Das Internet der Dinge

Im Rahmen der Ringvorlesung Industrie 4.0
SS 2016, Universität zu Köln

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Contents

1. What is the Internet of Things
2. Connected Devices Perspective
3. Connected Data Perspective
4. Conclusion
History

- Term introduced 1999 by Kevin Ashton at Auto-ID Labs
- Originally used to refer to a global network of RFID enabled objects
- Many related terms: M2M Comm., Ubiquitous / Pervasive Computing, Cyber Physical Systems, Wireless sensor networks, IIoT, IoE, ...
Definition: Internet of Things

“A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.” [ITU 2012]

In Other Words...

- Things connected to the Internet
- That enable ‘advanced services’
Internet Connected Things

- An (IoT) thing is a **physical object** that is augmented with embedded electronics.

- Most basic thing: **identifiable object** (e.g. based on embedded passive RFID tags)

- More advanced: **sensing / smart object** (e.g. based on embedded microcontroller, sensors / actuators and comm. interface)
http://www.tekreport.net/post/2016/02/26/smart-appliances
Livescribe Echo Smartpen (2010)
Sensoria Fitness smart socks (2015)

Athos smart training clothes (2015)

Samsung NFC suit (2015)

fitbit charge HR (2015)
UC Berkeley’s Smart Dust (2001)

- Experimental system for autonomous sensing and communication in cubic mm
- Optical comm.
- Using corner cube retro-reflector and steered laser
- No commercial solution (so far)
Networked Processors in Cars

http://www.heise.de/ct/03/14/170/
IoT System Overview

Smart Things → IoT Gateways → Online Services
Important Technology Trends

1. Computing
   - Miniaturization
   - Affordability

2. Sensing
   - Variety
   - Availability

3. (Wireless) Transmission
   - Communication
   - Energy transmission
The Connected Life by 2020

2011
9 Billion
Total Connected Devices

2011
6 Billion
Mobile Connected Devices

2020
24 Billion
Total Connected Devices

2020
12 Billion
Mobile Connected Devices

Revenue Opportunity for Mobile Network Operators in 2020

$1.2 Trillion
7x increase on 2011 expected revenues

Revenue opportunity for connected devices in vertical sectors

- Health: $69 Billion
- Automotive: $202 Billion
- Consumer electronics: $445 Billion
- Utilities: $36 Billion

North America: $241 Billion
Europe: $305 Billion
Middle East: $17 Billion
Latin America: $92 Billion
Asia Pacific: $447 Billion
Expected Business Impact of the IoT

Everybody agrees that the IoT will be huge...

- McKinsey Global Institute: $2.7-$6.2 trillion annually by 2025
- General Electric: $32.3 trillion (46% of today’s global economy today) total worth
- Cisco: $14.4 trillion net profit over next decade

IoT Market Opportunities

1. Data and process integration across full value chain and product lifecycle

2. New business models and services based on (seemingly) unrelated data
Hype Cycle for Emerging Technologies, 2015

http://www.gartner.com/newsroom/id/3114217
Two Views on IoT

Connected Things vs Connected Data
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Connected Devices

- Everything becomes a smart object / thing
- Things networked using Internet technologies (e.g. IP)

- Things use Internet services to cooperate, i.e. the majority of users of services are devices and services instead of humans
IoT: Connected Devices

- 2008: more devices than users in the Internet
- 2020: 50 billion devices

[source: Cisco]
IoT: Connected Devices

Topics include e.g.

- Low power (machine-to-machine) networking
- Ad hoc (system) auto configuration and self-organisation
- Scalable Internet Infrastructure (bandwidth, number of devices, networks)
# A Typical IoT Protocol Stack

## TCP/IP Internet Stack:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Protocol Stack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>TCP, UDP, ICMP</td>
</tr>
<tr>
<td>Internet</td>
<td>IPv4, IPv6</td>
</tr>
<tr>
<td>Link</td>
<td>Ethernet, WLAN</td>
</tr>
<tr>
<td>Application</td>
<td>HTTP, RTP</td>
</tr>
</tbody>
</table>

- Hundreds / thousands of bytes

## IoT Stack:

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<tr>
<td>Transport</td>
<td>UDP, (TCP), ICMP</td>
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<tr>
<td>Internet</td>
<td>IPv6 with 6LoWPAN</td>
</tr>
<tr>
<td>Link</td>
<td>IEEE 802.15.4</td>
</tr>
<tr>
<td>Application</td>
<td>CoAP, MQTT, XMPP</td>
</tr>
</tbody>
</table>

- Tens of bytes
Internet = IoT?

Established Internet protocols have been very successful

Why do we need new / modified ones?
A Typical Internet Device

- High performance multicore 64bit CPUs
- Gigabytes of RAM
- Terabytes of HDD
- Multithreading OS with standard TCP/IP stack
A Typical IoT Device

- Low power 8bit microcontroller
- Kilobytes of RAM & ROM
- No / restricted OS support

Adafruit FLORA (Arduino compatible) smart textile board
Challenges

- Data item sizes
- Inefficient content encoding
- Huge overhead, difficult parsing
- Not optimised for energy saving
- (Relatively) large buffers needed
- Dedicated end-point addressing
- Pull vs. push
**A Typical IoT Protocol Stack**

<table>
<thead>
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<th>IoT Stack:</th>
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<tr>
<td>CoAP / MQTT / XMPP</td>
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<td>IEEE 802.15.4</td>
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</table>

- **CoAP**: (binary) redesign of HTTP with push ability
- **MQTT**: (loosely coupled) message queues
- TCP typically too much overhead
- **6LoWPAN**: adaptation layer for IPv6
- **802.15.4**: low-power, low-cost, low speed, low range WLAN alternative
IEEE 802.15.4

- Low range: 10 m
- Low speed: up to 250 kbit/s
- Low cost & power: ~10 times less than WLAN

- Optimised for (infrequent) sending of small (sensor) messages
802.15.4 Network Topologies

**Star network**
Comm. only with PAN coord.

- PAN coordinator
- Reduced function device
- Full function device

**Peer-to-peer network**
Comm. with everyone in range

- Communication flow

802.15.4 Channel Frequencies

Since April 2009: 314–316 MHz, 430–434 MHz, 779–787 MHz bands in China (802.15.4c); 950–956 MHz band in Japan (802.15.4d); since August 2007 (IEEE 802.15.4a): ultra-wideband (UWB) PHY in 3 ranges: below 1 GHz, between 3 & 5 GHz, between 6 & 10 GHz.

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Connected Data

- Things (continuously) create data about their physical surroundings
- Data is made available on the Internet, i.e. the majority of data is created automatically by smart things instead of humans
- Aka: big data
IoT: Connected Data

Topics include e.g.

- Interoperable data models (e.g. RDF)
- Data management and querying (e.g. CQELS)
- Data analytics (big data)
Connected Data: Today

- New content: 300h of video per minute
- 432,000h of video per day
- 236 TByte per day
- 164 GByte per minute

YouTube
Problem: Data Size

43.9 Million PKW (Germany, 1.1. 2014)

3-4 GByte / min per PKW

154 PByte / min

(source: Kraftfahrt-Bundesamt)
Problem: Data Heterogeneity

http://www.flickr.com/photos/69730904@N03/8813574238/

common data models
(A) Solution: Linked Data
The Linked Open Data Cloud

Over 200 open data sets with more than 25 billion facts, interlinked by 400 million typed links, doubling every 10 month!

see: http://lod-cloud.net/

BestBuy
Overstock.com
Facebook
US government
UK government

BBC
New York Times

LinkedGeoData
Two Key Ingredients

1. RDF – Resource Description Framework
   Graph based Data – nodes and arcs
   - Identifies objects (URIs)
   - Interlink information (relationships)

2. Vocabularies (Ontologies)
   - provide shared understanding of a domain
   - organise knowledge in machine-comprehensible way
   - give an exploitable meaning to the data
Why Graphs and Ontologies?

Wikipedia.org

- Cities: Dublin
- 84421 km²
- Geo: IslandOfIreland
- Geo: hasCapital
- Geo: area
- Geo: hasLargestCity

EU: RepublicOfIreland

Gov.ie

- Gov: hasTaoiseach
- Person: Enda Kenny
- Gov: hasDepartment
- IE: DepartmentOfFinance

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Goal: Integrating IoT in LOD Cloud

http://www.flickr.com/photos/69730904@N03/8813574238/

Linked Data
Advantages of IoT Linked Data

- IoT becomes part of the WWW
- Open, independent standards and platforms
- Global, established developer base
- Extensible, open world

... but there is a problem
Linked Data and IoT

http://www.flickr.com/photos/69730904@N03/8813574238/
# Challenges

<table>
<thead>
<tr>
<th></th>
<th>‘classical LD’</th>
<th>IoT LD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamism</td>
<td>static, offline analysis</td>
<td>Highly dynamic, online analysis</td>
</tr>
<tr>
<td>System resources</td>
<td>HPC, multicore CPUs, GBs RAM, TBs/PBs storage, fixed electrical power grid connection</td>
<td>Embedded processors, kBs RAM, storage?, battery operated</td>
</tr>
<tr>
<td>Security and access control</td>
<td>manual, coarse grained access control</td>
<td>automated, fine grained access control</td>
</tr>
</tbody>
</table>
From Self-describing Data & Devices

- **Self-describing sensors (RDF)**
- **Extended W3C SSN Ontology**

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To Self-describing Systems

Semi-automatic annotation with additional metadata

- Self-sufficient sensor nodes
- Central environment model

Export as standard SPARQL end point
To Semantic Event Streams

IoT Systems → LOD Cloud → Semantic Event Processing → Client
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What is the Internet of Things?

Imagine a World Were...

- Every physical object is enhanced with a computer
- The Internet integrates all these computers – wherever they are
- Computers detect their physical surroundings – including their users
- ...
What is the Internet of Things?

...  
- All this data is integrated, analysed and made available globally – in (near) real-time
- Results are send back to control / adapt the physical world

The world becomes observable and programmable in real-time
What will Become Possible?

- Never forgetting anything you see or hear – forever?
- Knowing what someone feels?
- Knowing who has touched an object you have just acquired?
- Changing your environment by waving a hand or thinking?
- Detecting and influencing thinking?
- Predicting the future?
- ...
Questions

Linked Data

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