Give Agents Some REST: A Resource-oriented Abstraction Layer for Internet-scale Agent Environments

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Objective	To engineer multi-agent systems (MAS) that are **Internet-scale**, **open**, and **support humans-in-the-loop**.
Approach	Reuse the **design rationale** behind the modern Web architecture to address the three above-mentioned challenges in an integrated manner.
Novelty	Apply REST and use *hypermedia as the engine of application state (HATEOAS)* to design the **agent environment** as a **distributed hypermedia application**.

Motivation

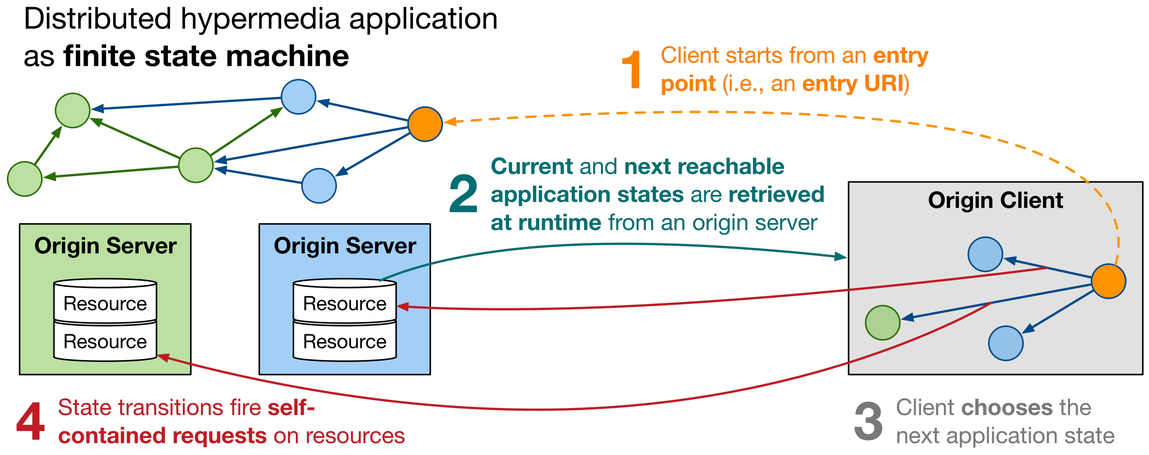
Three important challenges for future research on engineering MAS are to design *agent environments* that [6]:

1. support **large-scale MAS**;
2. can cope with **open MAS** in which components are deployed and evolve independently from one another at runtime;
3. support **humans-in-the-loop**.

Observation The World Wide Web *was designed* to be an *Internet-scale* and *open* software system [5], and intended to *assist humans* in a wide range of processes [1].

How the Web Works: HATEOAS

HATEOAS is a **core tenet** of the modern Web architecture [5].



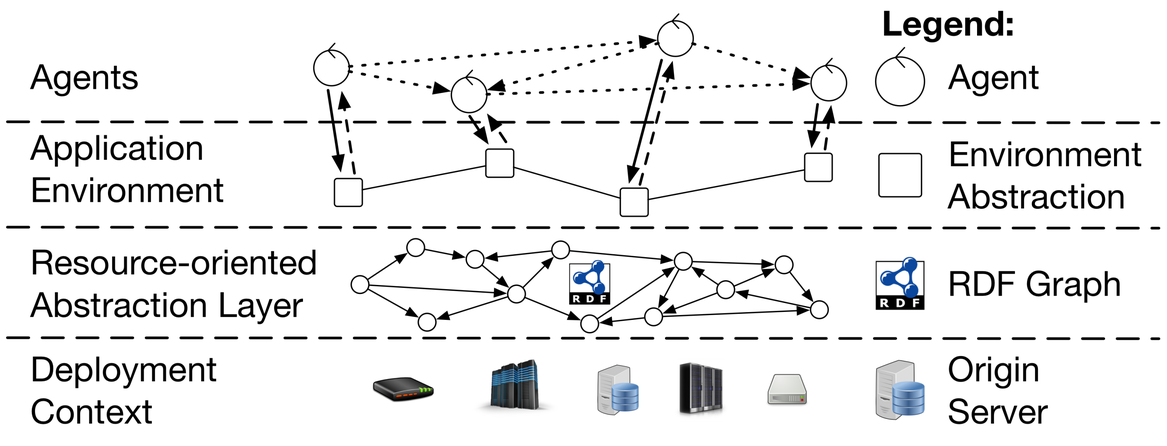
Hypermedia-driven Interaction In any given application state, software clients retrieve *at runtime* from origin servers: (i) what are the *next reachable application states*, and (ii) *how to transition to those states* (e.g., via HTTP requests).

- URIs, possible transitions, and requests to implement those transitions are **never hardcoded** into clients => **loose coupling**

Contribution: Hypermedia-driven Agent Environments

Core Idea Use *hypermedia* and *HATEOAS* to decouple the *application environment* (i.e., the programmable part) from its *deployment context* (e.g., physical devices, digital services).

End Goal Enable software clients (e.g., software agents, MAS platforms, Web browsers) to *discover* and *interface* with components in their deployment context *at runtime*.



Approach We introduce a **resource-oriented** and **hypermedia-driven abstraction layer** for agent environments.

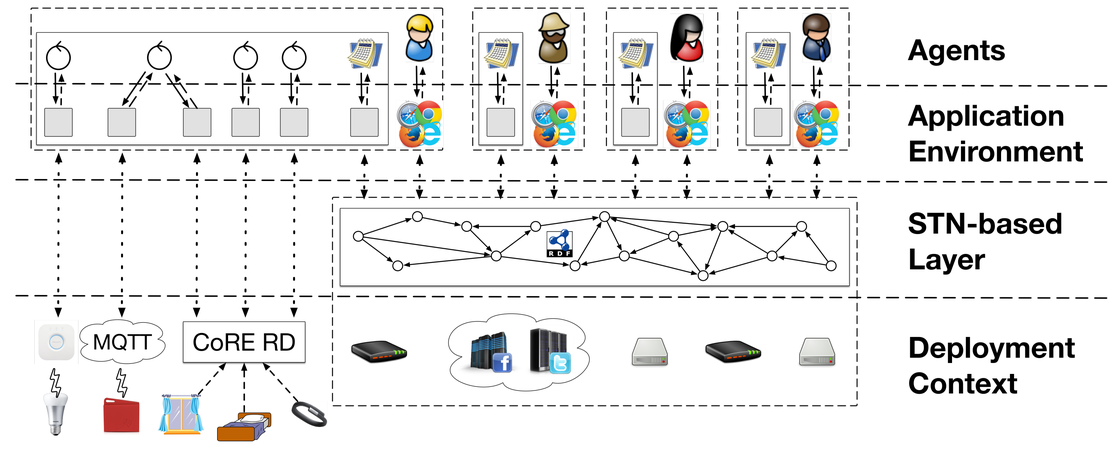
- Higher-level environment abstractions (e.g., infrastructures to mediate agent interactions, search engines for agent environments) can then be implemented on top of the proposed lower-level abstraction layer.

Socio-technical Networks and HATEOAS To tackle the HATEOAS constraint, we use *socio-technical networks (STNs)* [3], that is *dynamic* networks of *humans*, *software agents*, and *artifacts* interrelated in a meaningful manner via *typed relations* (e.g., friendship, ownership, provenance, colocation, hosting).

- The **state** of an STN is represented in RDF using the *STN ontology* (http://w3id.org/stn).
  => software agents can *reliably navigate* and *act on* the STN-based agent environment
- **Typed relations** are represented *explicitly* in the agent environment in a *uniform manner*.
  => *dynamic discoverability* for *open* and *distributed* MAS
- **Semantic descriptions of Web APIs** are *linked into the hypermedia* via *hosting relations*.
  => *loose coupling* for *Internet-scale* MAS

Proof of Concept: The Wake-up Call

Application Scenario David's *calendar agent* interacts with other agents in his household (i) to keep track of David's sleeping schedule, and (ii) to wake him up if there is an upcoming event. If the agents fail to wake up David, the calendar agent searches David's distributed social graph to *delegate* this goal to one of his friends.



Technologies: JaCaMo [2], STN platform [4], Twitter Public API, Facebook Graph API, Californium [7], Californium Tools [8], Philips Hue, Texas Instruments SensorTag

The **hypermedia-driven agent environment** is deployed over heterogeneous Web services (i.e., Twitter, Facebook, multiple STN platforms) and constrained devices:

- **Internet-scalability**: the application environment uses semantic descriptions *discovered* and *interpreted at runtime* in order to interface with Twitter, Facebook, and the STN platforms.
- **Openness**: the calendar agent is able to *navigate* the distributed environment to *discover* and *interact with* other software agents or with humans available in the system *at runtime*.
- **Humans-in-the-loop**: the calendar agent is able to cooperate with humans via Twitter in order to prevent David from missing his event.

Conclusions

The World Wide Web provides a suitable *middleware* for MAS that are *Internet-scale*, *open*, and *support humans-in-the-loop*.

We have demonstrated an approach to engineer Web-based MAS using hypermedia and STNs.

Similar to how the Web enables the discovery of Web pages, STNs enable the discovery of humans, software agents, and artifacts through the Web.

References

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