From a World-Wide Web of Pages to a World-Wide Web of Things

Interoperability for Connected Devices

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The Internet of Things

Still very immature, but with massive potential

Lack of interoperability at the application level
  ● Data silos are holding back the potential

Open or closed system?
  ● Closed systems incentive: control
  ● Open systems prompt: reduced costs and increased market size
  ● Re-prise of “the Web”
Isolated IoT products create data silos

- Vendors use fixed cloud address for devices to upload data to
- Incompatible protocols, formats and data models

Silos hinder creation of services that combine different data

How to enable easy integration of data sources?

The Web is the framework that offers a unifying approach:

- For simplifying application development across many platforms
- For metadata as a basis for discovery, interoperability, and open markets of services
Many Potential IoT Application Areas

- Smart Homes
- Wearables
- Healthcare
- Power & Environment
- Smart Cities
- Manufacturing
Manufacturing: Past – Present – Future

Past: Disruptive changes
- From cottage industry to mass production
- Computerisation
  - Enterprise resource planning and order processing
- Globalization
  - Low cost transport of goods and materials
  - Offshoring for cheaper labour costs

Future: smart manufacturing
- Seismic shifts as companies embrace the Internet of Things
  - Michael Porter: “How Smart Connected Products are Transforming Competition”
What is driving change?

- Shorter delivery times
- Volatile markets
- 24/7 service
- Shorter product life cycles
- More individualized customer wishes

Source: Bosch
Smart Manufacturing

Shift from mass production to tailored production
- Custom finished products to match unique needs
- Reduced time from design to delivery
- Flexible production systems to meet changing needs
- Open markets of services

Smarter systems
- Importance of models and metadata
- Production planning
- Monitoring and optimisation
- Cost reduction
- Easier integration

Tesla’s new production line
The Web and W3C
Mission: lead the Web to its full potential

- The Web is the world's largest vendor-neutral distributed application platform

Founded by Sir Tim Berners-Lee, inventor of the Web

- 400+ Members
- Member-funded international organisation

Develops standards for Web and semantic technologies

- HTML, CSS, scripting APIs, XML, SVG, VoiceXML, Semantic Web and Linked Data etc.
- Developer oriented, enabling cooperation between organisations with very different backgrounds
- W3C patent policy for royalty free standards
- W3C staff of engineers actively participating in standardisation
- Increasingly involved in verticals: Mobile, TV, Automotive, Digital publishing
Why is Semantics Important?

What is the relevance to digital automation?

- Shared vocabularies for entities and their relationships
- Describing the software objects that stand for physical or abstract “things”
- When searching for services with a given semantics
- To facilitate the design of service compositions
- Optimal planning for flexible production of bespoke products

W3C Semantic Web Standards Stack

[Image of W3C Semantic Web Standards Stack]
A Growing Cloud of Linked Data, but
... potential interop problems with IoT
Web of Things
Technology stack
Web of Things

The Web is fuelling a transition from costly monolithic software to open markets of apps
Applications act on software objects that stand for things

- Local “things”
- Remote “things”

Rich descriptions for every “thing”

- Data models, semantics, metadata
- Ontologies that describe “things”

Things don’t need to be connected

- Abstract entities and unconnected physical objects
## Communications Stack – Clean separation of concerns

<table>
<thead>
<tr>
<th>Application Developer (WoT focus)</th>
<th>Application</th>
<th>Things</th>
<th>Transfer</th>
<th>Transport</th>
<th>Network</th>
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</table>
| Application                       | Scripts that define thing behaviour in terms of their properties, actions and events, using APIs for control of sensor and actuator hardware | Software objects that hold their state  
Abstract thing to thing messages  
Semantics and Metadata, Data models and Data | Bindings of abstract messages to mechanisms provided by each protocol, including choice of communication pattern, e.g. pull, push, pub-sub, peer to peer, etc. | REST based protocols, e.g. HTTP, CoAP  
Pub-Sub protocols, e.g. MQTT, XMPP  
Others, including non IP transports, e.g. Bluetooth | Underlying communication technology with support for exchange of simple messages (packets)  
Many technologies designed for different requirements |
| Platform Developer (IoT focus)    |             |        |          |          |         |
Different platforms using different technology standards, different protocols and different data formats

Web of Things as abstraction layer over these platforms

Application logic decoupled from the underlying platforms

Servers rely on rich metadata to communicate
Industry specific groups are in best position to define vocabularies for each vertical.

W3C core metadata vocabularies used across application domains
One Level Deeper on Horizontal Metadata
Core metadata applicable across application domains

- Thing descriptions
  - Links to thing semantics
  - Data models and relationships between things
  - Dependencies and version management
  - Discovery and provisioning
  - Bindings to APIs and protocols

- Security related metadata
  - Security practices
  - Mutual authentication
  - Access control
  - Terms and conditions – relationship to “Liability”
  - Payments
  - Trust and Identity Verification
  - Privacy and Provenance
  - Safety, Compliance and Resilience

- Communication-related metadata
  - Protocols and ports
  - Data formats and encodings
  - Multiplexing and buffering of data
  - Efficient use of protocols
Web of Things
Value
Enabling Vertical and Horizontal Integration

- Distributed services
- Platform of platforms
- Uniform addressing
- Data and metadata

**Business Level**
- High levels of abstraction
- Integration along the supply chain

**Web of Things**
- Integration along the value chain
- Low levels of abstraction

**Field Level**

*value chain* – the process or activities by which a company adds value to an article, including design, production, marketing, and the provision of after sales service

Things = Industrie 4.0 Components

Industrie 4.0 Assets
Enabled by semantics, metadata and data models

- Discovery of services
  The benefits of a lingua franca, and its limitations
- Composition of services
  From different vendors for an open market of services
- Monetization of services
  Support for a wide variety of models
- Security, privacy, safety, compliance, trust, resilience
- Scaling on multiple dimensions
  From microcontrollers to massive cloud-based server farms
Large companies want their suppliers to integrate with their software systems for greater efficiencies

- Integration along the supply and value chains

SMEs find this enabling – the cost of developing the corresponding software is reduced

- Replacing costly monolithic software with cheaper apps & services
Enables an Open Market of Things

Apps for connecting suppliers and consumers
- Analogous to marketplaces of apps for smart phones
- SME’s can script apps to suit their specific needs

Marketplace features
- Discovery, reviews, recommendations, ranking/reputation
- Dynamic composition to match given requirements
- Automated negotiation of contracts to save time and money

Lifecycle support
- Developing, testing, publishing, vetting, updates, obsolescence
Web of Things
Activity
W3C Web of Things Interest Group

Workshop in Berlin (June 2014)
- Launch of Web of Things IG in 2015
- Chaired by Jörg Heuer, Siemens
- Task forces
  - Thing descriptions
  - APIs and protocols
  - Discovery and provisioning
  - Security, privacy and resilience
  - Communications and collaboration

Strong emphasis on implementation experience
- Demos and plug-fests

Face to face meetings
- Past: Munich, Sunnyvale, Sapporo, Sophia Antipolis
- Joint meetings with IRTF Thing to Thing Research Group
- Future: Montreal, Canada (April 2016); Beijing, China (July 2016); Lisbon, Portugal (September 2016)

Plan: smart automation task force
- Other application domains to follow

Liaisons with industry alliances and SDOs to drive convergence
Liaisons and Collaborations

Reaching out to industry alliances and SDO’s to drive convergence to unleash the potential

- Plattform Industrie 4.0
  - Especially the “semantics” subgroup
- Industrial Internet Consortium
- Open Connectivity Foundation
- OPC Foundation
- IETF/IRTF
- oneM2M
- AIOTI

AIOTI
Members of the Web of Things Interest Group
The Interest Group (IG) is working on

- Use cases, requirements, technology landscape and plans for launching working groups (WG)
- IGs prepare the ground for standards but don’t develop standards
- WGs are chartered to develop standards (W3C Recommendations)

We’re collecting ideas including

- Horizontal metadata vocabularies (things, security, communications)
- Serialisations of metadata, e.g., as JSON-LD
- APIs and bindings to specific protocols and platforms

Web of Things Working Group to be launched in 2016
The Bottom Line

The Web is essential for realizing the full potential of the IoT.

The Web provides a unifying framework for semantic interoperability.

The Web acts as a global marketplace for suppliers and consumers of services.
Work with us to build the Web of Things!

For more information on W3C see:

www.w3.org