

# Pody: A Solid-based Approach to Embody Agents in Web-based Multi-Agent Systems

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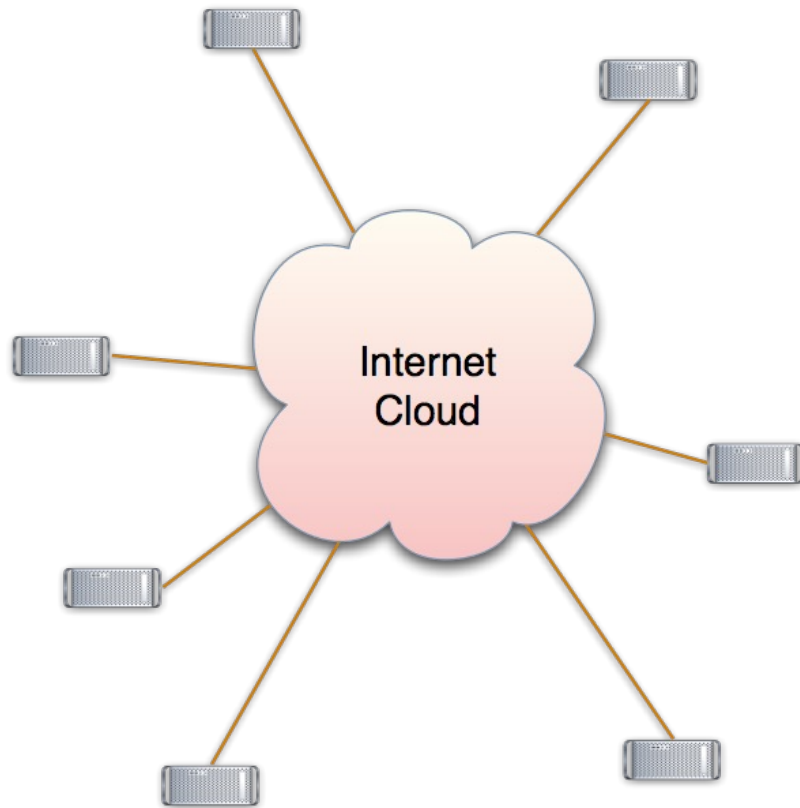
<sup>1</sup>Mines Saint-Étienne, CNRS, UMR 6158 LIMOS, Saint-Étienne, France

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<sup>5</sup>Universidad Politécnica de Madrid, Madrid, Spain



Source: <https://www.w3.org/2008/Talks/0610-rpi-tbl/>



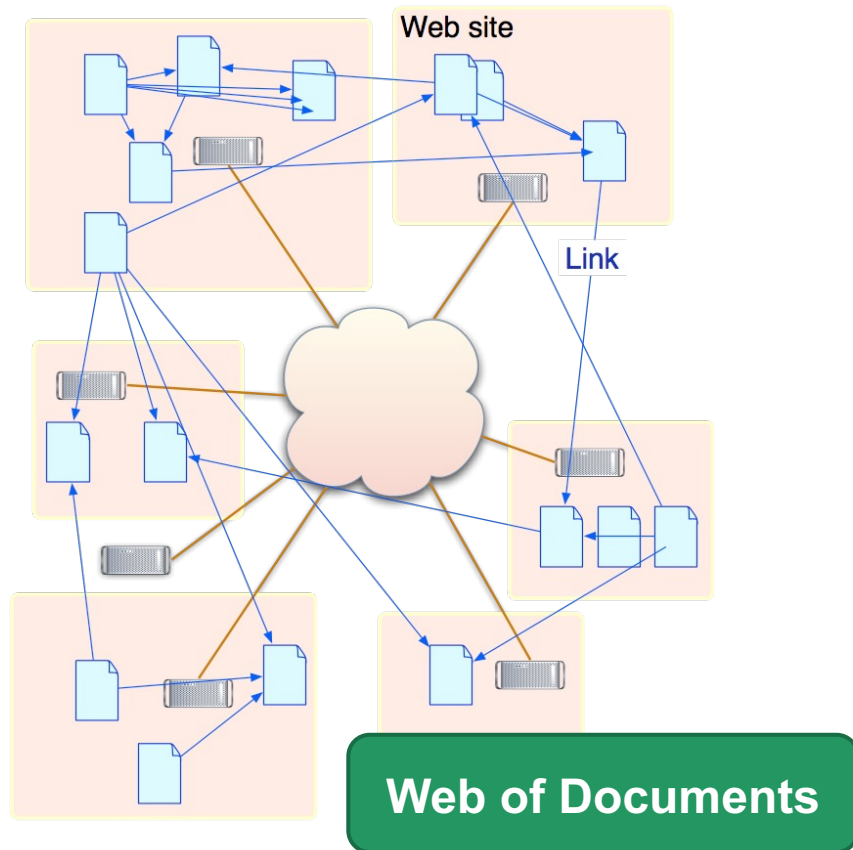
 Dagstuhl Seminar 23081  
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( Feb 19 – Feb 24, 2023 )

<https://www.dagstuhl.de/23081>

**“It’s not the computers — It’s the documents”**  
Sir Tim Berners-Lee, Levels of Abstraction: Net, Web Graph, 2007.  
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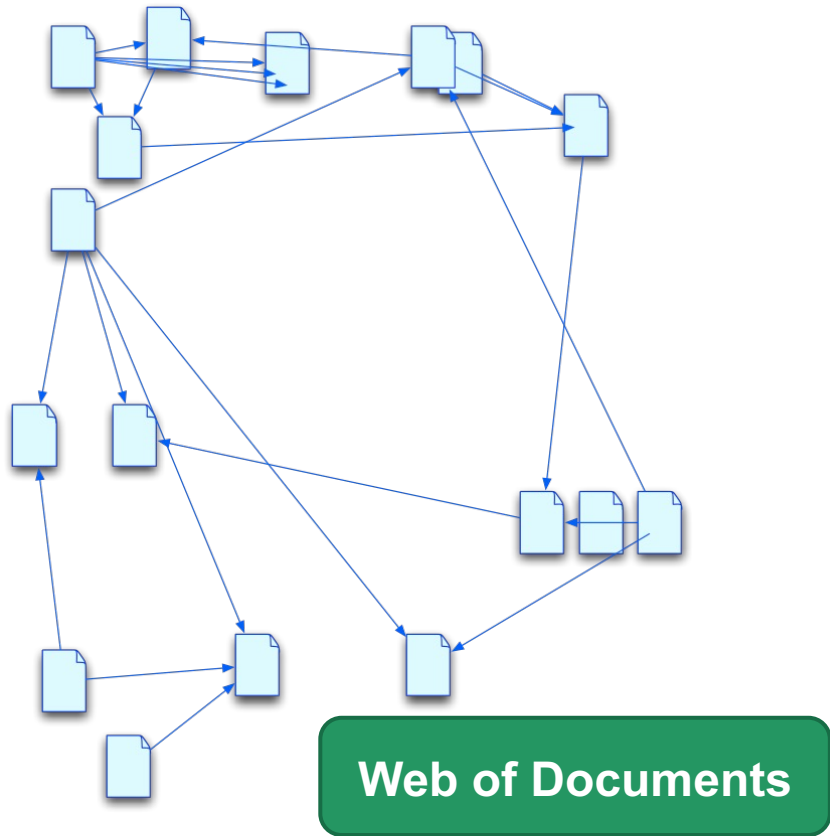
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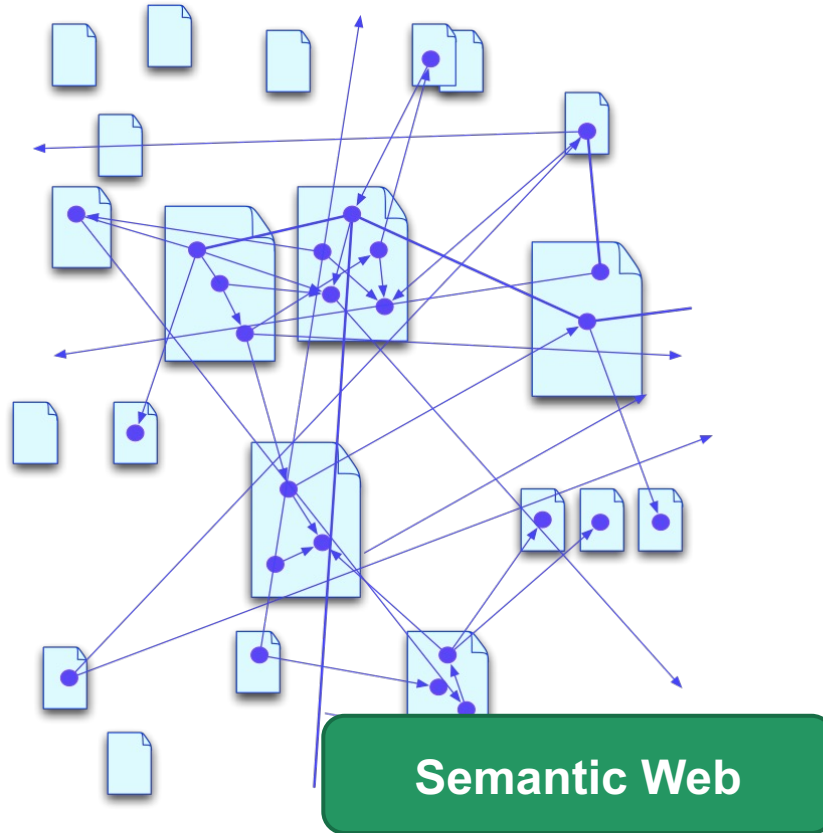
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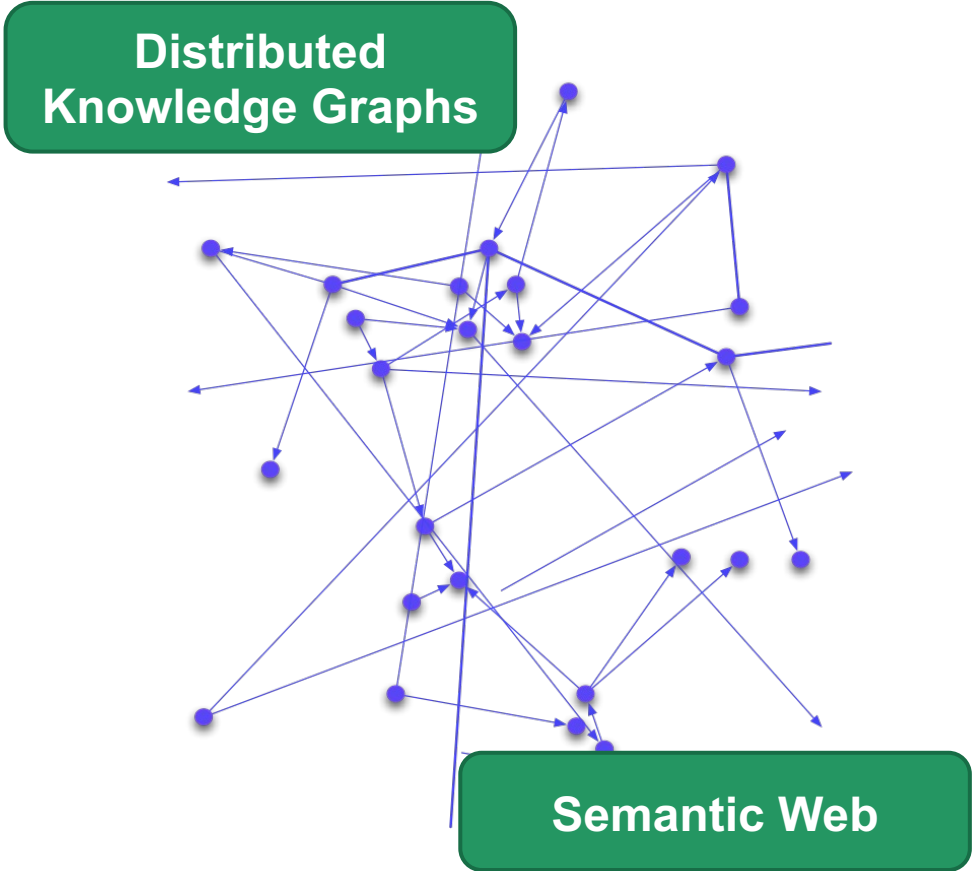
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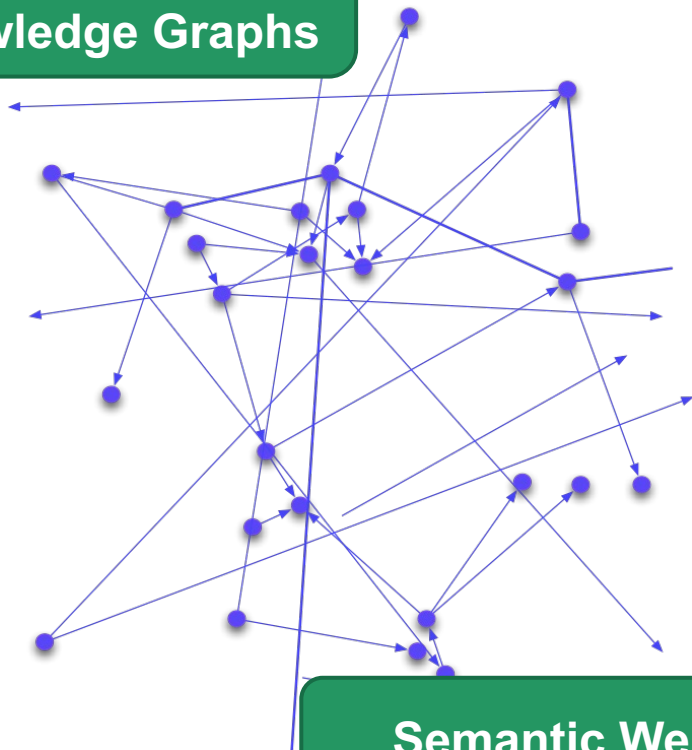
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Distributed Knowledge Graphs



Semantic Web


Source: <https://www.w3.org/2008/Talks/0610-rpi-tbl/>

Where is the place of agents in this view?



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# Situatedness and Embodiment

**Intelligent, rational behavior** is innately linked to the environment an agent occupies and is not disembodied

## The Web Robots Pages

Web Robots (also known as Web Wanderers, Crawlers, or Spiders), automatically. Search engines such as Google use them to index the web for email addresses, and they have many other uses.

On this site you can learn more about web robots.

- [About /robots.txt](#) explains what /robots.txt is, and how to use it.

## Robots Exclusion Protocol

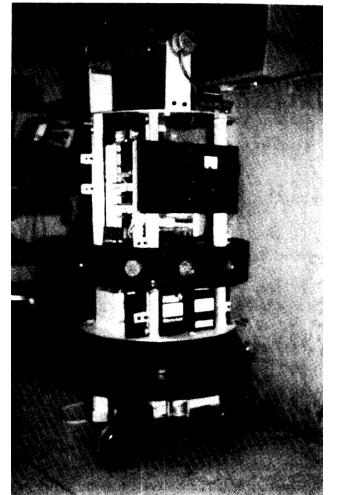
<https://www.robotstxt.org/>

“Where are all the intelligent agents?”

— James Hendler, IEEE Intelligent Systems, 2007

“Once dynamic and open systems become the norm, they’ll need to adopt agent technologies as fundamental.”

— Peter McBurney and Michael Luck, IEEE Intelligent Systems, 2007



[Brooks, 1985]

## Summary

ClueBot NG is an anti-vandal bot that tries to detect and revert vandalism quickly and automatically.

From Wikipedia, the free encyclopedia

This user account is a bot operated by Cobi (talk), Rich Smith (talk), and DamianZaremba (talk). It is used to make automated or semi-automated edits that would be extremely tedious to do manually, in accordance with the bot policy. It is currently approved and currently active – the relevant request for approval can be seen here.

Emergency bot shutoff button



Administrators: Use this button if the bot is malfunctioning. (direct link)

Non-administrators can report a malfunctioning bot to Wikipedia:Administrators' noticeboard/Incidents.

## Wikipedia’s Content Agents

[https://en.wikipedia.org/wiki/Wikipedia\\_bots](https://en.wikipedia.org/wiki/Wikipedia_bots)

## ChatGPT

Examples

\*Explain quantum computing in simple terms\* →

Capabilities

Remembers what user said earlier in the conversation

Limitations

May occasionally generate incorrect information

\*Got any creative ideas for a 10 year old's birthday?\* →

Allows user to provide follow-up corrections

May occasionally produce harmful instructions or biased content

\*How do I make an HTTP request in Javascript?\* →

Trained to decline inappropriate requests

Limited knowledge of world and events after 2021

<https://chat.openai.com/>

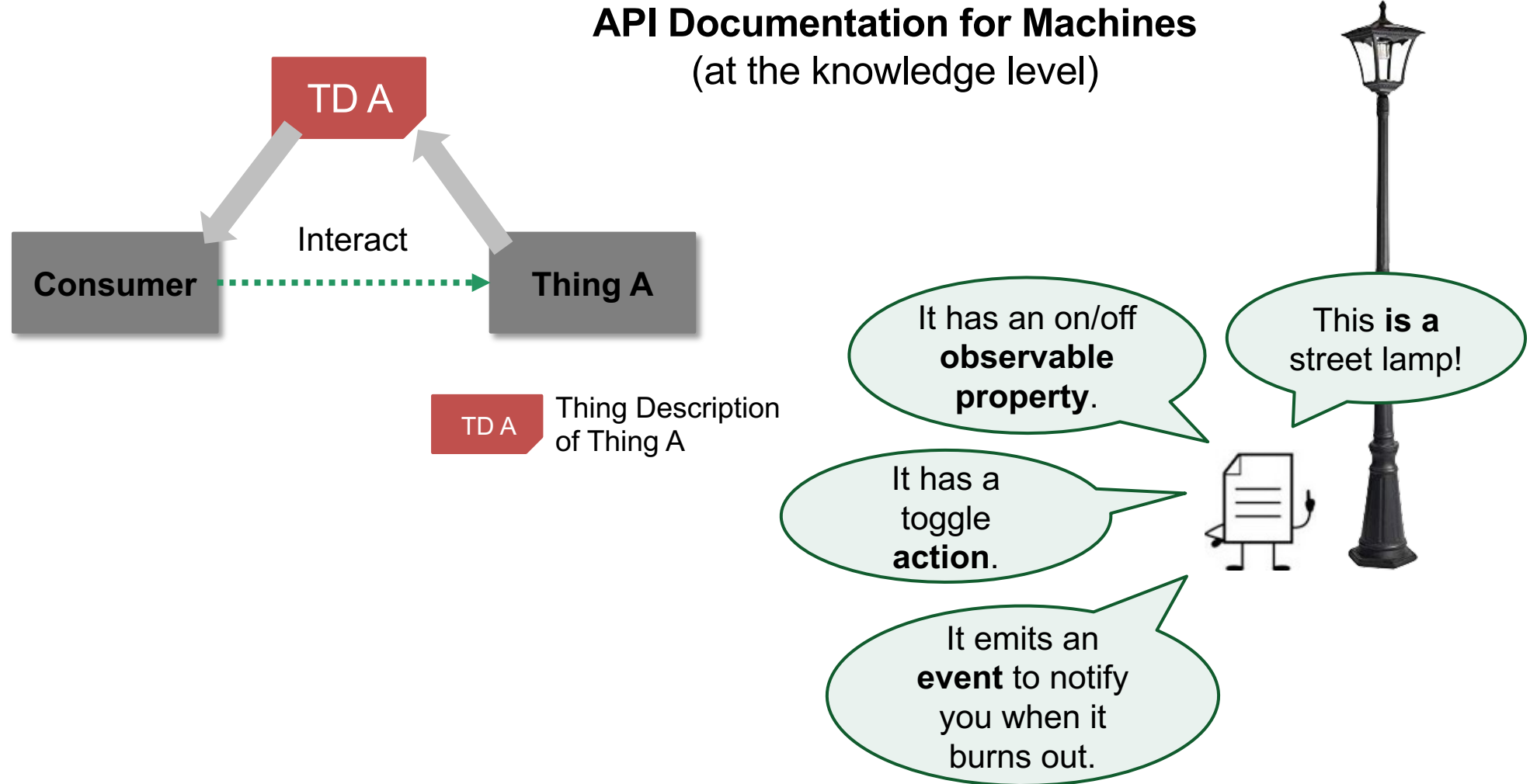
Pattie Maes. *Modeling Adaptive Autonomous Agents*. Artificial Life 1 (1\_2): 135–162. 1993.

Michael Wooldridge. *Intelligent Agents*. In *Multiagent Systems, Second Edition* (ed. Gerhard Weiss), 2013.

Rodney A. Brooks. *A Robust Layered Control System for a Mobile Robot*. MIT A.I. Laboratory, A.I. Memo No. 864, 1985.

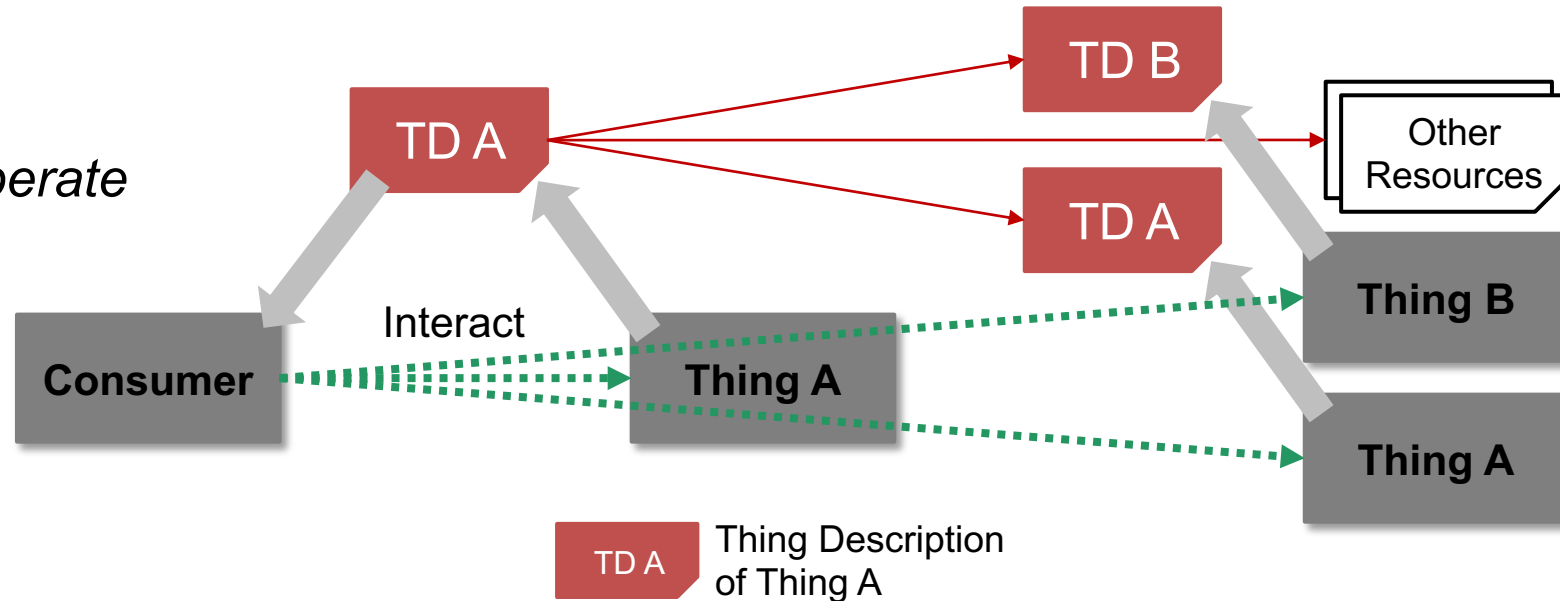


# The W3C Web of Things



# The W3C Web of Things

**Ideally:**  
*arrive-and-operate*



Matthias Kovatsch et al. (eds.), Web of Things (WoT) Architecture, W3C Recommendation, 2020.

The **Web of Things** unlocks new practical use cases for more intelligent agents on the Web

Such agents also need to be **situated** and **embodied** on the Web

Introduction

Representing Agents on the Web

Embodied Agents in Web-based MAS

A Call to Action

# FIPA Agent Identifier Description

Globally unique agent identifiers:

`<agent-name>@<home-agent-platform>`

Frame Ontology	agent-identifier fipa-agent-management	Parameter	Description	Presence	Type	Reserved Values
		name	The symbolic name of the agent.	Mandatory	word	df@hap_name ams@hap_name
		addresses	A sequence of ordered transport addresses where the agent can be contacted. The order implies a preference relation of the agent to receive messages over that address.	Optional	Sequence of url	
		resolvers	A sequence of ordered AIDs where name resolution services for the agent can be contacted. The order in the sequence implies a preference in the list of resolvers.	Optional	Sequence of agent-identifier	

## FIPA Agent Management Ontology

Source: <http://fipa.org/specs/fipa00023/SC00023K.html>

Requires **custom middleware** for resolving agent names to transport addresses

On the Web, a natural choice would be to use **URIs** to identify agents

But what should happen when we dereference the URI of an agent?



## ISSUE-14: What is the range of the HTTP dereferer

### httpRange-14

#### What is the range of the HTTP dereference function?

State:

CLOSED

Product:

Raised by:

[Tim Berners-Lee](#)

Opened on:

2002-03-25

Description:

TBL's argument that HTTP URIs (without "#") should be understood as referring to documents, not ca

[httpRange-14] Resolved

From: Roy T. Fielding <fielding@gbiv.com>

Date: Sat, 18 Jun 2005 21:25:42 -0700

Message-Id: <3fc8037bc096da8c801ebc8c1295e09b@gbiv.com>

<http://lists.w3.org/Archives/Public/www-tag/2005Jun/0039.html>

Related Actions items:

No related actions

Related emails:

**From:** Roy T. Fielding <[fielding@gbiv.com](mailto:fielding@gbiv.com)>

**Date:** Sat, 18 Jun 2005 21:25:42 -0700

**Message-Id:** <3fc8037bc096da8c801ebc8c1295e09b@gbiv.com>

**To:** W3C TAG <[www-tag@w3.org](mailto:www-tag@w3.org)>

As everyone here knows, the TAG has spent a great deal of time discussing the httpRange-14 issue, as described at

<http://www.w3.org/2001/tag/issues.html#httpRange-14>

I am happy to report that we came up with a reasonable compromise solution at the recent TAG f2f meeting at MIT.

<TAG type="RESOLVED">

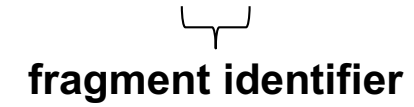
That we provide advice to the community that they may mint "http" URIs for any resource provided that they follow this simple rule for the sake of removing ambiguity:

- a) If an "http" resource responds to a GET request with a 2xx response, then the resource identified by that URI is an information resource;
- b) If an "http" resource responds to a GET request with a 303 (See Other) response, then the resource identified by that URI could be any resource;
- c) If an "http" resource responds to a GET request with a 4xx (error) response, then the nature of the resource is unknown.

</TAG>

# Representing People on the Web

<https://www.w3.org/People/Berners-Lee/card#i>

  
fragment identifier

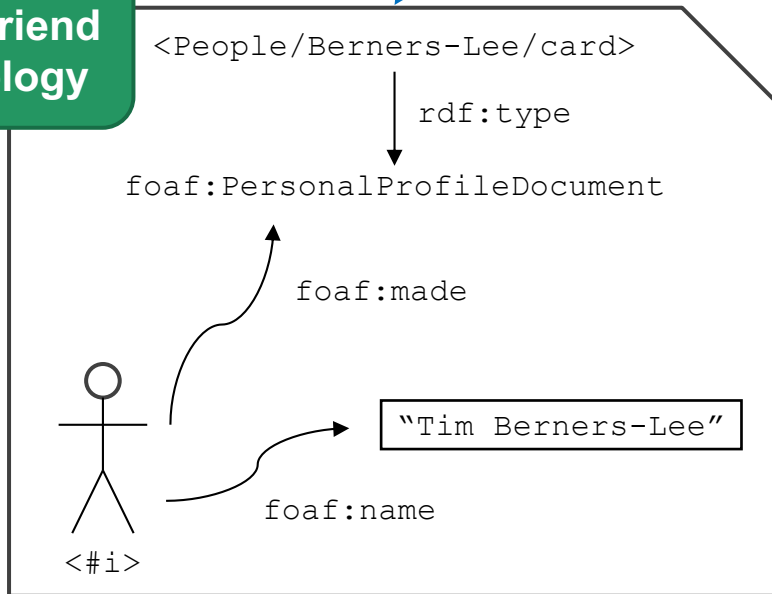
# Representing People on the Web

<https://www.w3.org/People/Berners-Lee/card#i>

identifies

identifies

Friend-of-a-Friend (FOAF) Ontology



RDF Document



Non-Information Resource

An agent's URI dereferences to an  
(authoritative) **Agent Description**

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix pody: <http://someuri.ext/pody/> .
@prefix solid: <http://www.w3.org/ns/solid/terms#> .

<#agent-desc> a foaf:PersonalProfileDocument ;
  foaf:primaryTopic <#bus101> .

<#bus101> a foaf:Agent ;
  foaf:name "Self-driving Bus 101" ;
  # Link to a communication interface (e.g., mailbox, news feed, etc.)
  pody:contact <mbox> ;
  # Link to preferences (entry point to different kinds of preferences)
  pody:preferences <pref> ;
  # Links to the OpenID Provider that will validate the authentication
  # (part of the Solid protocol)
  solid:oidcIssuer <https://oidc.example> ;
  # Links to a relevant image of the bus
  foaf:img <images/picture.jpg> .
```



# Representing Agents on the Web

An agent's URI dereferences to an (authoritative) Agent Description

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix pody: <http://someuri.ext/pody/> .
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  pody:preferences <pref> ;
  # Links to the OpenID Provider that will validate the authentication
  # (part of the Solid protocol)
  solid:oidcIssuer <https://oidc.example> ;
  # Links to a relevant image of the bus
  foaf:img <images/picture.jpg> .
```

```
@prefix td: <https://www.w3.org/2019/wot/td#> .
@prefix hctl: <https://www.w3.org/2019/wot/hypermedia#> .
@prefix pody: <http://someuri.ext/pody/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<mbox> a td:Thing;
  td:hasActionAffordance [
    a pody:SendMessage ;
    td:name "send-mail";
    td:hasForm [
      hctl:hasTarget "https://domain.ext/mbox/inbox"^^xsd:anyURI
    ]
  ] .
```

# Representing Agents on the Web

An agent's URI dereferences to an (authoritative) **Agent Description**

The Agent Description may link to one or more **Agent Bodies**

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix pody: <http://someuri.ext/pody/> .
@prefix solid: <http://www.w3.org/ns/solid/terms#> .

<#agent-desc> a foaf:PersonalProfileDocument ;
  foaf:primaryTopic <#bus101> .

<#bus101> a foaf:Agent ;
  foaf:name "Self-driving Bus 101" ;
  # Link to a communication interface (e.g., mailbox, news feed, etc.)
  pody:contact <mbox> ;
  # Link to preferences (entry point to different kinds of preferences)
  pody:preferences <pref> ;
  # Links to the OpenID Provider that will validate the authentication
  # (part of the Solid protocol)
  solid:oidcIssuer <https://oidc.example> ;
  # Links to a relevant image of the bus
  foaf:img <images/picture.jpg> .
```

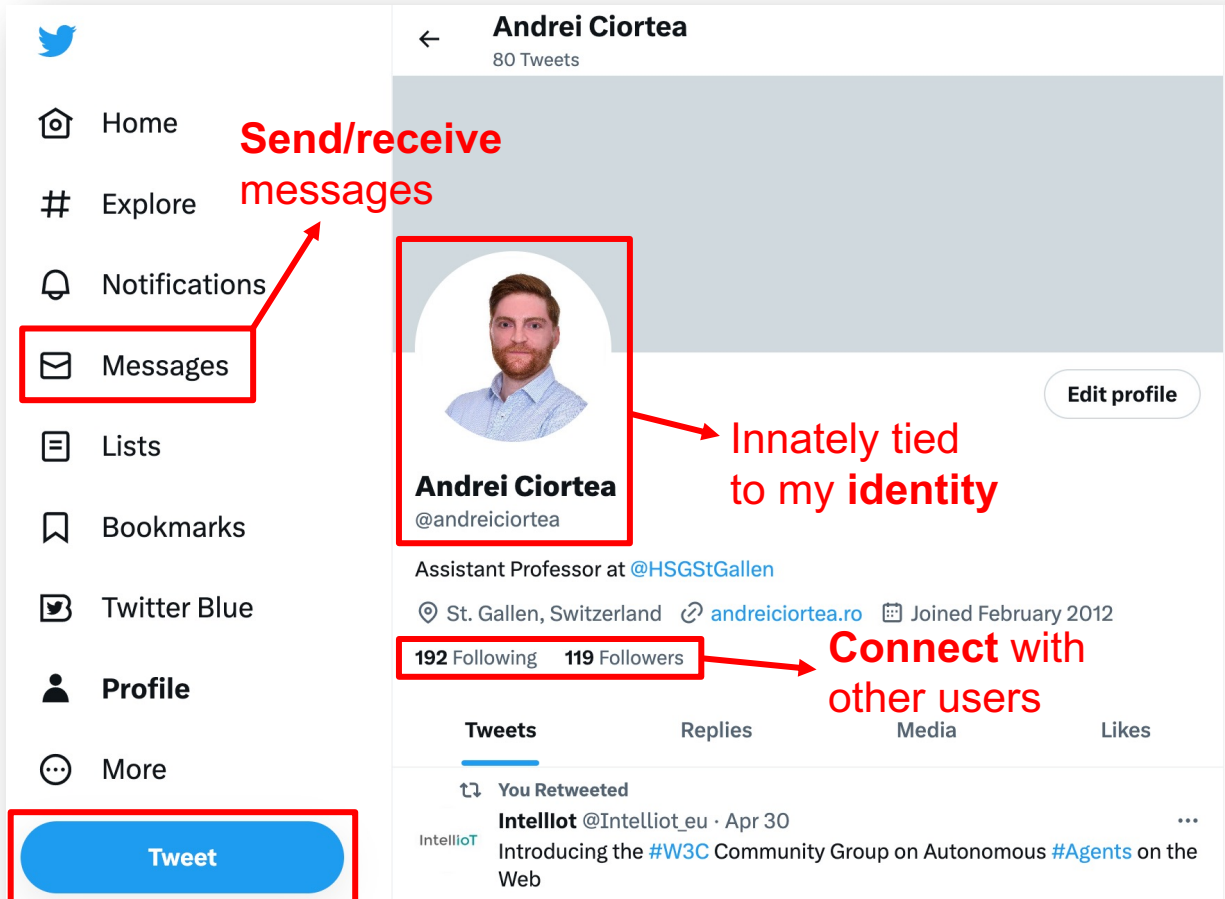
```
@prefix td: <https://www.w3.org/2019/wot/td#> .
@prefix hctl: <https://www.w3.org/2019/wot/hypermedia#> .
@prefix pody: <http://someuri.ext/pody/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<mbox> a td:Thing;
  td:hasActionAffordance [
    a pody:SendMessage ;
    td:name "send-mail";
    td:hasForm [
      hctl:hasTarget "https://domain.ext/mbox/inbox"^^xsd:anyURI
    ]
  ] .
```

```
@prefix acl: <http://www.w3.org/ns/auth/acl#> .

<pref> acl:accessControl [
  acl:accessTo <mbox> ;
  acl:agent <http://example.edu/p/Alice#Msc>,
    <http://example.com/people/Mary/card#me> ;
  acl:mode acl:Read
] .
```

# “Embodying People” on the Web?

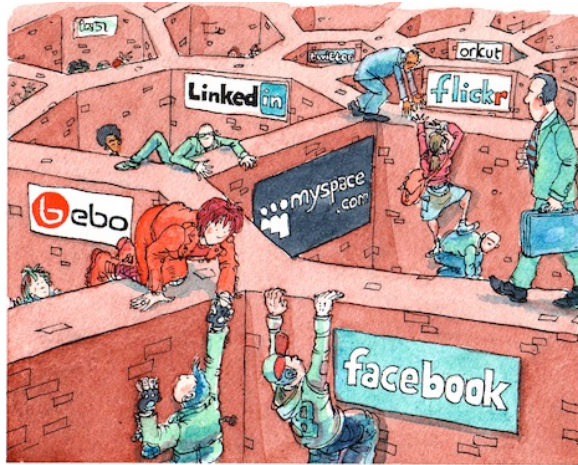


Holds my context on Twitter

Allows me to participate on Twitter

Other users observing my account would typically assume I am the entity acting through the account

# Re-decentralizing the Web



The Web vs. “Walled Gardens”

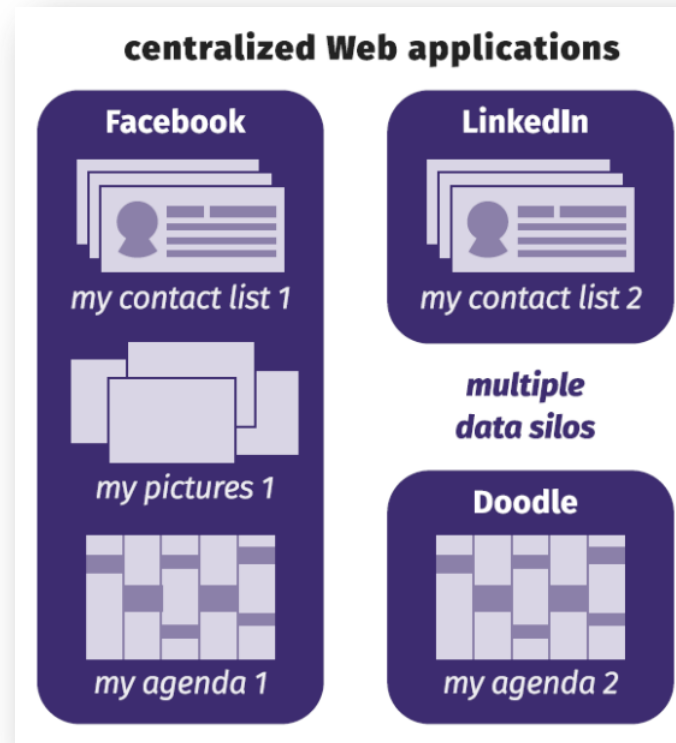
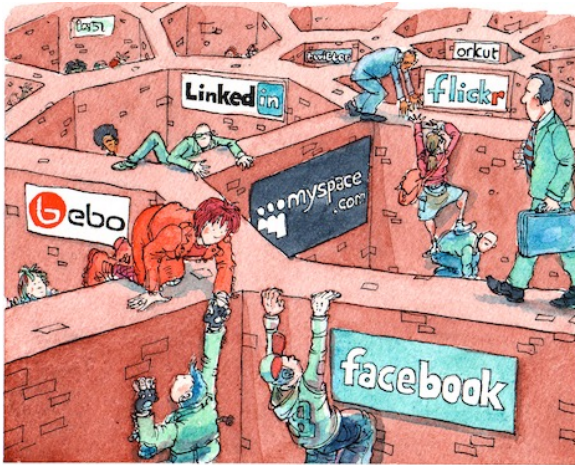


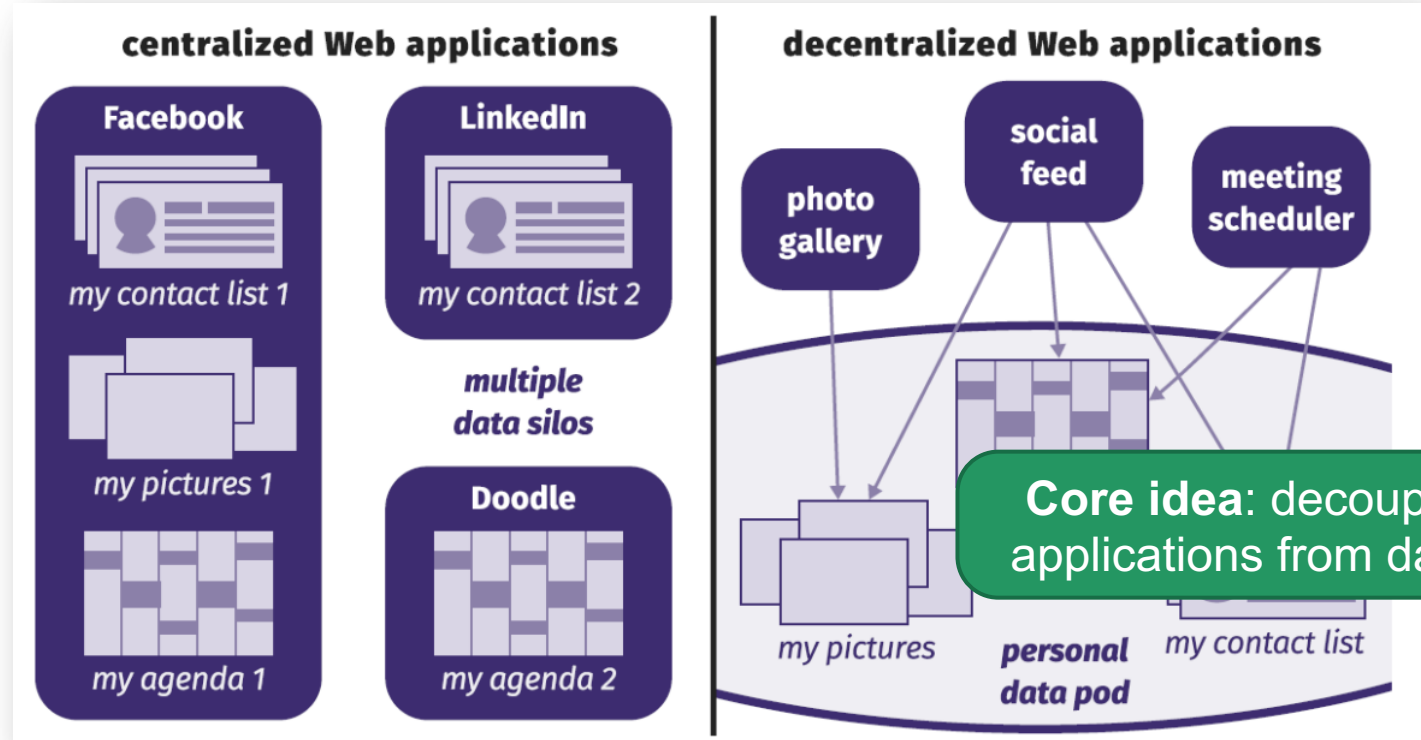
Image source: <https://ruben.verborgh.org/blog/2017/12/20/paradigm-shifts-for-the-decentralized-web/>  
Tim Berners-Lee, Socially Aware Cloud Storage, 2009: <https://www.w3.org/DesignIssues/CloudStorage.html>



# Re-decentralizing the Web



The Web vs. “Walled Gardens”



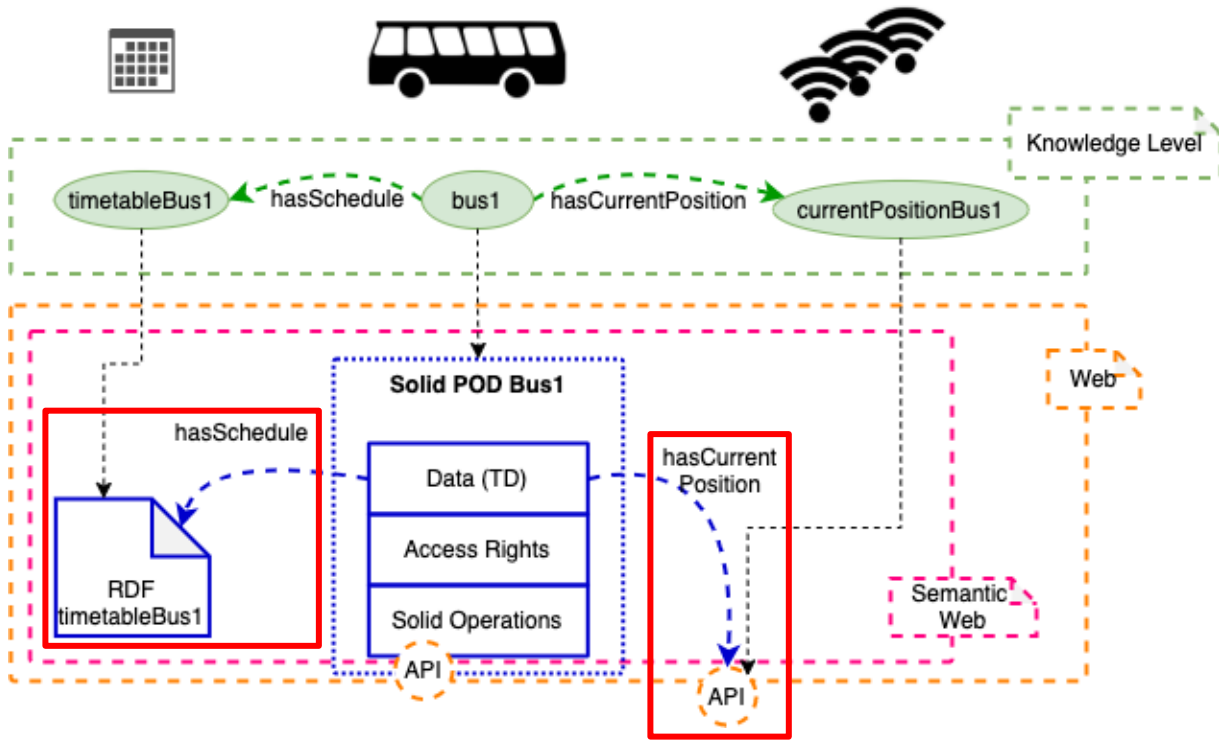
Solid (Social Linked Data)

<https://solidproject.org/>

Image source: <https://ruben.verborgh.org/blog/2017/12/20/paradigm-shifts-for-the-decentralized-web/>  
Tim Berners-Lee, Socially Aware Cloud Storage, 2009: <https://www.w3.org/DesignIssues/CloudStorage.html>

# Example: A Solid-based Agent Body (Pody)

Entry Point



```

@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix pody: <http://someuri.ext/pody/> .
@prefix solid: <http://www.w3.org/ns/solid/terms#> .

<#agent-desc> a foaf:PersonalProfileDocument ;
  foaf:primaryTopic <#bus101> .

<#bus101> a foaf:Agent ;
  foaf:name "Self-driving Bus 101" ;
  # Link to a communication interface (e.g., mailbox, news feed, etc.)
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  pody:preferences <pref> ;
  # Links to the OpenID Provider that will validate the authentication
  # (part of the Solid protocol)
  solid:oidcIssuer <https://oidc.example> ;
  # Links to a relevant image of the bus
  foaf:img <images/picture.jpg> .
  
```

A **standard Solid pod** is essentially a “data vault”: the **default set of affordances** it provides to agents is quite limited

- but if we consider the **environment as a first-class abstraction** in Web-based MAS, we open a **new design space** for agents that are **situated** and **embodied** on the Web

There is a **rich design space** for engineering  
**Web-based Multi-Agent Systems** that we have yet to explore!



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## AUTONOMOUS AGENTS ON THE WEB COMMUNITY GROUP

This community group is interested in the design of Web-based Multi-Agent Systems (MAS) for the deployment of world-wide hybrid communities of people and artificial

<https://www.w3.org/community/webagents/>



Seville, Spain & online

<https://www.w3.org/2023/09/TPAC/>

# Any Questions / Comments / Doubts / Concerns?



<https://freepik.com>