Enabling Open Markets for the Web of Things

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Huge potential, but lots to do...

- Most work to date has been about the Internet of Things from the perspective of sensors and transport protocols
- But most of the money will come from services
  - ***Services, Not Sensors****: Gartner expects Internet of Things vendors to top $309 billion in direct revenue by 2020, with most of that money deriving from services.*
- Today, we see problems with product silos
  - No provision for 3rd parties to add value
  - This is holding back the huge potential

Standards as key to success

- Open standards to break out of product silos
  - *The trick will be whether hardware companies will push hard enough for **standardization** so they can capitalize on services revenue. Companies that see themselves as pure hardware manufacturers are likely doomed, but those that see beyond the "things" to instead **focus on the services** built on the "Internet," the future is very bright.* Matt Asay, MongoDB
- He could have added that successful companies need to focus on **growing the ecosystems**
  - Product silos have limited appeal for 3rd party developers
- Standards create market opportunities
- Can we repeat the run away success of the early Web?

Web standards for services

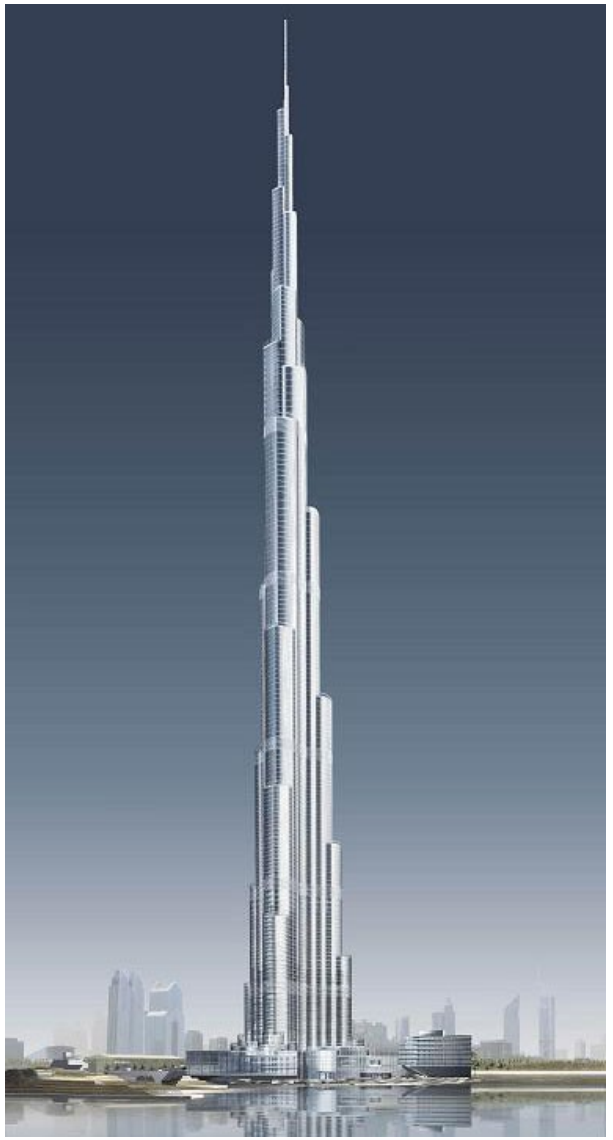
- Web technologies are expected to be very important,
  - e.g. JavaScript and open standards for data formats, interface definitions, security, privacy, federated services, ...
  - *Eventually, something like HTML, the language of the web, will be required to make the internet of things realize its potential. "Interoperability is critical,"* says Mike Bell, head of wearables at Intel.
- It's time for the Web of Things!
  - Standards at the app/service layer above the IoT

Internet of Things as the Foundations

Dubai Tower

- Sensors, Actuators and IoT protocols

Web of Things as the Skyscraper



- Focus on application & service layer
  - Where the big money is!
  - Breaking out of the silos
  - Web scale
- Open markets & ecosystems
  - Discovery & provisioning
  - Rich descriptions & data models
  - Interoperability
- Security & Resilience

Data in Context & Real World Models

- Applications and services often need data at a higher level than the raw data provided by sensors
- Moreover, data needs to be interpreted in the context of other sources of information
- The same applies to control systems whose actions need to be translated in context into actions on lower level entities
- The Web of Things needs to be able to model the real world at different levels of abstraction, and to enable open markets with free competition of services across these levels.
- Things as virtual representations of objects

Things & Avatars

- What do we mean by **things**?
  - Connected devices with sensors and actuators
  - Things don't need to be connected to the Internet
  - Things don't even need to be physical objects
    - People, concerts, companies, the 70's, etc.
- Each thing can have one or more virtual representations – **avatars**
  - Avatars have identities, rich descriptions, services
  - Have URIs and are accessible via web technologies
- Challenges for security, trust and privacy

The Web of Things

A huge variety of potential application domains including ...

Application Domains

- Smart homes and living
  - Home heating & lighting, home entertainment, home healthcare, home security, sports …
- Building automation for hotels, offices, retail
- Construction
- Smart Transport
- Smart Utilities & Smart Grid
- Next Generation Hospitals
- Next Generation Manufacturing
  - Germany's Industrie 4.0

Cyberphysical Systems

- Control loop that bridges sensors and actuators
  - Smart buildings, smart grid, smart traffic control
- Can be expressed at multiple levels of abstraction
  - Delegation of low level control to controllers near to the network edge
    - When there are requirements for low latency
    - When there is a need for tightly coordinated synchronized control over multiple actuators
- Match protocols to latency & jitter requirements
  - Latency may be subordinate to transactional robustness
- Opportunities for pushing scripts to controllers

W3C Web of Things Workshop
Berlin, June 2014

W3C Web of Things Workshop
Berlin, June 2014

Workshop report: http://www.w3.org/2014/02/wot/report.html

Who participated

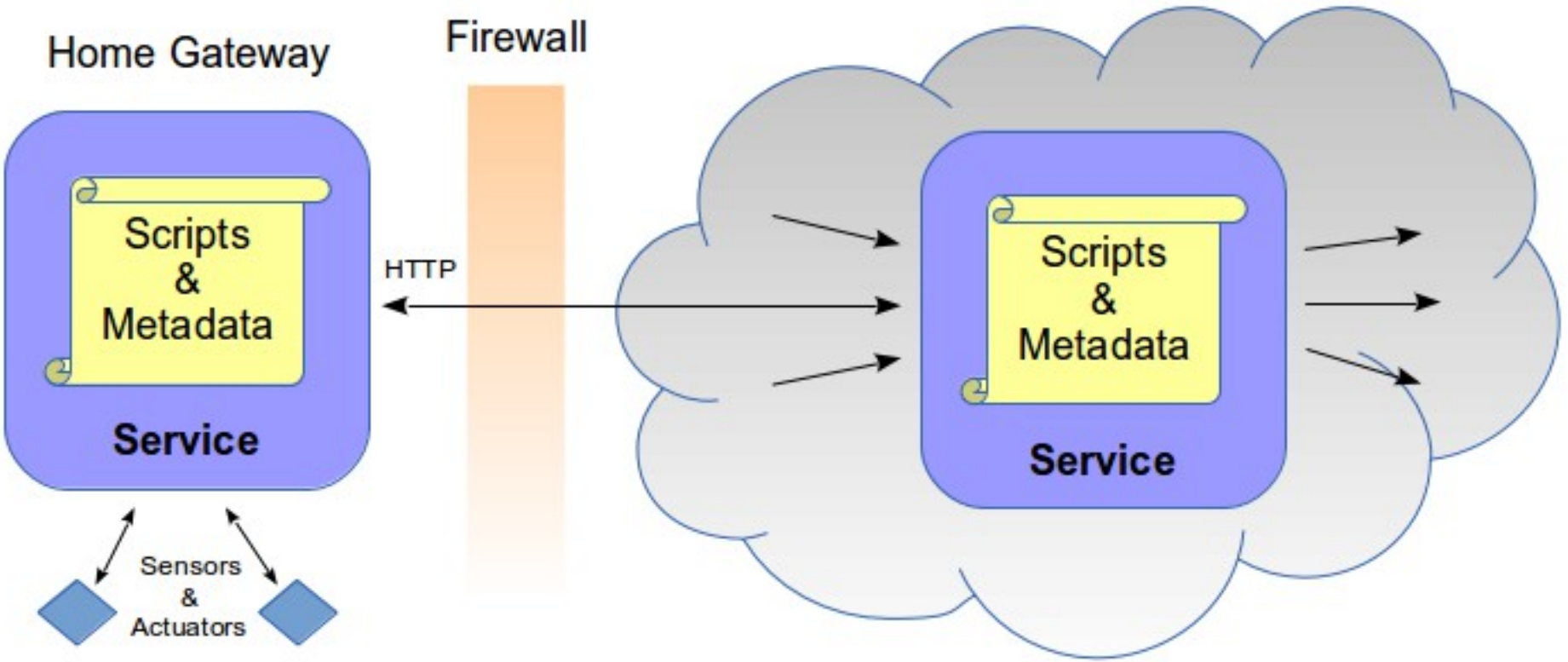
- We had 120 participants with major players including the following companies

ACCESS	Evrythng	Nokia
Algebraix	Fujitsu	NTT Communications
ARM	HP	Oberon microsystems
Beijer Electronics	Huawei	Orange
BITKOM	IBM	Panasonic
Bosch Rexroth	Intel	Plantronics
Canon	KDDI	Siemens
Cisco	Layer 7	Sony
Deutsche Telekom	LG Electronics	Telecom Italia
Ericsson	Monohm	Toshiba

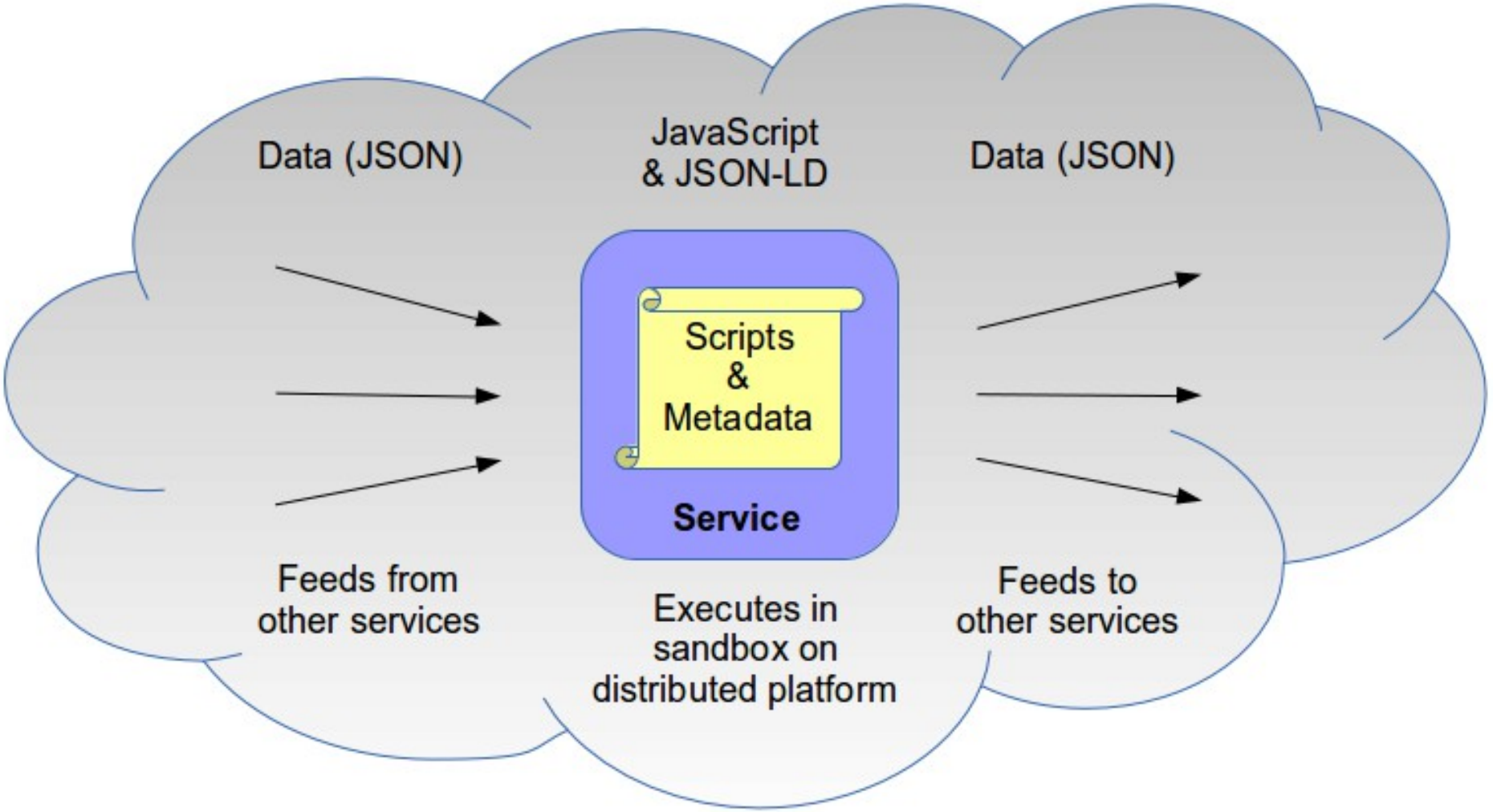
Opportunities for Scripting

- Scripting languages have a bright future
  - **Browsers** for direct access
    - e.g. via Bluetooth Low Energy from smart phone
  - **Service platforms** in the cloud or network edge, e.g. home hubs and servers in your phone/tablet
  - **Device gateways** bridging IoT protocols and the Web, and simplifying service development
- Where practical use same APIs across all 3
- Decoupling scripts from transport protocols

Service Platforms

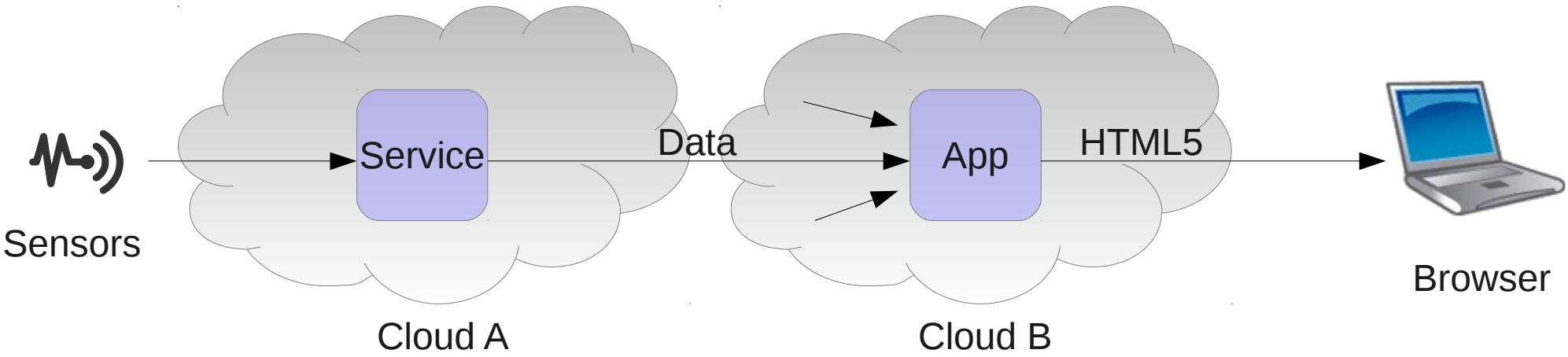


Federated Cloud-based Services



Underlying use of HTTP/COAP, Web Sockets, and EXI/JSON for RESTful services.

Applications and Services



Services feed other services and/or web applications

What's needed for open markets of WoT services?

- Removing barriers to free competition
- Data modelling standards
- Service descriptions and dependencies
- Discovery and trust management
- End to end security and privacy
- Bridging the gap between WoT and IoT
- Relationship between apps/service layer and the network layer
- Monetization – see W3C work on payments
- Provisioning and lifecycle management

Next Steps

- We're drawing up plans to charter a
  W3C Web of Things Interest Group
  - Following precedent of W3C Web & Mobile, Web & TV Interest Groups
- Collaboration on gathering use cases, requirements, identifying gaps, best practices, and proposing work items for standardization in W3C Working Groups
- Draft charter available at
  - http://www.w3.org/2014/09/wot-ig-charter.html
- Contact Dave Raggett <dsr@w3.org> if you are interested in getting involved

Proposed Deliverables

- Use Cases and Requirements for the Web of Things
- Survey of Existing Practices and Standards Relevant to the Web of Things
- Guidelines on Best Practices
- Requirements for Open Markets of Products and Services for the Web of Things
- End to End Security for the Web of Things
- Resilience for the Web of Things

IoT Technologies

Hypertext Transfer Protocol (HTTP) may be used for powered devices with a wired network connection or support for WiFi. HTTP is often used in conjunction with the Representational state transfer (REST) design pattern. HTTP is a client-server protocol, but can be used in a polling mode to handle requests pushed to the device by a server.

Web Sockets is similar to HTTP, but allows for asynchronous message transfer in either direction. Web Sockets is often used with JSON for remote method invocation and event notification.

Constrained Application Protocol (CoAP) is designed as an IP protocol for embedded or constrained devices. It translates easily to HTTP for integration with the Web and RESTful APIs. It also supports notifications pushed from a server to the device. CoAP is often used together with 6LoWPAN for short range wireless connections

6LoWPAN is short forIPv6 over Low power Wireless Personal Area Networks. It is layered on top of the IEEE 802.15.4 standard for the physical layer and media access control for personal area networks, and may be used in conjunction with CoAP.

ZigBee is a low power wireless communications technology optimized for devices requiring a very long battery life. ZigBee is layered on top of the IEEE 802.15.4 standard for the physical layer and media access control for personal area networks.

Near Field Communications (NFC) is a very short range wireless technology and can be used to access sensor readings, and operate door locks, or to open the browser in a smart phone to a URL for a web page relating to the tagged object.

Bluetooth is a short range technology with a suite of profiles for different categories of applications. Bluetooth Low Energy (BLE) offers extended battery life. It can be used for exchange of small amounts of data, either in a broadcast mode or for bidirectional connections. This is expected to be of increasing importance for applications running on smart phones or tablets. The W3C Bluetooth Community Group is drafting an API based upon the GATT profile for BLE, and Google have proposed the use of BLE for broadcasting URLs as part of their vision for the Physical Web.

There are a lot of these and they are continuing to evolve ...

IoT Technologies

ANT is a proprietary sensor network technology operating in the 2.4 GHz band. It can be used to transfer small amounts of data across networks with hundreds of sensors.

DASH7 is designed for long lived battery operated sensor networks, it works in the 433 MHz unlicensed band. The range is up to 1000m depending on power levels and data rates. Like ZigBee and BLE, DASH7 is aimed at transferring small amounts of data, and unsuitable for audio or video.

KNX for buildings s a standardized (EN 50090, ISO/IEC 14543), OSI-based network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus). The KNX standard is administered by the KNX Association. KNX can be realized over a mix of networking technologies, e.g. twisted pair cable, powerline networking, radio (KNX-RF), infrared and conventional ethernet.

EnOcean is a similar protocol to KNX for sensors that are self powered, e.g. harvesting energy when you push a switch that is sufficient for sending 2 or 3 packets. The sensors are quite expensive (e.g. 60 CHF) but available for motion sensors (light and thermal IR), beds, seats, window handles and so forth.

Infrared is widely used for remote control of TVs, air conditioners etc. Infrared was popular for PDAs and laptops in the late 90's and early 2000's, but lost ground to RF technologies such as WiFi and Bluetooth. Infrared is making a comeback for fast transmission of photos from phones to printers etc.

Universal Serial Bus (USB) s an industry standard defining cables, connectors and protocols. It is widely used for connecting devices to computers, e.g. keyboards, mouse pointers, hard drives for storage, game controllers, and also for connecting to printers, scanners, digital cameras, smart phones and tablets. USB is designed to power devices and is commonly used for charging device batteries, replacing the need for a separate cable.

Wireless USB (WUSB) is a standard for connecting devices using a wide band protocol in the 3.1 GHz to 10.6 GHz region. The range is 3 to 10m.

IoT Technologies

IEEE 1394 (Firewire) is a serial connection designed for high speed transfers, and similar in some ways to USB. IEEE 1394 has lost ground to USB as the latter has increased in speed, and due to the need for a separate power connection for Firewire devices.

WiFi ISO 802.11 is a local area network technology for managed or ad hoc networks in 2.4 GHz or 5 GHz bands.

Machine to Machine (M2M) is a generic term for wired or wireless communication technologies between devices. Mobile network operators are promoting cellular M2M, e.g. based upon GSM data modules, for applications such as smart meters.

Low Throughput Network (LTN) is a wide area wireless technology defined by ETSI, and offers long range and minimal battery consumption.

Weightless is a protocol for using white space spectrum for exchanging data between a base station and thousands of client devices. Base stations are directly connected to the Internet. Clients are allocated a schedule of times and frequencies to communicate with their base station. A database is used to avoid interference with local terrestrial TV broadcasts.

MQTT is a lightweight publish-subscribe protocol based upon TCP/IP connections. It is intended for embedded/constrained devices, and needs to be used in conjunction with a message broker.

XMPP is an XML based protocol used for presence, instant messaging, and real-time communication and collaboration.

Efficient XML Interchange (EXI) is a binary format for structured data that is suitable for embedded/constrained devices and offers further compression when used with a specific XML schema. It may be used in conjunction with CoAP.

JavaScript Object Notation (JSON) is a textbased representation for structured data that is increasingly popular with Web developers. JSON-LD is a set of conventions for using JSON for linked data.

Opportunity to simplify services by abstracting away from IoT connectivity technologies

- Easier development
- Less to learn
- Robustness to change

Browser based services

- Growth of wearables
  - Sports and personal health
- Home healthcare
- Home entertainment
- Home security
- Home automation
- NFC for tap based interaction
- Bluetooth Low Energy
- CoAP and other IoT protocols?

Bluetooth

- Innovations around Bluetooth Low Energy
  - Apple iBeacon, Paypal Beacon, ...
- W3C Bluetooth Community Group
  - http://www.w3.org/community/web-bluetooth/
  - Use cases
  - Draft API
- Using BLE to broadcast URIs to nearby phones
  - Google's Physical Web
  - Event stream for Service Worker?

NFC WG

http://www.w3.org/2012/nfc/

- Near field communications
  - Very short range for tap based interaction
  - NFC WG chartered in 2012
- NFC hardware is increasingly widely deployed
  - **Apple iOS**, no NFC API as yet
  - **Google Android**, see Chrome NFC API
  - **Microsoft Windows Phone**, see Proximity API
  - **Firefox OS**, see Web API
  - **Tizen**, see W3C NFC API
- W3C NFC API
  - http://www.w3.org/TR/2014/WD-nfc-20140114/

NFC API

- Possible use cases
  - Tap to play e.g. a peer to peer game
  - Tap to share e.g. coupons, contacts
  - Tap to control another device via handover
  - Tap to connect via WiFi or Bluetooth handover
  - Tap to read NFC tag
  - Tap to write NFC tag

NFC API

- Reading and writing NDEF messages on NFC tags
- Sending and receiving NDEF messages with peers (e.g. smart phone or other device)
- Bluetooth and WiFi pairing (handover)
- Card emulation is **not** yet supported
  - But could be in future specification

Device Gateways

- Bridging the gap between IoT and the Web
  - i.e. IoT connectivity techologies and Web technologies
- Identifying the device and selecting the appropriate drivers
  - Opportunity for JavaScript libraries
    - Need for low level IoT technology APIs
    - Updatable for enhancements and fixing security flaws
      - Constrained devices may not be directly updatable
- Bridging the security domains
  - IoT devices with limited resources
  - Firewalls and Network Address Translation
  - Web facing identity and authentication
- Support for discovery and registration

Service Platforms

- JavaScript platforms hosting services for the Web of Things
- Home hubs
  - Which could also function as gateways
    - Together with short range IoT controllers around the house
- Embedded in phones and tablets
  - Microsoft's Thali open source project
- Cloud based for scalability
  - Operated by large Internet companies
  - Superstores for apps and services

Discovery

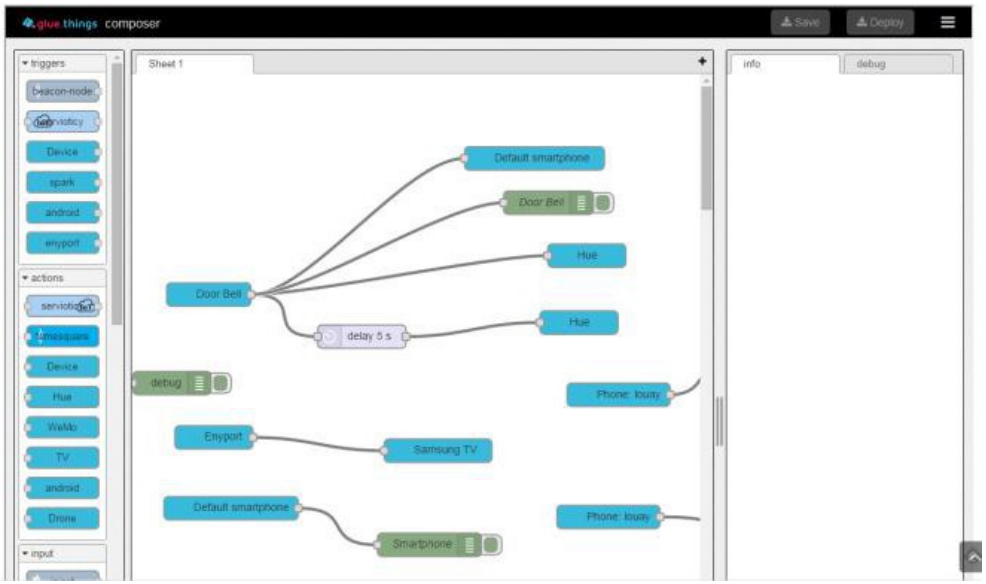
- When installing a new device
  - Need easy way to discover device and register it with service platform
  - Range of techologies available
    - Zeroconf and UPnP on WiFi
    - PIN on Bluetooth
    - Barcode or NFC
    - etc.
- End user seeking app/service
- Developer building composite service

Service Composition

- Connecting the output of one service to the input of another
  - Possibily across platforms hosted by different vendors
- Or more generally where one service has a dependency on another
- Requires rich descriptions
  - What is the purpose of this service?
  - What interfaces does the service expose?
  - What are the service's dependencies?
  - Who is authorised to access this service?
  - Are there any data handling policies to agree to?
  - Is it free or is there a fee of some kind?

Service Composition

- Efficient automatic composition:
  e.g. 300 mS to chain 2000 services
  - Configuration of Smart Environments Made Simple
    - Simon Mayer (ETH-Zurich)
      IoT 2014
  - Based upon semantic descriptions
- Visual user interfaces for manual composition
  - Node.RED and derivatives



Intent Based Search

- The role of the Web of Things for smart search
  - End user types in search string
  - Search engine recognizes intent and extracts machine interpretable properties
    - Combines this with info about user (subject to privacy preferences)
  - Search engine sends request to services that have registered for this intent
    - RESTful API for the intent
  - Services invoke other services as needed and then send back their results
    - This can involve dynamically composed services as appropriate to the user's request
    - Result could be a composition for later use
  - Search engine blends these into nicely formatted results page
  - In a fraction of second the users are able to view the answer to their question

End to End Security

- Security is critical to the Web of Things
  - Smart phones have many embedded sensors
  - There will be an increasing number of sensors all around us pretty much wherever we go
  - Privacy from snooping and safety from attackers
- Encryption is just the starting point
- Need for strong authentication of users, devices, services, and apps
  - Role of secure elements, hardware tokens, biometrics, etc.
- Identity management and *know your customer*
- Trust and endorsement by trusted 3rd parties

Resilience

- To rapidly changing demand load
  - Comet Shoemaker-Levy effect
    - Collision with Jupiter in July 1994 causes server meltdown
- Heterogeneous mix of device vendors and versions
  - Abstraction layers and design for flexibility
- Hardware and software faults
  - Inevitable when there are so many devices
  - Tolerance to failures, e.g. missing sensors
- Cyber attacks by criminals and hostile states
  - Defense in depth as the key principle
  - Monitoring and trip wires
  - Security Zones

The Web is about to become a whole lot bigger!

Questions?