



ference: https://en.wikipedia.org/wiki/Gephi#/media/File:Social\_Network\_Analysis\_Visualization.png Grandjean, Martin (2014). CC BY-SA 3.0

# Conceptual design of a digital twin based on semantic web technologies in the smart home context

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#### **Objectives and steps of development**

#### **Conceptual design of the Digital Twin for the Smart Home**

- Data modelling with the WoT Thing Description
- Extension and concretisation of the WoT basic model
- Scheme Choice

#### Implementation of the Digital Twin

- IKT WoT-Framework
- Integration into the Cyber Physical System

#### **Conclusion and outlook**





- Manufacturer-neutral abstraction of device and building descriptions to implement semantic interoperability
- Basis for the vision "Building as a Service (BaaS)"
- Simplification for service developers by providing uniform and machinereadable descriptions
- Reliable infrastructure (e.g. device discovery, security)
- Implementation of cross-trade use cases (e.g. intelligent energy management)
- Datasource for machine learning and AI systems

#### **Steps of development**







- Generally: digital representation of physical objects, systems or processes
- There is no specific definition
  - $\rightarrow$  Establish a common understanding and definition
- Definition of the components of the Digital Twin for a Smart Home
  - Thing description device description, properties, actions and events
  - Interface description description of access methods and interfaces
  - Location-View description of the location of devices and functions
  - Hardware-View description of the physical device specification
- Software development of the Digital Twin in the Java programming language
- Use of an RDF triplestore as database for the Digital Twin

#### **Conceptual design of the Digital Twin** Data modelling with WoT Thing Description



- Standardization by W3C with the support of well-known industry players
- The WoT Thing Description defines a formal model and a generally valid representation of Web Things
  - Description of metadata and interfaces of devices/things
  - Abstraction of physical or virtual entities
  - Description of interactions
- Representation in JSON format with JSON-LD processing
- JSON-LD represents knowledge about devices/ things in a machine readable format

## **Conceptual design of the Digital Twin**

Data modelling with WoT Thing Description





3rd International IEEE Conference AND workshop in Óbuda on Electrical and Power Engineering

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#### **Conceptual design of the Digital Twin** Data modelling with WoT Thing Description





#### **Conceptual design of the Digital Twin**

Extension and concretisation of the WoT basic model





#### **Conceptual design of the Digital Twin**

Extension and concretisation of the WoT basic model

IKT Institut für Kommunikationstechnik

• Location View – Location of devices and functions

Vocabulary term	Description	Assignment	Туре					
id	unique location id	mandatory	String					
@type	semantic type	optional	List of String					
title	title of the location	mandatory	String	WoT Thing Description				
description	location description	optional	String					
geo	geocoordintes	optional	GeoCoordinates	Sch	ema.org	•		
address	postal address	optional	PostalAddress		Vocabulary term	Description	Assignment	Туре
parts	sub parts of the location	optional	List of BuildingPart		id	unique location id	mandatory	String
					@type	semantic type	optional	List of String
					title	title of the location	mandatory	String
Currently own structure - in future possibly use of					description	location description	optional	String
other model	s (e.g. BIM, BOT,	SAREF)			parts	sub parts of the location	optional	List of Build

#### **Conceptual design of the Digital Twin** Scheme Choice

- Schemes as semantic extension for the WoT Thing Description (semantic markup)
- Two schemes are analysed first
  - 1. Mozilla WoT Capability Schema
  - 2. iotschema.org
- Choosing the iotschema due to the distribution at Thing Descriptions



Reference: https://github.com/iot-schema-collab/intro-materials/blob/master/iotschema-intro-overview.pdf



### **Conceptual design of the Digital Twin** Scheme Choice





#### **Implementation of the Digital Twin**

- Overview of the Digital Twin
   with its basic components
- In addition to the static information (e.g. Thing Description), the Digital Twin contains dynamic condition values
- Basic services use the Digital Twin to implement higher-level functionalities







- Implementation of a WoT Thing Description equivalent class model
  - Thing t = Thing.builder().context(contexts).id(thingId).title(title).
     description("A web connected color light").
     atType(Arrays.asList("Thing","iot:Actuator")).securityDefinitions(secDef).
     security(security).properties(properties).actions(actions).build();
- Object serialisation to JSON-LD format

```
{
   "@context": [...],
   "id": "https://ikt-systems.de:443/MyLamp1",
   "title": "My Lamp 1",
   "security": ["basic_sc"],
   "@type": ["Thing","iot:Actuator"],
   "description": "A web connected color light",
   "properties": {
      "level": {...
```

#### Implementation of the Digital Twin IKT WoT-Framework



- Object triple mapping into an RDF Triplestore
- Knowledge access by SPARQL (Protocol And RDF Query Language)

Subject	Predicate	Object	Context						
<u>_:node1dnuspbaax1</u>	<a href="http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;">http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/1999/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.w3.org/199/02/22-rdf-syntax-ns#type&gt;"&gt;http://www.syntax-ns#type&gt;"&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type=""&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type=""&gt;http://www.syntax-ns#type=""&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type=""&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type="""&gt;http://www.syntax-ns#type="""&gt;http://www.syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/syntawa/""""&gt;http:/</a>	< <u>https://www.w3.org/2019/wot/td#Thing&gt;</u>							
<u>_:node1dnuspbaax1</u>	<a href="https://www.w3.org/2019/wot/td#securityDefinitions">https://www.w3.org/2019/wot/td#securityDefinitions</a>	_:node1dnuspbaax2							
<u>_:node1dnuspbaax1</u>	<https: 2019="" td#title="" wot="" www.w3.org=""></https:>	<u>"My Lamp 1"</u>							
<u>_:node1dnuspbaax1</u>	<https: 2019="" td#description="" wot="" www.w3.org=""></https:>	"A web connected color light"							
<u>_:node1dnuspbaax1</u>	<https: 2019="" td#hascontexts="" wot="" www.w3.org=""></https:>	_:node1dnuspbaax3							
nodetdnusphaavt	<a href="https://www.w2.org/2010/wot/td#basContexts">https://www.w2.org/2010/wot/td#basContexts</a>	nodetdnusphaav4							
<pre>Select ?s where {</pre>									

### Implementation of the Digital Twin

Integration into the Cyber Physical System







- WoT Thing Description enables a flexible abstraction of devices/things
- This makes the Thing Description suitable as the basis for a Digital Twin in the IoT-Smart Home environment
- By adding a location and hardware view to the basic model further use cases in the smart home context are possible.
- The IoT schema extends the semantic description by device capabilities, interaction patterns and property values
- The prototype implementation of the Digital Twin in the IKT shows a practice-oriented realisation of the concept



Upcoming research work:

- Implementation of a Web Thing Directory
- Implementation of cross-trade use cases
- Automated ontology and schema mapping
- Use of semantic data for ML/AI

SENSE project, "Semantic, interoperable Smart Home" [Online]. Available: https://projekt-sense.de/









# Thanks for your attention!