

INDUSTRIAL INTERNET OF THINGS (IIOT)
PART 5: SEMANTIC INTEROPERABILITY / DIGITAL TWINS



AV Lecture in Summer Term 2018

Dr.-Ing. Alexander Willner



THE LAST LECTURE

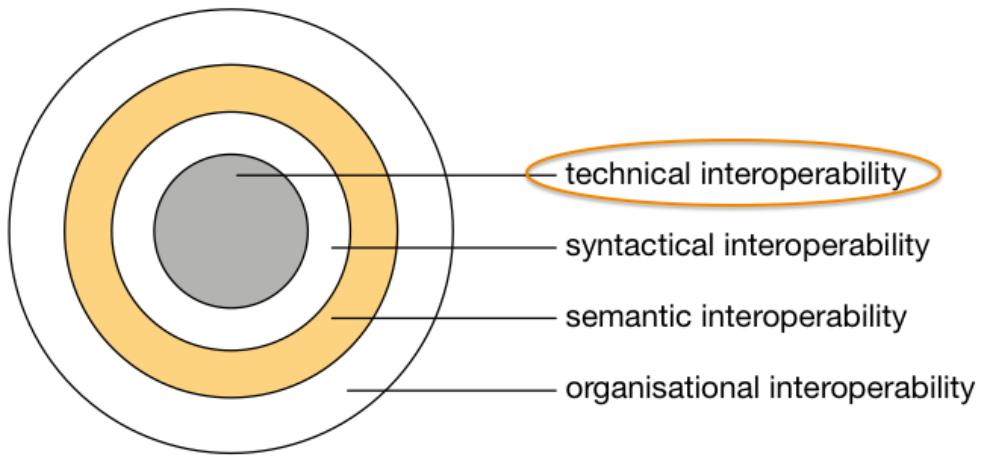
5 minutes



- Last lecture we talked about aspects 2 and 3

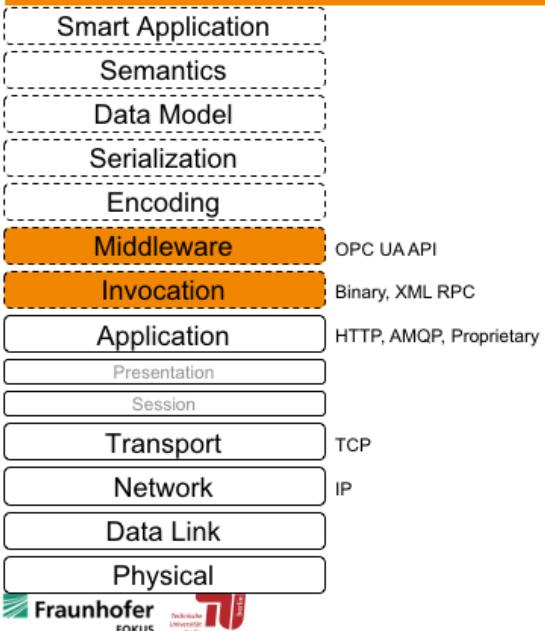
DIFFERENT LEVELS OF INTEROPERABILITY

ETSI White Paper: Achieving technical interop.



- We finished the part about technical interoperability

OPEN PLATFORM COMMUNICATIONS UNIFIED ARCHITECTURE



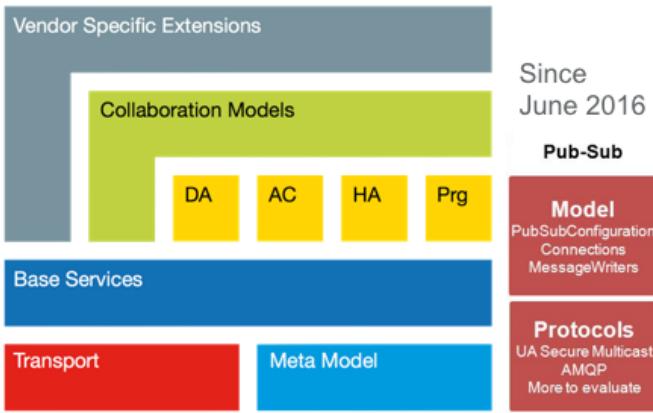
Background: Automation.
Application: Vertical.

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We talked about the most important middleware in the manufacturing context: OPC UA

OPC UA LAYER MODEL

OPC Foundation



Collaboration Models / Companion Models: domain expert models

Meta Model: generic object model

Transport: SOAP or TCP

Base Service: query, subscribe, method invocation, ...

DA: Data Access

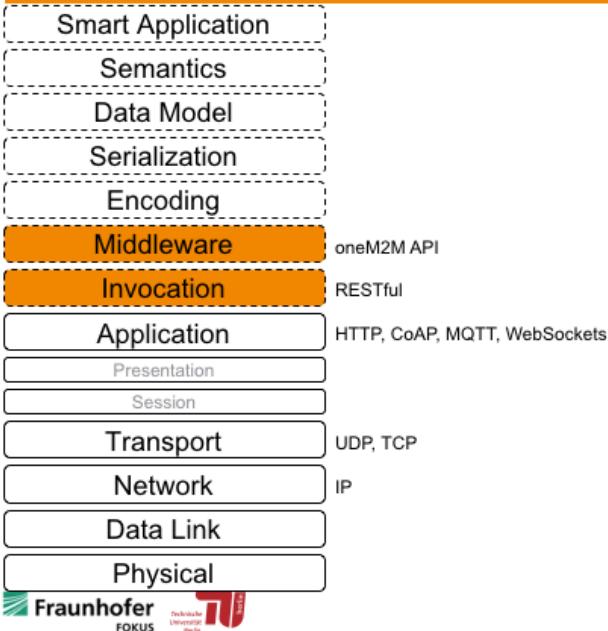
HA: Historical Access

AC: Alarms and Conditions

Prg: Program

The overall architecture of OPC UA

ONEM2M

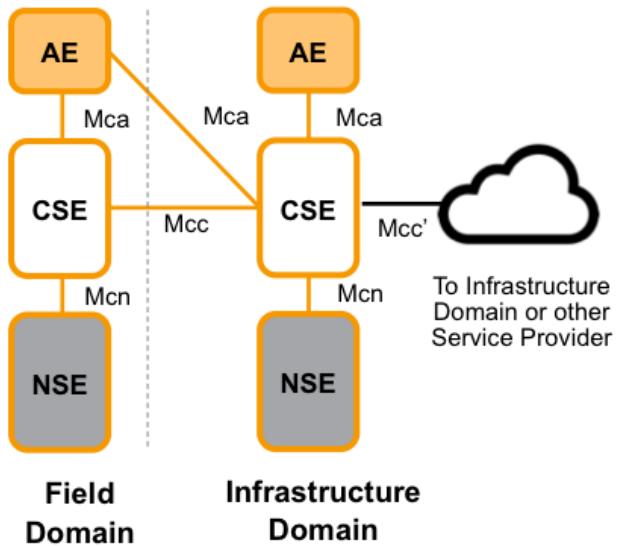


Background: Telecom.
Application: Horizontal.

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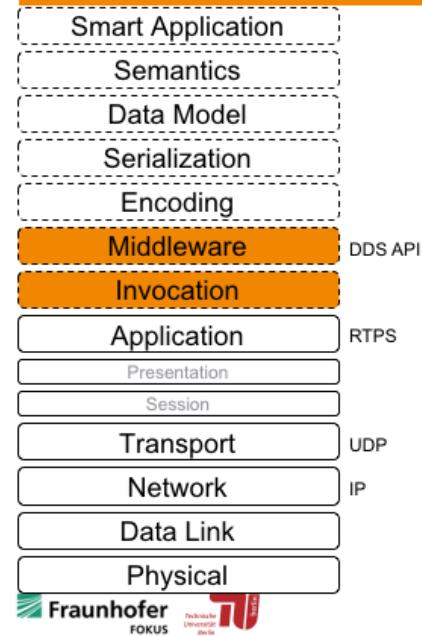
- We talked about an important middleware for horizontal integration

ONEM2M GENERAL ARCHITECTURE



- The overall architecture of oneM2M

DATA-DISTRIBUTION SERVICE API



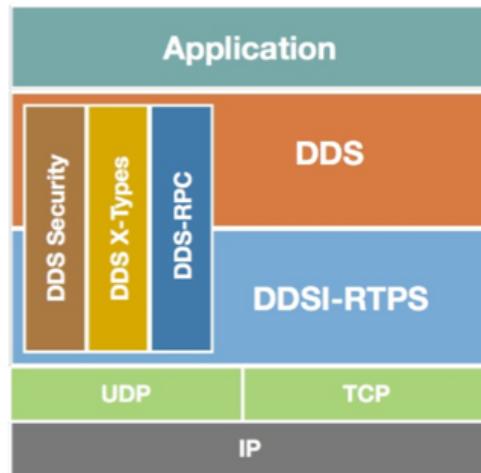
Background: Defense.
Application: Horizontal.

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- We talked about DDS, which has been standardized by OMG, which has a close relation to the IIC

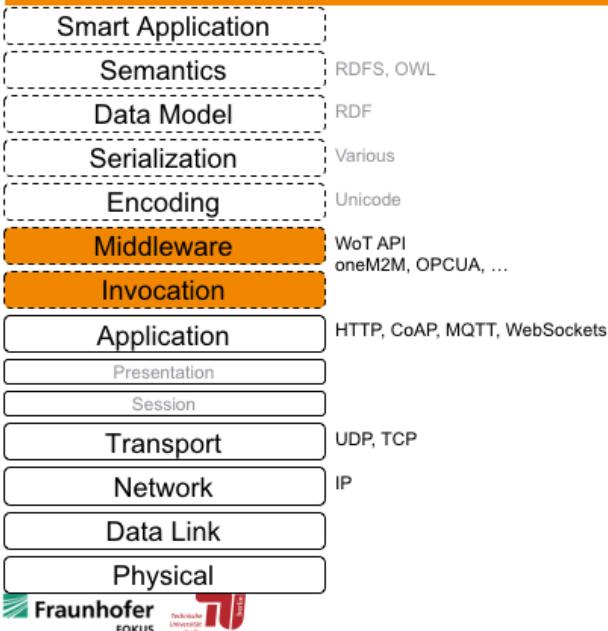
DDS STANDARD STRUCTURE

Prism Tech



- The overall architecture of a DDS node

W3C WEB OF THINGS (WoT)



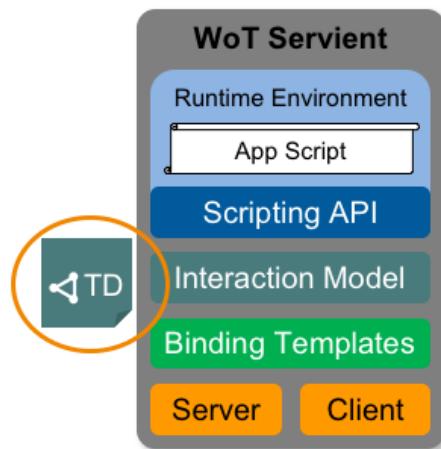
Background: lack of interoperability across platforms

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- We talked about the W3C WoT approach to enable interoperability between the middleware systems

W3C WOT BUILDING BLOCKS

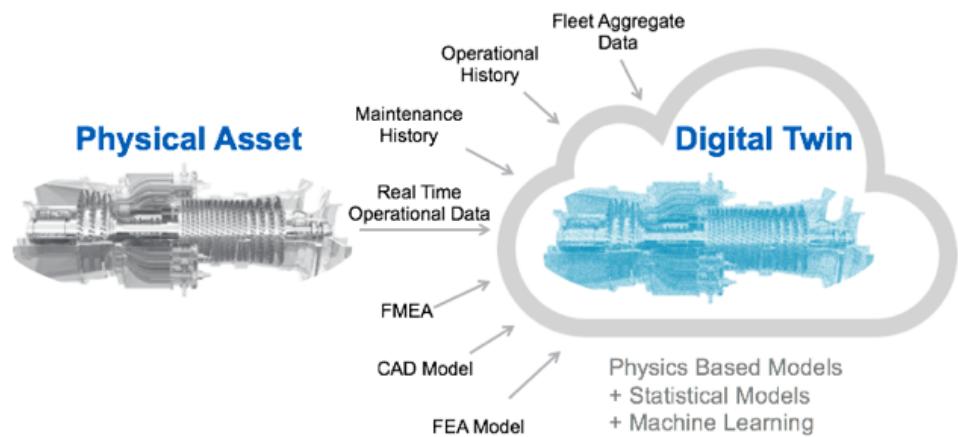
Based on W3C WoT Intro slides



- The architecture of a W3C WoT node
- Things Description (TD) as the core interoperability aspect

REMINDER: DIGITAL TWIN

Source: <https://www.gelandgas.com>



FMEA = Failure Mode Effect and Analysis
FEA = Finite Element Analysis
CAD = Computer Aided Design

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- Semantically, distributed description of digital twin might be the core of future interoperability
- Extends the concept for initial simulation towards a fully interconnected graph of knowledge

NEW LANGUAGE FOR MACHINES (1 MIN)



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<https://youtu.be/OvfU1NbCJQQ>

- Working on a language for machines in the Industrial IoT

WEB OF THINGS THINGS DESCRIPTION EXAMPLE

The diagram illustrates the components of a Web of Things Thing Description (TD) example. It features four thought bubbles connected by dashed lines to a central JSON-LD code snippet:

- JSON-LD (Linked Data)** (Orange bubble): Points to the first line of the JSON-LD code.
- W3C WoT TD vocabulary** (Teal bubble): Points to the "@context" section of the code.
- domain-specific ontology** (Dark Blue bubble): Points to the "name": "MyLEDThing" and "base": "coap://myled.example.com:5683/" sections.
- JSON Schema** (Pink bubble): Points to the "outputData" section of the code.

```
{ "@context": [ "http://w3c.github.io/wot/w3c-wot-td-context.jsonld", { "domain": "http://example.org/actuator#" } ], "@type": "Thing", "name": "MyLEDThing", "base": "coap://myled.example.com:5683/", }, "interactions": [ { "@type": ["Property", "domain:onOffStatus"], "name": "status", "outputData": {"valueType": {"type": "boolean"}}, "writable": true, ... }
```

- A number of acronyms/concepts/technologies that we want to understand today

THE LAST LECTURE

Questions?

MOTIVATION: SYMBOLIC ARTIFICIAL INTELLIGENCE

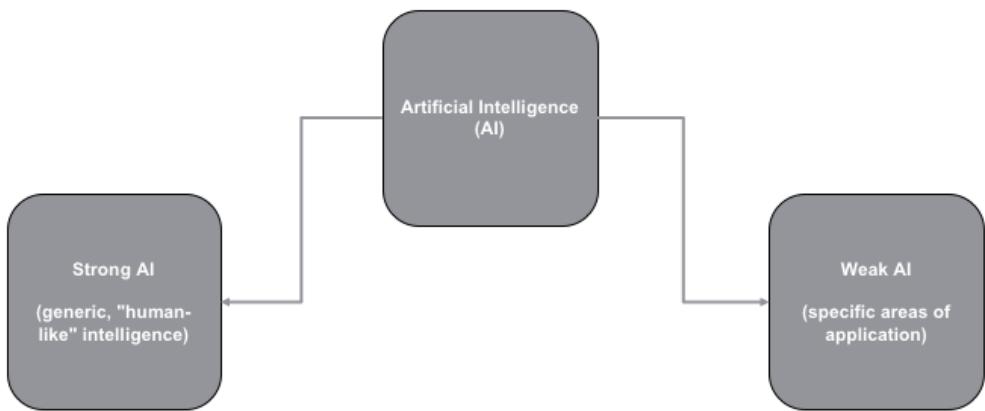
5 minutes

What is artificial intelligence?

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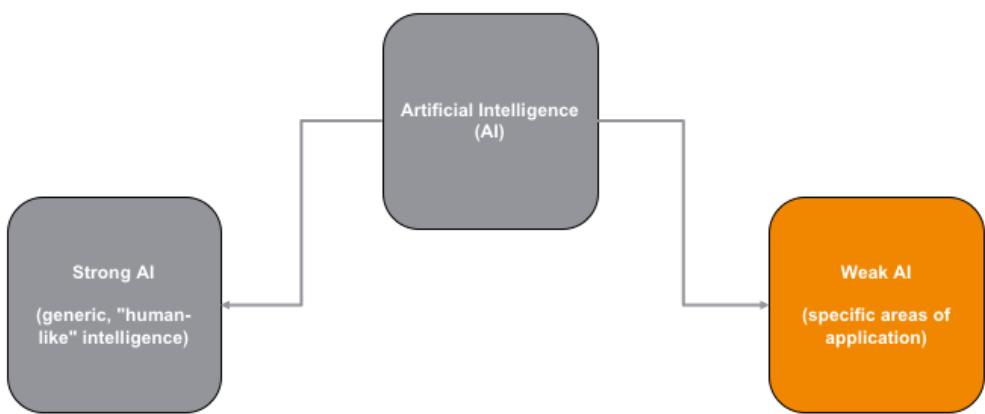
- Subfield of computer science/mathematics since the mid/end of the 1950s (see Dartmouth Conference)

CLASSIFICATION



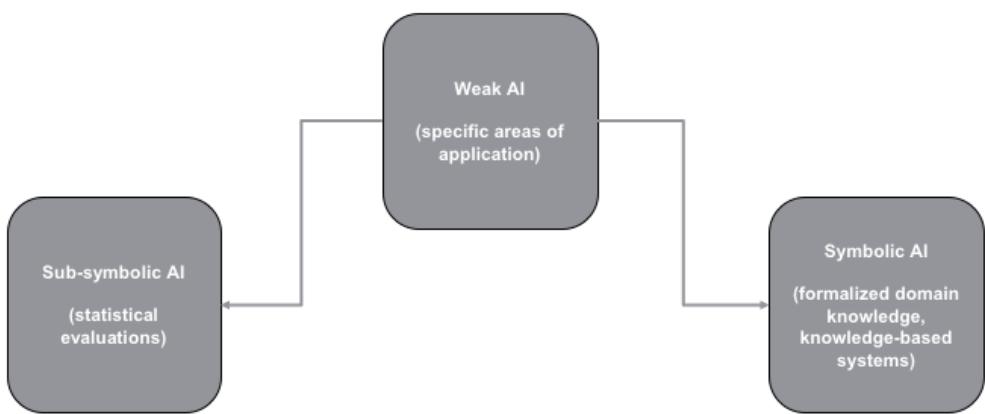
- Basically distinguish between strong and weak AI

CLASSIFICATION



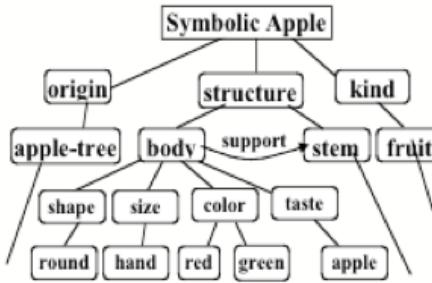
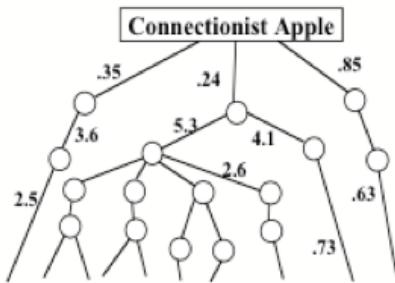
- Even if intelligent digital assistants try to simulate a strong AI (natural speech synthesis), the focus is on the combination of different weak, application-related AI technologies.
- Many know it from interactions with the digital assistants on the mobile phones.

METHODOLOGICAL APPROACHES



- Basically, two methodological approaches are to be distinguished, which also complement each other
- Sub-symbolic AI: new attraction due to artificial neuronal networks
- Symbolic AI: we already started to talk about this

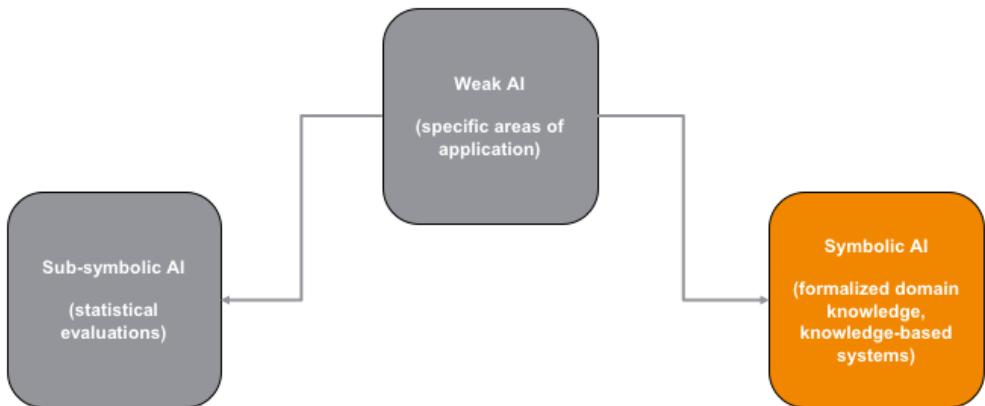
VISUAL COMPARISON



Source: Marvin Minsky: "Logical vs. Analogical or Symbolic vs. Connectionist or Neat vs. Scruffy". In Artificial Intelligence at MIT, Expanding Frontiers, Patrick H. Winston (Ed.), Vol.1, MIT Press, 1990.

- Left: sub-symbolic AI (statistics) → implicit generation of knowledge through certain weightings / target metrics (e.g. reinforcement learning)
- Right: symbolic AI (logic) → an explicit, formal description of knowledge

METHODOLOGICAL APPROACHES



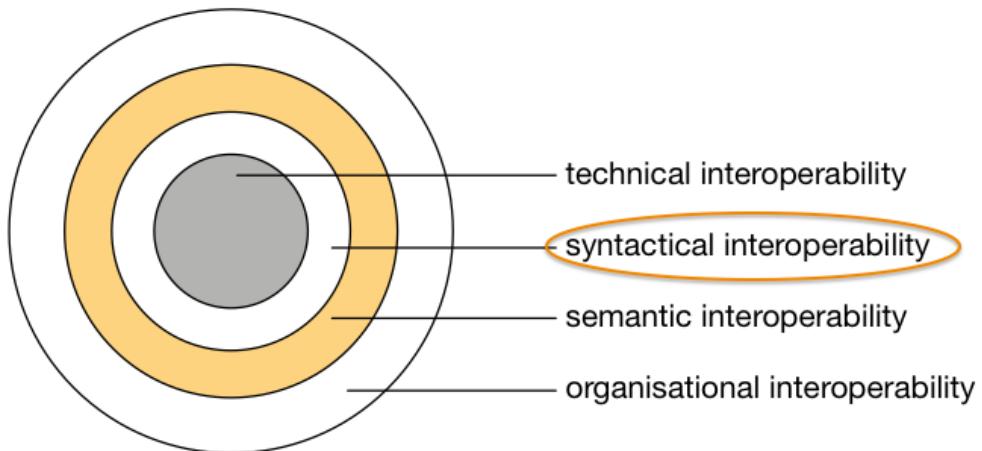
- Let us focus on symbolic KI to allow for interoperability between machines
- It's the formal description of information on which you can infer implicit knowledge based on reasoning

SYNTACTICAL INTEROPERABILITY

8 minutes

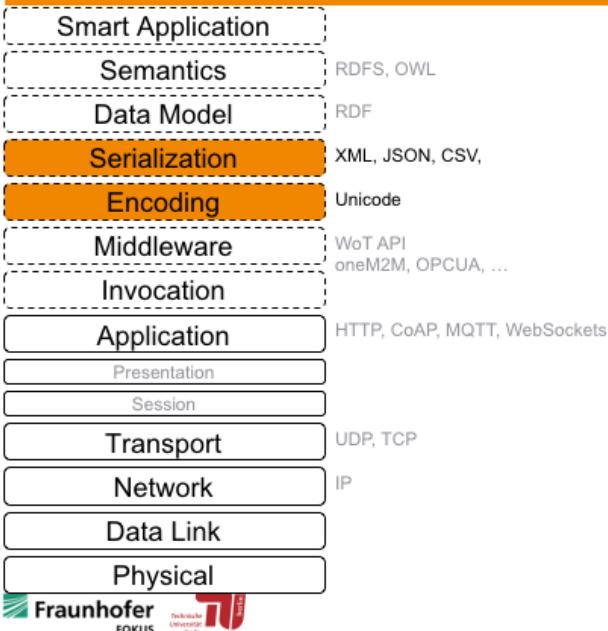
DIFFERENT LEVELS OF INTEROPERABILITY

ETSI White Paper: Achieving technical interop.



- Now moving to the next layer
- A simple and thin layer

SYNTAX



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- Two main aspects

UNICODE

Clipboard

Text copied/cut within Guacamole will appear in the interface between the client and server clipboards.

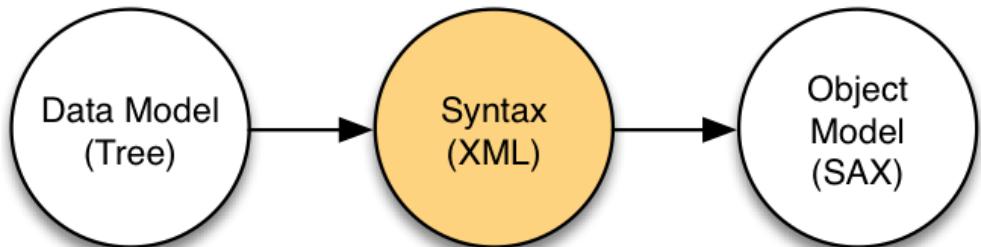
Umlaut



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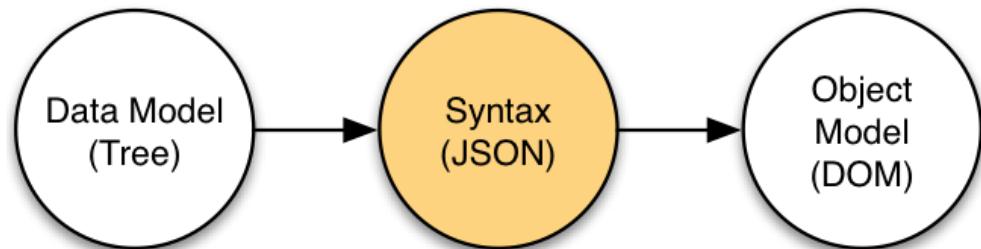
- Basic concept for any serialization
 - Unicode is NOT the same as UTF-8
 - Encoding issues still nowadays. Yester downloaded a vcf file with German umlauts...

SYNTAX VS. OBJECT MODEL & DATA MODEL



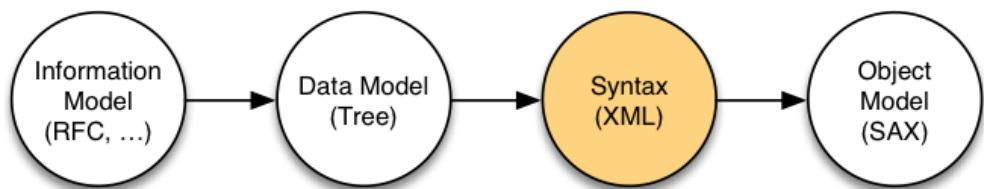
- Typical view as developer, e.g. XML Schema, XML file, SAX object
- SAX=Java API for XML

SYNTAX VS. OBJECT MODEL & DATA MODEL



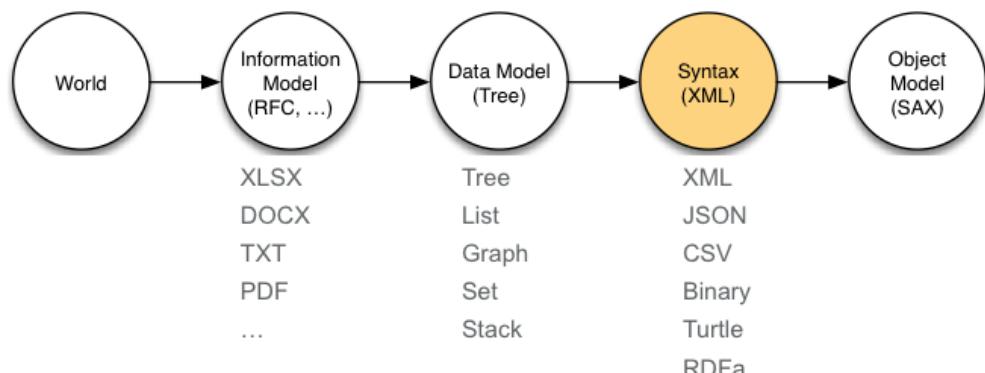
- JSON is just another serialization of a tree data model
- DOM = Document Object Model

SAME INFORMATION & DATA MODEL



- Both might describe the same underlying information

SAME WORLD CONCEPT



- This information model is an abstraction of a real word concept
- Usually human readable (from humans for humans)
- Examples

DIFFERENT SYNTAX, SAME MEANING

XML

```
<university name="tu-berlin">
    <department>AV</department>
</university>
```

XML

```
<department name="AV">
    <university>tu-berlin</university>
</department>
```

JSON

```
{
  "department": {"-name": "AV", "university": "tu-berlin"}
}
```



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- Same information encoded differently
- Structure implied “semantics”
- At the end, the serialization is not important
- However, for interoperability we either have to use the same serialization or have translators

SYNTACTICAL INTEROPERABILITY

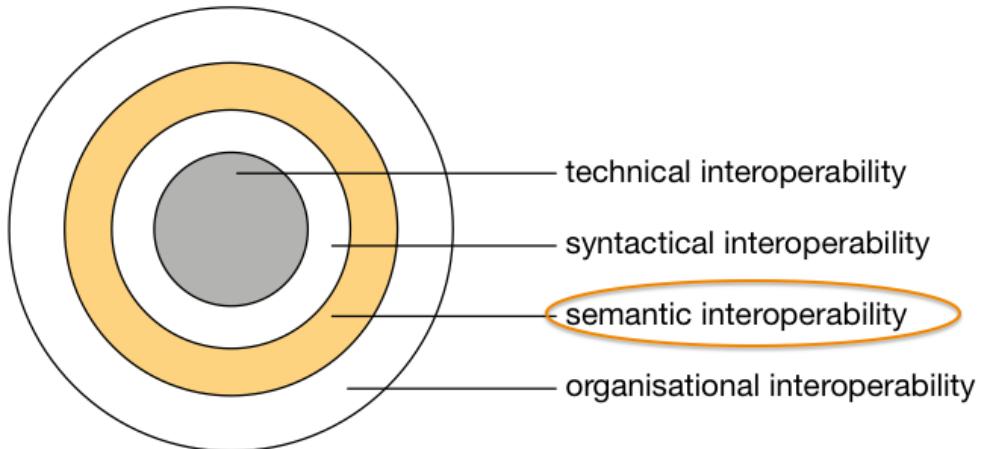
Questions?

SEMANTIC INTEROPERABILITY

12 minutes

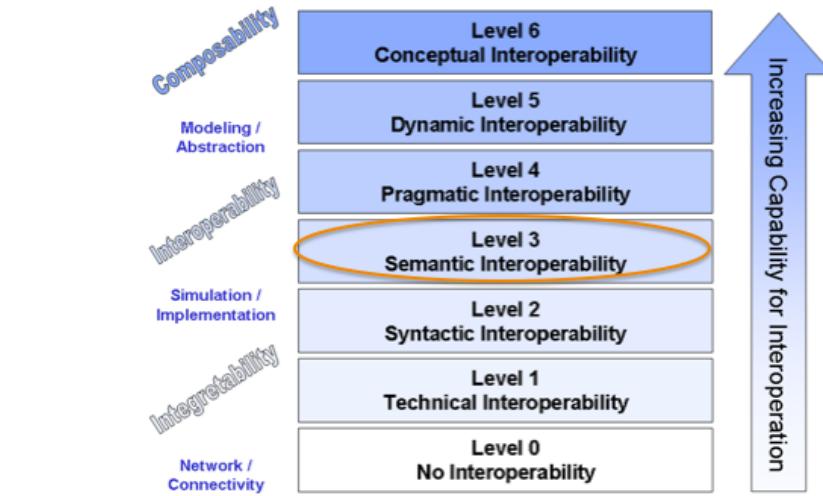
DIFFERENT LEVELS OF INTEROPERABILITY

ETSI White Paper: Achieving technical interoperability



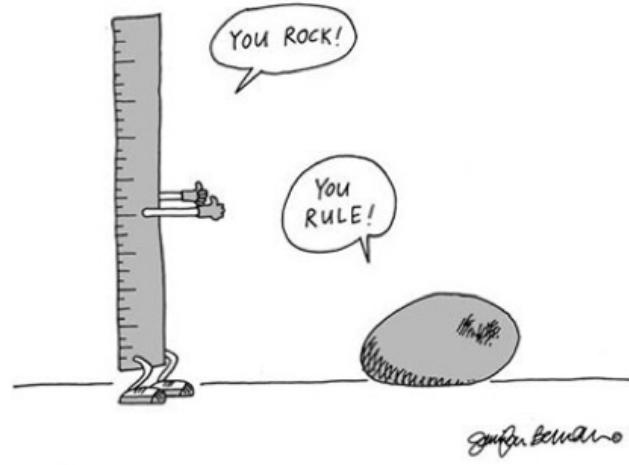
- Finally, the semantic layer
- The last layer we'll cover

DIFFERENT LEVELS OF INTEROPERABILITY (EXTENDED)



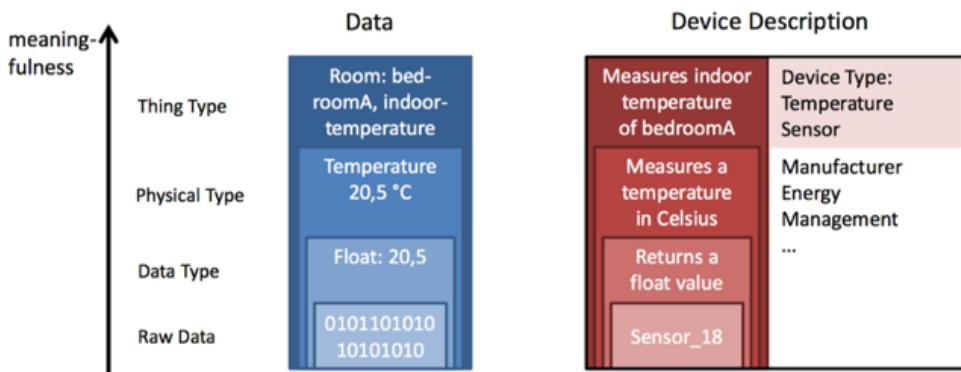
- There are more interesting levels
- Pragmatic interoperability: methods and procedures → Remember: Asset Administration Shell!

IT'S ALL ABOUT SEMANTICS (=MEANING)



LEVELS OF MEANINGFULNESS

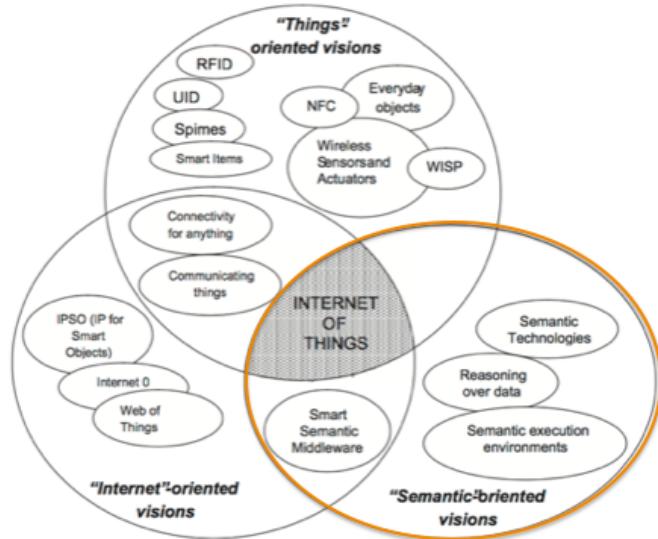
OneM2M TR0007 Study of Abstraction & Semantics



- Raw data: a list of "0" and "1"
- Data type: Interpretation of the raw data. Probably content of the basic lectures.
- Physical type: Metadata on the meaning of the data
- Building on this, an ever-growing knowledge graph of metadata can be generated → room temperature in Building X in City Y with Mayor Z born in Year A, as well as writer B, the...

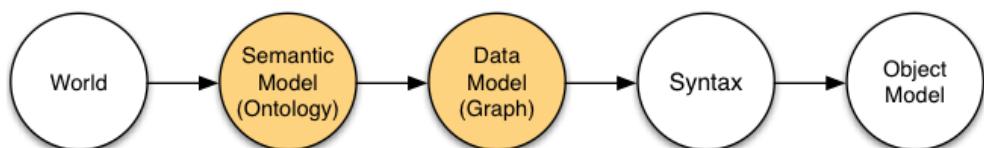
GOT | CONVERGENCE OF DIFFERENT VISIONS

Atzori, Luigi: The Internet of Things: A survey



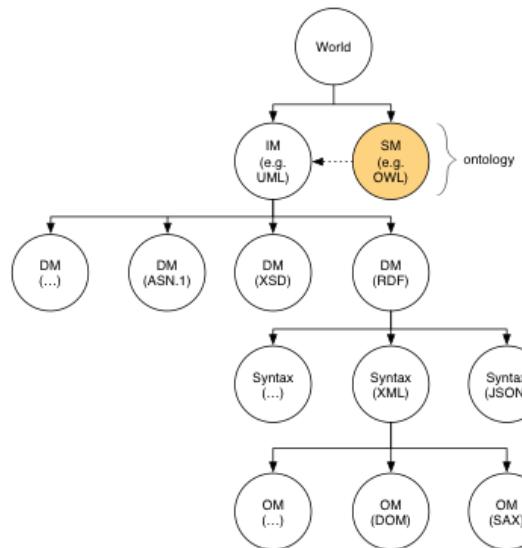
- Another part of the overall IoT visions: IP + Things + Semantics
- Note the different terminology used in this example!

SEMANTIC MODEL



- Moving from human readable information models to formal information models
- Moving from lists or trees to graph data models

SEMANTIC MODELS



- Another view
- UML is already a formal information model
- So is the OPC UA information model
- However, with semantic information models we move towards symbolic KI capabilities

SEMANTIC INTEROPERABILITY IN DIFFERENT FIELDS OF APPLICATION

Federated Grids



HP Computing

Federated Testbeds



Future Internet

Federated Clouds



Interclouds

Federated Networks



Multidomain SDN

Federated Things



Cyber Physical Systems

- Use of semantic information models in different fields of application

SEMANTIC INTEROPERABILITY IN DIFFERENT FIELDS OF APPLICATION

Microsoft



facebook.



Google



Fraunhofer
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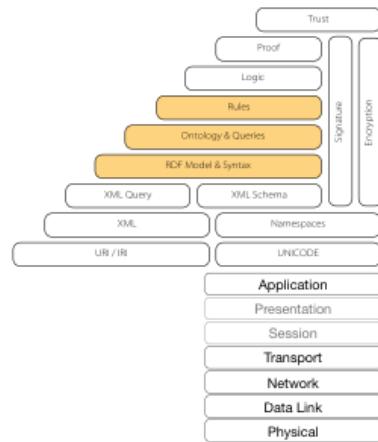
TU
Technische Universität Berlin

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- Use of semantic information models in different products

THE SEMANTIC WEB IS ONE POSSIBLE IMPLEMENTATION



- The Semantic Web is ONE possible implementation of the related subsymbolic KI mechanisms

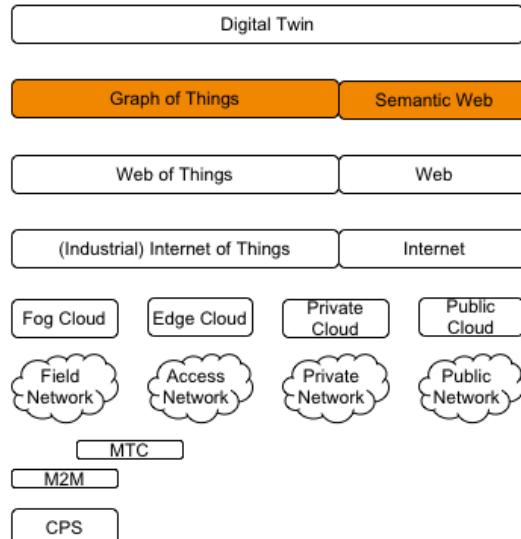
SEMANTIC INTEROPERABILITY

Questions?

THE SEMANTIC WEB

8 minutes

TERMINOLOGY



- The application of semantic web technologies for interoperable communication within the Internet of Things

GRAPH OF THINGS USE OF THE SEMANTIC WEB WITHIN THE IOT



The **Semantic Web** is the extension of the World Wide Web that enables people to share *content* beyond the boundaries of applications and websites. [<http://semanticweb.org>]
Roots in discussions started 2001.



- It's origin from the web community
- Formal languages as such have a way longer history

WHERE IS THE SEMANTIC WEB? (2010)

Ivan Herman, W3C: Tutorial on Semantic Web



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- CAN be applied to web pages, but it's ONLY ONE example

WHERE IS THE SEMANTIC WEB?

Ivan Herman, W3C: Tutorial on Semantic Web



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- Annotated within HTML → RDFa serialization (RDF in attributes)

WHERE IS THE SEMANTIC WEB?



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- Also modern web pages are using RDFa

WHERE IS THE SEMANTIC WEB?

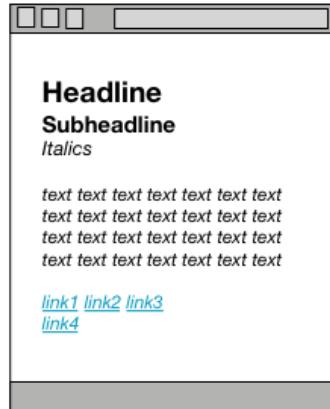
```
[awi@i3dhcp057:~]$ curl www.google.de
<!doctype html><html itemscope="" itemtype="http://schema.org/WebPage" lang="de"><head><meta content="text/html; charset=UTF-8" http-equiv="Content-Type"><meta content="/logos/doodles/2017/gilbert-bakers-66th-birthday-6816396013076480.8-law.gif" itemprop="image"><meta content="66. Geburtstag von Gilbert Baker" property="twitter:title"><meta content="66. Geburtstag von Gilbert Baker. #127987;#127752; #GoogleDoodle" property="twitter:description"><meta content="66. Geburtstag von Gilbert Baker. #127987;#127752; #GoogleDoodle" property="og:description"><meta content="summary_large_image" property="twitter:card"><meta content="#GoogleDoodles" property="twitter:site"><meta content="https://www.google.com/logos/doodles/2017/gilbert-bakers-66th-birthday-6816396013076480.8-law.gif" property="twitter:image"><meta content="https://www.google.com/logos/doodles/2017/gilbert-bakers-66th-birthday-6816396013076480.8-law.gif" property="og:image"><meta content="449" property="og:image:width"><meta content="200" property="og:image:height"><meta content="http://www.google.com/logos/doodles/2017/gilbert-bakers-66th-birthday-6816396013076480.3-2xa.gif" property="og:url"><meta content="video_other" property="og:type"><title>Google</title><script>(function(){(window.google||(KEI:'3SwxPcFJpobWLtxAqW',kEXPi:'1352552,1353571,1353935,3708031,37080347,3708045,37080433,4029815,4831109,4032678,4036527,4039268,4043492,4048539,4048347,4063220,4064984,4065787,4072364,4072776,4076095,4076997,4077582,4078430,408763,4081838,4081164,4085472,4090550,4091860,4091428,4092183,4093313,4094533,4095364,4095918,4096324,4096939,4097153,4097284,4097478,4097792,4097929,4097955,4097971,4098986,4098721,4098724,4098752,4181429,4181750,4183469,4183475,4184085,4184284,4184527,4185085,4185155,4185178,4185317,4186084,4187288,4187397,4187410,4187413,4187428,4187555,4187628,4188580,4188538,4188540,4189316,4189436,4189489,4189498,4189539,4189631,4110087,4119381,4118426,4118656,4111128,4111423,4111915,4121009,4112041,4112306,4112636,4113181,4114876,4115269,4115408,4115543,4185385,4058229,4058893,4058991,4059373,4059816,4051834,10200883,19002329,19002339,19002378,19002411,19002428,19002422,19002440,19002444,19002446,41027342',authuser:0,kscs:'c9f918fe_24'});google.khl='de';})();function(google){l=google.li=google.getELI=function(a){for(var b=a;ba){(a.getAttribute('eid')));a=a.parentNode;return b};google.getELI=function(a){for(var b=nul;a&&a.getAttribute('eid')));a=a.parentNode;return b};google.https=function(){return "https://www.location.protocol);google.ml=function(){return null};google.wl=function(a,b){try{google.ml(Error,a,[1,b]);catch(c{});google.time=function(){return new Date().getTime()};google.log=function(a,b,c,d,g){a=log.url(a,b,c,d,g);if(''!=a){b=new Image;var e=google.lc,f=google.li;e.src=f;b.onerror=b.onload=b.on";
```



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- Again: ONE possible application of Semantic Web Technologies are web pages (=largely distributed, heterogeneous, federated and linked resource database)
 - NOT limited to web pages

WHERE IS THE SEMANTIC WEB?



- Needed as soon knowledge representation is directed towards machines, not humans
-> IoT

CONVERTING FROM ONE SERIALIZATION TO ANOTHER

<http://rdf-translator.appspot.com>

The screenshot shows a web browser window titled "RDF Translator, powered by RDFLib 4.1.2". The URL "https://www.google.de" is entered in the input field. Below the input field are two radio buttons: "Input: RDFa" (selected) and "Output: Pretty RDF/XML". A "Submit" button is present. At the bottom, there is a "Copy To Clipboard..." button. The main content area displays the generated RDF/XML code:

```
<html version="1.0" encoding="UTF-8">
<rdf:RDF>
<desc about="http://www.google.de">
<dc:title>Google</dc:title>
<dc:creator>Gilbert Baker</dc:creator>
<dc:subject>#GoogleLogo</dc:subject>
<dc:image><a href="https://www.google.com/images/doneGeo/2017/gilbert-baker-44th-birthday-4014394013074480.s-l160.gi"><img alt="Google logo featuring Gilbert Baker's AIDS quilt design" /></a></dc:image>
<dc:width>480</dc:width>
<dc:height>320</dc:height>
<dc:format>image/jpeg</dc:format>
<dc:type><a href="https://www.google.com/images/doneGeo/2017/gilbert-baker-44th-birthday-4014394013074480.s-l160.gi"><img alt="Google logo featuring Gilbert Baker's AIDS quilt design" /></a></dc:type>
<dc:description>#44. Geburtstag von Gilbert Baker. <a href="https://www.google.com/images/doneGeo/2017/gilbert-baker-44th-birthday-4014394013074480.s-l160.gi"><img alt="Google logo featuring Gilbert Baker's AIDS quilt design" /></a></dc:description>
</desc>
</rdf:RDF>
```



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- Agnostic towards its serialization: RDFa, XML, N3, JSON, ...
- Remember the last slide about syntactic interoperability

THE SEMANTIC WEB

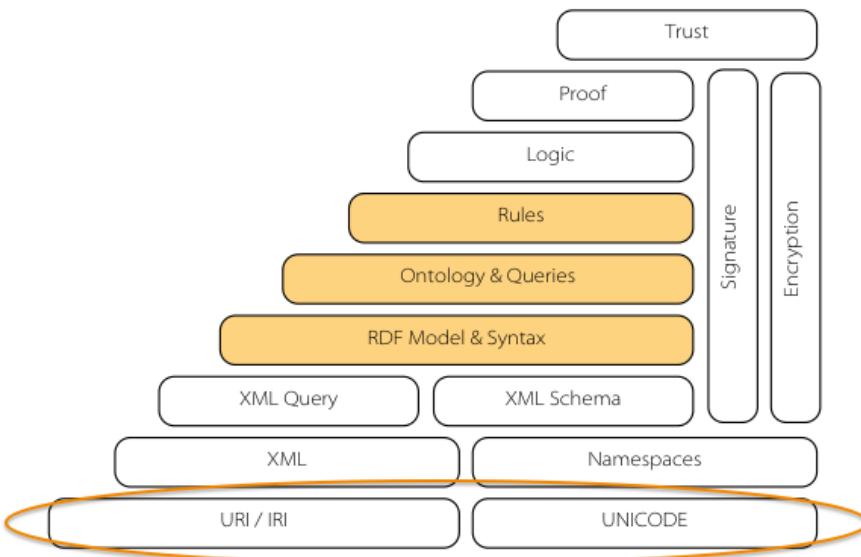
Questions?

SEMANTIC WEB LAYER CAKE

URI

3 minutes

SEMANTIC WEB LAYER CAKE



URI

- **Name:** Uniform Resource Identifier (URI)
 - URN: Uniform Resource Name (RFC 3406)
 - URL: Uniform Resource Locator (RFC 1738)
- **Description:** String of characters used to identify a resource
- **Form:** scheme://[:user[:password]@]host[:port]][/path][?query][#fragment]

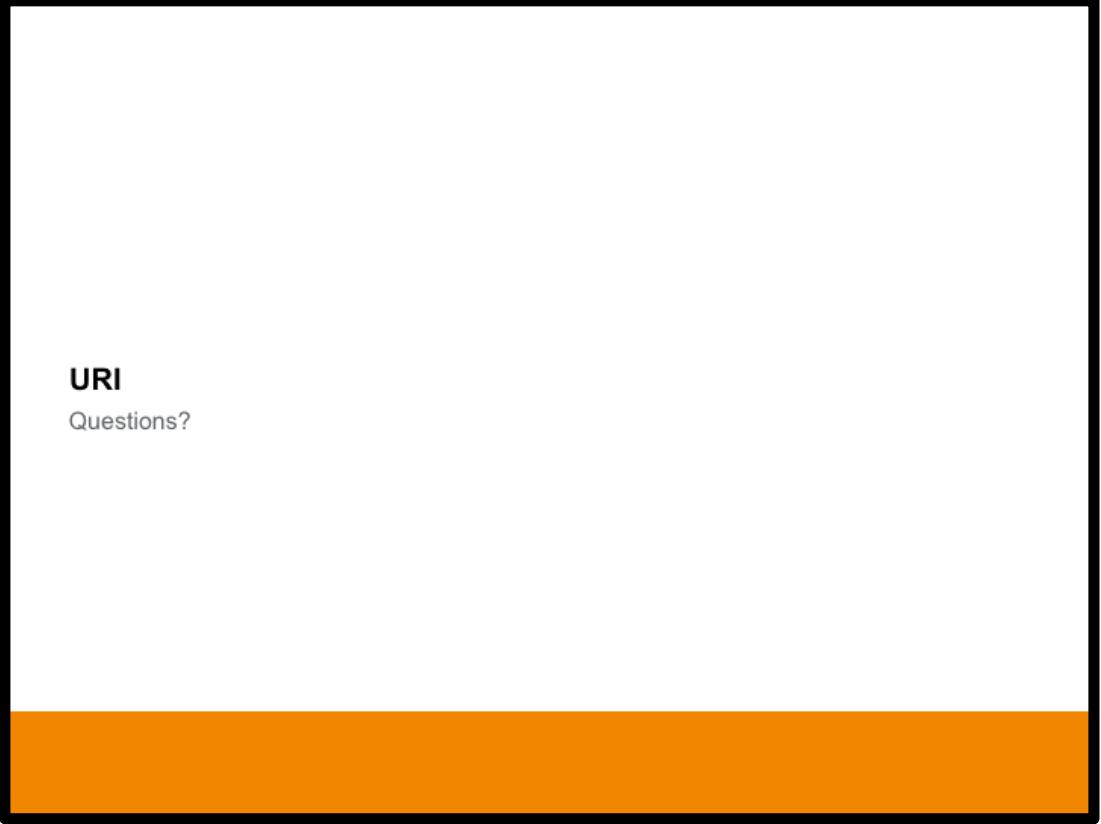
- **Examples**

- URN: urn:isbn:3827370191 (International Standard Book Number)
- URL: http://av.tu-berlin.de/team/#willner
- URL: mailto:alexander.willner@tu-berlin.de

- Core concept is the unique identification of concepts in a largely distributed manner

IRI

- **Name:** Internationalized Resource Identifier (RFC 3987)
- **Description:** String of characters used to identify a resource using Unicode.
- **Example** (percent-encoding)
 - <https://en.wiktionary.org/wiki/Πόδος> →
<https://en.wiktionary.org/wiki/%E1%BF%AC%CF%8C%CE%B4%CE%BF%CF%82>
- **Examples** (IDN - Internationalized Domain Name, punycode translation)
 - <http://例子.卷筒纸> → <http://xn--fsqu00a.xn--3lr804guic/>
 - <http://www.paypal.com> → <http://www.xn--80aa0cbo0j.com>
(not www.paypal.com)
 - <http://example.com/a-top-level-domain.com/>
(not <http://example.com/a-top-level-domain.com/>)



URI

Questions?

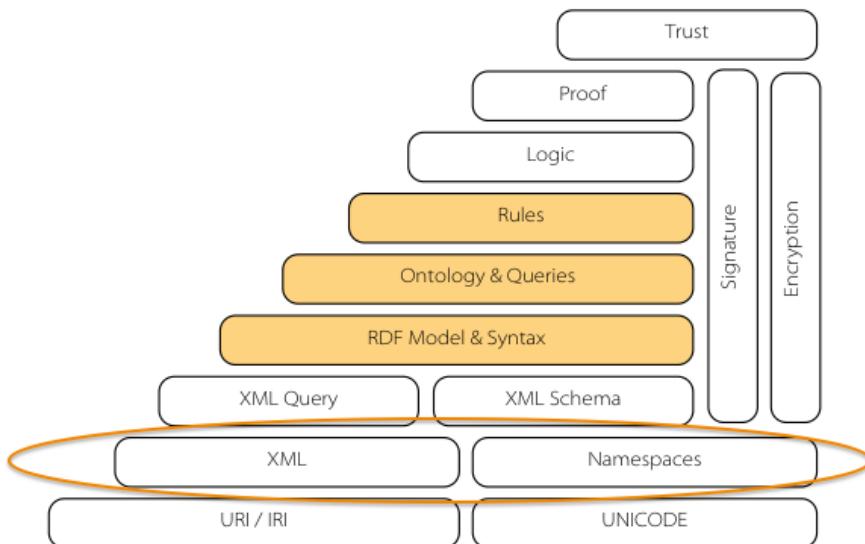


XML AND NAMESPACES

Skipped

- As the serialization doesn't matter

SEMANTIC WEB LAYER CAKE



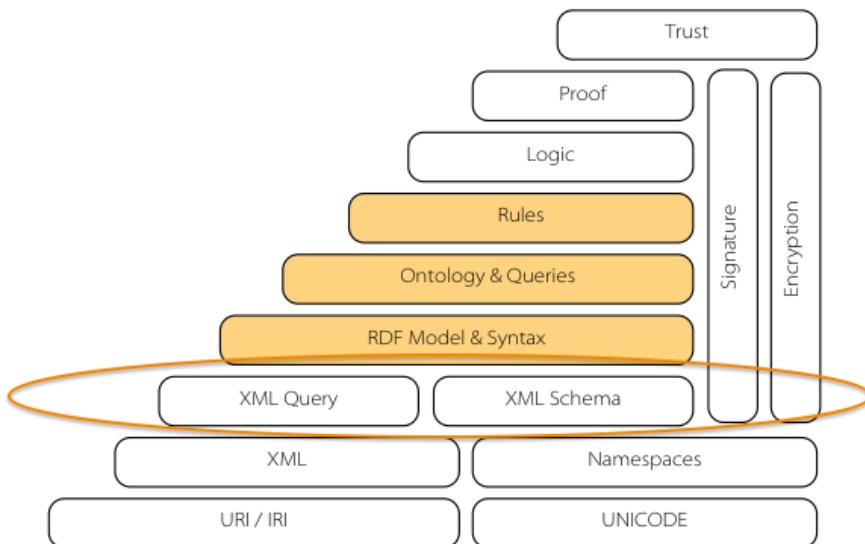
XML AND NAMESPACES

Skipped

XML QUERY AND SCHEMA

Almost skipped

SEMANTIC WEB LAYER CAKE



JSON SCHEMA

- **JSON Schema:** Defines the syntax of a JSON document (it's a tree structured data model)
- **Example JSON:**
 - { "name": "George Washington", "birthday": "February 22, 1732"}
 - { "first_name": "George", "last_name": "Washington", "birthday": "1732-02-22"}
- **Example JSON Schema:**
 - { "type": "object", "properties": { "first_name": { "type": "string" }, "last_name": { "type": "string" }, "birthday": { "type": "string", "format": "date-time" } }}
- **Basic types:** string, integer, number, object, array, boolean, null

- As seen in the WoT TD example
- To be used for simple verification processes

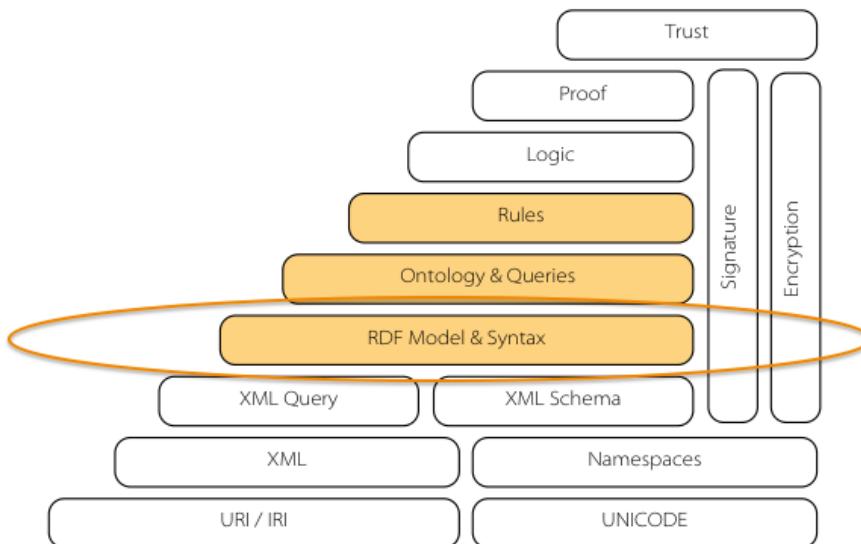
XML QUERY AND SCHEMA

Questions?

RDF

10 minutes

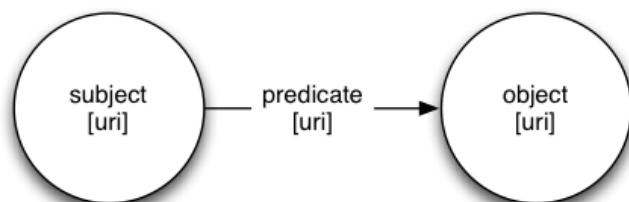
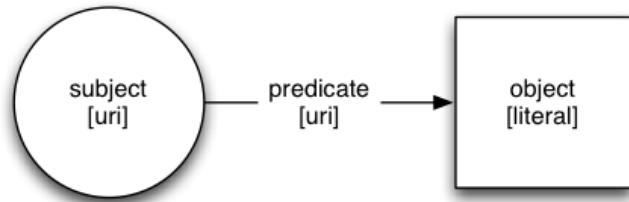
SEMANTIC WEB LAYER CAKE



RDF

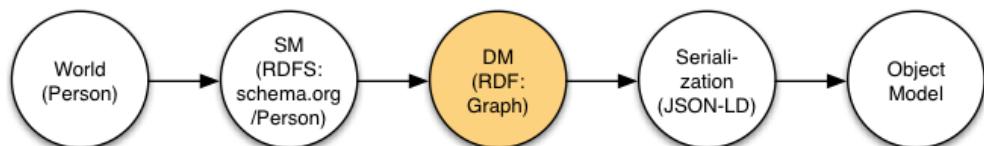
- **Name:** Resource Description Framework
- **Model:** It's just a labeled, directed multi-graph (not an XML tree)
- **Idea:** Triplets using URIs (Subject - Predicate - Object)
- **Advantages:** RDF is actually both, a graph data model and an initial vocabulary to define types and relationships (first simple form an ontology)
- **Examples:**
 - <urn:nasa:sensor:hubble> <rdf:type>
<http://nasa.gov/resource/type/telescope>
 - <mail:alexander.willner@tu-berlin.de> <foaf:name> "Alex"

A DIRECTED, LABELLED MULTI-GRAF “ON TOP” OF XML, JSON, ...



- The object can either be a literal (concrete data, no extension from here) or the object can be a URI (possible extensions from here)
- **Important:** this combination (subject-predicate-object) is also called a triplet

RDF IS A GRAPH DATA MODEL



- RDFS = RDF Schema
- <http://schema.org/Person> formally describes what a person is

RDF

- **Serialization:**
 - XML (application/rdf+xml)
 - N3 (Notation 3)
 - Turtle
 - JSON-LD
 - RDFa
 - ...
- **Disadvantage:** RDF defines mainly the way how to write information and only partly what to write.
- **Example (in turtle):**

```
:alex :talksWith :duck .
```



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- RDF is a model, not a syntax

RDF

- **Example (JSON-LD)**

```
{ "@context": "http://schema.org/",  
  "@type": "Person",  
  "name": "Alexander Willner",  
  "url": "http://av.tu-berlin.de/willner"  
}
```

- **Example (N3)**

```
[] a schema:Person ;  
  schema:name "Alexander Willner" ;  
  schema:url <http://av.tu-berlin.de/willner> .
```

- **Example (RDF/XML)**

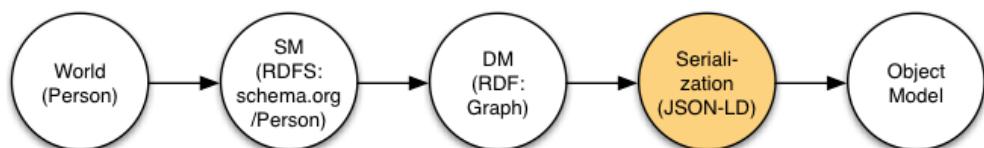
```
<rdf:RDF>  
  <rdf:Description rdf:nodeID="xxxx">  
    <rdf:type rdf:resource="http://schema.org/Person"/>  
    <schema:name>Alexander Willner</schema:name>  
    <schema:url rdf:resource="http://av.tu-berlin.de/willner"/>  
  </rdf:Description>  
</rdf:RDF>
```

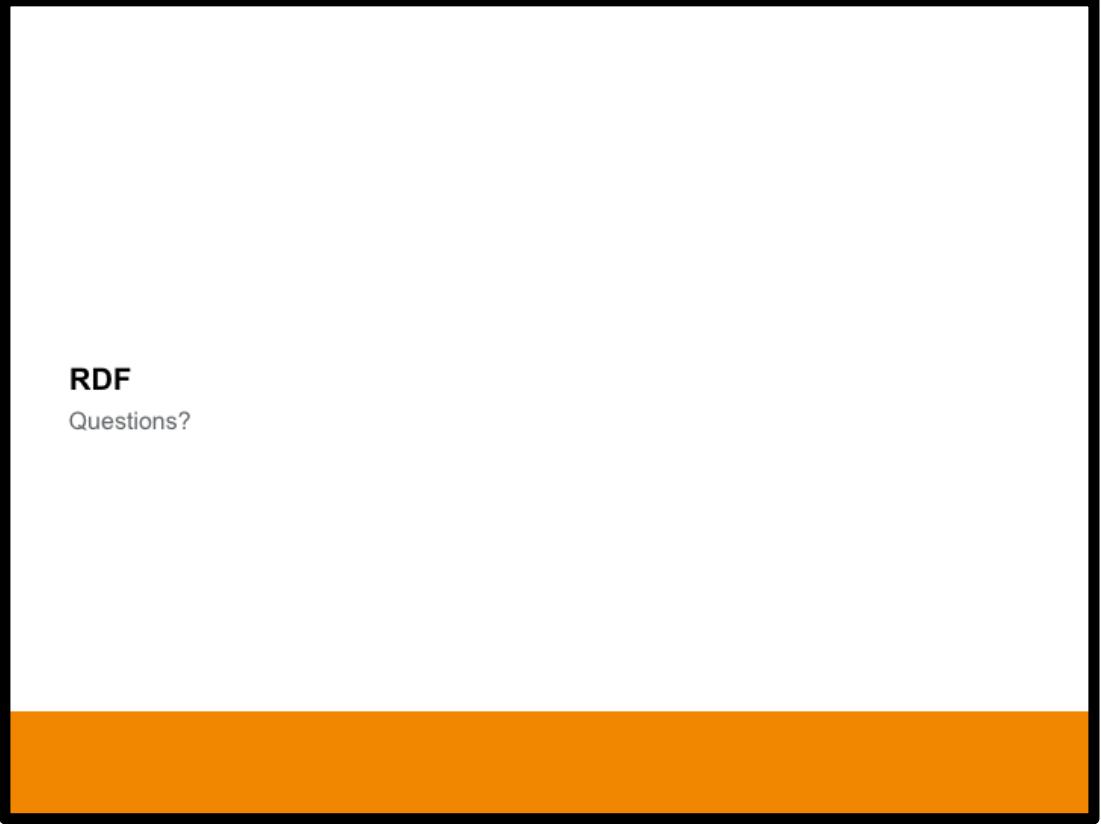


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- Three different serializations of the same information
- JSON-LD example -> see W3C WoT

JSON-LD IS ONE POSSIBLE SERIALIZATION OF AN RDF GRAPH





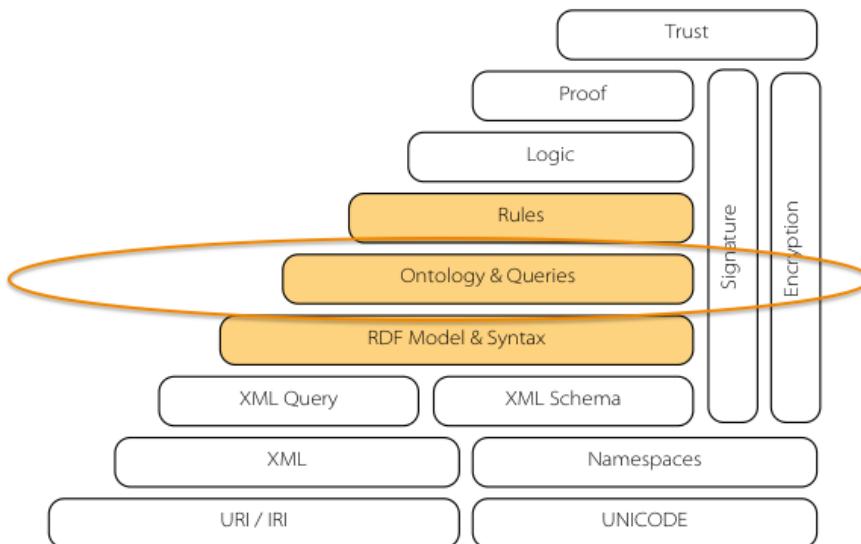
RDF

Questions?

ONTOLOGIES AND QUERIES

15 minutes

SEMANTIC WEB LAYER CAKE



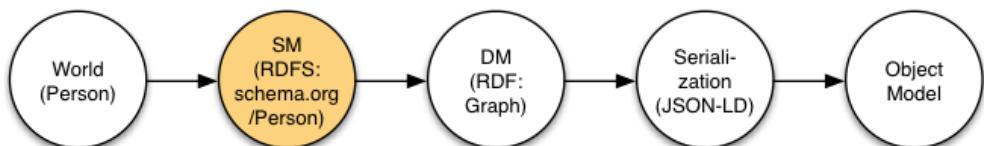
ONTOLOGIES | DEFINITION

- **In General:** The terminology and concepts are often not well used (fuzzy)
- **Vocabulary:** list of unambiguous, non-redundant explicit terms (maybe w/o meaning)
- **Taxonomy:** organized vocabulary into a (poly-)hierarchical structure
- **Thesaurus:** networked vocabulary using associative relationships
- **Meta-Model:** rules on how to construct models within a domain
- **Definition:** An ontology
 - formally represents knowledge
 - as a hierarchy of concepts
 - within a domain,
 - using a shared vocabulary
 - to denote the types, properties and interrelationships
 - of those concepts.

ONTOLOGIES | RDFS

- **Ontology:** Describes the semantic – the meaning of a resource.
- **Resource Description Framework (RDF):**
Has already limited ontology support by providing **rdf:type**.
- **Resource Description Framework Schema (RDFS)**
 - Officially the “RDF Vocabulary Description Language”
 - The term “Schema” is retained for historical reasons.
 - Defines legal uses of various classes and relationships.
 - Introduces for example rdfs:subClassOf or rdfs:range.
- **Example** – schema.org:
“[...] a collaborative [...] activity [...] to create, maintain, and promote schemas for structured data on the Internet, on web pages, in email messages, and beyond.” (schema.org)

AN ONTOLOGY IS A FORMALIZED INFORMATION MODEL



- <http://schema.org/Person> formally describes what a person is

VOCABULARY: SCHEMA.ORG

http://schema.org

The screenshot shows the schema.org Person page. At the top, there's a navigation bar with links for Home, Schemas (which is highlighted), and Documentation. Below the navigation, the title "Person" is displayed, along with its canonical URL: <http://schema.org/Person>. A breadcrumb trail shows "Thing > Person". A brief description follows: "A person (alive, dead, undead, or fictional)." Usage statistics indicate "Over 1,000,000 domains". A "Properties from Person" table lists the following properties:

Property	Expected Type	Description
additionalName	Text	An additional name for a Person, can be used for a middle name.
address	PostalAddress or Text	Physical address of the item.
affiliation	Organization	An organization that this person is affiliated with. For example, a school/university, a club, or a team.
alumniOf	EducationalOrganization or Organization	An organization that the person is an alumni of. Inverse property: alumni .
award	Text	An award won by or for this item. Supersedes awards .



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ONTOLOGIES | OWL

- **Name:** Web Ontology Language.
- **Idea:** Very expressive knowledge representation language
- **Advantages:** Way higher expressivity. Adds many property characteristics/restrictions (e.g. symmetry and transitivity), mappings (e.g. owl:sameAs or owl:equivalentClass) and complex classes.
- **Examples:**
 - <<http://av.tu-berlin.de/willner>>
<owl:sameAs>
<<http://www.av.tu-berlin.de/willner>>
 - <http://de.dbpedia.org/resource/Fraunhofer-Institut_für_Offene_Kommunikationssysteme>
<owl:sameAs>
<http://dbpedia.org/resource/Fraunhofer_Institute_for_Open_Communication_Systems>

- OWL is based on description logics, that are a family of logics that are decidable fragments of first-order logic

REPOSITORY: DBPEDIA.ORG

The screenshot shows a web browser window displaying the DBpedia.org website. The URL in the address bar is <http://de.dbpedia.org>. The main content area features a green header with the DBpedia logo and the text "Fraunhofer-Institut für Offene Kommunikationssysteme". Below the header, the URL http://de.dbpedia.org/resource/Fraunhofer-Institut_für_Offene_Kommunikationssysteme and the label "AN ENTITY OF TYPE Thing" are visible. A large green square icon with a white cloud and dots is centered on the page. Below the icon, there is a table with three rows of data:

rdfs:label	Fraunhofer-Institut für Offene Kommunikationssysteme @de
dbpedia-owl:wikiPageLength	11260
dbpprop:de:gnd	10123133

In the bottom left corner, there are logos for Fraunhofer FOKUS and TU Berlin. In the bottom right corner, there is a small orange number "88" and the text "© Fraunhofer FOKUS".

<http://dbpedia.org>

QUERIES

- **Queries:** Query & Update information in an RDF graph (similar to SQL)

- **Types:** SPARQL (SPARQL Protocol And RDF Query Language)

- **Example:**

```
PREFIX nasa: http://nasa.gov/ontology/0.1/
SELECT ?theLabel
WHERE {
  ?resource a nasa:Telescope .
  ?resource rdfs:label ?theLabel .
}
```

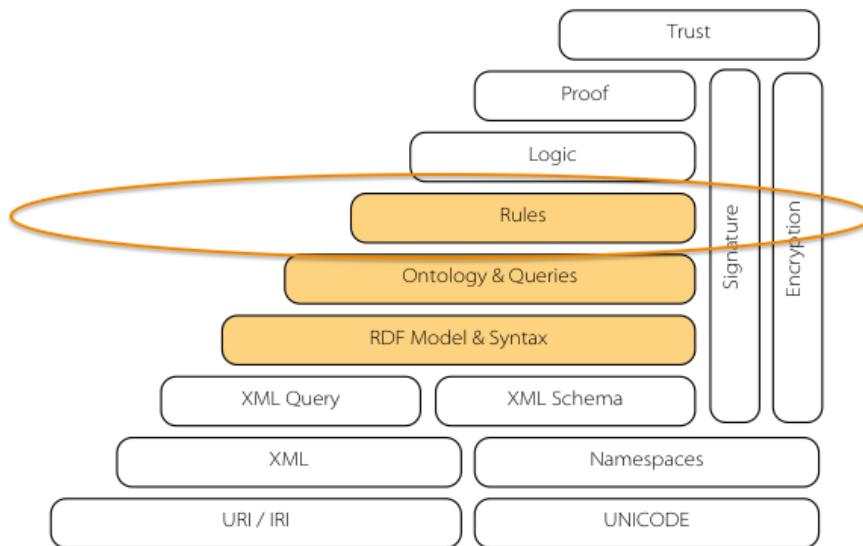
- More powerful than SQL (e.g. it support the search for transitive relations in the database)

ONTOLOGIES AND QUERIES

RULES

5 minutes

SEMANTIC WEB LAYER CAKE



Underlying concept is formal logic: propositional logic, predicate logic, description logic, rule-based systems, ...

RULES



- Based on this formal knowledge representation we can now infer implicit knowledge using reasoning
- In this example we also gain the knowledge that penguins are not very good in reasoning

RULES

- **Rules:** Simple way of encoding knowledge
- **Reasoning:** Automatically draw logical consequences based on rules
- **Example:**
hasParent(?x1,?x2) \wedge hasBrother(?x2,?x3) \Rightarrow hasUncle(?x1,?x3)
- **Example (Apache Jena):**
[RuleA: (?A :cheaper ?B), (?B :cheaper ?C) \rightarrow (?A > :cheaper ?C)]
[RuleB: (?Y :isFriendOf ?X) \rightarrow (?X :isFriendOf ?Y)]

- RuleA \rightarrow transitiveRule
- RuleB \rightarrow symmetricRule
- It's possible to infer knowledge that has not been described explicitly in the graph

RULES

- **Note:** the afore mentioned rules can already be implemented using **owl:SymmetricProperty** and **owl:TransitiveProperty** annotations instead.
- **Inference Engine:** understands the semantics and expand the number of triplets.
- **Example (in turtle):**
 - Input

```
:john rdf:type :man .  
:man rdfs:subClassOf :human .
```
 - After Reasoning

```
:john rdf:type :man .  
:man rdfs:subClassOf :human .  
:john rdf:type :human .
```
 - **Query:** SELECT ?s WHERE { ?s rdf:type :human }

- So after the reasoning process I can query for all object of type “:human” and will get back “:john”, although this was not defined explicitly beforehand

RULES

Questions?

LINKED OPEN DATA

10 minutes



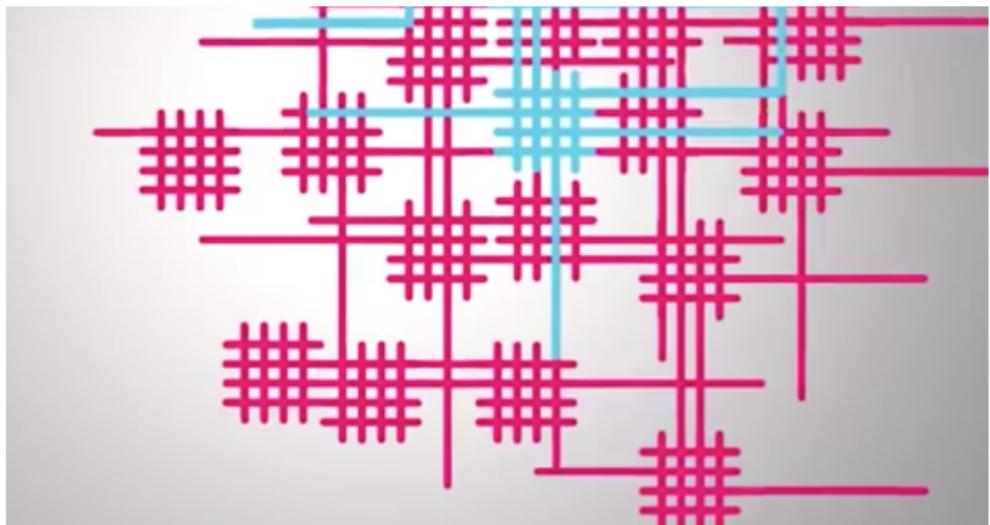
- To building formal knowledge graphs we need data



- we need (ideally open) linkable, formal data

LINKED OPEN DATA (4 MIN)

<https://youtu.be/lju4wT9uBIA>



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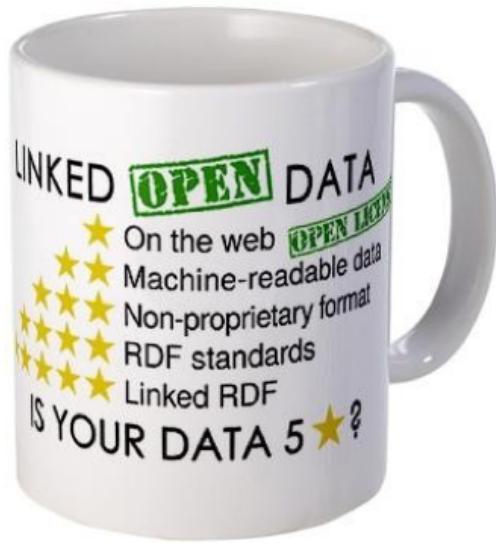
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5 STAR LINKED OPEN DATA

Tim Berners Lee



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5 STAR LINKED OPEN DATA

Ivan Herman, W3C, Tutorial on Semantic Web

★ Available on the web (whatever format), but with an open license (e.g. an image scan)

★★ Available as machine-readable structured data (e.g., excel instead of an image scan)

★★★ As before, but using a non-proprietary format (e.g., CSV instead of excel)

★★★★ All the above, plus use open standards (RDF & Co.) to identify things, so that people could point at your stuff

★★★★★ All the above, plus link your data to other people's data to provide context

LINKED RDF

Rules

1. All kinds of conceptual things have names that start with HTTP.
2. Looking up these HTTP names I will get back some data in a standard format.
3. That information got relationships to other things that is related and starts with HTTP.

Basics

1. Use URLs as names for things
2. Use HTTP URLs so that people can look up those names.
3. Provide useful information about what a name identifies (RDF, SPARQL, etc.)
4. Include links to other URLs. So that they can discover more things.

DATA HUB REPOSITORY FOR OPEN DATA

The screenshot shows the homepage of datahub.io. At the top, there's a navigation bar with 'Log in' and 'Register' buttons. Below the header, the 'datahub' logo is displayed with the tagline 'The easy way to get, use and share data'. A large, colorful data visualization consisting of several overlapping bell-shaped curves in shades of yellow, orange, and red is centered on the page. To the right of the visualization, there's a card for a dataset titled 'Census Division Boundary File'. The card includes a preview of the data, download links for 'CSV' and 'JSON', and a rating of 4 stars. Below the visualization, there are two main sections: 'Give your data a home' and 'Find data'. The 'Give your data a home' section encourages users to publish datasets and manage groups. The 'Find data' section allows users to search for datasets and receive updates. At the bottom of the page, a dark banner reads 'the free, powerful data management platform from the Open Knowledge'. The Fraunhofer FOKUS and TU Berlin logos are at the very bottom.

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DATA HUB REPOSITORY FOR OPEN DATA

OpenSpending (3)
Linking Open Data (3)
Service-centric Net... (2)
Climate Data (2)
Where Does My Money... (1)
Linked Education Cloud (1)
Institute of Inform... (1)
Show More Organizations
Tags
lod (29)
format-rdf (18)
published-by-third-... (17)
no-provenance-metadata (17)
no-license-metadata (17)
lodcloud-diagram-20... (16)
derefl-vocab (16)
no-vocab-mappings (10)
lodcloud-diagram-20... (10)
government (8)
Show More Tags
Formats

39 datasets found for "berlin"

Order by:

haushalt_berlin_2010 2011

my first attempt of uploading Berlins (Germany) spending. Any comments appreciated.

Berlin Offener Haushalt

Bund Offener Haushalt shows the complex data of Berlin's budget. It also gives access to the data in an open and re-usable format, part of package:offener-haushalt

[application/csv](#) [JSON](#)

B3Kat - Library Union Catalogues of Bavaria, Berlin and Brandenburg

Joint Union Catalogue of 200 academic libraries in the german states of Bavaria, Berlin and Brandenburg. The data contains descriptions of 28Mio. titles and 60Mio. holdings...

[application/xls](#) [HTML](#) [JSON](#) [example/turtle](#) [text/turtle](#)

Berlin_Budget_2012-2013

Budget of Berlin



Haushalt Berlin 2012-2013

Der Haushaltserwurf für das Land Berlin für die Jahre 2012 und 2013.

World Factbook (FU Berlin)

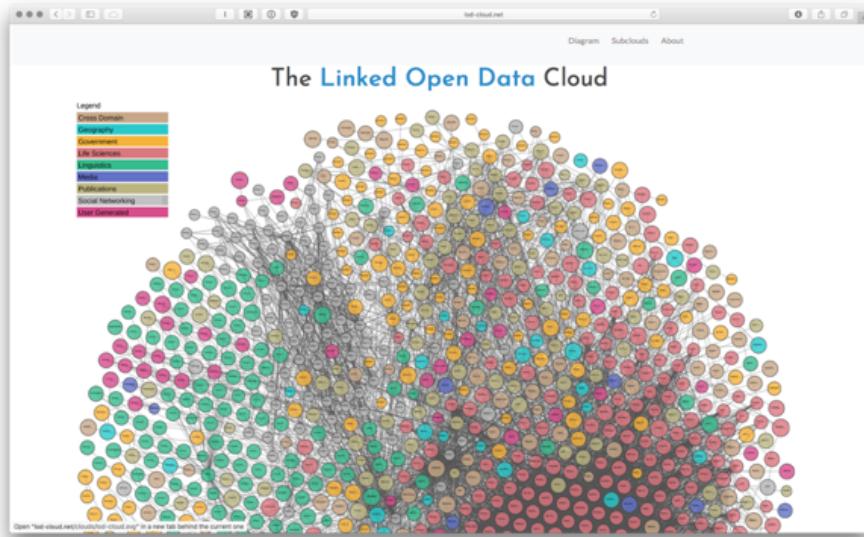
A partial RDF conversion of the CIA World Factbook, package:cia-world-factbook.

[application/xls](#) [example/rdf+json](#) [RDF](#)



LINKED OPEN DATA CLOUD DIAGRAM

<http://lod-cloud.net>



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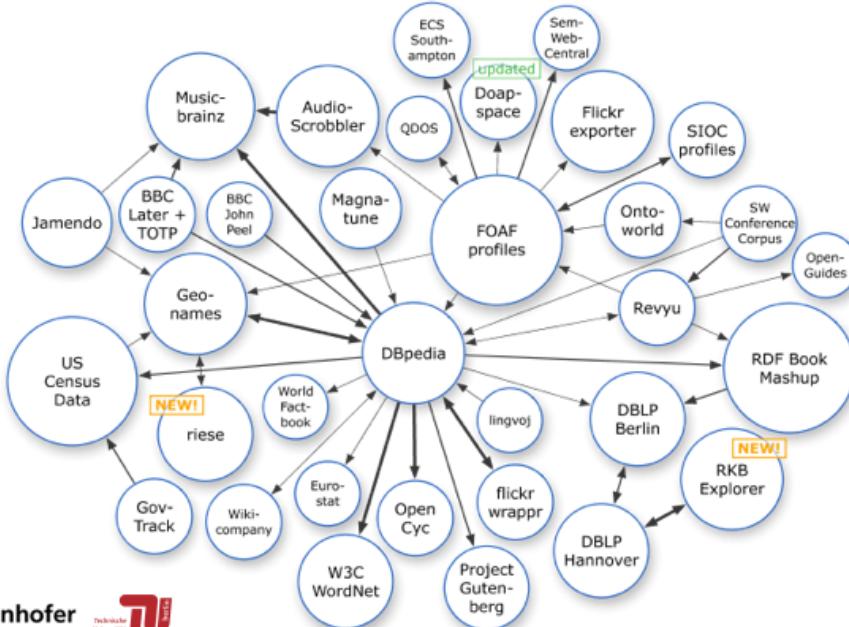
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LOD CLOUD REQUIREMENTS

[...] The LOD cloud diagram [...] shows datasets that have been published in Linked Data format [...]. It is based on metadata collected and curated by contributors to the Data Hub." (<http://lod-cloud.net>)

1. There must be *resolvable http:// (or https://) URIs*.
2. They must resolve, with or without content negotiation, to *RDF data*.
3. The dataset must contain *at least 1000 triples*.
4. The dataset must be connected via *RDF links* to a dataset that is already in the diagram.
5. Access of the *entire* dataset must be possible via *RDF crawling, dump, or SPARQL*.

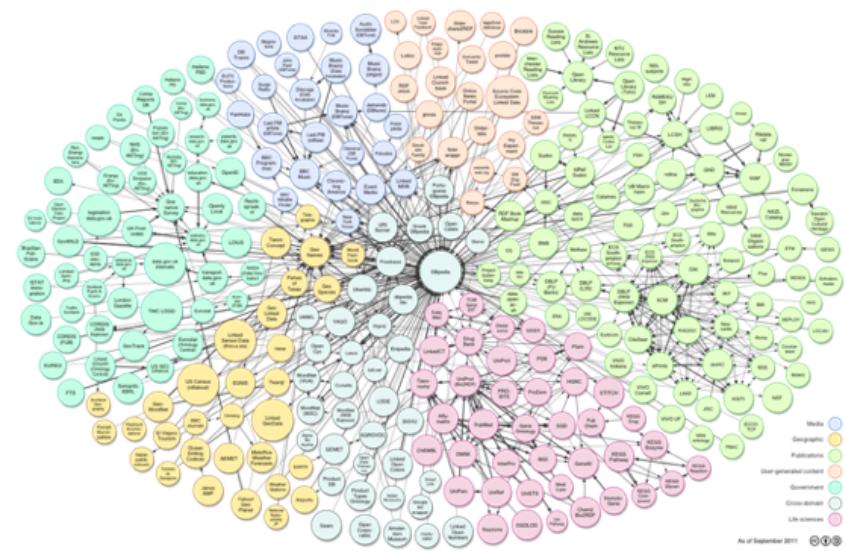
LINKED OPEN DATA (LOD) CLOUD DIAGRAM (2008, > 30 DATASETS)



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Courtesy of Richard Cyganiak and Anja Jentzsch

LINKED OPEN DATA (LOD) CLOUD DIAGRAM (2014, > 500 DATASETS)



Source: <http://lod-cloud.net>

- This version is the most used one in other presentations and publications

LINKED OPEN DATA (LOD) CLOUD DIAGRAM (2014, > 500 DATASETS)



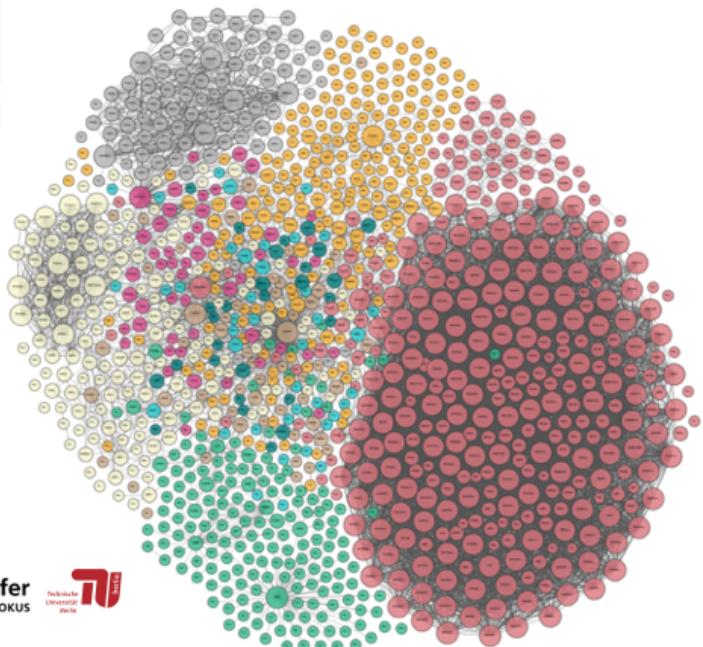
Source: <http://lod-cloud.net>

- Dbpedia as a central dataset

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SEMANTIC WEB | LINKED OPEN DATASETS (2017, > 1000 DATASETS)

Legend
Cross Domain
Geography
Government
Life Sciences
Languages
Mathematics
Publications
Social Networking
User Generated
Incoming Links
Outgoing Links



<http://lod-cloud.net>

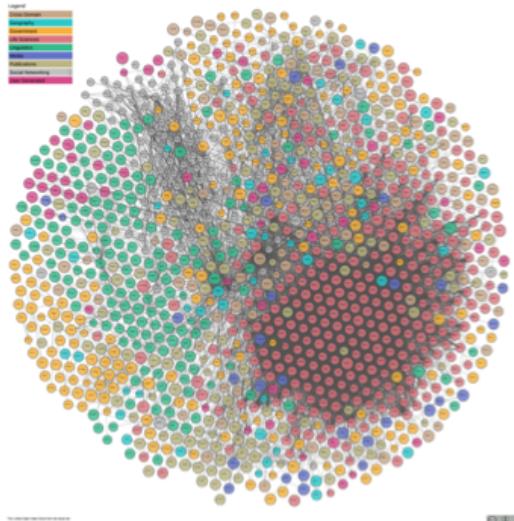
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SEMANTIC WEB | LINKED OPEN DATASETS (2018, > 1000 DATASETS)



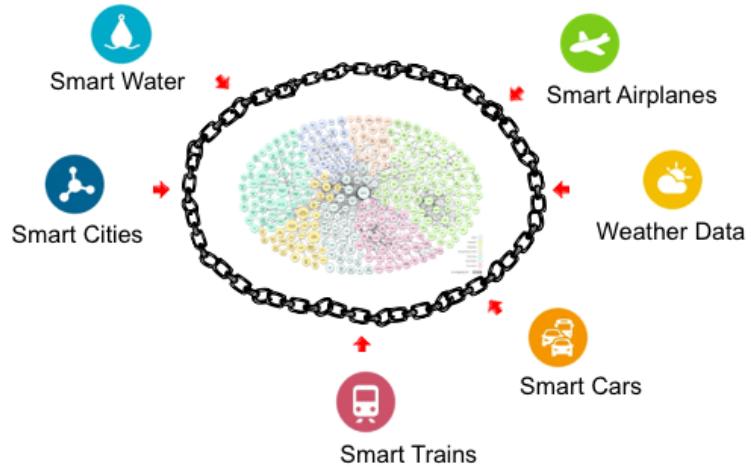
<http://lod-cloud.net>

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VISION: CONNECT ALL DATA FROM ALL (IOT) DATA SOURCES



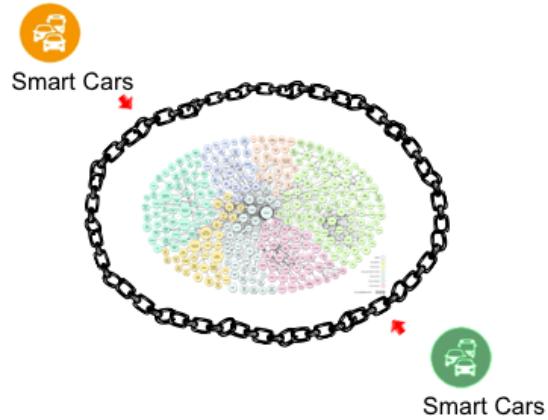
LINKED DATA

Questions?

ONTOLOGY MAPPING PROBLEM

Skipped

ISSUE: USING DIFFERENT ONTOLOGIES FOR THE SAME DOMAIN



- Assuming the same concept (e.g. car) is described with two different ontologies

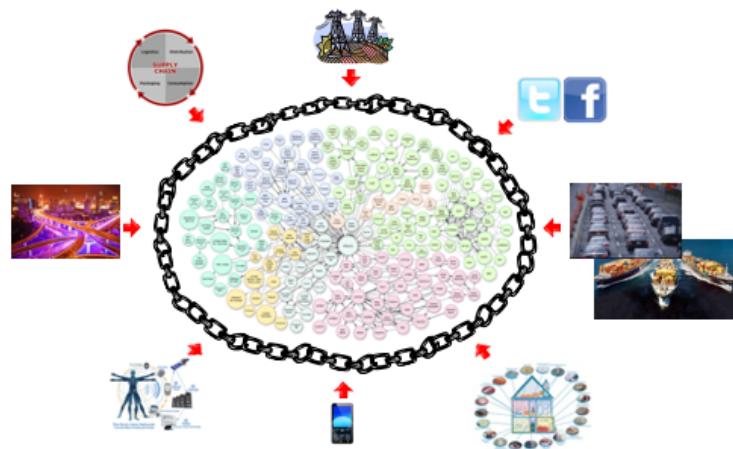
ONTOLOGY MAPPING PROBLEM

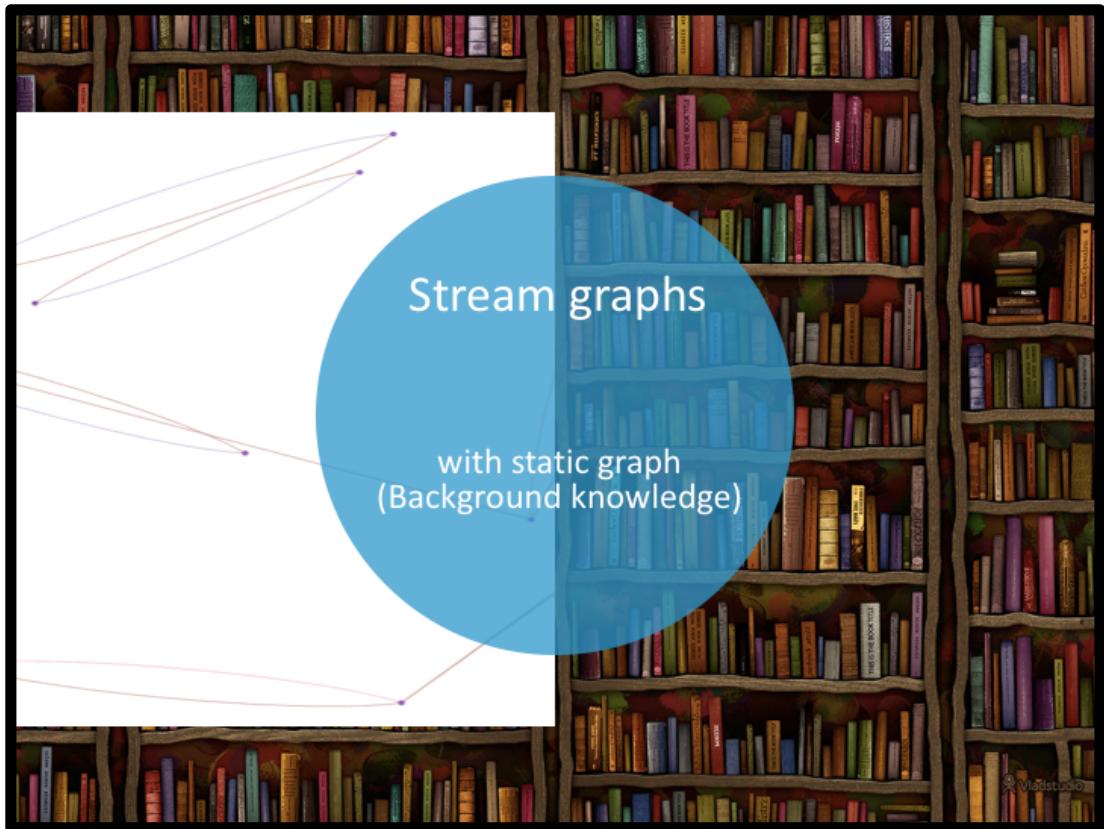
Skipped

STREAM PROCESSING EXAMPLE

3 minutes

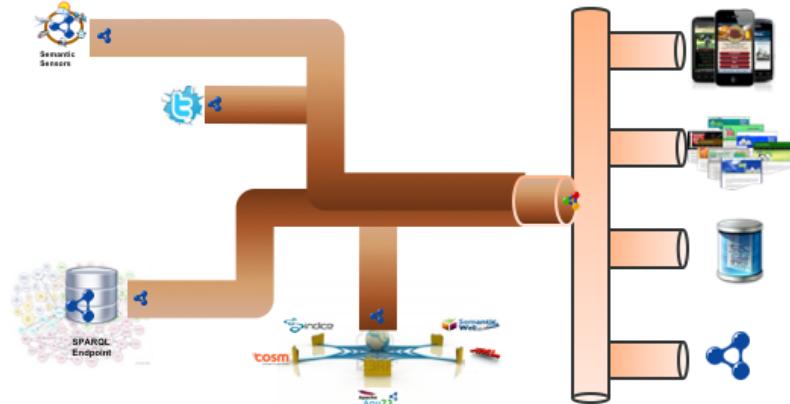
ADDING DYNAMIC DATA TO THE LOD CLOUD





- Dynamic part
- Static part

LINKED STREAM DATA



- Dynamic RDF triplets are combined with queries from static triple stores to answer application specific questions

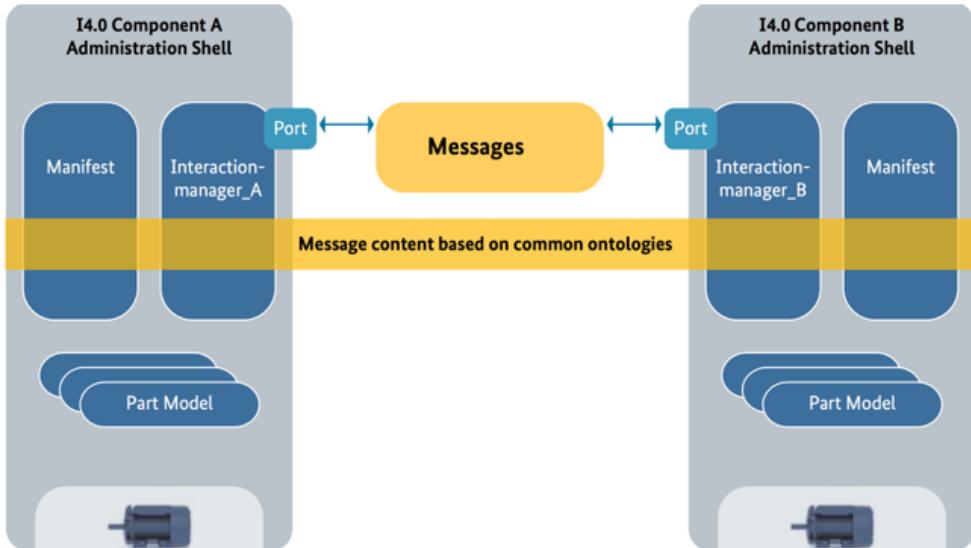
STREAM PROCESSING EXAMPLE

Questions?

OUTLOOK

2 minutes

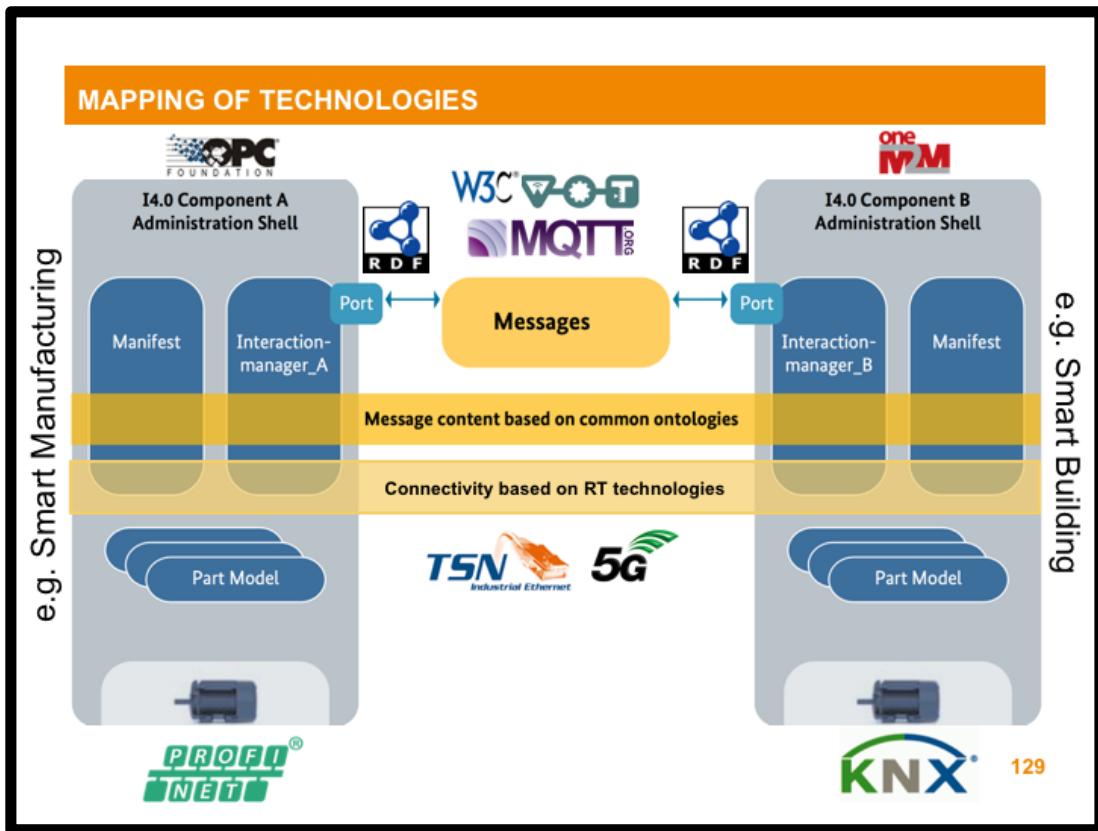
EXCHANGE OF MESSAGES BETWEEN I4.0-COMPONENTS



Based on Platform Industrie 4.0

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- Representation by the Plattform Industrie 4.0
- We already talked about I4.0 components and what an administration shell is



- How the technologies we already learned about relate to each other

WHERE IS THE CLOUD IN THIS CONTEXT?