Autonomous Agents on the Web (WebAgents) Community Group

Andrei Ciortea, Rem Collier, Ege Korkan, and Antoine Zimmermann

TPAC 2025

Interoperability Task Force

W3C Community Group Draft Report

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WebAgents Community Group Report on Interoperability for Agents on the Web

Draft Community Group Report 09 November 2025

Latest published version:
none

Latest editor's draft:
https://w3c-cg.github.io/webagents/TaskForces/Interoperability/Reports/report-interoperability.html

Editors:
Andrei Ciortea (Inria and University of St.Gallen)
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Your Name

Feedback:
GitHub w3c-cg/webagents (pull requests, new issue, open issues)

Abstract

Advances in large language models (LLMs) that can follow instructions an
autonomous agents and multi-agent systems. Like previous generations o
designed for specific tasks, highlighting the need for open networks of a

https://bit.ly/webagents-interop

What should be the **role of the Web** in the emerging landscape of Agentic AI?

What are the **relevant standards** within and maybe also outside the W3C?

What are the **standardization gaps** (if any)?

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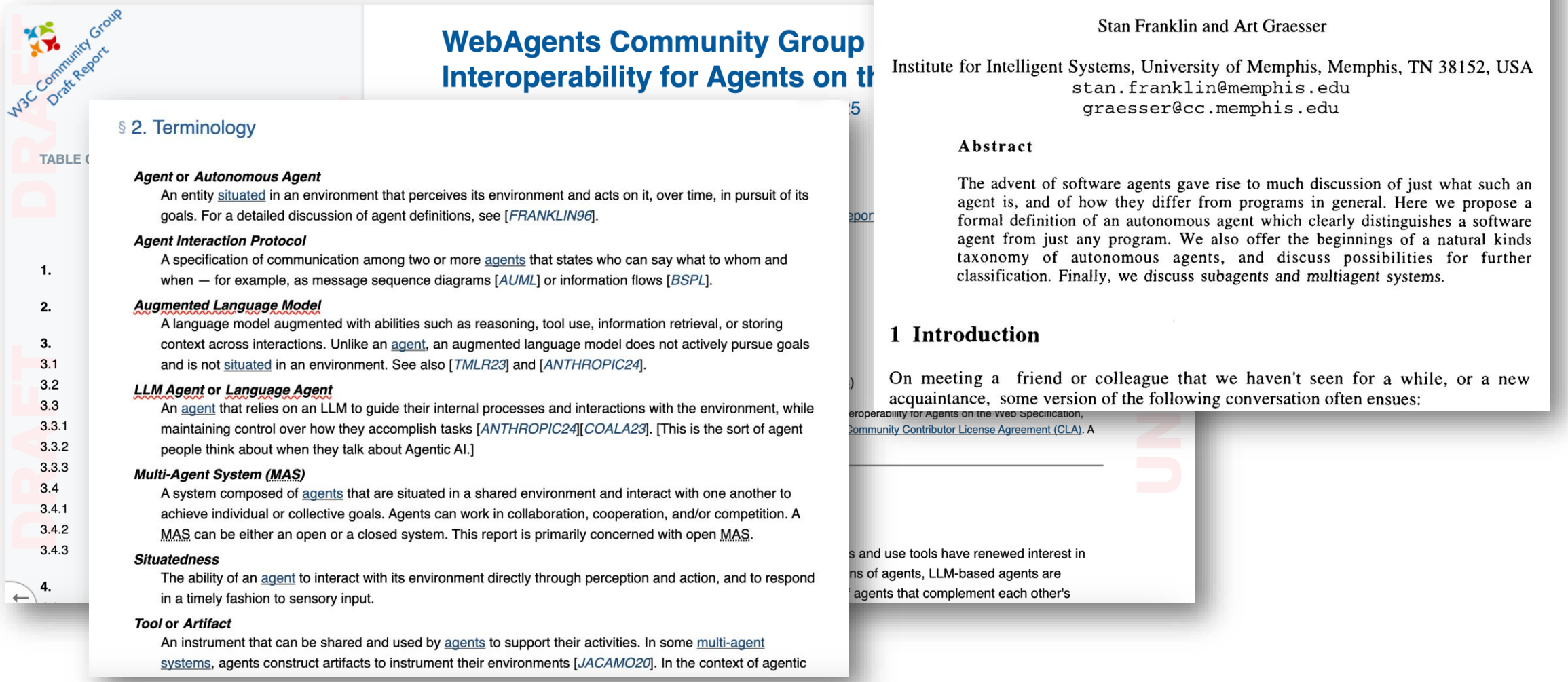
1996



Is It an Agent, or Just a Program?:
A Taxonomy for Autonomous Agents

Stan Franklin and Art Graesser

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stan.franklin@memphis.edu
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Abstract

The advent of software agents gave rise to much discussion of just what such an agent is, and of how they differ from programs in general. Here we propose a formal definition of an autonomous agent which clearly distinguishes a software agent from just any program. We also offer the beginnings of a natural kinds taxonomy of autonomous agents, and discuss possibilities for further classification. Finally, we discuss subagents and multiagent systems.

1 Introduction

On meeting a friend or colleague that we haven't seen for a while, or a new acquaintance, some version of the following conversation often ensues:

W3C Community Group Draft Report

WebAgents Community Group
Interoperability for Agents on th

§ 2. Terminology

Agent* or *Autonomous Agent
An entity situated in an environment that perceives its environment and acts on it, over time, in pursuit of its goals. For a detailed discussion of agent definitions, see [*FRANKLIN96*].

Agent Interaction Protocol
A specification of communication among two or more agents that states who can say what to whom and when — for example, as message sequence diagrams [*AUML*] or information flows [*BSPL*].

Augmented Language Model
A language model augmented with abilities such as reasoning, tool use, information retrieval, or storing context across interactions. Unlike an agent, an augmented language model does not actively pursue goals and is not situated in an environment. See also [*TMLR23*] and [*ANTHROPIC24*].

LLM Agent* or *Language Agent
An agent that relies on an LLM to guide their internal processes and interactions with the environment, while maintaining control over how they accomplish tasks [*ANTHROPIC24*][*COALA23*]. [This is the sort of agent people think about when they talk about Agentic AI.]

Multi-Agent System (MAS)
A system composed of agents that are situated in a shared environment and interact with one another to achieve individual or collective goals. Agents can work in collaboration, cooperation, and/or competition. A MAS can be either an open or a closed system. This report is primarily concerned with open MAS.

Situatedness
The ability of an agent to interact with its environment directly through perception and action, and to respond in a timely fashion to sensory input.

Tool* or *Artifact
An instrument that can be shared and used by agents to support their activities. In some multi-agent systems, agents construct artifacts to instrument their environments [*JACAMO20*]. In the context of agentic

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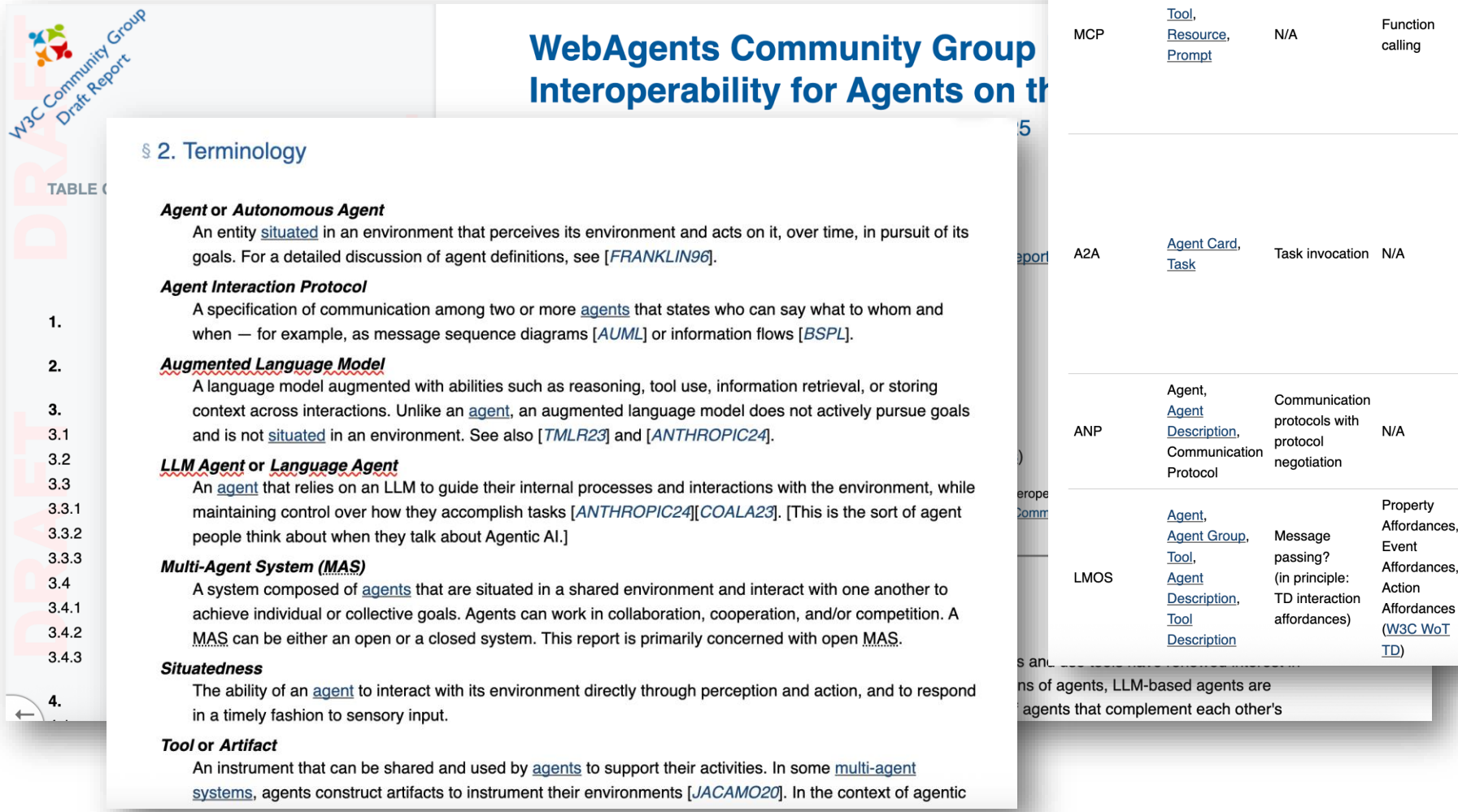

	Relevant Concepts	Agent Interaction	Tool Use	Identifiers	Descriptions	Discovery Mechanisms	Arch. Style
MCP	Tool, Resource, Prompt	N/A	Function calling	Strings (Tools and Prompts), URIs (Resources)	Tool definition, Resource descriptions, Prompt definitions, (JSON)	Directories (via */list)	Client-Server with streaming RPC connectors (JSON-RPC 2.0, Streamable HTTP)
A2A	Agent Card, Task	Task invocation	N/A	Strings?	Agent Card, Task description, (JSON)	Well-known URIs, Directories	Async. Client-Server with streaming RPC connectors and webhooks (JSON-RPC 2.0, HTTP+SSE)
ANP	Agent, Agent Description, Communication Protocol	Communication protocols with protocol negotiation	N/A	W3C DID with custom Web-based Agent DID Method	Agent Description (RDF/JSON-LD)	Directories	Peer-to-Peer? (WebSocket subprotocol)
LMOS	Agent, Agent Group, Tool, Agent Description, Tool Description	Message passing? (in principle: TD interaction affordances)	Property Affordances, Event Affordances, Action Affordances (W3C WoT TD)	Uniform identifiers (IRIs, W3C DIDs)	Agent Description, Tool Description (W3C WoT TD; JSON, RDF/JSON-LD)	DNS-SD/mDNS, Well-known URIs, Directories (W3C WoT Discovery)	W3C WoT Arch.? with protocol bindings for HTTP and WebSocket subprotocol

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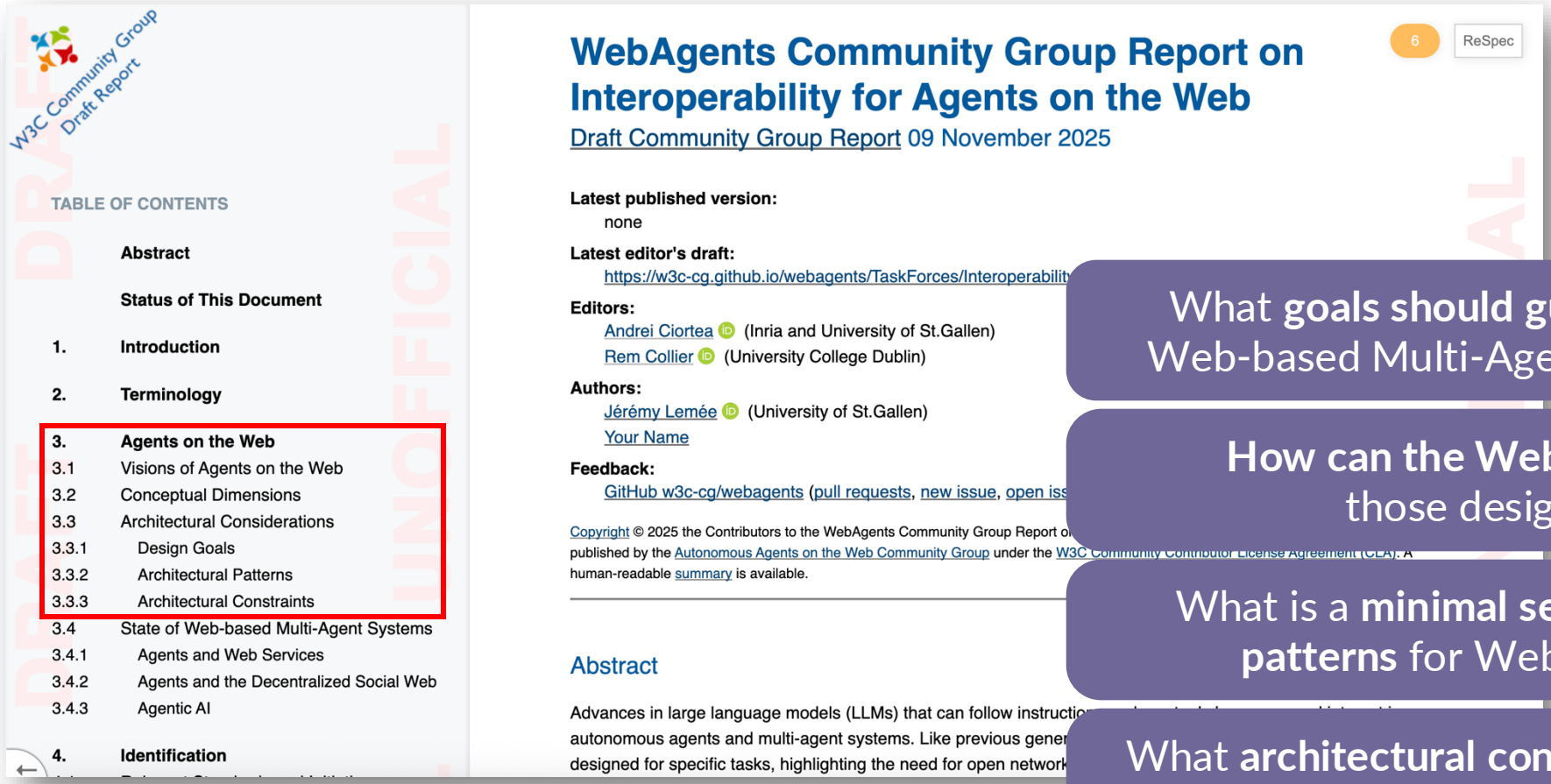

What **goals should guide** the design of Web-based Multi-Agent Systems (MAS)?

How can the Web contribute to those design goals?

What is a **minimal set of architectural patterns** for Web-based MAS?

What **architectural constraints** do we need in order to fully leverage the Web?

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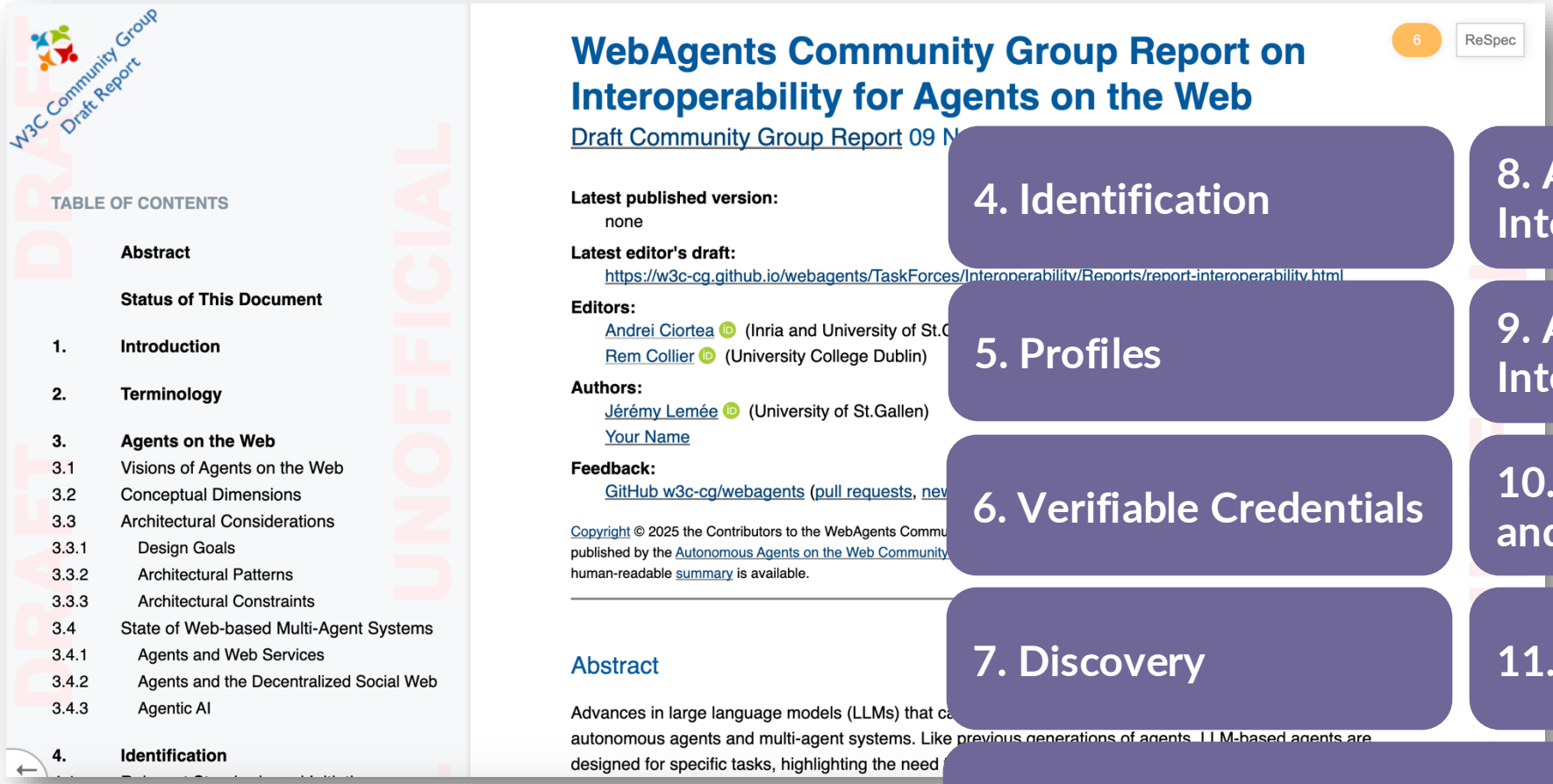


4. Identification

5. Profiles

6. Verifiable Credentials

7. Discovery

8. Agent-to-Agent Interaction

9. Agent-Environment Interaction

10. Policies, Norms, and Accountability

11. Security and Privacy

12. Conclusions: A Roadmap for Agents on the Web

Hypermedia Multi-Agent Systems (hMAS)

Visions of Agents on the Web

From Web-based MAS to hMAS

Architectural Design of hMAS

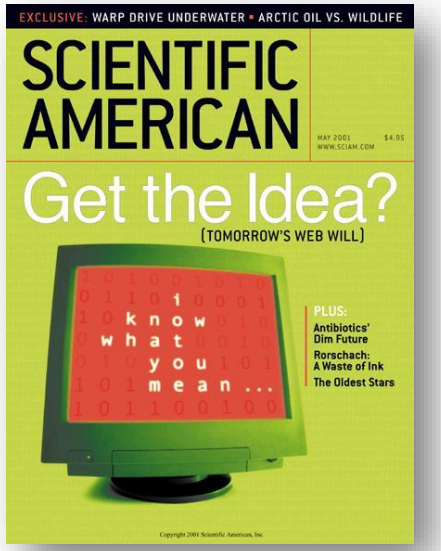
- Design Goals
- Architectural Patterns
- Architectural Constraints

Demonstrator

Visions of Agents on the Web: A Web for Machines

"(...) in fact documents on the web describe **real objects** and **imaginary concepts**, and give particular **relationships** between them. (...) This means that machines, as well as operating on the web information, **can do real things**."

— Sir Tim Berners-Lee 1994
http://www.w3.org/Talks/WWW94Tim/



The Semantic Web

A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities

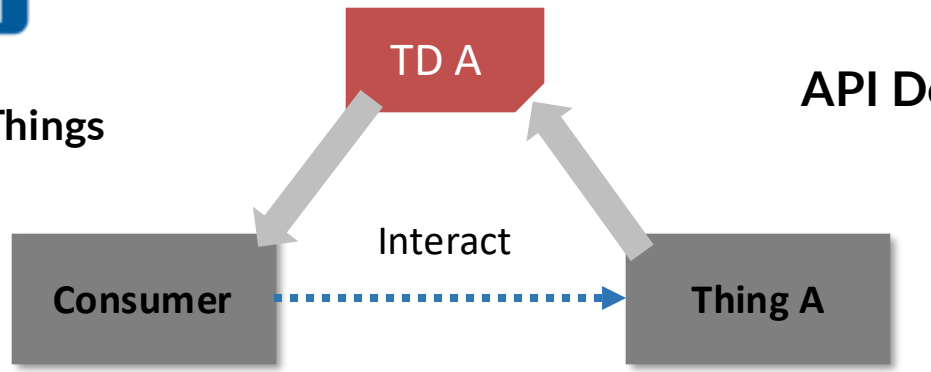
By Tim Berners-Lee, James Hendler and Ora Lassila

The entertainment system was belting out the Beatles' "We Can Work It Out" when the phone rang. When Pete answered, his phone turned the sound down by sending a message to all the other *local* devices that had a *volume control*. His sister, Lucy, was on the line from

Tim Berners-Lee, Jim Hendler, Ora Lassila. Scientific American, 2001.

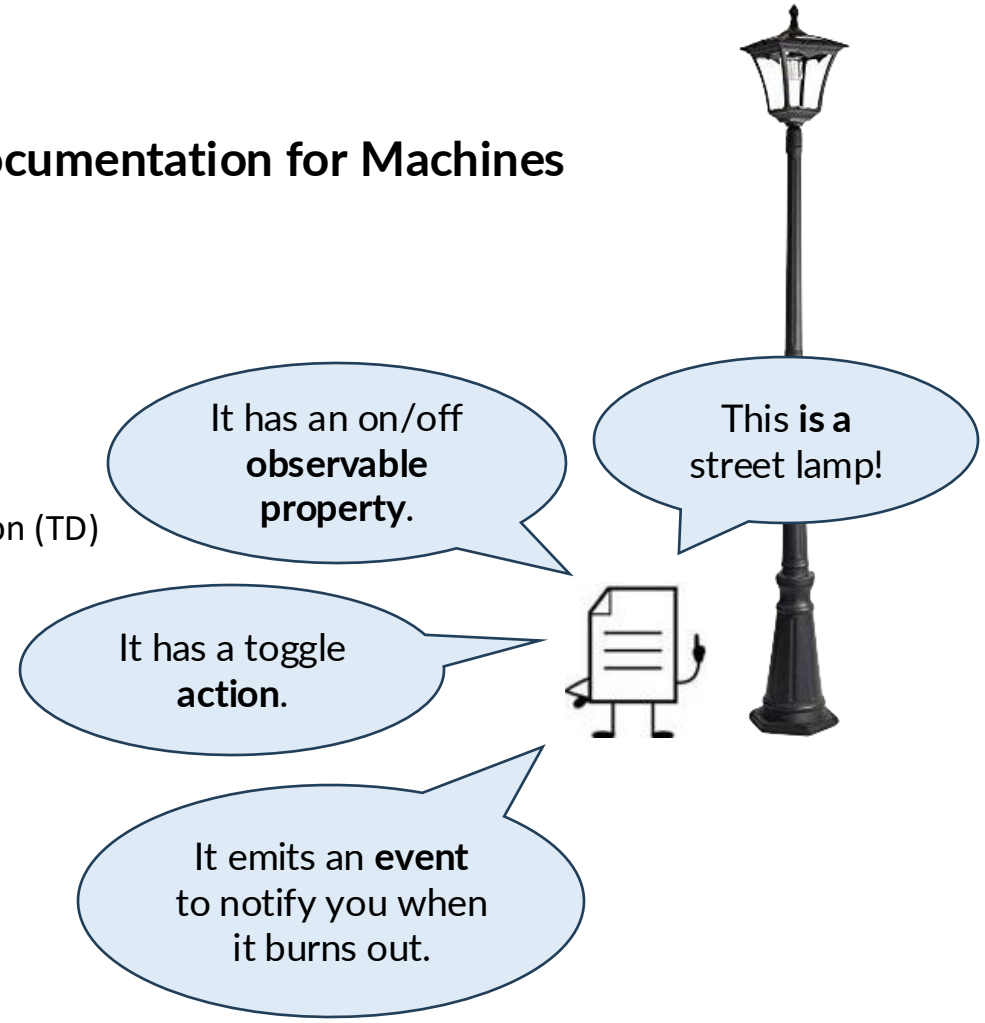
Visions of Agents on the Web: A Web for Machines

W3C Web of Things



TD A Thing Description (TD) of Thing A

API Documentation for Machines



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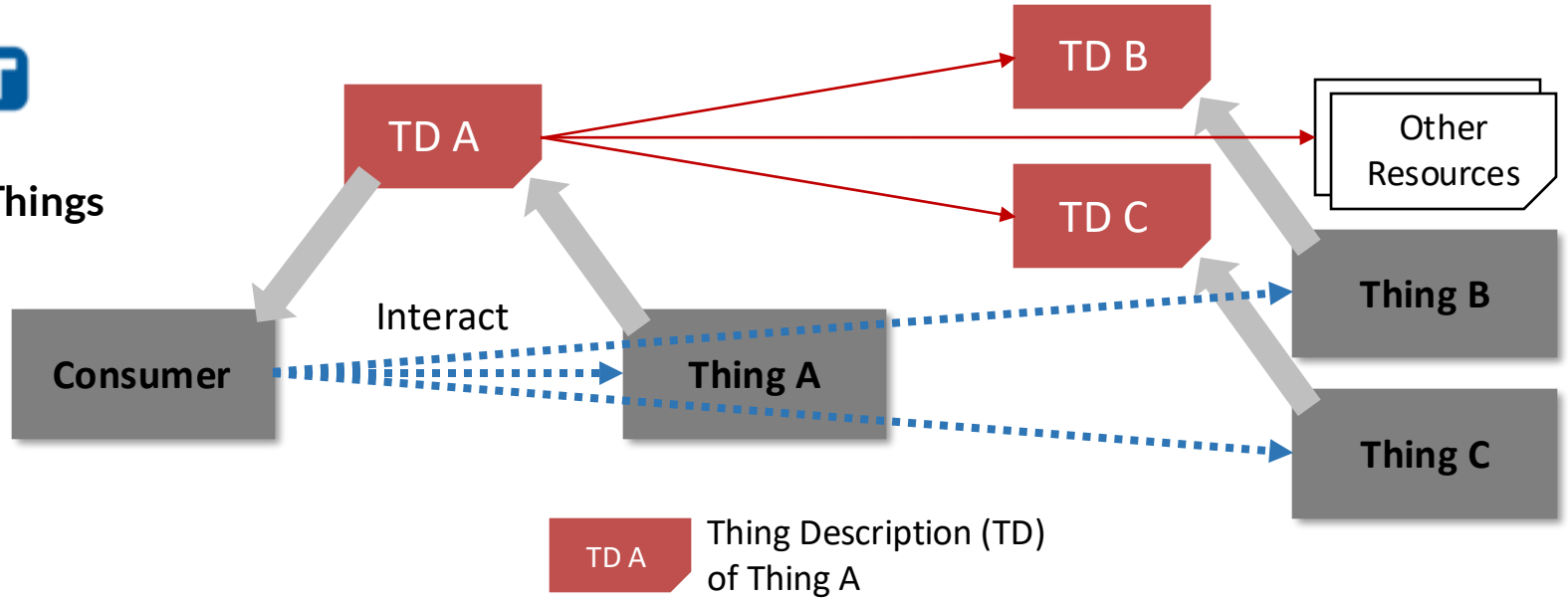

Lagally *et al.* (eds.), Web of Things (WoT) Architecture 1.1, W3C Recommendation, 2023.

Ideally: consumers ***arrive-and-operate*** in any standard **W3C Web of Things environment**

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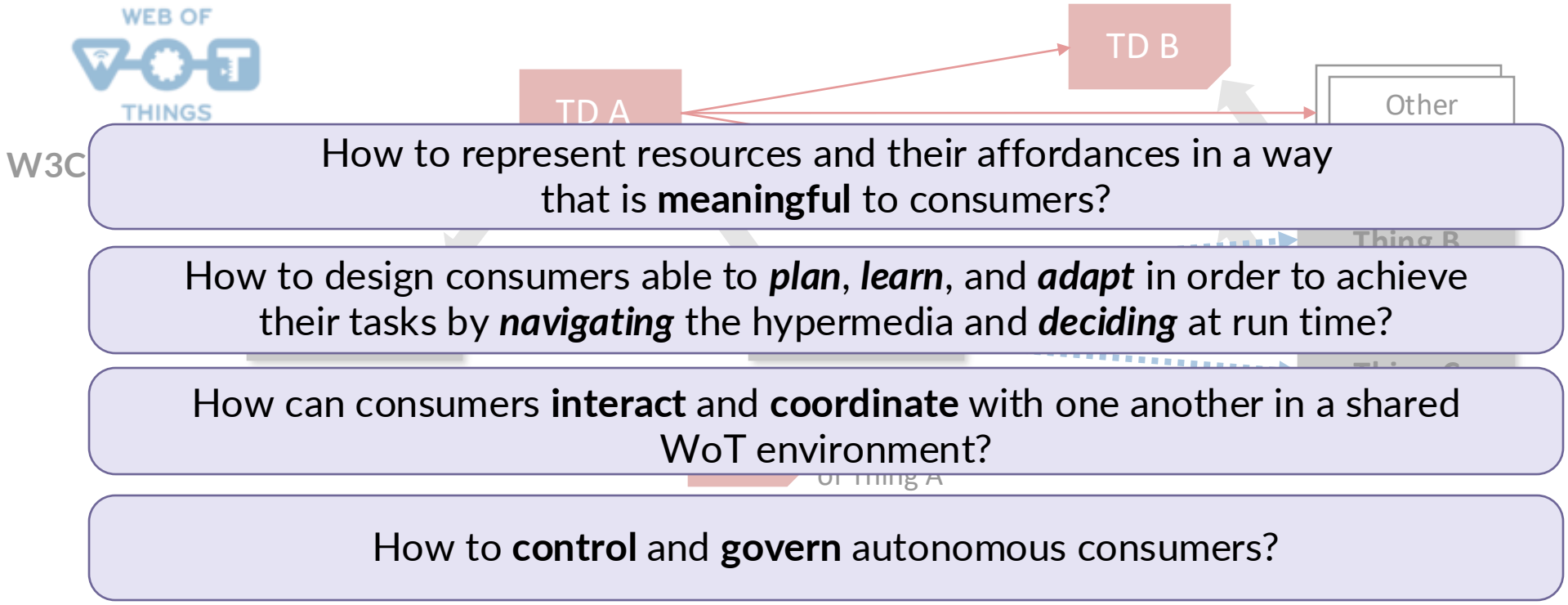


How to represent resources and their affordances in a way that is **meaningful** to consumers?

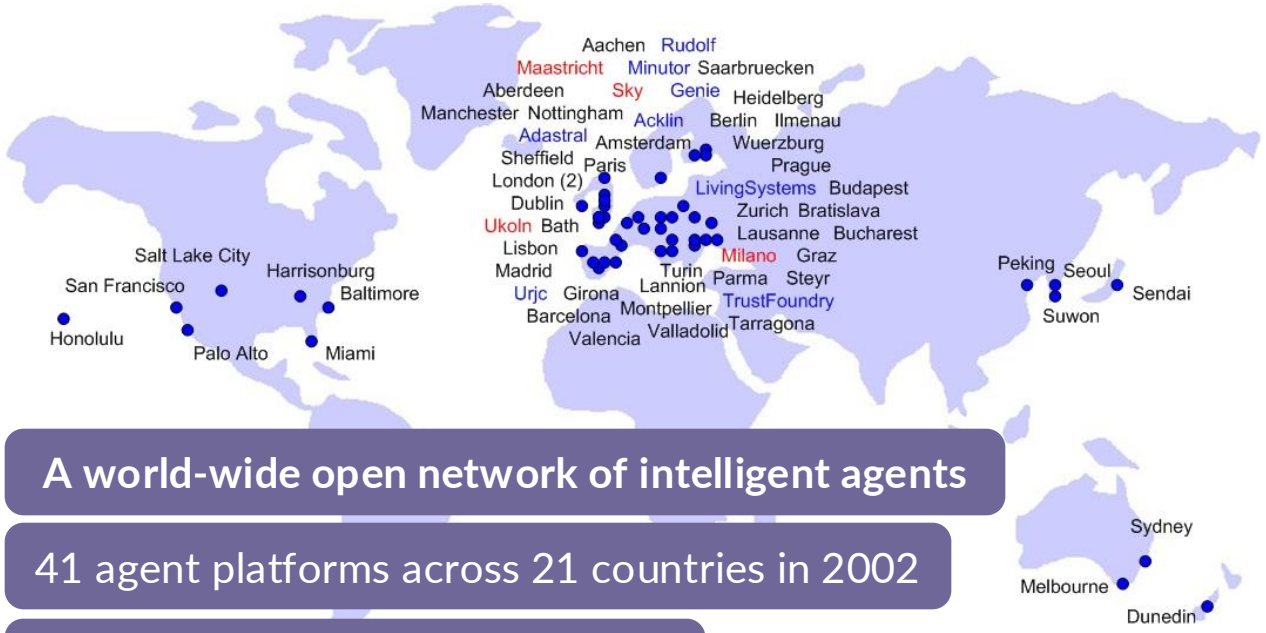
How to design consumers able to ***plan***, ***learn***, and ***adapt*** in order to achieve their tasks by ***navigating*** the hypermedia and ***deciding*** at run time?

How can consumers **interact** and **coordinate** with one another in a shared WoT environment?

How to **control** and **govern** autonomous consumers?

Ideally: consumers ***arrive-and-operate*** in any standard **W3C Web of Things environment**

Visions of Agents on the Web: FIPA & AgentCities



A world-wide open network of intelligent agents

41 agent platforms across 21 countries in 2002

160 registered platforms in 2005

AgentCities
(Wayback Machine; April 3, 2007)

Foundation for Intelligent Physical Agents (FIPA)

26 specifications

Identifier	Title
SC00001	FIPA Abstract Architecture Specification
SC00008	FIPA SL Content Language Specification
SI00014	FIPA Nomadic Application Support Specification
SC00023	FIPA Agent Management Specification
SC00026	FIPA Request Interaction Protocol Specification
SC00027	FIPA Query Interaction Protocol Specification
SC00028	FIPA Request When Interaction Protocol Specification
SC00029	FIPA Contract Net Interaction Protocol Specification
SC00030	FIPA Iterated Contract Net Interaction Protocol Specification
SC00033	FIPA Brokering Interaction Protocol Specification
SC00034	FIPA Recruiting Interaction Protocol Specification
SC00069	FIPA ACL Message Representation in Bit-Efficient Specification

Required **custom-built middleware** (e.g., for resolving agent names)

https://web.archive.org/web/20240621071356/http://fipa.org/
https://web.archive.org/web/20070403205629/http://www.agentcities.org/Network/

Visions of Agents on the Web: DARPA CoABS & DAML

DARPA Control of Agent Based Systems (CoABS)

- DARPA vision: to bring together multiple, heterogenous technologies to ***autonomously*** respond to ***dynamic*** and ***evolving*** scenarios
- **CoABS Grid**: the middleware integrating heterogeneous agent-based systems, object-based applications, and legacy systems

Large-scale applications with up to **10.000 agents**

[Kahn & Della Torre Cicalese, 2003]

Problem: **semantic interoperability in open systems**

DARPA Agent Markup Language (DAML)

- Proposed by J. Hendler to address the knowledge problem for agents
  - helped kick-start the **Semantic Web**
  - **distributed ontologies** using Web links

Signaled a shift from custom-built middleware to **leveraging the Web's existing infrastructure**

Terry R. Payne: Autonomy, the Web and Knowledge-based Services (keynote), HyperAgents 2025.
Martha L. Kahn and Cynthia Della Torre Cicalese. CoABS Grid Scalability Experiments. JAAMAS. 2003.

Hypermedia Multi-Agent Systems (hMAS)

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From Web-based MAS to hMAS

Architectural Design of hMAS

- Design Goals
- Architectural Patterns
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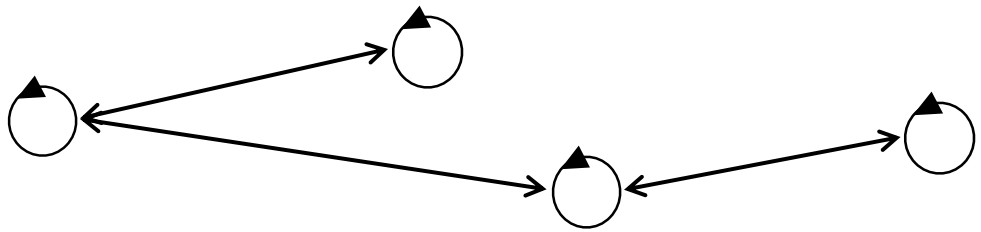
MAS and the Web in the Early 2000s



What about the Web?

The Web as a transport layer in MAS:

- WS-* standards (SOAP, WSDL, etc.)
- FIPA Agent Message Transport Protocol for HTTP
  http://www.fipa.org/specs/fipa00084/SC00084F.html

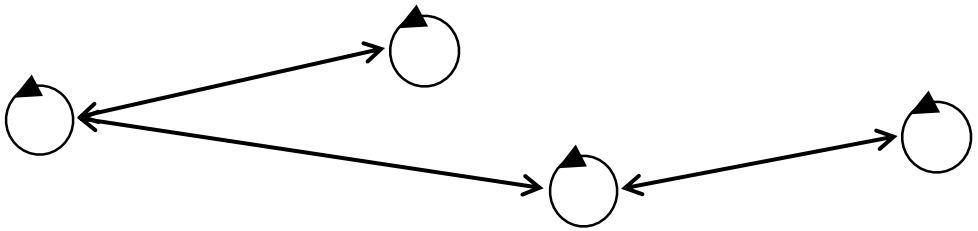
MAS remain **outside** of the Web and are **misaligned** with the Web architecture.

Two developments since:

- **conceptual dimensions** for engineering MAS
- the role of **hypermedia** in Web service design

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.

MAS — More Than Just Agents



What about the Web?

Environment [Weyns et al., 2007]

- workshop series: *Environment for Multiagent Systems (E4MAS)*

Organization [Boissier et al., 2006]

- workshop series: *Coordination, Organizations, Institutions, and Norms in Agent Systems (COIN)*

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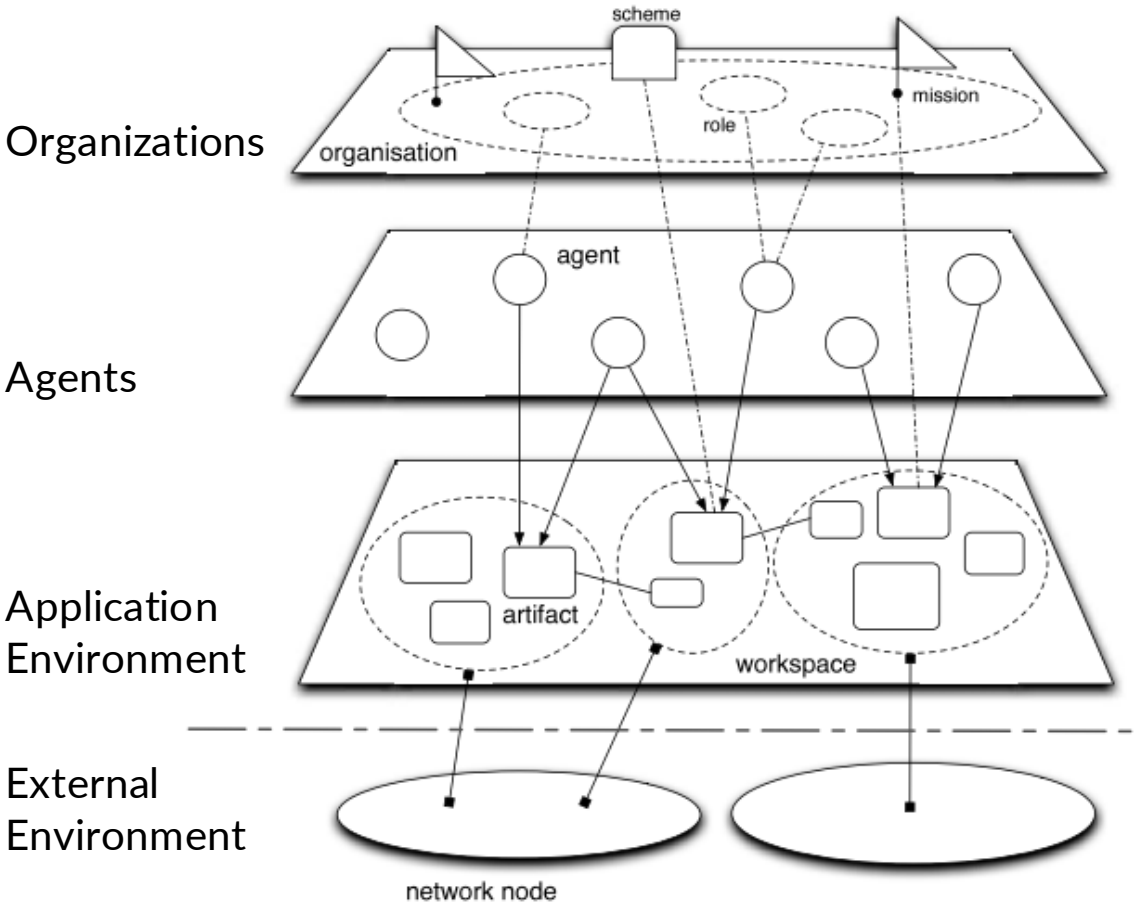

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O. Boissier, R.H. Bordini, J.F. Hübner, A. Ricci, and A. Santi, Multi-agent oriented programming with JaCaMo, Science of Computer Programming, Volume 78, Issue 6, 2013.

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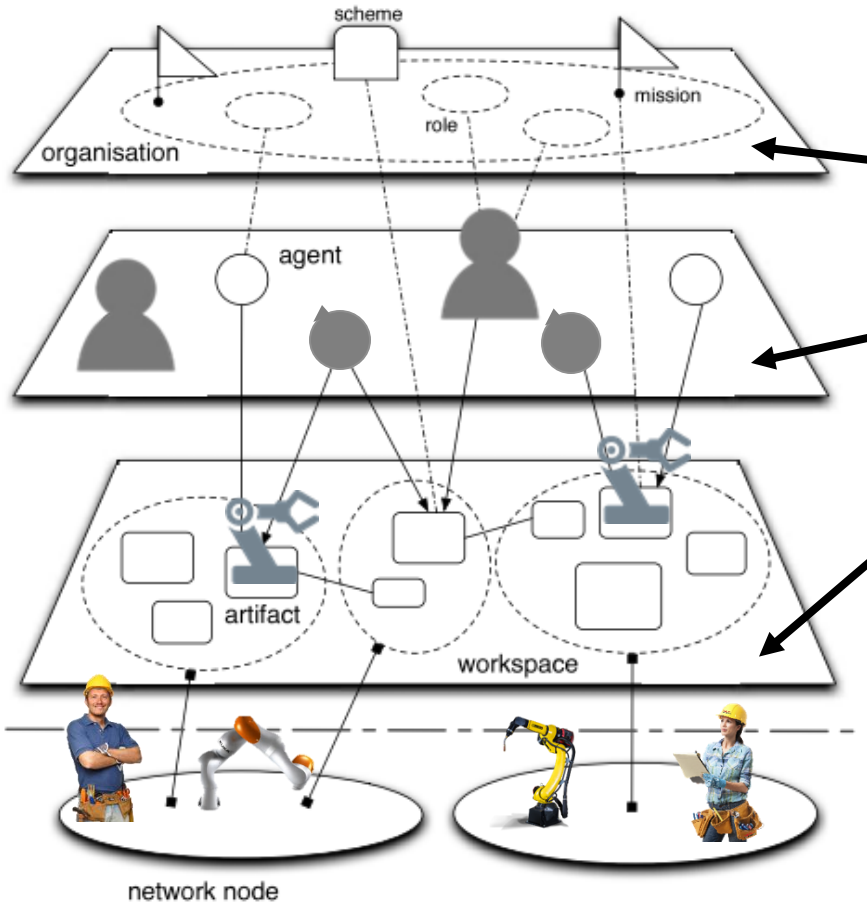

JaCaMo Meta-Model [Boissier et al., 2013]

Hybrid Manufacturing Organizations @ Siemens
[Ciortea et al., 2018]

collectives of people and artificial agents working towards common goals

autonomous behavior

non-autonomous behavior

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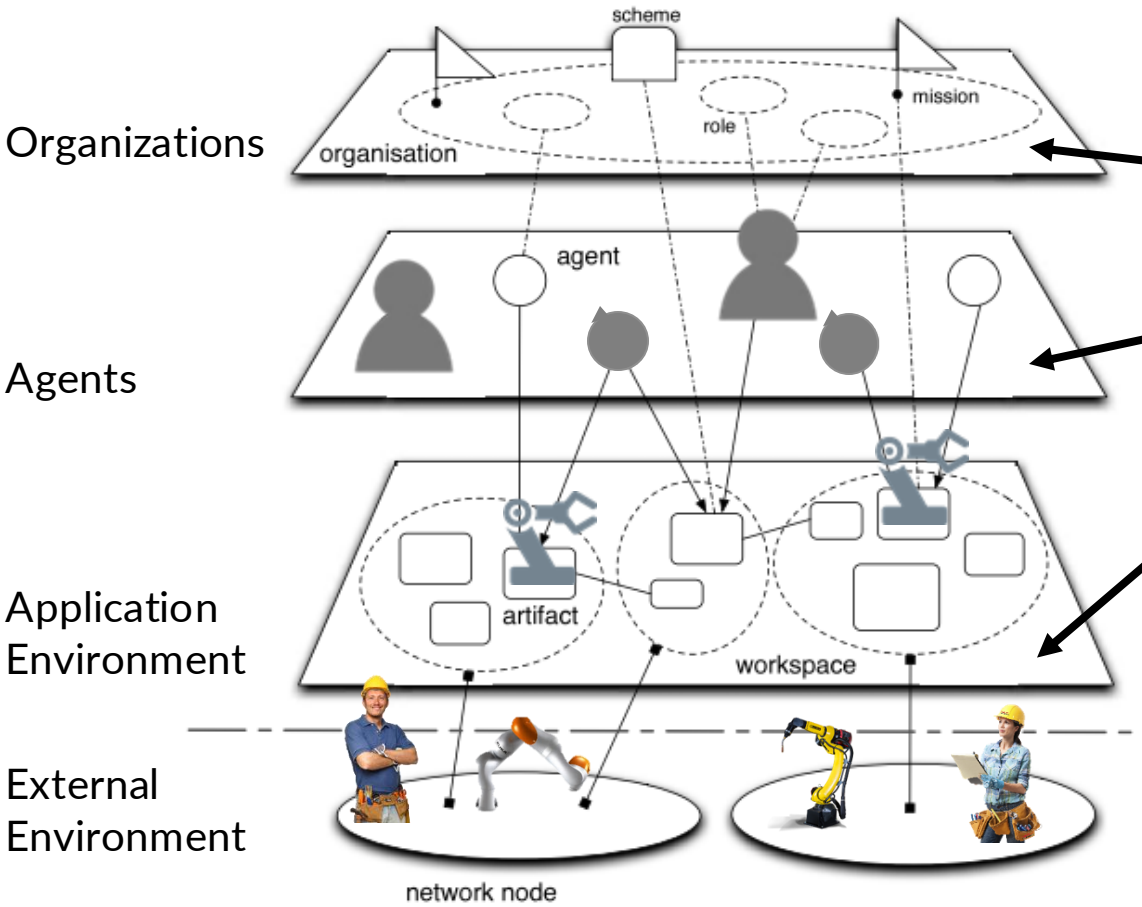

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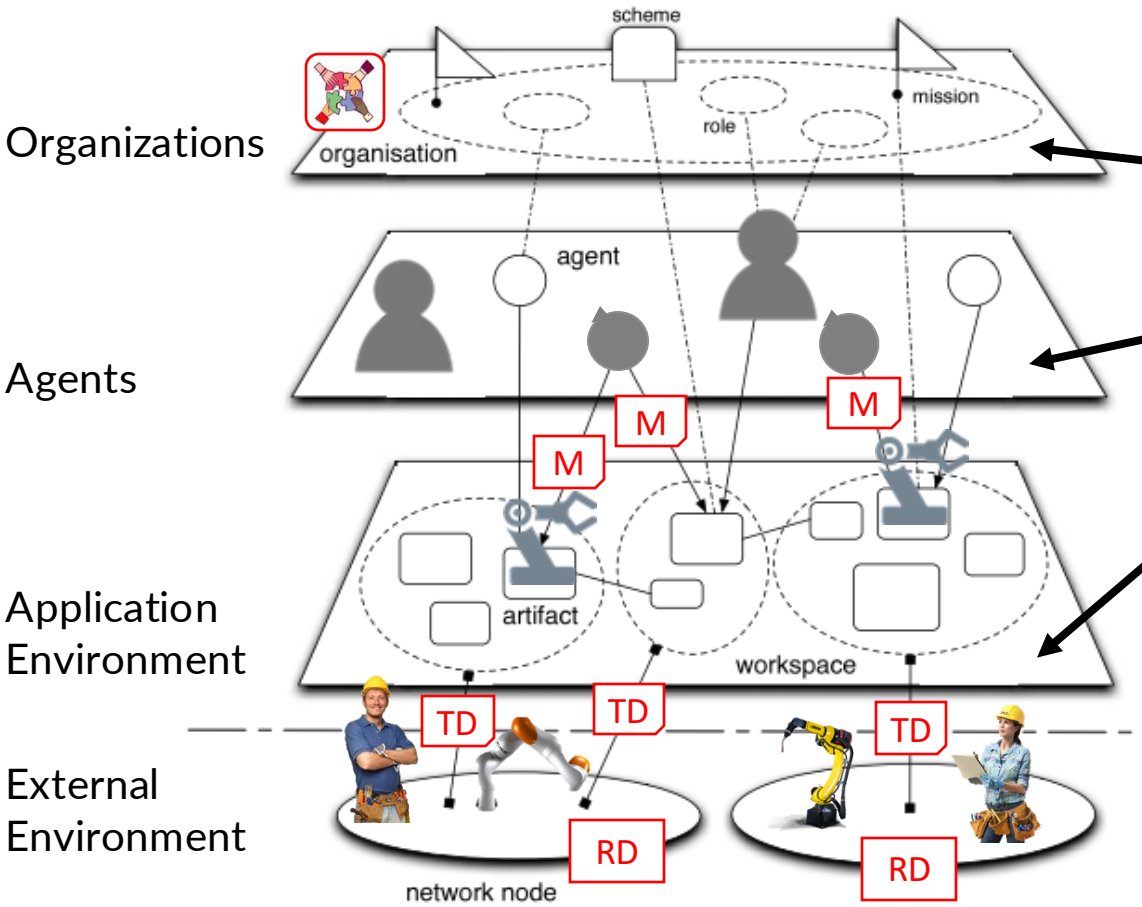

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Hybrid Manufacturing Organizations @ Siemens
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non-autonomous behavior

Web Resources

- Semantic Specs. of Organizations
- M — Artifact Manuals (functionality desc.)
- TD — W3C WoT Thing Desc. (interface desc.)
- RD — Resource Directory
- WoT Devices

Andrei Ciortea, Simon Mayer, and Florian Michahelles. Repurposing Manufacturing Lines on the Fly with Multi-Agent Systems for the Web of Things, AAMAS 2018.
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The Role of Hypermedia in the Web Model

Mon 20 Oct 2008

REST APIs must be hypertext-driven

Posted by Roy T. Fielding under software architecture, web architecture

[51] Comments

I am getting frustrated by the number of people calling any HTTP-based interface a REST API. Today's example is the SocialSite REST API. That is RPC. It screams RP

What needs to be done to make the REST architectural style clear on the notion that hypertext is a constraint? In other words, if the engine of application state (and hence the API) is not being driven by hypertext, then it cannot be RESTful and cannot be a REST API. Period. Is there some broken manual somewhere that needs to be fixed?

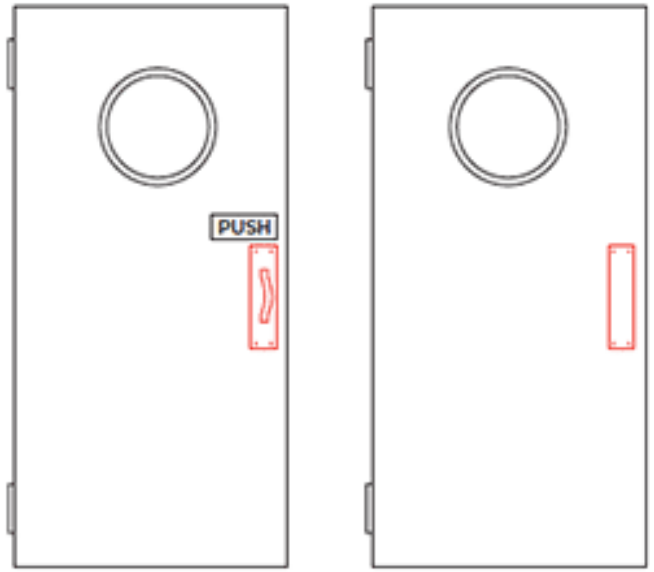
https://roy.gbiv.com/untangled/2008/rest-apis-must-be-hypertext-driven

The Role of Hypermedia in the Web Model

"When I say [hypermedia] I mean the simultaneous presentation of information and controls such that the **information becomes the affordance** through which **the user obtains choices** and **selects actions**."

– Roy T. Fielding, *A Little REST and Relaxation*, ApacheCon Europe, 2008

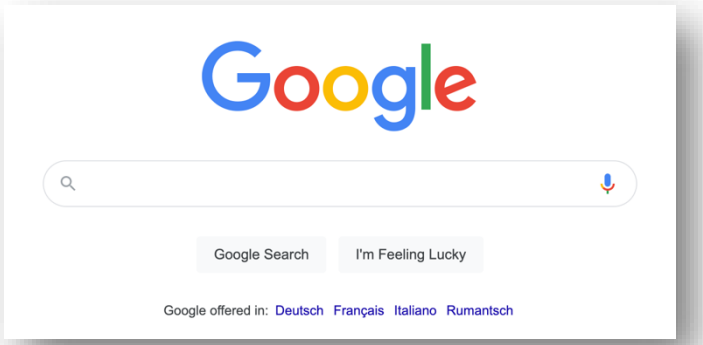
Affordances in everyday life:



How do affordances look like **on the Web**?

I am a hyperlink!

I am not a hyperlink.



http://google.com

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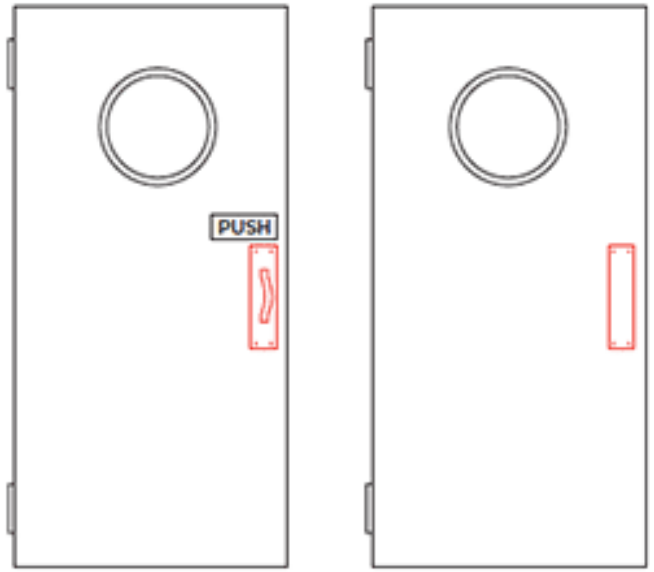

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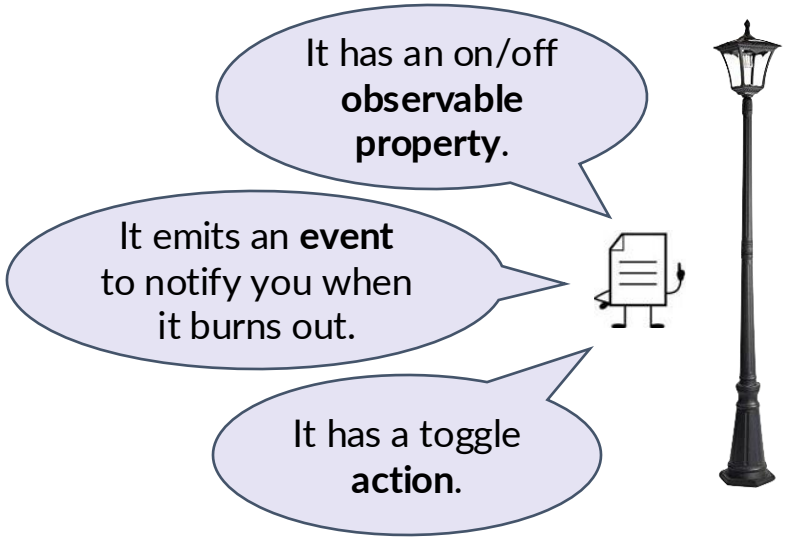

W3C WoT Thing Description
(API Documentation for Machines)

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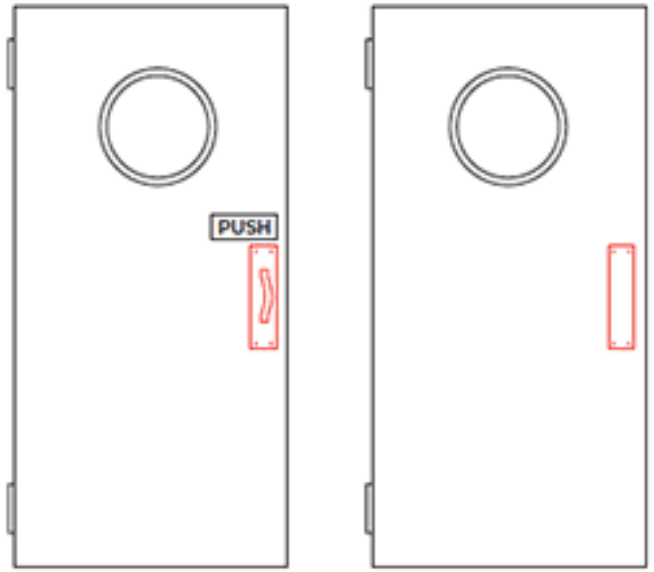

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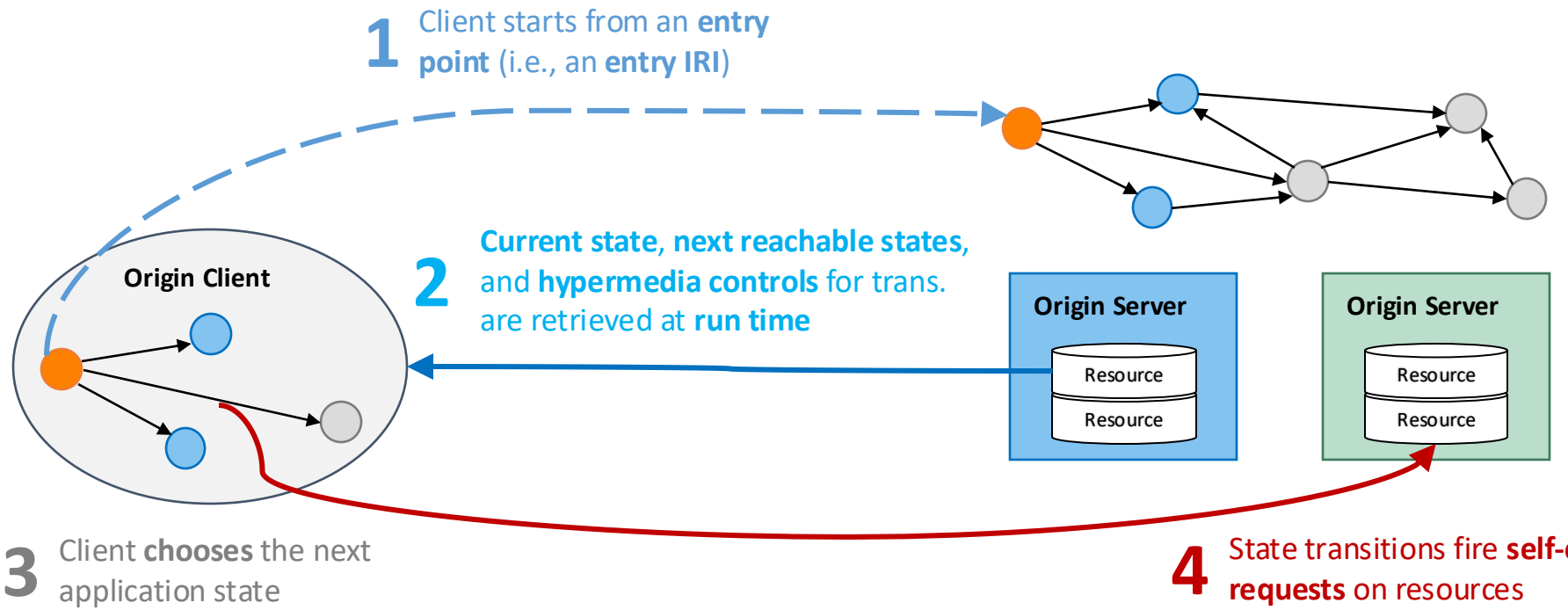

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Hypermedia-driven interaction "decouples" the Web architecture:

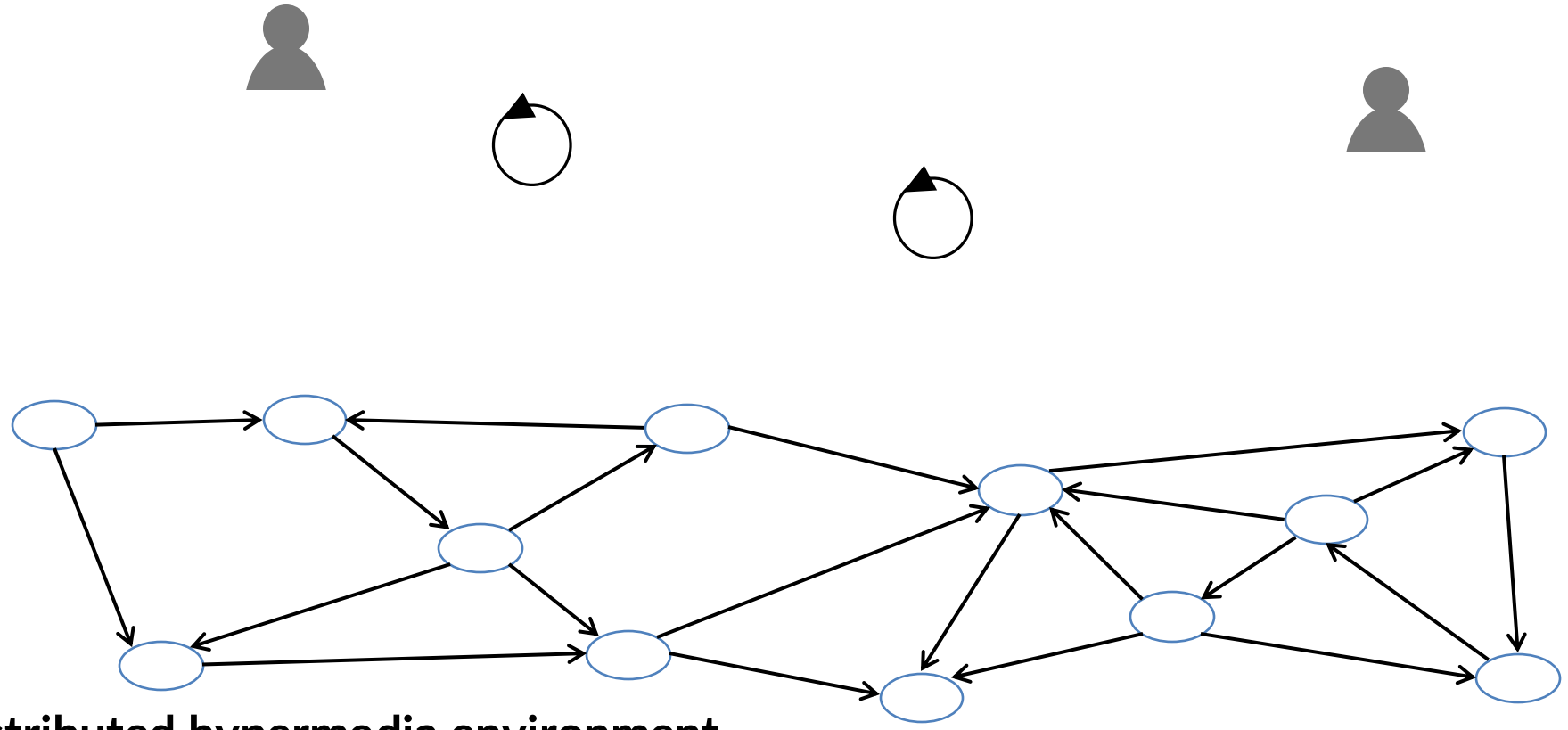
- **IRIs**, possible transitions to **next application states**, and the **means to transition** to those states are advertised in the hypermedia – they are **never hard-coded** into clients!

  ⇒ components can be ***developed***, ***deployed***, and can ***evolve independently*** from one another

Hypermedia Multi-Agent Systems (hMAS)

The Web is no longer a **hidden transport layer**, but a **rich application layer**!

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



Distributed hypermedia environment

Andrei Ciortea, Olivier Boissier, and Alessandro Ricci: Engineering World-Wide Multi-Agent Systems with Hypermedia, EMAS 2018.
Andrei Ciortea, Simon Mayer, Simon Bienz, Olivier Corby, and Fabien Gandon. Autonomous search in a social and ubiquitous Web. Pers Ubiquit Comput. 2020.

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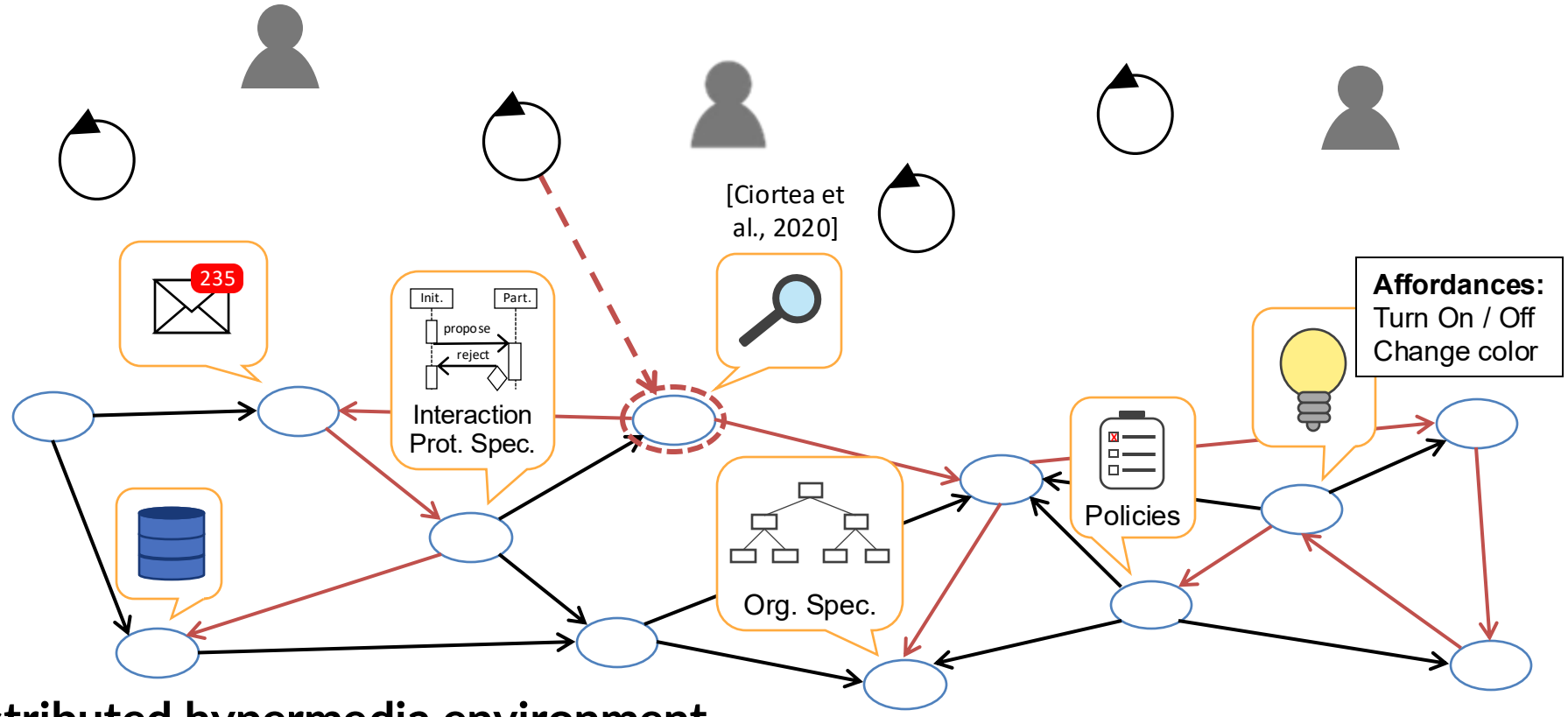

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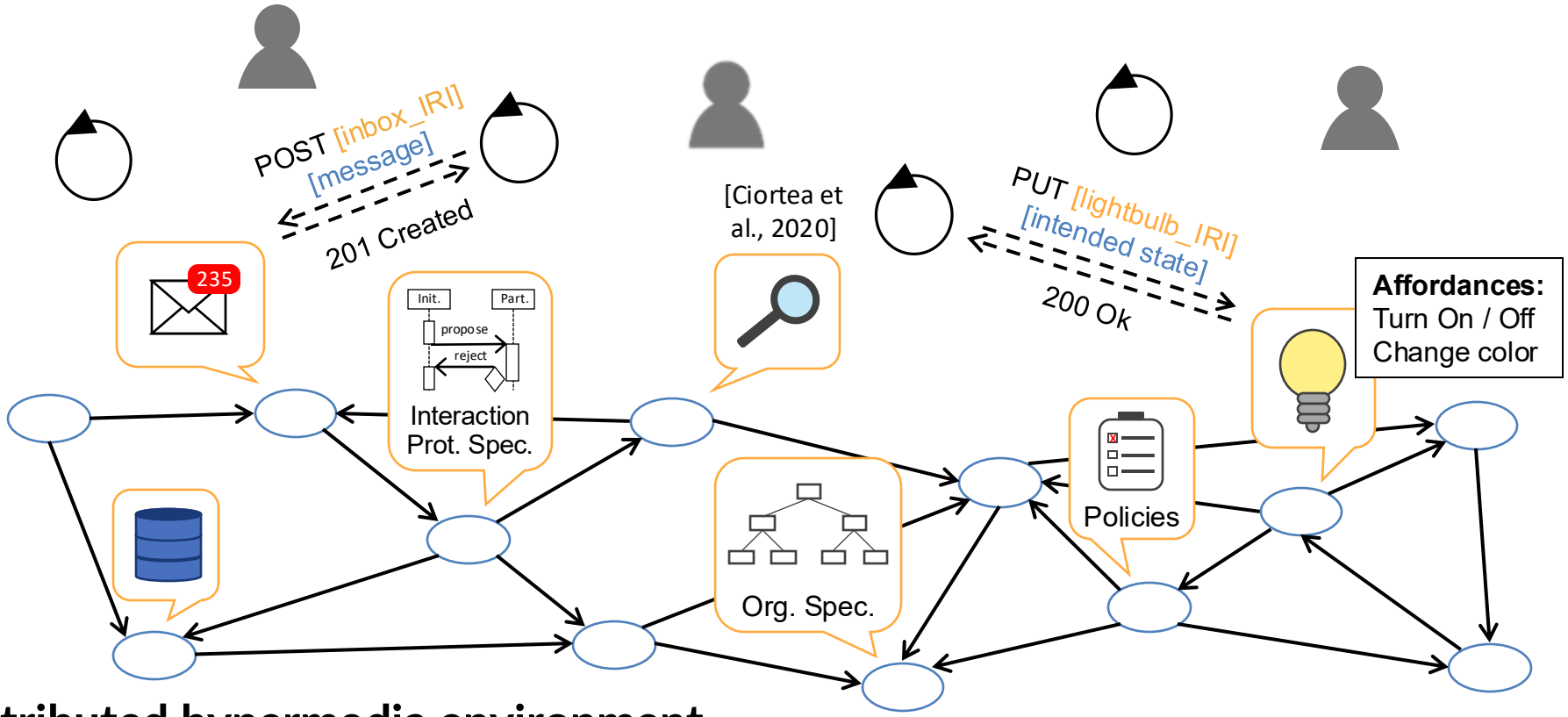

Uniform Action

Distributed hypermedia environment

Andrei Ciortea, Olivier Boissier, and Alessandro Ricci: Engineering World-Wide Multi-Agent Systems with Hypermedia, EMAS 2018.
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Hypermedia Multi-Agent Systems (hMAS)

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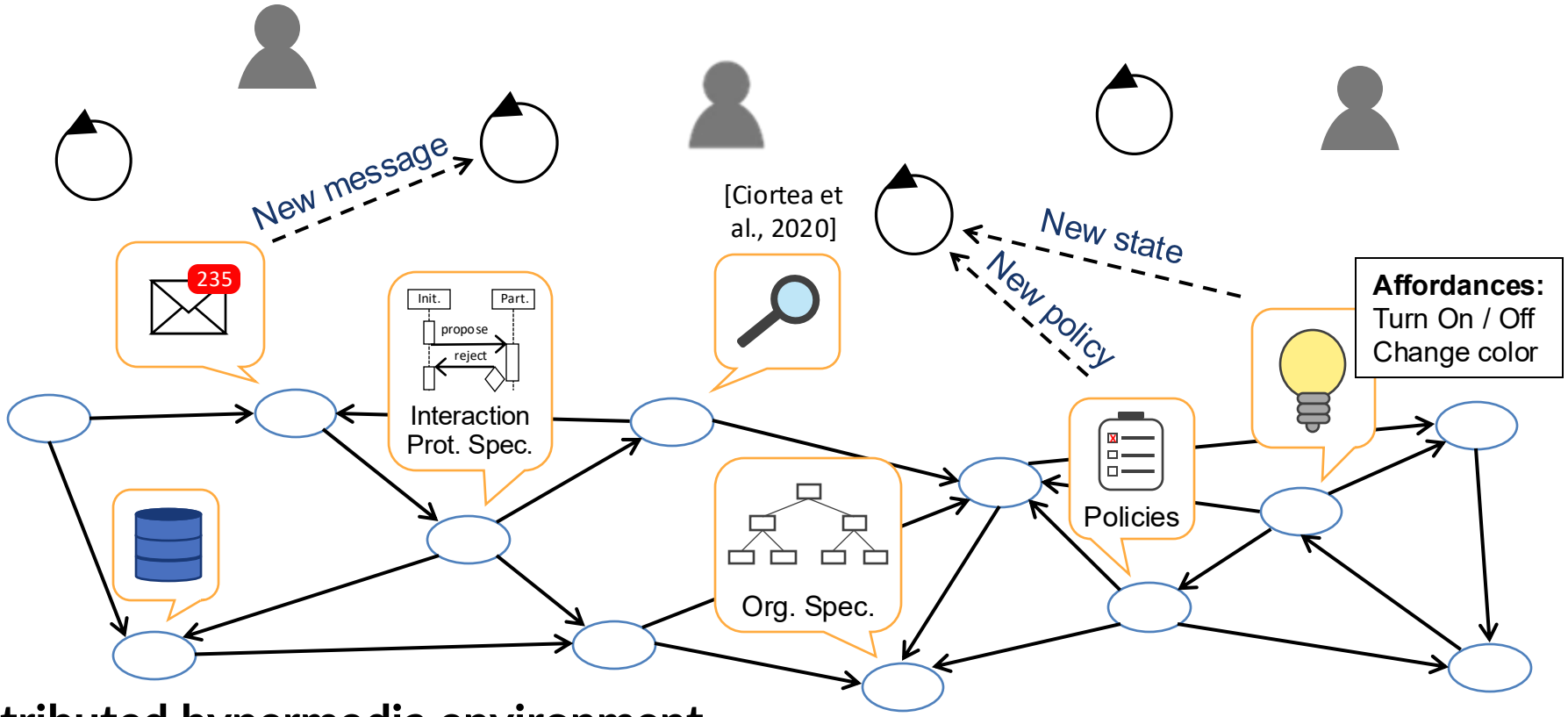

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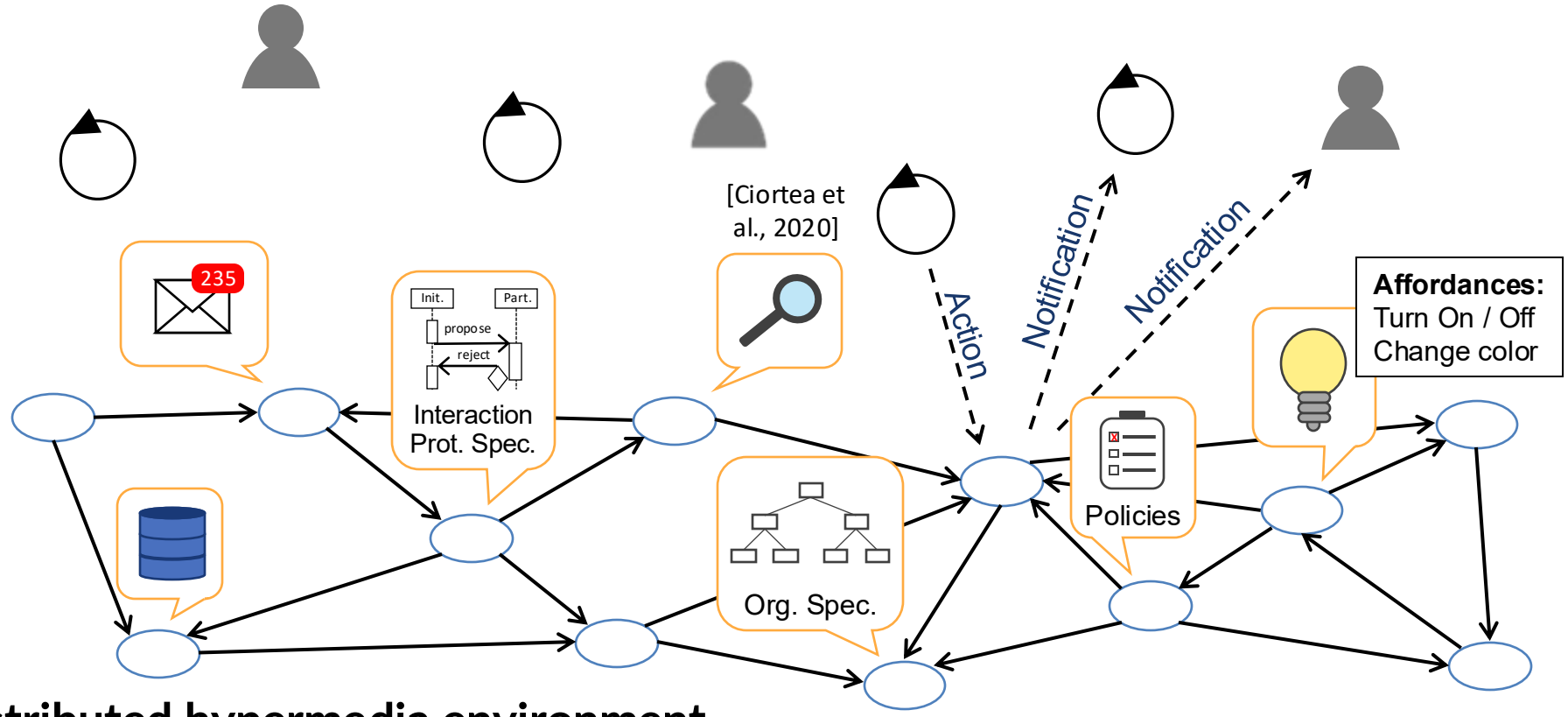

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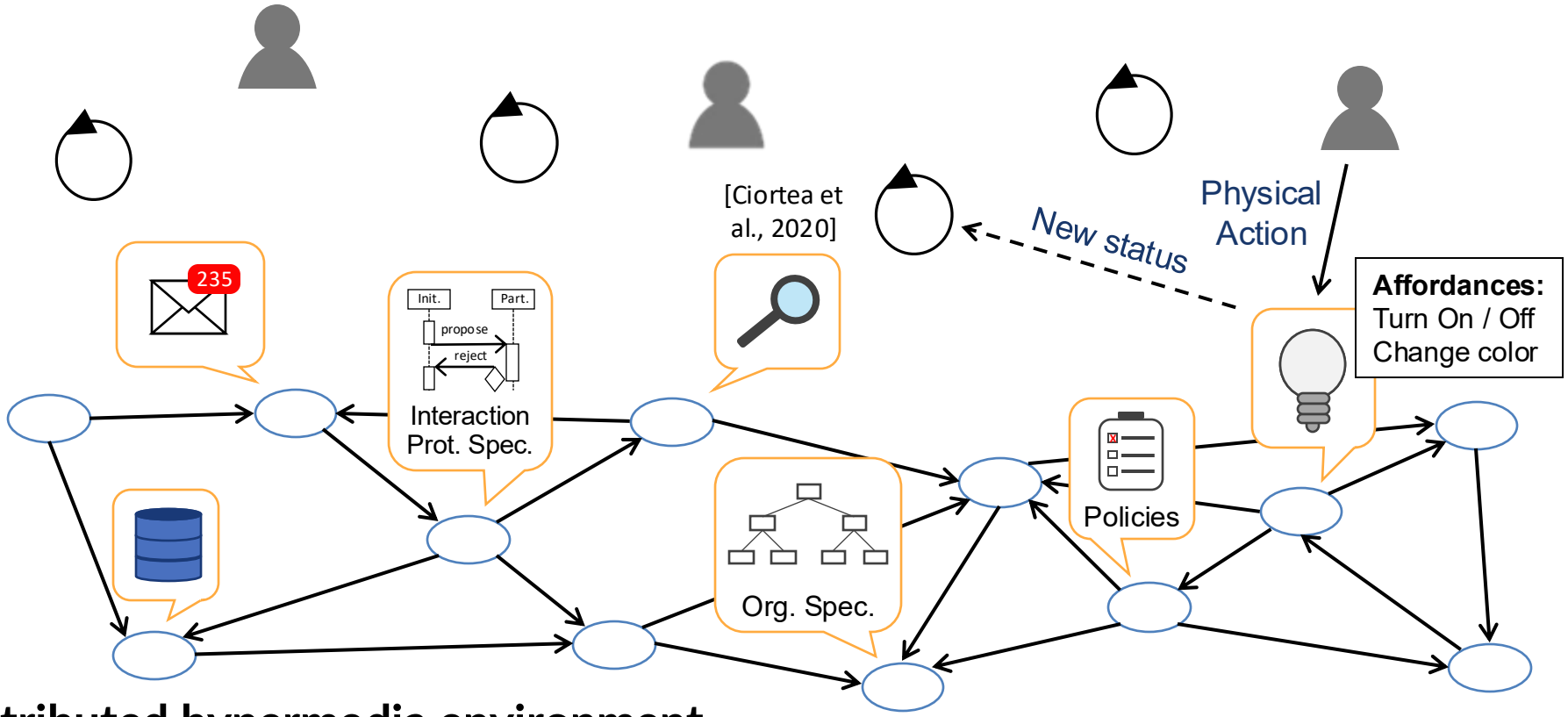

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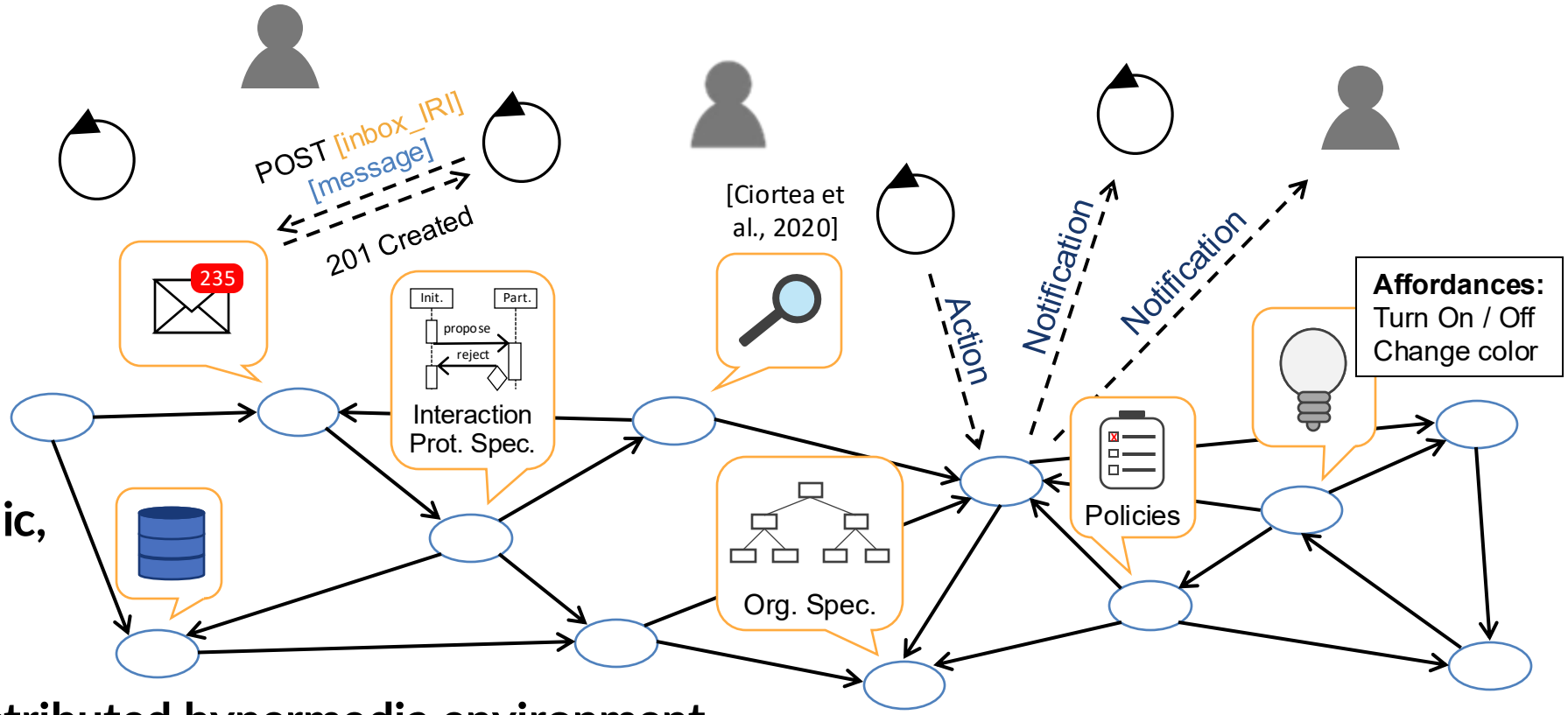

Rich, dynamic, ecosystems

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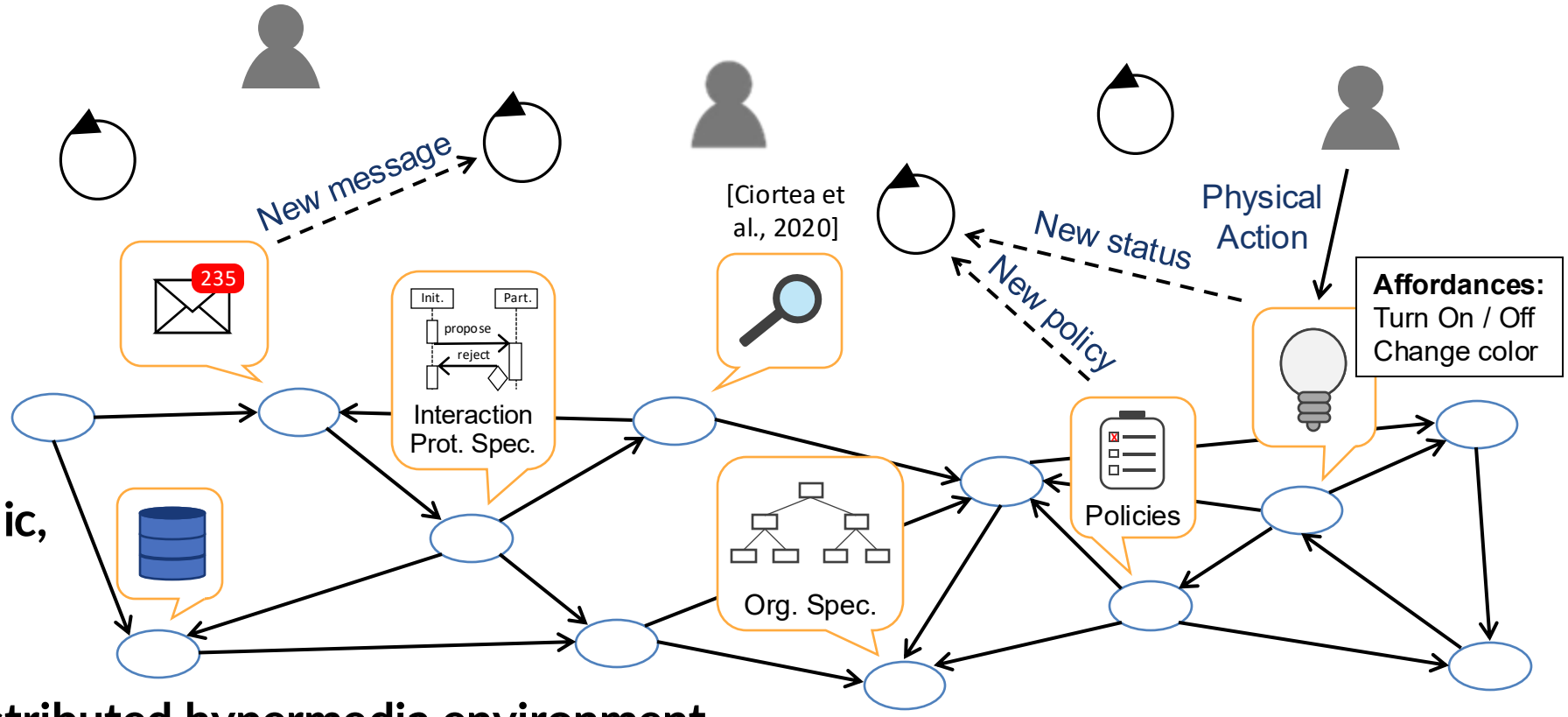

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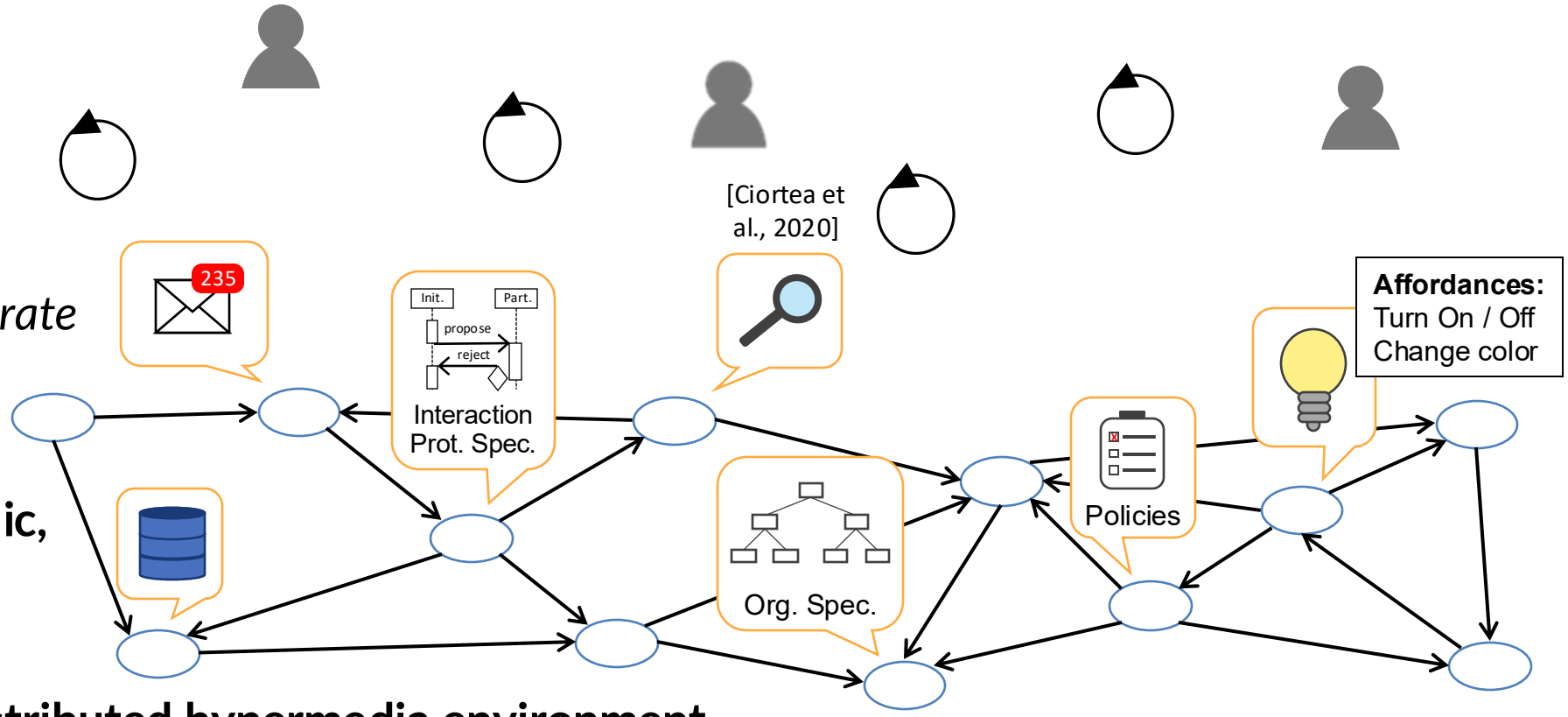
Hypermedia Multi-Agent Systems (hMAS)

The Web is no longer a **hidden transport layer**, but a **rich application layer**!

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

Ideally:
arrive-and-operate

Rich, dynamic, ecosystems



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Hypermedia Multi-Agent Systems (hMAS)

What if we strip away the hypermedia?

The Web is no longer a ~~**hidden transport layer**, but a~~ **rich application layer**!

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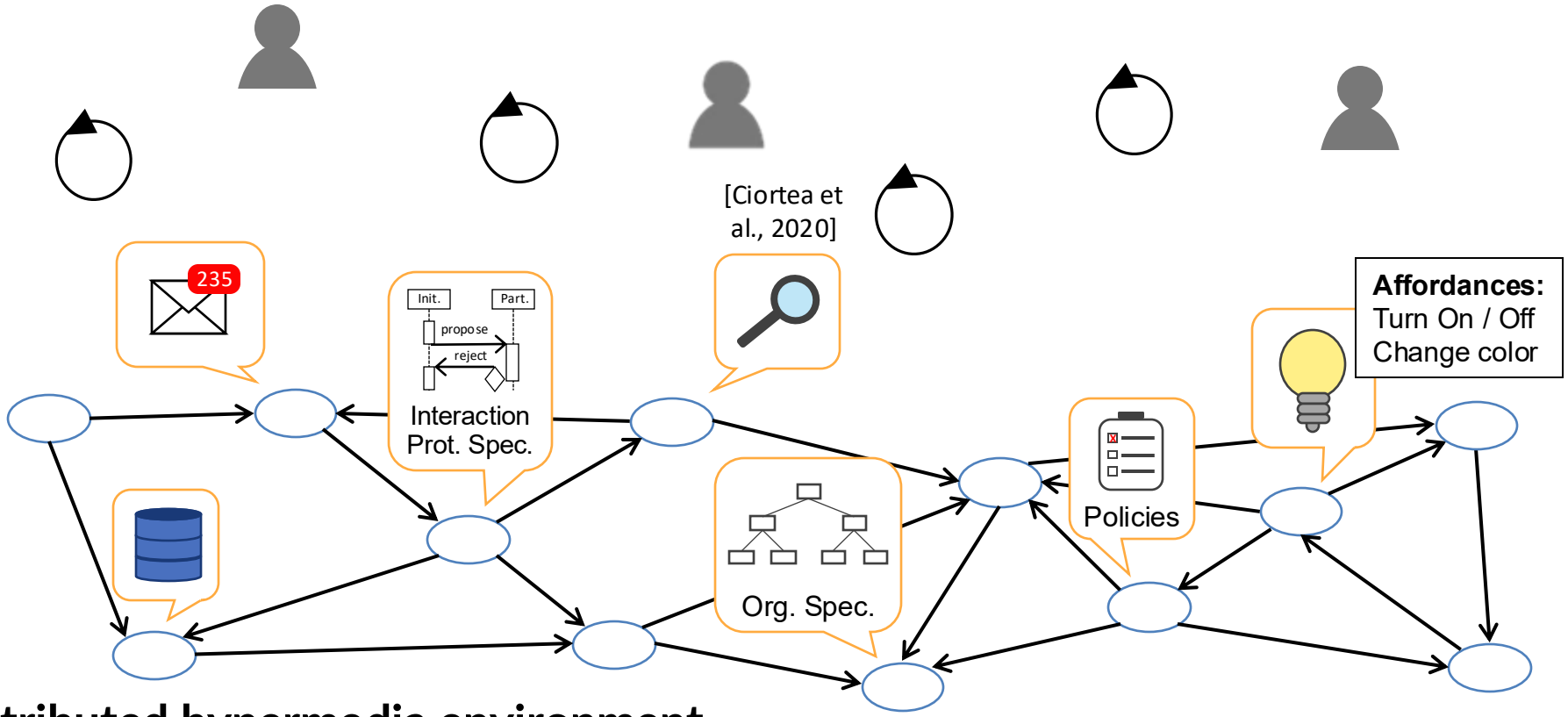

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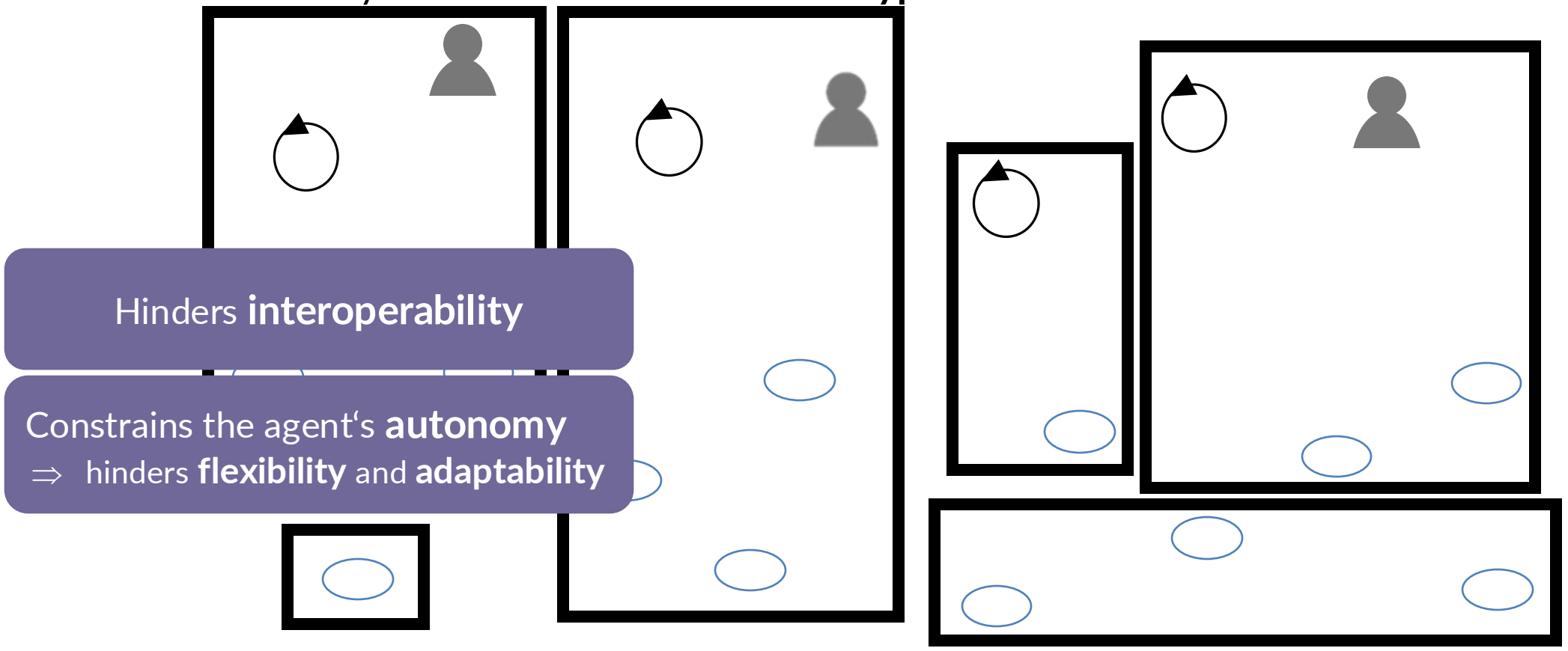

Hinders **interoperability**

Constrains the agent's **autonomy**
⇒ hinders **flexibility** and **adaptability**

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Hypermedia Multi-Agent Systems (hMAS)

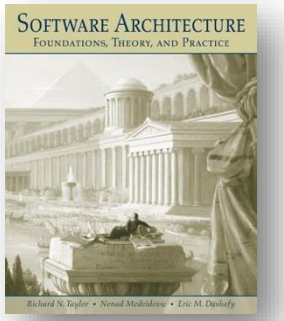
Visions of Agents on the Web

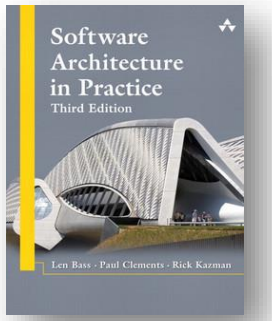
From Web-based MAS to hMAS

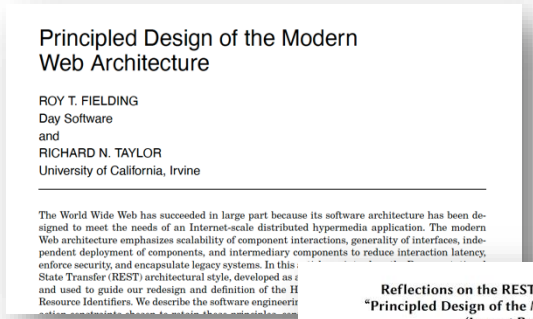
Architectural Design of hMAS

- Design Goals
- Architectural Patterns
- Architectural Constraints

Demonstrator







etc.

Design Goals: System Level

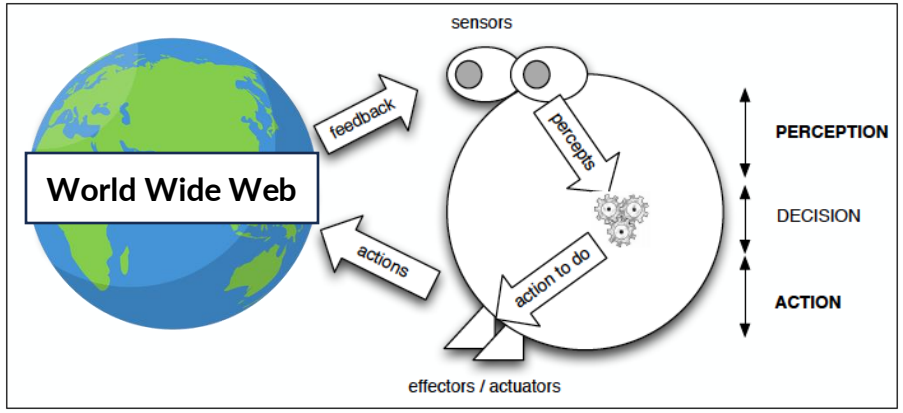
Defining characteristic of agents

Enables agents to discover and interact with one another on the open Web

Fundamental not only to intelligent agents but also to Web user agents in general

Agent-level Design Goals

Design Goal	*Description*
Situatedness	The agent interacts with its hypermedia environment directly through perception and action, and responds in a timely fashion to sensory input.
Embodiment	The agent is represented explicitly in the hypermedia environment, allowing end-users and other agents to discover and interact with it.
Value Alignment	The agent acts in ways that are consistent with the goals, preferences, and interests of its end-user, and that respect human values, ethical principles, societal norms, and fundamental human rights.



[Bordini *et al.*, 2007]

https://w3ctag.github.io/user-agents/

Rafel Bordini et al., *Programming Multi-Agent Systems in AgentSpeak using Jason*. John Wiley & Sons, 2007.

Design Goals: System Level

Central design goals for deploying MAS at scale on the open Web

Observation: core strengths of the Web as a world-wide, open, and long-lived system

Hypothesis: MAS can inherit these strengths if they align with the Web architecture

Necessary for agents to perceive their hypermedia environments

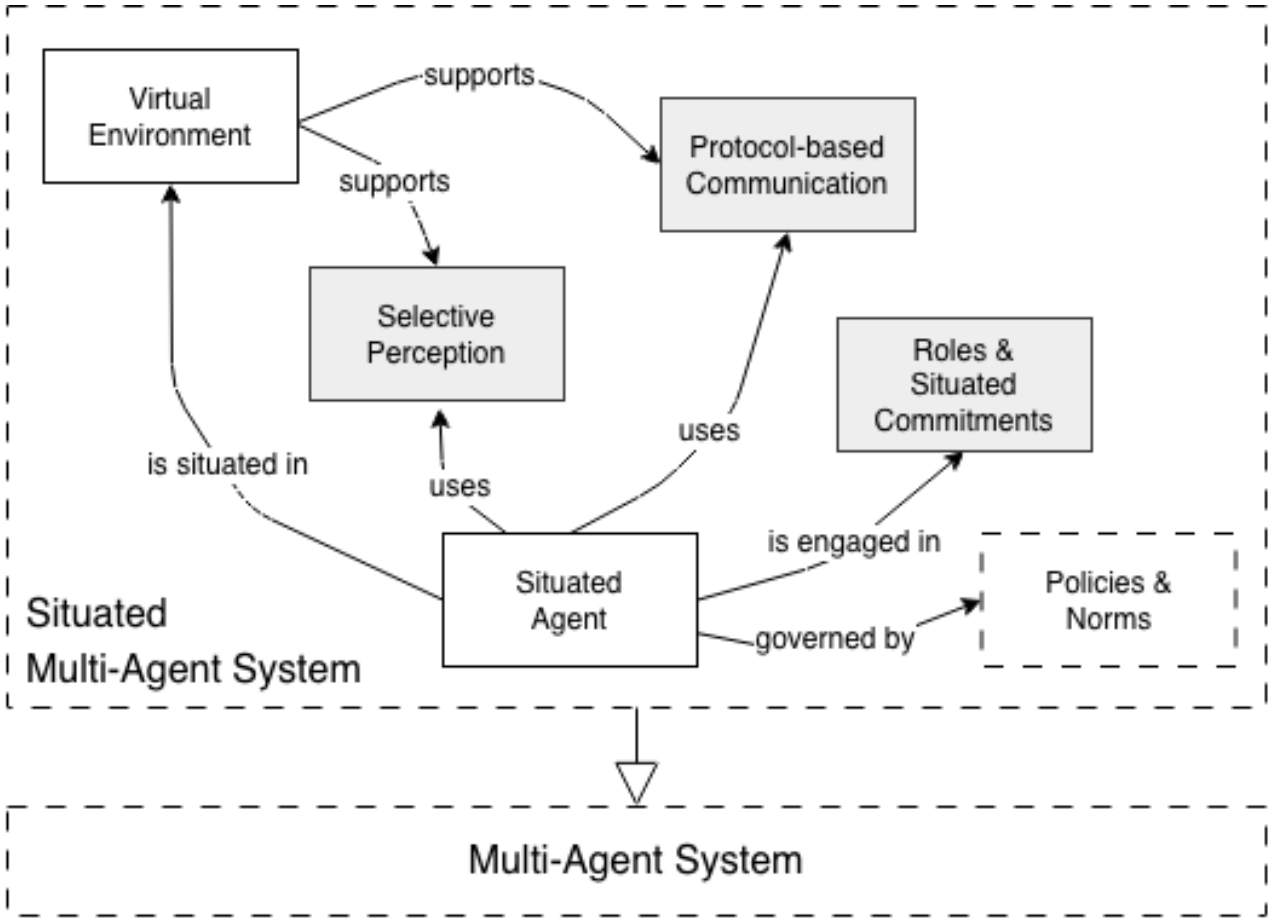
Prerequisite for accountability, explainability, and trust

Fundamental and even more critical for agents on the *open* Web

System-level Design Goals

Design Goal	*Description*
Scalability	The system can support growing numbers of end-users, agents, tools, and other resources across geographical and organizational boundaries.
Interoperability	The system uses Web standards to enable the integration of components developed independently, and to support communication and interaction with other systems.
Extensibility	The system can be expanded with new functionality and resources.
Evolvability	The system can accommodate changes at run time without disrupting existing functionality.
Discoverability	The system enables end-users and agents to discover the rest of the system starting from a single entry URL.
Resource Monitoring	The system enables the selective monitoring of resources, allowing agents and end-users to perceive and react to relevant changes.
Transparency	The system enables the representation, inspection, and reproduction of autonomous behaviors and interactions.
Security	The system provides sufficient assurance for the autonomous discovery of and interaction with agents, tools, and other resources.

Architectural Patterns for MAS



Danny Weyns: *Architecture-based Design of Multi-Agent Systems*. Springer. 2010.

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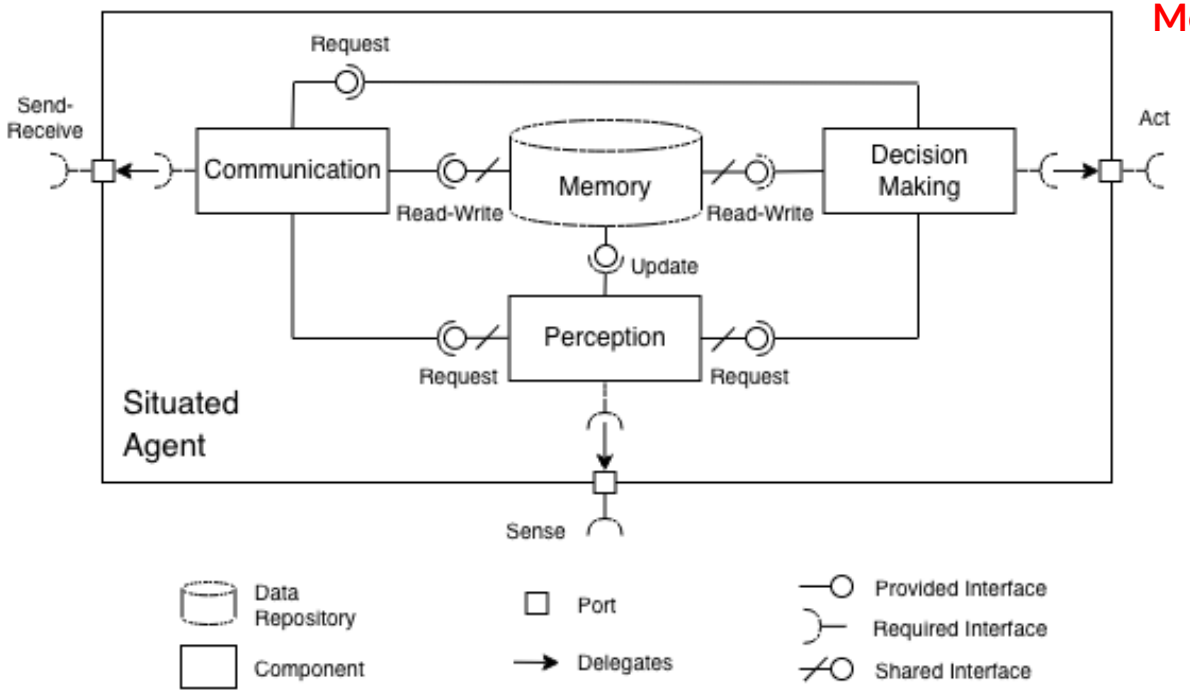
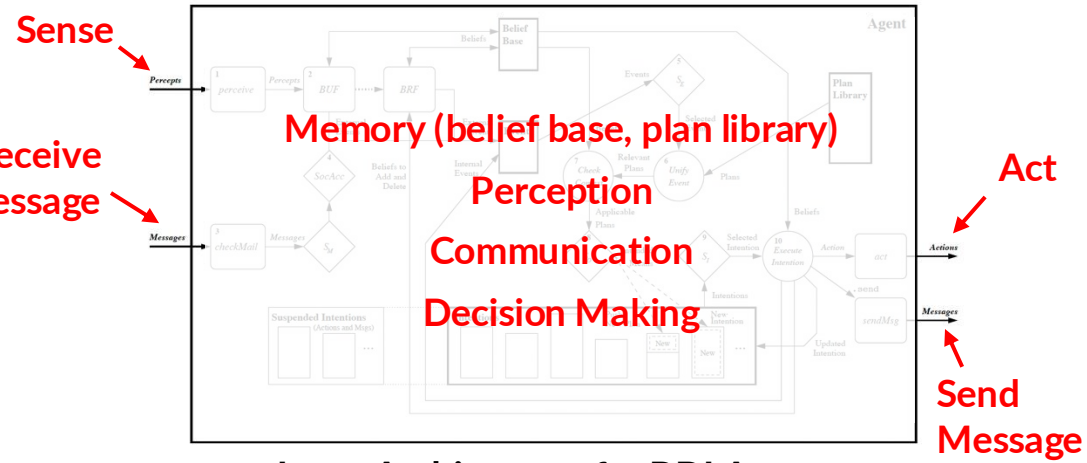
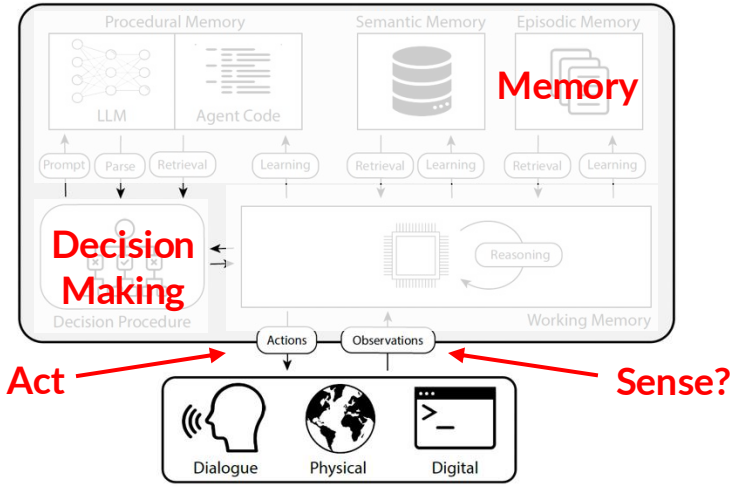


Note: not all components or their interfaces may be needed in a given implementation



Jason Architecture for BDI Agents
[Bordini *et al.*, 2007]



Cognitive Architectures for Language Agents (CoALA)
[Summers *et al.*, 2024]

Rafel Bordini et al., *Programming Multi-Agent Systems in AgentSpeak using Jason*. John Wiley & Sons, 2007.
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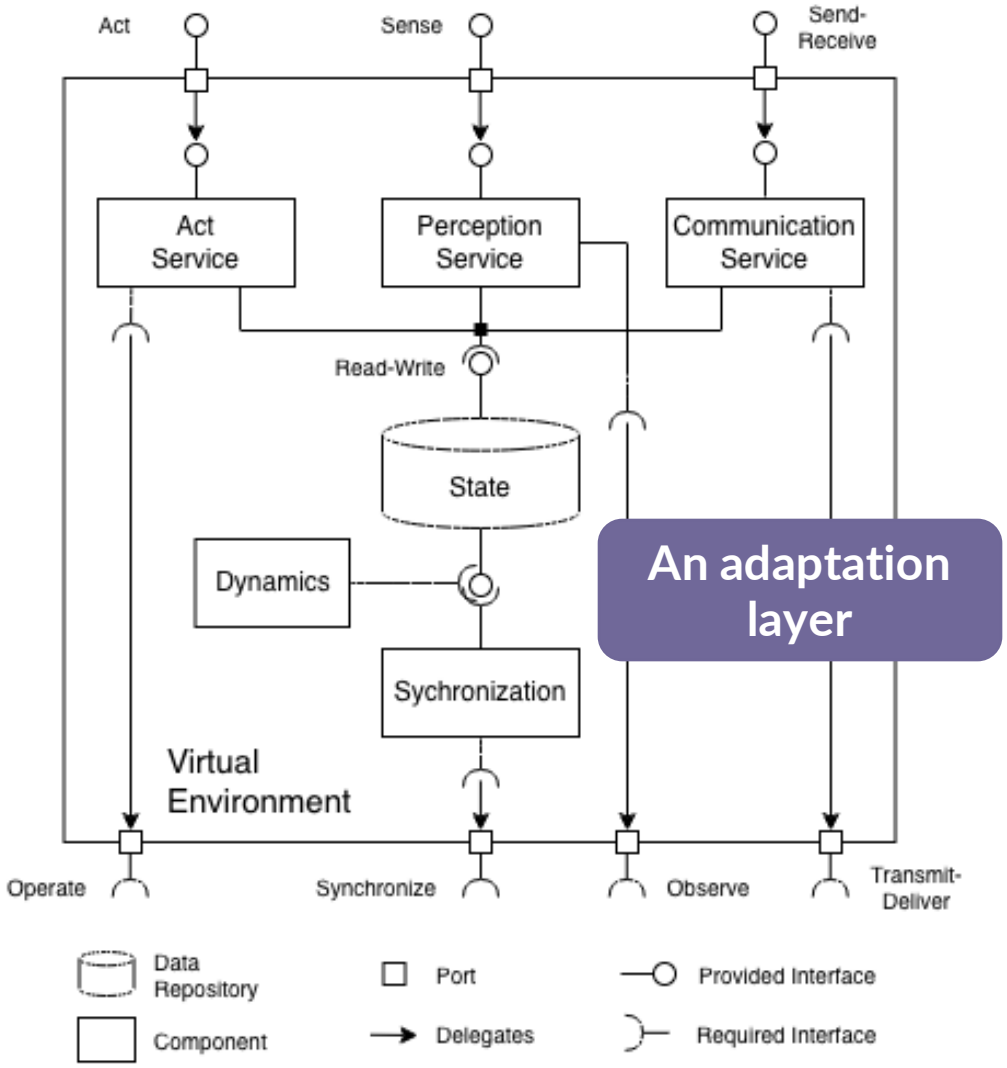

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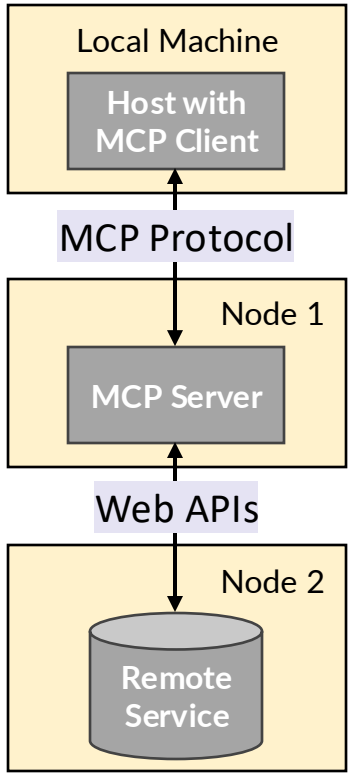
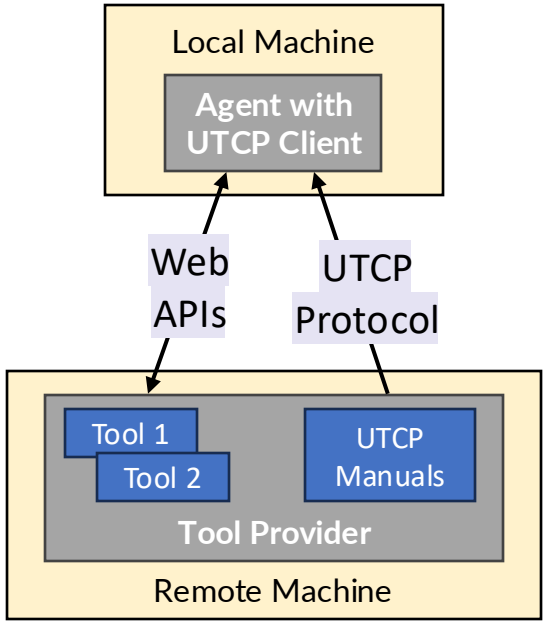


Model Context Protocol (MCP)



Universal Tool Calling Protocol (UTCP)

MCP example adapted from:
https://modelcontextprotocol.io/specification/2025-06-18/architecture#core-components

Hypermedia Multi-Agent Systems (hMAS)

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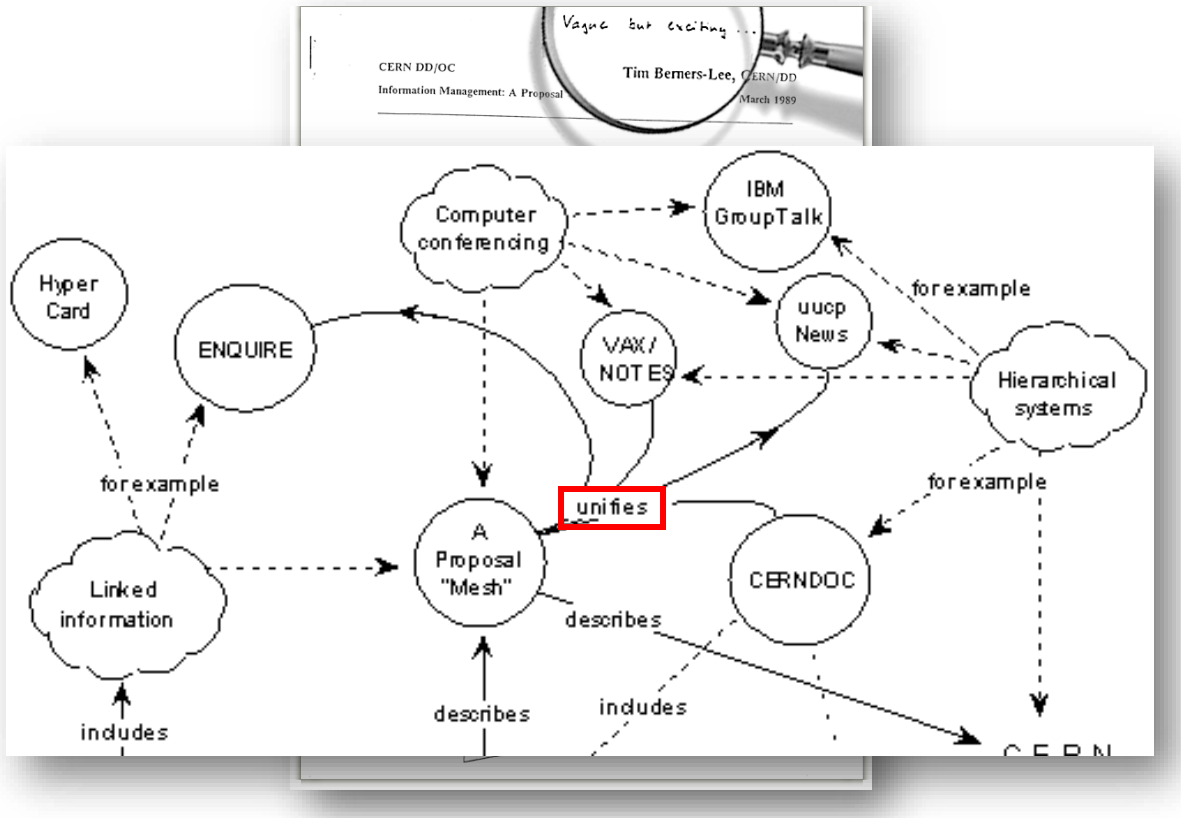
Demonstrator

Architectural Constraints

Principle 1 (Uniform resource space): All entities in a Hypermedia MAS, and the relations among them, should be represented in a uniform, resource-oriented manner consistent with the Web architecture.



Key idea: to **integrate** existing systems behind a **simple hypertext interface** for all users

The Web as an "**application integration system**"
— Roy T. Fielding, FSE'17 Keynote

http://info.cern.ch/Proposal.html

Roy T. Fielding, Rohit Kare, Richard Taylor. FSE'17 Keynote: https://www.youtube.com/watch?v=6oFAmQUM8ws

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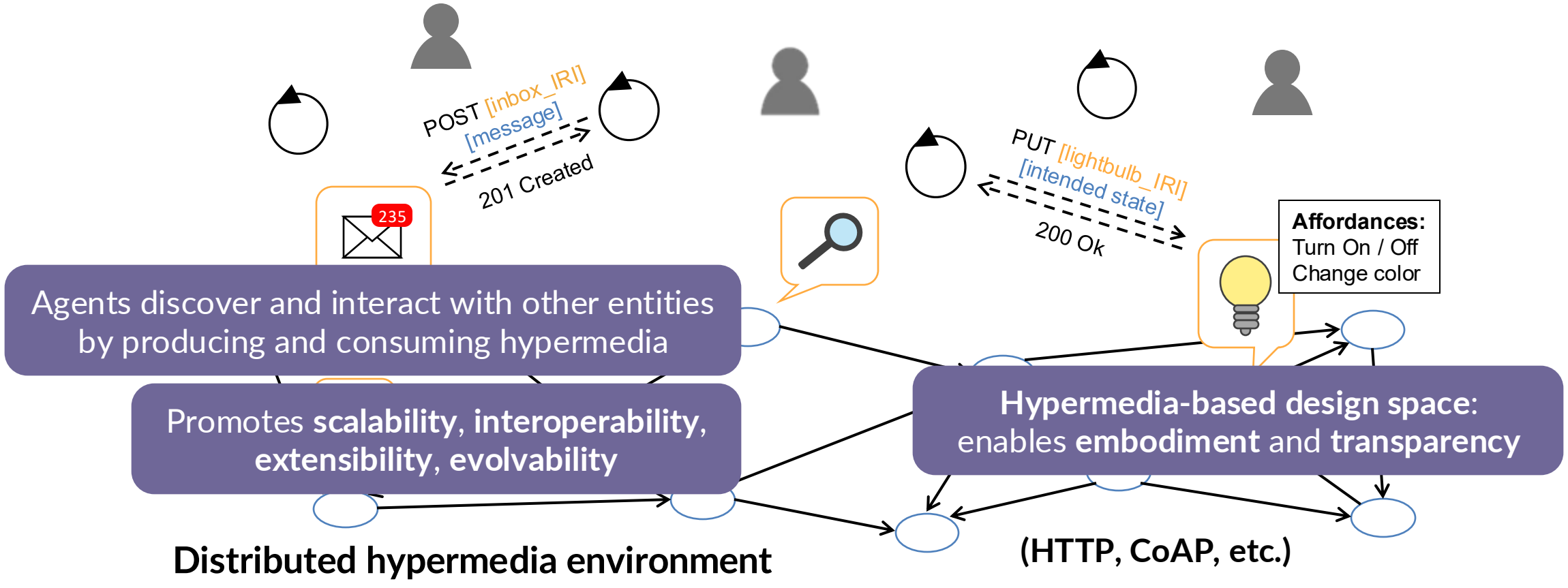
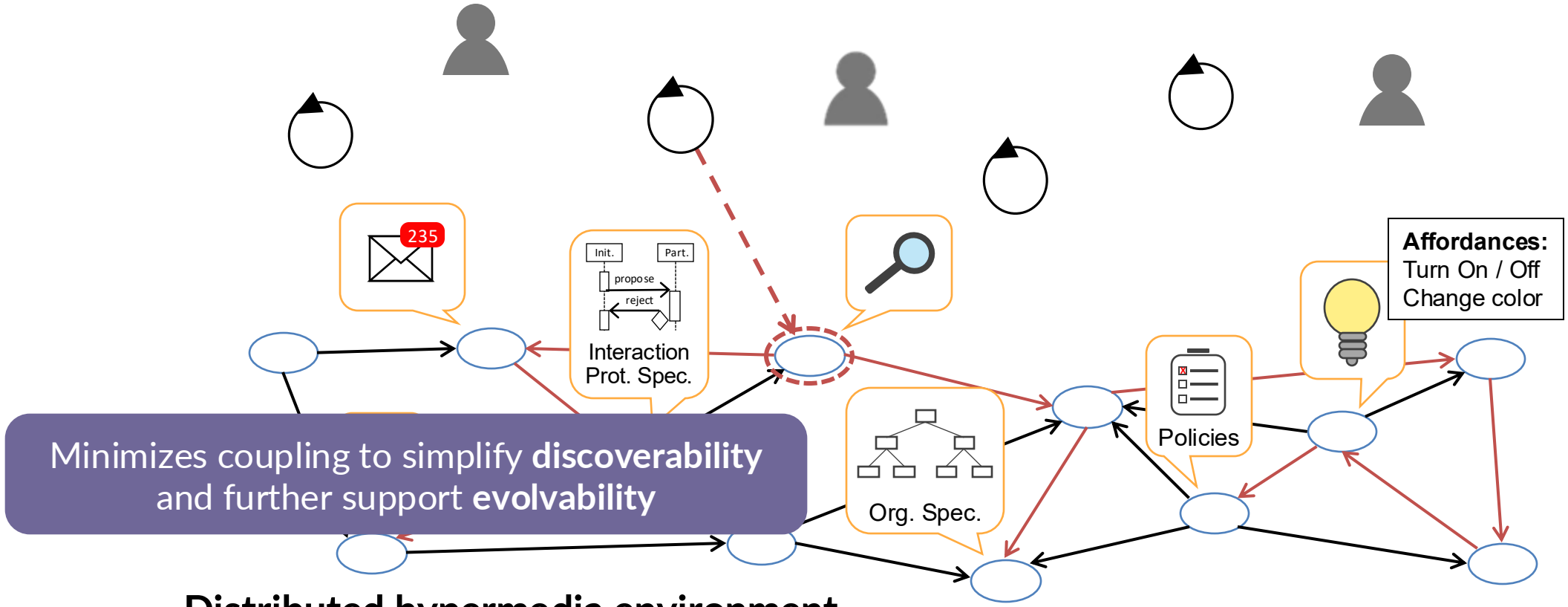


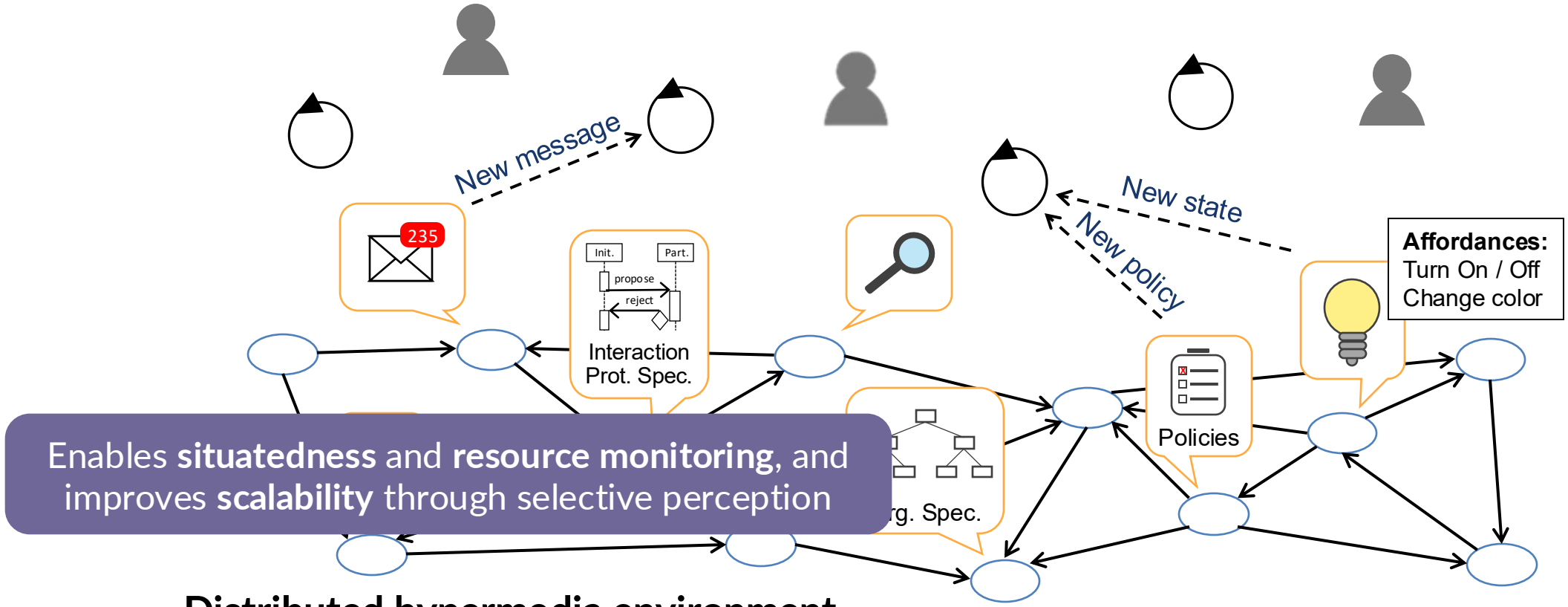
Architectural Constraints

Principle 2 (Single entry point): A Hypermedia MAS should expose one or more entry URLs from which the rest of the system and the means to participate in it can be discovered through hyperlinks.



Architectural Constraints

Principle 3 (Observability): A Hypermedia MAS should enable agents to selectively monitor and receive updates about relevant resources and events in their virtual environments using Web standards.



Enables **situatedness** and **resource monitoring**, and improves **scalability** through selective perception

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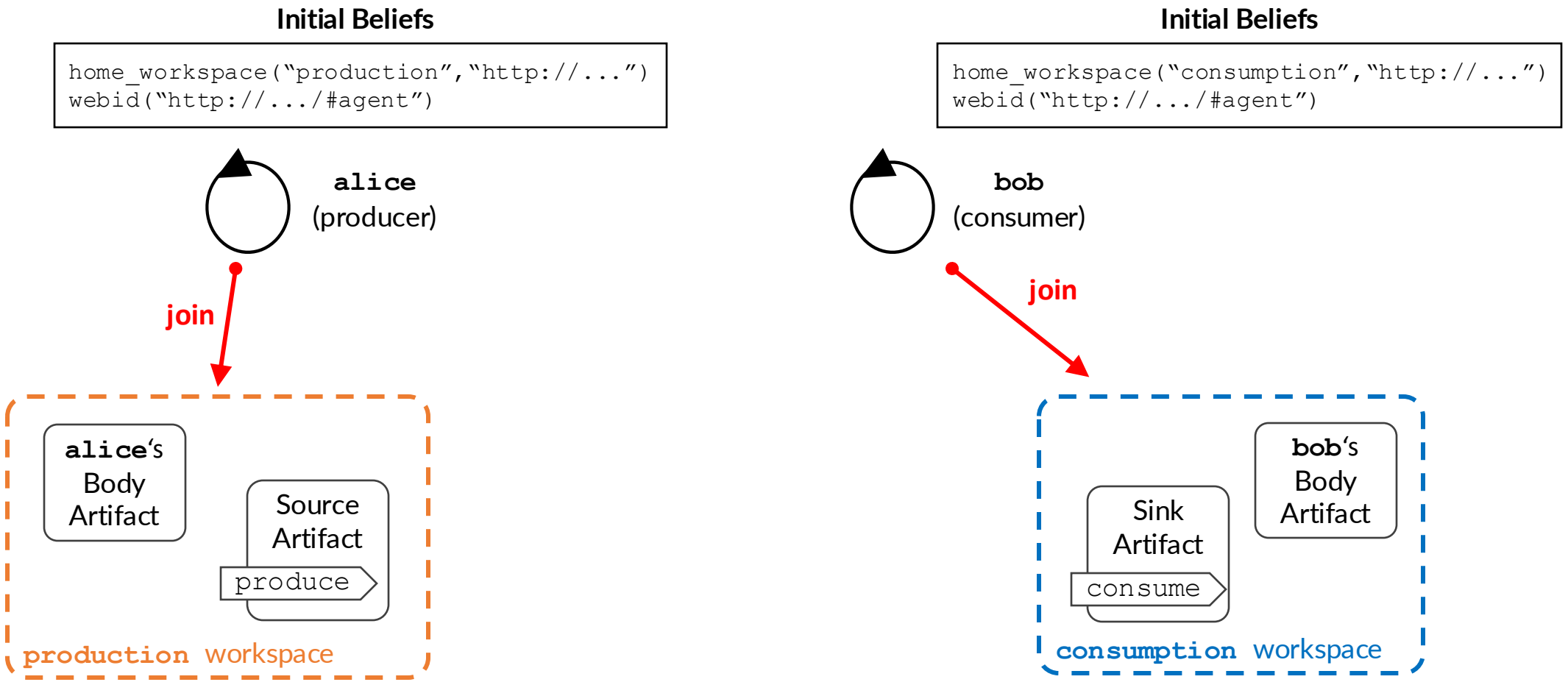
A producer/consumer scenario with 2 BDI agents in a **distributed hypermedia workspace** for manufacturing

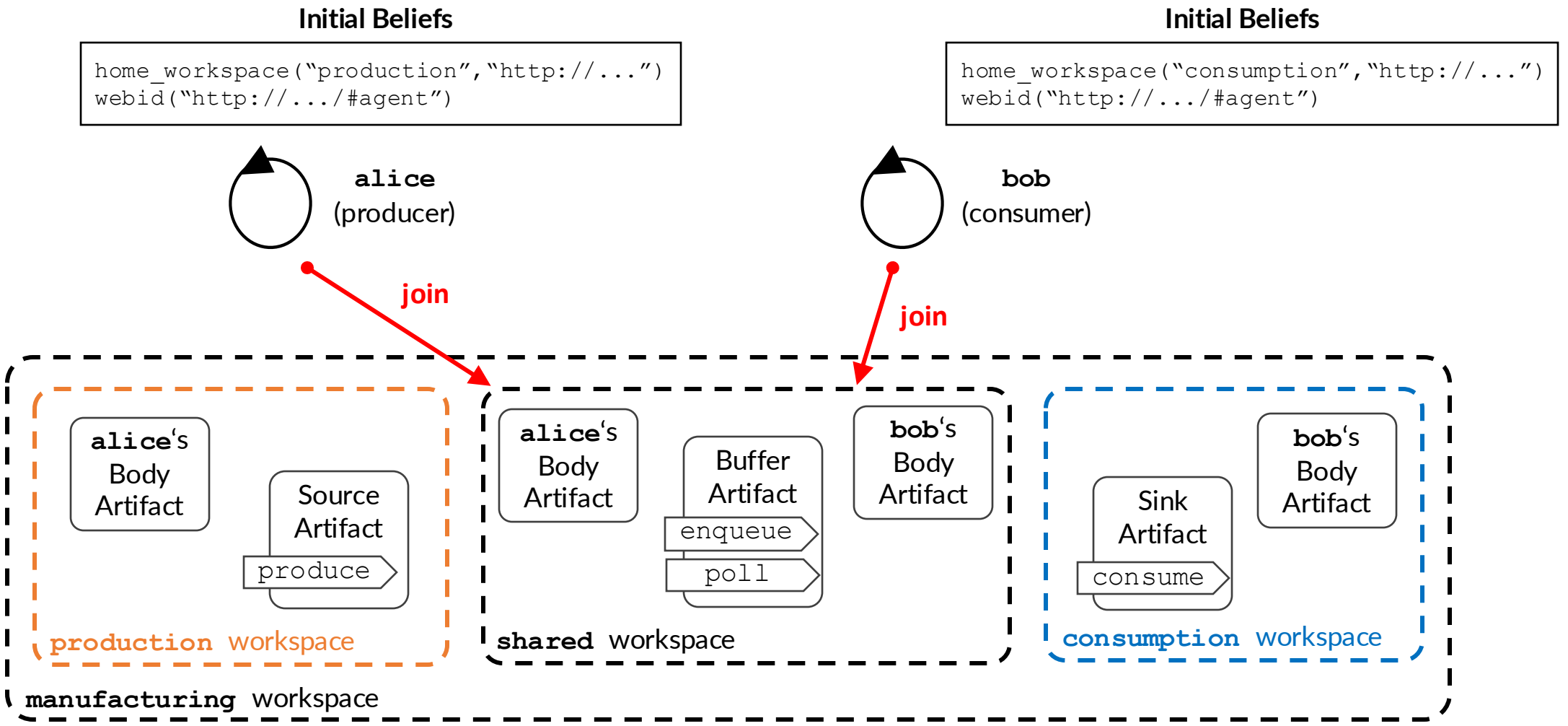
Toy example, but with **rich interactions**

Demonstrator



(different colors represent the different nodes used in the deployment)

Demonstrator



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Demonstrator

Initial Beliefs

```
home_workspace("production","http://...")
webid("http://.../#agent")
```

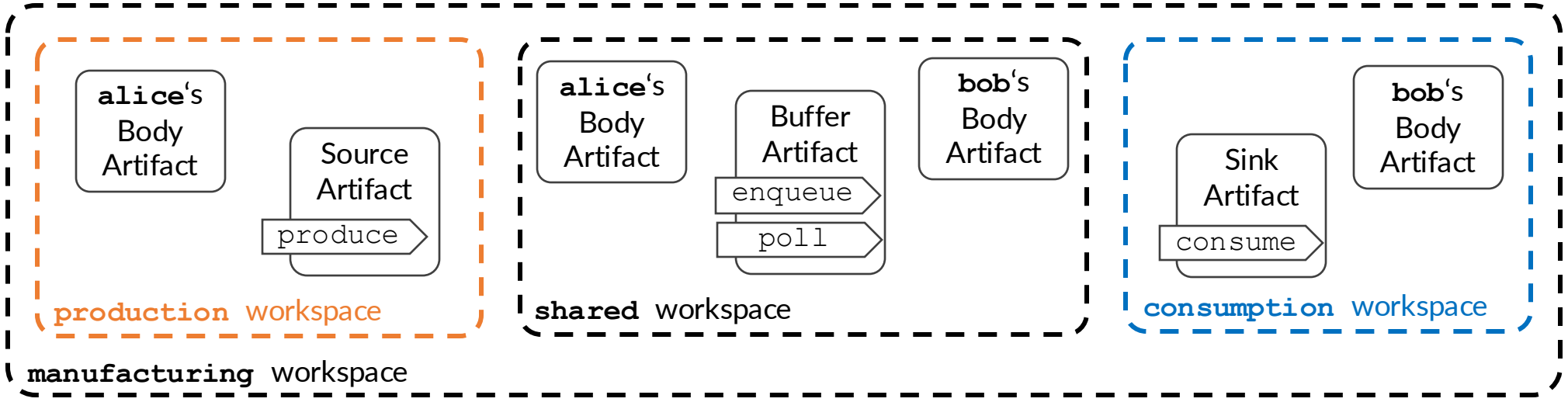
alice
(producer)

Initial Beliefs

```
home_workspace("consumption","http://...")
webid("http://.../#agent")
```

bob
(consumer)

(alice and bob start producing, transferring, and consuming items)



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Thank you!