Introduction to the Internet of Things

Credits:
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Marco Zennaro, PhD
ICTP

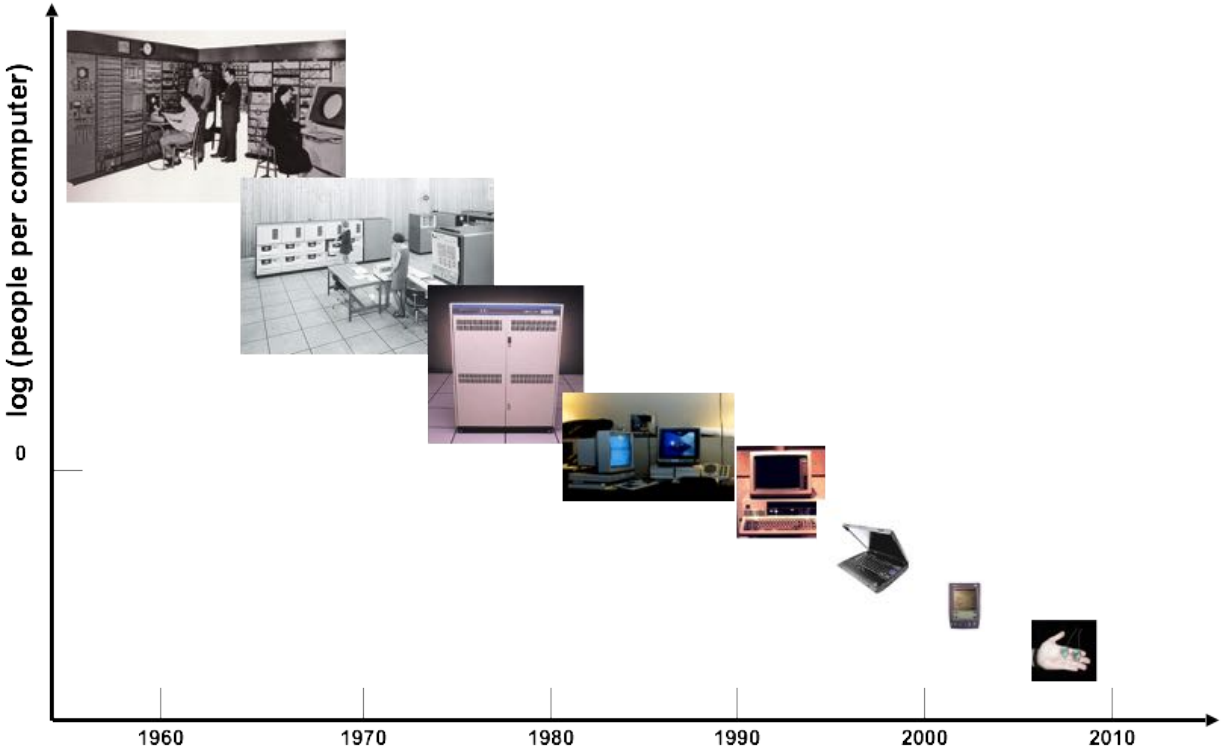
Hands-on, 5': Defining IoT

What does *Internet of Things* mean to you?

Write down your definition on a post-it.

We will check out the result together.

Vision



[Culler:2004]

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 **1930**s, 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.

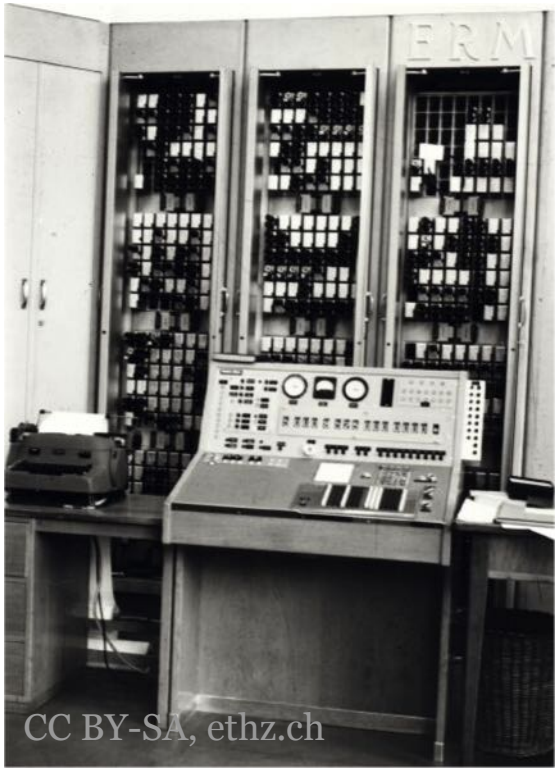
Moore's law

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

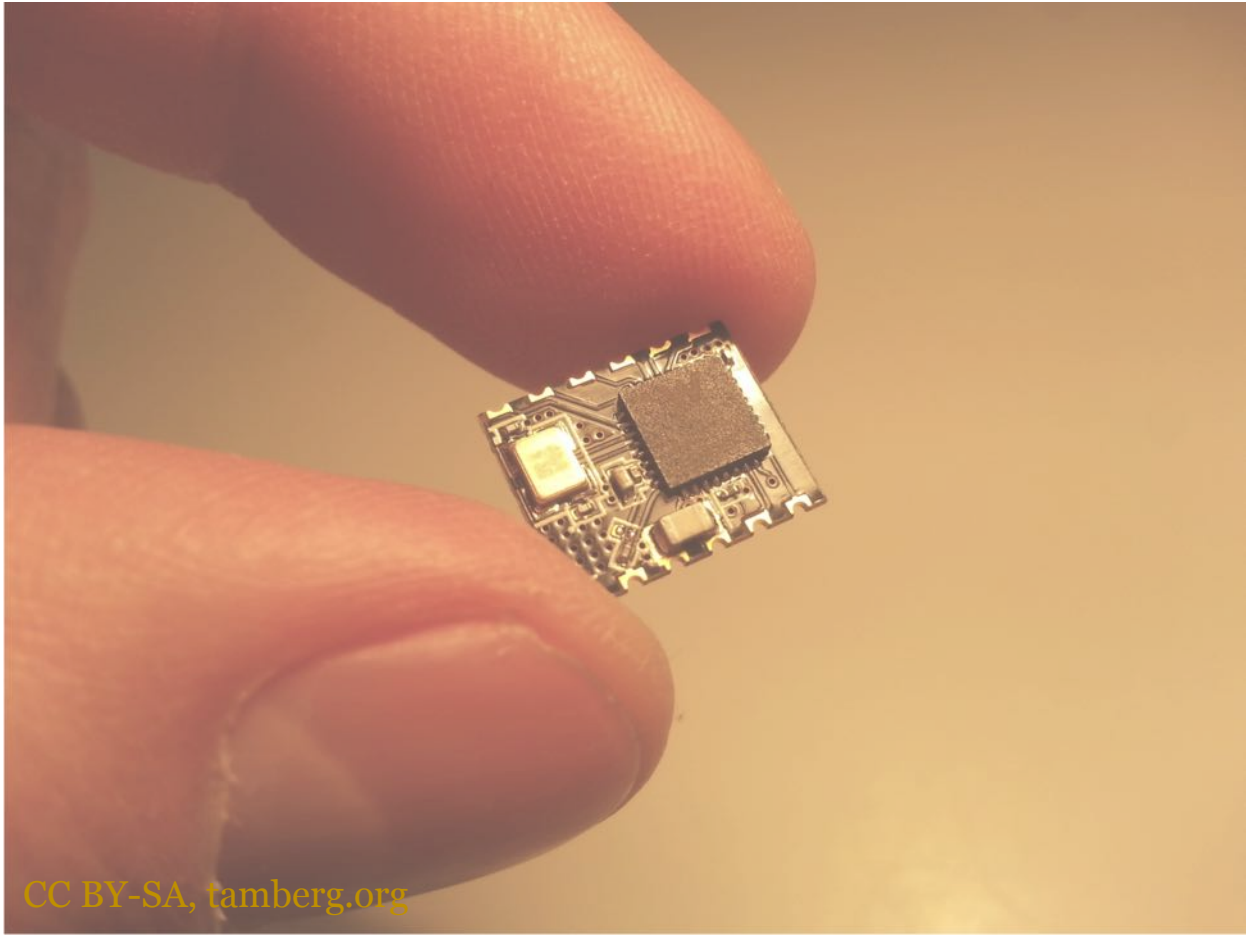
Gordon Moore, a founder of Intel, noted this in 1965.

=> 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

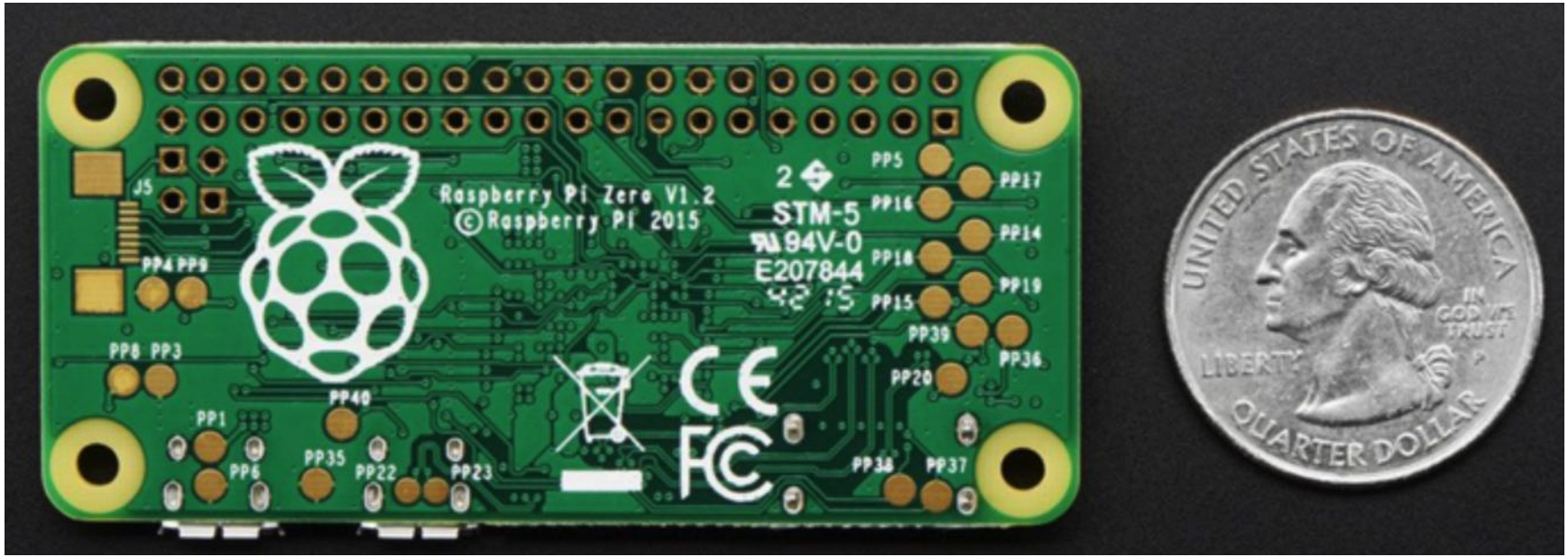


CC BY-SA, ethz.ch



CC BY-SA, tamberg.org

RPi zero: $5


Raspberry Pi Zero V1.2
©Raspberry Pi 2015
STM-5
94V-0
E207844
J5
PP4 PP9
PP8 PP3
PP40
PP1
PP6
PP35
PP22
PP23
PP5
PP16
PP18
PP15
PP39
PP20
PP38
PP37
PP17
PP14
PP19
PP36
UNITED STATES OF AMERICA
LIBERTY
IN GOD WE TRUST
QUARTER DOLLAR

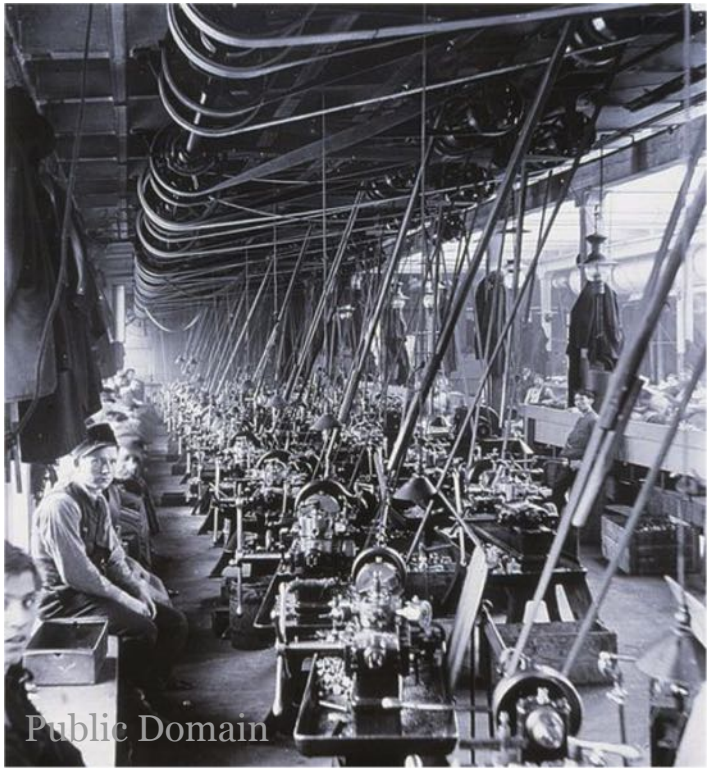
Ubiquitous computing

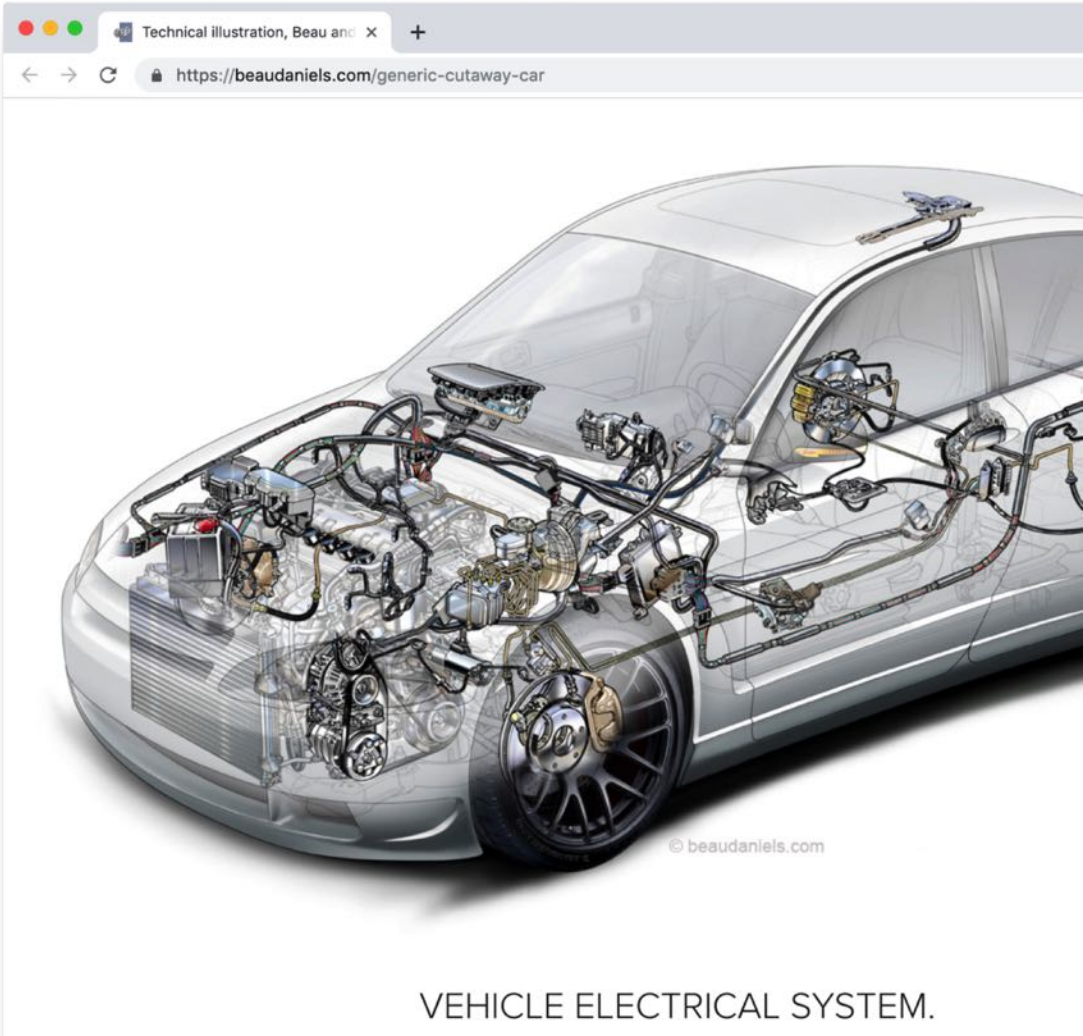
"The idea of integrating computers seamlessly into the world at large [...] *Ubiquitous computing*"

"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


Technical illustration, Beau and
https://beaudaniels.com/generic-cutaway-car
© beaudaniels.com
VEHICLE ELECTRICAL SYSTEM.

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.

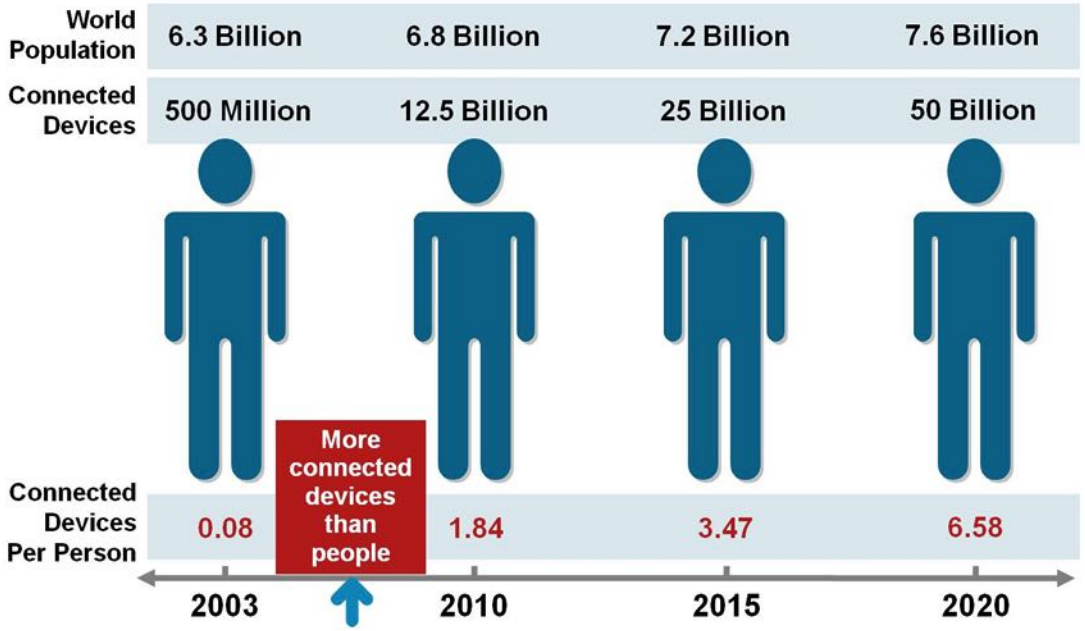
Fundamental characteristics — ITU

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

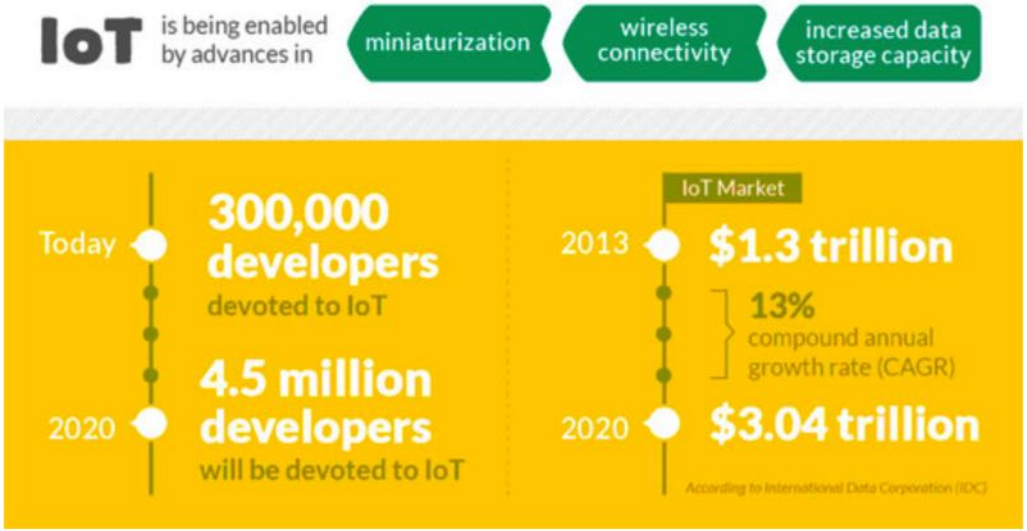
Enormous scale: The number of devices that need to be managed and that communicate with each other will be at least an order of magnitude larger than the devices connected to the current Internet. The ratio of communication triggered by devices as compared to communication triggered by humans will noticeably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

Predictions



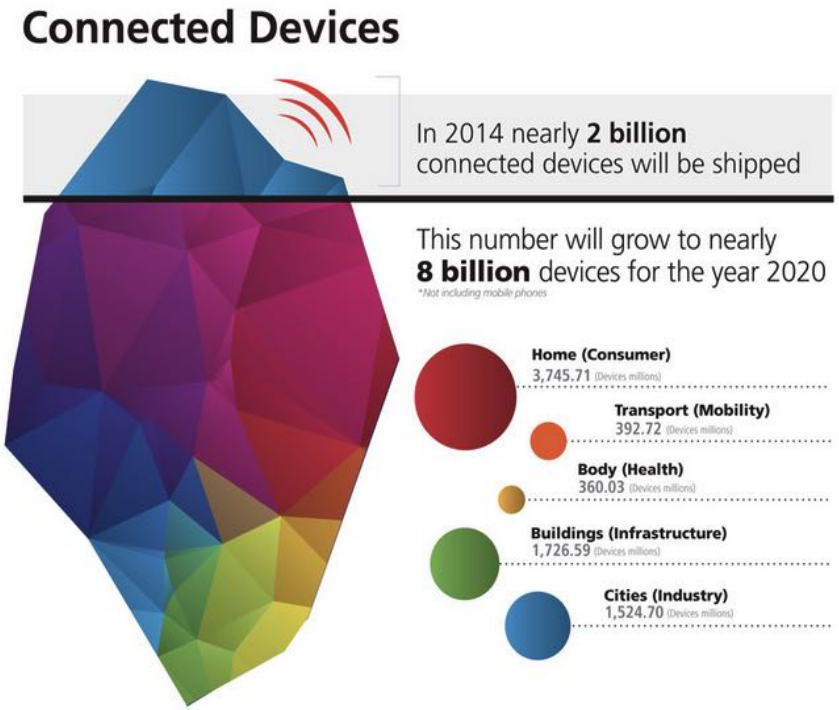
Source: Cisco IBSG, April 2011

Predictions



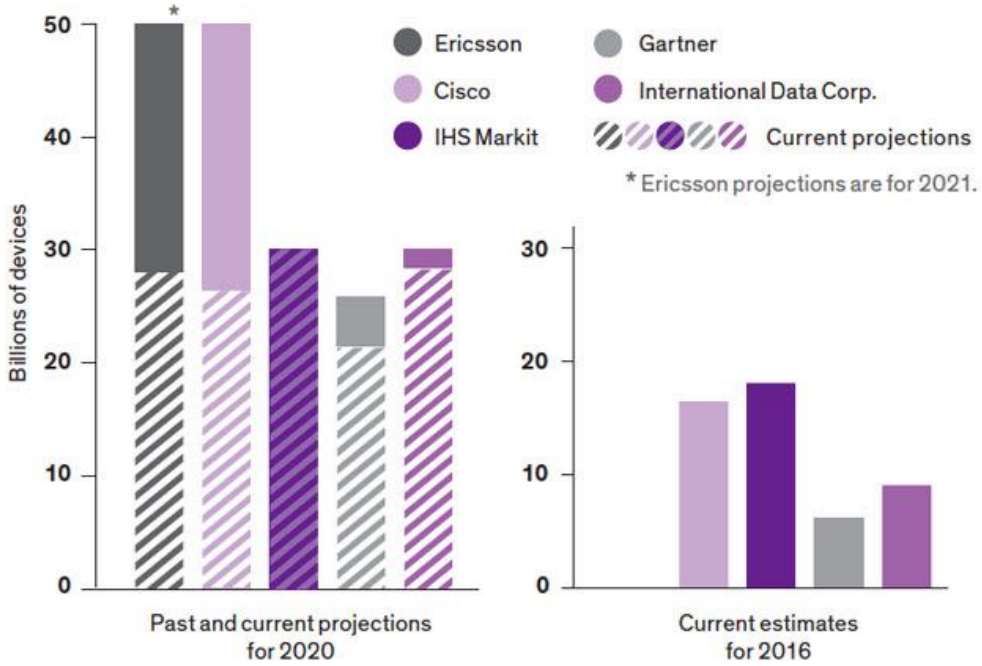
PwC's 6th Annual Digital IQ survey

Predictions



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

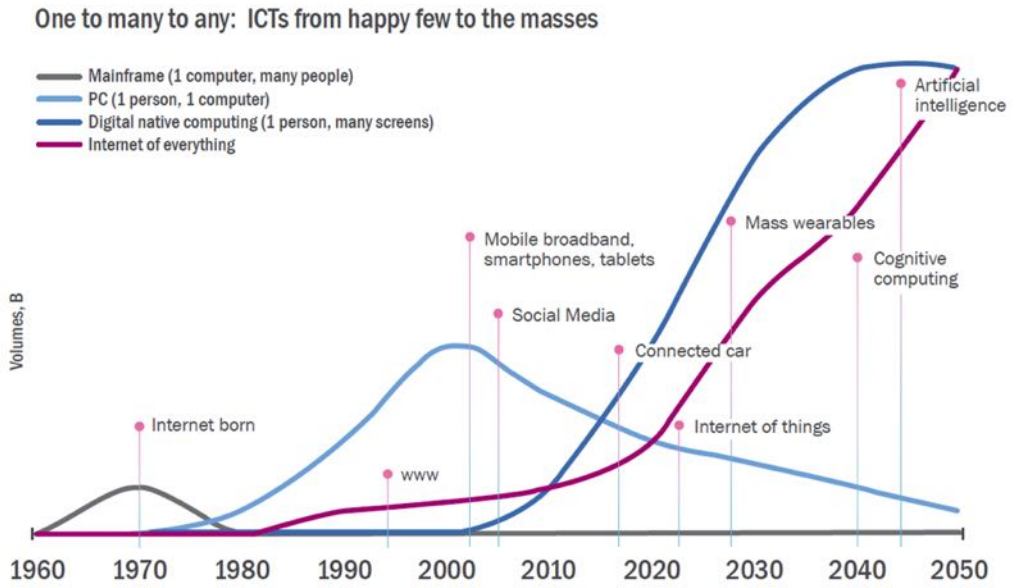
Internet of Fewer Things



http://spectrum.ieee.org/telecom/internet/the-internet-of-fewer-things

One to many to any

History of the future



Connectivity

Ability to communicate with another computer.

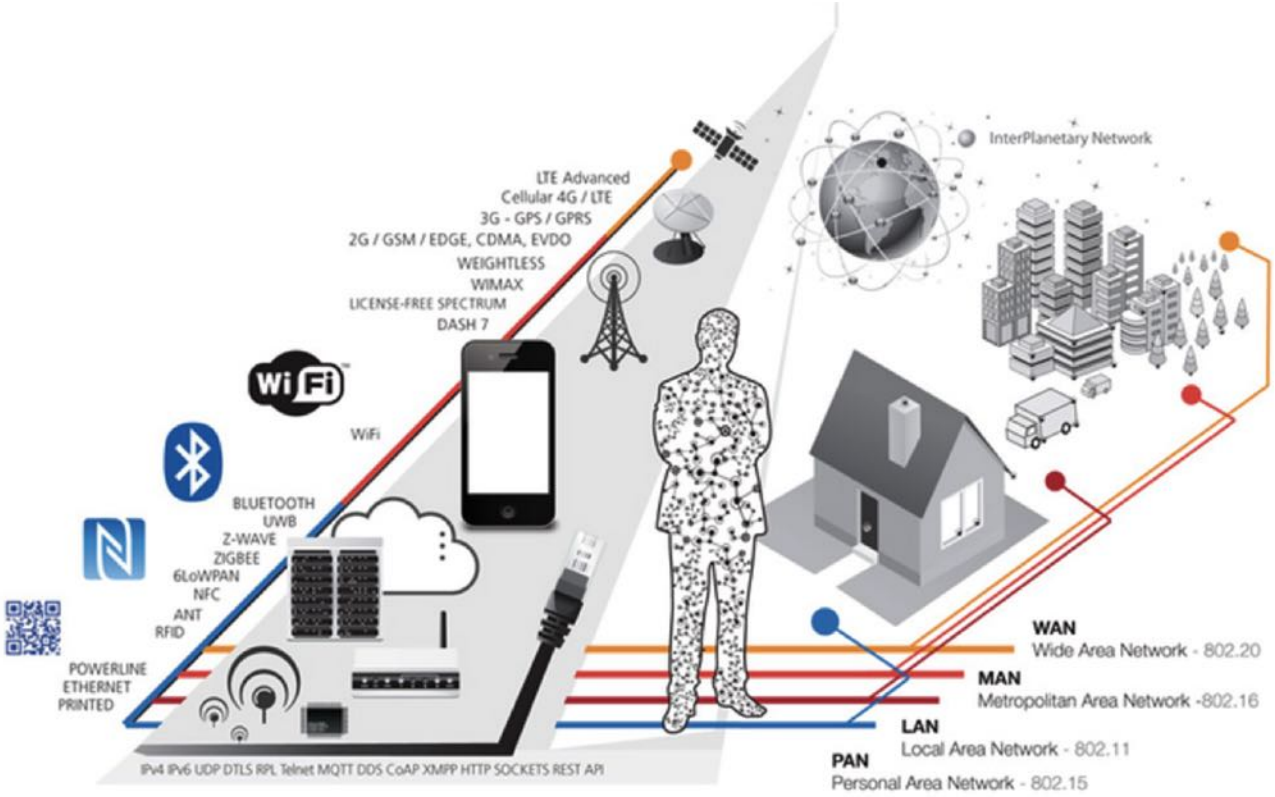
Personal area network (PAN, e.g. BLE, Zigbee).

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.

Good Night Lamp, linked lamps to share presence.

Nest Thermostats | Keep You

https://nest.com/thermostats/

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

Proven energy savings.
Can pay for itself in two years or less.[1]

Turns itself down when you're away.

Control it from anywhere.[2]

Remote temp sensing.
Learn more >

Meethue.com | Welcome to the

https://www2.meethue.com/en-us

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 - Bo

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.

goodnightlamp.com

Not Secure | goodnightlamp.com

Turn a Big Lamp on and Little Lamps which you've given away turn on too. Anywhere in the world.

Use the Good Night Lamp to tell a loved one 'now's a good time for a chat', 'I'm thinking of you' or 'call me when you get home'. You decide. As your family grows or moves away, you can add as many Little Lamps as you want.

ambient™

Ambient Umbrella

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

Citizen sensing

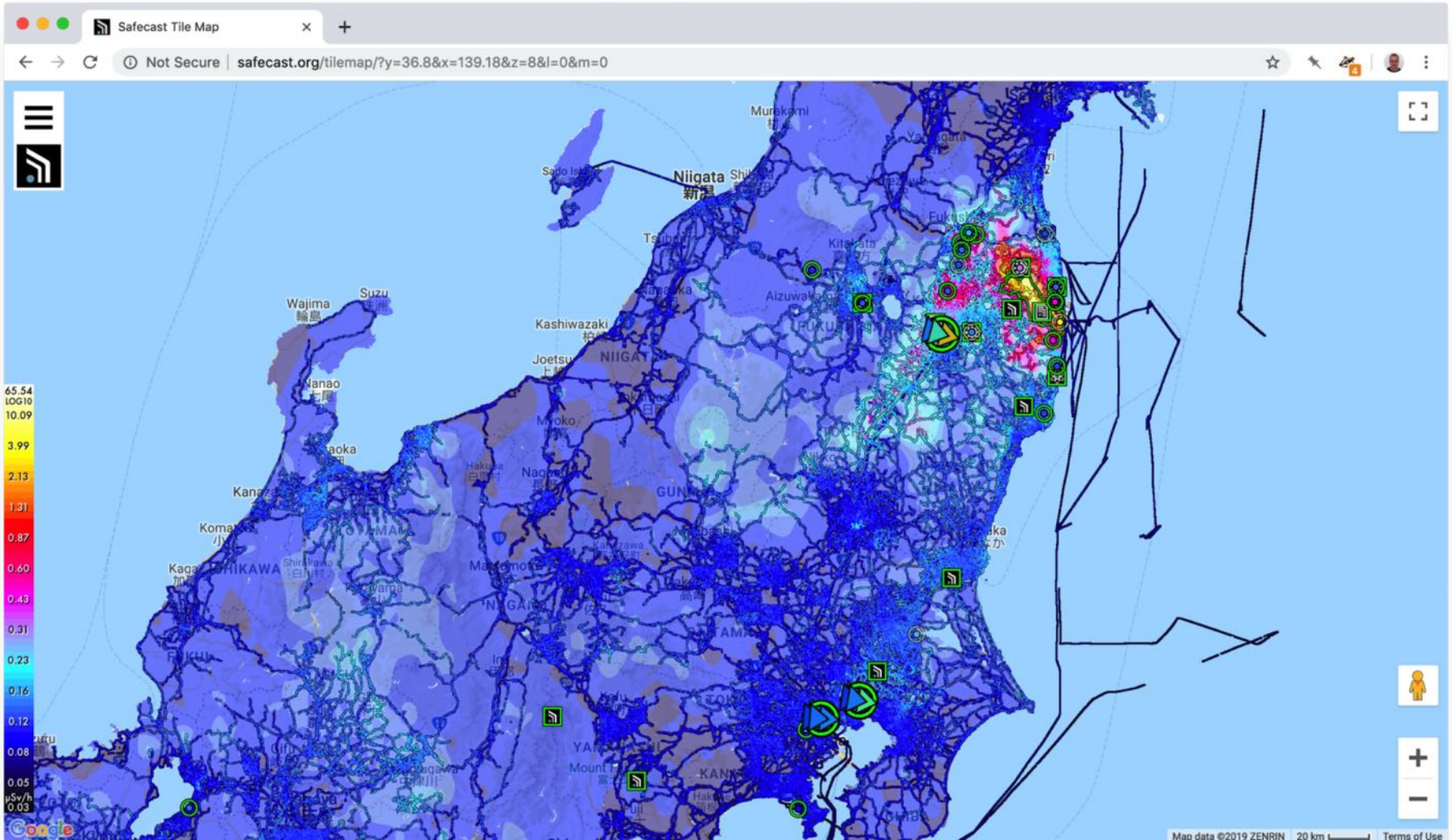
Self-built sensors, open data, nonprofit, e.g.

Safecast.org, a crowdsourced radiation map.

Oxford Flood Network, measuring water levels.

Luftdaten.info, particles and nitrogen oxides map.

Smart Citizen Kit, air quality.


Safecast Tile Map
Not Secure
safecast.org/tilemap/?y=36.8&x=139.18&z=8&l=0&m=0
Murakami
Niigata
新潟
Sado Island
Wajima
輪島
Suzu
Kashiwazaki
Joetsu
NIIGATA
Nanao
Myoko
Kanazawa
Komatsu
Kaga
ISHIKAWA
Nagano
Matsumoto
Aizuwa
Kitakata
Fukushima
GUNMA
YAMANASHI
Mount Fuji
KANAGAWA
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
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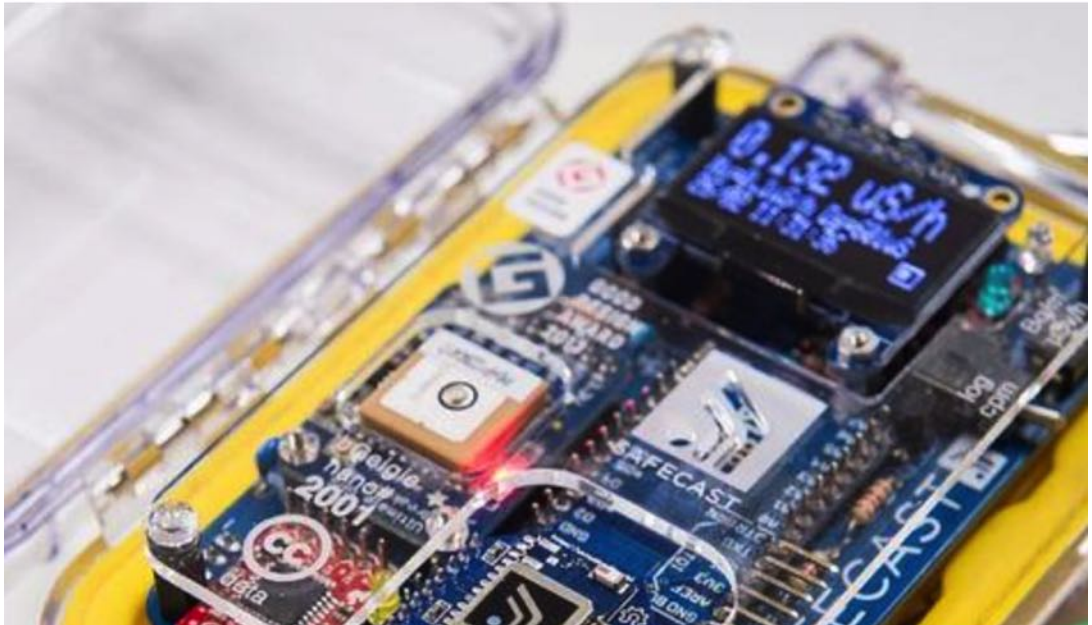
μSv/h
Google
Map data ©2019 ZENRIN
20 km
Terms of Use



SAFECAST
BGEIGIE NANO

Oxford Flood Network — Love

Not Secure | www.love-hz.com/oxford-flood-network

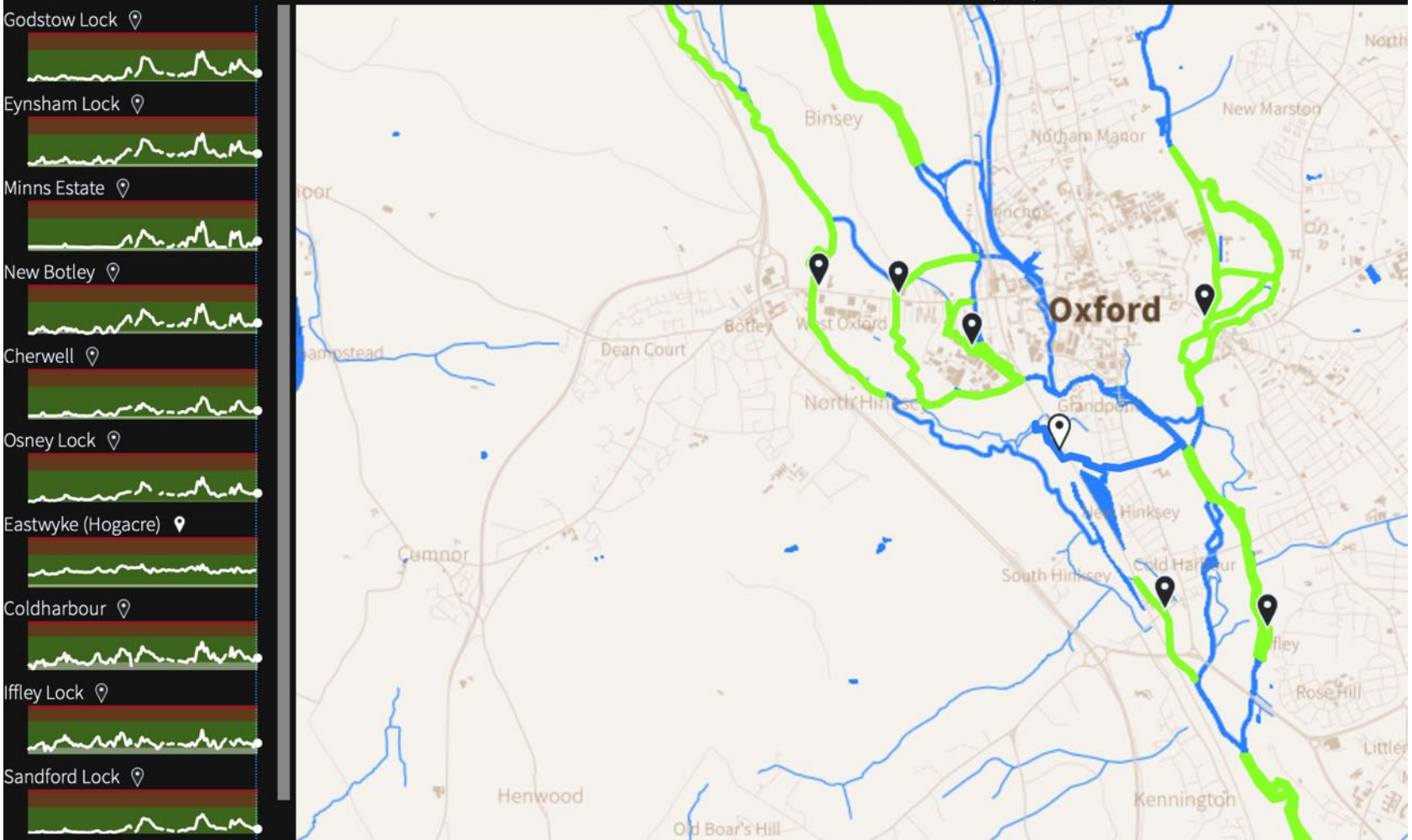
Love Hz

HOME / PRODUCTS / CASE STUDIES / BLOG / CONTACT

Citizens, Building a Smart City

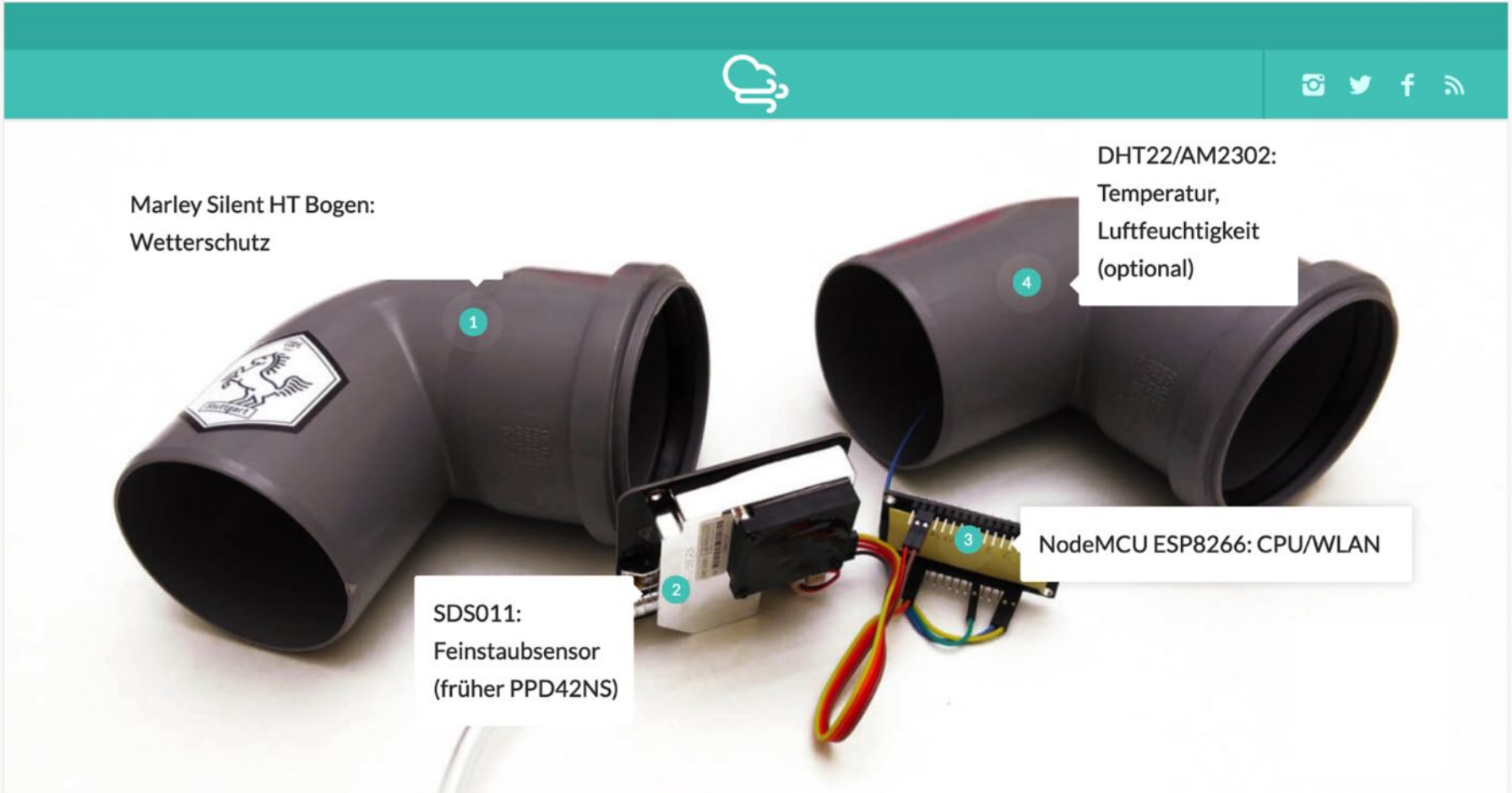
Flood Network

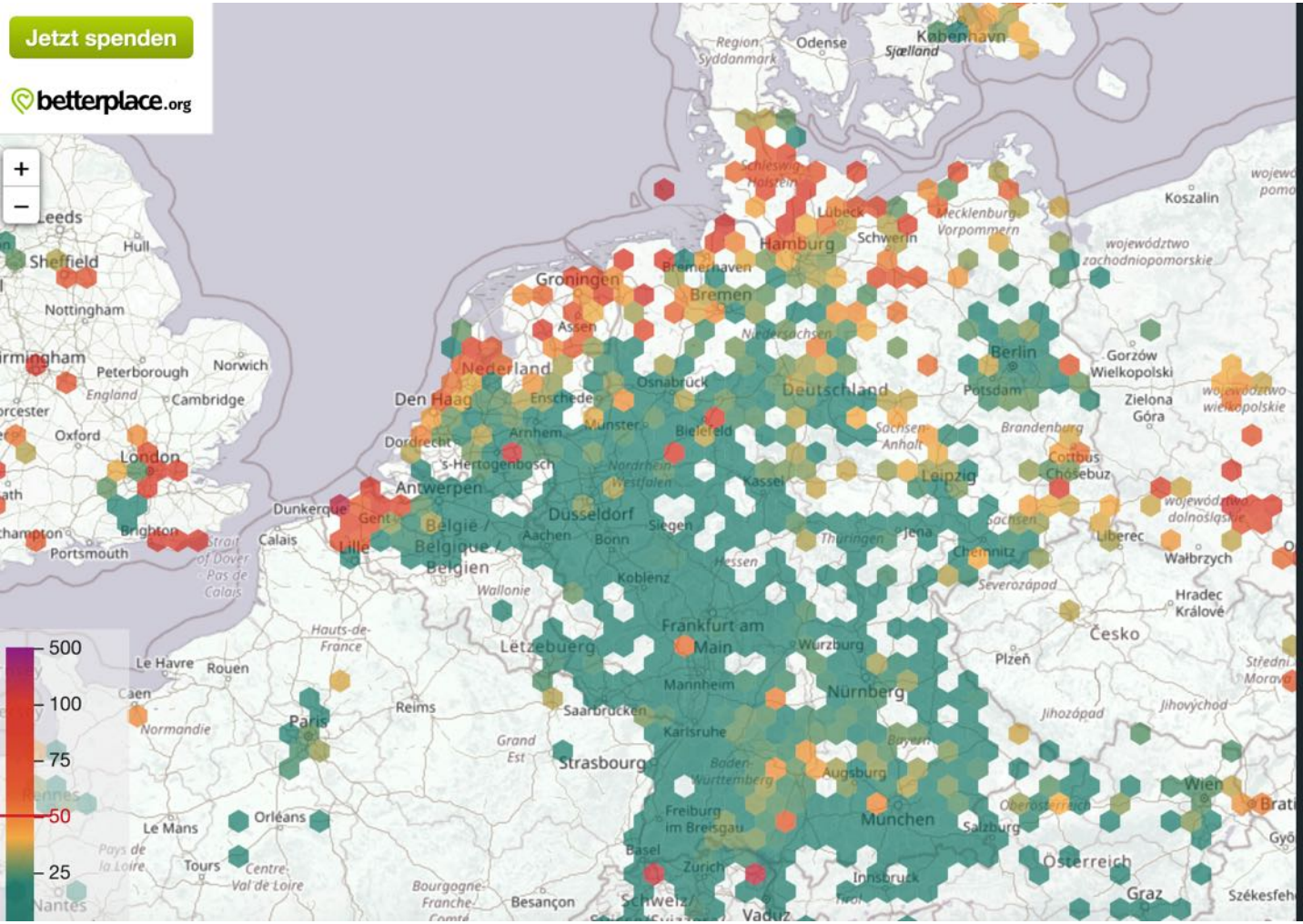
Live River Levels (Beta)



luftdaten.info – Feinstaub selb

https://luftdaten.info





(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


SMART CITIZEN
ARDUINO AT HEART

Industrial IoT

"Industry 4.0", cyber-physical systems.

Predictive maintenance (know what *will* break).

Anomaly detection (find *unknown* issues).

Live feedback (from *deployed* engines).

Civil Aerospace – Rolls-Royce

https://www.rolls-royce.com/products-and-services/civil-aerospace.aspx

971.40 GBX +22.60 GLOBAL

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Latest updates on our Trent engine family

IoT reference model

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

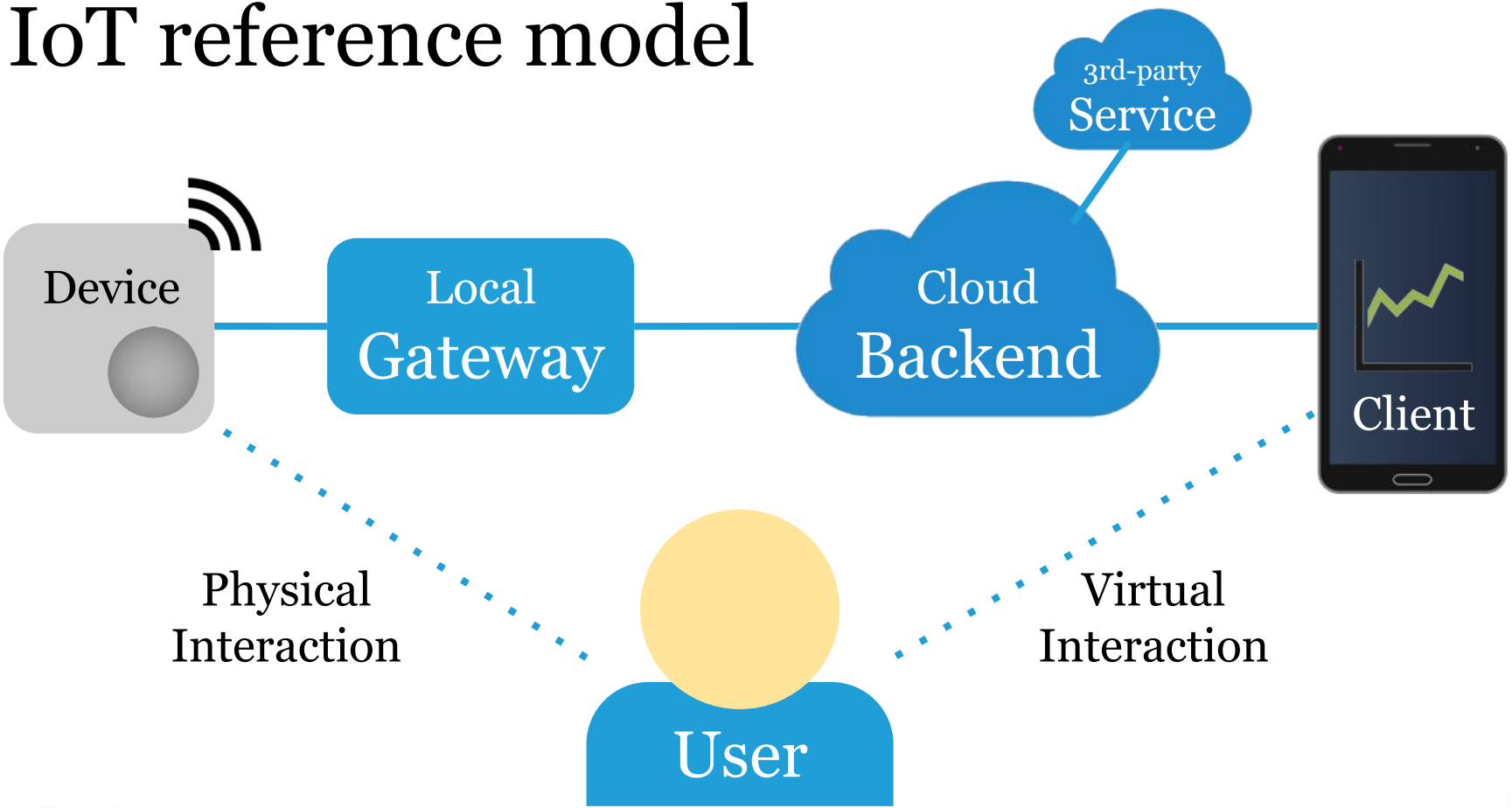
Gateway, ~~hub~~, ~~bridge~~ (in the local network).

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.

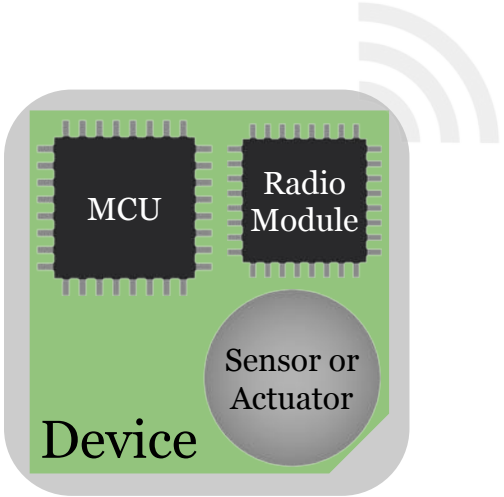
Connectivity on the chip or as an external module.

Microcontroller (MCU) with constrained resources.

Small, slow processor, limited memory, low power.

Often battery powered or harvesting energy.

Device

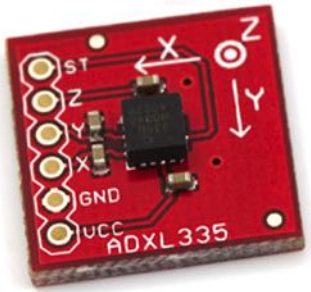

MCU
Radio Module
Sensor or Actuator
Device


AVELON
turn your information into benefit
Hardware type
AVEMM01
Carrier
TTN
SW version
2.1
Initial setup
600 / 6
Integrated with Alcedo Cloud
CC BY-SA, tamberg.org

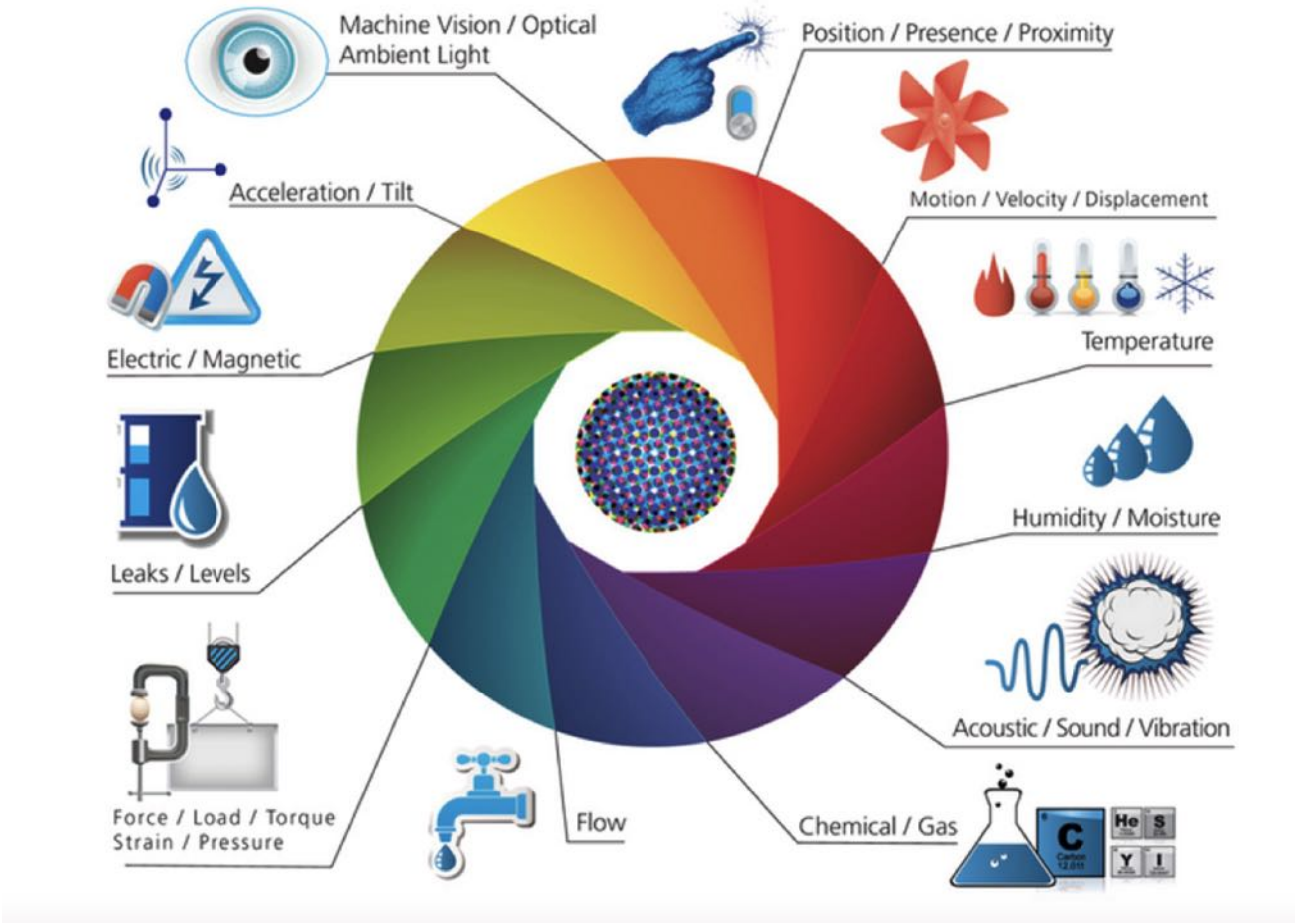
Sensors

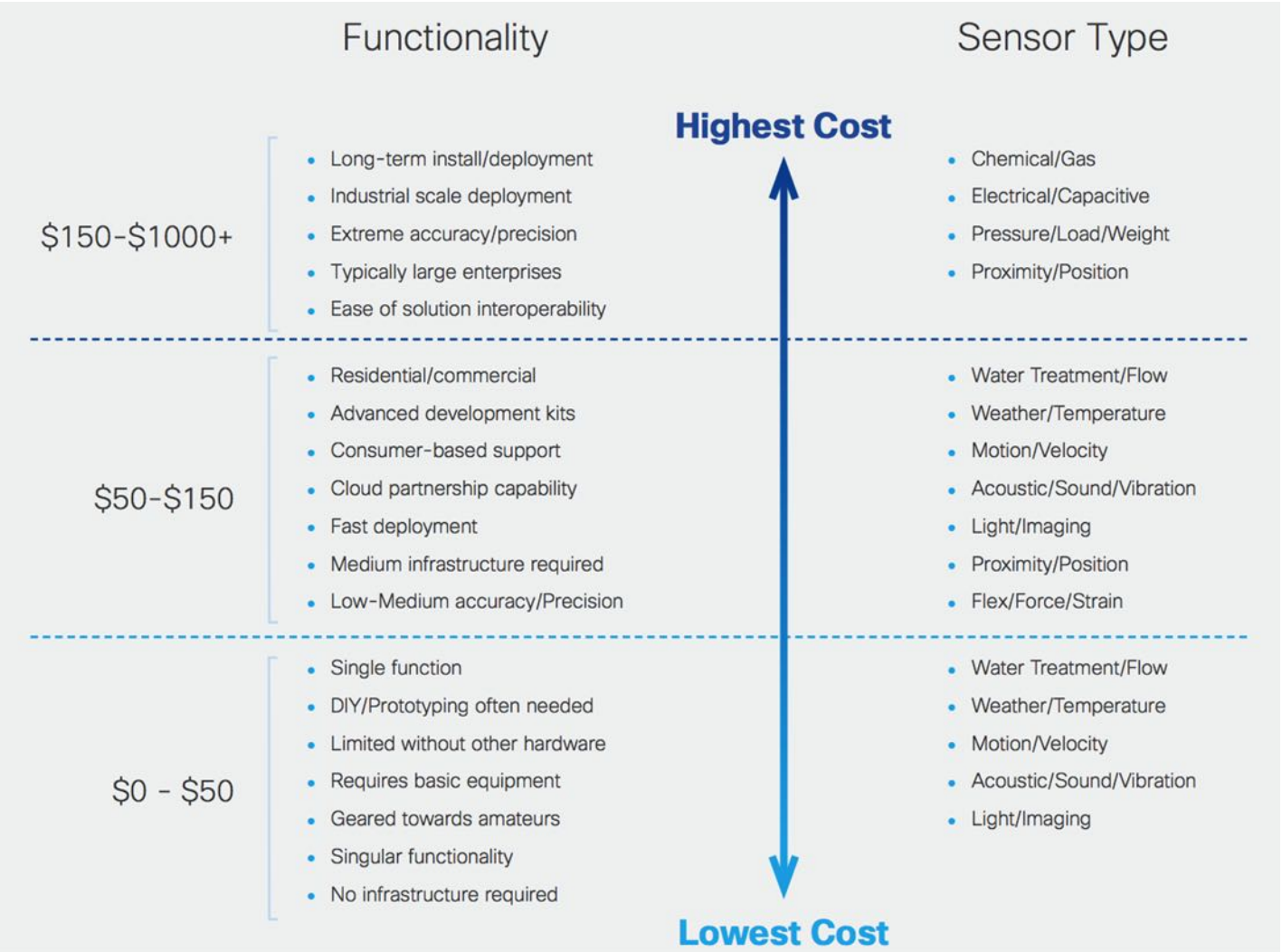
Convert physical properties to electrical signals.

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



Sensors

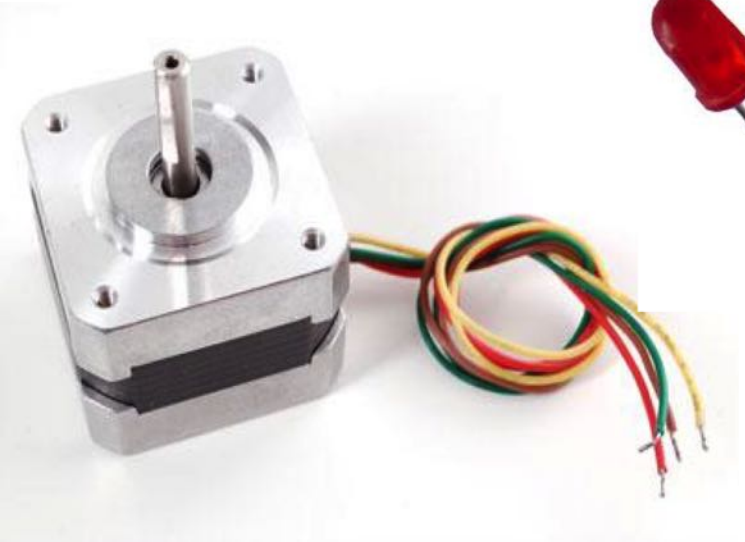

Machine Vision / Optical
Ambient Light
Position / Presence / Proximity
Acceleration / Tilt
Motion / Velocity / Displacement
Electric / Magnetic
Temperature
Humidity / Moisture
Leaks / Levels
Acoustic / Sound / Vibration
Force / Load / Torque
Strain / Pressure
Flow
Chemical / Gas


Functionality
Sensor Type
Highest Cost
$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
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 - Indoo

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

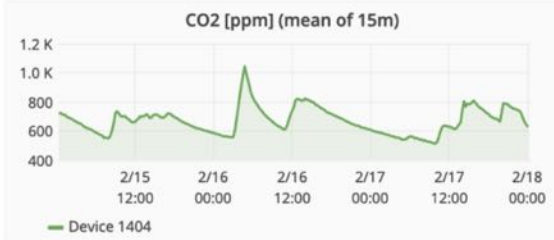
decentlab

CO2, temperature, and humidity sensor

Node 1404 (CO2)

LoRa infrastructure provided by

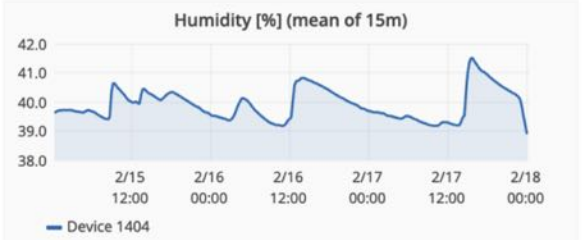
THE THINGS NETWORK



Current

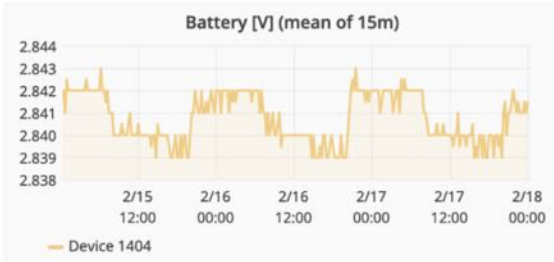
625.5

ppm



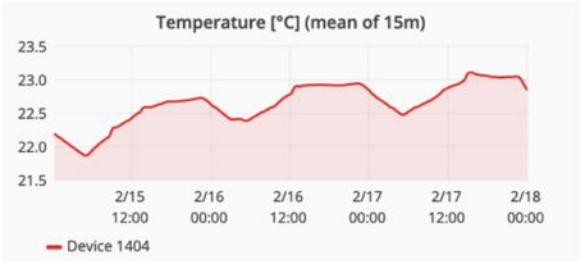
Current

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 for guidance.

Your WiFi-connected thermost

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

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 Sch
Harvard University. His new book, "Click Here to Kill Everybody," will be pub
November 3, 2016

Late last month, popular websites like Twitter, Pinterest, Reddit and P
most of a day. The distributed denial-of-service attack that caused the
vulnerabilities that made the attack possible, was as much a failure of
it was of technology. If we want to secure our increasingly computerize
world, we need more government involvement in the security of the "I
and increased regulation of what are now critical and life-threatening
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

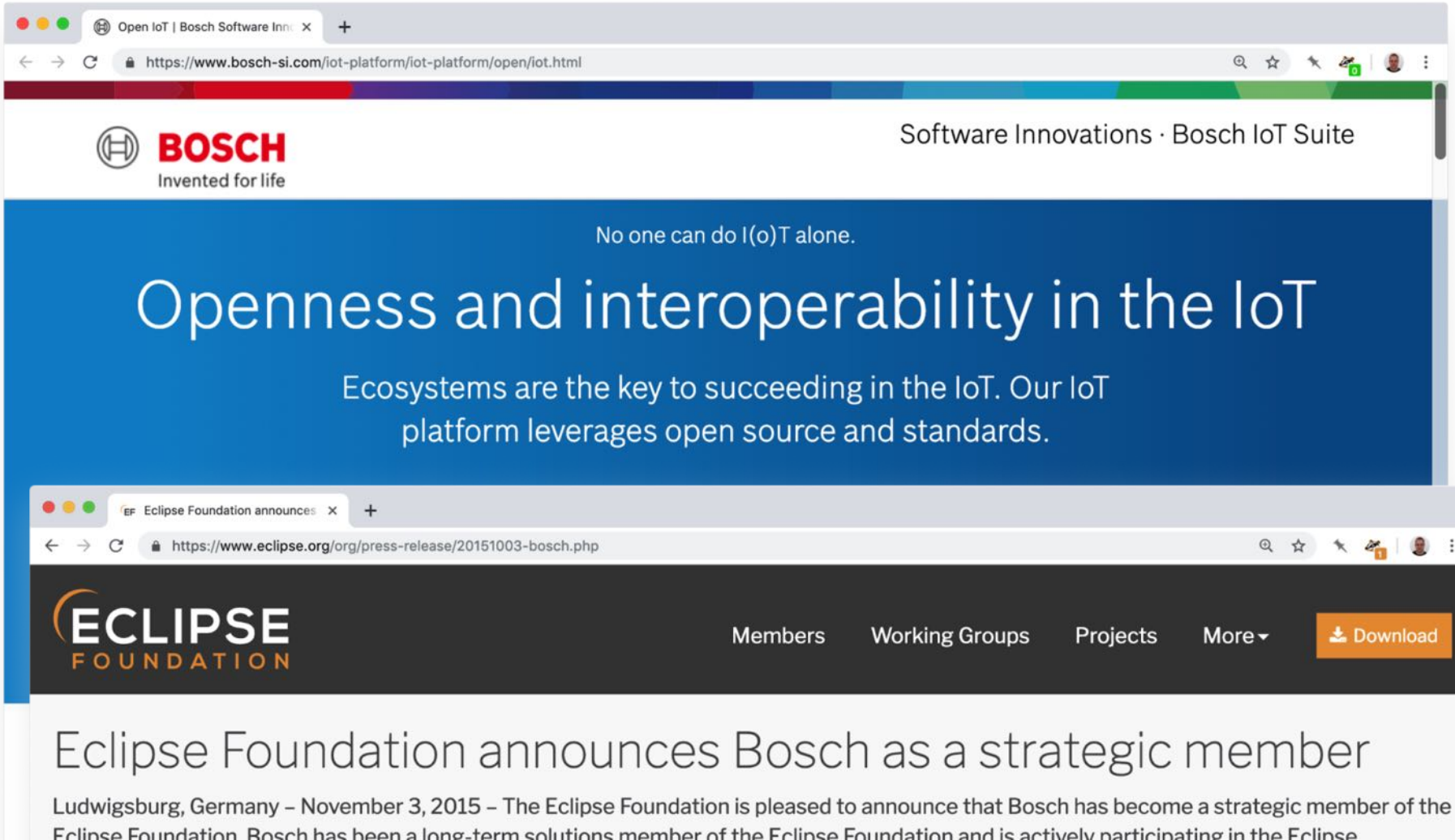
https://twitter.com/jeremiahg/status/78957408345313...

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 Inn
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 I(o)T 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
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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?

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