The Internet of Things – Bridging the Silos

Still very immature, but with massive potential

Lack of interoperability at the application level

Many platforms and associated standards
- Addressing broad range of different requirements
- End to end security challenging across platforms

Fragmentation and Silos are holding back the potential

Open or closed system?
- Closed systems incentive: control
- Open systems prompt: reduced costs and increased market size

- Need for wide adoption of shared open standards

IoT Landscape

The IoT Standardisation Challenge

❖ AIOTI WG03 IoT Standardization landscape (and still extending)

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
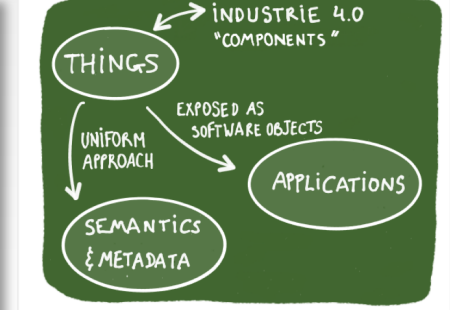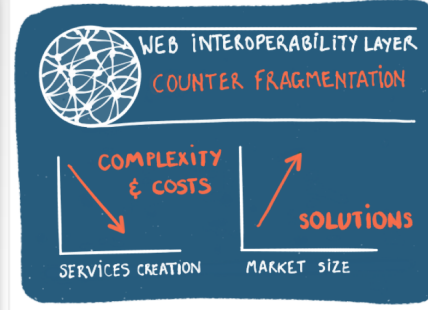- Increasingly involved in verticals: Mobile, TV, Automotive, Digital publishing
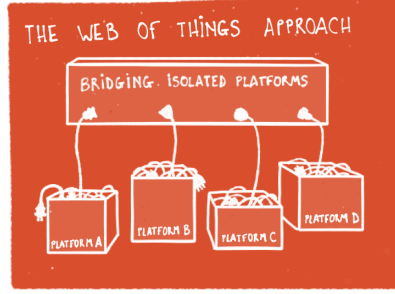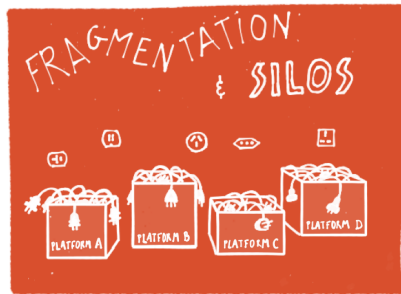
What we want to avoid …

Web of Things – Inter-Platform standards for interoperability

The Web will enable a transition from costly monolithic software to open markets of apps

Analogy with early days of networking

Before the Internet, there were many non-interoperable network technologies

- IP made it simple to interconnect networks and create interoperable services independent of the network technologies
- The Internet grew exponentially as the opportunities were realised
- Likewise for the Web which took over from isolated information services

Direct analogy with today's IoT silos
and their lack of interoperability

- The Web of Things is the equivalent of IP for semantic interoperability and end to end security
- The Web of Things will enable explosive growth as the barriers to interoperability are torn down

Web of Things
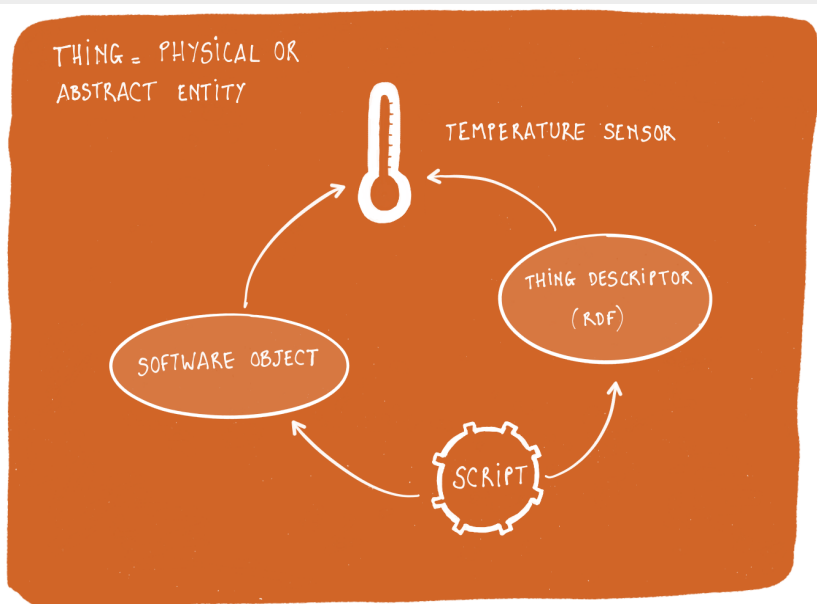
Applications act on software objects that stand for things

- 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

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

Proxies

URI

Thing   Thing

Sensor

client script   Thing Description   server script

Actuator

Server A
(or web browser)

Server B
(or web browser)
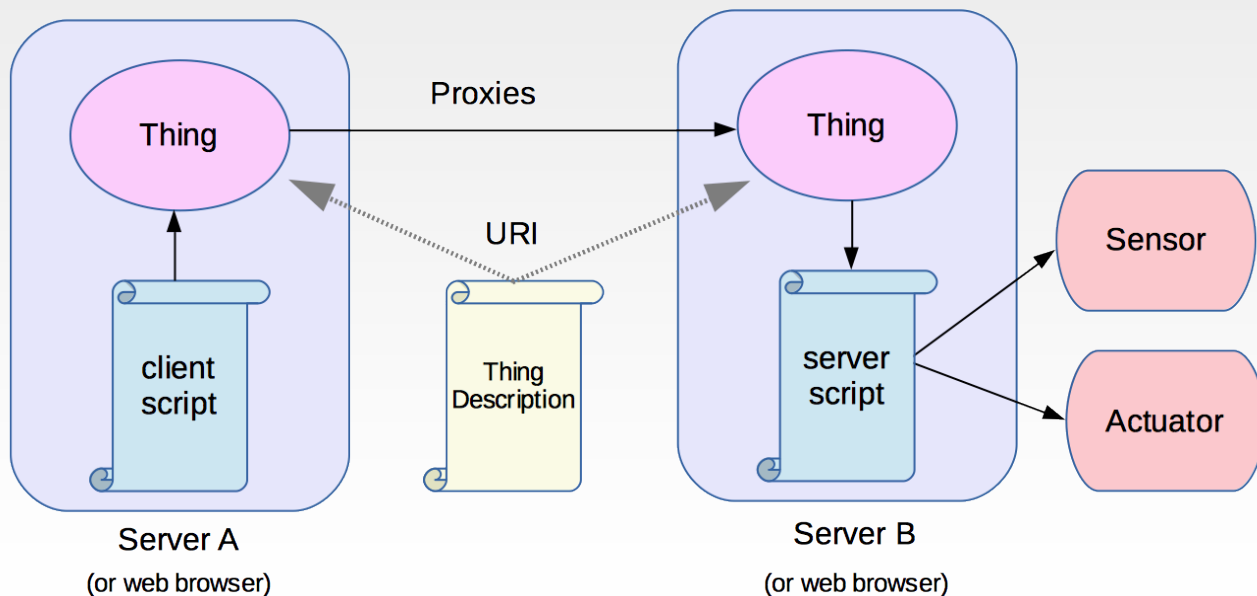
Communications Stack – Clean separation of concerns

Application Developer (WoT 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
Platform Developer (IoT focus)	**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

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

Web of Things for the Maker Community

Open source projects are underway, e.g.
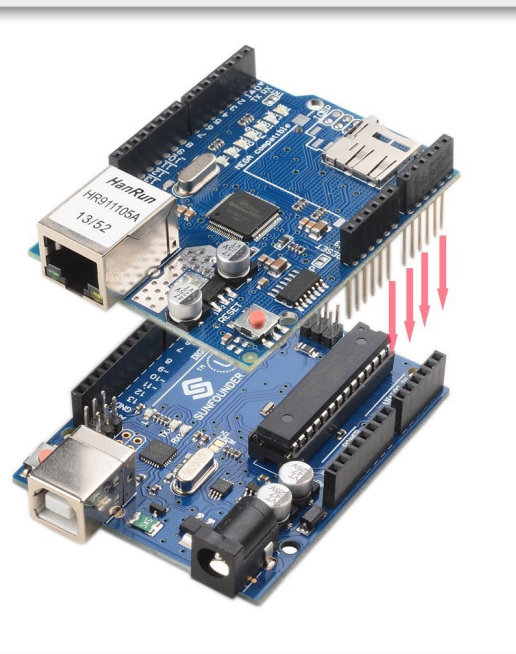for the Arduino and more powerful MCUs

Arduino Ethernet Shield

- 16 KB RAM
- MicroSD card slot
- Controlled through SPI bus
- Polling or H/W interrupt
- Cost: 4.75 GBP on eBay
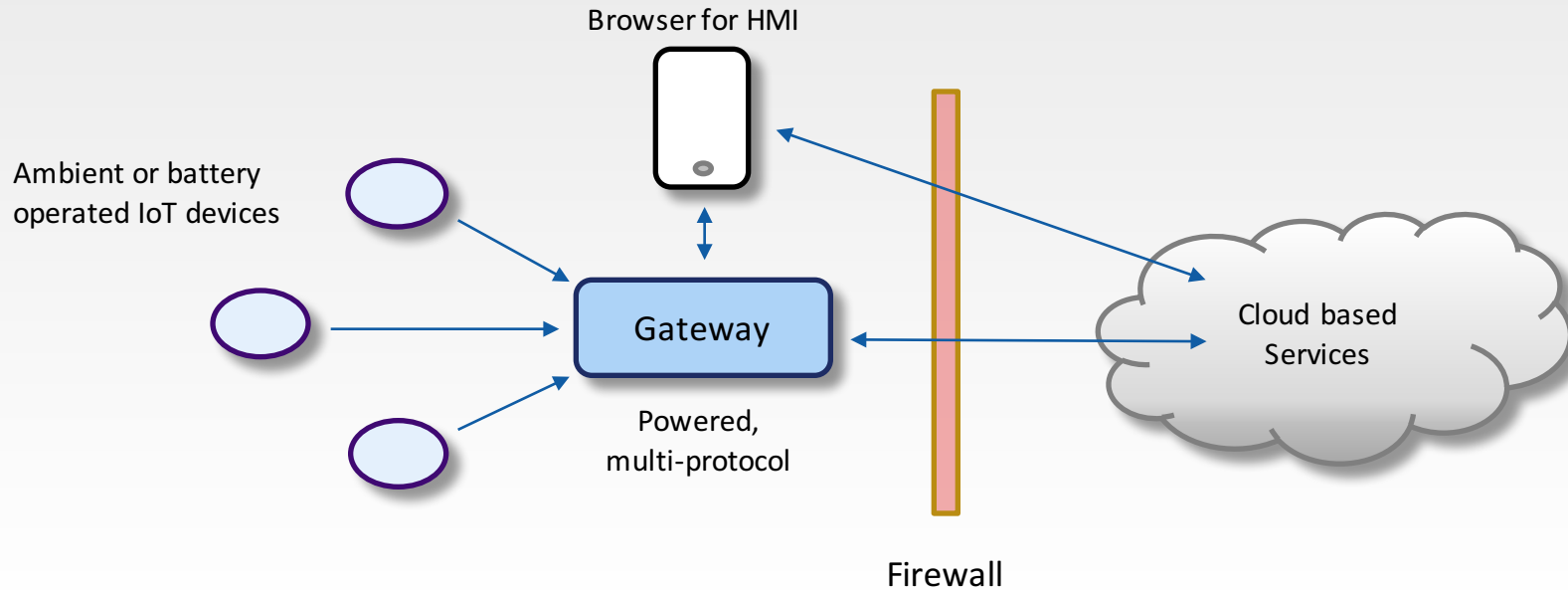
Arduino Uno with ATmega328P MCU

- 2 KB RAM
- 1 KB EEPROM
- 32 KB FLASH
- Lots of I/O pins
- Cost: 2.33 GBP on eBay

https://github.com/w3c/wot-arduino

The Web of Things in the Home

What kinds of metadata do we need for this?

- Thing lifecycles, data and interaction models
  - As exposed to the applications

- How to interoperate with another platform?
  - Mapping from thing descriptions to platform specific protocols
    - IP address and port for IP based protocols
    - Paths for REST based protocols such as CoAP & HTTP

- What communication patterns to use?
  - Push, pull, pub-sub, peer to peer
  - Real-time requirements
  - Transactional robustness & rollbacks
  - Multiplexing and buffering
  - Sleepy ambient & battery powered devices

- Semantic models of things and their constraints

Data & Interaction Models

Must be rich enough to cover broad range of use cases and platforms

- Properties, actions and events carry values
  - Actions are asynchronous and can be passed a value, and may return a sequence of values

- Values as basic types
  - Null, true, false, numbers, strings

- Compound values
  - Arrays
  - Sets of name/value pairs
  - Things
  - Streams

- Integrity constraints
  - On single values, e.g.
    - min/max, integer/float
  - Across multiple values
  - Cardinality constraints
  - Need for path expressions

- Complications
  - Proxy chains
  - Early and late binding
    - Partially defined types
  - Cyclic dependencies across things
  - Software dependencies
   - Metadata constraints (versioning)

Semantics

- Needed to ensure that platforms share the same meaning for the data they exchange

- Simple approach is to define semantics as part of the system specifications
  - But this makes it easy to lose track when data is stored and passed to other systems, or when a system evolves to address changing requirements

- Better approach is to tag data as belonging to an ontology that describes the relationships between concepts in a machine interpretable way
  - What kind of a thing is it?
    - e.g. a temperature sensor
  - What are the domain constraints?
    - temperature sensors must describe their physical units, which must be from the set {Kelvin, Celsius, Fahrenheit}
    - Other ontologies could describe the location of the sensor and what it is measuring

Semantics

- Ontologies allow information to be exchanged meaningfully in a way that is independent of the data formats used for its transmission

- Ontologies further allow for checks that the information is consistent with the domain models

- This can cover richer constraints, e.g. temporal constraints across actions and properties

- W3C has a suite of standards for the Semantic Web and Linked Data
  - RDF, XML, SPARQL, RDF-S, OWL, RIF, JSON-LD, RDF in CSV, . . .

- Enable semantic based search and composition of services
  - Ensure that compositions will use interoperable services
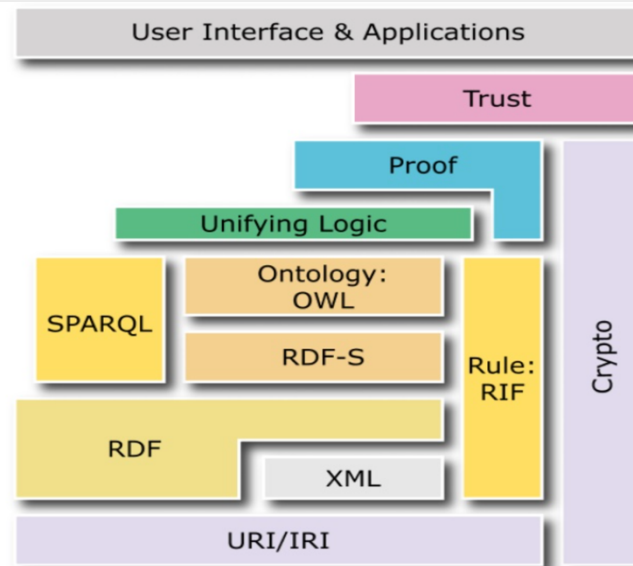
Open Questions

- What needs to be standardised and how?

- What are best practices and how can their use be encouraged?

- W3C is in a good position to standardise cross domain ontologies

- Industry specific groups need to standardise domain specific ontologies

- Different contexts place different requirements on domain models

- Ideally the ontologies are modularised to allow for easy extension

- Further challenges from divergence between weakly coupled communities

What can we learn from the Web?

- Tim Berners-Lee, inventor of the Web, was keen for websites to add semantic annotations

- Tim's original hopes for web sites to mark up their data failed to get traction

- Microformats, a widely talked about alternative to RDFa, also failed to get traction

- Web developers weren't getting enough benefits for the effort they invested

- Search engine vendors to the rescue!
  - Simple flat semantics documented on schema.org
  - Instant benefit via how your website is presented in web search results
    - showing a restaurant on Google maps, along with the opening times

Implications for the Web of Things

- We need a way to search for services based upon their names, human readable descriptions and machine interpretable semantic descriptions

- We need a way to compose services with the assurance that a given composition will work as expected. This implies the need to check for semantic interoperability

- We need to look after security* and privacy.
  - End to end security necessitates shared assumptions in respect to trust models, otherwise, platforms will only be able to share data that is marked as publicly accessible
  - Privacy and confidentiality are about the agreements between consenting parties.
  - This relates to privacy preferences, privacy policies, sticky policies that remain associated with data as it is passed through the network, the need to track provenance to ensure that data is handled in accordance with the agreement with the data owner, Service level agreements, Machine readable terms & conditions, Payments, and Automated negotiation.

In a general sense, including integrity, safety and resilience

Web of Things

Activity

Where Next? W3C Web of Things Activity

- W3C is chartering a Web of Things Working Group to standardise horizontal metadata vocabularies
  - This group is expected to launch later this year

- W3C Web of Things Interest Group is re-chartering
  - Expected to boost its work on reaching out to industry alliances and SDOs
    - Including Industrie 4.0
  - Interoperability tests across platforms using open source implementations
  - Further joint papers planned on security, privacy and requirements for open markets of services
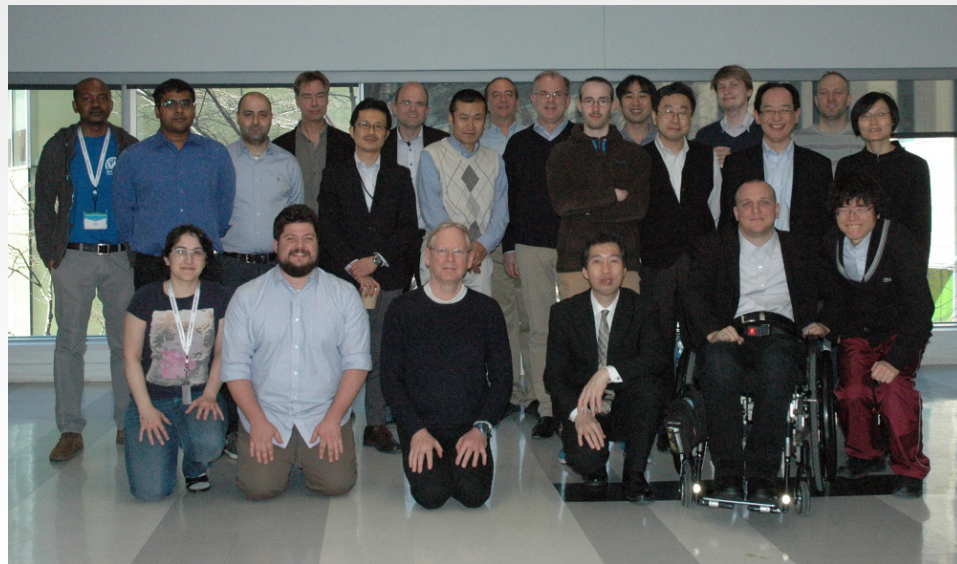
W3C Web of Things Interest Group

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
- Helps to build a shared understanding

Montreal Face to Face, 11-13 April 2016

Members of the Web of Things Interest Group

# Joint White Paper on Semantic Interoperability

- Contributors are individuals from a range of industry alliances and standards development organisations
  - Editors from W3C, oneM2M, IEEE P2413

- Inspiration from many of the papers on semantic interoperability

- Illustrate the concept in terms of some use cases, along with the requirements, and views on how to enable semantic interoperability within and across IoT platforms

- Discuss best practices for ontology design and distinguish cross domain (horizontal) metadata and domain specific (vertical) metadata

- Once we have a stable version we will invite wider expert review and update the document accordingly

- We will seek broad dissemination of the document and will publish under a Creative Commons License

- We hope that the development process will help shape a common perspective across contributors and that the white paper will influence the agendas of working groups across the industry

Liaisons and Collaborations

Reaching out to industry alliances and SDO's to drive convergence to unleash the potential
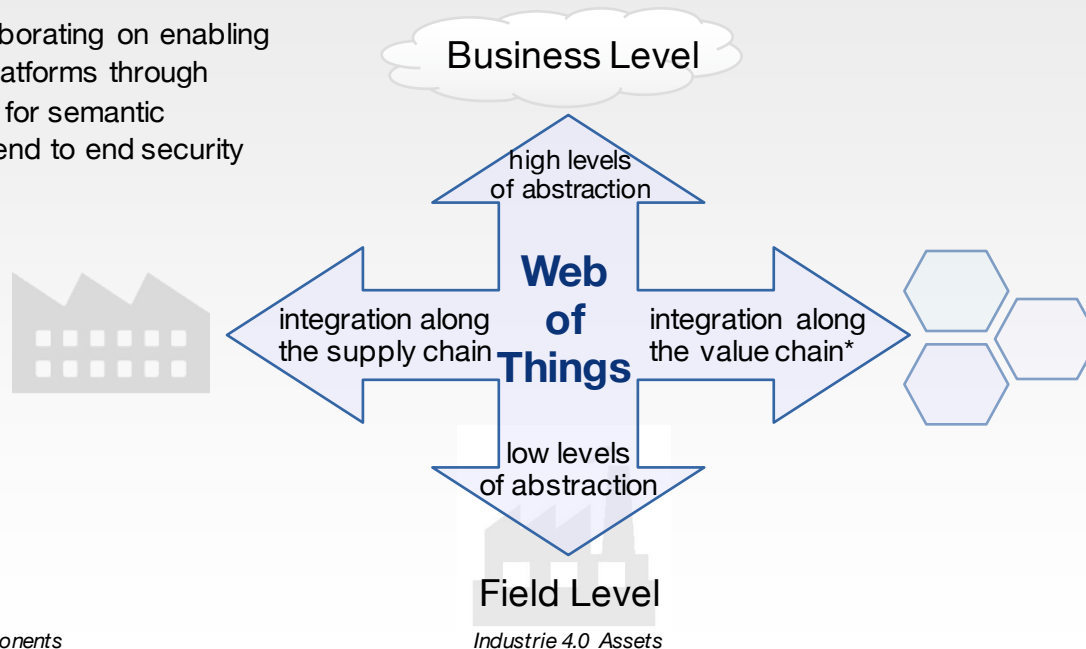
- Plattform Industrie 4.0

    Especially the "semantics" subgroup

- Industrial Internet Consortium

- Open Connectivity Foundation

- OPC Foundation

- IETF/IRTF

- oneM2M

- AIOTI
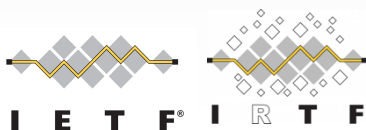
Enabling Vertical and Horizontal Integration for Realising the Potential for Digital Automation

W3C and OPC collaborating on enabling integration across platforms through metadata standards for semantic interoperability and end to end security

Business Level

high levels of abstraction

Web of Things

integration along the supply chain

integration along the value chain*

low levels of abstraction

Field Level

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

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 for a Working Group including

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

Web of Things Working Group to be launched in 2016
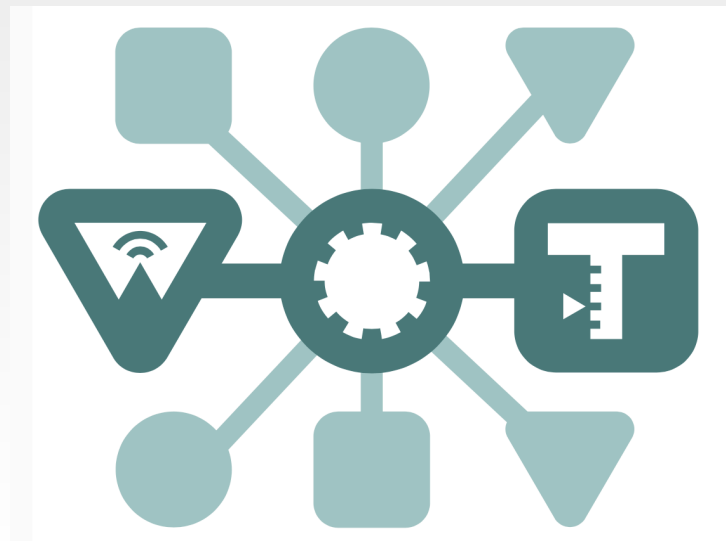
Web of Things

What, why, how, actions

C-level corporate decision makers

What is the problem to be addressed?

Fragmentation of the IoT into many non-interoperable platforms

Why is it important?

Solving this will enable exponential growth as we saw with the Internet and the Web

- The network effect: Metcalfe's law

How it is to be solved?

Inter-platform standards that play an analogous role to IP for connecting previously incompatible networks

- Decoupling applications from protocols
- Enabling different platforms to interoperate
- Complementing, not competing, with platforms

What action are we seeking?

Commit to join W3C & assign staff to participate in Web of Things groups

Ensure your company is in the driving seat for the open IoT

SDO's and Industry Alliances

What is the problem to be addressed?

Difficulty of creating services spanning different platforms due to a lack of semantic interoperability and a miss match of assumptions around trust and security

Why is it important?

Solving this would enable exponential growth in services like we saw for IP and the Web

How it is to be solved?

Inter-platform standards defining an interlingua for metadata, and shared assumptions in respect to end to end security across different platforms

What action are we seeking?

Active collaboration on integration with the Web of Things and alignment of marketing messages

Engineers and Developers

What is the problem to be addressed?

- Fragmentation of platforms and IoT technologies, and high cost of integration with a piecemeal approach
- Barriers for semantic interoperability and end to end security

Why is it important?

- Simpler, faster, more flexible application development
- Leveraging existing services and communities in the Web ecosystem
- Be part of the next big thing, strong growth in job opportunities

How it is to be solved?

- Open standards for Web based abstraction layer, complementing existing platforms and standards, and enabling platforms to interoperate securely

What action are we seeking?

- Joint work on experimental implementations that explore what it means to integrate with the web of things – help to create evaluation kits, and spread the word
- Joint work on white papers to forge a shared understanding across companies, alliances and SDOs
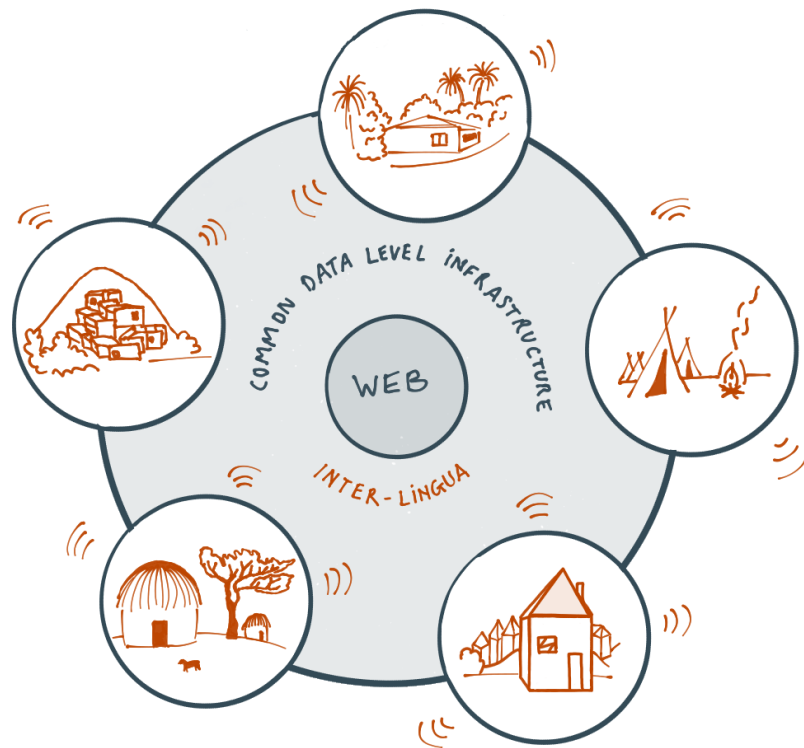
The Bottom Line

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!