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 incentives?

- Closed systems: control and faster time to market
  - The speed advantage evaporates once tooling for open standards is available
- Open systems: reduced costs and greatly increased market size
  - Open standards give customers greater confidence in sustainability

Bridging the Silos

Isolated IoT products create data silos

- Vendors use fixed cloud address for devices to upload their 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

With thanks to Major Clanger

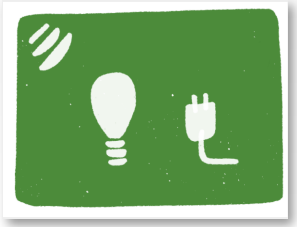
Many Potential IoT Application Areas

each evolving rich capabilities

Smart Homes

Wearables

Healthcare



Power & Environment

Smart Cities

Manufacturing

Smart Manufacturing

Shift from mass production to tailored production

- Bespoke finished products to match unique needs
- Reduced time from design to delivery
- Flexible production systems to meet changing needs
- Open markets of services (customizable apps)

Smarter systems

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

The Web and W3C

World Wide Web Consortium

Mission: lead the Web to its full potential

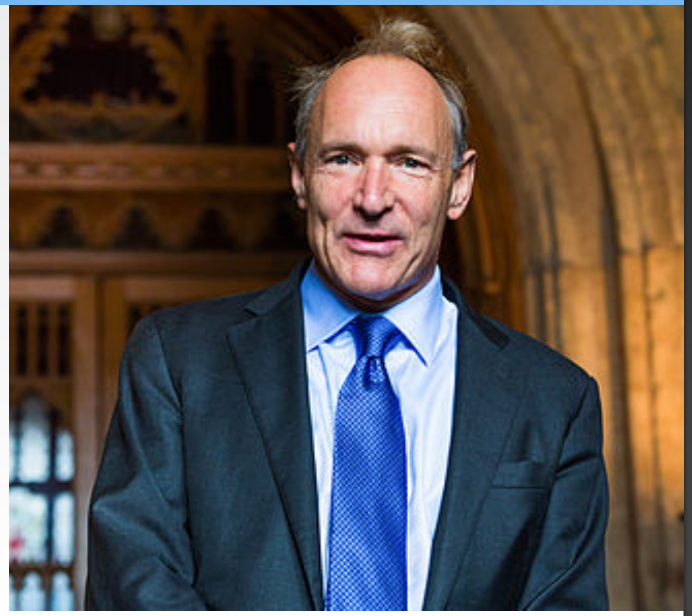
- The Web is the world's largest vendor-neutral distributed application platform

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

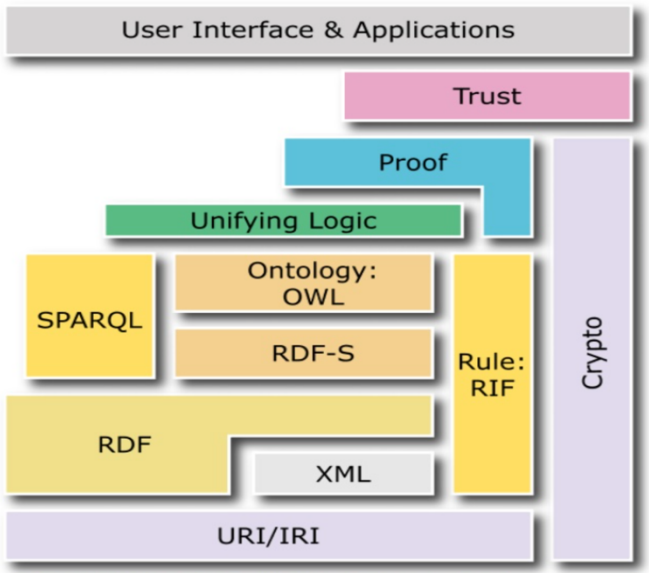


Why is Semantics Important?

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

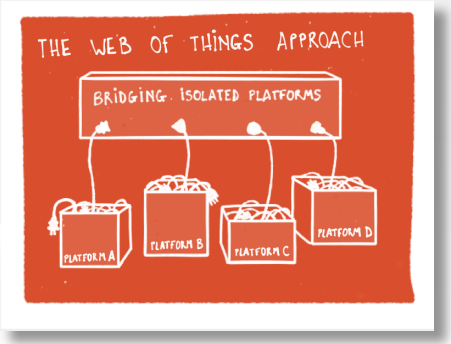
W3C Semantic Web Standards Stack

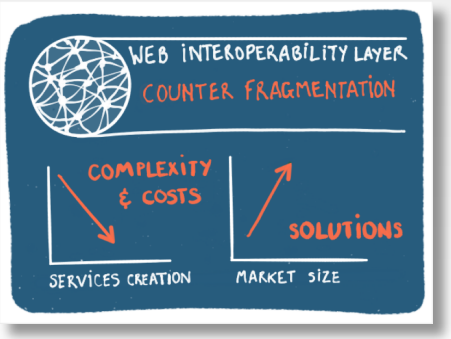


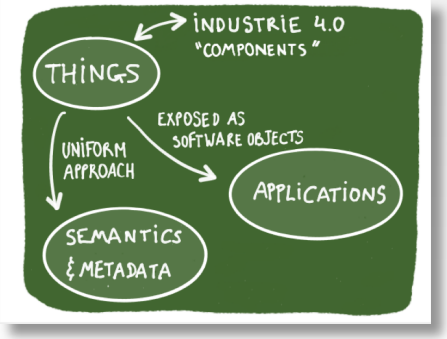
Web of Things

Technology stack

Web of Things

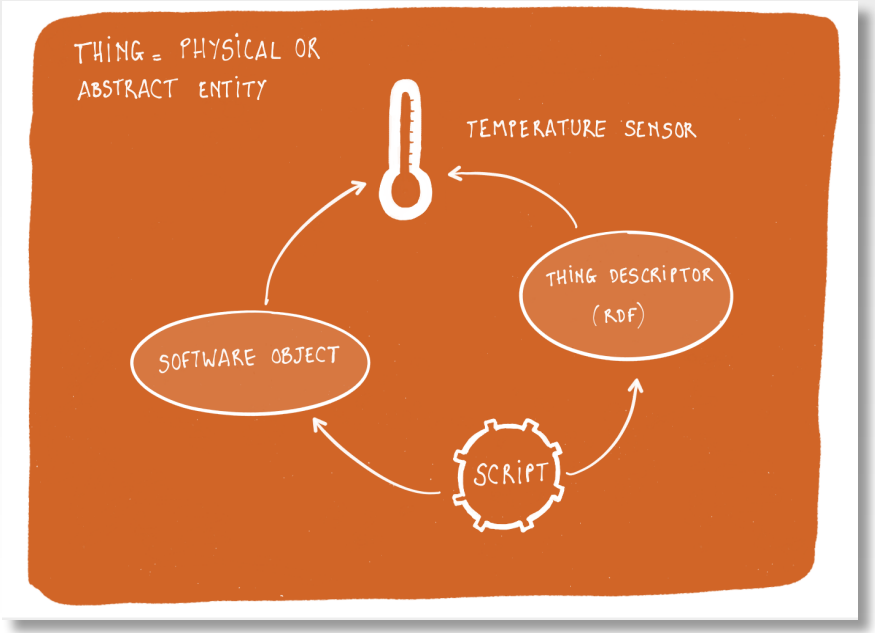






The Web is fuelling a transition from costly monolithic software to open markets of apps

Things



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

Scalability

Web of Things servers can be realised at many scales from microcontrollers to clouds

Home Hub: home/office server for access to smart home and wearables, running behind firewall

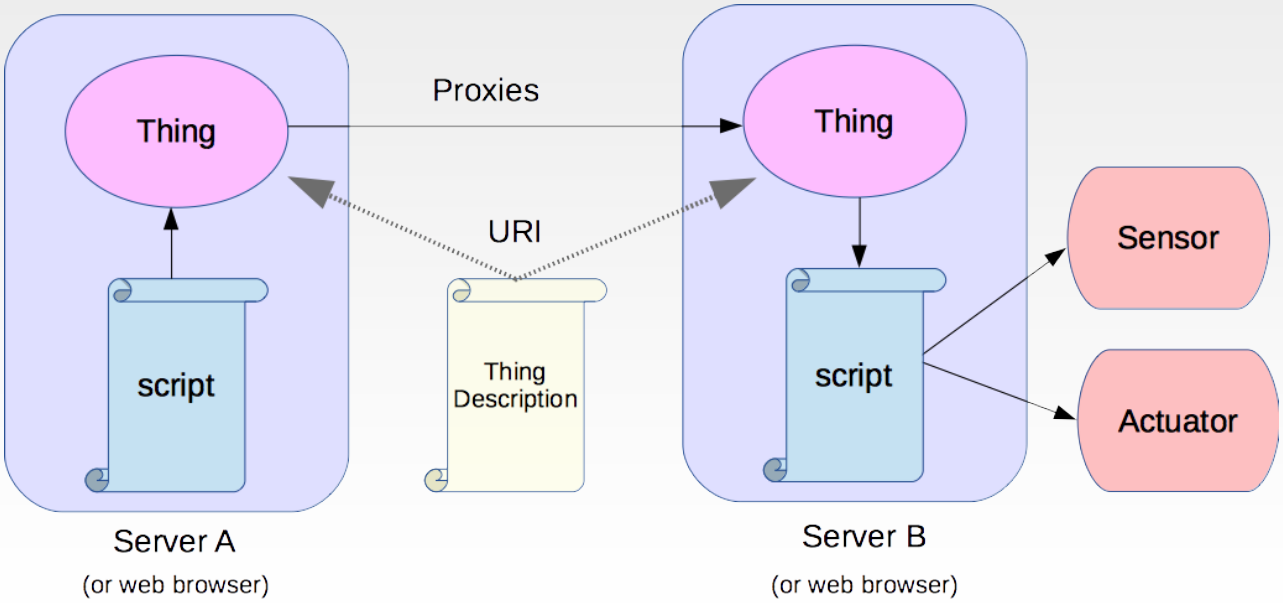
Micro-controller: resource constrained, IoT devices or gateways, CoAP, running behind firewall

Smart Phone: personal server for access to smart home and wearables

Cloud-Based: highly scalable server for many users, devices and working with big data

Distributed Web of Things

- Thing descriptions can be used to create proxies for a thing, allowing scripts to interact with a local proxy for a remote entity
- Scripts can run on servers or as part of Web pages in Web browser for human machine interface
- Thing topologies
  - Peer to Peer, Peer to Peer via Cloud, Star, Device to Cloud, Star to Cloud



Distributed Intelligence

Taking a distributed approach to designing complex systems of systems, placing processing and storage where it is most needed

The ability to upload scripts into web of things servers on different scales, and using different control languages

- Abstraction layers for sensing
  - Progressive stages of interpretation
    - Combining sensor data with other sources of information
    - Inferred events
    - Machine learning
  - Monitoring to check all is well
  - Reducing the burden on cloud based systems
- Abstraction layers for actuation
  - Progressively map high level intent to low level actuation
  - Synchronisation across clusters of devices
- Abstraction layers for control
  - Control links sensing to actuation
    - Implementing control at multiple levels of abstraction

Communications Stack – Clean separation of concerns

Application Developer (WoT focus)

Platform Developer (IoT focus)

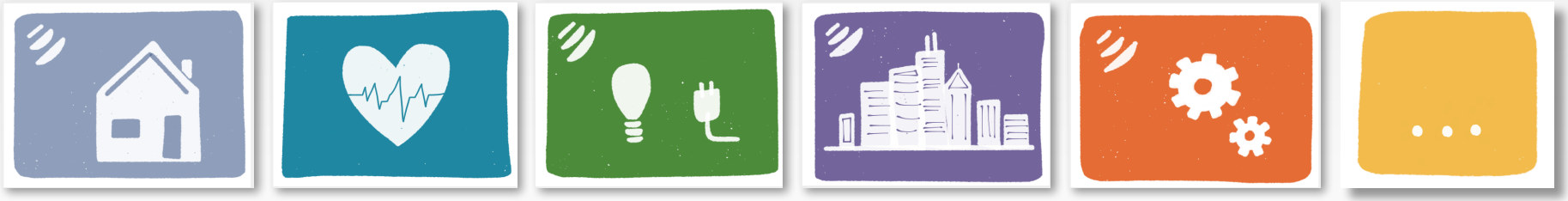
Application	Scripts that define thing behaviour in terms of their properties, actions and events, using APIs for control of sensor and actuator hardware
Things	Software objects that hold their state Abstract thing to thing messages Semantics and Metadata, Data models and Data
Transfer	Bindings of abstract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

Metadata as key to Platform of Platforms

- 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
- Encouraging re-use and the role of intermediaries
- Formal versus informal metadata

Horizontal and Vertical Metadata Vocabularies

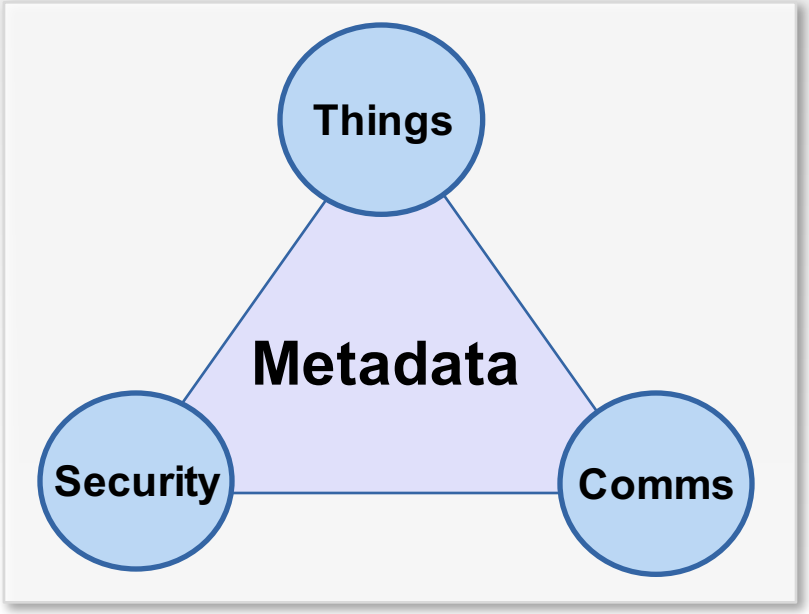
Industry specific groups are in best position to define vocabularies for each vertical



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
- Devices that sleep most of the time

Data Models

- Core types, e.g. null, boolean, number, string, array, …
- Things and streams as first class data types
- Early and late binding
- Integrity constraints for robustness
- Multiple serializations, e.g. JSON and XML
- Need to be usable on resource constrained devices

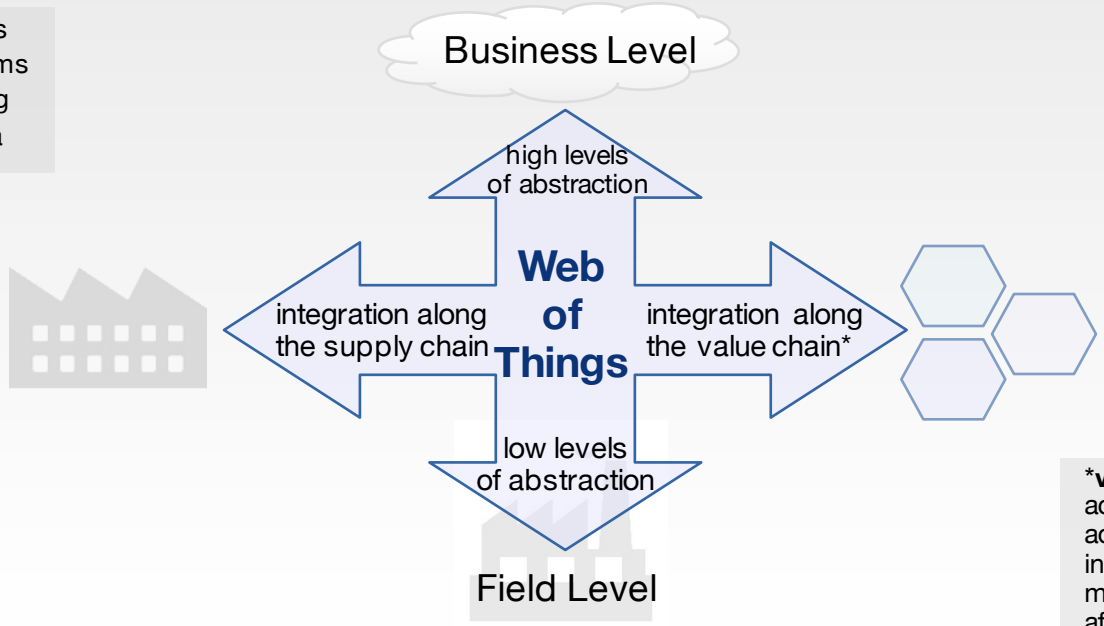
Need to support a broad range of requirements, e.g. current value, time stamped data logs, regular stream of samples, and piecewise approximations for continuously changing values for measurements or actuation

Web of Things

Value

Enabling Vertical and Horizontal Integration

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



Things = Industrie 4.0 Components

Industrie 4.0 Assets

*__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

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
  - Scaling across communities and the inevitability of change

Business Value for the Web of Things

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

- White paper on semantic interoperability as a way to build a shared understanding and roadmap

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

Members of the Web of Things Interest Group

Web of Things Working 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

Thank you!