The Internet of Things

An open-source perspective

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- What is the Internet of Things ?
- What are the things in the Internet of Things ?
- IoT technologies
- What's the use of IoT ?
- IoT application range
- An open IoT ?
- Open source IoT projects

- The term is very trendy !
- Everybody understands what it is
- But no agreed upon definition yet

A metaphor:
The interconnection of everything, including physical objects in a Web of things

The origin

- The term was first coined by Kevin Ashton, former director at Auto-ID in 1999
- An Internet with data about physical objects, where data is gathered automatically and seamlessly
- Focus is primarily on the kind of data and the way it is gathered
- Influenced mainly by logistics' concerns

The contribution of Ubiquitous computing

- Processing power becomes so cheap and tiny, that it may be embedded into any objects
- An Internet where potentially any object, not only servers, laptops and phones may connect to the network
- The focus is more on what connects to the Internet

Whatever the definition
- IoT is part of the future Internet
- IoT will blur boundaries between the digital world and the physical world
  - Physical objects will exists in the digital world
  - Digital actions may impact directly on a wide range of physical objects
- With the IoT, the environment will become the interface
  - Physical objects may become the medium for various digital actions

Potentially anything !

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A bike
- Equipped with an RFID tag in the attachment point

A sheep
- With an electronic ear tag
- A low-frequency RFID tag

Your bagages at the airport
- An RFID chip (EPC gen2 VHF) bag tag

A bluetooth toothbrush
- It can talk to your mobile phone !

Medical devices
- A bluetooth scale
- A bluetooth tensiometer
- Collect your data on your tablet or mobile phone

Implantable medical devices
- A pacemaker
- Insulin pumps
- Remotely monitored
- Remotely configured

Smart meters

- Gas / Water / Electricity

Smart shoes
- Pressure sensors
- Bluetooth connection to a mobile phone
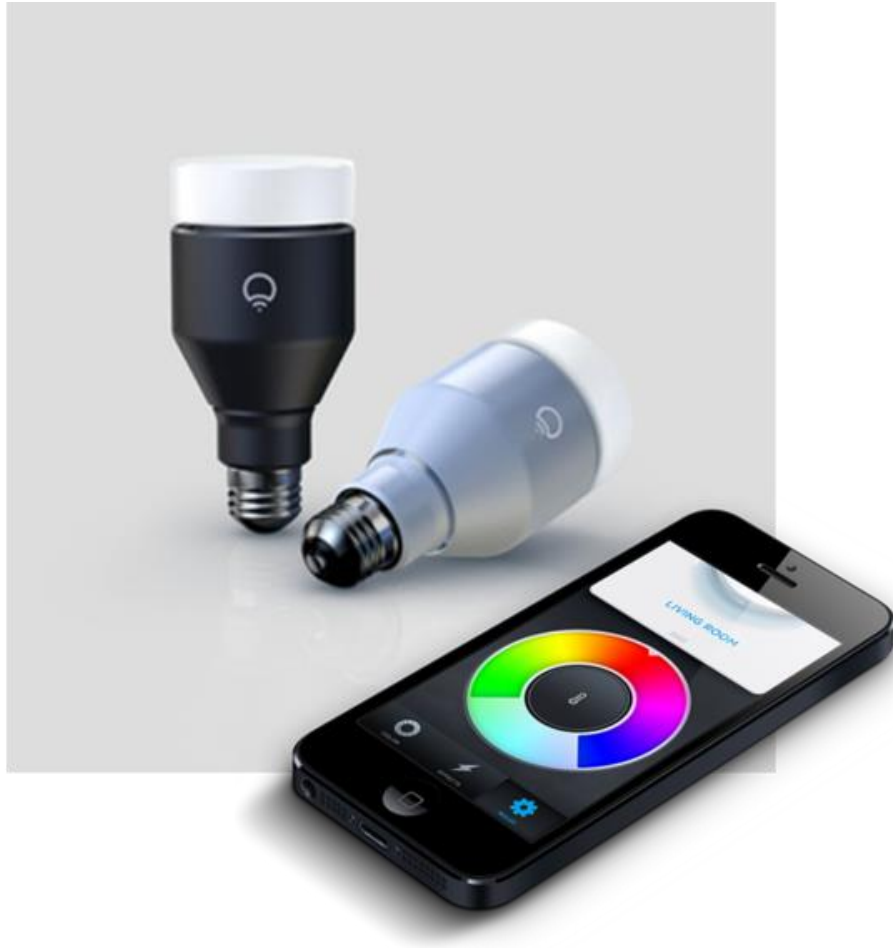- And a coach application on mobile phone

Home automation
- Wireless sensors / actuators
- Batteryless devices
- Enocean Radio protocol

A hotel room door lock

- Unlocks with an RFID card

Led bulbs

- Controlled with a mobile application over Wi-Fi
- Firmware update over 6lowPAN

Connected tires
- Built-in RFID chip
- With pressure sensors
- And temperature sensors

A connected bin
- Displays dynamic ads
- Tracks smart phones on the street
- Collects MAC addresses

A wide range of technologies

- Micro-electronic
- MEMS
- Energy harvesting / energy efficiency
- New materials
- RFID
- Radio technologies
- Security / Cryptography
- Cloud computing
- Big data

It is not a revolution ! (Or maybe it is ?)

- Enabled by continuous progress in miniaturization / energy efficiency / storage / …
- An **evolution** of
  - Already existing
  - Vertical solutions and technologies

- The revolution will arise from the explosion in the number of connected devices (50 billions in 2020).
- And from the new uses that will be invented and made possible by the availability of data and connected things

What's the use of IoT ?

"We're physical, and so is our environment. Our economy, society and survival aren't based on ideas or information – they're based on things. You can't eat bits, burn them to stay warm or put them in your gas tank. Ideas and information are important, but things matter much more. Yet today's information technology is so dependent on data originated by people that our computers know more about ideas than things"

Kevin Ashton, 1999

From basic to more advanced capacities

1. Identifying things
2. Authenticating things
3. Tracking / monitoring things
4. Controlling things
5. Delegating to things

Identifying things

- The most basic capacity
- Unique identifier for every thing
- EPC (GS1) vs. IPV6 addresses
- Who controls and allocates identifiers
- Retail and logistics industry

Authenticating things
- Knowing with certainty the identity of a thing
- Advanced RFID tags enabling digital signatures
- Promising to fight counterfeiting
- In some countries, authentication of drugs will become mandatory soon

Tracking things
- Where things are / Where they were last seen
- Location-based services
- Logistics and advertising industry
- Management of mobile assets in general

Monitoring things
- Monitor some properties of things
- Typically wireless sensors networks
- Energy industry
- Insurances
- Environmental monitoring systems

Controlling things
- Acting remotely on things
- Smart grid
- Home automation
- Anti-theft systems
- …

Delegating to things
- Allowing things to take some actions without human intervention
- Home automation
- Safety systems
  - The automatic 112 emergency calls from cars

The sky is the limit, but these are some typical applications:
- Smart grids
- Smart Home
- Smart Transport / mobility
- Smart cities
- Smart Health

- **Smart grids**
  - Smart energy meters
  - Smart appliances
  - Smart lights
  - Smart HVAC
  - …

Smart Home

- Domotic & Home automation
- Environmental monitoring
- Energy efficiency / energy metering
- Remote monitoring and control / Home security
- Smart appliances
- Interaction with the smart grid
- Home entertainment systems

Smart Transport / mobility

- Remote monitoring and diagnostics for vehicles
- Real-time location of vehicles
- Vehicle to vehicle communication
- Vehicle to infrastructure communication
- Traffic management and control
- …

Smart cities

- Air pollution monitoring systems
- Noise monitoring systems
- Smart parking management systems
- Smart lighting systems
- …

Smart Health
- Fall detection
- Patient location tracking
- Remote patient monitoring
  - Monitoring of medical parameters
  - Monitoring of drug delivery
- Implantable medical devices (Body area network)
- Independent leaving (Smart home)
- Drug counterfeiting prevention

The open IoT manifesto

- Open as a proven ecosystem model
- Open as inclusive
- Open as a security best practice
- Open to foster innovation
- Open to cope with interoperability challenges
- Open as a way to enhance trust

Open as a proven ecosystem model

- IoT challenges not so far from those face by the Internet 20 years ago
- Open communities / open standards and open source greatly contributed to a dazzling success

Open as inclusive

- From business-driven to citizen-centric
- Shared governance

Open as a security best practice
- Security is a major challenge for IoT
- Growing number of connected devices
- Each device represents a potential target for a cyber-attack
- Traditional manufacturers start producing connected objects
- They sometimes lack of appropriate cyber-security culture
  - Hotel room door lock
  - Pacemakers / insulin pumps

Open to foster innovation

- Vertically integrated market with vertically integrated proprietary platforms
- The situation of the computer industry 30 years ago
  - Network effects
  - Switching costs
  - High up front R&D costs
- Open standards
  - Lower entry barriers / Encourage competing implementations

- **<u>Open standards and sources foster innovation, because they enable to build on the shoulders of giants</u>**

Open to cope with interoperability challenges

- Tremendous value from the composition of different systems and domains into larger systems
- IoT is a vertically integrated market with vertically integrated proprietary platforms
  - Massive interoperability issues
- Definition and wide adoption of open standards is a prerequisite for IoT to become reality

The promising iToothBrush v1.0

- A brand new 🍍 Pineapple Inc product !
- A Bluetooth toothbrush
  - Packed with accelerometers and gyroscopes
- A multimedia coach
  - Monitors in real-time the toothbrush's movements
  - Displays live advices on a two-way mirror

The marvelous iToothBrush v2.0

- A mobile application
  - Your dental hygiene data is stored on the cloud
  - Analyses your habits
  - Charts performance indicators and evolution
- Face recognition and tracking
  - Live feedback and advices superimposed on your face

The not so marvellous iToothBrush v2.0

- You start receiving twice a day promotional coupons for another toothpaste brand
- Your health insurance company notifies you that your dental premium will increase by 20%, because of your substandard habits
- You realize the damn thing
  - Is in your bathroom
  - Has a camera
  - Has Wi-Fi and Internet connection !

How trustful is it ?

Open as a way to enhance trust

- Software is everywhere and trustworthiness becomes less visible
- Trustworthiness implies:
  - Things' data are secured:
    - Availability / Confidentiality / Integrity
    - No repurposing of data
  - The things are robust
    - Mission critical constraints
  - The things are safe
    - Safety critical constraints

Open as a way to enhance trust
- Openness is a security best practice
- Openness increase transparency and thus helps to build trust
- Open standards and open source ease certification
  - Reuse of certified open source commoditized components
  - Ease inspection of third-party
- Open eco-system that puts trust, user control and transparency at its heart in order to gain the confidence of everyday users and citizens

Some facts
- Already an impressive number of open IoT projects
- Many include both open software and open hardware
- Some are already quite standard in commercial products
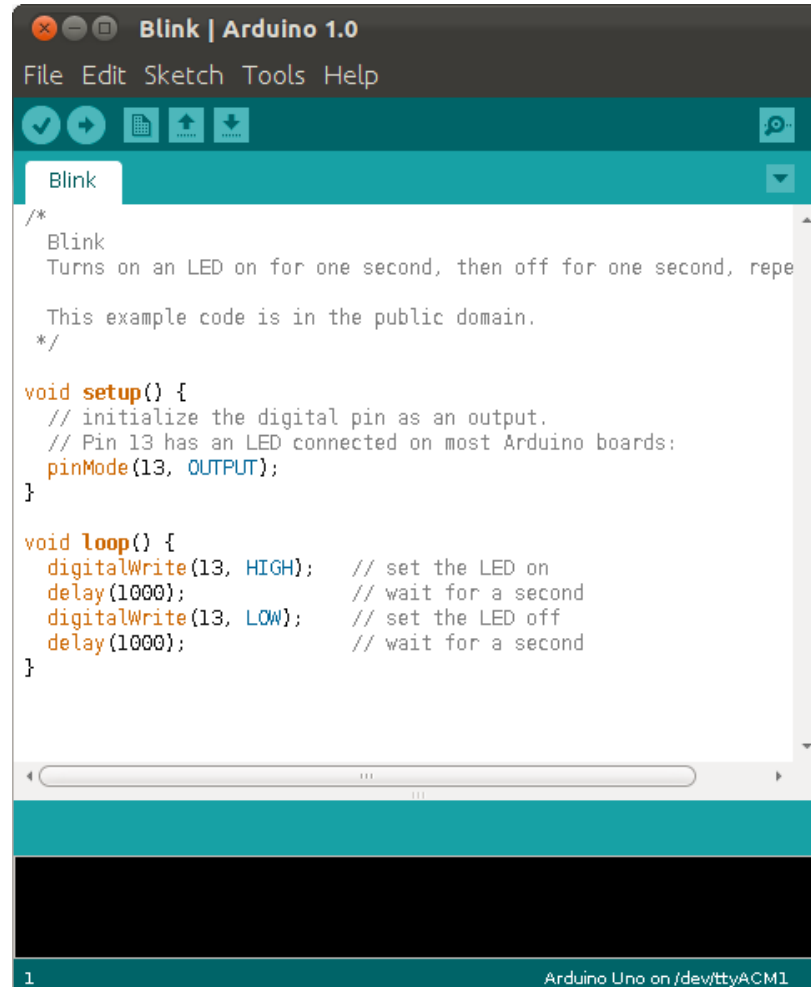
The featured projects
- MQTT
- Arduino
- Contiki

- **M**essage **Q**ueuing **T**elemetry **T**ransport
- An **OASIS** <u>open standard</u>
- Contributed initially by IBM and Eurotech
- An M2M / IoT connectivity protocol
- An extremely lightweight publish / subscribe message protocol
  - A kind of lightweight **AMQP** (**OASIS** open standard)

- Principles (Client / Broker / Topics)

- Brokers run on servers
- Brokers as services on the cloud (Xively, …)
- Clients run on various platform
  - Mobile phones (iPhone, Android, Windows Phone)
  - Development platforms (Arduino, Netduino, Mbed, …)
  - Browsers (JS / web sockets)
  - Industrial platforms (embedded boards / SCADA / gateways)
  - Pacemakers
  - Infotainment in cars
  - GPS trackers
  - Home automation / Smart meters

- Several <u>open source</u> implementations
  - Mosquitto (mosquito.org) C/C++/Phyton client and broker
  - Paho (www.eclipse.org.paho) C/C++/Java/JS client
  - RabitMQ (www.rabbitmq) MQTT adapter, broker

- A hardware and software open source project
- Simple / cost effective prototyping and DIY hardware platform
- With many hardware extensions: The shields
- And a complete open source software platform (GNU GPL v2)
  - IDE,
  - Compilers
  - libraries
  - Many non-Arduino platforms also use the Arduino software platform
- Used in many IoT / Connected objects projects

- Simple Java-based IDE
- Simple and intuitive for non-programmers
- C / C++ programming
- No real operating system
- Relies on GNU toolchain / LibC and Wire OSS

- Many variants, offsprings of the Arduino project

TinyDuino
- A small size Arduino compatible platform
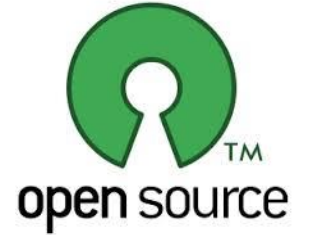
FLORA
- An Arduino compatible platforms for wearable computing

EDUCA DUINO
- An Arduino compatible platform targeting education projects

netduino
- An open .NET platform
- Compatible with Arduino shields

- **Contiki**
  - An open-source operating system (BSD-style License)
  - Developed in C
- **Instant Contiki**
  - A complete development environment
  - Runs in a dedicated Linux virtual machine
- **Cooja**
  - A network simulation tool
  - Enables to simulate networks of Contiki running nodes

- Targets specifically IoT devices
  - Low-cost / battery-operated / low-power
  - Full IPV6 support
  - Wireless communication (6lowpan)
- Can be used to build wireless sensor networks (IEEE 802.15.4)
  - Relay / multi-hop communication
  - Radio stacks works even in low power mode (ContikiMAC)

- Used in many open source and commercial products
  - Cities Smart light networks
  - Networks of light bulbs
  - Networks of smart energy meters

Thanks !