Defragmenting the IoT
with the Web of Things

Enabling Open Markets of Services

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FIWARE Summit, Porto
8 May 2018
Defragmenting the Internet of Things

- The Internet of Things refers to connected sensors and actuators and the idea of digital twins
  - Huge potential across many application sectors
- But highly fragmented with myriad technologies and a lack of interoperability for devices and platforms
  - This imposes market friction and holds back the potential
- W3C is defining Web standards to unlock the potential for open markets for suppliers and consumers of services
  - Interoperability at the higher levels where the value is highest
- Web of Things (= web of digital twins)
  - Services decoupled from underlying communication technologies
  - Things as software objects with properties, actions and events
  - Linked Data as basis for describing things and their relationships
  - Interoperable discovery and composition of services

Green shoots in a parched environment
Web of Things Workshop hosted by Siemens, Berlin, 2014

- W3C workshops as a way to bring stakeholders together to discuss a particular technical area
  - Is there broad agreement on what’s needed?
  - Is it timely to start work on it?
  - Who would participate in such work?

W3C Web of Things Interest Group launched in 2015, followed by the Working Group in 2017
Describe & Complement Existing IoT Systems

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Any IoT Device
- Application
- SDK
- Data Model
- Protocol

Provide **semantic metadata** that uniformly describes how to interact with Things

Implicit interaction model, typically not well documented

The IoT has a plethora of protocols, often dialects due to custom options

Define a **common runtime** for IoT applications that mimics Web development

Every SDK and library is different, so that app development is expensive

Capture each protocol once in a uniform template that describes how to configure common protocol stacks (e.g., CoAP or MQTT) to send the message expected by the Thing

With thanks to Matthias Kovatsch
W3C WoT Plans for next 12-18 months

- Web of Things Working Group progressing work items to Candidate Recommendations
  - Thing descriptions and serialisation as JSON-LD 1.1
    - Programming language neutral description of things as objects
    - Work on application sector specific vocabularies is out of scope
  - Scripting API
    - Platform-independent application-facing API for Thing-to-Thing interaction and Thing lifecycle management
  - Declarative Protocols Bindings
    - For common protocols, e.g. HTTP, CoAP, WebSockets, MQTT
  - Security and Privacy Guidelines
    - How to enable end-to-end security across different IoT platforms
  - Short term charter extension may be needed to advance work items to CR

- Re-chartering the Web of Things Interest and Working Groups
  - Current charters expire at the end of 2018
  - Scope and objectives for future work is now under discussion
Things and cloud instead of things to cloud

Remote Access and Synchronization

Web Integration

Web Browser
- App Script
- Scripting API
- Interaction Model
- Binding Templates

Direct Thing-to-Thing Interaction

Thing
- Application Logic
- Scripting API
- Interaction Model
- Binding Templates

Cloud

WoT Host
- Digital Twin
- Orchestr. Client
- Digital Twin
- Scripting API
- Interaction Model
- Binding Templates

Edge

WoT Host
- Virtual Thing
- Orchestr. Client
- Proxy Thing
- Scripting API
- Interaction Model
- Binding Templates

Integrate and Orchestrate Devices

Existing Device

Existing Device + Thing

Complement Existing Devices 6/15

With thanks to Matthias Kovatsch
Web Architecture as Key to Interoperability

- Web Architecture is based upon three core aspects
  - URIs as addresses for resources
  - Standard data formats, such as HTML, which embed links to other resources
  - Standard protocols for retrieving resources such as HTTP

- For the IoT this translates to
  - URIs for naming things
  - Linked Data as the basis for describing things (JSON-LD, Turtle, ...)
    - Dereference thing URIs to obtain thing descriptions
  - Standard protocols such as HTTP and WebSockets that fulfil 99% of use cases
    - Gateways at the network edge to address myriad IoT protocols

- Interoperability star rating
  - Let’s be inspired by Tim Berners-Lee’s star rating for data!
Open question: complementing or subsuming existing IoT frameworks?

- Enabling open markets for suppliers and consumers of services
  - Discovery based upon thing metadata (objects, semantics, context)
  - Design and deploy service compositions
  - Centralised marketplaces and **much larger** distributed marketplaces

- Duplicating the success of the Open Web of Pages
  - Exponential growth over many years and now over 2 billion websites

- Focus is on the Internet **not** the network edge!
  - Use gateways to strengthen security and decouple myriad IoT protocols
  - Use HTTP and WebSockets for Things supplied and consumed over the Internet as part of the Open Web of Things
  - Avoid need for developers to provide complex protocol binding information

- Web of Things as major simplification for Internet based services
  - Replacing siloed standards and isolated proprietary ecosystems
Adaptation to Variation in Devices

- Manufacturers seek to differentiate their products from their competitors
- Manufacturers often offer customers a choice from a product range
  - Low end models offering just the basic features
  - More expensive models offering extra features
- Web of Things applications that can adapt to variations in device capabilities and how these are exposed as thing properties, actions and events
- Based upon semantic descriptions of things and the context in which they are used
  - Linked from thing descriptions that describe the object model (properties, actions, events)
  - Involves the need for domain specific vocabularies
- A very good reason for learning how to use semantic technologies!
Semantic Interoperability

- Interoperability can be defined at multiple layers of abstraction
  - Physical, Network, Transport protocols, data formats and encodings, and higher layers
- The Web of Things enables semantic interoperability
  - Agreement on the meaning of data as well as its format and type
  - A temperature measurement of the engine block in degrees Celsius
- Important for composability of services
  - e.g. identifying need for conversion of units of measure

Interoperability Testing: Web of Things

- Test interoperability between Web of Things platforms
  - Testing at WoT API level, **not** protocol level
  - Suite of things to cover thing description specification
- Platform A hosts application that exposes suite of test things
- Platform B hosts application that consumes suite of test things
- Design these things as test harnesses that connect to F-INTEROP test manager via separate communication channel
  - e.g. WebSockets as convenient protocol with reliable bidirectional asynchronous messaging using JSON messages
  - Web page as user interface for test management
  - Things use Web of Things API to invoke and monitor test results on behalf of test manager
  - Web app as a lightweight alternative to F-INTEROP?
Opportunities for FIWARE

• To take on a pivotal role in driving exponential growth of services through adoption of the Web of Things so that
  • FIWARE is to Web of Things as Apache HTTP is to Web of Pages

• Convergence on Linked Data as framework for semantics
  • FIWARE Context Broker in relation to Linked Data
    • Adding value to the Linked Data core standards
  • Discussion on NGSI-LD in respect to W3C & Linked Data
    • Coordination on messaging on work by each organisation
  • Plans for W3C Workshop on next steps for Linked Data
    • More details in a later slide
Data Management and Governance

- Data is increasingly of strategic importance to enterprises
- Need to connect data and metadata
  - Industry 4.0 and tracking components throughout lifecycle
  - Public health concerns and complex food supply chains
  - Ethical concerns about how consumer products are produced
  - Need to address evolving requirements for privacy
- Data governance: data quality, data models, metadata, security, trust, provenance and privacy
  - This calls for a consistent enterprise wide approach
- Enterprise knowledge graphs as the solution
  - Reality of data management across heterogeneous distributed systems
  - W3C’s suite of standards for the Web of Data
    - Including work on dataset catalogues – DCAT-rev
Learning from two decades of experience with RDF and Linked Data

- Plans for W3C Workshop late 2018 in Europe
- Identifying opportunities for new standards
  - Extending RDF to embrace Property Graphs
    - Annotations on relationships
    - Amazon’s Blazegraph
  - Digitally signed RDF graphs – e.g. ontologies
    - Where you want to ensure graph hasn’t been modified
  - Addressing scalability for communities with differing requirements
    - Context sensitive data mappings for vocabularies with overlapping semantics
  - Blending ideas from Cognitive Science, Sociology, ...
    - Dealing with incomplete, uncertain and inconsistent knowledge
    - Unlocking the potential for machine reasoning with natural language

- What’s needed to support Enterprise Knowledge Graphs?
Thank You!
Open Source Implementations

- Open-source W3C WoT reference implementation
  - node-wot (WoT Host) NodeJS + TypeScript
  - Thingweb Java (WoT Host) Java
  - Thingweb Directory Java + Apache Jena
  - Thingweb UI AngularJS
- More tools expected to follow
- https://github.com/thingweb
WoT Plugfests to Explore Ideas

With thanks to Matthias Kovatsch
Co-funded by the European Commission

W3C Liaisons – Web of Things as Neutral, Horizontal, Cross-domain Solution

Web of Things: “glue in between”

- IETF
- OPC UA
- oneM2M
- OCF

- Plattform Industrie 4.0
- LWM2M / IPSO
- Fairhair
- BACnet
- Modbus

- Running code
- Collaborations
- Official W3C Liaison

With thanks to Matthias Kovatsch
Who’s Who

• WoT WG Chairs
  • Matthias Kovatsch (Siemens), Kazuo Kajimoto (Panasonic), Michael McCool (Intel)

• WoT IG Chairs
  • Matthias Kovatsch (Siemens)
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