From a world-wide web of pages to a world-wide web of things – Interoperability for Connected Devices

Contents

- IoT as a catalyst for change
- The Web and W3C
- Semantics & Metadata
- The Web of Things
- W3C standards activity for the Web of Things
- Getting involved

Manufacturing: Past, Present and Future

- Disruptive changes in the past
  - From cottage industry to mass production
    - Standardization as key to cost reduction
  - Computerisation
    - Enterprise resource planning and order processing
    - Numerically controlled mills, lathes and robots
  - Globalization
    - Low cost transport of goods and materials
    - Offshoring for cheaper labour costs
  - Cheap ubiquitous networking
    - Accelerating the pace of globalization
- Coming next – smart manufacturing
  - Seismic shifts as companies embraces the IoT

The Internet of Things

- Still very immature, but with massive potential
- Over hyped and a lack of interoperability
  - Still at the top of Gartner's Hype cycle
  - Bewildering choice of technologies
  - Data silos that are holding back the potential
- Whether to pursue an open or closed system?
  - Large companies may be tempted to pursue a closed system that they can control
  - Open systems based upon open standards will win out due to reduced costs and increased market size
  - Analogy with local toll roads vs nationwide freeways

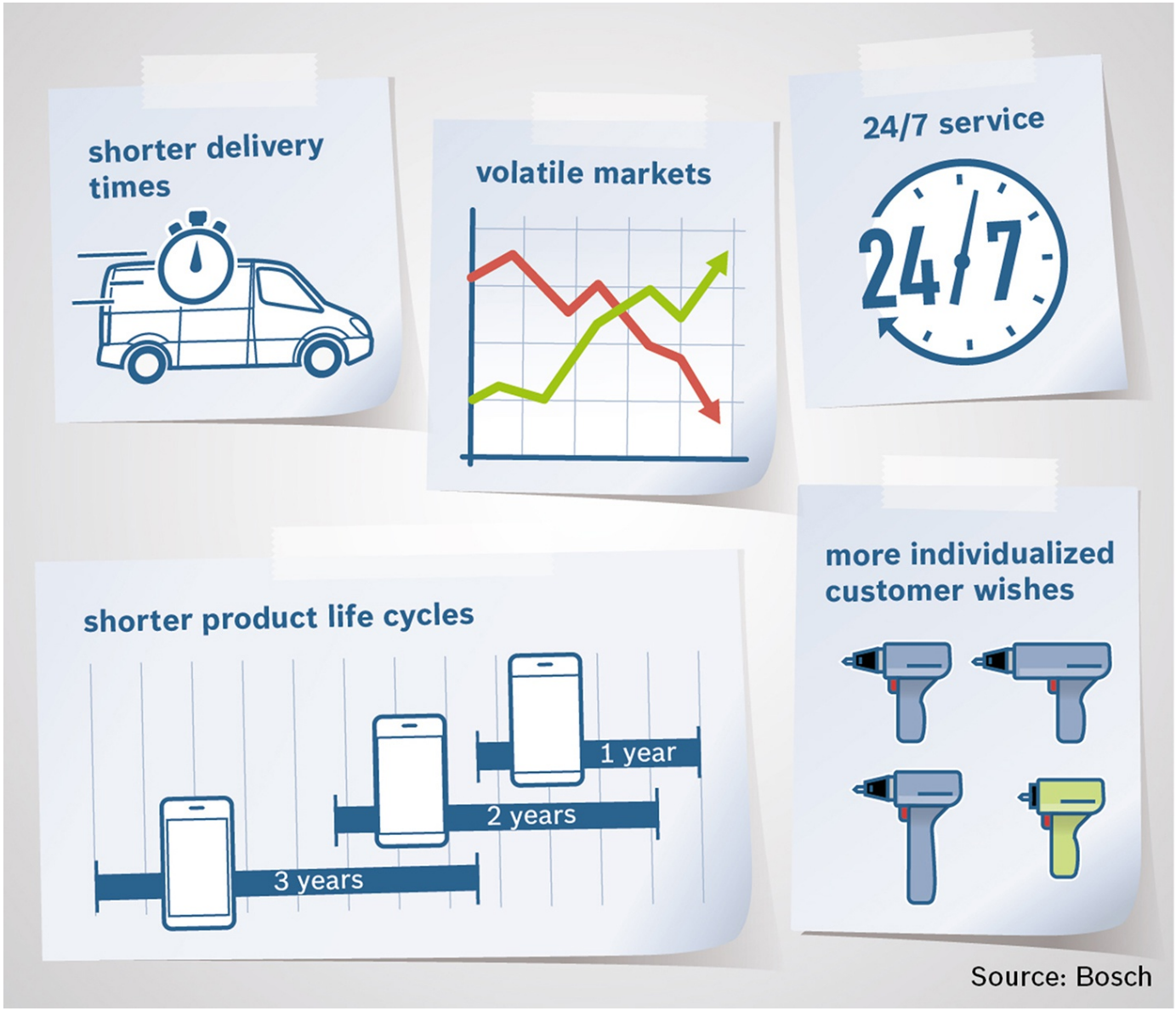
IoT Applications

- Smart environmental control with energy savings in the home and reduced peak demand on the grid
- Wearables and augmented reality for context based notifications
- Assisted living and home-based healthcare
- Guidance to nearby parking spaces in smart cities
- Richer engagement with customers through proactive maintenance and software based product enhancements
- Smart manufacturing of bespoke products

Bridging the Silos

- Today's IoT products are isolated, creating data silos
  - Devices that upload data to a fixed cloud address determined by the product vendor
  - Devices that use incompatible protocols and formats
- It is hard to create services that combine data from different silos
- We need a framework that sits at a level above the silos, enabling easy integration of data sources
- The Web provides just such framework
  - Uniform approach to addressing independent of platforms
  - Uniform approach for metadata as a basis for discovery, interoperability, and open markets of services

What is Driving Change?



Smart Manufacturing

- Shift from mass production to bespoke production
  - Emphasis on tailoring finished products to match each customer's unique needs
    - Focus on design skills
    - Mass production for “standard” parts
  - Reduced time from design to delivery
    - Re-shoring of production
  - Flexible production systems that can be rapidly reconfigured to meet changing needs
  - Open markets of services
- Smarter systems
  - Importance of models and metadata
    - Production planning
    - Monitoring and optimisation
    - Cost reduction
    - Vertical integration across different levels of abstraction
    - Horizontal integration across different functional areas
  - Integration along the value and supply chain

Tesla's new production line

Evolution not Revolution

- Companies have a big investment in existing technologies
  - The equipment and the expertise in operating them
- Gradual introduction of model based techniques
  - Models of production equipment and materials
  - Support for production planning
  - Integration with live data feeds
- Role of Web Technologies for bridging platforms
  - Uniform framework for semantics, data & metadata
  - Abstraction layer to simplify application logic
  - Bindings to existing digital automation technologies

The Web & W3C

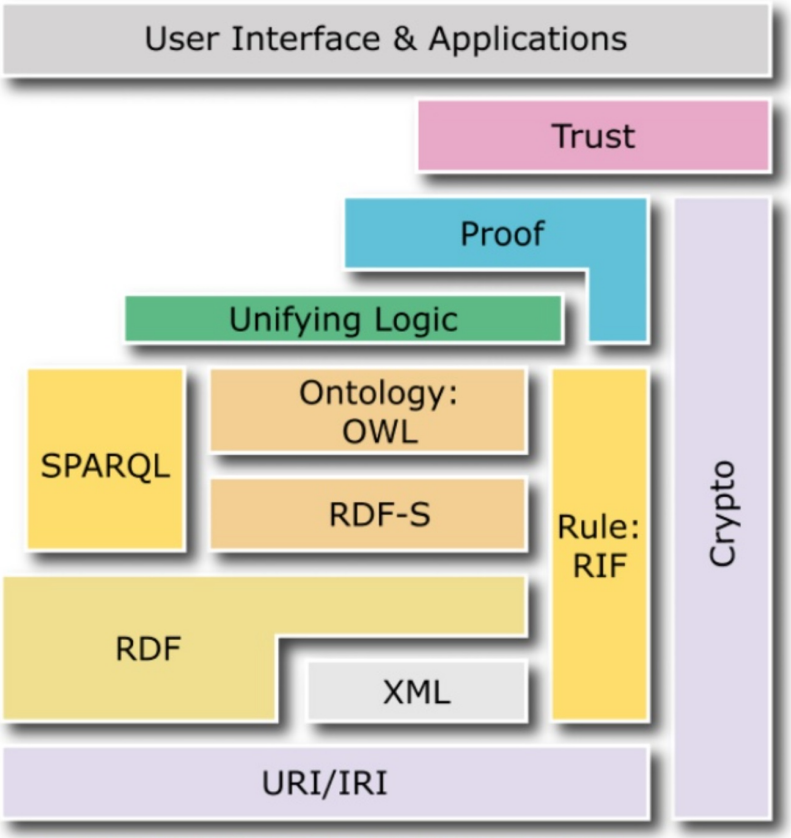
W3C WORLD WIDE WEB consortium

- W3C's mission to lead the Web to its full potential
  - World's largest vendor & OS neutral distributed application platform
- Founded by Sir Tim Berners-Lee inventor of the Web
- Over 400 Members
- W3C is a member funded international organisation focusing on developing standards for Web & semantic technologies, e.g.
  - HTML, CSS, scripting APIs, XML, SVG, VoiceXML, Semantic Web and Linked Data, …
  - We're developer oriented, and enable 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, Electronic publishing

Why is Semantics Important?

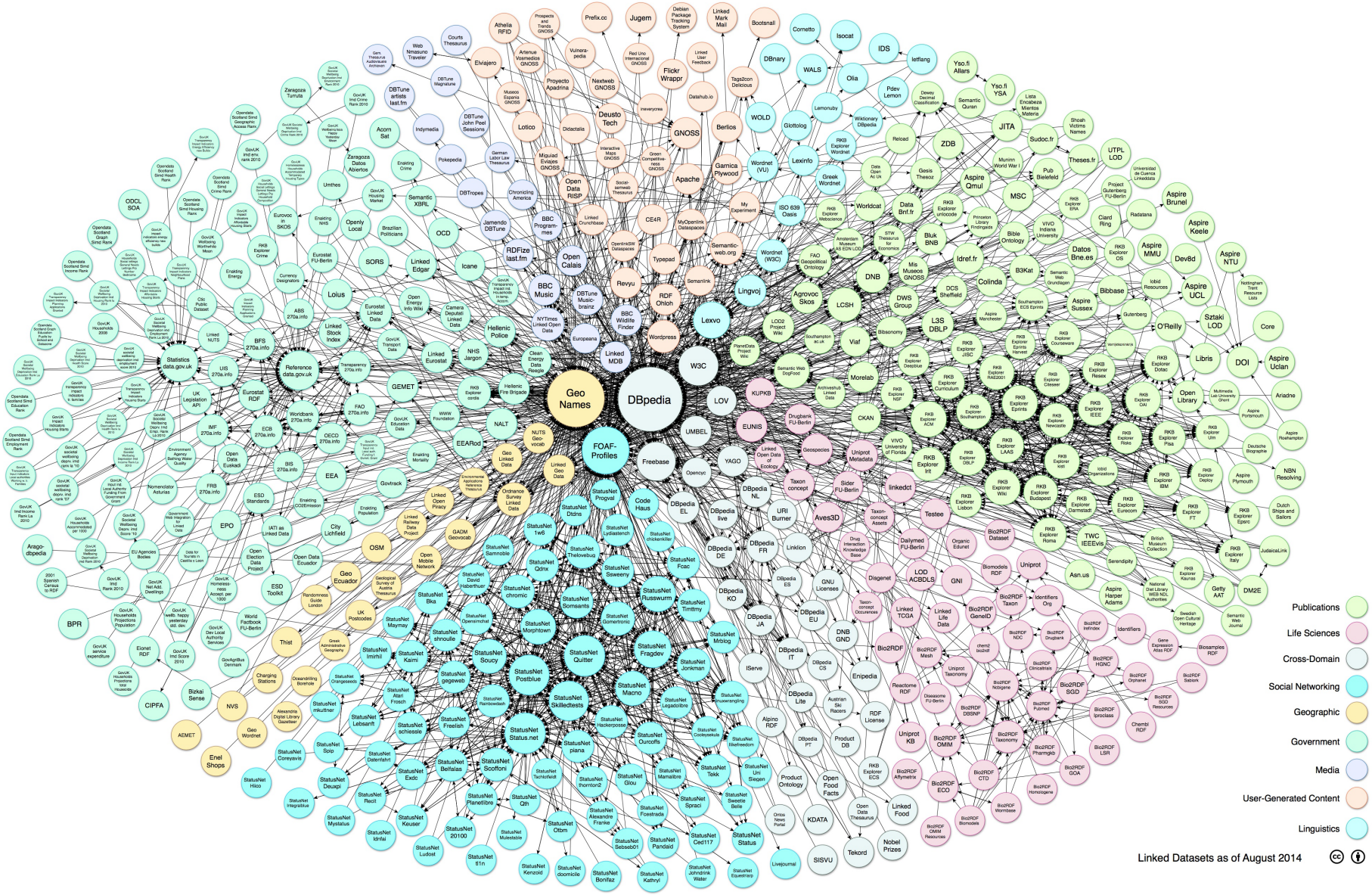
- What is the relevance to digital automation?
  - Shared vocabularies for entities and their relationships
  - Describing the software objects that stand for “things”
  - Verifying that a data source and sink are compatible and have the same semantics
  - When searching for services with a given semantics
  - To facilitate the design of service compositions
  - Optimal planning for flexible production of bespoke products
  - To enable simulation prior to deploying changes to cyber-physical systems
  - To enable fault diagnosis based upon causal models

W3C Semantic Web Standards Stack



With thanks to Fabien Gandon

A Growing Cloud of Linked Data



Web of Things

Web of Things

- The Web of Things is designed to appeal to developers by reducing the cost and complexity for creating services
  - Clean separation of abstraction layers
- A uniform approach to services that scales across devices, platforms and domains
- This will pave the way to an open market for services on the scale of the Web
  - Increased market size for solutions
- We're reaching out to developers to help W3C to address the challenges and lead the Web of Things to its full potential!

Things

I4.0 Component = "Thing" in Web of Things

- Applications act on software objects that stand for "things"
  - Software objects on behalf of local "things"
    - Sensors and actuators connected to this device
  - Software objects as proxies for remote "things"
    - Enables distributed control
  - Servers manage communication along proxy chains
    - Using the metadata associated with a "thing"
- Every "thing" has a URI for its name
  - As per Resource Description Framework
  - Used for the thing's data model, data, semantics & other metadata
  - Ontologies that describe "things"

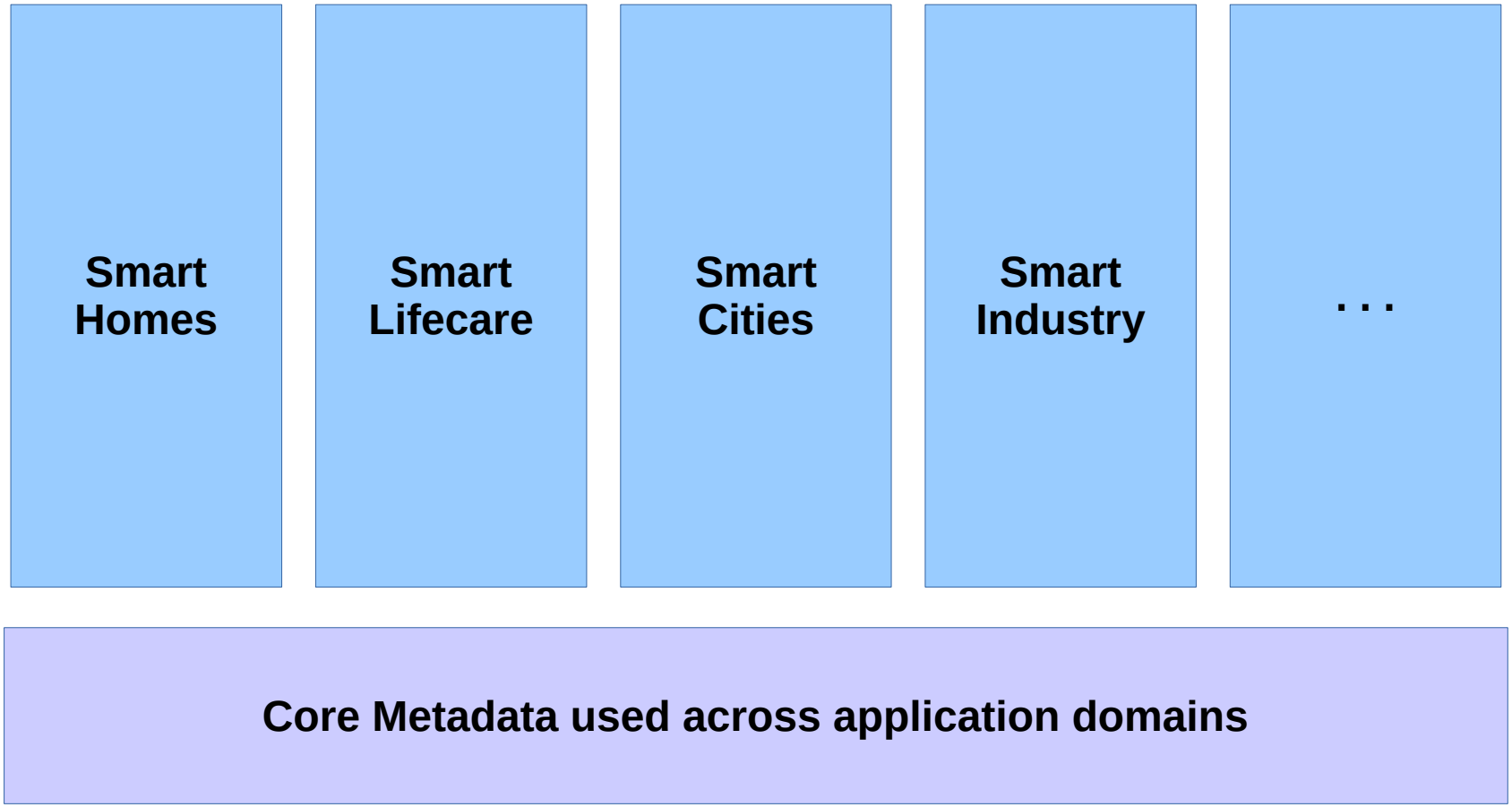
Web of Things

- Making life easier for application developers by providing a **simple scripting** model
  - **Things** standing for physical and abstract entities
  - **Things** as software objects with **properties**, **actions** and **events**
  - **Things** with **rich descriptions** formalised in RDF
  - Applications scripts **decoupled** from underlying protocols which can be selected according to need
    - **Servers can further choose** which **communication patterns** to use, e.g. push, pull, pub-sub and peer to peer as appropriate
    - Potential for **multiplexing data** from multiple sensors
    - Potential for **buffering sensor data** (optimise battery, network)
    - Dealing with **battery operated devices that sleep a lot**
    - Dealing with **real-time** requirements
  - Reliant upon **shared semantics and rich metadata**
    - Using W3C's Resource Description Framework
- Server creates software object based upon the thing's description

Abstraction Layers

Application	Scripts that define thing behaviour in terms of their properties, actions and events, using APIs for control of sensor and actuator hardware
Things *(I4.0 Components)*	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, ...
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)

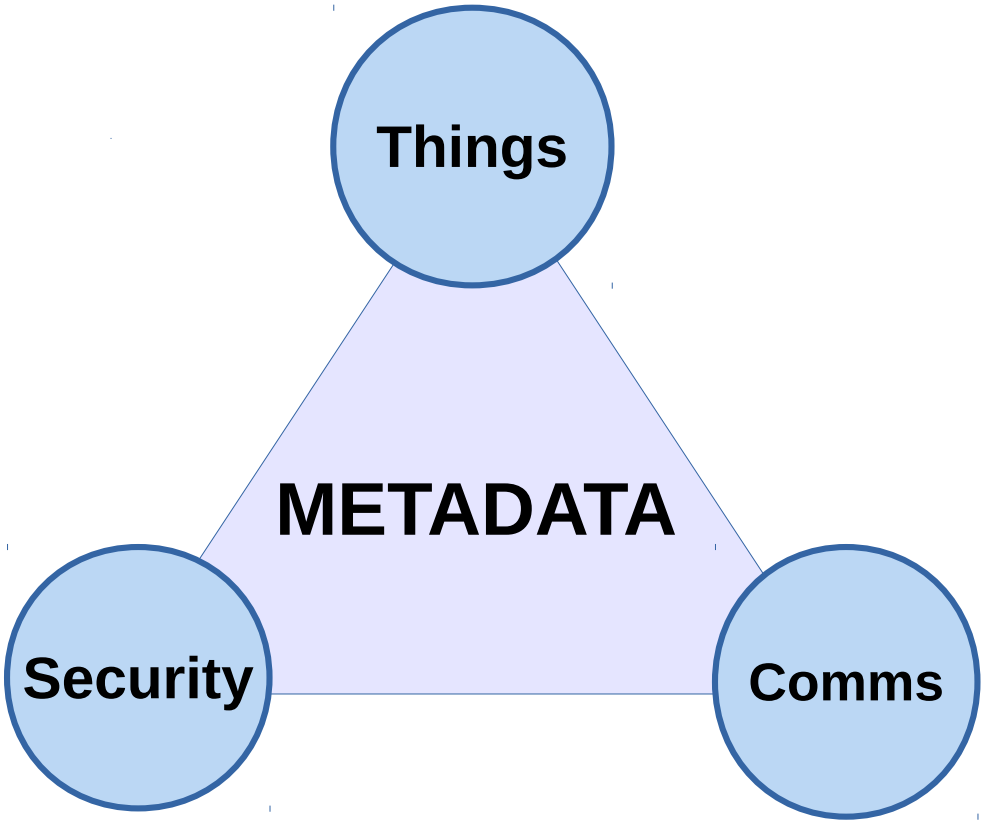
Horizontal and Vertical Metadata



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

W3C view of Horizontal Metadata

Core metadata applicable across application domains



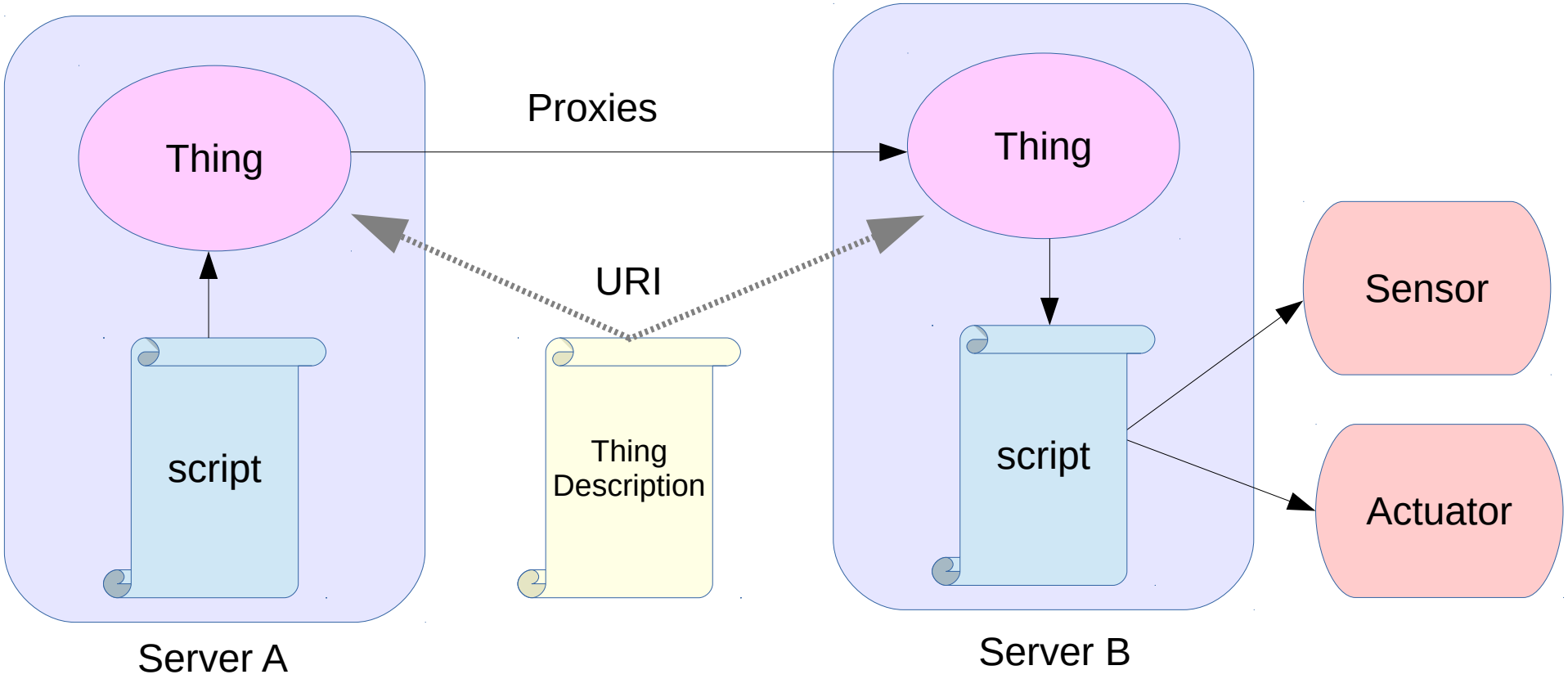
- **Thing descriptions**
  - Links to thing semantics
  - Data models & relationships between things
  - Dependencies and version management
  - Discovery and provisioning
  - Bindings to APIs and protocols
- **Security related metadata**
  - Security practices
  - Mutual authentication
  - Access control
  - Terms & conditions
    - Relationship to “Liability”
  - Payments
  - Trust and Identity Verification
  - Privacy and Provenance
  - Safety, Compliance and Resilience
- **Communication related metadata**
  - Protocols and ports
  - Data formats & encodings
  - Multiplexing and buffering of data
  - Efficient use of protocols
  - Devices which sleep most of the time

Challenges

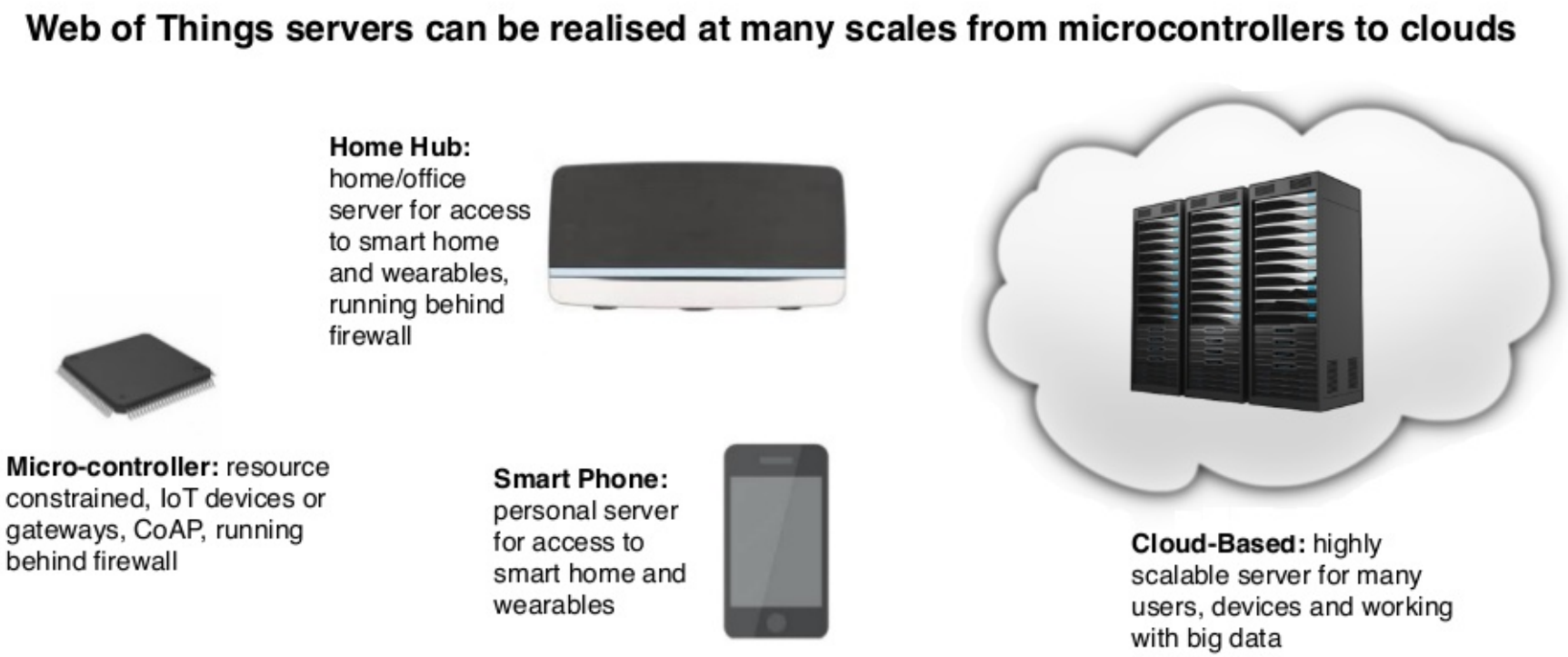
- **Open Standards** for vocabularies for semantics, metadata and data models
  - Key to enabling web scale markets for services
- **Discovery** of services
  - The benefits of a *lingua franca*, and its limitations
- **Composition** of services
  - From different vendors for an open market of services
- **Monetization** of services
  - Support for a wide variety of models
- **Security**, privacy, safety, compliance, trust, resilience
- **Scaling** on multiple dimensions
  - Scaling across **devices** from microcontrollers to massive cloud based server farms
  - Scaling across **platform and services** from different vendors and built upon different standards
  - Scaling across application **domains**
- The inevitability of evolutionary change in complex ecosystems
  - Weakly coupled communities will evolve independently
  - How to support “trade” across these communities

Distributed Web of Things

- Thing descriptions can be used to create proxies for a thing, allowing scripts to interact with a local proxy standing for a remote entity
  - Web page scripts in browser can create proxies for things on servers

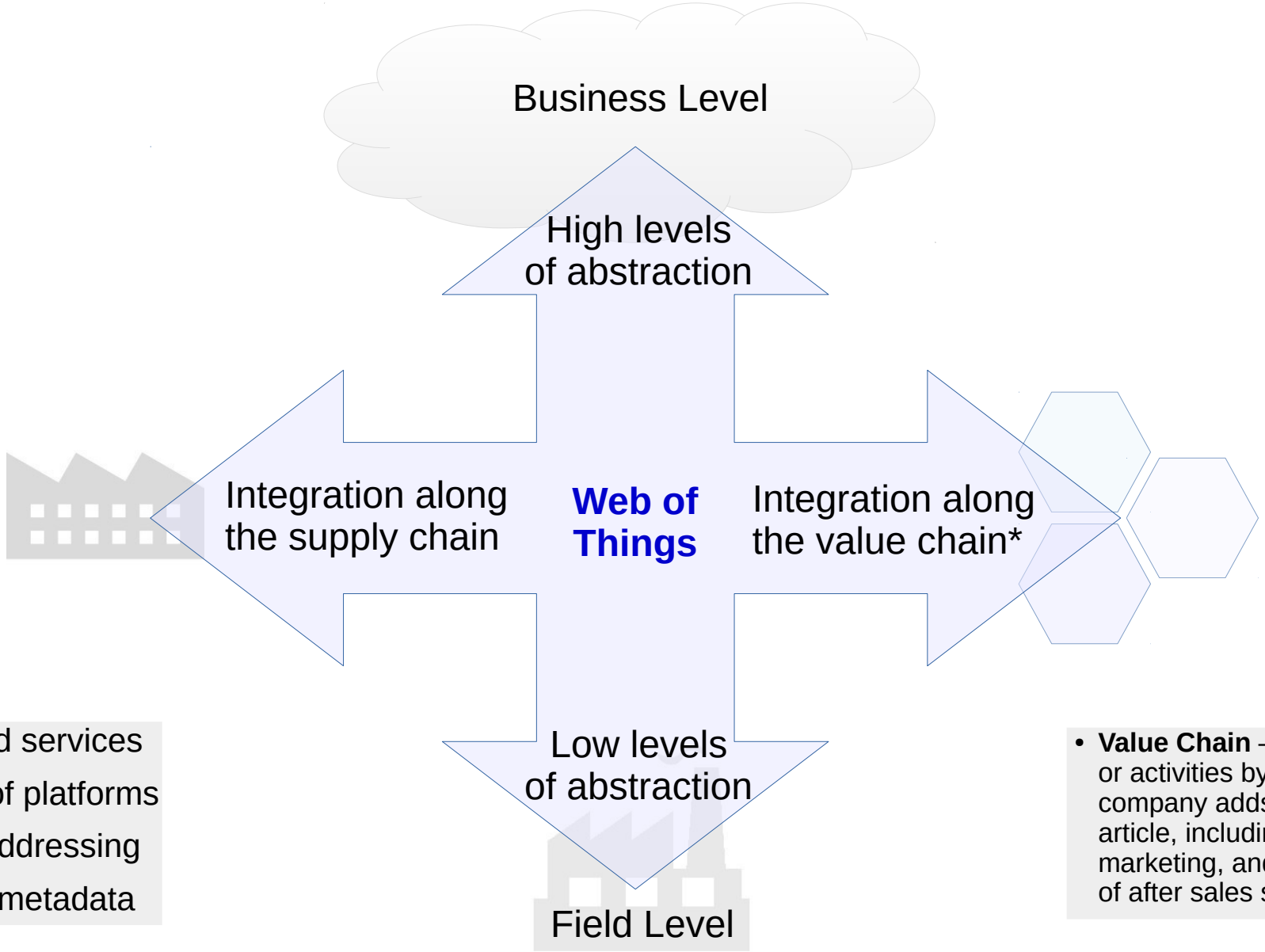


Web Servers at Many Scales



Servers are free to choose which control languages they support
Precompile service behaviour for constrained devices

Web of Things as Enabler for Vertical & Horizontal Integration



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

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

Lowering the Barrier for Integration

- Large companies want their suppliers to integrate with their software systems for greater efficiencies along the value chain
- SMEs find this challenging – the cost of developing the corresponding software is a significant barrier
- The Web of Things can simplify this through an abstraction layer above existing systems
- Open markets of services as a way of commoditizing building blocks

Open Standards for Open Markets of Things

- Connecting suppliers and consumers
  - Integration along the value chain
- Software and hardware
  - As individual components
  - As assembled systems
- Different business models
  - Direct purchase, subscription, pay as you go, …
- Hosted stores vs fully distributed marketplaces
  - Open standards to counter fragmentation
- Marketplace features
  - Discovery, reviews, recommendations, ranking/reputation
  - Dynamic composition to match given requirements
  - Automated negotiation of contracts to save time & money
- Lifecycle support
  - Developing, testing, publishing, vetting, updates, obsolescence

Web of Things Activity

Web of Things at W3C

W3C Web of Things Interest Group: http://www.w3.org/WoT/IG/

- W3C Workshop in Berlin in June 2014
- Launch of Web of Things Interest Group in 2015
  - Chaired by Joerg 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 plugfests
  - Face to face meetings
    - Past: Munich, Sunnyvale, Sapporo
    - Joint meetings with IRTF Thing to Thing Research Group
    - Future: Jan '16 Nice, France, April '16 Cambridge, USA July '16 Beijing, China September '16 Lisbon, Portugal
  - Plan to launch smart automation task force
  - Liaisons with industry alliances and SDO's to drive convergence
    - Including IIC & I4.0

W3C Web of Things Interest Group

Plans for Launching Web of Things Working Group

- The Interest Group is working on
  - Use cases, requirements, technology landscape and plans for launching working groups
  - W3C Interest Groups prepare the ground for standards but don't develop standards
  - W3C Working Groups 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 & platforms
- We expect to launch the WoT WG in 2016

Benefits of the Web of Things

- Reduced costs and increased market size through open web technology standards for an open market of services
  - Counter fragmentation and realize the massive potential!
- W3C is unique in tackling the IoT from the perspective of app developers
  - Freeing app developers from complexities of protocols and communication patterns
  - These can be chosen to match specific needs of each context
- Our approach is a platform of platforms
  - Making it easy to build services spanning devices from microcontrollers to cloud based server farms
  - Services spanning platforms from different vendors and different technology standards
  - Services that bridge domains for exciting new applications
  - Simple approach to scripting, together with rich models for semantics and metadata, based upon W3C's proven strengths with the Resource Description Framework and a suite of associated standards
- Don't get stuck in a technology silo – use the power of the Web to free up your choices and maximize your chances of success!

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Discussion?