From the Internet of Things to a Web of Systems

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The Evolution of Internet of Things

source: Casaleggio Associati *The Evolution of Internet of Things* 2011
WoS is the combination of the ubiquitous internet and decentralized intelligence in industrial domains

WoS is the combination of internet of things with smart networked devices and domain know how
Different types of Web of Systems
Enabler for brown field and green field approaches

<table>
<thead>
<tr>
<th>1) 'Connected Systems'</th>
<th>2) 'Smart Systems'</th>
<th>3) 'Interacting Systems'</th>
<th>4) 'App-powered Systems'</th>
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<td>IP-connected devices (sensors, actuators...), supplying &quot;big data&quot; to a central IT system.</td>
<td>Intelligence in the micro controllers of Smart Networked Devices communicating via web-services with a common semantic. Create added value through local intelligence.</td>
<td>A mesh of interacting Smart Networked Devices creating self-aware Smart Networked Systems, potentially a &quot;digital twin&quot;. Decentralized, distributed intelligence.</td>
<td>Enhance products by offering Services for e.g. extended features. Additional opportunities along the Life Cycle.</td>
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Internet of Things | Web of Systems | Services | Tools |
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<td>SW Update</td>
<td>Add on service</td>
<td>Simulation</td>
<td>Engineering</td>
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What exactly are the "things" in the Web of Systems?

"Fractal" view on Things – an example

Is every product/system a "thing"?
• A thing can be a small sensor or a large building, depending on the viewpoint and task
• Not every small sensor needs to be a "thing" (i.e. act in the WoS)
Agenda

Introduction

About us

Projects

conclusions
Research Team Web of Things

Research Silicon Valley

- Internet Technologies
  - Consumerization
  - App ecosystems
  - OpenFlow
- Web Technologies
  - Web Services
  - Web Architecture
  - Semantic Web
- Central Programs and Industry Initiatives

Emerging Technologies

- Human-robot modelling
- Wearable Sensing
- Activity Streams

Share your ideas with us
Let’s grow together

usa.siemens.com/wot
Together with academic partners, startups and corporate research groups we explore the application of web technologies to Siemens business fields.
The Internet of Things should leverage web technologies for...

1. ...embedding sensing/acting, connectivity, and processing into objects.

2. ...designing objects with the characteristics and paradigms of the web.

3. ...incorporating applications/control - also from third parties.
Agenda

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The missing link (movie)

https://www.youtube.com/watch?v=qx8YAzZwWGU
In order to make machines responsive they have to be able to communicate across device levels.
Semantically Enriched Events Brokerage

Brokering events in semantically enriched Web of Things environments

...for filtering state changes!

Example: a (light) switch switches no predefined number of (light) actuators, depending on currently controlled room space or an energy-saving policy.
Activity Streams (AS)
- Origins in social media platforms, adopted in other fields (e.g., software project management)
- We use them for more general events by defining extension properties
  - “New health data has become available!”
  - “The robot has picked up object X!”

ASbase
- Consumes events in the Activity Streams format
- Supports both request/response and publish/subscribe patterns
- Clients can query and subscribe using a filtering mechanism (based on MongoDB querying)
- Prototype online, first client interactions: [http://russet.ischool.berkeley.edu:8080](http://russet.ischool.berkeley.edu:8080)

Goal: Applicability to a broad range of Siemens businesses
- Make it flexible, sturdy, and (re)usable: Many different use cases and lots of testing!
Integrate Functionality across WoT Devices

I have **order #12** prepped for pickup!

We have a few **pending orders** for car doors!

I’ll take care of that!
Embed semantic functional service descriptions in smart things representations

What?
Describe what a service does

How?
Describe service API
Given coordinates in my workspace, I can pick up an object at that location!

**Precondition** → **Postcondition** ∧ **Service Request**

**What?**
Describe what a service does

**How?**
Describe service API

Object Coordinates → Object picked up

Send HTTP PUT to robot.net
Given coordinates in my workspace, I can pick up an object at that location!

Precondition $\rightarrow$ Postcondition $\land$ Service Request
Semantic reasoning engines can process these descriptions and automatically combine services to achieve a user goal.
This enables the goal-driven configuration of smart environments!
I want the robot to hold the car door.

Send an **HTTP GET** request to **carDoor.net** to obtain its position. Next, send this position to **robot.net** in an **HTTP PUT** request.
Responsive Machines: Teaching Collaboration

Universal Robotics UR5

Environment Representation
• Modeling as **semantic facts**
• Robot **reacts** to environmental changes

Human-Robot Collaboration
• Human kinematic model
I want the robot to hold the car door.

GET carDoor.net

200 OK [ Door Position ]

PUT carDoor.net [ Door Position ]

200 OK
The ASbase Project

Goal: Facilitate integration of heterogeneous data sources, algorithms, and consumers

Example: Personal Healthcare
- Wearables supply health/wellness data about patients
- Doctors can use this data in the diagnosis process
- Need for selecting relevant bits of the data
  - Dependent on the patient’s condition!
Goal: Facilitate integration of heterogeneous data sources, algorithms, and consumers

Example: Industrial Maintenance
- Sensors provide data streams
- Maintenance personnel can make use of this data
- Need for **selecting relevant** bits of the data
  - Dependent on the problem at hand!
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Semantically Enriched Events Brokerage

How do these “interested parties” know what to subscribe to?

You should subscribe to <position>

Semantic Subscriptions Service

I’m interested in anything that happens in my working environment!
Semantically disambiguated events

How do “interested parties” work with APIs using different models or terminology?

I’m interested in the amount of **weight** my collaborator can lift!
Semantically Enriched Events Brokerage

Events occur

Semantic Disambiguation Service

Our service republishes these as API-agnostic activities

service brokers provide access to interested subscribers

A reasoner and knowledge base support them

Semantic Subscriptions Service

Interested parties subscribe to events
Next, the world!

- Lightweight event tracking scales nicely
- Semantic integration mediates information-heavy tasks such as disambiguation or filling in the gaps
- Neither of these is domain specific
  - Tools such as browsing would apply in any domain
  - Tools such as inferencing would apply to any model
- Future demonstrations
  - Greater complexity in semantic relationships
  - Event chaining such as task planning and execution
  - Vertical integration where agents view and use the same information in different ways
Web of Things requires a stack of technologies for smart things and applications

Technology: Communication Stack for Smart Things

- Self-organization
- Data Access and Manipulation
- Seamless Data Exchange
- QoS / Realtime

- Ethernet / TSN
- Wireless
- IPv4 / IPv6

- Plug & Play
- Orchestration
- Service Description (Semantics)
- Service
- Service
- Service

Application Logic
Questions to be answered

How to manage smart things with regards to…
...describing needs, characteristics, service offerings?
...establishing collaboration among devices?
...balancing performance, reliability and security?

How to describe data and control in order to…
...enable “Plug and Automate Functionality”?
...mediate between data models of embedded devices?
...integrate vertical standards into the semantic web technology stack (e.g. RDF, OWL)?

How to leverage smart things and big data processing by…
...moving run-time procedures between cloud and edge?
...harvesting domain knowledge and context information?
...keeping control of determined and well defined process?
Thank you very much!

Questions?

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