

# Semantic Interoperability in 1,200s

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I am **Victor Charpenay**, associate professor Institut Mines-Télécom (IMT) and member of the LIMOS computer science research lab. I am based in **Saint-Étienne**.



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My research topic is **semantics** for the **Web of Things**.

System Compatibility

Interoperability

Semantic Interoperability

Summary

# System Compatibility

**1,080s**

## System Compatibility

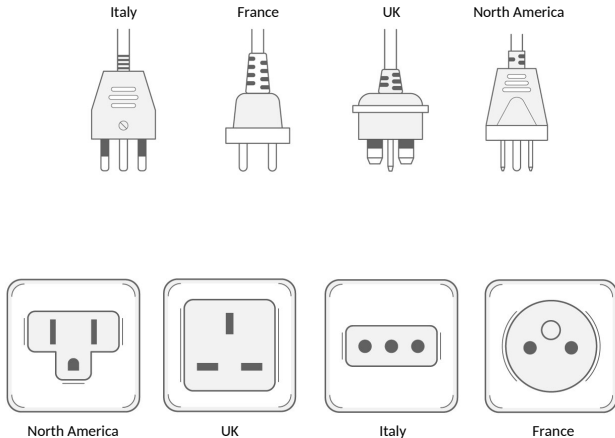


Figure: Power plug (in)compatibility across countries

## System Compatibility

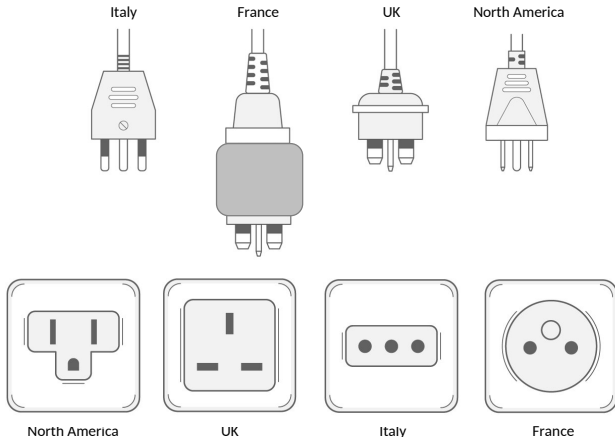


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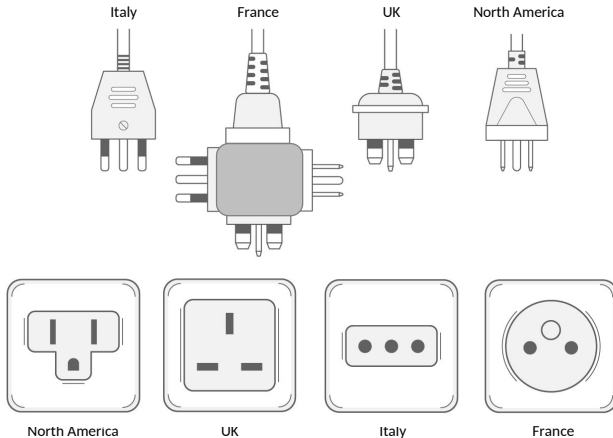


Figure: Power plug (in)compatibility across countries



## System Compatibility

The **combination** of compatible systems generally implies **new functionalities**.

Compatibility is achieved via **standardization**.

# Interoperability

**960s**

## Interoperability

Interoperability is an intangible form of **compatibility** between systems.

**Interoperability** is the ability of two or more systems or components to **exchange information** and to **use the information** that has been exchanged<sup>1</sup>.

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<sup>1</sup>IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries, IEEE, 1990

## Interoperability

In theory, interoperability is realized via **standard interaction protocols.**

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In practice, interoperability is most commonly realized via **(Web) APIs**.

## Interoperability

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Web users should be able to **get access** to the data they produce on one platform and **give access** to that data to another platform.



We can either **force Facebook** to make it **more difficult** for [shadowy influence brokers] **to access your data** without Facebook's explicit approval (...) or we can bar Facebook from using technical and legal countermeasures to shut out new companies, co-ops, and projects that offer to **let you talk to your Facebook friends without using Facebook's tools<sup>2</sup>**.

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<sup>2</sup>Cory Doctorow, "*Competitive Compatibility: Let's Fix the Internet, Not the Tech Giants*," Communications of the ACM, October 2021

## Interoperability

Microsoft Office



Google Docs



OnlyOffice



Google Drive



OneDrive



Dropbox



Evernote

Figure: (Lack of) interop. between text editors and document storage services

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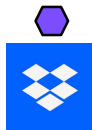
OnlyOffice



Google Drive



OneDrive



Dropbox

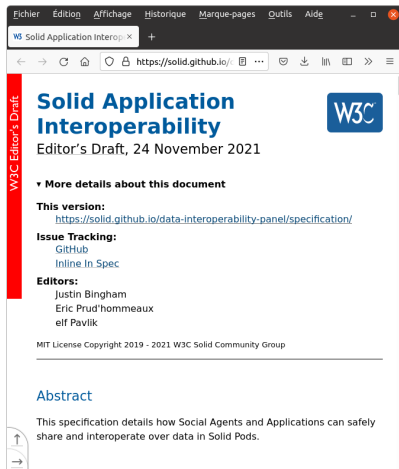


Evernote

Figure: (Lack of) interoperability between text editors and document storage services

# Interoperability

The **Solid project** (Social Linked Data) aims to provide Web-based standards to produce and consume personal data.



The screenshot shows a web browser window with the address bar displaying <https://solid.github.io/>. The page title is "Solid Application Interoperability" and it is labeled as an "Editor's Draft, 24 November 2021". The W3C logo is visible in the top right corner. A red vertical bar on the left side of the page contains the text "W3C Editor's Draft". The main content area includes a section titled "More details about this document" with the following information:

- This version:** <https://solid.github.io/data-interoperability-panel/specification/>
- Issue Tracking:** [GitHub](#), [Inline In Spec](#)
- Editors:** Justin Bingham, Eric Prud'hommeaux, elf Paviik

At the bottom of the page, there is a section titled "Abstract" with the text: "This specification details how Social Agents and Applications can safely share and interoperate over data in Solid Pods."

# Semantic Interoperability

**660s**

The European Telecommunication Standard Institute (ETSI) identified several levels of interoperability<sup>3</sup>.

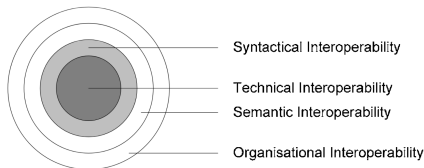


Figure: Different levels of interoperability (source: ETSI)

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<sup>3</sup>Hans van der Veer and Anthony Wiles, Achieving Technical Interoperability - The ETSI Approach, ETSI White Paper, April 2008

## Semantic Interoperability

Assuming syntactic interoperability by exchanging documents in the OpenDocument Format (ODF), text editors may still not be able to **interpret** the content of these documents.



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In that case, **semantic interoperability** is still not guaranteed.

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```
time,hmdt,lumi,temp,location  
1636954288932759918,, ,19.9,emse/fayol/e4/S431H  
1636954288981725847,54.7,, ,emse/fayol/e4/S431H  
...
```

Figure: Sensor measurements (CSV) with unresolved ref. to room S431H

## Semantic Interoperability

**Semantic interoperability** is the ability of two or more systems or components to **share a common interpretation** of the information that has been exchanged.

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If two systems agree on how to interpret data, they must use the **same concepts** to describe that data.

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The two systems have the same ***ontology***.

An **ontology** is a formal description of **concepts and relationships** that can **exist for a community** of human and/or machine agents<sup>4</sup>.

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<sup>4</sup>Steffen Staab and Rudi Studer, Handbook on Ontologies, Springer, 2010



Ontologies are typically expressed as logical **axioms** over a well-defined **vocabulary**.

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<sup>5</sup>Aidan Hogan *et al.*, Knowledge Graphs, Morgan & Claypool, 2021

Ontologies are typically expressed as logical **axioms** over a well-defined **vocabulary**.

They allow for **ontology-based data access** and **ontology alignment**, so that data from several sources is integrated into a single Knowledge Graph<sup>5</sup>.

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<sup>5</sup>Aidan Hogan *et al.*, Knowledge Graphs, Morgan & Claypool, 2021

# Semantic Interoperability

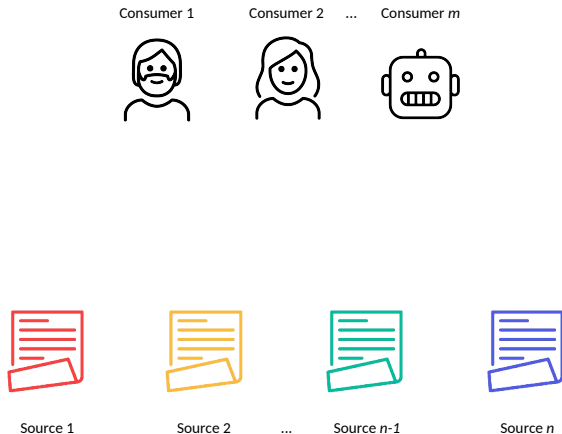


Figure: Semantic interoperability via ontologies

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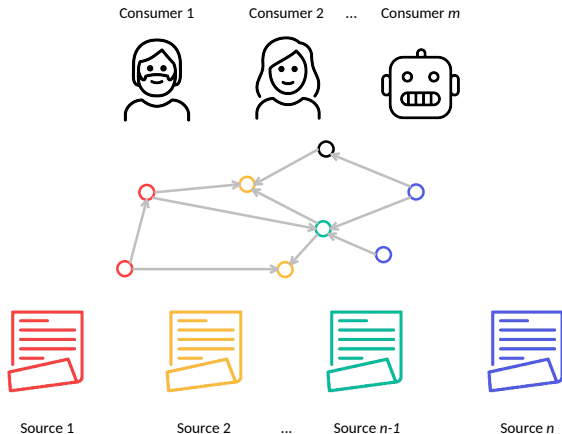


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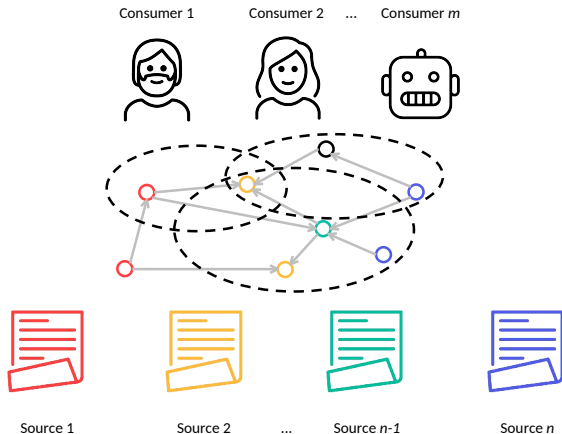


Figure: Semantic interoperability via ontologies

How to “formally describe” concepts and relationships?

# Semantic Interoperability

How to “formally describe” concepts and relationships?

The World Wide Web Consortium (W3C) answers the question from a technical perspective with the **Semantic Web** technology stack.

The Resource Description Framework (**RDF**) provides a common framework for expressing [**information about resources**] so it can be exchanged between applications without loss of meaning.

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<sup>6</sup>Frank Manola, Eric Miller and Brian McBride, RDF 1.1 Primer, W3C, June 2014.



The Resource Description Framework (**RDF**) provides a common framework for expressing **[information about resources]** so it can be exchanged between applications without loss of meaning.

**Resources can be anything**, including documents, people, physical objects, and abstract concepts<sup>6</sup>.

---

<sup>6</sup>Frank Manola, Eric Miller and Brian McBride, RDF 1.1 Primer, W3C, June 2014.

## Semantic Interoperability

RDF triples can state e.g. the type of an online document and how its parts (such as an address) relate to other resources.

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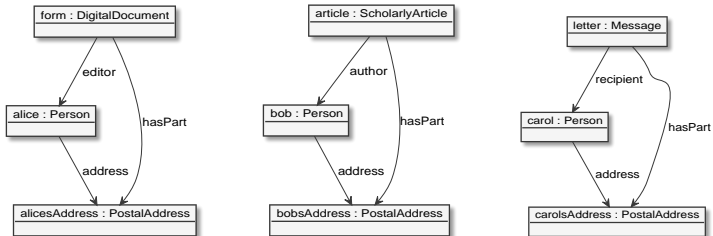


Figure: RDF triples describing various documents with schema.org

## Semantic Interoperability

RDF triples can also describe datasets (such as a CSV history of sensor measurements).

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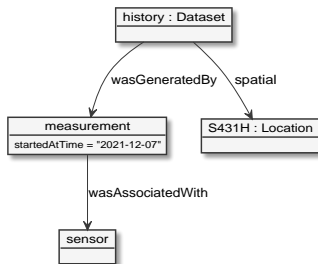


Figure: RDF triples describing a CSV history with DCAT

## Basics

```
resource rdf:type concept .
```

## Intermediate

```
concept rdf:type rdfs:Class .
```

```
concept rdfs:subClassOf otherConcept .
```

```
property rdf:type rdfs:Property .
```

```
property rdfs:domain concept .
```

## Advanced

```
concept rdf:type owl:Class .
```

```
concept owl:unionOf ( concept1 concept2 ... ) .
```

```
property rdf:type owl:ObjectProperty .
```

```
property rdf:type owl:SymmetricProperty .
```

## Semantic Interoperability

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The Simple Knowledge Organization System (**SKOS**) standardizes how to define **taxonomies** (i.e. hierarchies of concepts).

The RDF Schema (**RDFS**) standardizes how to define **basic vocabularies** (i.e. class names and property names) for Knowledge Graphs.

The Web Ontology Language (**OWL**) standardizes how to define **expressive ontologies** (i.e. axioms) for any kind of logical theory.

## Semantic Interoperability

Semantic interoperability is obtained when the resource descriptions of various data sources are **specializations** of a **common generic ontology**.

## Semantic Interoperability

The International Data Space Association (IDSA) has created an ontology, based on DCAT, to ensure semantic interoperability across **data spaces**<sup>7</sup>.

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<sup>7</sup>Sebastian Bader *et al.*, The International Data Spaces Information Model – An Ontology for Sovereign Exchange of Digital Content, ISWC, 2020

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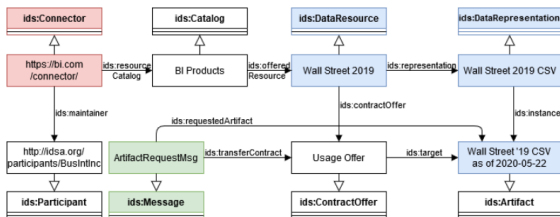


Figure: IDS core classes and example instances

<sup>7</sup>Sebastian Bader *et al.*, The International Data Spaces Information Model – An Ontology for Sovereign Exchange of Digital Content, ISWC, 2020

## Summary

**60s**

**Semantic interoperability** is essential in **data-intensive** applications.

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**Semantic Web standards** play an important role in guaranteeing **minimal interoperability**.

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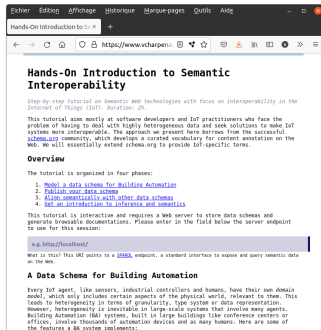
**Semantic Web standards** play an important role in guaranteeing **minimal interoperability**.

Several degrees of interoperability can be achieved '**as-you-go**' via incremental **ontology engineering**.





<https://www.vcharpenay.link/talks/iot-semantic.html>



The screenshot shows a web browser window with the following content:

- Hands-On Introduction to Semantic Interoperability**
- Step-by-step tutorial on Semantic Web technologies with focus on interoperability in the Internet of Things (IoT). Duration: 2h.
- This tutorial aims mostly at software developers and IoT practitioners who face the problem of having to deal with highly heterogeneous data and seek solutions to make IoT systems more interoperable. The approach we present here borrows from the successful [schema.org](http://schema.org) community, which develops a curated vocabulary for content annotation on the Web. We will essentially extend schema.org to provide IoT-specific terms.
- Overview**
- The tutorial is organized in four phases:
  1. [Model a data schema for Building Automation](#)
  2. [Publish your data schema](#)
  3. [Align semantically with other data schemas](#)
  4. [Set an introduction to inference and semantics](#)
- This tutorial is interactive and requires a Web server to store data schemas and generate browsable documentations. Please enter in the field below the server endpoint to use for this session:
- What is this? This URL points to a [SPARQL](#) endpoint, a standard interface to expose and query semantic data on the Web.
- A Data Schema for Building Automation**
- Every IoT agent, like sensors, industrial controllers and humans, have their own domain model, which only includes certain aspects of the physical world, relevant to them. This leads to heterogeneity in terms of granularity, type system or data representation; however, heterogeneity is inevitable in large-scale systems that involve many agents. Building Automation (BA) systems, built in large buildings like conference centers or offices, involve thousands of automation devices and as many humans. Here are some of the features a BA system implements:

**Thank you.** Questions?