

# Introduction to the Internet of Things

Credits:

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ICTP



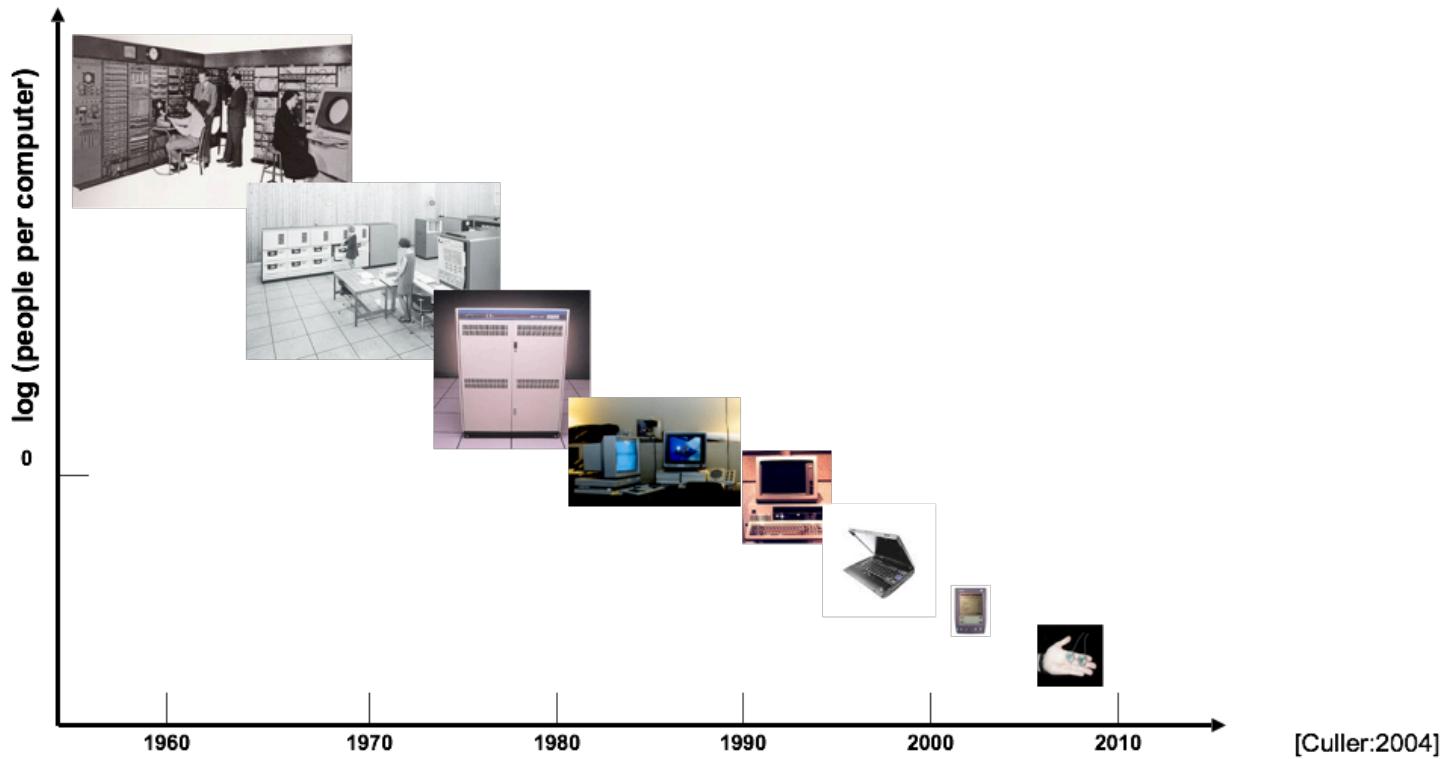
# Hands-on, 5': Defining IoT

What does *Internet of Things* mean to you?

Write down your definition on a post-it.

We will check out the result together.

# Vision



# Internet of Things (IoT)

"Internet-connected computers, with sensors and actuators." — [@tamberg](#)

"Physical objects with a Web API." — [@hansamann](#)

IoT: "Global network of computers, sensors and actuators, connected through Internet protocols."

*Web* of Things: "RESTful Web services that measure or manipulate physical properties." — [@gsiot](#)



# Internet of Things (IoT)

“The IoT can be viewed as a global **infrastructure** for the information society, enabling advanced services by interconnecting (**physical** and **virtual**) things based on existing and evolving interoperable information and communication technologies (ICT).”— **Recommendation ITU-T Y.2060**

# History of IoT (not new!)

The first telemetry system was rolled out in Chicago way back in **1912**. It is said to have used **telephone lines** to monitor data from power plants.

Telemetry expanded to weather monitoring in the **1930s**, when a device known as a **radiosonde** became widely used to monitor weather conditions from balloons.

# History of IoT (not new!)

Broad adoption of M2M technology began in the 1980s with wired connections for **SCADA** (supervisory control and data acquisition) on the factory floor.

In the 1990s ADEMCO built their own **private radio network** because cellular connectivity was too expensive.

In 1995, Siemens introduced the **first cellular module** built for M2M.

# History of IoT (not new!)

“Machine to Machine” (M2M)  
(~1970s +)



Internet of Things Beginnings



Carnegie Mellon Internet Coke Machine (1982, 1990)



Internet Toaster (1990)



Trojan Room Coffee Pot (first webcam) (1991)

# Drivers of IoT

Small, inexpensive, low power computers.

Small, inexpensive, low power sensors.

Short and long range connectivity.

Cloud computing and storage.

Standard (IoT) protocols.

# Moore's law

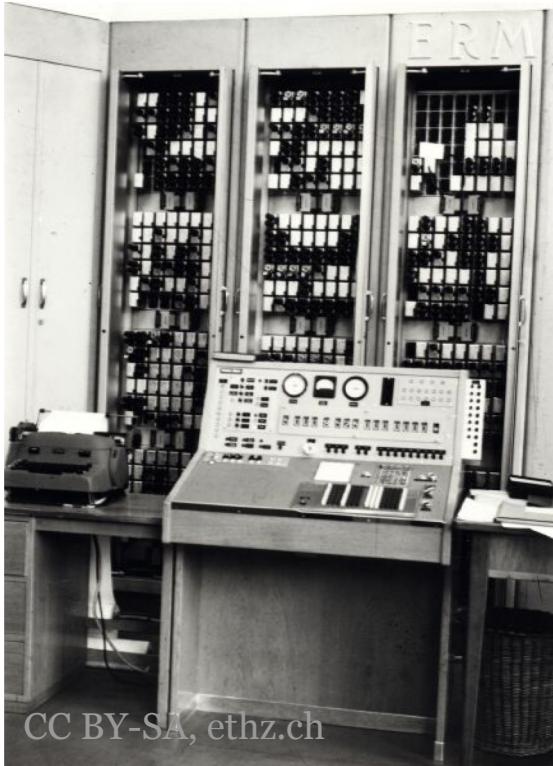
"Moore's law is the observation that the number of transistors in a dense integrated circuit doubles about every two years." — [Wikipedia](#)

Gordon Moore, a founder of Intel, [noted this in 1965](#).

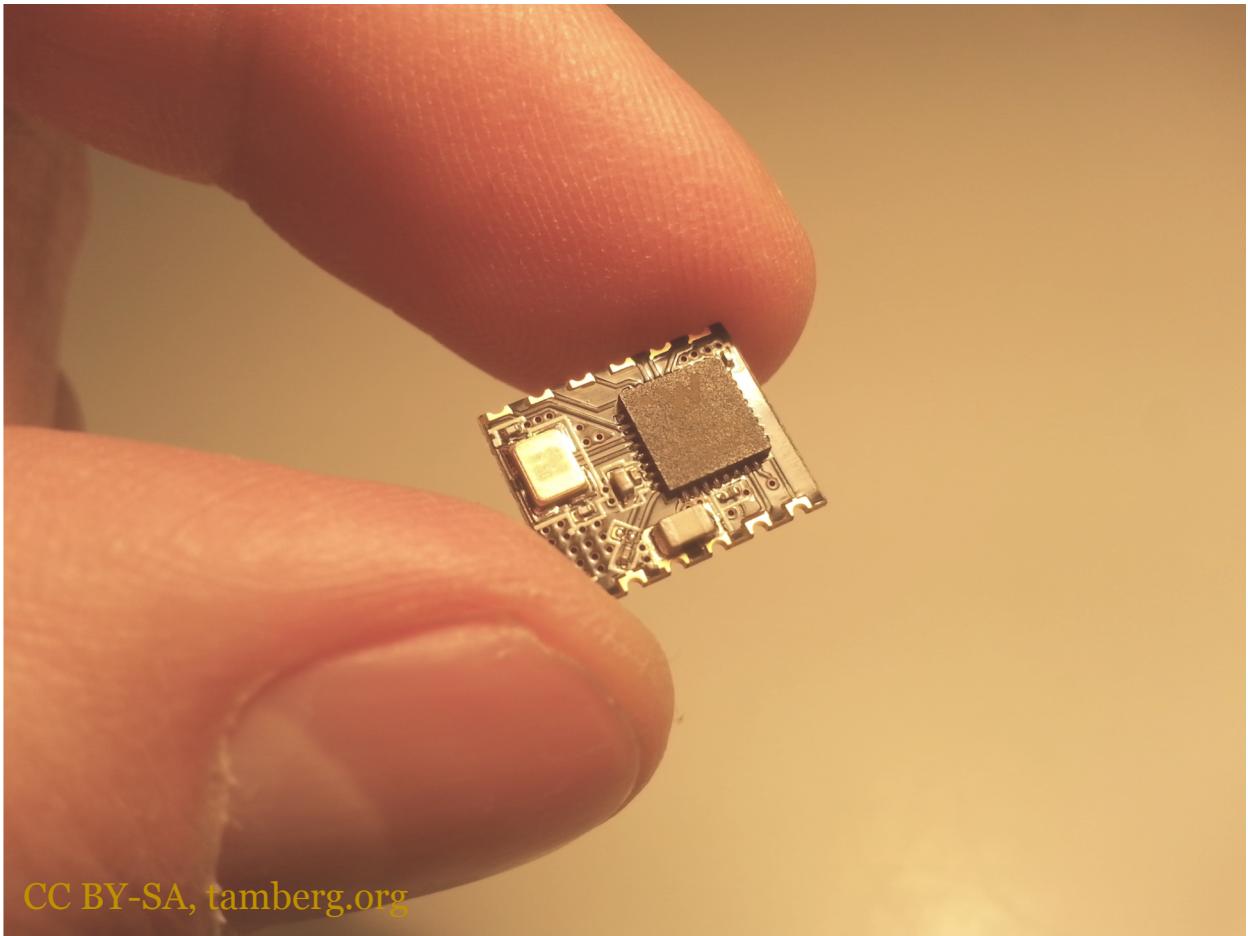
- => Computers become more powerful, less expensive.
- => The same power is available in a smaller package.
- => Small computers can be embedded into things.



# Moore's law

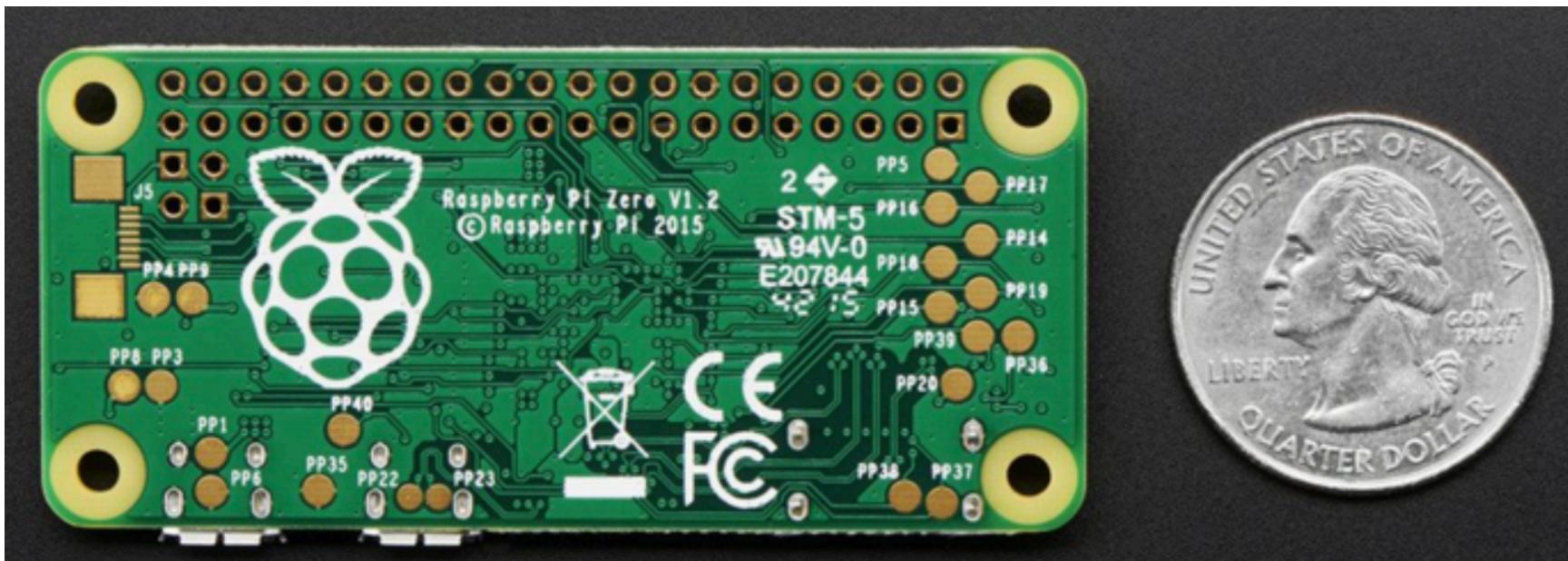


CC BY-SA, ethz.ch



CC BY-SA, tamberg.org

# RPi zero: \$5



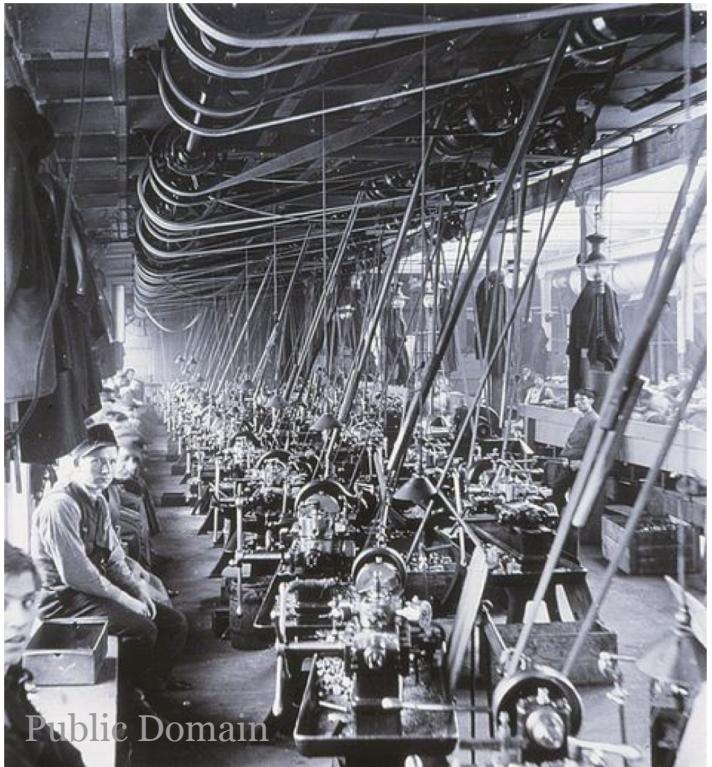
# Ubiquitous computing

"The idea of integrating computers seamlessly into the world at large [...] *Ubiquitous computing*"

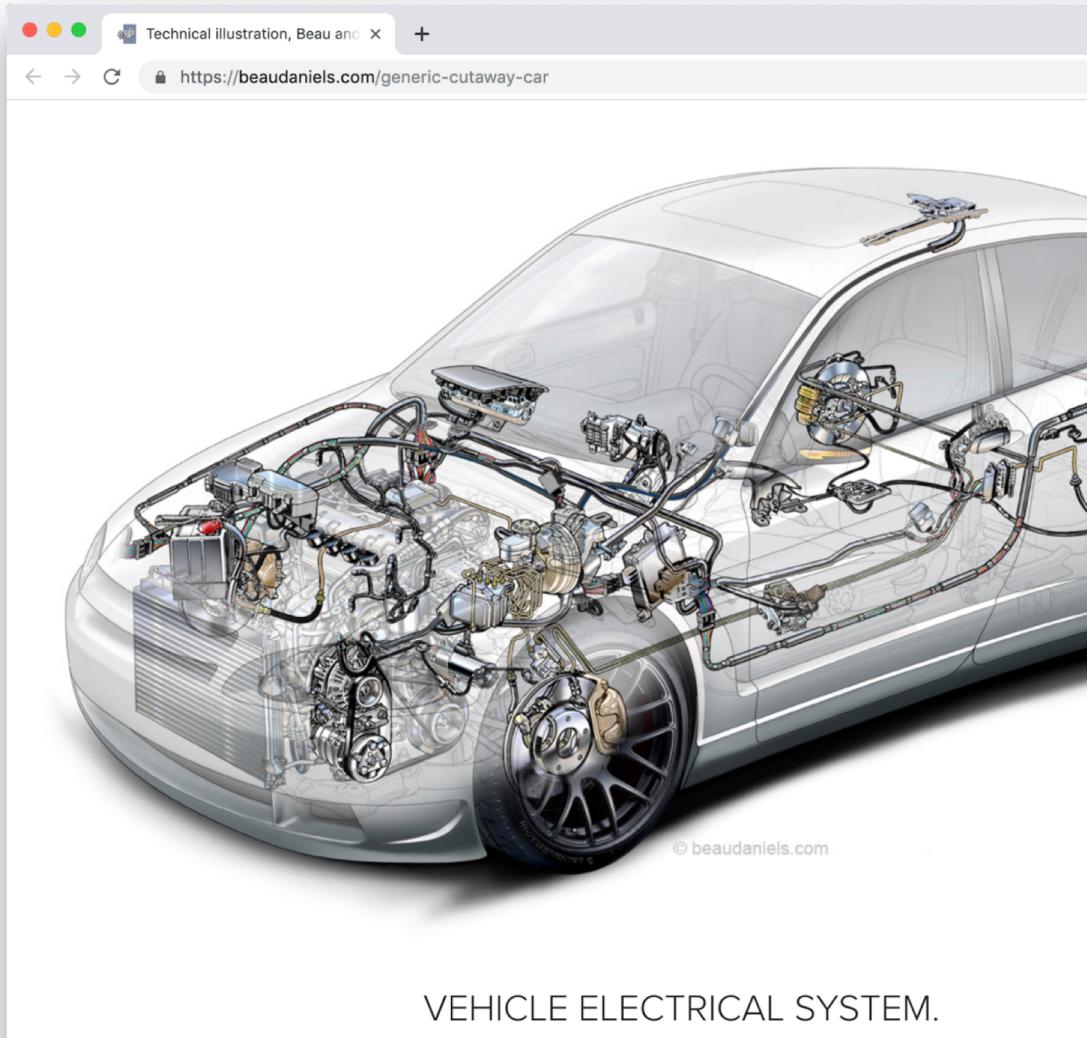
"How do technologies disappear into the background?  
The vanishing of electric motors may serve as an instructive example"

— Mark Weiser in [The Computer for the 21st Century](#)

# Motors: 1 vs. n



Public Domain



© beaudaniels.com

VEHICLE ELECTRICAL SYSTEM.

# Things – ITU definition

“Things are objects of the physical world (physical things) or of the information world (virtual world) which are capable of being identified and integrated into communication networks. Things have associated information, which can be static and dynamic.” – Recommendation **ITU-T Y.2060**

# Things – ITU definition

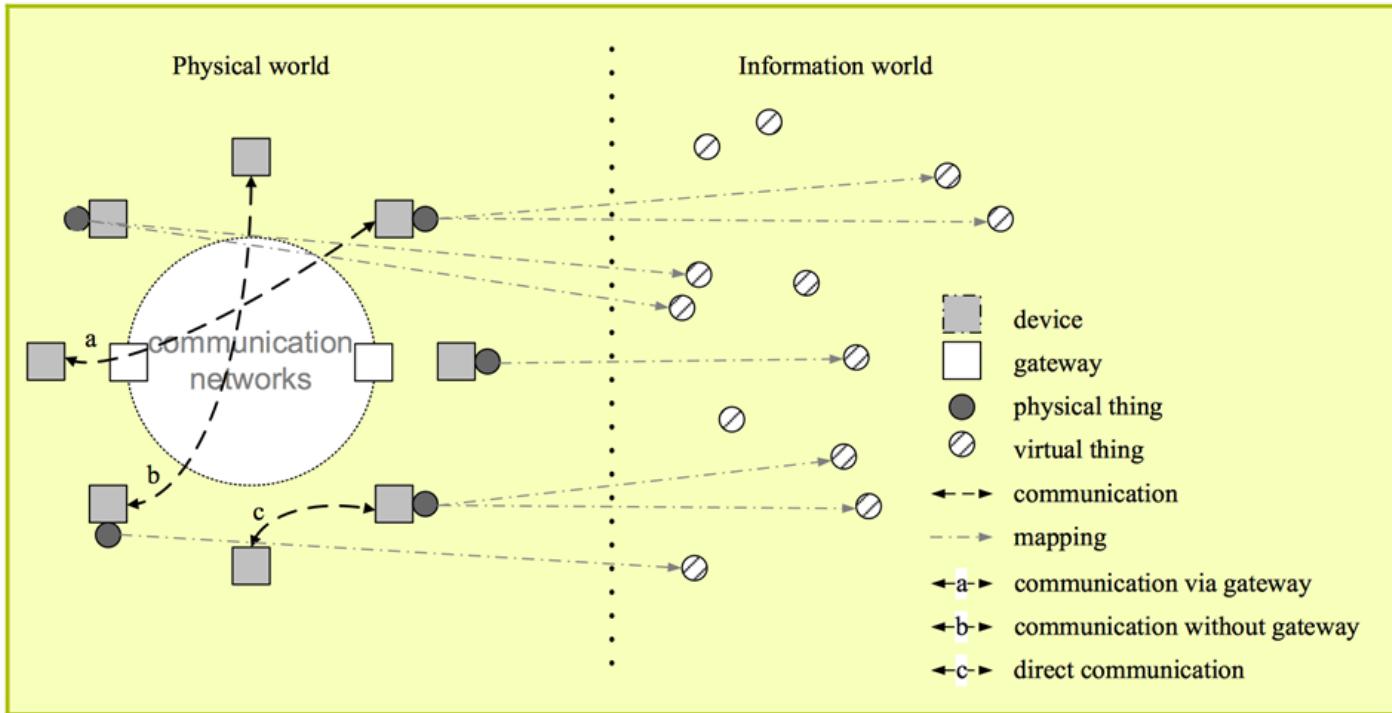
“**Physical** things exist in the physical world and are capable of being **sensed**, **actuated** and **connected**. Examples of physical things include the surrounding environment, industrial robots, goods and electrical equipment.” – Recommendation **ITU-T Y.2060**

# Things – ITU definition

“**Virtual** things exist in the information world and are capable of being **stored, processed** and **accessed**. Examples of virtual things include multimedia content and application software.”

– Recommendation ITU-T Y.2060

# Things – ITU definition



# Device – ITU definition

“A device is a piece of equipment with the **mandatory capabilities of communication** and optional capabilities of sensing, actuation, data capture, data storage and data processing. Some devices also execute operations based on information received from the information and communication networks.” — Recommendation ITU-T Y.2060

# Fundamental characteristics – ITU

**Interconnectivity:** With regard to the IoT, anything can be interconnected with the global information and communication infrastructure.

**Heterogeneity:** The devices in the IoT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.

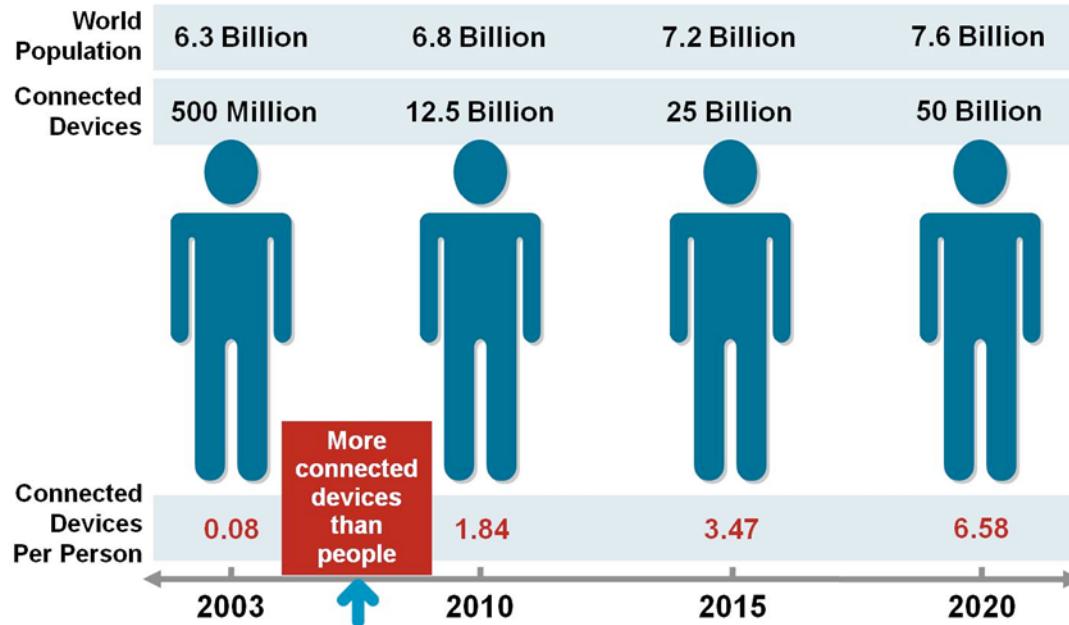
# Fundamental characteristics – ITU

**Dynamic changes:** The state of devices change dynamically, e.g., sleeping and waking up, connected and/or disconnected as well as the context of devices including location and speed. Moreover, the number of devices can change dynamically.

# Fundamental characteristics – ITU

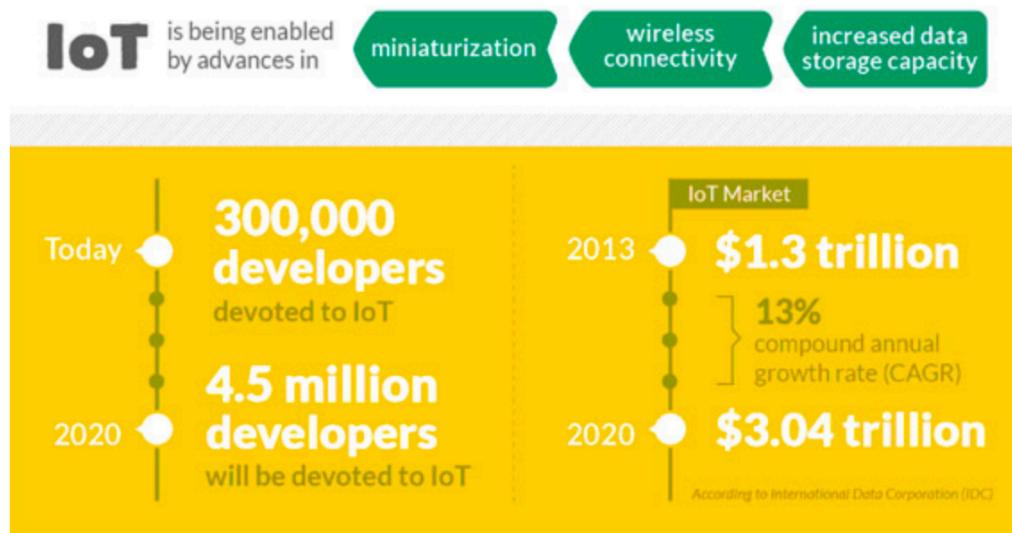
**Enormous scale:** The number of devices that need to be managed and that communicate with each other will be at least an order of magnitude larger than the devices connected to the current Internet. The ratio of communication triggered by devices as compared to communication triggered by humans will noticeably shift towards device-triggered communication.

# Predictions



Source: Cisco IBSG, April 2011

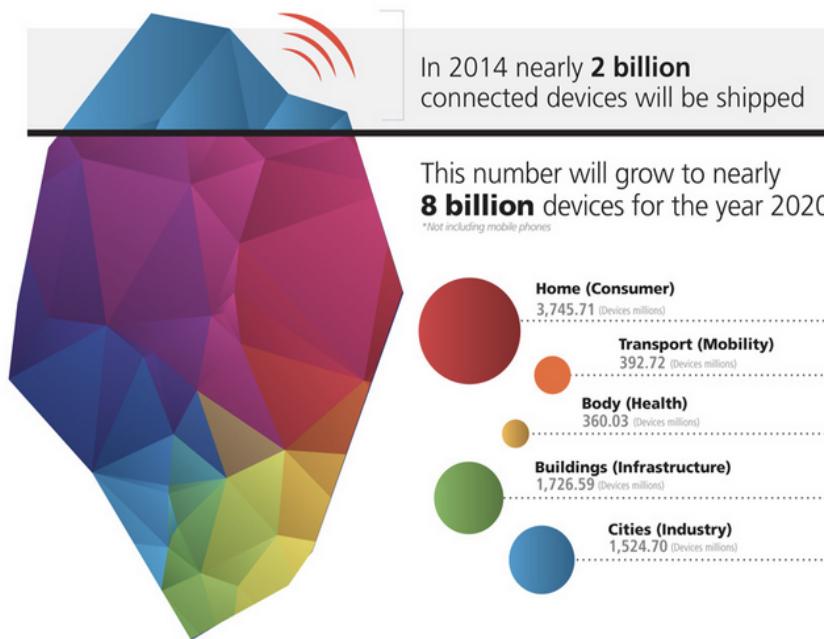
# Predictions



*PwC's 6th Annual Digital IQ survey*

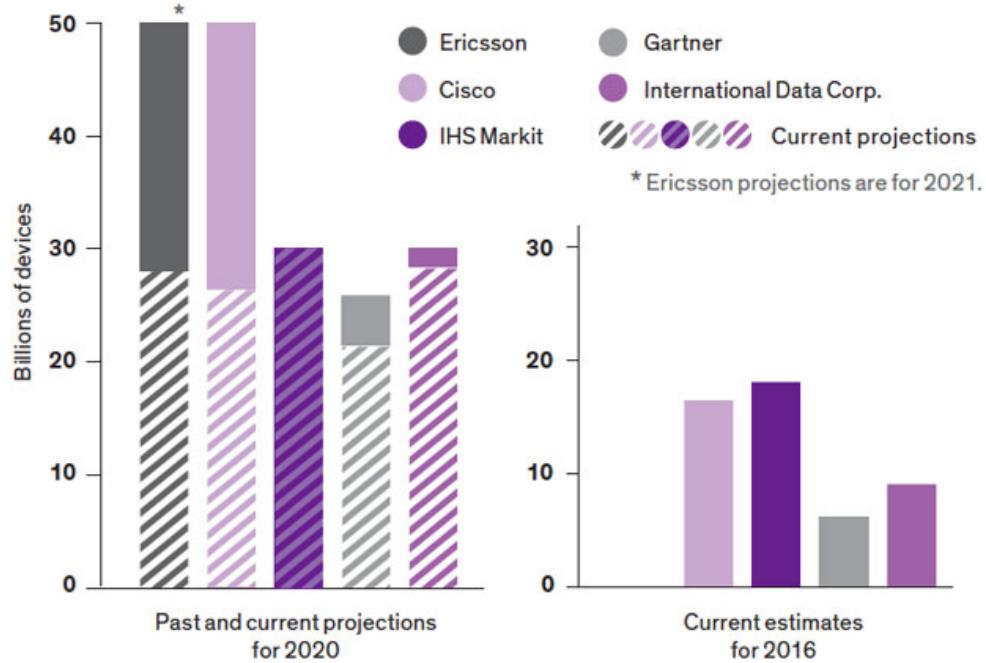
# Predictions

## Connected Devices



Source: <http://www.postscapes.com/what-exactly-is-the-internet-of-things-infographic/>

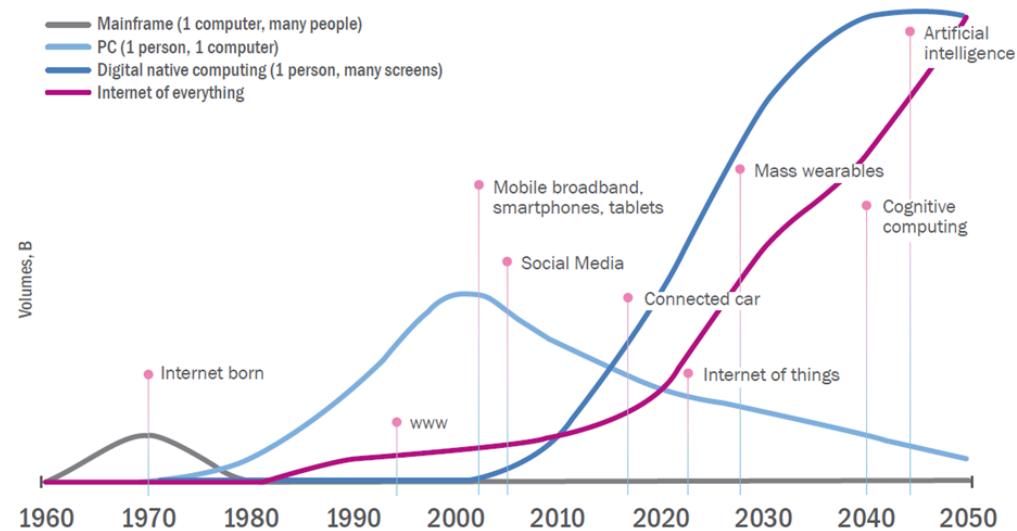
# Internet of Fewer Things



# One to many to any

## History of the future

One to many to any: ICTs from happy few to the masses



# Connectivity

Ability to communicate with another computer.

Personal area network (PAN, e.g. BLE, Zigbee).

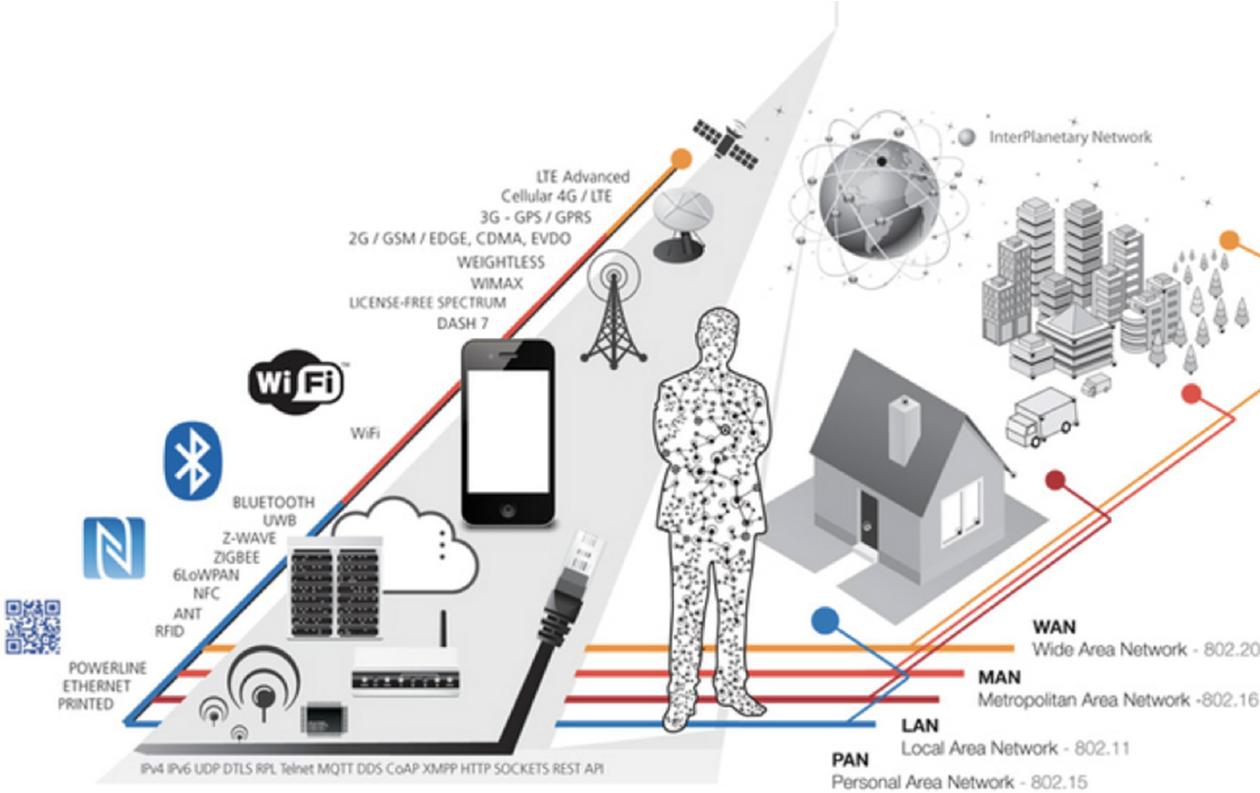
Local area networks (LAN, e.g. Ethernet, Wi-Fi).

Wide area networks (WAN, e.g. 3/4G, LoRaWAN).

The range grows from "room" to "building" to "city"  
(e.g. BLE, 30m; Wi-Fi, 100m; LoRaWAN, 2-15km).



# Connectivity



# Connectivity: key aspects

**Range** - are you deploying to a single office floor or an entire city?

**Data Rate** - how much bandwidth do you require? How often does your data change?

**Power** - is your sensor running on mains or battery?

**Frequency** - have you considered channel blocking and signal interference?

**Security** - will your sensors be supporting mission critical applications?

# IoT high level use cases

IoT enables these core use cases, in different flavors.

Efficiency (e.g. trash bins let you know they are full).

Convenience (e.g. remotely preheat a holiday home).

New insights (e.g. a crowdsourced air quality map).

Sectors include connected consumer products,  
citizen sensing, industrial IoT and many more.



# Connected products

Internet-connected consumer products, e.g.

[Nest](#), a connected, self-learning thermostat.

[Philips Hue](#), connected lights with a Web API.

[Withings Scale](#), logs your weight to a dashboard.



It's beautifully designed to keep you comfortable and help save energy.



[Proven energy savings.](#)  
Can pay for itself in two  
years or less.<sup>1</sup>



Turns itself down when  
you're away.



Control it from anywhere.<sup>2</sup>



Remote temp sensing.  
[Learn more >](#)



# Smart lights Smarter controls

Philips Hue is not just a smart bulb, it's a smart lighting system. The smart lights, Hue Bridge, and smart controls will forever change the way you experience light.



## Hue lights

These smart and energy-efficient LED lights come in a wide variety of shapes, sizes, and models to suit your space.



## Hue Bridge

The heart of your Philips Hue system, the Bridge acts as a smart hub, connecting your devices to your smart lights. You can add up to 50 Philips Hue lights and accessories to one Bridge.



## Hue app

Control your smart lights quickly and conveniently with the Philips Hue app.

Weight & BMI Wi-Fi Scale - Body

https://www.withings.com/us/en/body

## Meet your new accountability partner

Body offers a complete weight tracking experience tailored to individuals seeking easy, effective weight management. Weighing in is just the first step. Each session also provides instant feedback via weight trend and BMI screens, plus automatic sync to a free app on your smartphone, so you can track progress any time, anywhere.



ambient™

# Ambient Umbrella

Glowing intelligence  
lets you know that there's  
rain in today's forecast.



# Citizen sensing

Self-built sensors, open data, nonprofit, e.g.

[Safecast.org](#), a crowdsourced radiation map.

[Oxford Flood Network](#), measuring water levels.

[Luftdaten.info](#), particles and nitrogen oxides map.

[Smart Citizen Kit](#), air quality.





65.54  
LOG10  
10.09  
3.99  
2.13  
1.31  
0.87  
0.60  
0.43  
0.31  
0.23  
0.16  
0.12  
0.08  
0.05  
 $\mu\text{Sv/h}$

Google





# SAFECAST BGEIGIE NANO

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# Oxford Flood Network



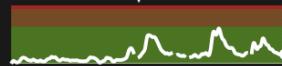
Citizens, Building a Smart City



# Flood Network

LIVE RIVER LEVELS (BETA)

Godstow Lock ⬤



Eynsham Lock ⬤



Minns Estate ⬤



New Botley ⬤



Cherwell ⬤



Osney Lock ⬤



Eastwyke (Hogacre) ⬤



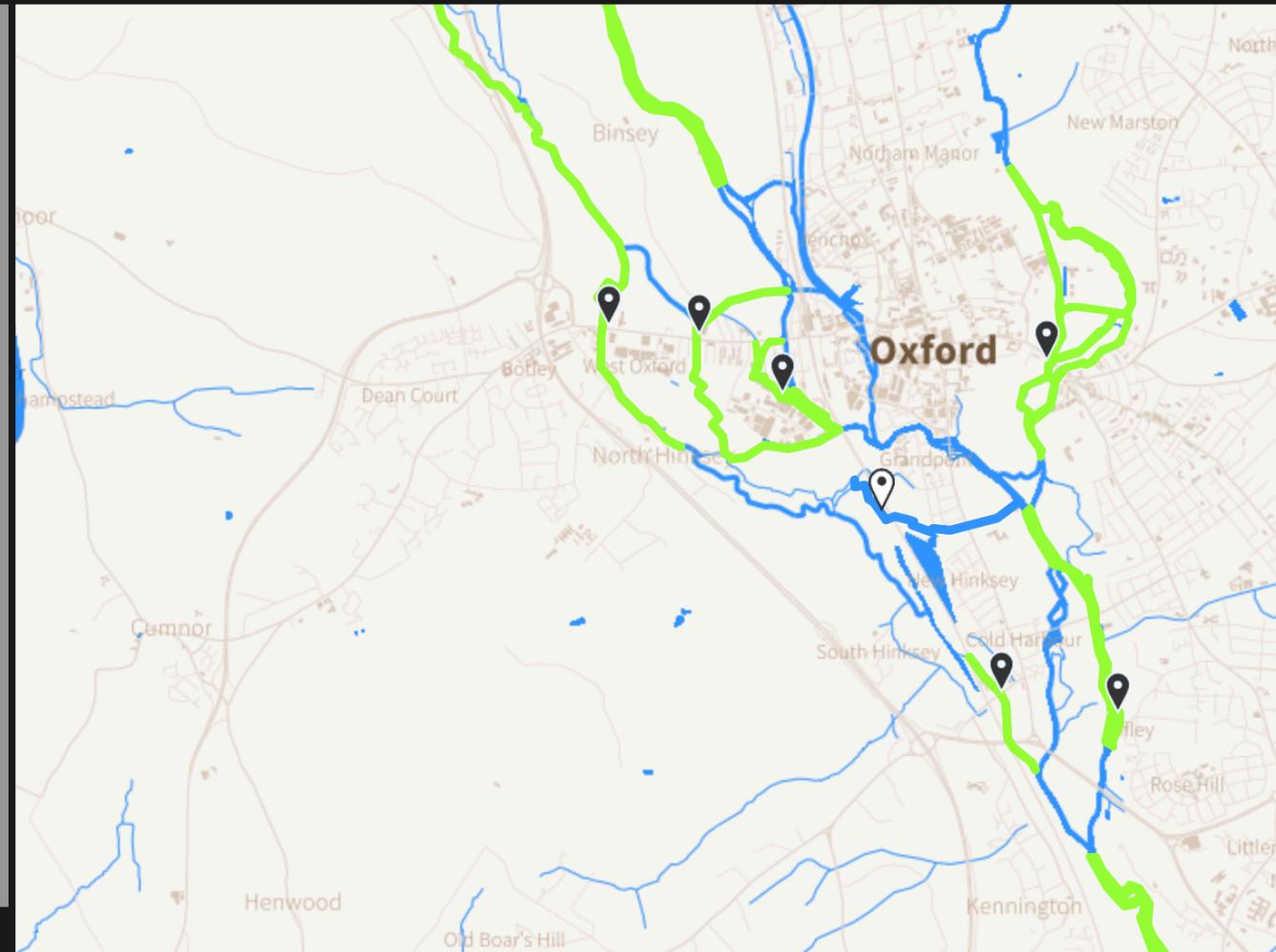
Coldharbour ⬤



Iffley Lock ⬤



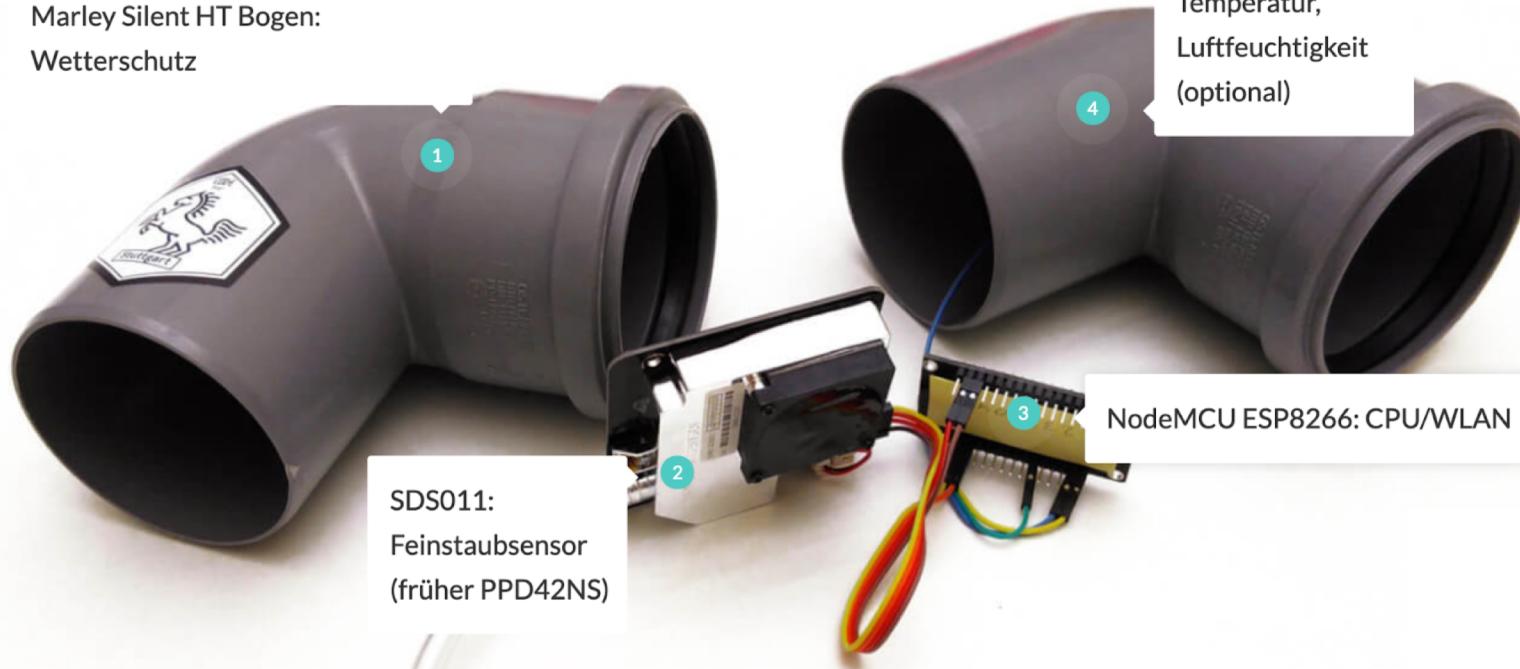
Sandford Lock ⬤



Marley Silent HT Bogen:  
Wetterschutz

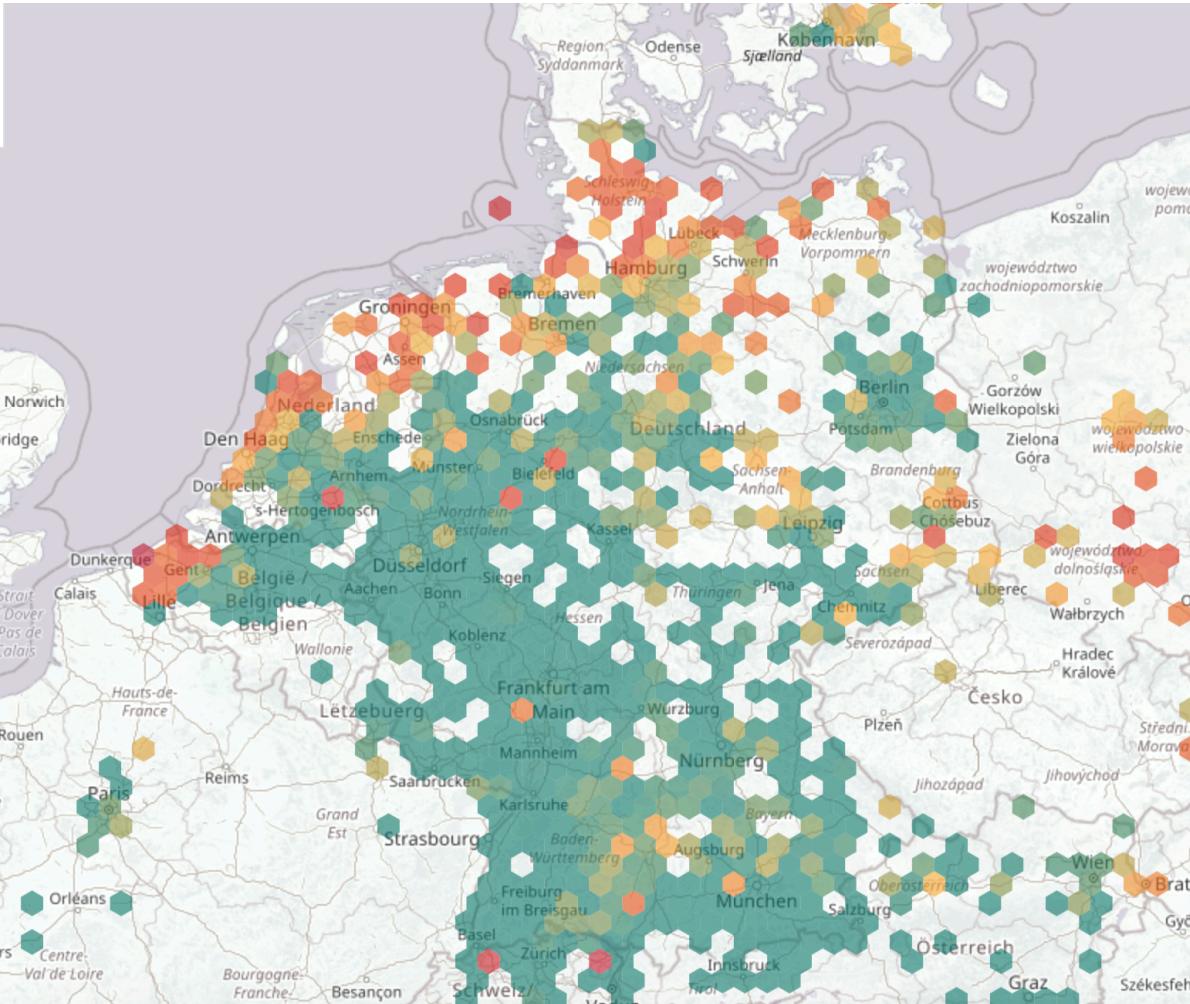
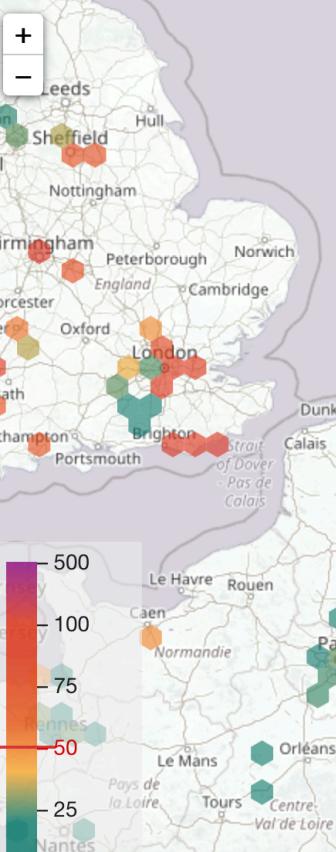


DHT22/AM2302:  
Temperatur,  
Luftfeuchtigkeit  
(optional)



Jetzt spenden

 betterplace.org



(close)

Erklärung einblenden

## #Sensors 4

Sensor ID	PM10 µg/m³	PM2.5 µg/m³
mean	14	9
(+) 2604	10	8
(+) 5827	15	8
(+) 5979	17	11
(+) 18366	15	10



# Industrial IoT

"Industry 4.0", cyber-physical systems.

Predictive maintenance (know what *will* break).

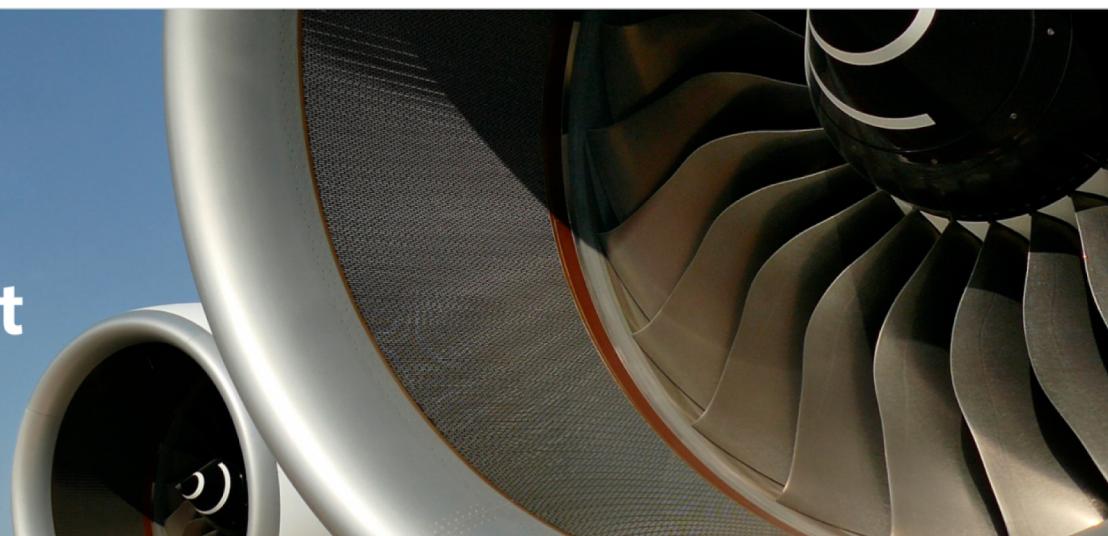
Anomaly detection (find *unknown* issues).

Live feedback (from *deployed* engines).

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# Discover the #PowerOfTrent



Latest updates on our Trent engine family

# IoT reference model

Device, thing, product (with sensors & actuators).

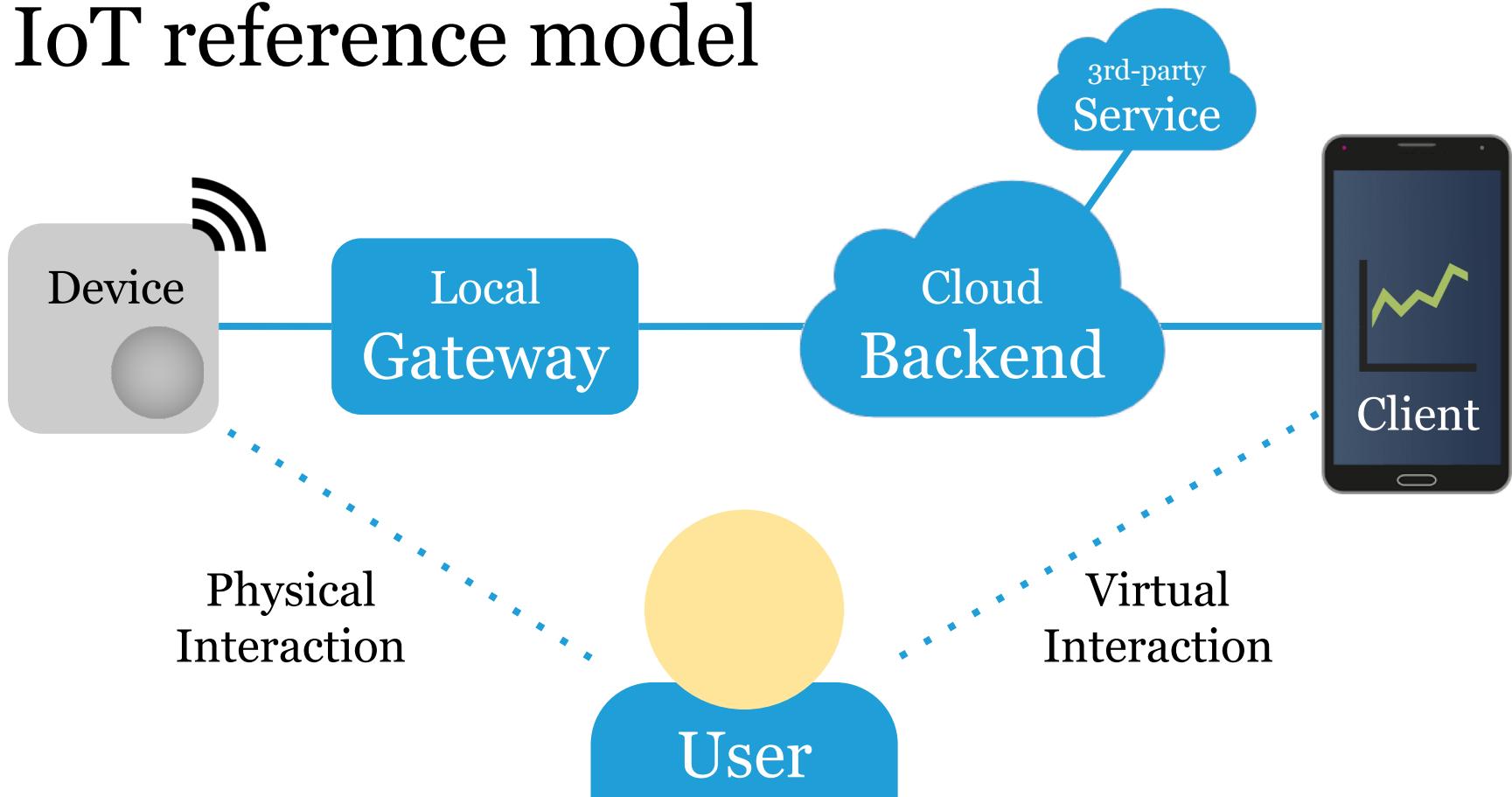
Gateway, hub, bridge (in the local network).

Backend (IoT platform, "in the cloud").

Client (app or 3rd-party service).

User (local or remote).

# IoT reference model



# Device

Embedded computer with sensors and actuators.

Connectivity on the chip or as an external module.

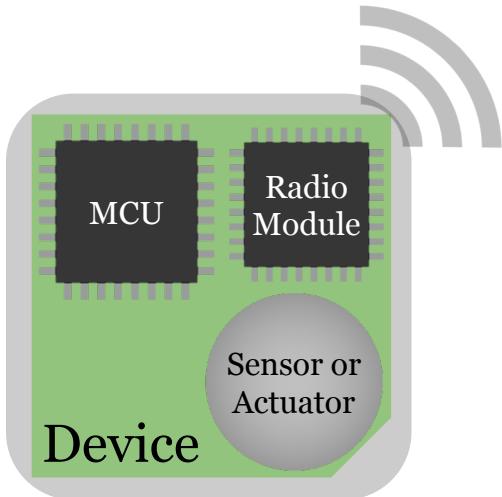
Microcontroller (MCU) with constrained resources.

Small, slow processor, limited memory, low power.

Often battery powered or harvesting energy.



# Device

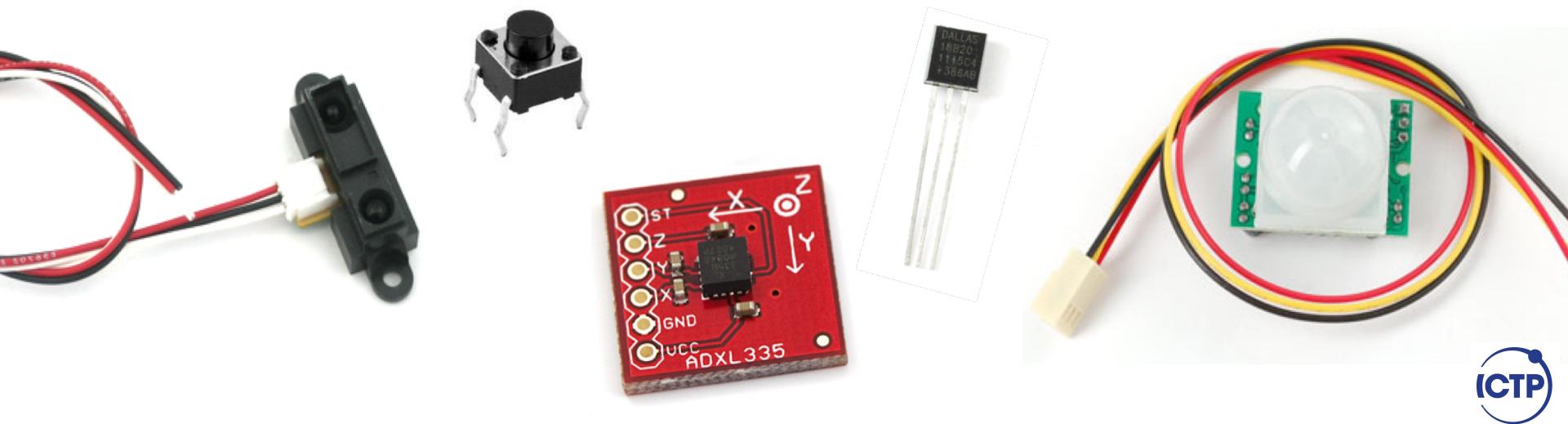


CC BY-SA, tamberg.org

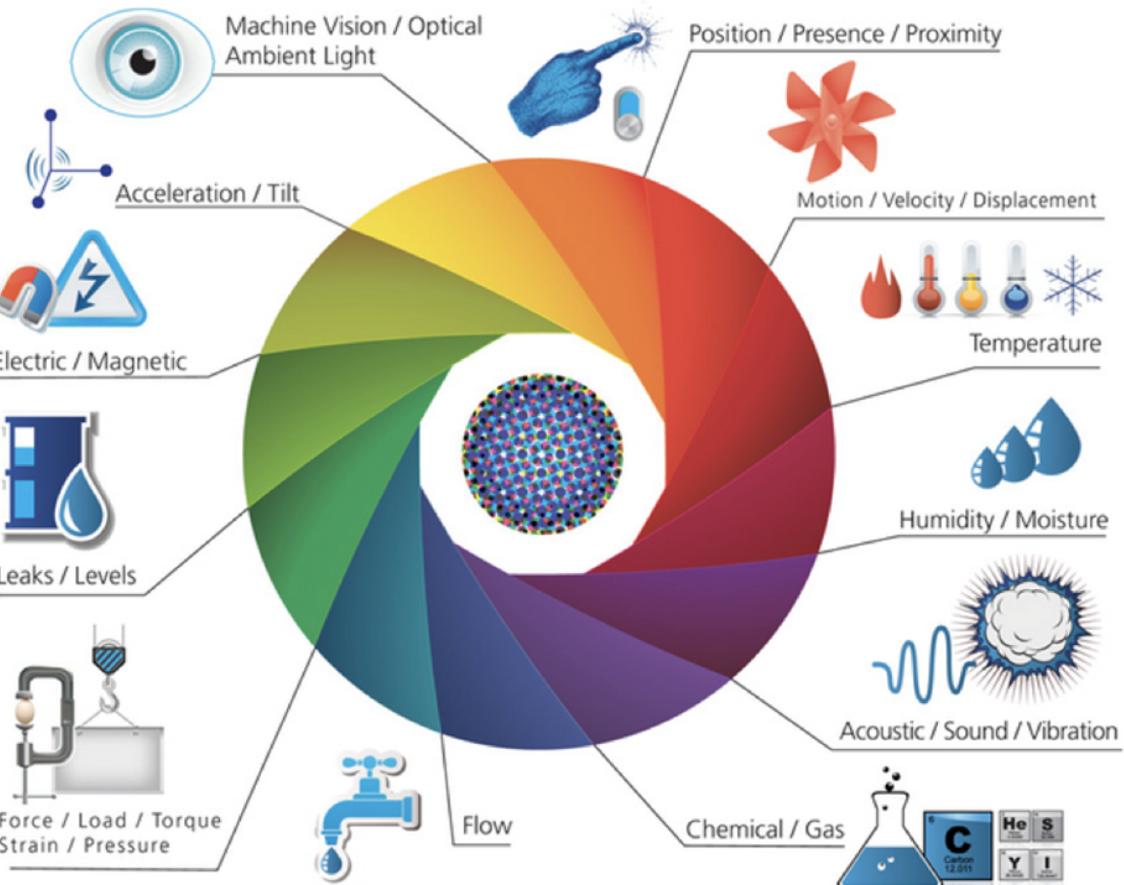
# Sensors

Convert physical properties to electrical signals.

E.g. temperature, sound, light, distance, flow.



# Sensors



## Functionality

## Sensor Type

\$150-\$1000+

- Long-term install/deployment
- Industrial scale deployment
- Extreme accuracy/precision
- Typically large enterprises
- Ease of solution interoperability

- Chemical/Gas
- Electrical/Capacitive
- Pressure/Load/Weight
- Proximity/Position

\$50-\$150

- Residential/commercial
- Advanced development kits
- Consumer-based support
- Cloud partnership capability
- Fast deployment
- Medium infrastructure required
- Low-Medium accuracy/Precision

- Water Treatment/Flow
- Weather/Temperature
- Motion/Velocity
- Acoustic/Sound/Vibration
- Light/Imaging
- Proximity/Position
- Flex/Force/Strain

\$0 - \$50

- Single function
- DIY/Prototyping often needed
- Limited without other hardware
- Requires basic equipment
- Geared towards amateurs
- Singular functionality
- No infrastructure required

- Water Treatment/Flow
- Weather/Temperature
- Motion/Velocity
- Acoustic/Sound/Vibration
- Light/Imaging

Highest Cost

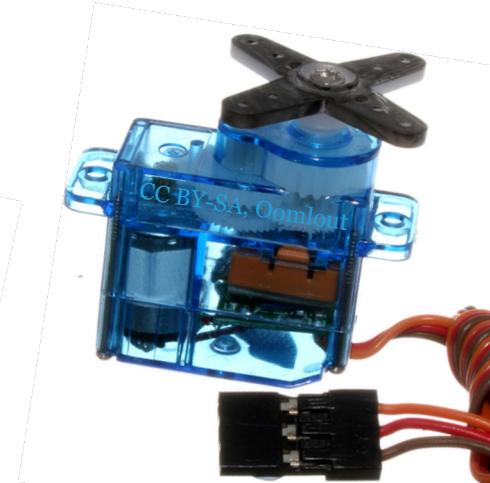
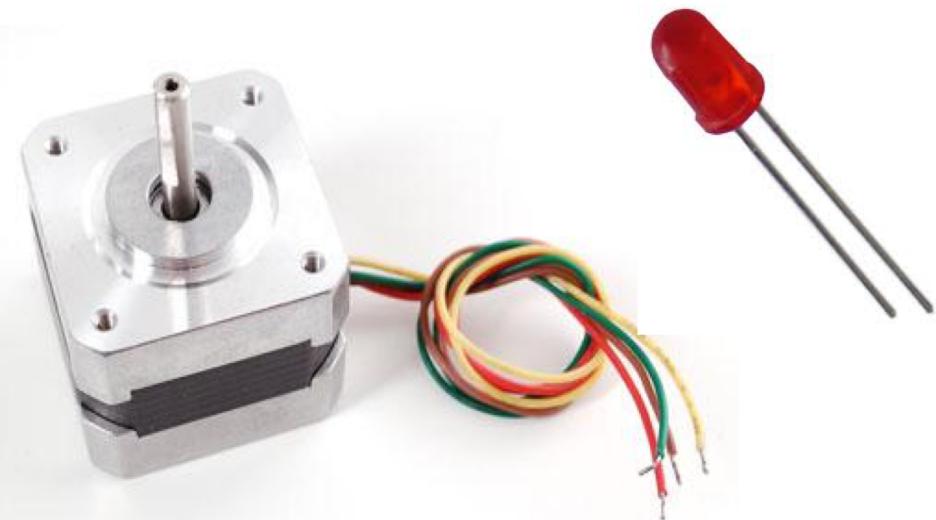


Lowest Cost

# Actuators

Convert electrical signals to physical properties.

E.g. light, movement, sound, heat, current.



# Gateway

Connects local devices/network to the Internet, e.g.

LoRaWAN to Wi-Fi gateway (TTN indoor gateway).

LoRaWAN to 4G gateway (TTN outdoor gateway).

Zigbee to Ethernet gateway (Philips Hue bridge).

Or the Wi-Fi router itself (for Wi-Fi devices).

Transparent, depending on the perspective.



# Backend

Backend server(s), service endpoint "in the cloud" or local.

Provides data to clients, receives commands.

High availability, scalability, bandwidth.

Can provide storage or data analysis.

Can call 3rd-party (Web) services.

# Client

Client app, e.g. dashboard or 3rd-party service client.

Reads measurement data from devices via backend.

Writes control data to the device via backend.

Multiple client apps can share a backend.

Decentlab Data Access - Indo... X +

https://demo.decentlab.com/dashboard/db/indoor-air-quality-demo?refresh=15m&orgId=3

Indoor Air Quality Demo

Zoom Out Last 3 days Refresh every 15m Sign in

LoRa WAN demo project by



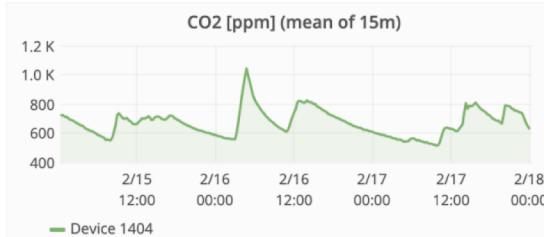
[CO<sub>2</sub>, temperature, and  
humidity sensor](#)



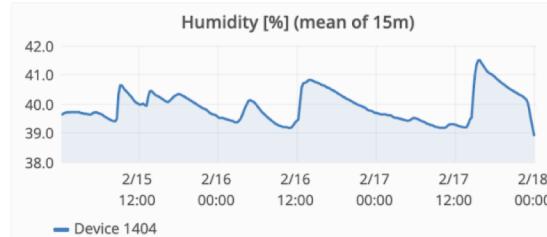
Node [1404](#) (CO<sub>2</sub>)



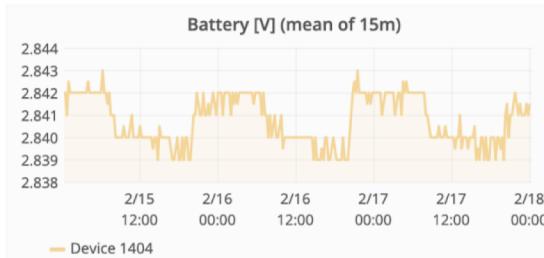
LoRa infrastructure provided by



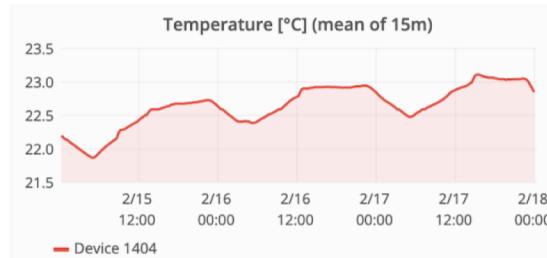
Current  
**625.5**  
ppm



Current  
**38.9 %**



Current  
**2.84 V**



Current  
**22.84 °C**



# Important IoT System Qualities

**Security**, to keep devices, network & backend secure.

**Privacy**, to keep people in control of their own data.

Interoperability, to become part of an ecosystem.

Openness, standards & open source build trust.

See, e.g. [betteriot.org principles](https://betteriot.org/principles) for guidance.



top Your WiFi-connected thermostat x +

The Washington Post (WP Company LLC) [US] | https://www.washingtonpost.com/posteverything/wp/2016/11/03/your-wifi-connected-thermostat-can-take-down-the-whole-internet/... ☆ ⚡ 5 | 🧑 :

Sections ⌂

The Washington Post  
Democracy Dies in Darkness

# Your WiFi-connected thermostat can take down the whole Internet. We need new regulations.

The government has to get involved in the “Internet of Things.”



By **Bruce Schneier**

Bruce Schneier is a security technologist and a lecturer at the Kennedy School of Government at Harvard University. His new book, "[Click Here to Kill Everybody](#)," will be published November 3, 2016

Late last month, popular websites like Twitter, Pinterest, Reddit and Facebook went down for most of a day. The [distributed denial-of-service attack](#) that caused the outage, which exploited the vulnerabilities that made the attack possible, was as much a failure of society as it was of technology. If we want to secure our increasingly computerized world, we need more government involvement in the security of the “Internet of Things,” and increased regulation of what are now critical and life-threatening devices. It’s no longer a question of if, it’s a question of when.

First, the facts. Those websites went down because their domain name

Jeremiah Grossman on Twitter x +

https://twitter.com/jeremiahg/status/78957408345313... Q ⚡ 0 | 🧑 :

**Jeremiah Grossman** ✅  
@jeremiahg

Follow

As Bruce Schneier recently explained about IoT-device security, "The market can't fix this because neither the buyer nor the seller cares."

11:08 PM - 21 Oct 2016

Open IoT | Bosch Software Innovations

https://www.bosch-si.com/iot-platform/iot-platform/open/iot.html

BOSCH  
Invented for life

Software Innovations · Bosch IoT Suite

No one can do IoT alone.

# Openness and interoperability in the IoT

Ecosystems are the key to succeeding in the IoT. Our IoT platform leverages open source and standards.

Eclipse Foundation announces

https://www.eclipse.org/org/press-release/20151003-bosch.php

**ECLIPSE FOUNDATION**

Members Working Groups Projects More ▾ Download

## Eclipse Foundation announces Bosch as a strategic member

Ludwigsburg, Germany – November 3, 2015 – The Eclipse Foundation is pleased to announce that Bosch has become a strategic member of the Eclipse Foundation. Bosch has been a long-term solutions member of the Eclipse Foundation and is actively participating in the Eclipse

# Summary

We defined IoT, understood the drivers behind it.

We looked at connected products in three sectors.

We know a simple reference model for IoT systems.

We've seen some patterns with varying connectivity.

# Feedback?

Email me [mzennaro@ictp.it](mailto:mzennaro@ictp.it)

