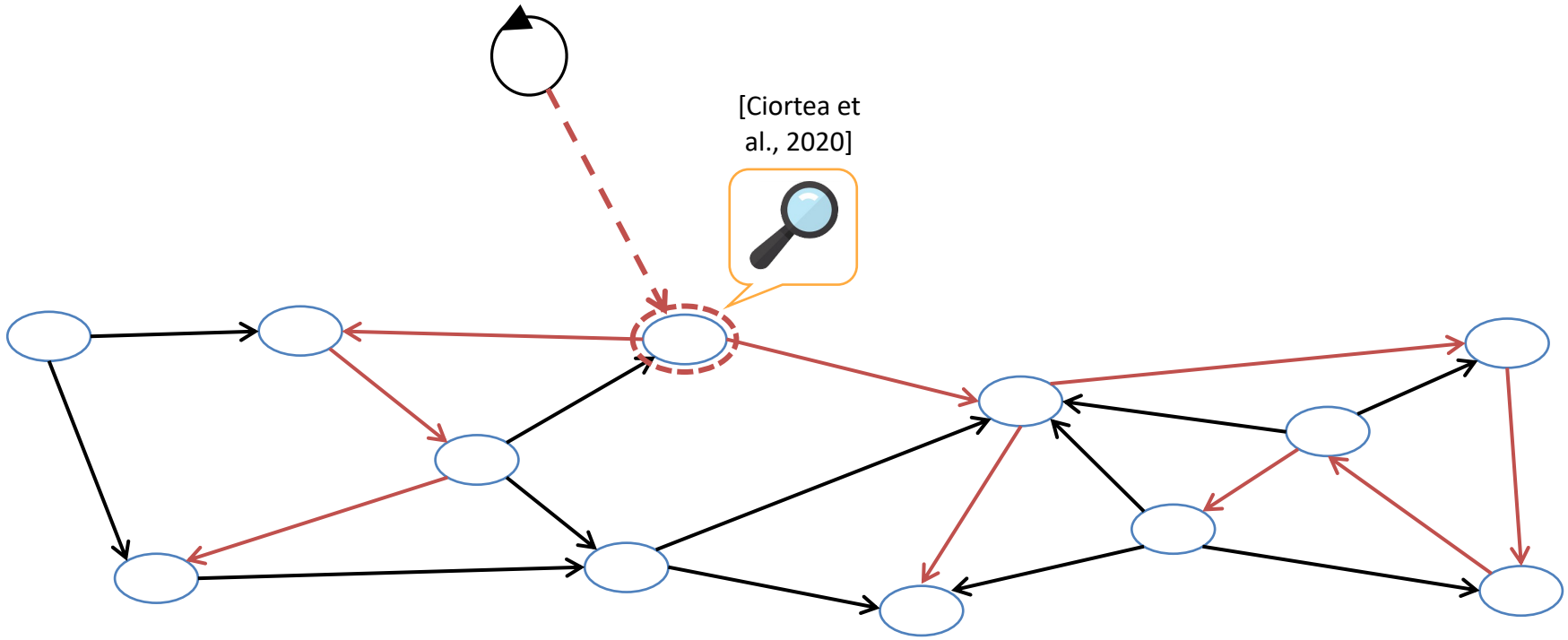

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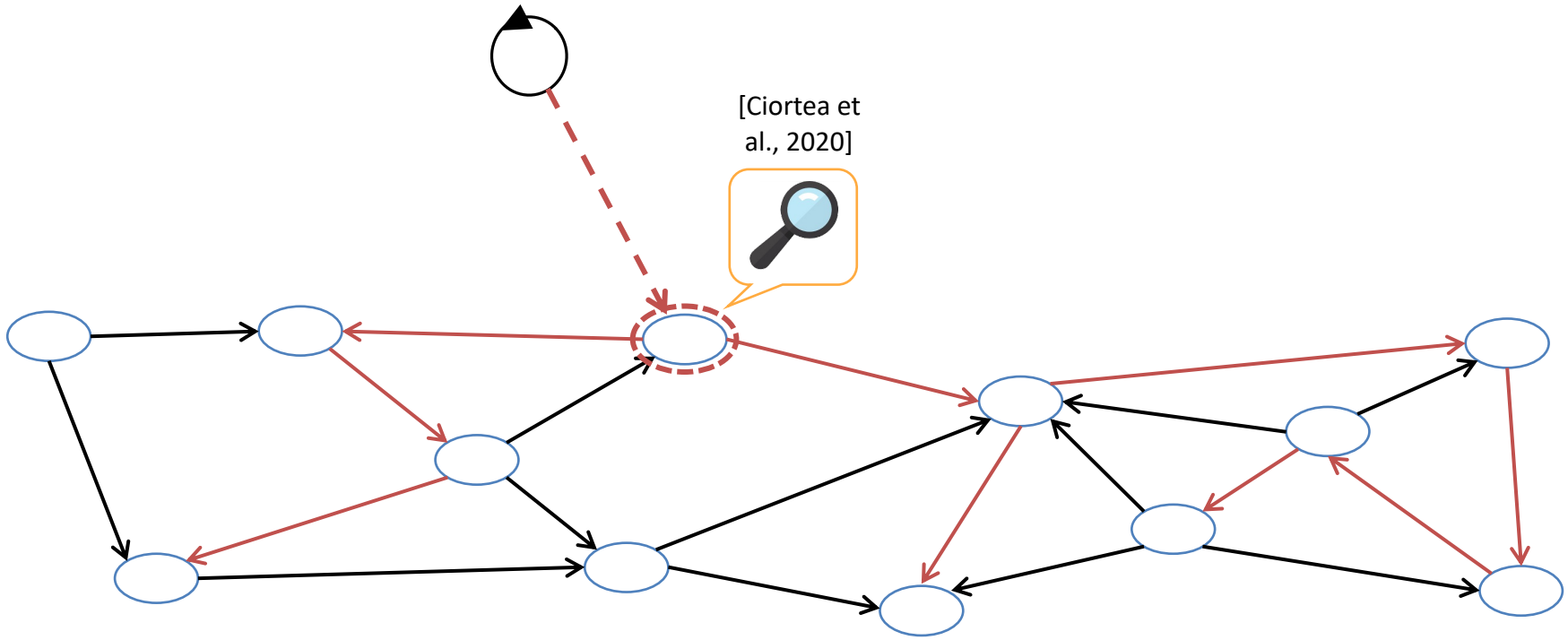
The systems are **weaved into the hypermedia fabric of the Web**



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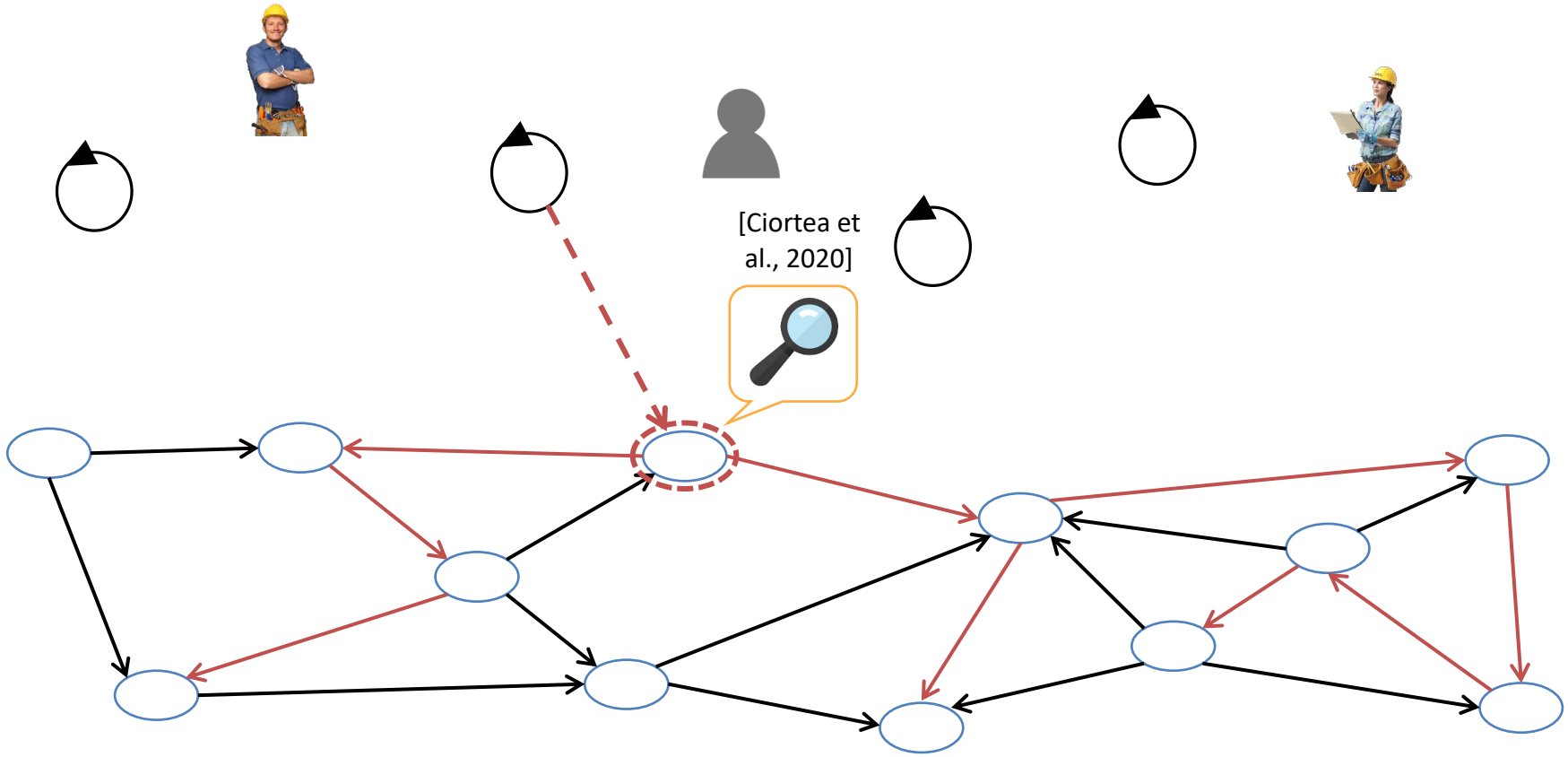

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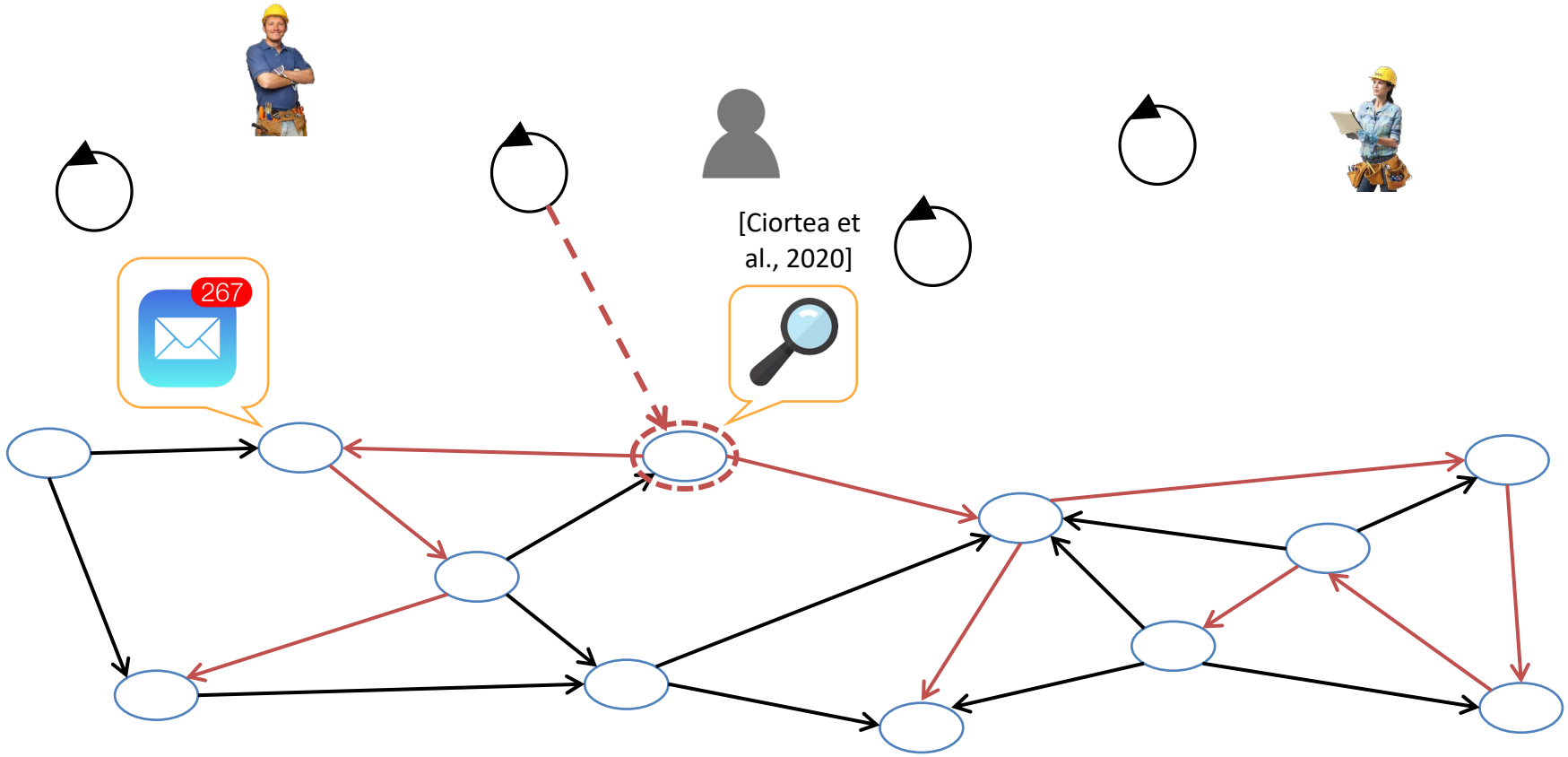

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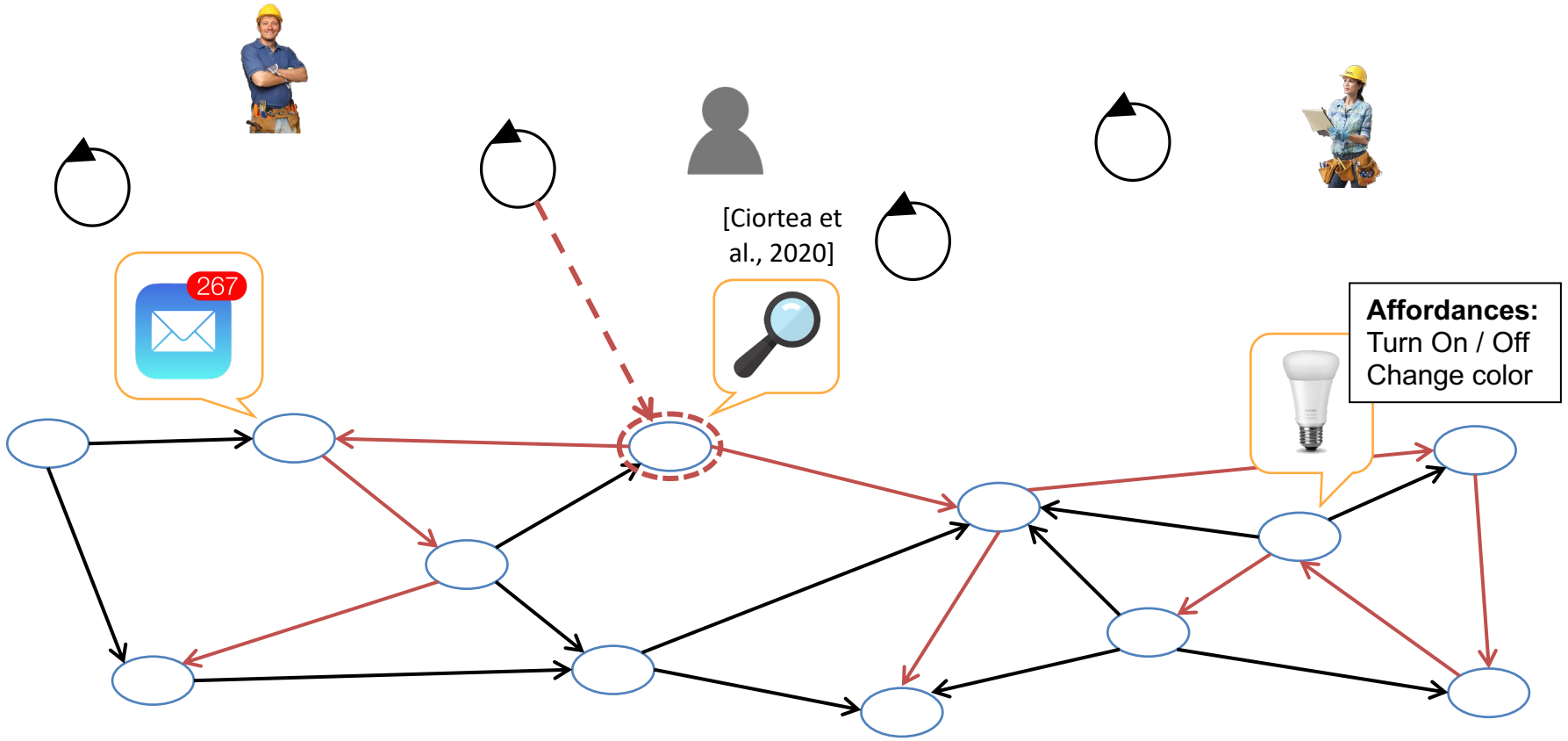

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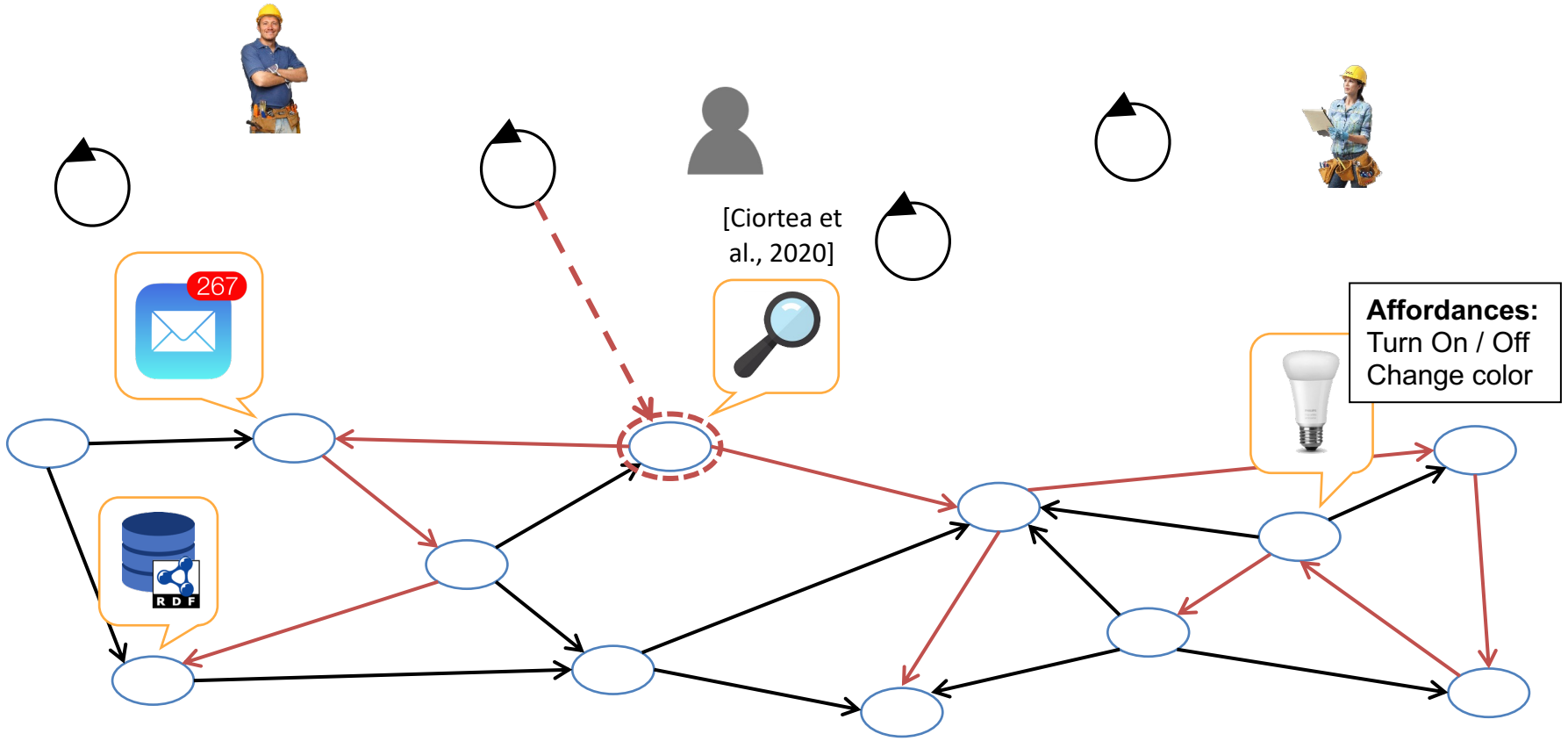

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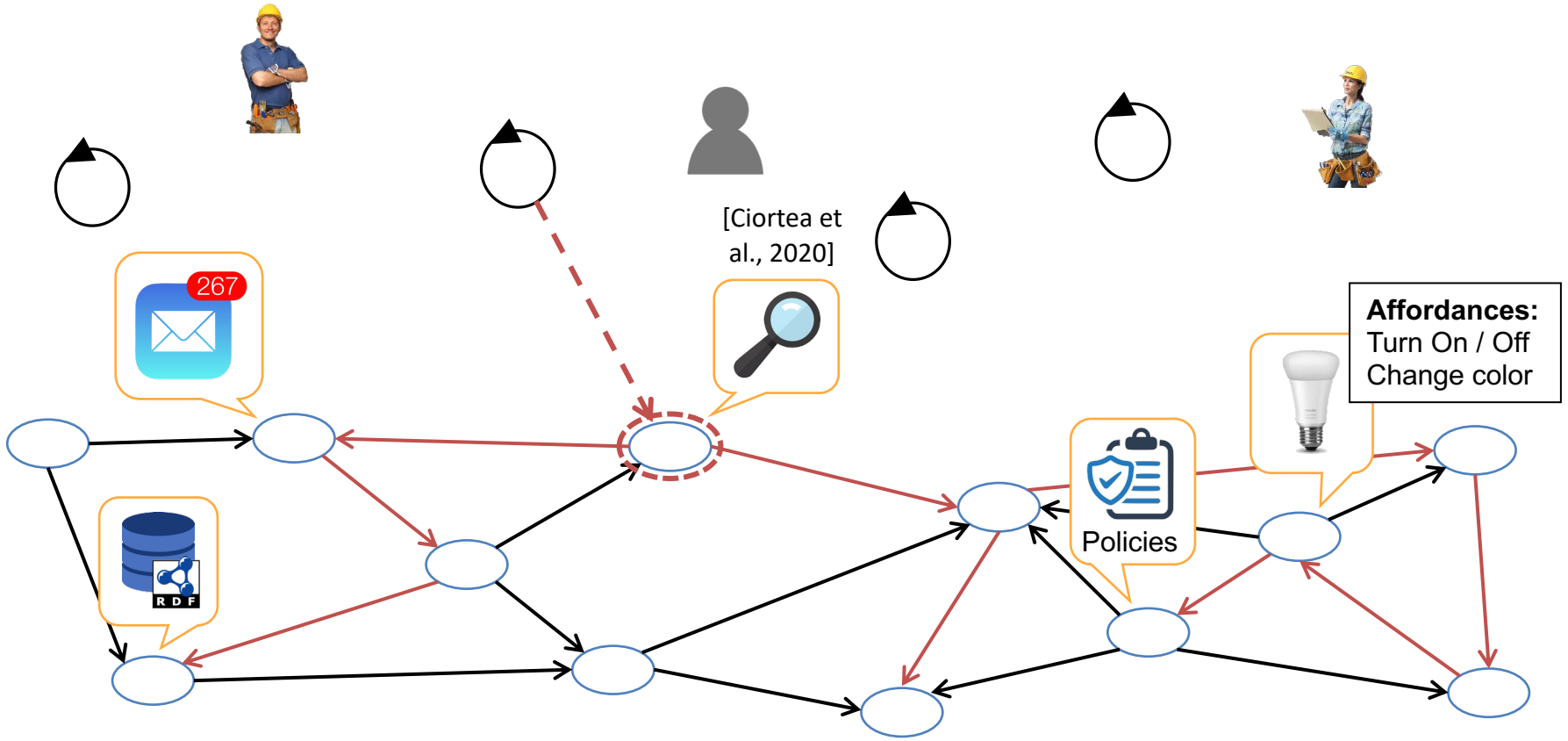

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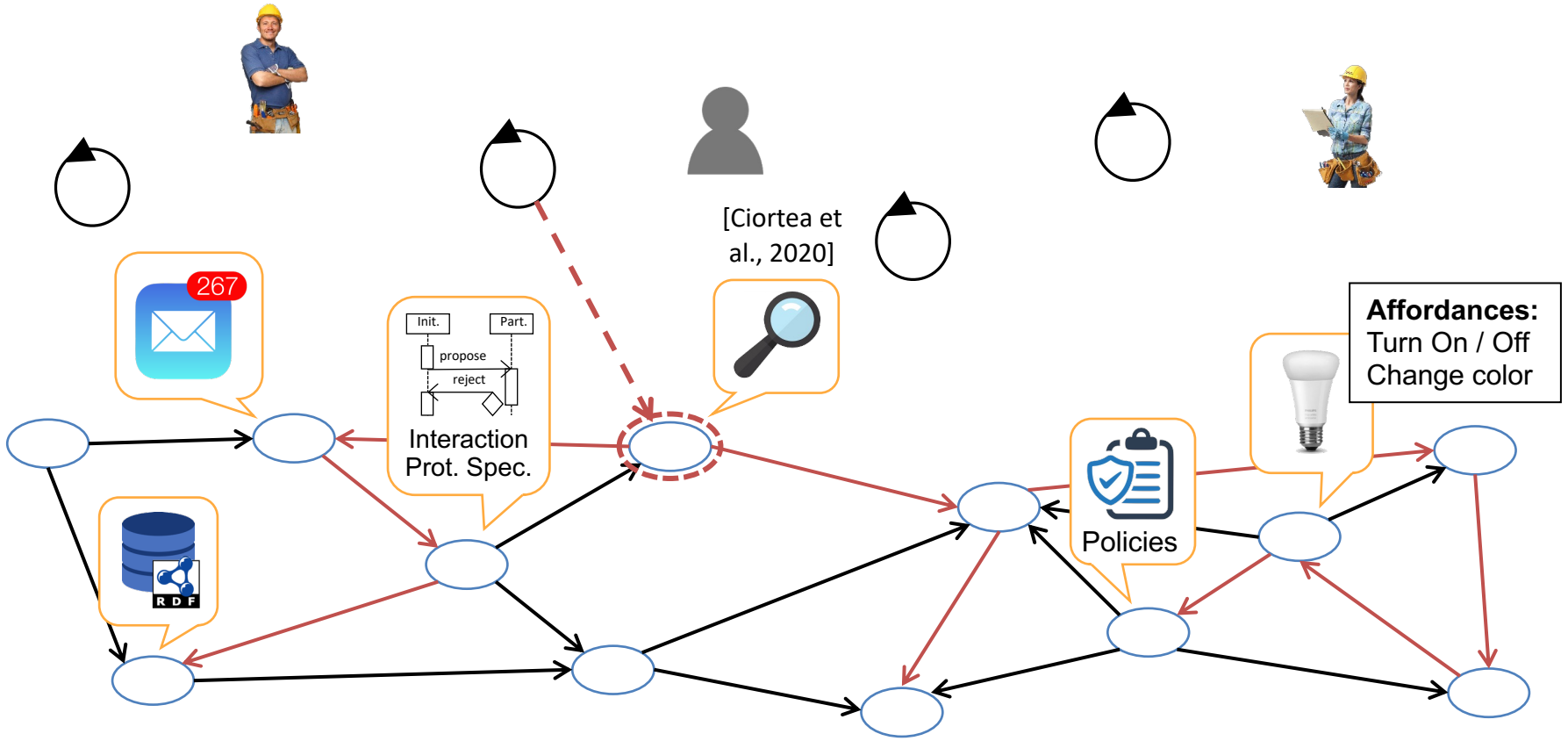

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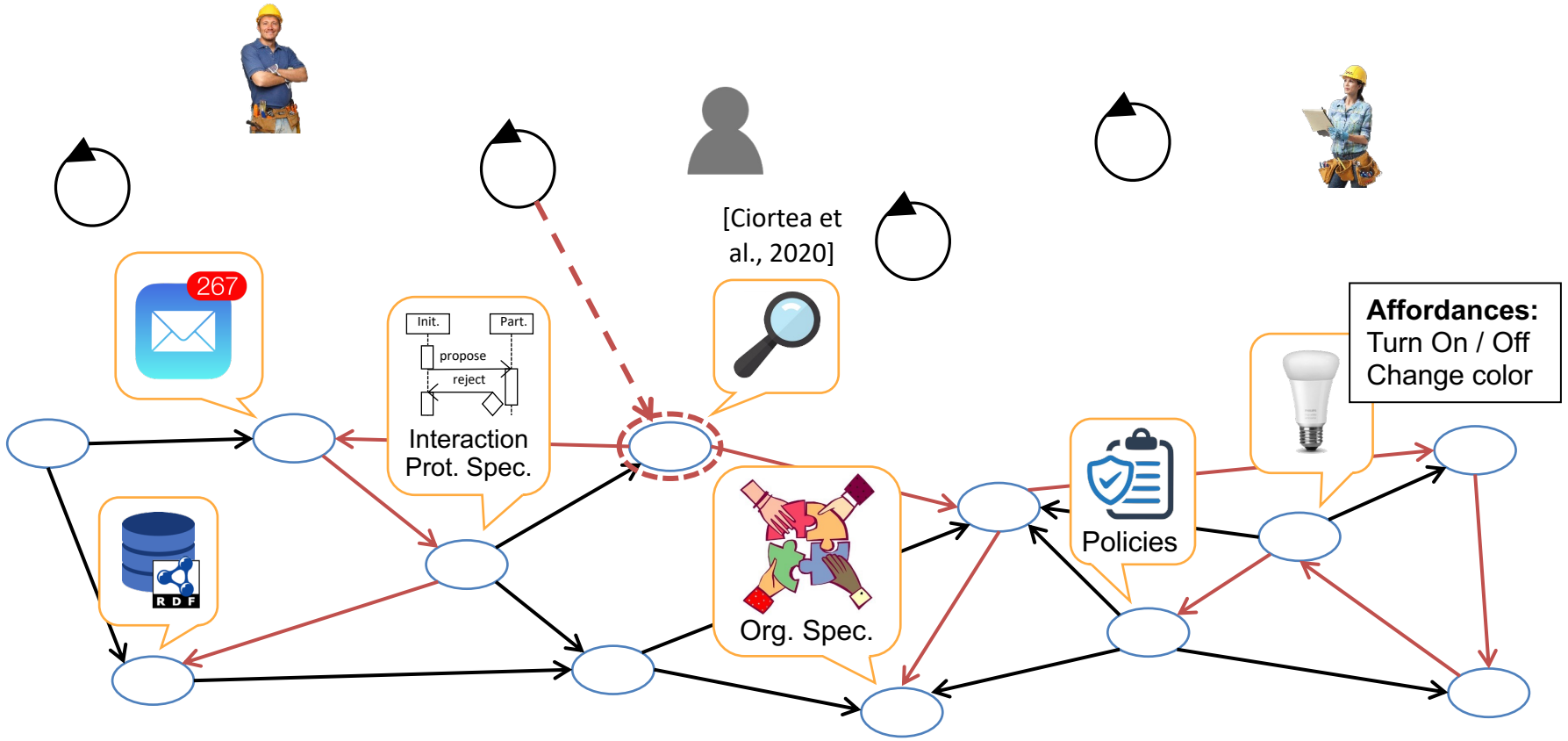

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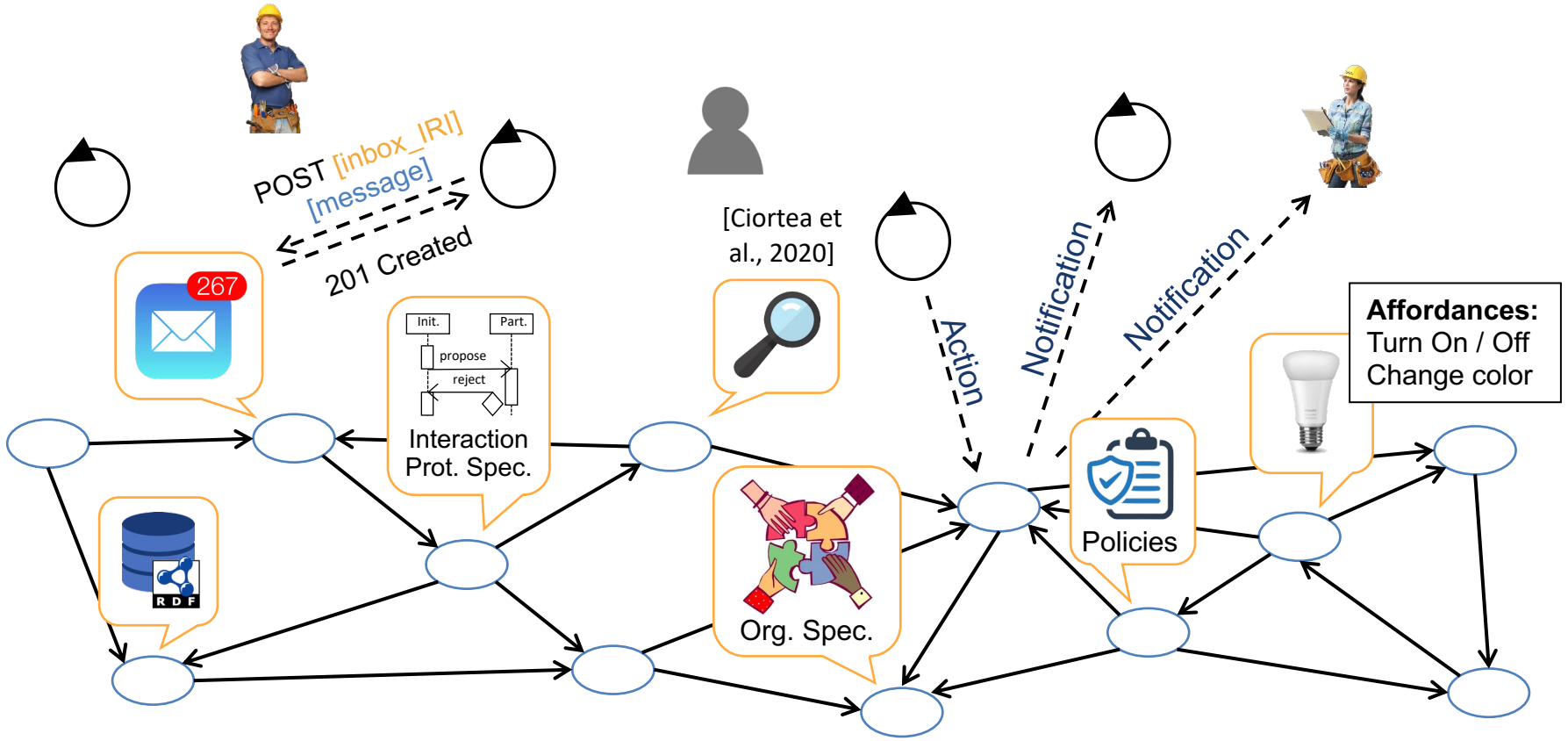

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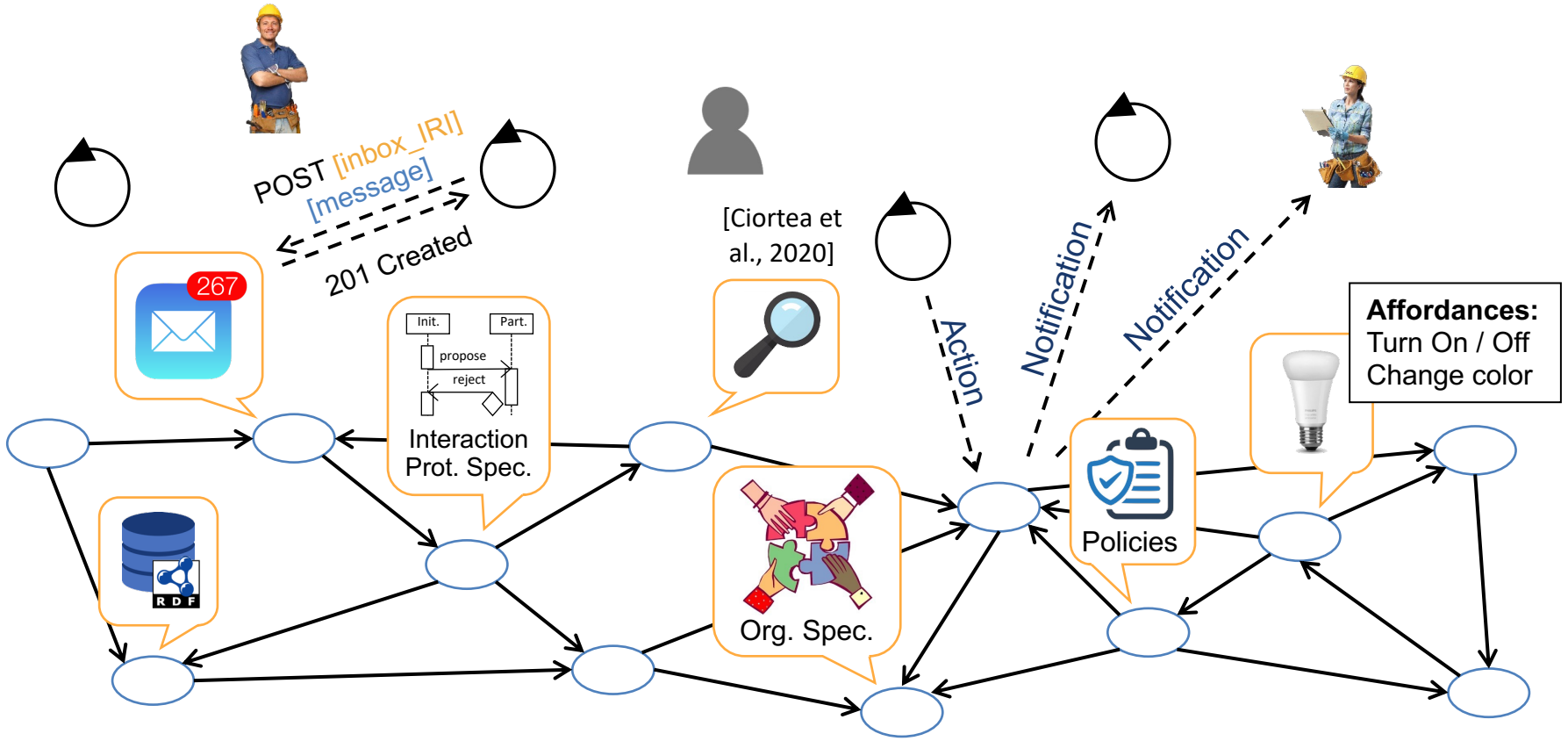

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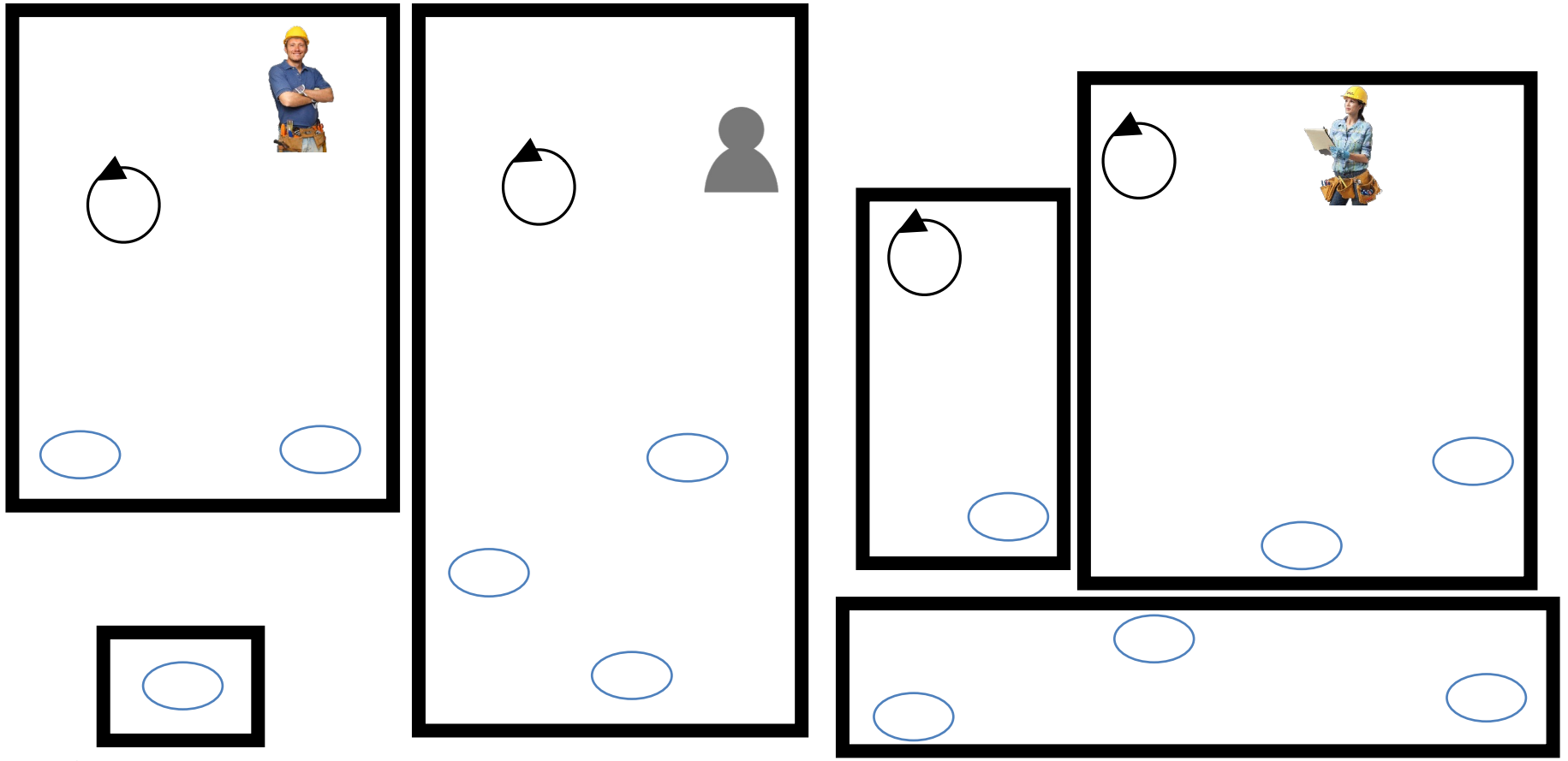

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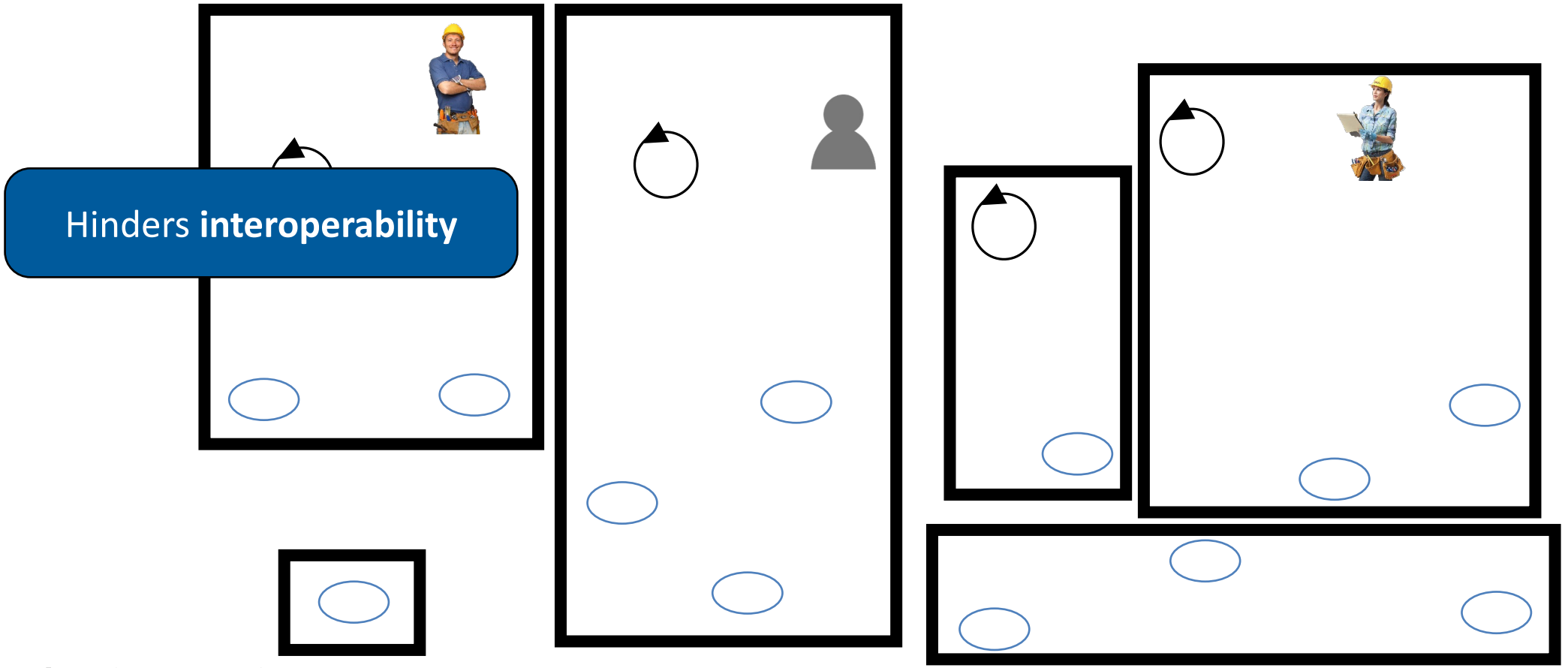

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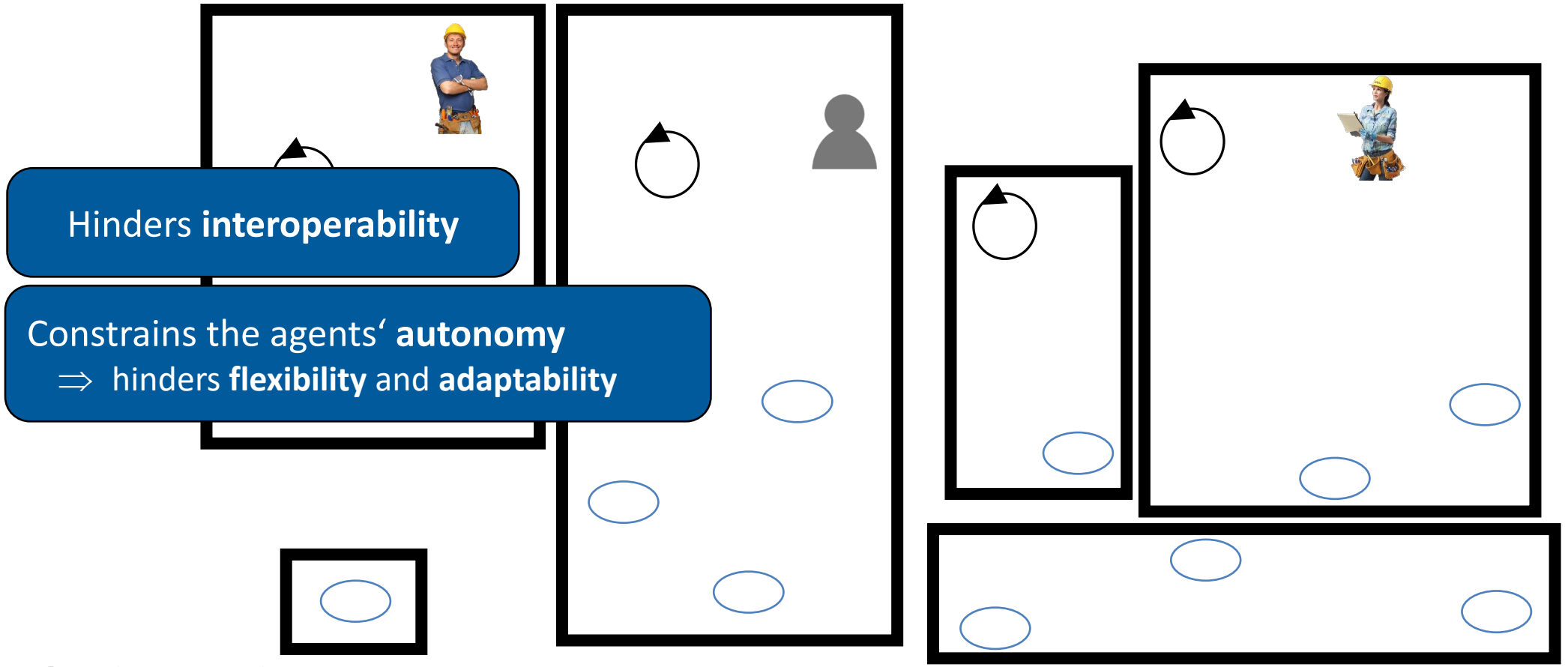

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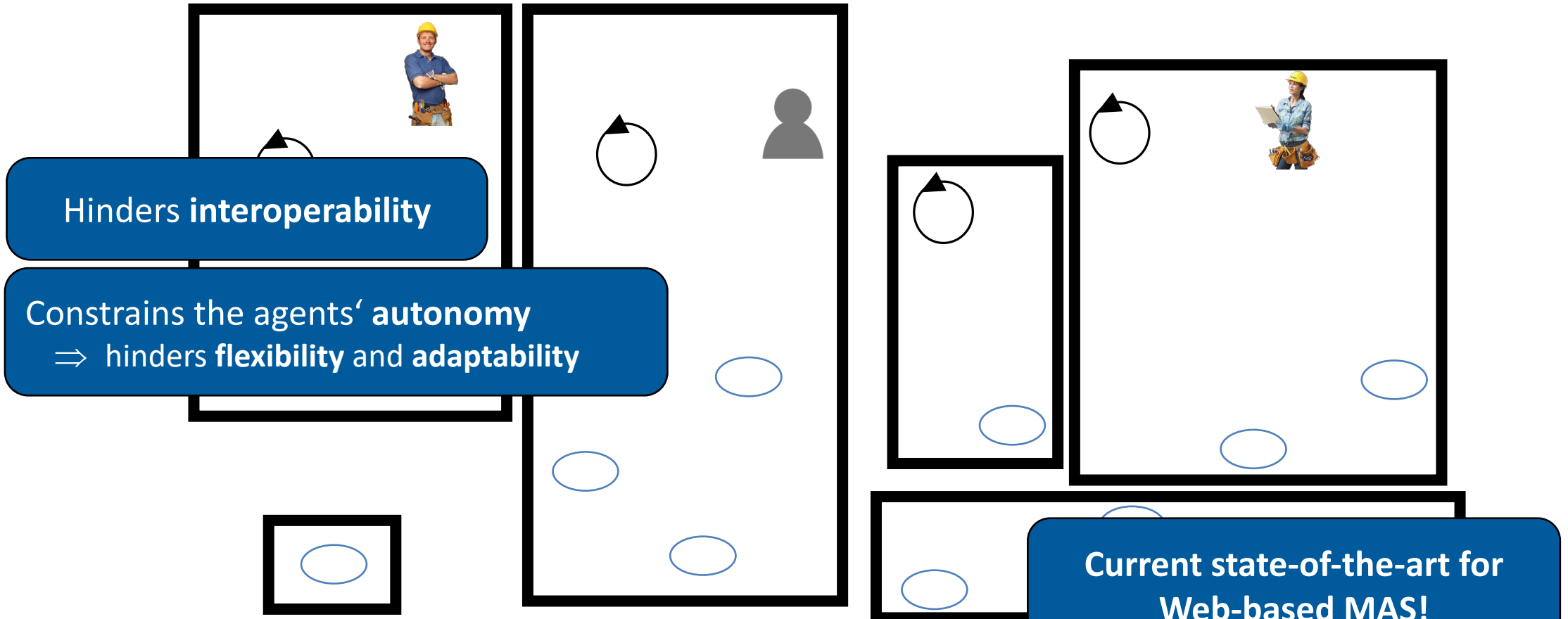

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Rem Collier

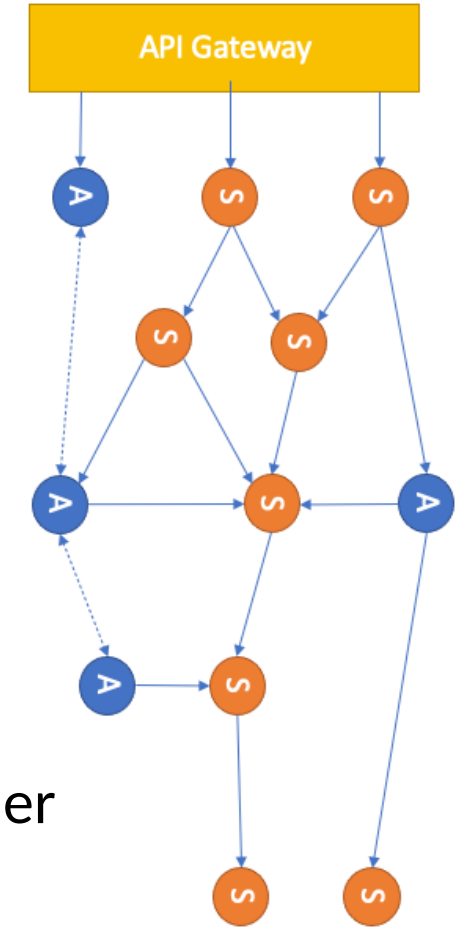
Multi-Agent Systems & Microservices

★ W3C TPAC 2023, Seville, 11–15 September ★

Multi-Agent MicroServices (MAMS)

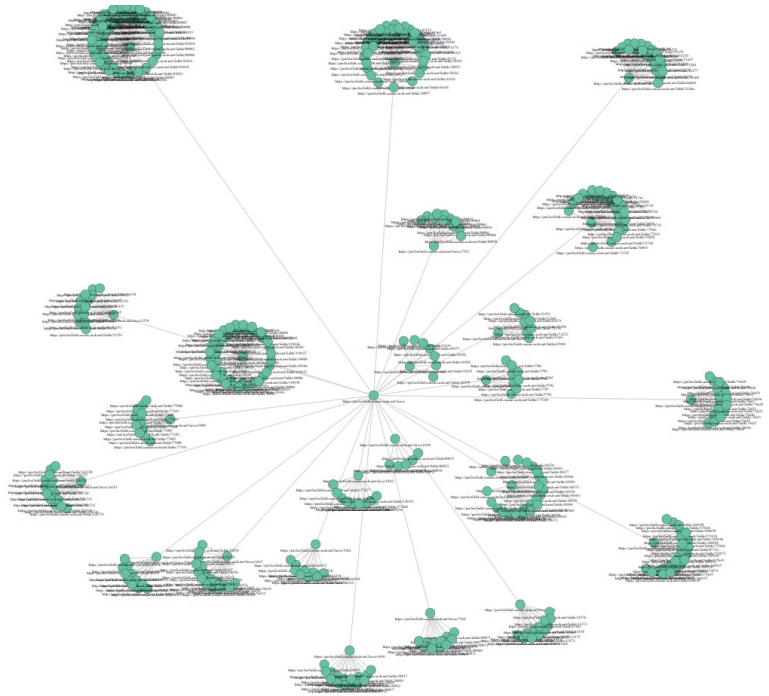
(Collier et al., 2019)

- Architectural Style for embedding MAS technologies within microservices architecture.
  - Enable integration between plain-old microservices (POMS) to and agent-oriented microservices (AOMS) **without** the need to learn MAS concepts.
- Adopts view of agents as hypermedia entities.
  - Agents have hypermedia bodies that are modelled as a set of resources.
  - External systems interact with MAMS agents through those exposed resources.
  - Agents also given the tools needed to interact directly with other hypermedia resources.
- The AOMS becomes a **black box** to the external services.



Enabling HATEOAS...

- Linked Data connecting loosely coupled resources.
  - Capturing high level relationships between resources as hyperlinks.
- RDF-based representations
  - Data as knowledge
  - Turtle / JSON-LD
- Embedding hypermedia controls.
  - Contextually relevant controls defined using the Hypermedia Controls Ontology
  - ...vs Open API specifications
- *Microservices are transformed into distributed knowledge graphs.*



```
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        "@type": [
            "hctl:Form",
            "Risk"
        ],
        "hctl:hasTarget": "http://farm-kg.net/field/123/risk",
        "hctl:forContentType": "application/json",
        "hctl:hasOperationType": "hctl:WritePropertyOperation"
    }
]
```
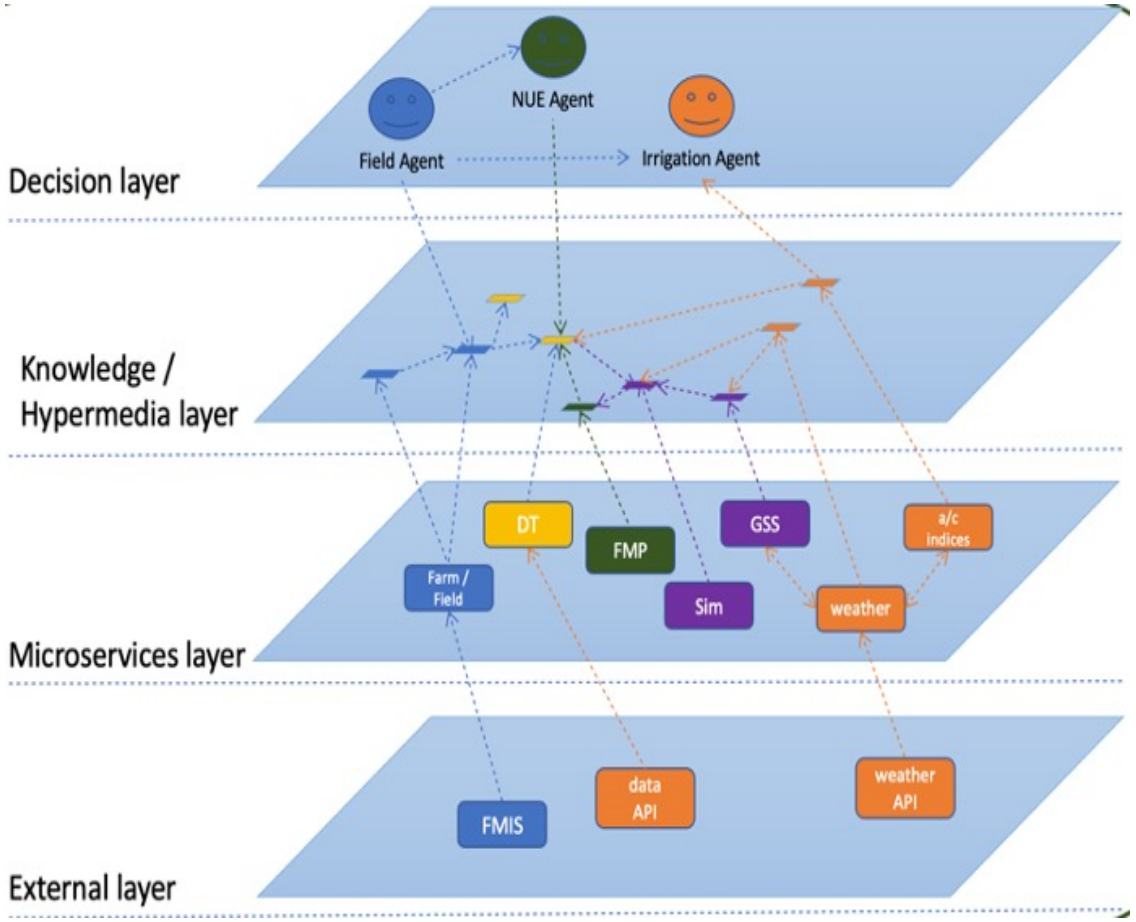
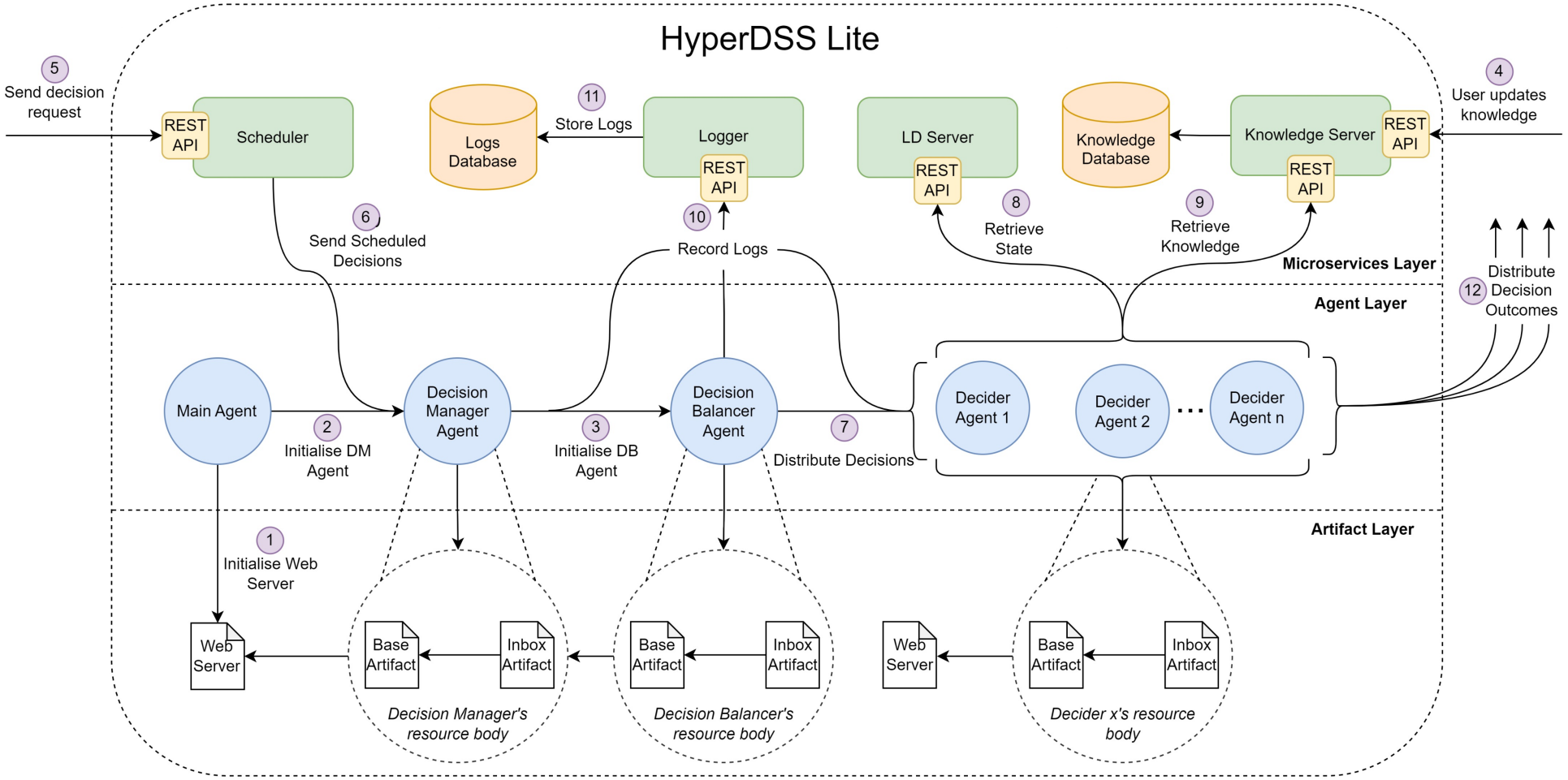

Knowledge Graphs for Smart Ag.

- Highly complex data sets drawn from diverse sources.
  - Sensors, Remote Sensing, Drones, Farm Machinery / Robots, Financial Markets, …
- Integration of Multiple Services
  - Spatial Data Services
  - Decision Support Services
  - Carbon Neutral Services
  - ML/AI Prediction Services
- *Leading to Semantic/Cognitive Digital Twins…*



Crop Optimization through Sensing, Understanding and viSualisation (CONSUS) SFI Strategic Partnership, €17.6M

MAMS-based Decision Engine



Università
della
Svizzera
italiana

Governing Communities of Distributed Autonomous Agents and People on the Web using Social Norms

Dr. Nicoletta Fornara

**Università della Svizzera italiana,
Lugano, Switzerland**

Research questions

How to **design** and **govern** communities of autonomous agents and people on the Web?

- How to **represent** and **reason** about policies and norms on the Web (terms of service, data licensing policies, user preferences, etc.)?
- How to coordinate, **monitor**, and regulate interactions in Web-scale communities of autonomous agents and people?
- How to preserve **privacy** on a Web populated with autonomous agents?

From Dagstuhl Seminar 23081

Existing solutions

- Models for the formal specification of social **norms/policies** (e.g. obligations, prohibitions, and permissions) and for automatic reasoning on norms that are used to provide monitoring of norms, what-if analysis, detection of inconsistencies
- Models that use **semantic web technologies** for defining some components of the norms and for reasoning on them: OWL-POLAR, T-Norm (rule-based), W3C ODRL, ODRL extension based on InstAL, …
- Solutions proposed by other communities: access control models, privacy policies models (PrivOnto), …

Missing elements, open problems (1)

- It is probably unthinkable that we would reach an agreement **on a common model** for specifying norms and policies for all web applications, perhaps it is more reasonable to take the path of studying which norms can be formalised with which languages and how to translate norms from one formalisation to another. An initial study in this direction is presented in [3]
- I am currently cooperating as a one of the co-chairs of the ODRL Community Group with other members for proposing a Formal Semantics for ODRL 2.2
  (link)

Missing elements, open problems (2)

- It is hard **to formalise** the norms and policies governing the use of data or digital assets, therefore methods have to be devised that can assist such formalization
- Vice versa it may be useful to describe in natural language the content of norms written in a formal language so that a human being can **understand them**

Missing elements, open problems (3)

- Lack of evaluation of the **performance** and **scalability** of the proposed mechanisms to monitor activation, fulfilment and violation of norms
- Activation, fulfilment, or violation of norms is evaluated on a representation of the **state of the world**. What ontologies is it better to use for such a representation? (for example Common Core Ontologies that extend from BFO?)

References

[1] Fornara, N., Roshankish, S., Colombetti, M. (2022). A Framework for Automatic Monitoring of Norms that Regulate Time Constrained Actions. In: Theodorou, A., Nieves, J.C., De Vos, M. (eds) Coordination, Organizations, Institutions, Norms, and Ethics for Governance of Multi-Agent Systems XIV. COINE 2021. Lecture Notes in Computer Science(), vol 13239. Springer, Cham. https://doi.org/10.1007/978-3-031-16617-4_2

[2] Fornara N., Sterpetti M. (2021) An Architecture for Monitoring Norms that combines OWL Reasoning and Forward Chaining over Rules. Proceedings of the Joint Ontology Workshops 2021 (JOWO 2021) Bolzano, Italy. September 11-18, 2021 https://ceur-ws.org/Vol-2969/paper8-DEMO.pdf

[3] Roshankish, S., Fornara, N. (2022). A Methodology for Formalizing Different Types of Norms. In: Baumeister, D., Rothe, J. (eds) Multi-Agent Systems. EUMAS 2022. Lecture Notes in Computer Science(), vol 13442. Springer, Cham. https://doi.org/10.1007/978-3-031-20614-6_20

Finding the Critical MAS(S): Resources and Representations Needed for Weaving a Web that Hosts Linked Multi-Agent Systems

Fabien Gandon, http://fabien.info @fabien_gandon

W3C TPAC - September 2023
WebAgents CG

Linked Multi-Agent Systems (MAS)

- Linking and interoperability of different MAS on the Web
- Hypermedia HMAS (hMAS) linked through their resources and representations
- Supporting knowledge augmentation for human and software agents

A small but viral first hMAS.

Web = distributed hypermedia that is the primary software architecture for Internet applications but not for Multi-Agent Systems, at least not yet.

- Find one use case that has the potential to reach a critical mass of usage and the tipping point of a network effect.
- Find incentives and added values for hMAS to be taken on by industry and developers.
- A catalogue of promising applications has less potential than a small but viral first application.

The right metadata soil for growing hMAS.

- Which metadata are specifically needed for hMAS ?
- Target metadata that have an impact on targeted adopters, largest users' community, etc.
- Minimum first set of metadata and their schemata to support a viral hMAS

hMAS in the effort of (re)decentralization

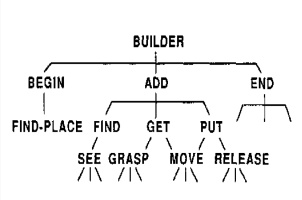
- Distributed AI has a long-awaited rendezvous with the Web.
- The notion of a SOLID-hMAS should be part of our reflections.
- Chicken and eggs question?
  - do we need a (re-)decentralized Web before envisaging agents on the Web?
  - should hMAS systems provide a course to (re-)decentralize the Web?
- Target full decentralization with no recentralization back-door: architecture, application data, schema…

Jérémy Lemée

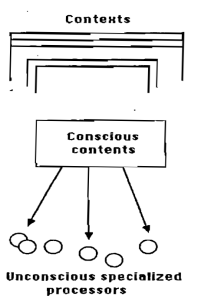
The Web as a Basis for a Global Cognitive Organization

★ W3C TPAC 2023, Seville, 11–15 September ★

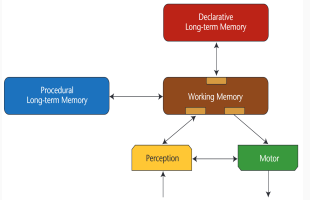
From Society of Mind to Web-based Cognitive Organizations



Society of Mind [1]



Global Workspace Theory [2]



Standard Model of the Mind [3]

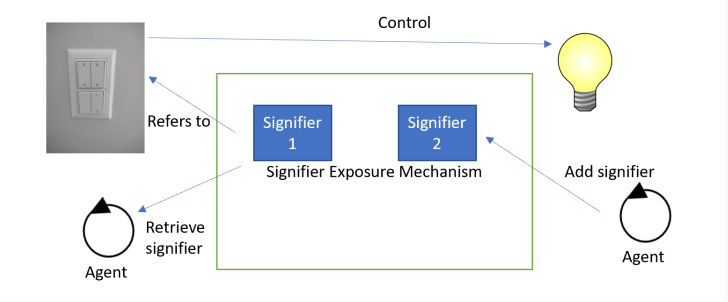
A system of complex agents interacting through the Web (implementing a Global Workspace, Working and Long-Term Memory) could better help each agents to achieve their goals due to enhancing their cognitive abilities.

[1] Minsky, Marvin. Society of mind. Simon and Schuster, 1988.

[2] Baars, Bernard J. A cognitive theory of consciousness. Cambridge University Press, 1993.

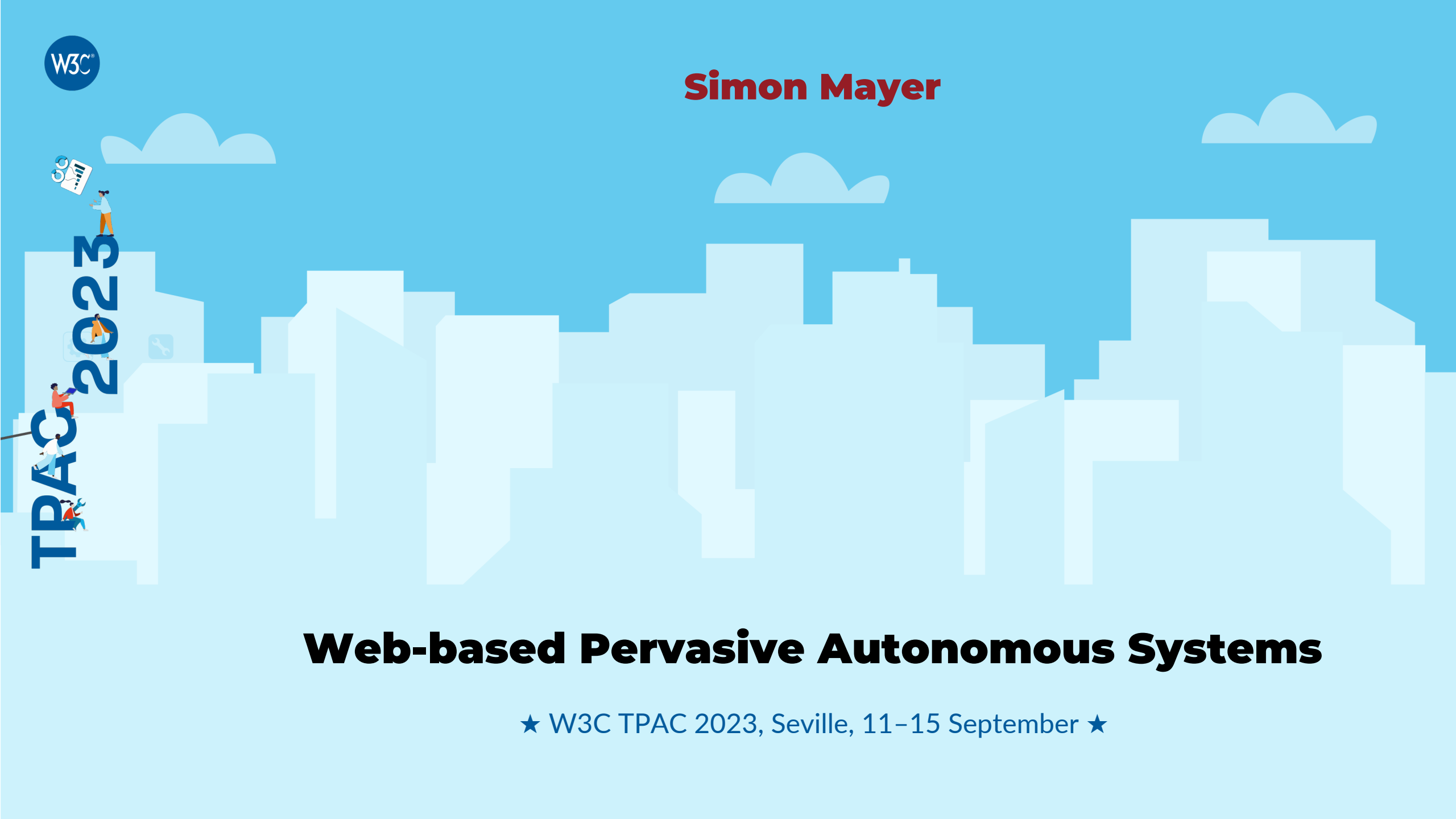
[3] Laird, J. E., Lebiere, C., & Rosenbloom, P. S. (2017). A standard model of the mind: Toward a common computational framework across artificial intelligence, cognitive science, neuroscience, and robotics. Ai Magazine, 38(4), 13-26.

From Signifier Exposure Mechanism to a Cognitive Architecture for Web-based Multi-Agent Systems



The Signifier Exposure Mechanism constitutes a first iteration towards creating a full global workspace on the Web.

This evolution will lead to the application of cognitive architectures to the design of cognitive architectures for Web-based Multi-Agent Systems.



Simon Mayer

Web-based Pervasive Autonomous Systems

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Julian Padget

Position Statement

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Wout Slabbinck
TPAC 2023
Autonomous agents for Personal Data Stores
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Digitization

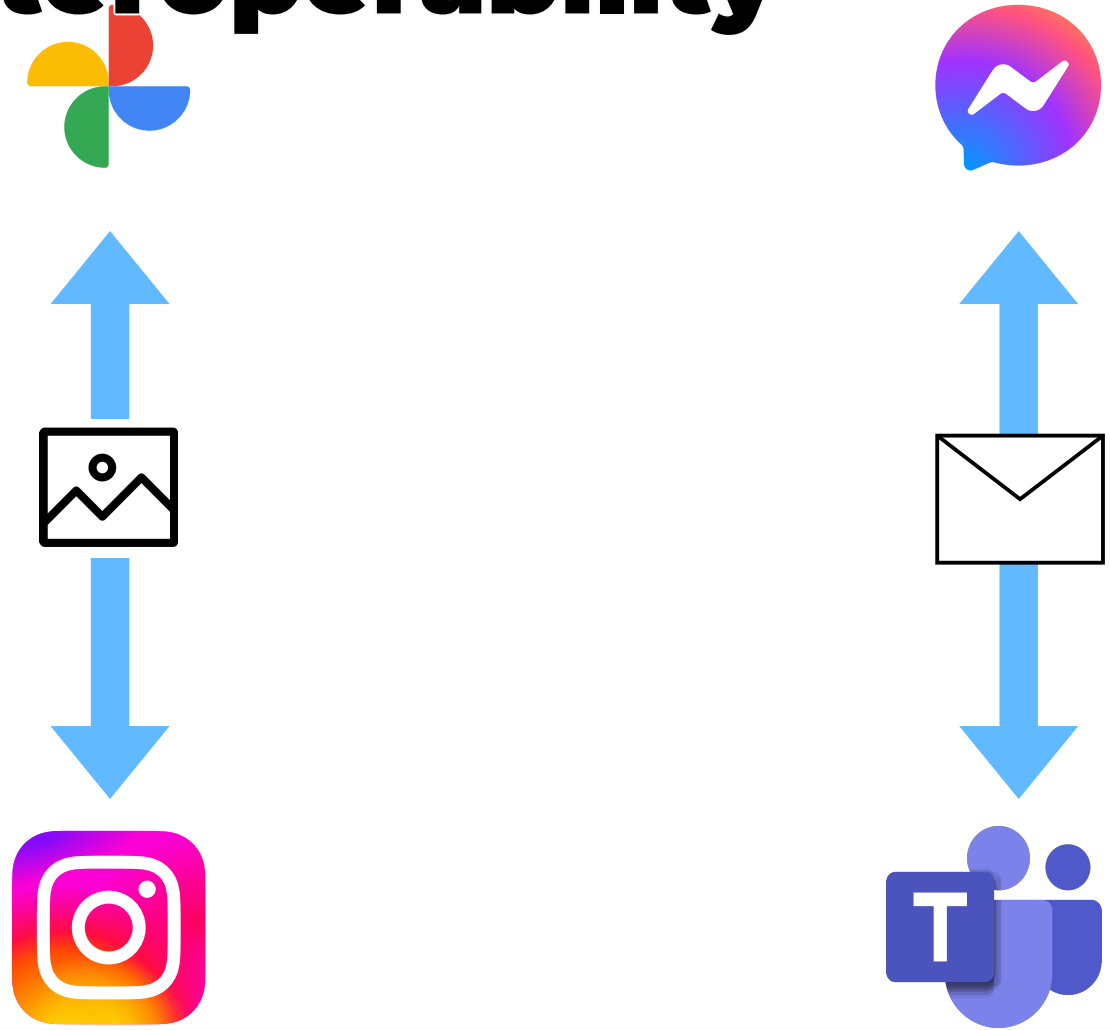
amazon

HELLO FRESH

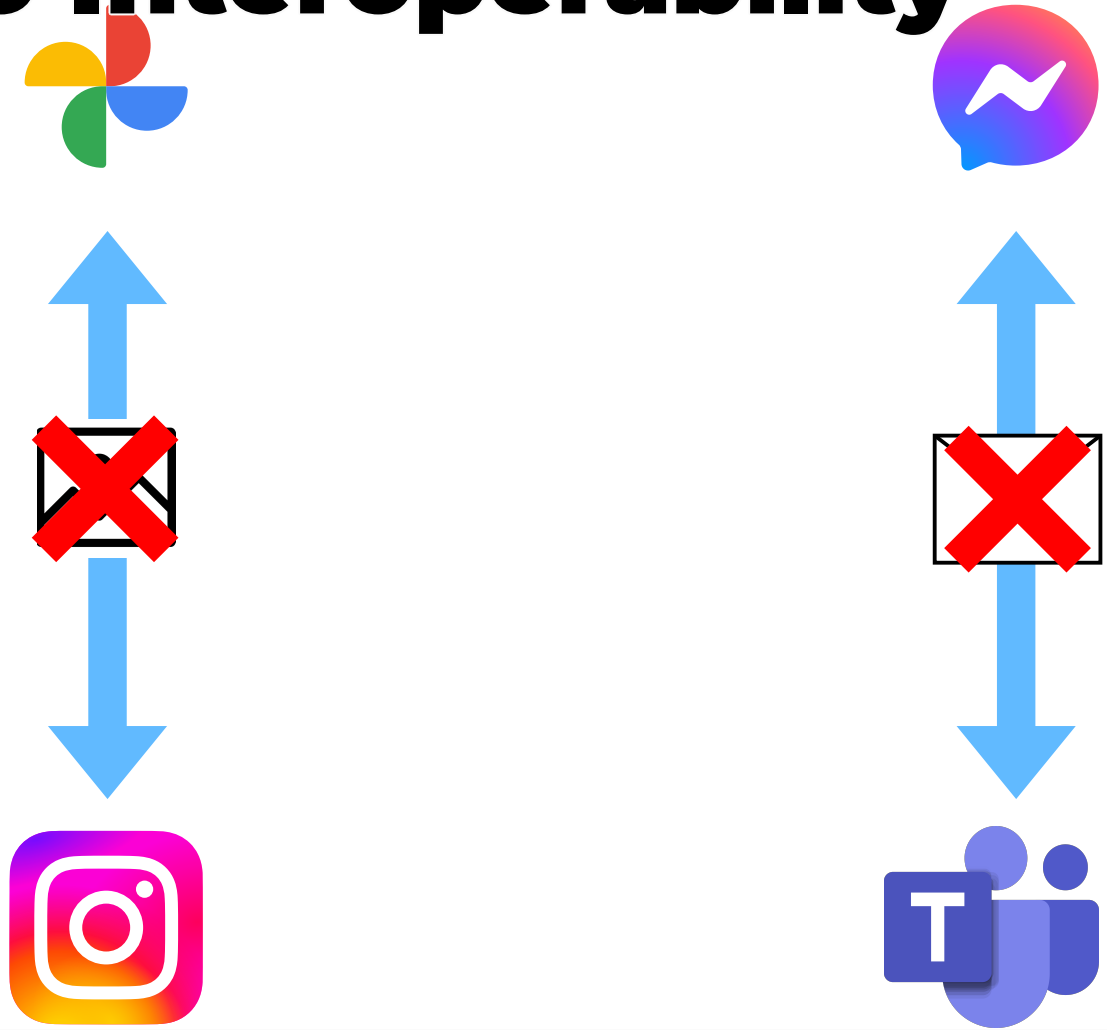
AliExpress™

Social Digitization

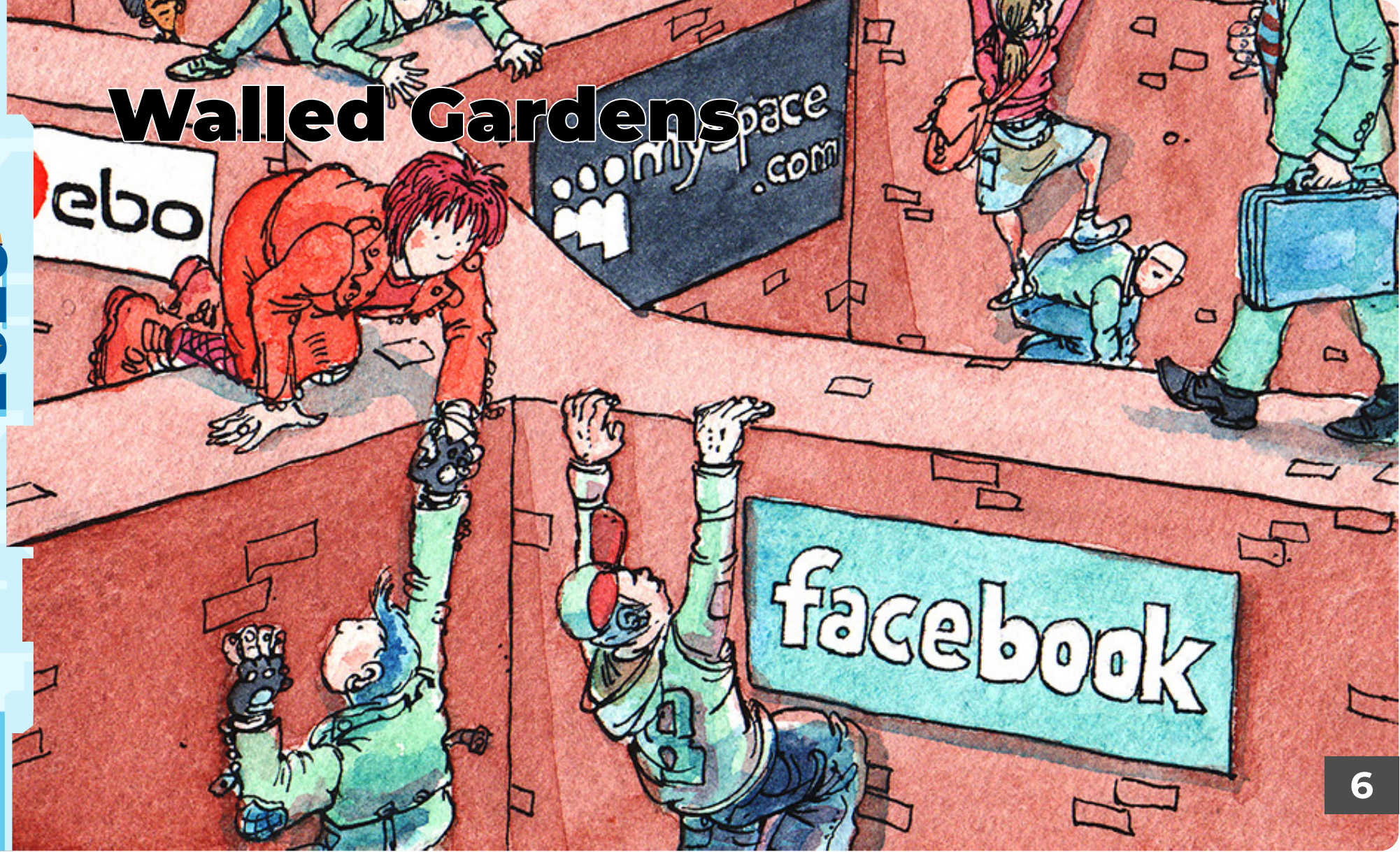
Interoperability



No Interoperability



Walled Gardens



Personal data stores

- Control over data
- Single source of truth
- Interoperability

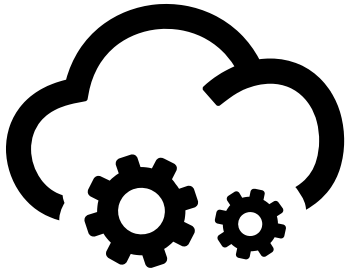
Solid

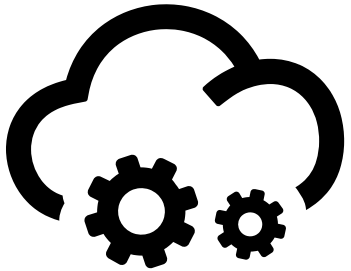
- Build on existing standards
- Seperating data from applications

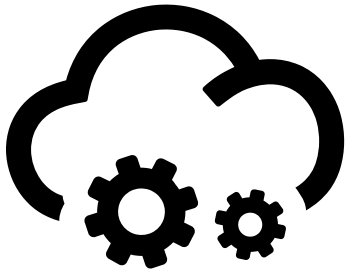
Solid Ecosystem

Application centric: Less focus on

- Integration with third parties
- Autonomous background tasks





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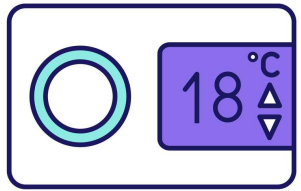
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Goal

Formalizing Web Agents for PDSs

- Discoverability
- Interface
- Embodiment

Position Statement

Scenario-Driven Development of *Context-Aware* Web Agent Frameworks

Alexandru SORICI

National University of Science and Technology POLITEHNICA Bucharest

My perspective

- Approaching WebAgents from the domain of ***Ambient Intelligence (AmI)***
- Focus on **proactive, human- / application- oriented interactions**
- My interest in AmI: organize and enable **desired** and **required *information flows* → *context management***

Scenario Driven Development

- AmI + context management experience => No “one size fits all” framework for diverse application requirements
- Scenario-Driven Development
  - Open Ecosystems for End-User Mashup of Agent Services
    - *Contained (small discourse domain)* ***goal-driven*** interactions with **decentralized data + decentralized control**
    - Socio-technical networks of people and software agents
  - Large scale B2B services
    - Applications in high impact industries: e.g. manufacturing and logistics, BMS, smart prosumer *local smart grids*

Contextualized Interactions

- In a scenario-driven development "*empowering the environment*" is key
  - Facilitate **interest / focus** driven access to the *web of data / web of services*
- HMAS frameworks **should** facilitate mechanisms to ***identify***, ***structure***, ***advertise*** and ***control access to*** *data* and *capabilities* that are **relevant** in the *context* of an interaction
- Position: context management is HMAS **should be** designed as an **environment middleware functionality**

Intersection with other Perspectives

- Making the environment a “first-class abstraction”
- Leverage affordance theory and signifiers as means to *filter* and *guide* interactions of humans and agents in an HMAS environment
- Find, index and promote resources and representations that enable HMAS functionality over the web

Socio-technical networking platforms for multi-agent collaboration on the Web

Antoine Zimmermann

★ W3C TPAC 2023, Seville, 11–15 September ★

Social networking activities

- Add a 1000th “friend” to your facebook profile so you can get **status updates** without maintaining active social interactions
- In response to an interesting **tweet**, ask your colleague to **create a Github issue** with a link to the original tweet and assign you to it
- Ask a **simple tech question** on an online forum that specialists can answer
- Follow your nerd friend who is **tweeting daily** about the local weather

A lot of those activities boil down to reading and posting text messages on social networking platforms

Asynchronous collab on the Web = exchange text messages

- A large part of people's collaboration on the Web happens by exchanging text messages
  - Post message – read message – respond to message
  - Blog post – comments
  - Git issue – comments
  - Tweet – retweet – respond to tweet
  - Wiki talk pages
  - Forum thread – respond to thread
  - Q&A
  - Product reviews
  - Status updates
  - IRC messages
  - Chat

Socio-technical networking activities

- Make friend with your **smart meter** at home so that you can get status updates without actively checking it
- In response to an interesting tweet, ask your **bot-colleague** to create a Github issue with a link to the original tweet and assign you to it
- Ask a simple tech question on an online forum that **chatGPT** can answer
- Follow an **automatic weather forecast agent** on tweeter
- Your **umbrella assistant** follows the weather agent to send you private messages when you need your umbrella/scarf/gloves

Collab via socio-technical networks (STNs) require few operations

- Few generic operations are needed for text-based collab:
  - Find list of message or thread
  - Read individual message/thread
  - Post new message/start discussion thread
  - Respond to existing message/thread
  - Private message vs. Public post
  - Register to platform
  - Follow/connect/befriend

Challenges

- First step: **automate participation of agents**
  - Provide machine-readable manuals for STN
  - Add semantic description of platforms telling agents how to do these operations (**ontology** of socio-technical networking platform + **thing description** + **auth method** e.g. WebID)
- Second step: **regulate** to avoid spam, misinformation, etc.
  - First done manually/with adhoc code
  - Then formalise descriptions of policies/norms
- Third step: **coordinate/autoorganise**
  - First, hard-code coordination in agents
  - Then formalise organisation models etc.