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Industrial Internet of Things | Van uitdaging tot praktijk

Kortrijk, maart-april 2019

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Deelnemerslijst

Industrial Internet of Things | Van uitdaging tot praktijk

Kortrijk, 12/3/2019 - 2/4/2019

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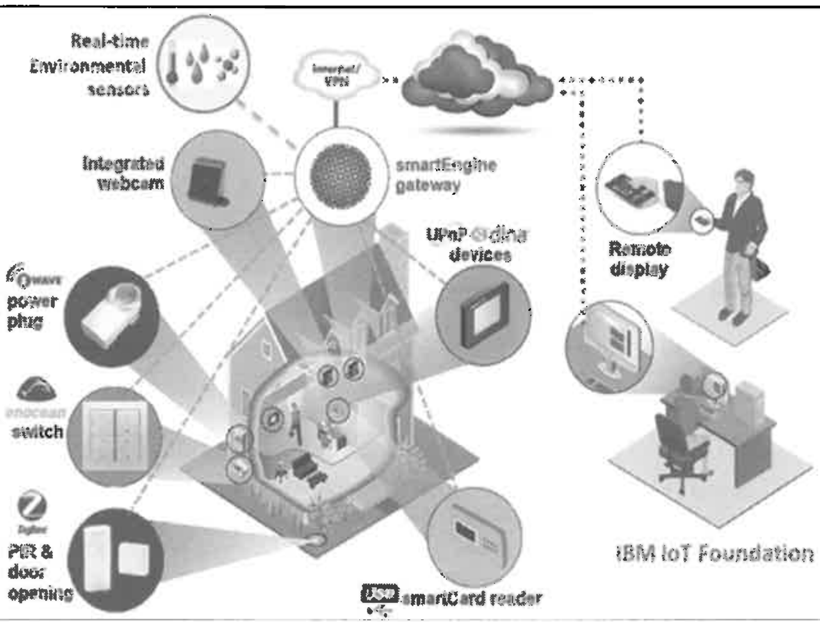
IoT Ecosystems in a Nutshell

A software perspective

Vincent Naessens
DistriNet, KU Leuven



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Bron: IBM IoT foundation

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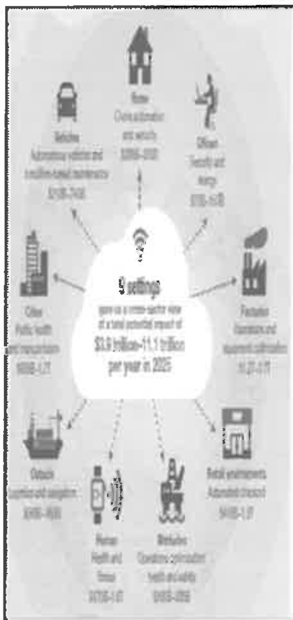

A "settings" lens helps capture all sources of value; we identify nine settings where IoT creates value

Setting	Description	Examples
Human	Devices attached to or inside the human body	Devices (wearables and ingestibles) to monitor and maintain human health and wellness; disease management, increased fitness, higher productivity
Home	Buildings where people live	Home controllers and security systems
Retail environments	Spaces where consumers engage in commerce	Stores, banks, restaurants, arenas—anywhere consumers consider and buy; self-checkout, in-store offers, inventory optimization
Offices	Spaces where knowledge workers work	Energy management and security in office buildings; improved productivity, including for mobile employees
Factories	Standardized production environments	Places with repetitive work routines, including hospitals and farms; operating efficiencies, optimizing equipment use and inventory
Worksites	Custom production environments	Mining, oil and gas, construction; operating efficiencies, predictive maintenance, health and safety
Vehicles	Systems inside moving vehicles	Vehicles including cars, trucks, ships, aircraft, and trains; condition-based maintenance, usage-based design, pre-sales analytics
Cities	Urban environments	Public spaces and infrastructure in urban settings; adaptive traffic control, smart meters, environmental monitoring, resource management
Outside	Between urban environments (and outside other settings)	Outside uses include railroad tracks, autonomous vehicles (outside urban locations), and flight navigation; real-time routing, connected navigation, shipment tracking

3 Bron: McKinsey Gloabal Institute – The Internet of Things: mapping the value beyond the hype KU LEUVEN

Key conclusions of McKinsey Report

- IoT ecosystems will enable new business models *(Anything-as-a-Service)*
- Big market share for **B2B applications**
- *Openness* and *interoperability* are crucial to **tackle vendor lock-in** challenges
- Gathered IoT data hardly used for **operational decision making**

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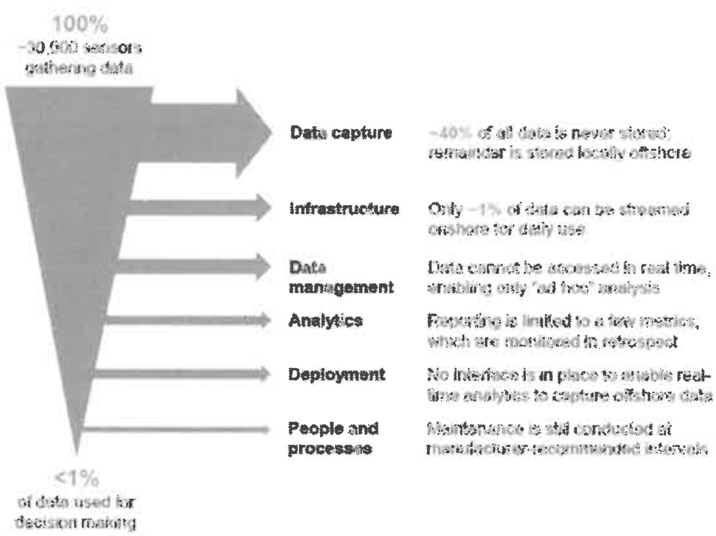
99 percent of data collected from 30,000 sensors on an oil rig was lost before reaching operational decision makers



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What is next?

- A taxonomy of IoT architectures
- Prevalent IoT components
- IoT communication technologies
- Authentication and authorisation approaches

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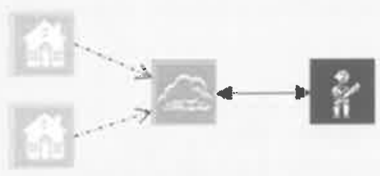
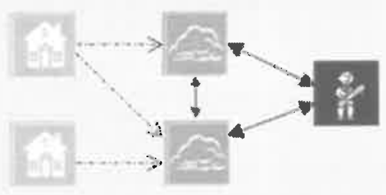
What is next?

- **A taxonomy of IoT architectures**
- Prevalent IoT components
- IoT communication technologies
- Authentication and authorisation approaches



A) CENTRALIZED IoT

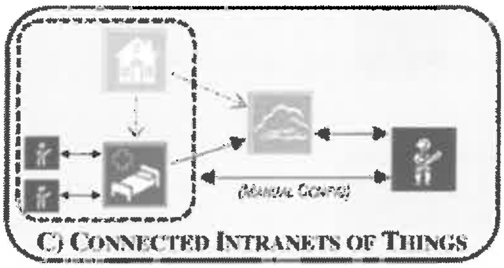
☺ Simple APIs
☺ Easy access control model
☹ Single-point-of-Failure
☹ Latency and bandwidth
☹ Privacy challenges



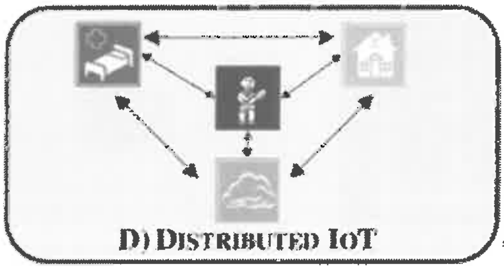
B) COLLABORATIVE IoT

😐 Multiple but simple APIs
😐 Partial failures / degradation of service
☺ Distributed bandwidth
☹ Latency
☹ Privacy challenges

Bron:
On the features and challenges of security and privacy in distributed internet of things
Rodrigo Roman , Jianying Zhou Javier Lopez



☺ Local data if failure
☺ Limited latency → real-time
☺ Scalable at edge
☹ Distributed authentication and access control



☺ High flexibility
☺ Low latency
☹ Expensive SW integrations
☹ Complex security management

in distributed internet of things
ying Zhou Javier Lopez

What is next?

- A taxonomy of IoT architectures
- **Prevalent IoT components**
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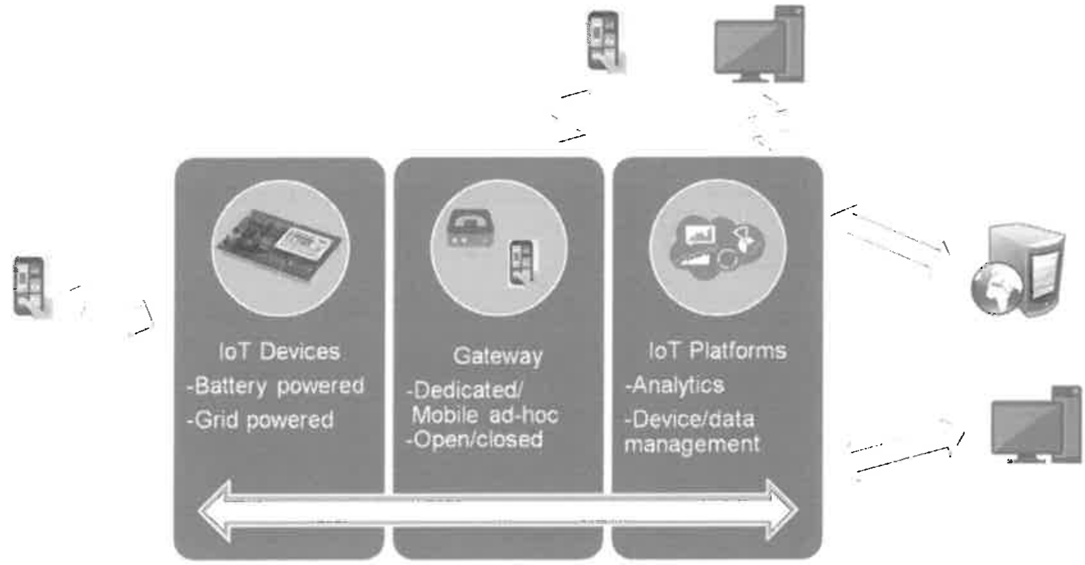

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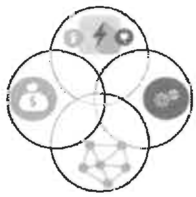
IoT Devices

- A device includes HW and SW that **directly interacts with the world**
  - Devices connect to a network to communicate with each other, or to centralized applications
  - Devices might be directly or indirectly connected to the Internet
- **IoT device development**
  - Develop own hardware
  - Use commercial development platforms
  - Integrate dedicated commercial IoT device (COTS)



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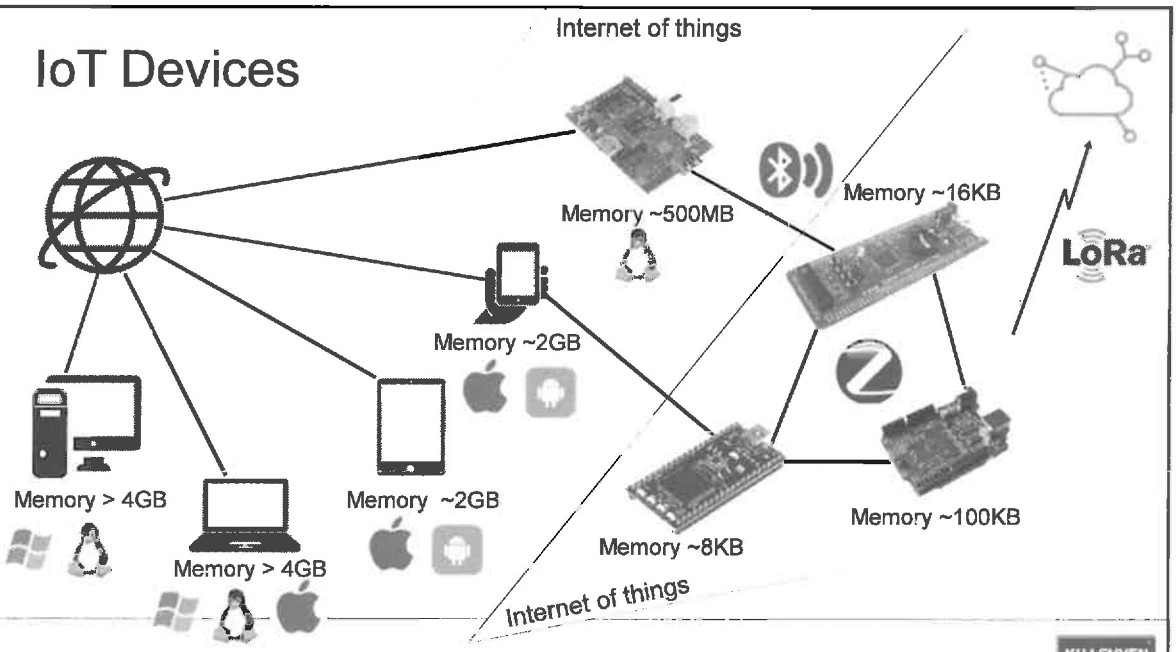
IoT Devices



IoT Devices

- Low-power communication stack
- Cache only small amounts of data
- Limited processing power

- **Low resource SW stack**
  - Network stack
  - RIOT OS
  - ARM Mbed OS
  - Contiki
  - Nucleus RTOS

- Standard IT communication stack
- Intelligence

- **IT SW stack**
  - WindRiver VxWorks
  - Android Things
  - Green Hills Integrity
  - Windows IoT Core

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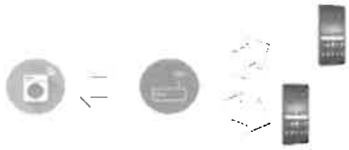
Gateways

- Protocol conversion
- Move data to the cloud

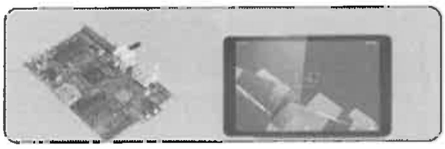
- Access control to IoT functionality
- Manage IoT devices in local network



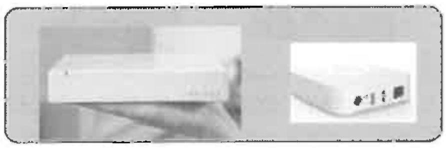
- **Intelligence on the edge**: processes data on behalf of a cluster of devices
  - Pre-processing of data
  - Fast response times

- End-user application platform (HMI)

Gateways



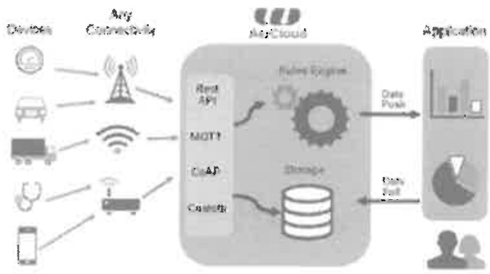
Custom dedicated gateways
-Embedded platforms
-COTS platform with custom apps
-Third-party software stacks



Commercial gateways
-Contain gateway software
-Tied to specific app domains
-often linked to back-end platform

IoT Platforms

- **Simplify the development of IoT ecosystems & applications**
  - Device management
  - Data aggregation & storage
  - Can provide rule-based event engines
  - User access management



- **Hide IoT complexity behind cloud APIs**
  - All IoT devices in one platform
  - Multi-platform heterogeneity

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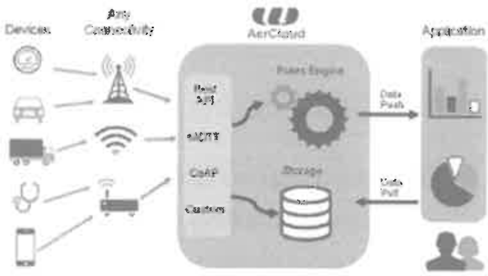
IoT Platforms

- Kaa (http://www.kaaproject.org)
- Weave (https://developers.google.com/weave/)
- Thingworx (http://www.thingworx.com)
- AllThingsTalk (http://www.allthingstalk.com/)
- Cariots (https://www.carriots.com/)
- Waylay http://www.waylay.io)
- Sierra Wireless' AirVantage (https://airvantage.net)
- …



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IoT Platforms

- IoT Software-as-a-Service (**SaaS**) focused platforms
- Infrastructure/Platform-as-a-Service (**IaaS/PaaS**) back-ends

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IoT Platforms

- **Application-domain specific back-ends**
  - Google Nest
  - FitBit

- **Infrastructure/Platform-as-a-Service (IaaS/PaaS) back-ends**
  - Focus on integration of business logic
  - Provide data mining libraries
  - Some platforms provide modules for IoT integrations

IBM Bluemix

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IoT Platforms → selection criteria

- **Functionality**
  - Supported analytics
  - Device management
- **Security and privacy**
  - Multi-user/tenancy support → multiple customers
  - Delivery models (cloud ⇔ on-premises)
- **Potential for scaling up**
- **IoT platform pitfalls**
  - Data ownership & processing
  - Vendor lock-in

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What is next?

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TCP/IP Model	IoT Stack	Web Stack
	IoT Applications; Device Management	Web Applications
Data Format	Binary, JSON, CBOR	HTML, XML, JSON
Application Layer	CoAP, MQTT, XMPP, AMQP	HTTP, DHCP, DNS, TLS/SSL
Transport Layer	UDP, DTLS	TCP, UDP
Internet Layer	IPv6/IP Routing; 6LoWPAN	IPv6, IPv4, IPSec
Network/Link Layer	IEEE 802.15.4 MAC; IEEE 802.15.4 PHY / Physical Radio	Ethernet (IEEE 802.3), DSL, ISDN, Wireless LAN (IEEE 802.11), Wi-Fi

Communication technologies for IoT ecosystems

- **Data formats**

- **Application layer communication technology**

Data formats

Heavyweight → *lightweight*

XML and HTML

JSON

BINARY

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Application layer communication technologies

- **Synchronous versus asynchronous communication**
  - *Synchronous*
    - Sender expects a response within a specified period
    - Sender blocks until he receives response
  - *Asynchronous*
    - Sender does not expect an immediate response
    - Sender does not block and carries out remaining tasks

Messaging model

Communicating nodes		Request/response	Publish/subscribe
	Heavyweight endpoints	HTTP, RPC	JMS, AMQP (Java Messaging Service)
	Lightweight endpoints	CoAP	MQTT

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Communication mechanisms between machines

- complex: CORBA, RPC
- Heavyweight web services: SOAP/WSDL

```
<?xml version="1.0"?>
<soap:Envelope
xmlns:soap="http://www.w3.org/2001/12/soap-envelope"
soap:encodingStyle="http://www.w3.org/2001/12/soap-encoding">
 <soap:body pb="http://www.acme.com/phonebook">
  <pb:GetUserDetails>
   <pb:UserID>12345</pb:UserID>
  </pb:GetUserDetails>
 </soap:Body>
</soap:Envelope>
```

- Lightweight web services: REST

```
http://www.acme.com/phonebook/UserDetails/12345
```

```
http://www.acme.com/phonebook/UserDetails?firstName=John&lastName=Doe
```

Posting
a SOAP envelope

Getting
an URL resource

HTTP
as
transport
mechanism

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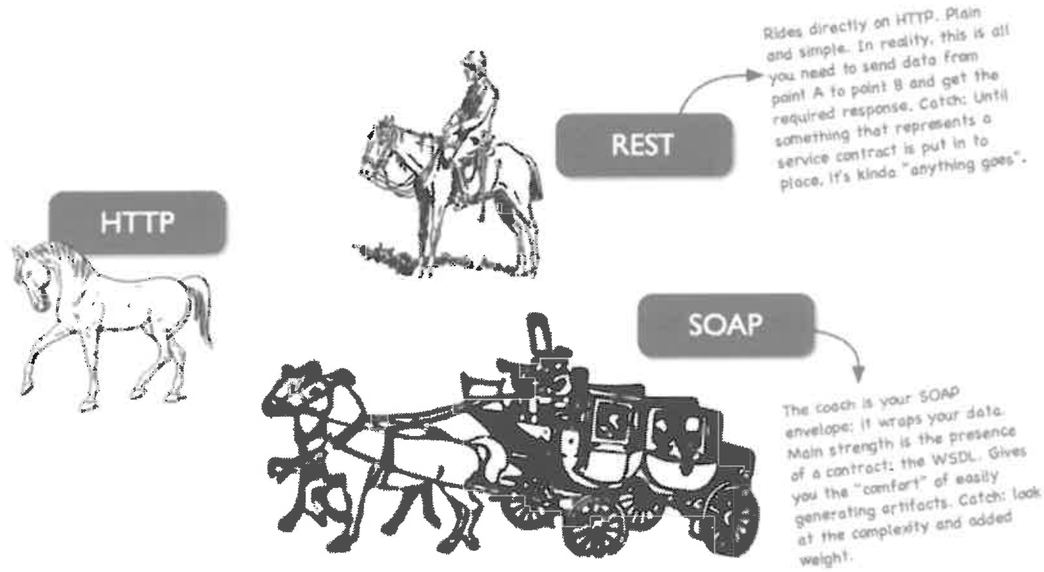

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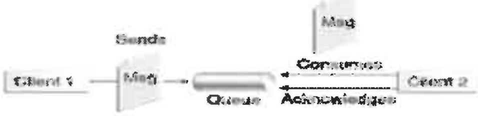
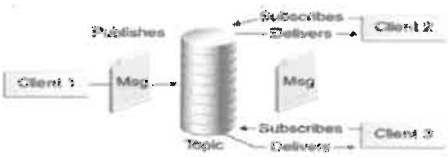
JMS (Java Messaging Service)

- **Strategy 1: Point-to-Point (PTP) Messaging domain**



- **Strategy 2: Publish/subscribe Messaging Domain (i.e by bulletin boards)**



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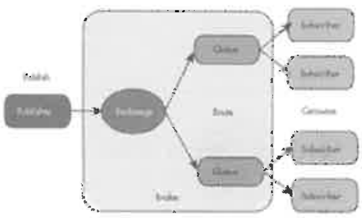
AMQP (Advanced Message Queuing Protocol)

- open standard application layer protocol for message-oriented middleware
- Previous standardizations of MW have happened at the API level (e.g. JMS)
- AMQP focuses on interoperability between multiple implementations
- Multiple message-delivery guarantee models:
  - *at-most-once*
  - *at-least-once*
  - *exactly-once*



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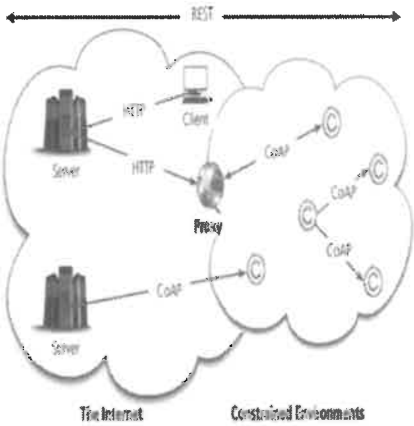
CoAP (Constrained Application Protocol)

- Very efficient RESTful protocol
  - `coap://…`
  - `GET, POST, PUT, DELETE`
- Ideal for constrained devices an networks
- Specialized for M2M applications
- CoAP can carry different types of payloads
- Easy to proxy to/from HTTP



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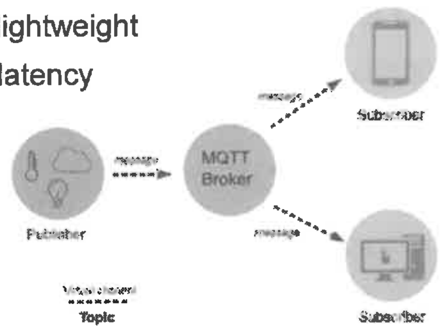
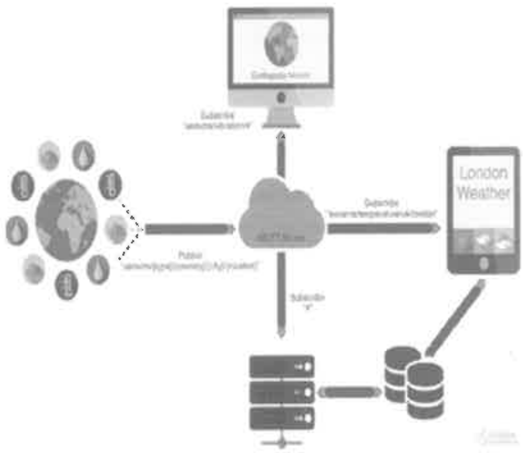
MQTT (Message Queue Telemetry Transport)

- Publish/subscribe messaging transport
- IoT connectivity protocol
- Very lightweight
- High latency





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Security concerns: why?

- Many different technologies
- Technologies cobbled together
- Interconnectedness
- Contrained nature → lightweight security
- Difficult to update devices
- Limited user interaction

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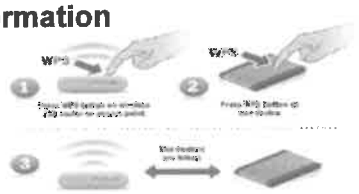
Security is a multifaceted concern → our focus...

- **Device Enrollment → key distribution**
- **Setting up secure channels**
- **Access Control Architectures**

Device Enrollment → key distribution

- **Strategy 1: Automated ad-hoc exchange of key information**
  - ☺ Simple integration of devices with infrastructure
  - ☹ Small vulnerability interval during information exchange
  - ☹ restricted to close-range devices



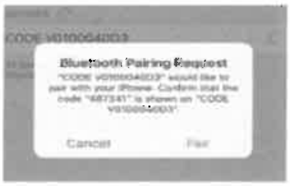
- **Strategy 2: environment based key distribution**
  - ☺ Establish shared key bsed on context-dependent info
  - ☺ Less vulnerable to MITM attacks

- User shakes both devices
- Both devices generate key based on measured accelerometer and gyroscope data

- Pacemaker and configuration device both monitor the patient's vital ECG
- Both devices generate a key based on the measure data

Device Enrollment → key distribution

- **Strategy 3: deploy devices with pre-loaded keys**
  - 😐 Active role of the device vendor/manufacturer
  - ☺ Can be used to lock devices
  - ☺ No vulnerability interval
- **Strategy 4: end-user or technician configuration**
  - ☹ Additional overhead for the user
  - ☹ Requires user interaction with IoT device
  - ☺ No vulnerability interval or location constraints



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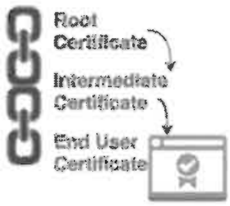
Setting up secure channels

- **Symmetric key infrastructures**
  - ☺ less resources (memory, power…)
  - ☹ less scalable
  - ☹ more management overhead
- **Asymmetric key infrastructures**
  - ☺ more scalable, more easy management
  - ☹ more resources → ECC mitigates problem



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Setting up secure channels

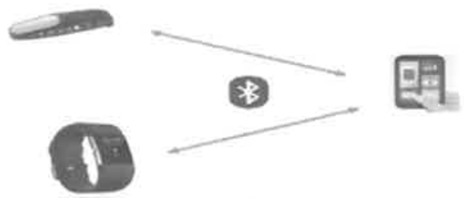
- **IoT network layer secure communication**
  - Protects the network from rogue devices
  - Built-in with most IoT communication standards

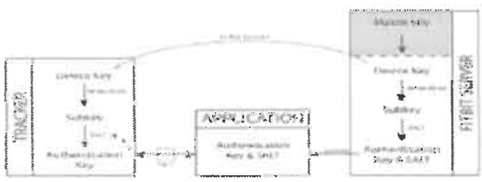
NB-IoT
sigfox
LoRa
ZigBee
WiFi

- **Application layer secure communication**
  - Realise application-level access control requirements
  - End-to-end data protection

Access control architectures

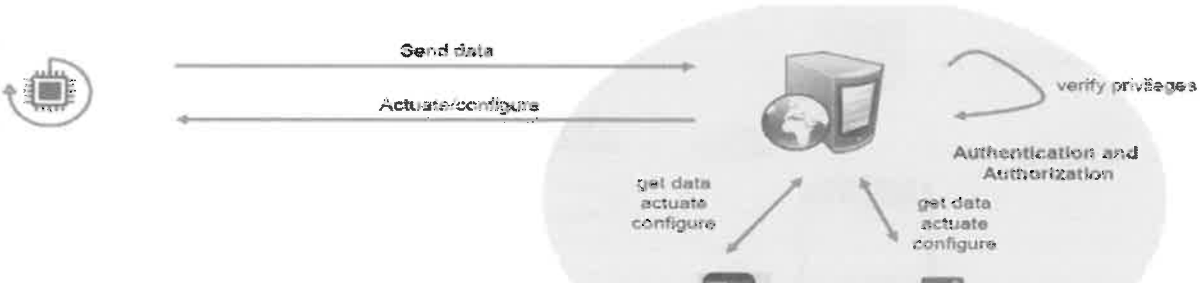
- **Strategy 1: Authentication and authorisation by IoT devices**
  - IoT device enforces access control policy
  - Limited flexibility → no user-based policies
  - Limited scalability → personal IoT systems
  - Often in combination with user-controlled pairing procedure





Access control architectures

- **Strategy 2: cloud/gateway-based access to IoT devices**
  - Delegate access to gateway or cloud
  - Other devices do not directly interact wth the device



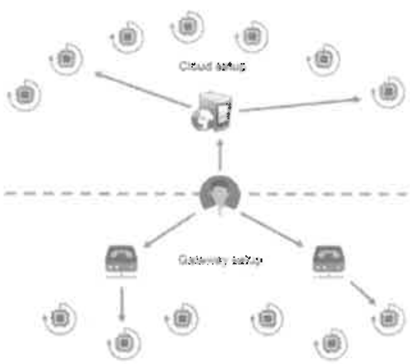
- *Low complexity for IoT devices*
- *Caching of data to lower load*
- *Modification of access policies immediately in effect*

Access control architectures

- **Strategy 2: cloud/gateway-based access to IoT devices**

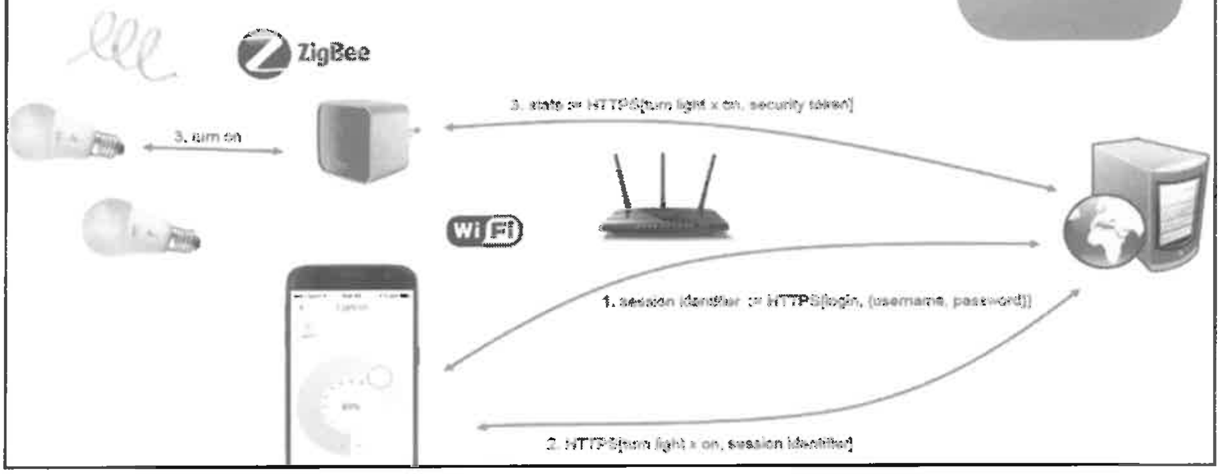
Cloud
- Great scalability
- Single-Point-of-Failure
- Protocol conversion at gateways

Gateway
- Increased management overhead
- Distributed access
- Increased privacy



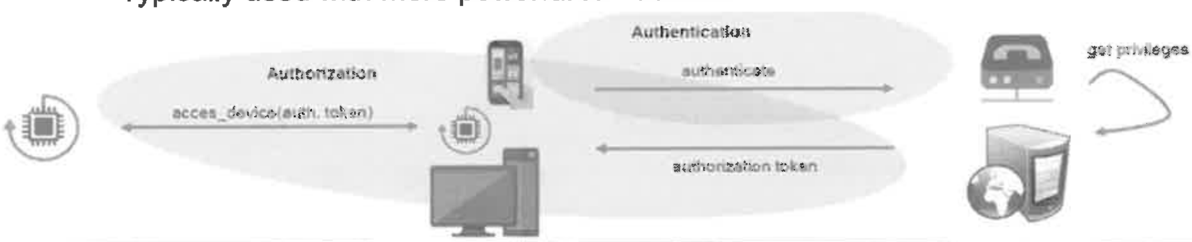
Access control architectures

- **Strategy 2: cloud/gateway-based access to IoT devices**



Access control architectures

- **Strategy 3: token-based access to IoT devices**
  - Gateway or cloud issues autorisation tokens
  - IoT device verify validity of the used autorisation tokens
  - Tokens subject to a specific scope (e.g. time, APIs…)
  - Typically used with more powerful IoT devices



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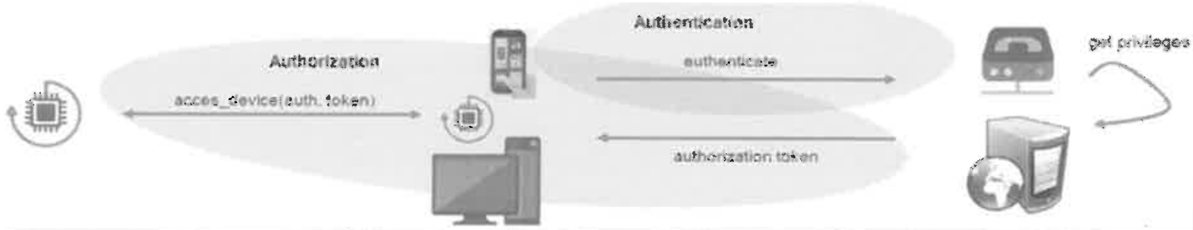
Access control architectures

- **Strategy 3: token-based access to IoT devices**
  - ☺ supports offline interactions with IoT devices
  - ☺ combines increased privacy with scalability/flexibility
  - ☺ less reliant on always-online/reachable cloud/gateway
  - ☹ access token management + revocation



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That's it…

- A taxonomy of IoT architectures
- Prevalent IoT components
- IoT communication technologies
- Authentication and authorisation approaches

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Connecting low power nodes in the Industrial IoT

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www.dramco.be

12 Maart 2019, Kortrijk

1 The **Things**, which are embedded with sensors and/or actuators

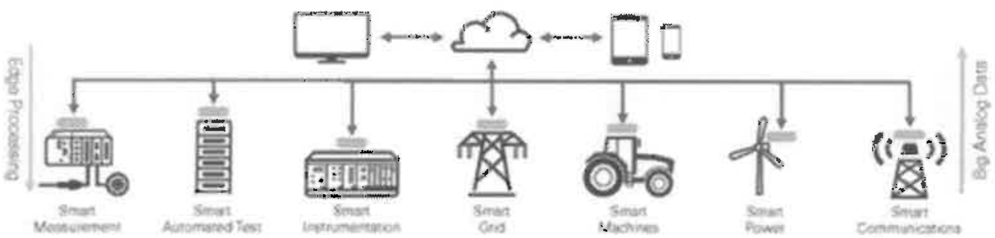
2 The **network** that connects them

3 The systems that **process data** to/from the Things

Focus of this lecture

source: https://www.linkedin.com/pulse/internet-things-iot-dummies-rajat-kochhar

The INDUSTRIAL context brings specific challenges



Enhanced Requirements for the IIoT

Reliability | Latency | Security | Upgradability

NATIONAL INSTRUMENTS

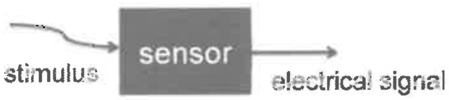
ni.com

IIoT in a variety of applications, hence diverse requirements

© Qualcomm

Wat is een sensor?

A sensor is a device that receives a stimulus
and responds with an electrical signal



Stimulus: quantity, property (feature), condition.

Often mentioned with friend:

An actuator is a device that takes an electrical signal as an input
and produces a physical response as an output.

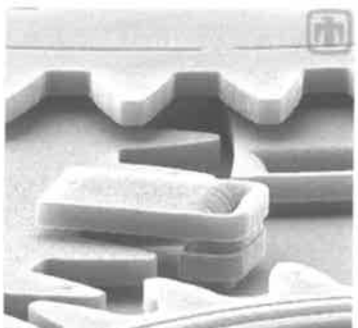
Een definitie door een Vlaamse wereldleider:

Sensors voor **een waaier** van parameters:
camera's, microfoons, gassensoren
accelerometers, gyroscopen, temperatuursensoren,
druksensoren, ... **werken samen**

MEMS: Micro-Electro Mechanical Systems

MEMS = Micro-Electro-Mechanical Systems
MEMS = Batch-fabricated miniature system with:

- Electrical and non-electrical (or not-only electrical) functionality
- Characteristic sizes ranging from nanometers to millimeters
- Sensors and actuators



http://www.memx.com/

Sensoren: indrukwekkende evolutie

IoT Sensors Reveal New Ways for Manufacturers to Cut Energy Usage

Removing inefficiencies on the factory floor and in the supply chain can cut costs

By Stacey Higginbotham

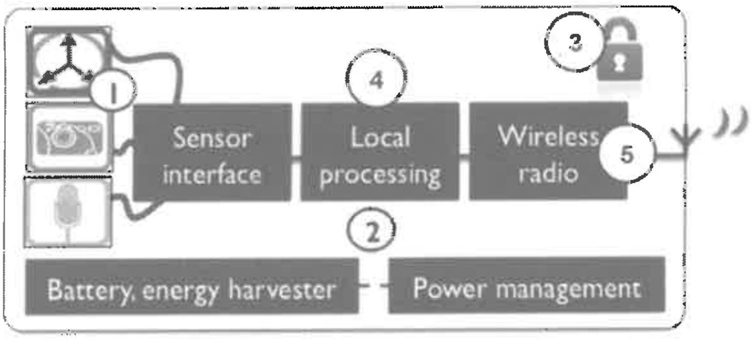
The next big effort to reduce carbon emissions and hold the line on climate change will be enabled by the Internet of Things. Companies can rethink their costs of operations, taking into account the energy used, with a combination of more granular data from cheap sensors and faster, more in-depth analytics from cheap computing.

At Schneider Electric's factory in Lexington, Ky., workers make electric components, including load centers and switches. The plant is four years into a company-mandated five-year

IEEE spectrum

Sept. 2018

'Slimme' sensoren kunnen rekenen en communiceren



Uitdaging 1: kleine oplossingen

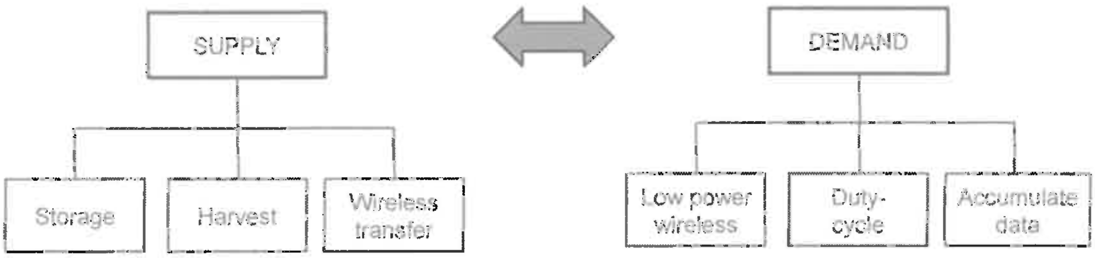
Oplossing: slimme integratie

- System-on-Chip (SoC) en/of System-on-Board
- 'Traditionele' chips en MEMs/NEMs
- Design reuse – design yourself (kosten-baten analyse)

Uitdaging 2: Vermogen en energie!

- It needs your full and continuous attention!
  1. Low power/energy engine(s)
  2. Driving the engine(s) efficiently
  3. Sleeping silently
- Energy consumption will drain your battery
- Power consumption will heat your system

Autonomous wireless devices: mastering the supply - demand balance



Energy supply: the options

- Batteries:
  - Considered the most viable solution for sensor nodes (with low power requirements, often deployed remotely)
  - Unfortunately, no matter how large the capacity of the battery or how efficient the protocols: batteries eventually drain out

- Harvesting:
  - Energy obtained ('harvested') from the environment
  - Transformed to electric (DC) power

- Transfer:
  - Near-field
  - Far-field: radio frequency transport

Energy storage: Battery categories and popular items

- Primary: single use devices
  - can provide high density and low initial cost
  - when drained out: replacement only option if further operation of the device is required or desired

- Secondary (rechargeable): multiple use devices

- Super-capacitor: allows fast and many recharges, embedded as stand-alone storage solution or in support of a battery

Selecting a battery: which characteristics to consider?

- Battery capacity: C (mA.h) – battery life (h)
  Consider average current *I* (mA) and duty cycle *n* (e.g. 2 min/hour):

$$t = \frac{C}{I.n}$$

- Voltage: nominal *and* stability

- Peak current delivery capability (potentially upgraded by super-cap)

- Life-time – self discharge

- Density: in terms of capacity/weight or capacity/volume

- Cost, ecological footprint, availability

Batteries: different capabilities

champion in density (today)

Battery type	Vol. Energy density Wh/dm³	Grav. Energy density Wh/kg	Self-discharge % per year	Cycle Life no.
Alkaline	300	125	4%	1
Ni-Cd	100	30-35	15-20%	300
Ni-MH	175	50	20%	300
Li-ion	200	90	5-10%	500

Popular, best-in-class, option: the lithium-ion battery

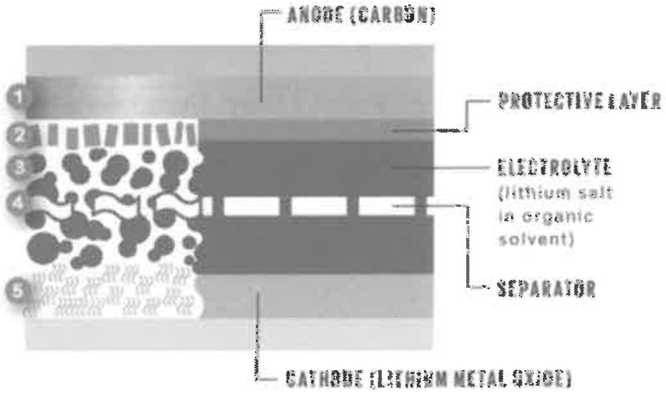
- Invented: first brought to market by Sony in 1991
- Lithium-ion batteries have significant advantages over nickel cadmium in terms of energy density, rapid recharging and cost.
- However: Their chemistry and cell structure present a potential risk of fire (estimated one in a million to one in 50 million).

The problem(s) with Li-ion batteries

At the heart of the matter: thermal runaway

Thermal Runaway in a Lithium-Ion Battery

1. Heating starts.
2. Protective layer breaks down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down, generating oxygen.



Solid state batteries: what and why?

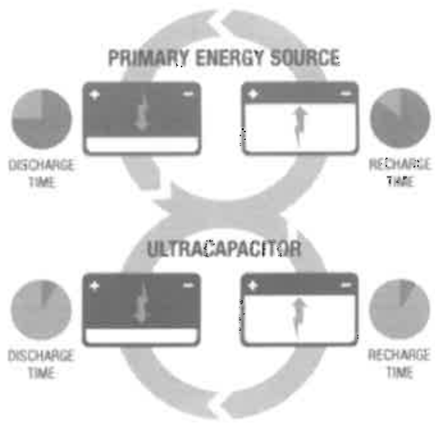
- Current batteries lack on desired specifications:
  - Density (in mAh/cm^3) not increasing at the same pace as energy needs
  - Demonstrated (!) safety risks
  - Chemicals can leak
  - Integration overhead

- Solid state batteries store energy based on a solid electrolyte
- They could offer better, safer, lighter, and less-expensive solutions, especially for the IoT
- Several technologies in development

Super- or ultra-capacitors: how they work

PRIMARY ENERGY SOURCES like internal combustion engines, fuel cells and batteries work well as a continuous source of low power. However, they cannot efficiently handle peak power demands or recapture energy in today's applications because they discharge and recharge slowly.

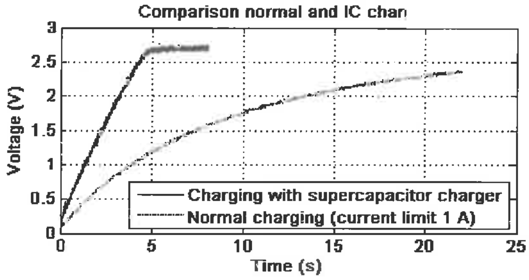
ULTRACAPACITORS deliver quick bursts of energy during peak power demands, then quickly store energy and capture excess power that is otherwise lost. They efficiently complement a primary energy source in today's applications because they discharge and recharge quickly.



© www.maxwell.com

Supercap charger: an illustrative case

- 3 F supercap
- Charging in < 5 seconds



Energy harvesting: reload in the field

'Free Electricity Folks'

Classes of energy harvesting resources

Energy Source	Type of Energy
Human	Kinetic, Thermal
Environment	Kinetic, Thermal, Radiation

Counting on the human ('bearer'):
active = ok
passive = problematic
Of specific interest for personal and wearable devices

Specifies source energy
For these types
diverse techniques exist
to transform to electric energy

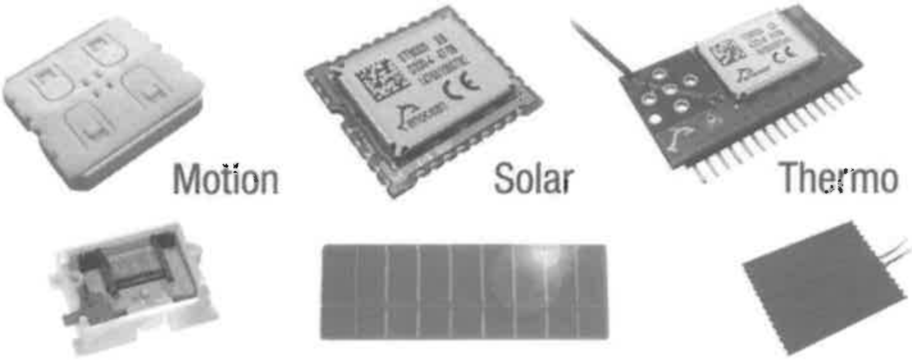
Options and their potential: mind the **significant** differences

Table 3.4 A comparison of typical power sources for energy scavenging.

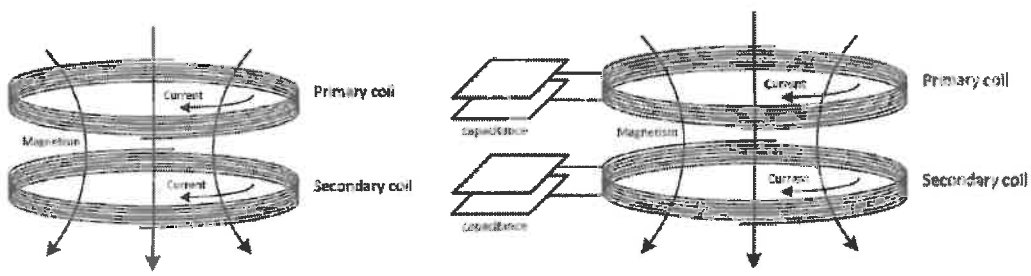
Energy source	Power density	Duration
Solar cell (direct sun light)	15 mW/cm^2	Continuous
Solar cell (well illuminated room)	10 μW/cm^2	Continuous
Piezoelectric	200 μW/cm^3	Operation (e.g. button push)
Temperature difference	40 μW/cm^3 / 5 °C	Continuous
Air flow	380 μW/cm^3 / 5 m/s	Continuous

Reference paper: Paradiso, J., Starner, T. Energy scavenging for mobile and wireless electronics. *Pervasive Computing, IEEE* 2005;4(1):18-27.

Energy harvesting devices: how they look like



Wireless power based on coupling : inductive and magnetic options



(a) Inductive Coupling (b) Magnetic Resonance Coupling

COUPLING is essential in near field transfer

Works both ways: absorption of energy INFLUENCES the load on the transmitter

Handy for personal devices – note the coil

A popular standard: Qi

Popping up in hotspots - getting integrated in furniture

Essential in many industrial applications: connector-free!

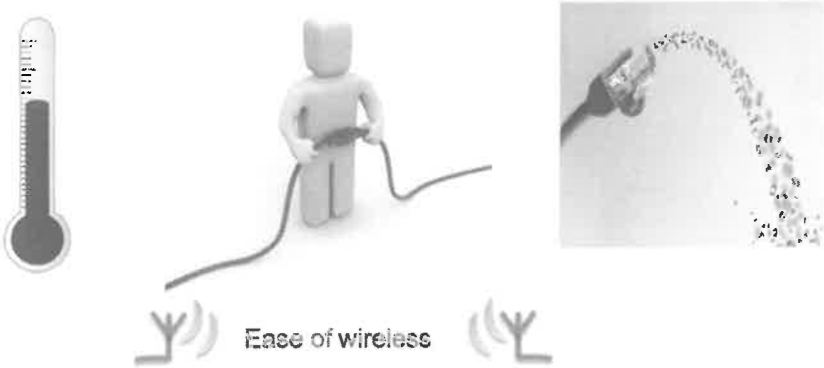
Uitdaging 3: Safety and security

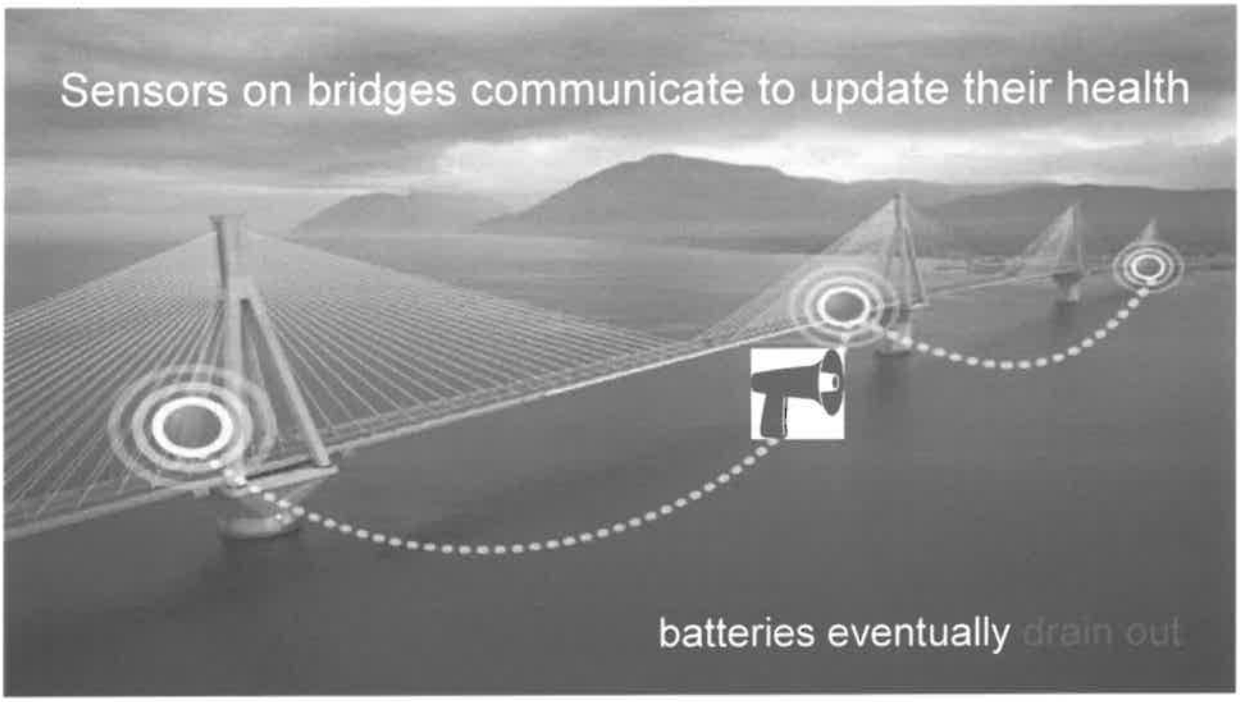
Uitdaging 4: Massive Data Processing

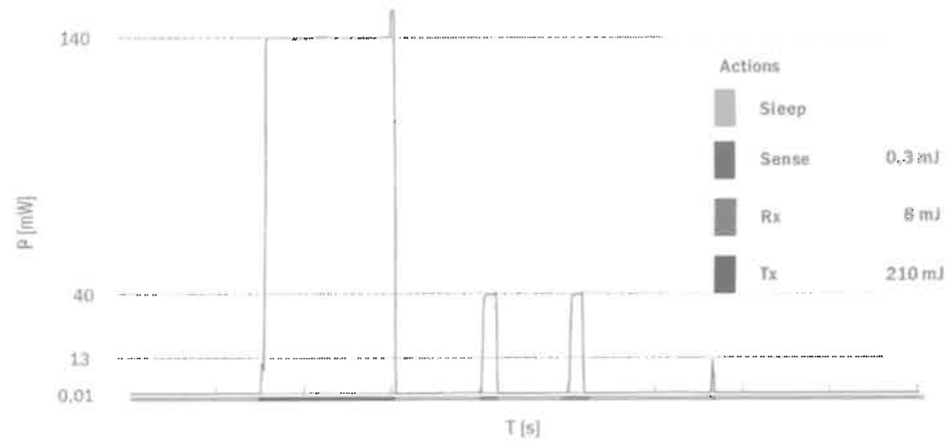
- Early data reduction

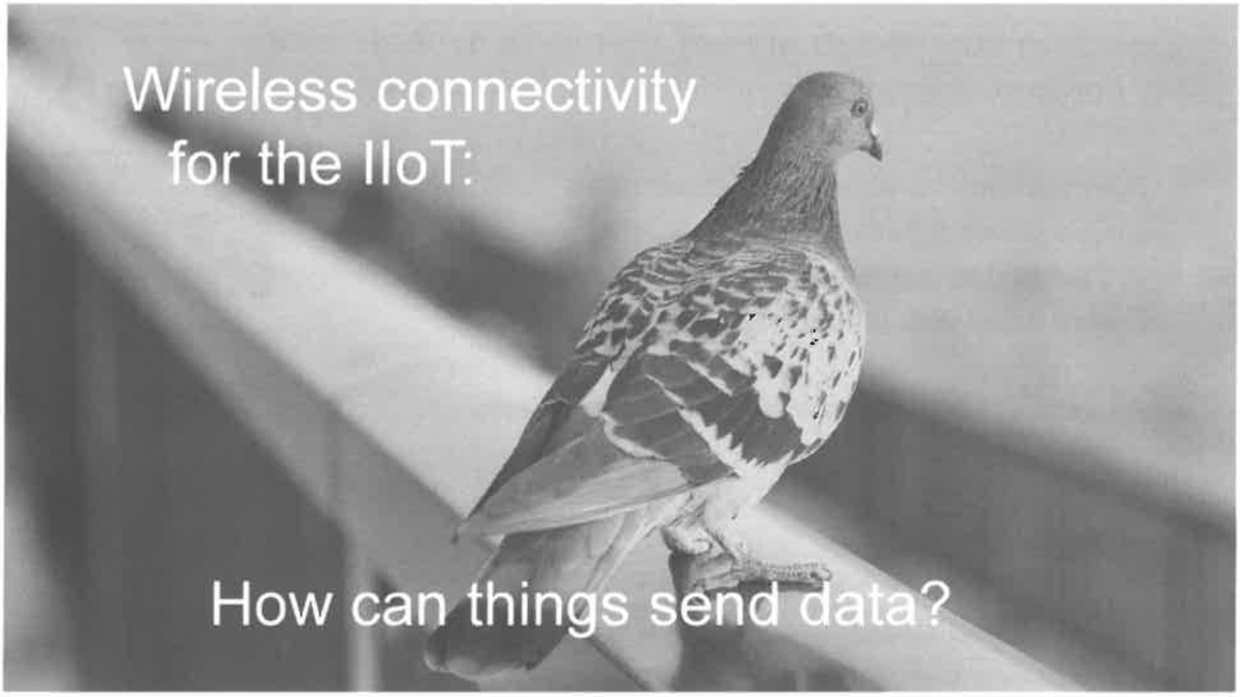
- Efficient processing algorithms

Uitdaging 5 – de grootste? Connectiviteit!

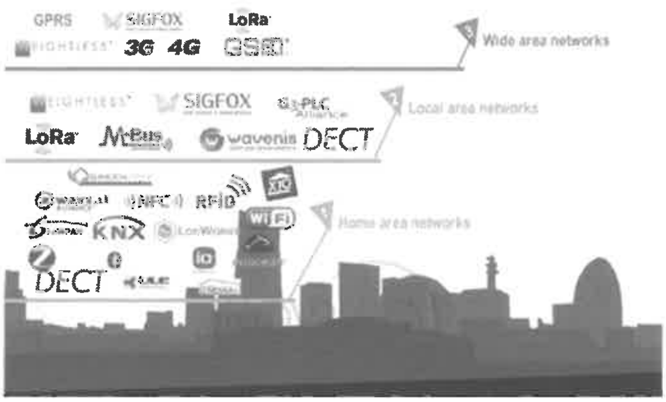








Opportuniteit: standaarden en systemen beschikbaar



Selecting an appropriate connectivity solution: what matters?

- Range: home – local area – wide area?
- Data rate – up and/or downlink
- Mobility
- Latency (~response time): maybe crucial for safety-critical control operations

- Interference: the unpredictable
  - Growing number of wirelessly connected devices
  - Operation in unlicensed bands and in open environments

- Reliability: %'s or 0.000x%'s?

Selecting an appropriate IoT connectivity technology: Power and size strictly constraint in many use cases

- Power options vs. autonomy requirements:
  - Grid power or battery?
  - Chargeable (e.g. outdoor solar cell – basement - …)?
  - How accessible (for battery replacement)?

- Accessibility: antenna needs to pick up the waves

- Integration:
  - Size/weight
  - Outdoor/indoor – humidity – radiation - …
  - Design - esthetics?

Selecting an appropriate connectivity solution: Non-Technical considerations

- Costs involved:
  - Devices
  - Development
  - License?

- HW/SW solutions availability (maybe from different vendors)
- Maturity
- Standard compliance – interoperability - roaming
- Expertise - support available?

IoT connectivity at long range: to license or not to license?

© Qualcomm

To pay or not to pay?

Exclusive use & managed services -> Quality of Service?

'Personal' (few m's)– area: bluetooth - flavors

Bluetooth 5

4 times speed, double range

> *"Bluetooth is revolutionizing how people experience the IoT. Bluetooth 5 continues to drive this revolution by delivering reliable IoT connections and mobilizing the adoption of beacons, which in turn will decrease connection barriers and enable a seamless IoT experience.* **Mark Powell, Executive Director of the Bluetooth SIG**

Local area sensing & control: Zigbee at help

ZigBee Alliance

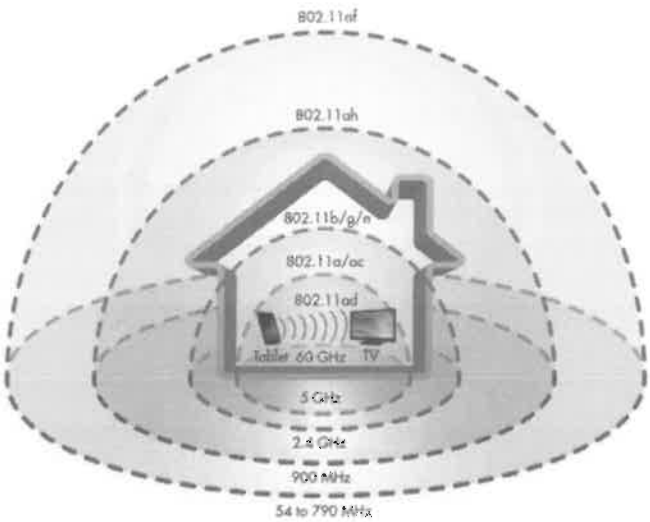
IEEE 802.15.4

ZigBee: operates on the IEEE 802.15.4 physical radio specification

Operates in unlicensed bands: 2.4 GHz, 900 MHz and 868 MHz

Supports mesh networking

'Common' WiFi and new flavors: the application view



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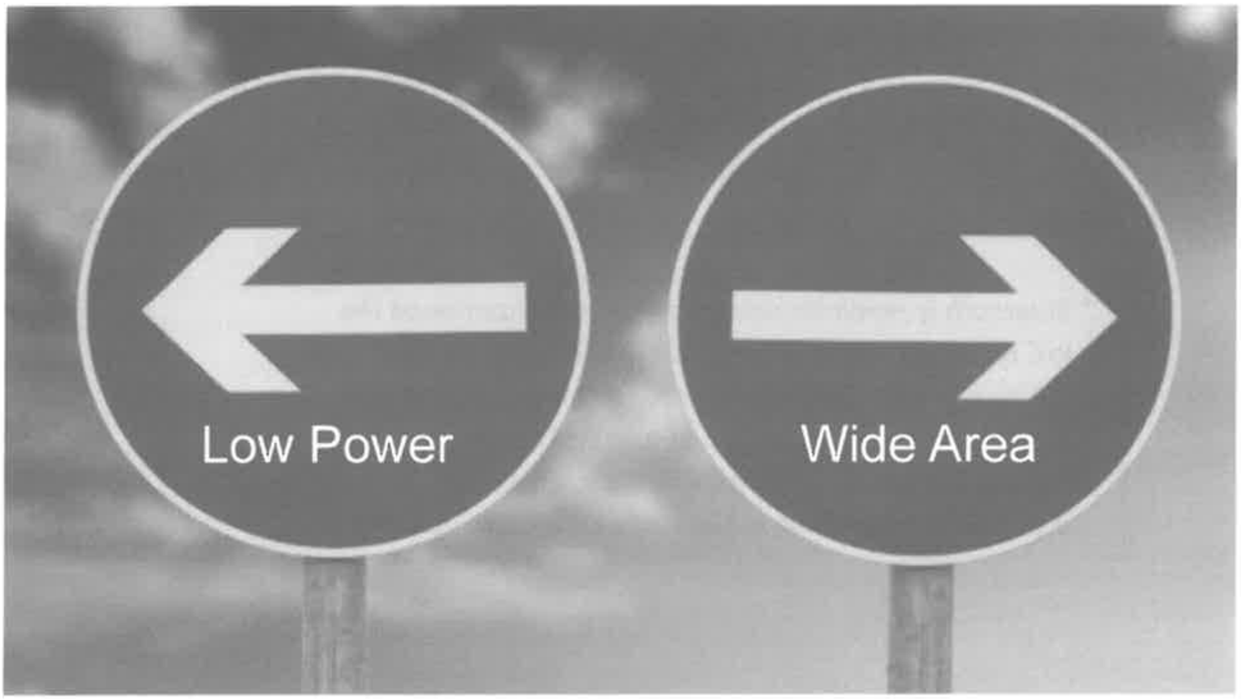


Cost

Mostly unlicensed spectrum (ISM bands)
Low chip and subscription cost

Data Rate

Simple coding
--> low data rate, low cost, low power

Energy

Reduce *radio on time*
Device induced communication, sleep, low data

Coverage

Lower frequency bands (i.e. sub-GHz)

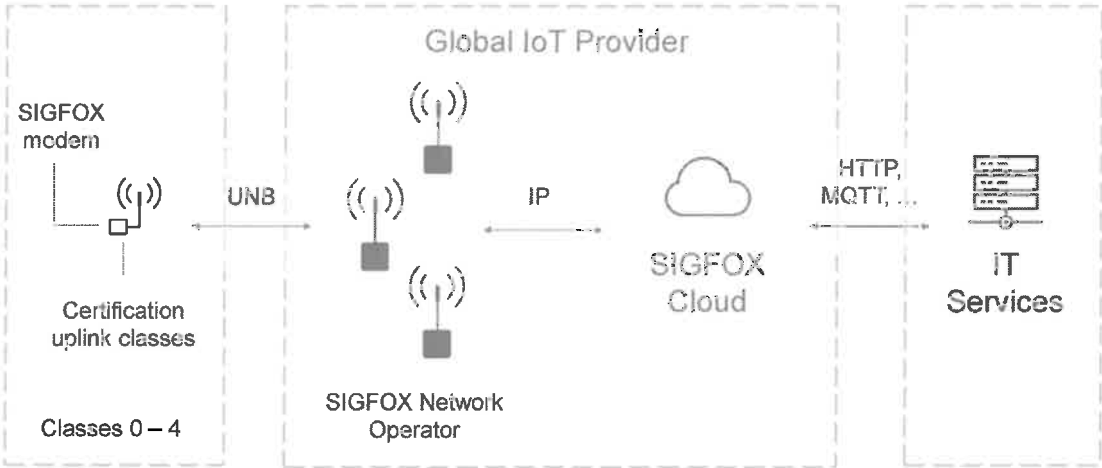
Topology

Predominantly single hop star-of-stars topology
Easy deployment → low installation and maintenance cost

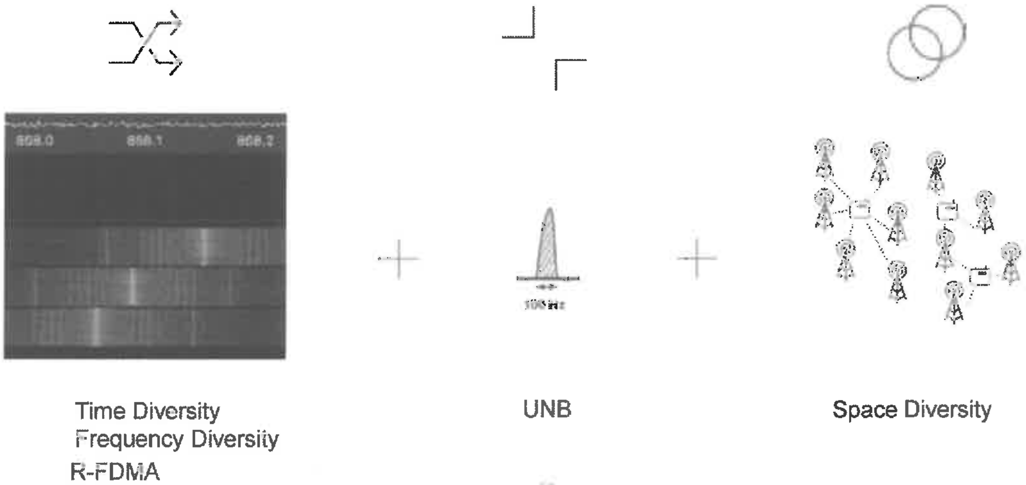
Same frequency and target applications, Different business model

RADIO CHIPS	NETWORK SUBSCRIPTION
Global IoT is enabled by other companies	Controls, Builds and Maintains the cloud Open for chip providers
Deploy your own network	**Become THE global IoT operator**
LoRa™	SIGFOX

SIGFOX: Global IoT provider in unlicensed 868MHz band



SIGFOX
Radio Technology – UL (EU)



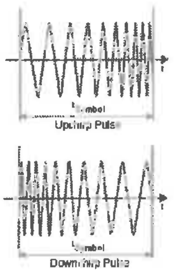
SIGFOX: Coverage as announced

Currently present in over 30 countries, they aim to cover 100% of the globe within the next few years.

LoRa & LoRaWAN

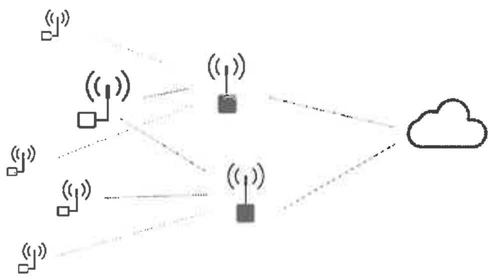
LoRa

= PHY
Radio modulation patented by Semtech
Based on Chirp Spread Spectrum (CSS)



LoRaWAN

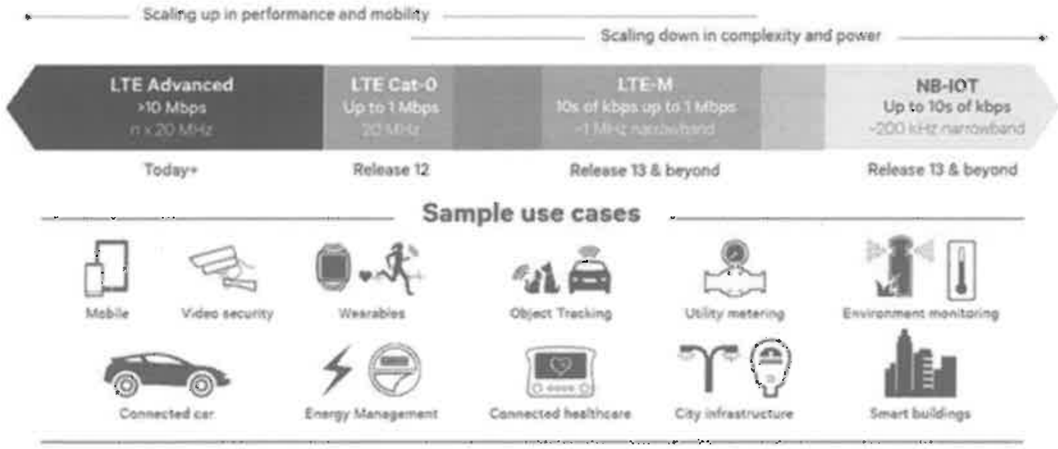
= MAC + System Architecture



A GLOBAL INITIATIVE

Cellular technologies for IoT: 3GPP standards are key

3GPP-LTE not longer only about higher speed



Cellular standards: how to make them better fit for IoT

1. Reducing complexity,
2. Improving battery life,
3. Enhancing coverage, (adverse environments e.g. underground parkings)
4. Enabling higher node density deployments.

EC-GSM-IoT
Backwards compatible design based on GPRS/EGPRS with added features such as improved coverage and energy efficient operation.

LTE-M
Reduced device complexity and coverage enhancements makes LTE competitive in the MTC market. Designed for low latency and high data rates.

-> 'retro fits'

NB-IoT
Features high deployment flexibility due to its low system bandwidth in combination with low device complexity, energy efficient operation and ubiquities coverage

-> New air interface

3GPP-LTE included 3 options for IoT in Release 13

A GLOBAL INITIATIVE

NB-IoT: the maximum service offer as specified

Uplink data rate	20 kbps
Downlink data rate	200 kbps
Payload size	1600 Byte
Range	15 km in urban environments 35 km in rural environments
Roaming available	Yes

Note: the name suggests 'Narrowband' = relative for cellular technologies
Offered rate > unlicensed LPWAN (Lora, Sigfox)

NB-IoT: Best fit current cellular technology for IoT

Cost

Licensed spectrum -> subscription
Low chip cost, low data volume/cost

Service

Relatively low data rate for cellular,
Higher than unlicensed LPWAN (LORA, SIGFOX)
Better service guarantees – licensed spectrum, centrally controlled, interference can be avoided

Energy

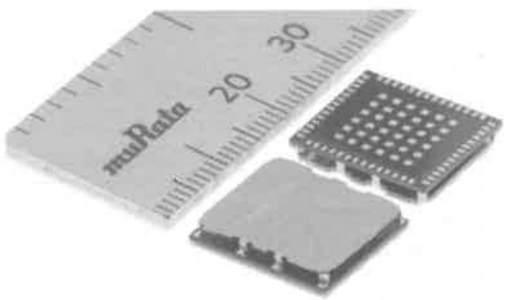
Considerably higher than LPWAN alternatives
Reduce *radio on time*

Coverage

Cellular network 'coverage guaranteed'
International standard: global scale – in progress

March '19: All three mobile operators now support NB-IoT in Belgium.

NB-IoT devices and networks gaining momentum as we speak

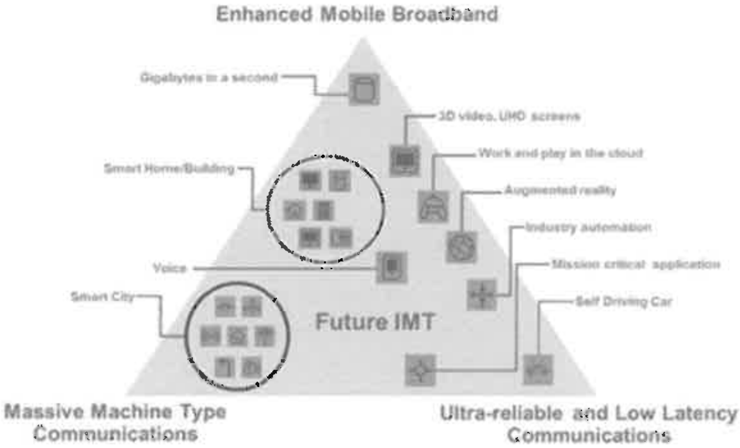


Murata's LBAD0ZZ1RX: 15.6x14.0x2.2mm

claimed to be the world's smallest
NB-IoT cellular wireless module.

Announced November 2018, Module by Murata, modem IC from Hisilicon (a Huawei company)

5G to support IoT: good intentions



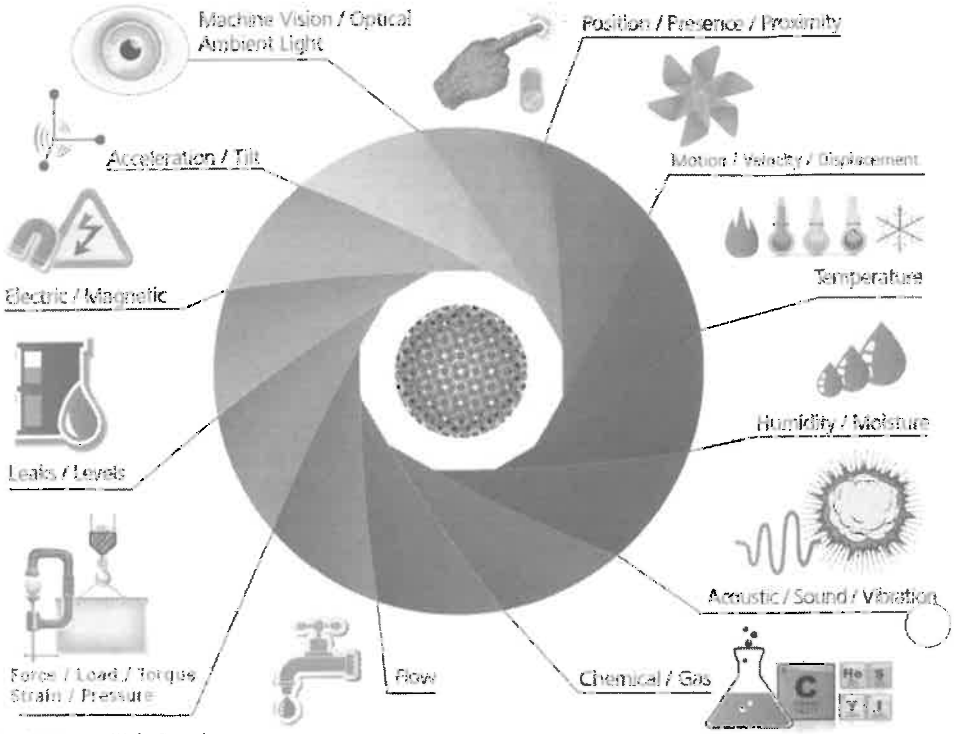
© ITU: vision and requirements for 5G

What is
The Internet of Things...

Sensors

- Temperature
- Vibration
- Acceleration
- Dust
- Noise
- Humidity
- Pressure
- Location
- Moisture...

More and more operate autonomous on batteries or energy harvesting



Source: Postscapes and Harbor Research

Connectivity

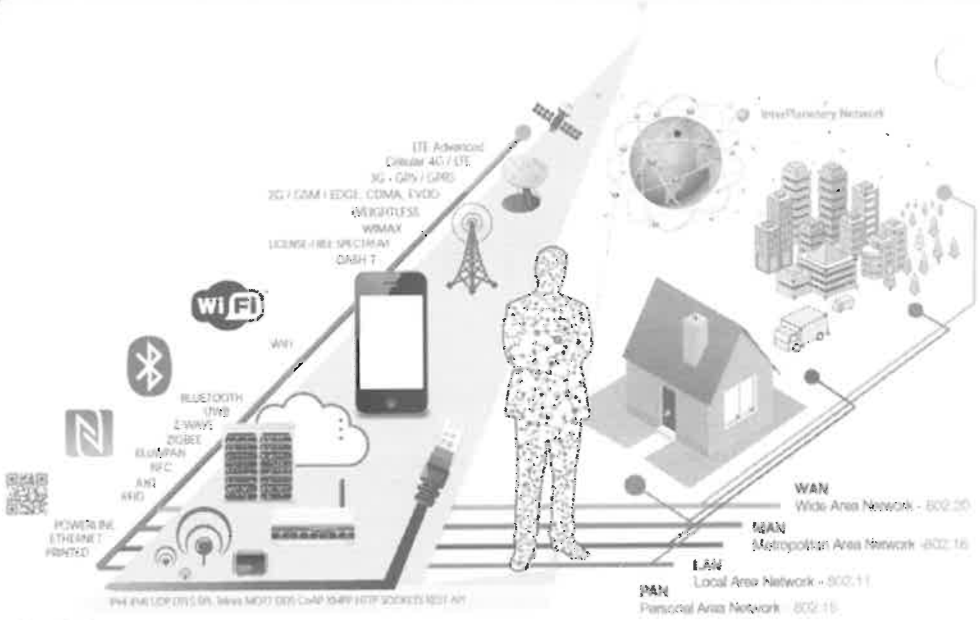
Heterogeneous networks

(PAN, LAN, WAN,...)

New IoT networks: LoRa, Sigfox, NB-IOT, etc
-> Long range, Low Power

Meshed & short distance:
Zigbee, Z-wave, BLE, etc

internet protocols:
MQTT, CoAP, STOMP, etc



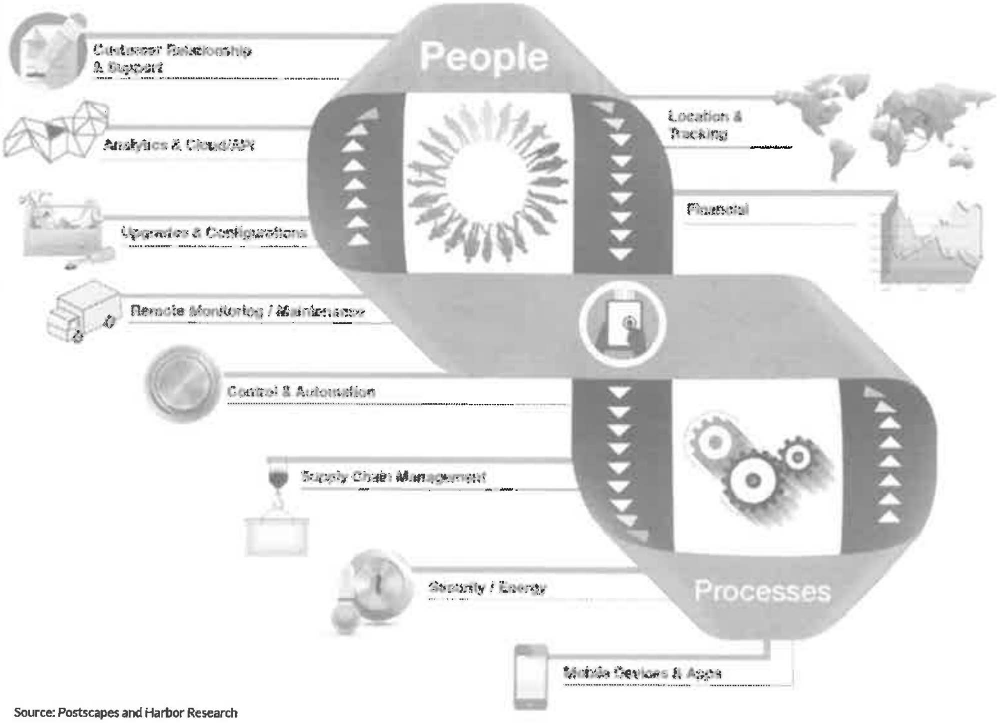
Source: Postscapes and Harbor Research

People & processes

Human <-> machines

Better decision taken,

- Monitor
- Control
- Improve
- up-to autonomous



Source: Postscapes and Harbor Research

What is The Internet of Things?

An interaction between

Sensors

Our world is changing into a digital neural system full of sensors ...

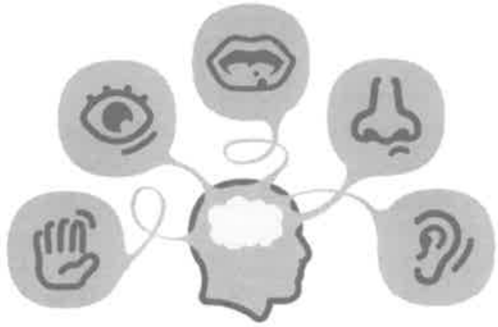
Connectivity

where the analog sensor inputs and outputs are aggregated via a network(.io) ...

People & processes

Data is processed to make better decisions, even autonomously

Human Intelligence vs Digital Intelligence



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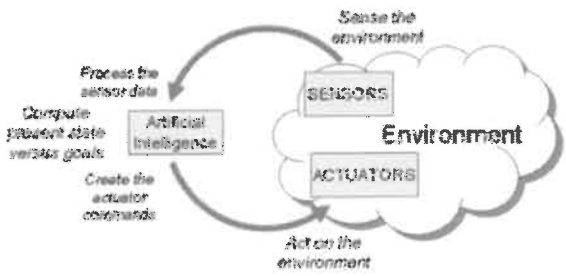
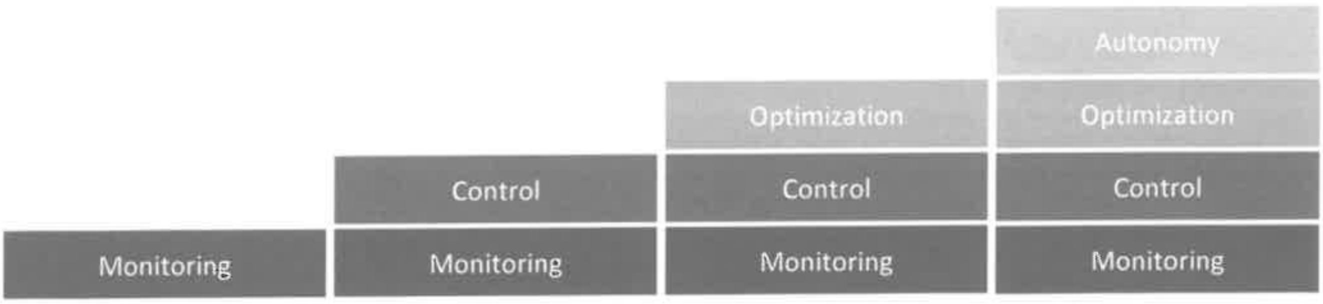


If we want to build Smart products with (near) human intelligence, sensing involves interpreting insights, sounds, smells, touch,.... and act on it based on cognitive thinking in (near) real time just as we humans do.

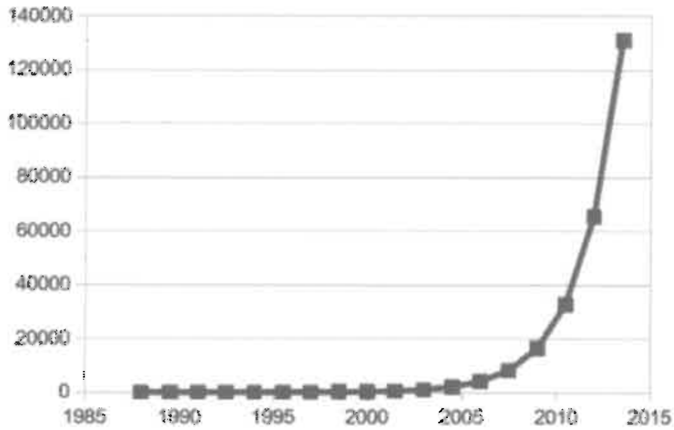
One way to define IoT categories

Monitoring, Control, Optimization, Autonomy build on each other



Why does this happen now?

Our exponentially growing knowledge of how we can simulate how the human brain works and exponentially growing availability of resources to build a 'digitized' brain are meeting today the minimum requirements to actually get it done. Once we achieve this goal, things will never be again as before...



Moore's Law states that the density of components in integrated circuits would double each 18 months (or about 4% per month). A computer now is around 130 000 times more powerful than in 1988.

The same exponential curve applies for the gain in knowledge how our human brain works.

COST DRIVERS

Why Now?

- Lower Hardware costs
- Lower connectivity costs
- Lower software costs
- Lower operational Costs (Cloud)

VALUE DRIVERS

Why Now?

(Real-Time) Data -> Better Insights

Better decision making through

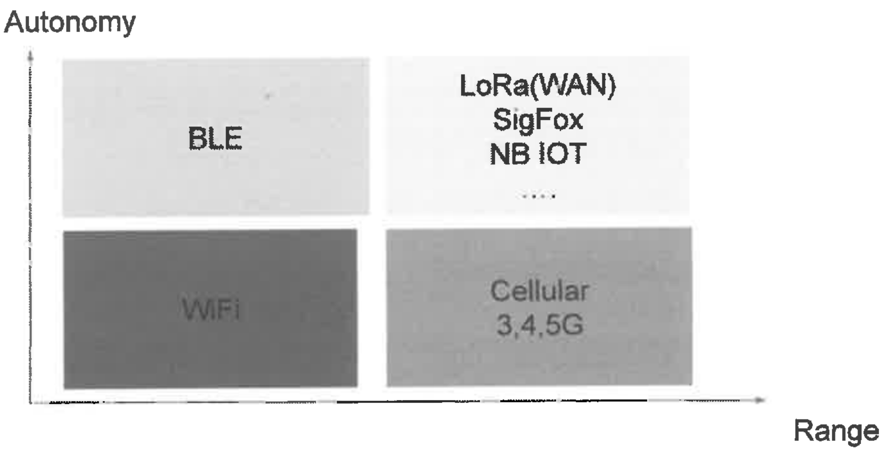
Smart Algorithms, ML & AI

New Technology Solutions

Why Now?

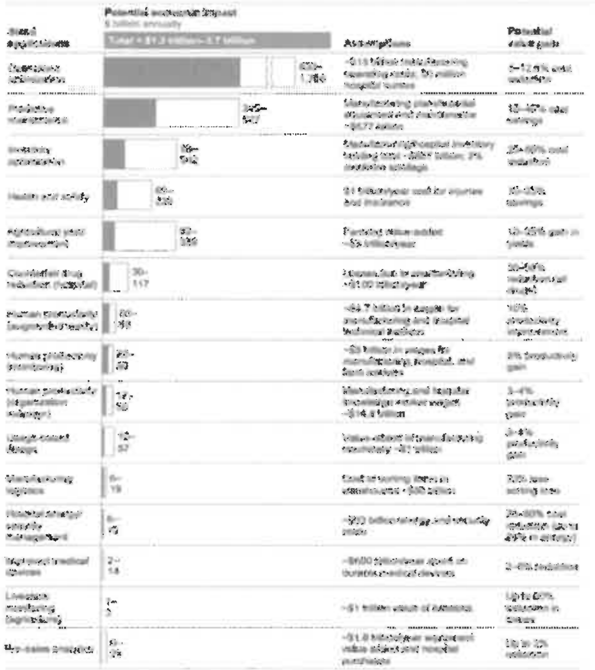
LPWAN fills the gap where Long Range and Autonomy are important.

Addressing the needs for the new digital world where everything is connected.



Opportunities…

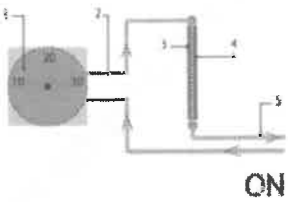
Industrial IoT:

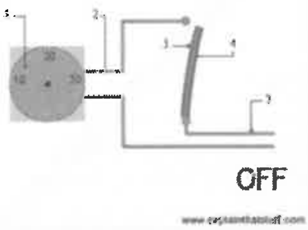


From discreet…
To Smart (IoT) Product

Example, The Thermostat...

Discreet





Connected

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Smart

- Presence detection
- Self learning (based on your whereabouts)
- Focus on outcome
- Programs itself
- Makes suggestions
- Provides convenience
- Insights
- Interconnects

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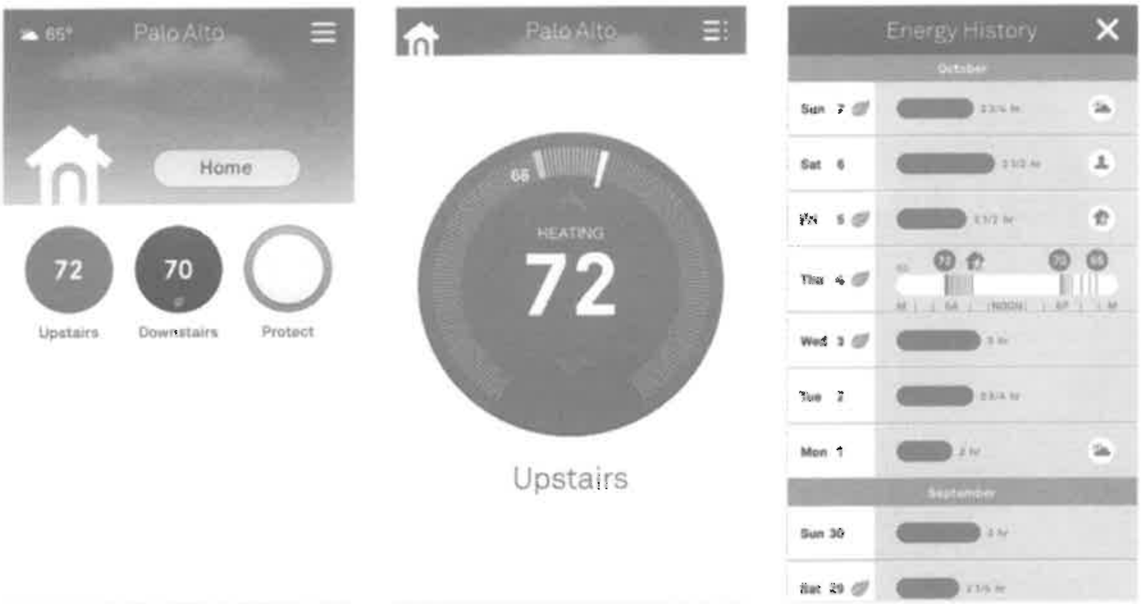
Insights



What does it take to build an IoT product?

Translation of a physical object to its 'digital representative'

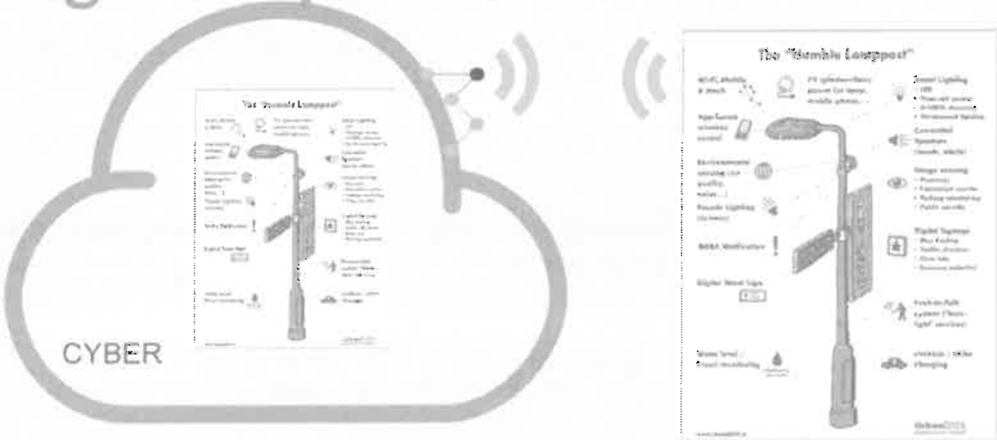
Source: Jason Warwick jason.warwick@urbandna.eu |September 2015

What is a digital representative?

ANALYTICS

DATA SERVICES

BUSINESS SYSTEMS



EXTERNAL SYSTEMS ⟷ DIGITAL REPRESENTATIVE (software defined) ⟷ PHYSICAL OBJECT (hardware defined)

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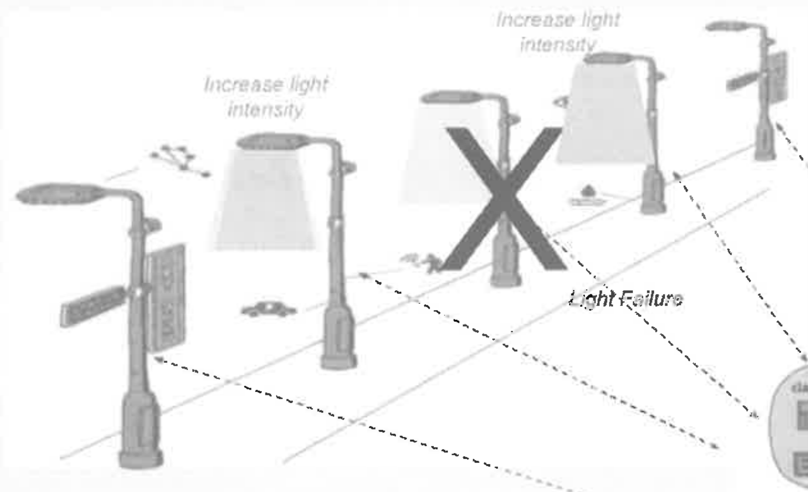
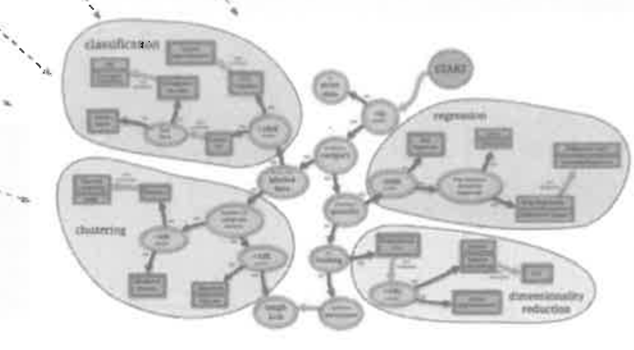


EXTERNAL SYSTEMS

"ADDING BUSINESS LOGIC"



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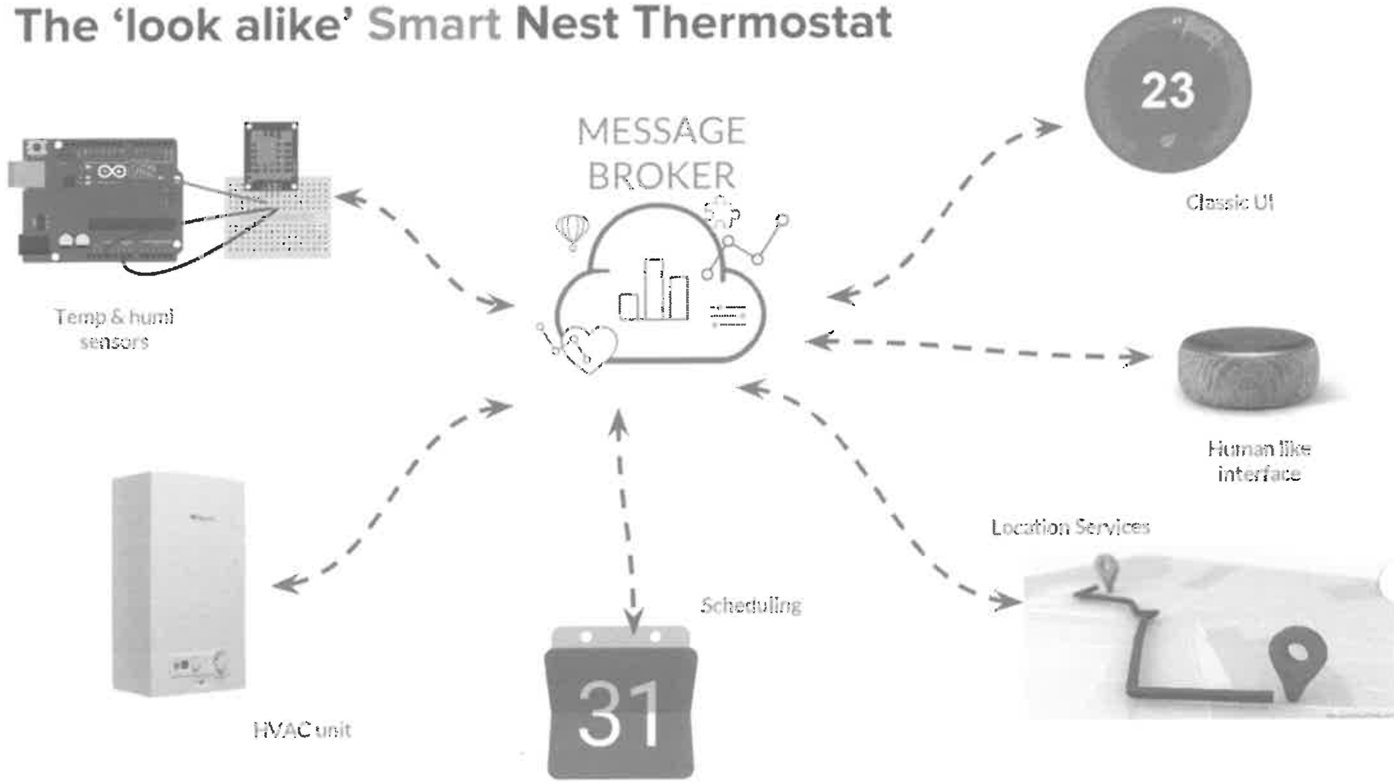
SmartPhone DEMO

a Systems of Systems Approach

The ‘look alike’ Smart Nest Thermostat



REST APIs

“A REST API allows to connect one software component with another.”

A REST API defines a set of functions which developers can perform requests and receive responses via HTTP protocol such as GET and POST

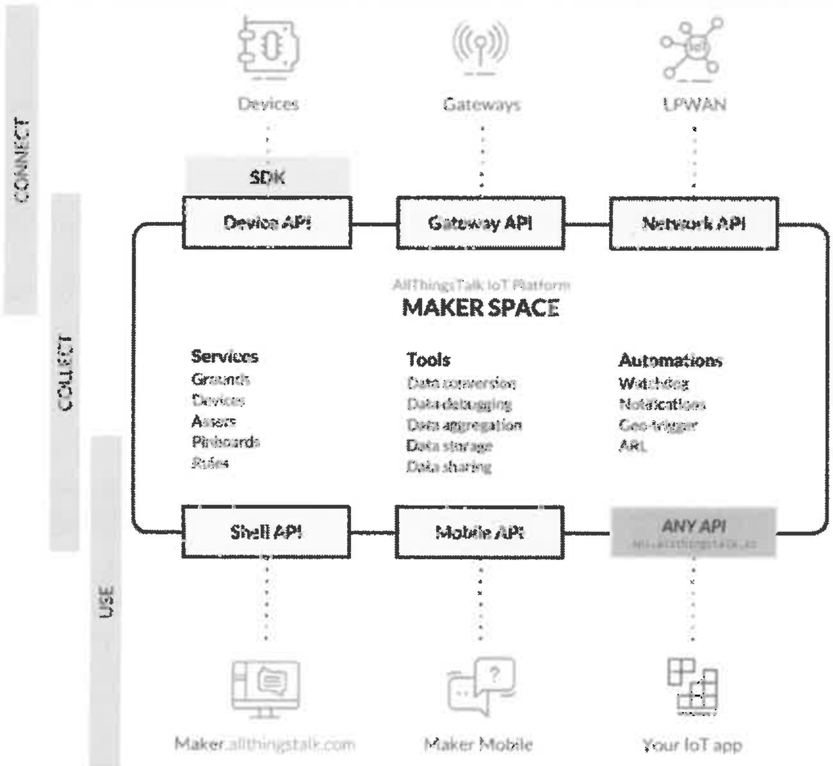
CLIENT —HTTP→ SERVER

Example:

Developers can use HTTP(S) API to access and modify resources
Because REST API's use HTTP, they can be used by practically any programming language and are easy to test

HTTP Methods

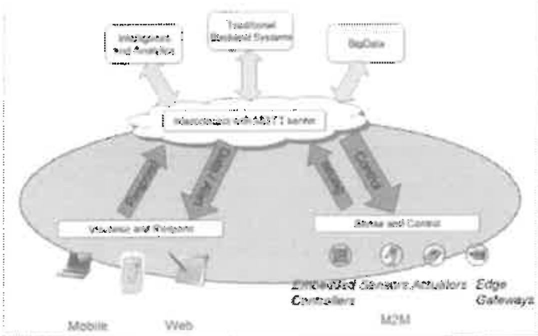
Open Rest API



MQTT Message Broker

MQTT is a connectivity protocol designed for M2M & IoT.

It is an extremely lightweight publish/subscribe messaging transport that is ideal for connecting small devices connected on networks with minimal bandwidth towards remote systems.



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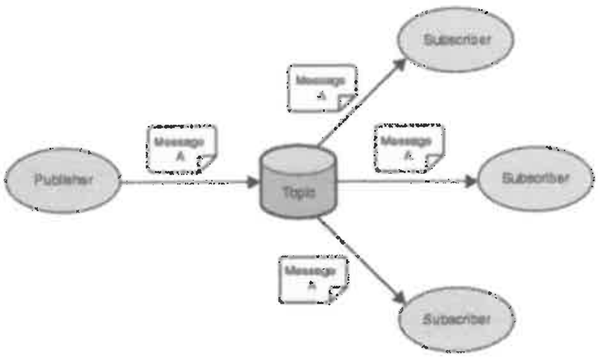
Pub/Sub Messaging (One-2-Many)



A Publish Subscribe messaging protocol allowing a message to be published once and multiple consumers (applications / devices) to receive the message providing decoupling between the producer and consumer(s)

- A producer sends (publishes) a message (publication) on a topic (subject)
- A consumer subscribes (makes a subscription) for messages on a topic (subject)

MQTT Topics

A topic forms the namespace
Is hierarchical with each "sub topic" separated by a /

<u>An example topic space:</u>

A house publishes information about itself on:

<country>/<region>/<postalcode>/<street>/<housenr>/feed/energyConsumption
<country>/<region>/<postalcode>/<street>/<housenr>/feed/solarEnergy
<country>/<region>/<postalcode>/<street>/<housenr>/feed/alarmState

And subscribes for control commands:

<country>/<region>/<postalcode>/<street>/<housenr>/command/energyPlan

MQTT Topics

A subscriber can subscribe to an absolute topic or can use wildcards:

- Single-level wildcards "+" can appear anywhere in the topic string
- Multi-level wildcards "#" must appear at the end of the string
- Wildcards must be next to a separator
- Cannot use wildcards when publishing

For example

- BE/OVL/9000/Veldstraat/1/energyConsumption
  - Energy consumption for house nr 1 in Gent Veldstraat
- BE/OVL/9000/+/+/energyConsumption
  - Energy consumption for all houses in Gent
- BE/OVL/9000/#
  - Details of energy consumption, solar and alarm for all houses with postal code 9000 in Belgium

MQTT versus HTTP (Lightweight)

		3G		Wifi	
		HTTPS	MQTT	HTTPS	MQTT
receive	messages / hour	1,708	160,278	3,628	263,314
	% battery / msg	0.01709	0.00010	0.00095	0.00002
	msgs (note losses)	240 / 1024	1024 / 1024	524 / 1024	1024 / 1024
send	msg / hour	1,926	21,685	5,229	23,184
	% battery / msg	0.00975	0.00082	0.00104	0.00016

Cisco Survey Reveals Close to Three-Fourths of IoT Projects Are Failing...

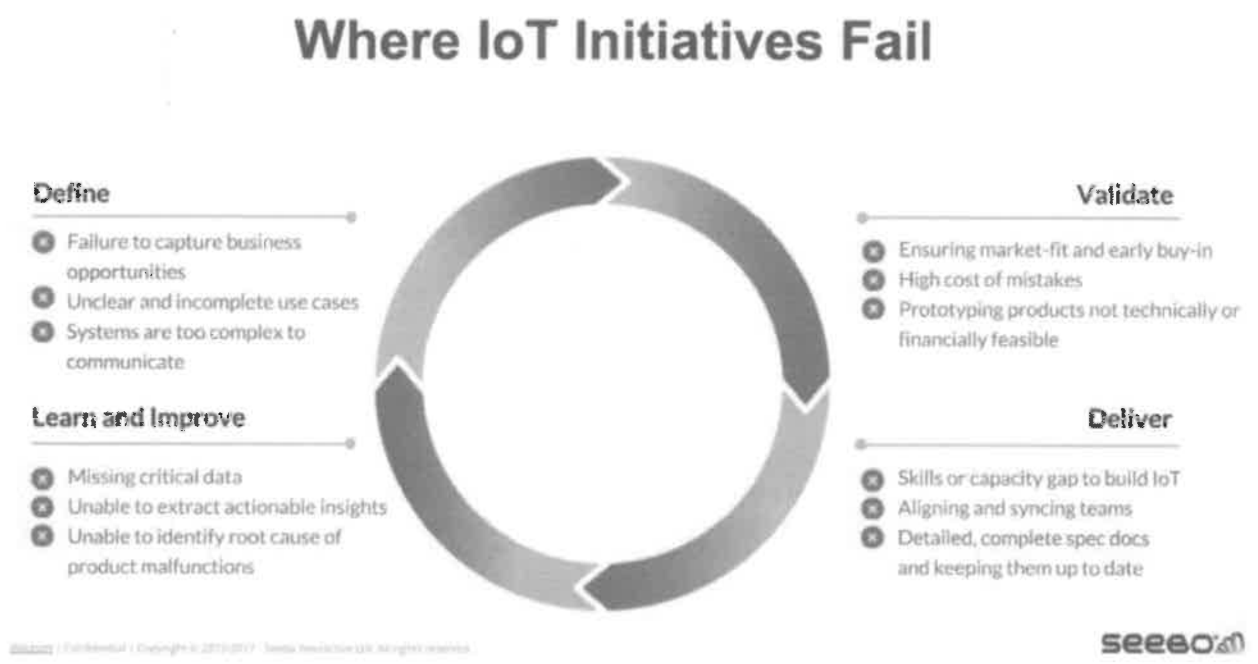
Key Findings:

1 - The "human factor" matters. IoT may sound like it is all about technology, but human factors like culture, organization, and leadership are critical. In fact, three of the four top factors behind successful IoT projects had to do with people and relationships:

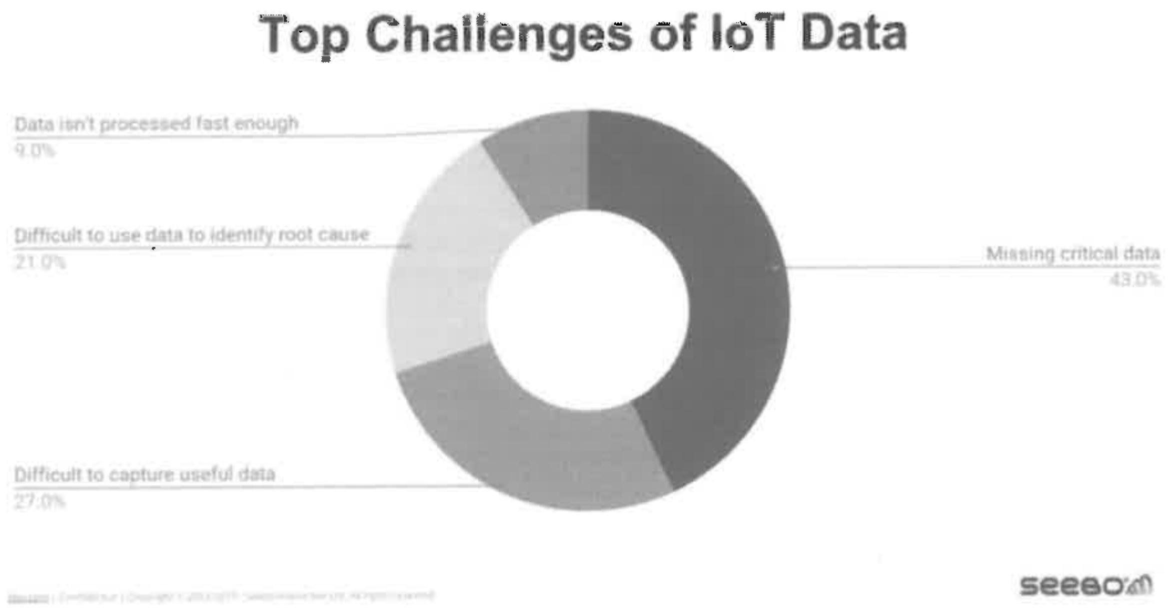
- Collaboration between IT and the business side was the #1 factor, cited by 54 percent.
- A technology-focused culture, stemming from top-down leadership and executive sponsorship, was called key by 49 percent.
- IoT expertise, whether internal or through external partnership, was selected by 48 percent.

In addition, organizations with the most successful IoT initiatives leveraged ecosystem partnerships most widely. They used partners at every phase, from strategic planning to data analytics after rollout.

Source: https://newsroom.cisco.com/press-release-content?articleId=1847422



Source: https://www.smartindustry.com/blog/smart-industry-connect/industry-4-uh-oh-why-iot-projects-fail/



Source: https://www.smartindustry.com/blog/smart-industry-connect/industry-4-uh-oh-why-iot-projects-fail/

Data Sharing

Evolution of sharing

It is estimated that less than one percent of the world's data is currently collected and analyzed, and of that, only 20 percent is searchable, while the remaining is locked in large businesses and institutions. Clearly, harnessing true value from data still has a long way to go and the data journey will evolve in three phases.

Intra-company data recycling

Data today is mostly recycled within an organization to improve operational efficiency. Hence, the initial IoT market focus has been on the transformation of internal processes, benefitting the company itself. In some cases, this also leads to enhanced customer experience.

Cross-company data sharing within supply chain: Gradually, as supply chains become more digital, data is shared across companies within the same verticals or supply chains as businesses realize that sharing data with other trusted parties increases supply-chain efficiency, and ultimately, the profit pool. There will be fair exchanges of data between trusted parties.

Cross-sector data integration

The third phase will see data being shared even more widely across industries and supply chains on open data marketplaces, enabling cross-sector efficiency and benefiting the whole economy. Potentially, in some markets, there will be an open marketplace for specific non-sensitive data, fundamental to the creation of new IoT use cases.

How do We go from here?

Let's try to simplify things...

Agile Tools
(for prototyping)

Toolset for an IoT solution

CONNECT

Sense & collect data on devices across various networks

COLLECT

Aggregate & normalise data from various data types

VISUALISE

Self-service BI and visual insights

USE & SHARE

Interpret, Analyse, add intelligence, share and control with people and systems

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Toolset for an IoT solution

CONNECT

Sense & collect data on devices across various networks

COLLECT

Aggregate & normalise data from various data types

VALUE DRIVERS

VISUALISE

Self-service BI and visual insights

USE & SHARE

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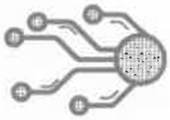
Toolset for an IoT solution



COST DRIVERS

CONNECT

Sense & collect data on devices across various networks

COLLECT

Aggregate & normalise data from various data types

VISUALISE

Self-service BI and visual insights

USE & SHARE

Interpret, Analyse, add intelligence, share and control with people and systems

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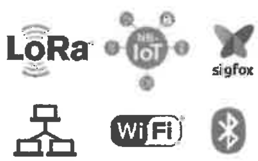
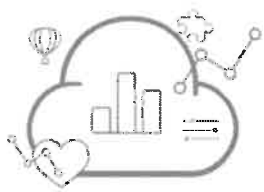
End-2-End IoT solutions

Things to cover

Hardware
Embedded development or integrate off-the-shelf hardware



Integrated networks
Automated subscription & connection to public or private IoT networks



IoT Middleware
Connect, collect, interprete & Automate

Applications
web and mobile apps + API for integration with backend

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Real use cases
(Beyond prototyping)

PoA

Business case

PoA is responsible of the life-buoys on pubic areas in the Port of Antwer to make sure the life-buoys and hooks are present and functional.

Problem?

- Responsability
- Cost-of-maintenance

What is the Product?

Connected (Life)Buoys & (Life)hooks & services

Facility Management

Business case

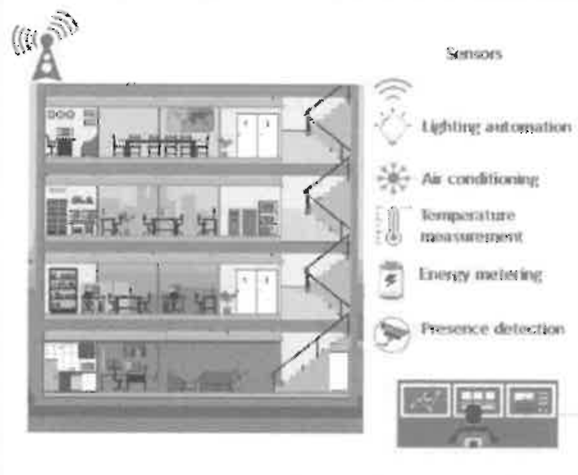
Efficient Meeting room handling

Problem?

- High level of no-shop ups
- Lack on meeting rooms

What is the Product?

A connected PIR sensor which unlocks meeting room reservations.



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Let's focus on the experience

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AllThingsTalk

postuniversitair centrum

Industrial IoT masterclass

"van discreet product naar IoT product"

Steven Sanders
Lieven Hollevoet

QUICKSAND
MICRO-ELECTRONICS

Quicksand **introduction**

IoT **challenges**

- energy & batteries
- LPWAN communication
- security

Use case: smart water valve

on the menu

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introduction

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engineering subcontractor
with research background

who?

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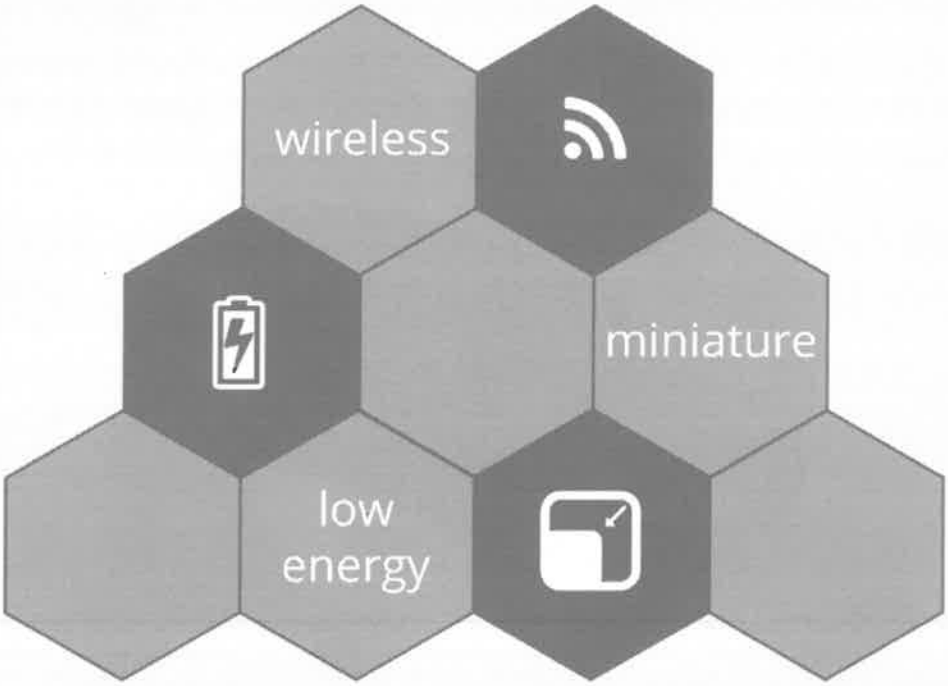

what we do

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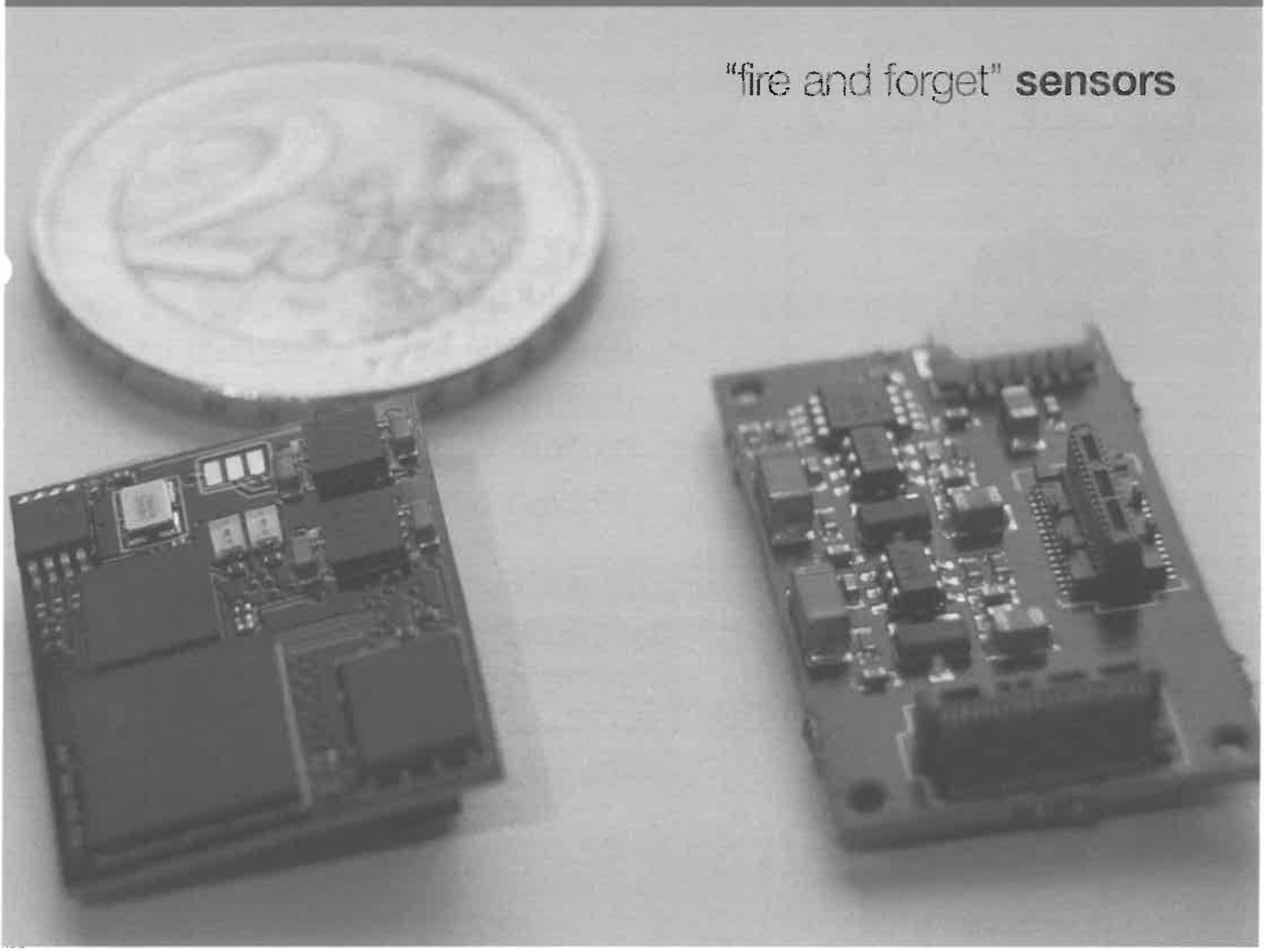
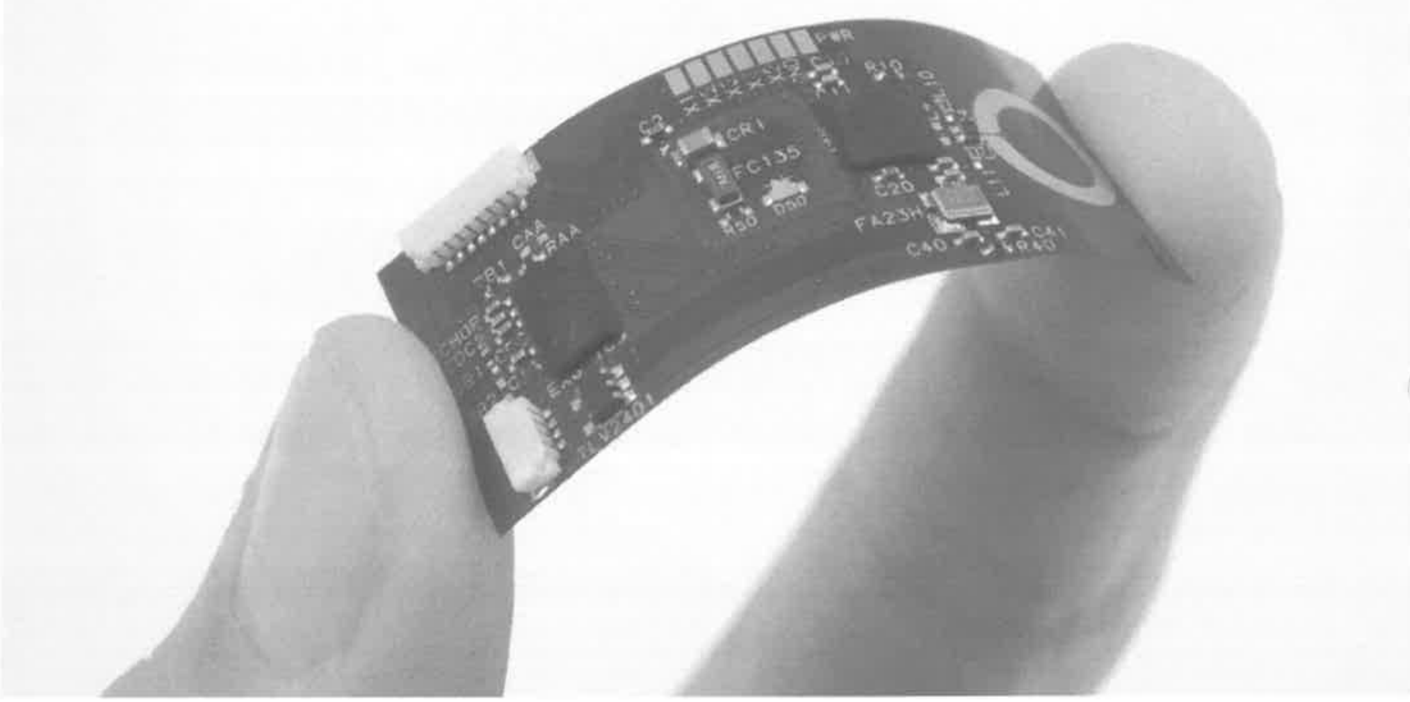
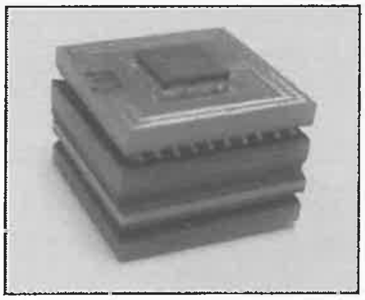


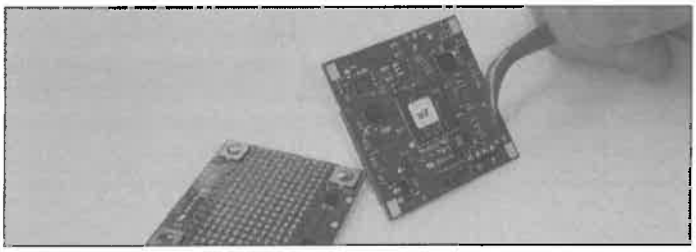




Zembro

- GSM voice call + 2G data
- GPS localisation
- Bluetooth BLE
- motion detection
- custom LED matrix display
- 14 days/single charge cycle

3 series of prototype hardware
full IP transfer to end customer



case: smart wearable

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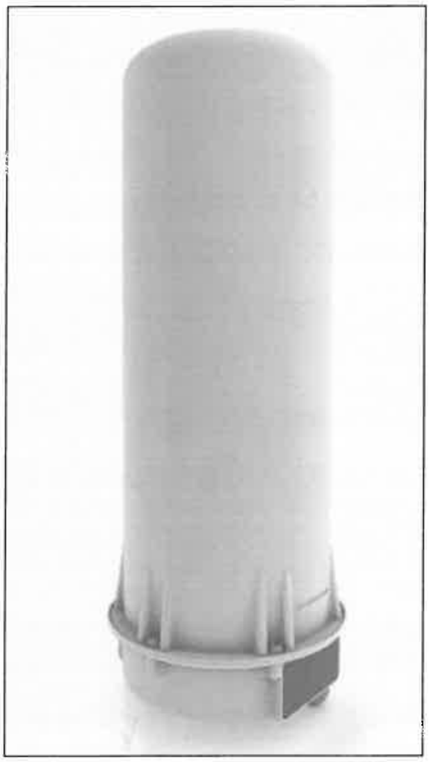
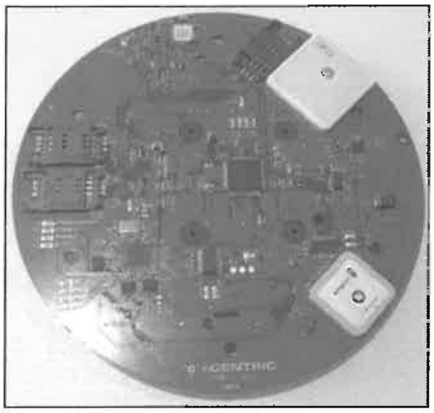
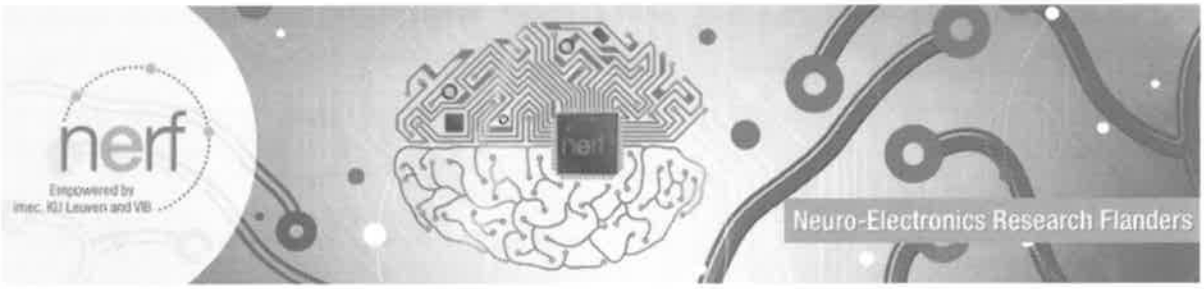


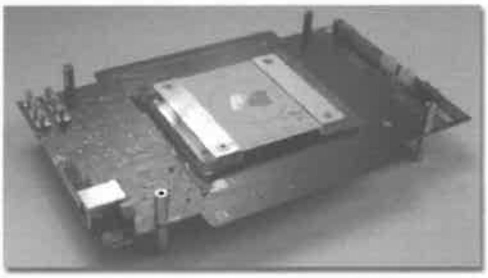
nCENTRIC
Streaming service

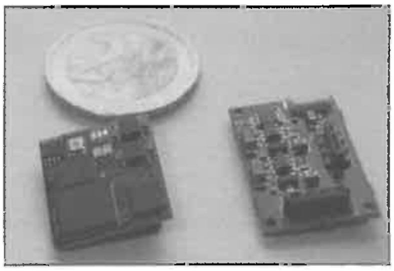


- satellite communication hub
- high speed USB hub
- GPS localisation
- multi standard antenna design

case: offshore satellite communication — QUICKSAND MICRO-ELECTRONICS







- high speed USB transfer of Neuray ASIC data
- on board local processing
- from large prototype to miniaturized version
- 90um line width

case: neurologic research platform — QUICKSAND MICRO-ELECTRONICS

metreco
smart mobile measuring

- temperature/pressure
- custom sensor modules
- custom handheld hardware
- proprietary RF protocol
- ultra low power design
- multi standard antenna design

case: smart mobile measuring system — QUICKSAND MICRO-ELECTRONICS

bloom
TECHNOLOGIES

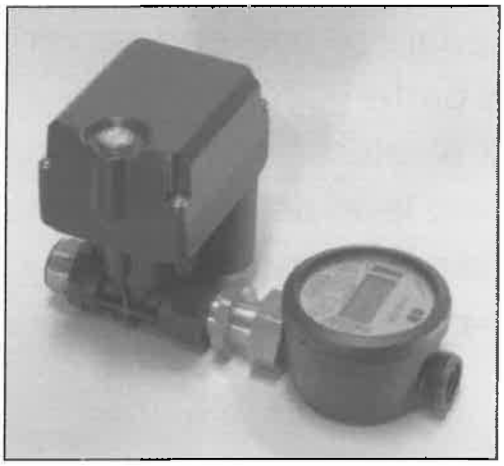
EXTREME TECH CHALLENGE

Branson's XTC
winner 2016

- 3-axis contraction detection
- Bluetooth BLE communication
- ultra low power
- miniaturization

first prototype hardware
full IP transfer to end customer

case: smart pregnancy monitoring patch — QUICKSAND MICRO-ELECTRONICS hydroko



- daily update to backend server
- 16 years battery lifetime
- SIGFOX wireless
- remote valve control
- leak detection
- best-in-class RF qualification

first device worldwide to communicate
bi-directionally over SIGFOX

SIGFOX

case: smart water valve

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hydroko

- SIGFOX + cellular
- Lithium battery rechargeable
- standard industrial casing
- custom foil
- OLED screen

SIGFOX

case: installer tool

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ENGIE Lab

- daily update to backend server
- 7 years battery lifetime
- SIGFOX wireless
- ultrasonic level detection
- temperature sensor
- best-in-class RF qualification

SIGFOX

case: ultrasonic level sensor

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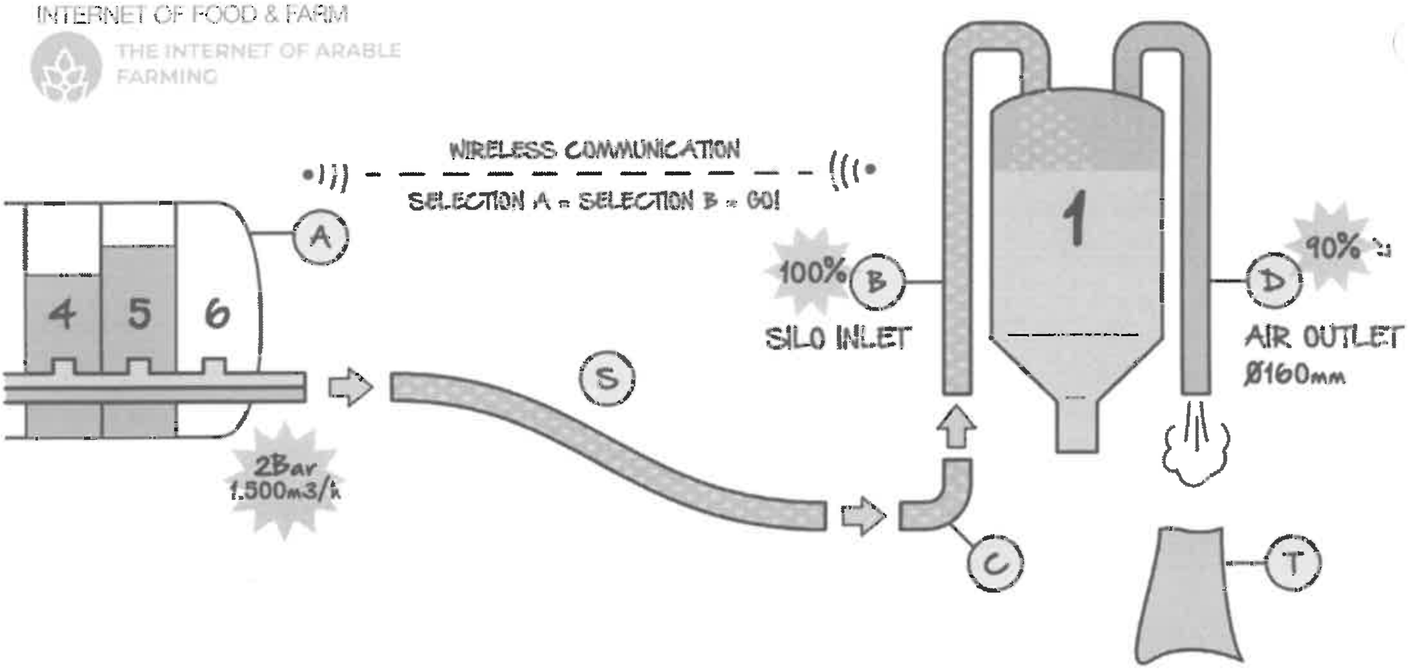
IOF 2020
INTERNET OF FOOD & FARM
THE INTERNET OF ARABLE FARMING

Smart Silo



case: IOF2020

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IoT challenges

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IoT challenges

energy consumption

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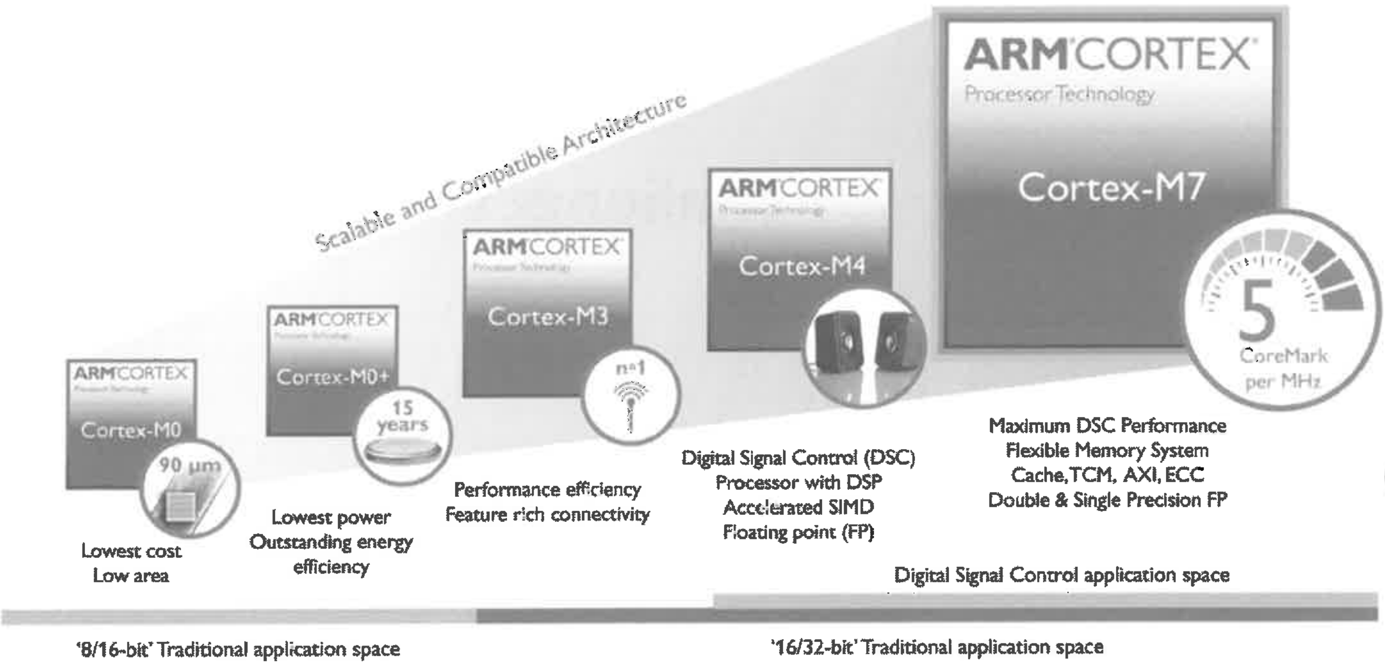
32bit microcontroller (r)evolution



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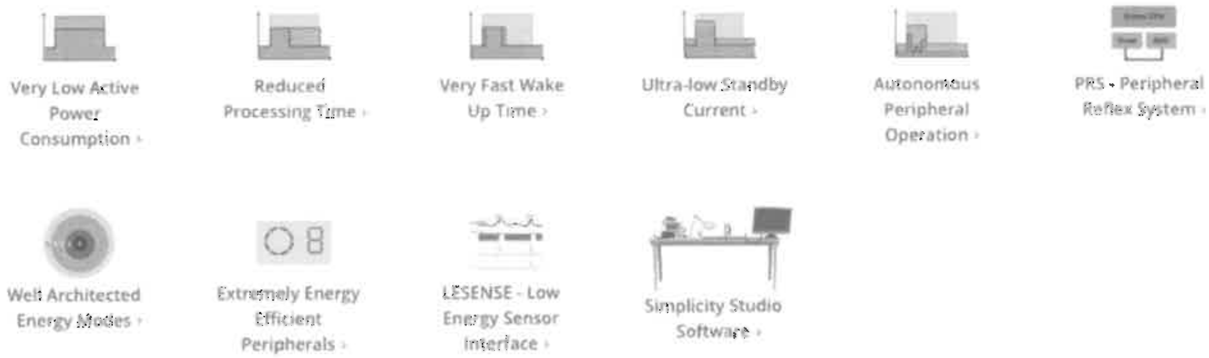
32bit microcontroller (r)evolution

SILICON LABS



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back of the envelope

SIGFOX: 60mA * 6s = 360mAs = 0.1mAh per TX

lifetime **8 years** = 2848 days
2 TX/day = 5696 transmissions

total **capacity**: 5696 * 0.1mAh = **570mAh**

correct?

step 2: power model

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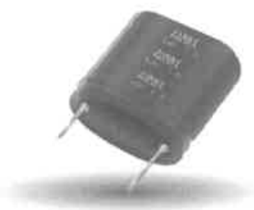
real world

Component	Average current (month interval)
CPU sleep current	4,00 uA
ultrasonic sensor	1,16 uA
SIGFOX communication	9,03 uA
CPU activity	1,85 uA
Peripherals/LDO/supercap	9,00 uA
Battery self-discharge	13,00 uA
total average	**38,04 uA**
Resulting system runtime on a battery of	3600 mAh cell
	11,08 years
	3944 days



saft

Solution identification

step 2: power model

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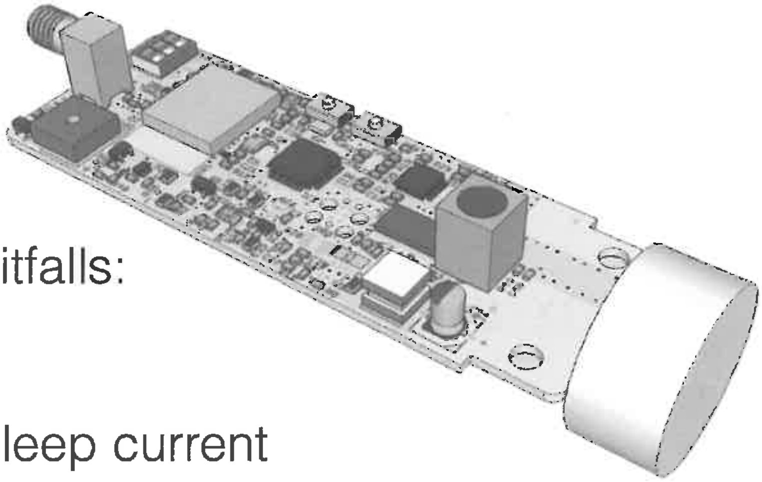
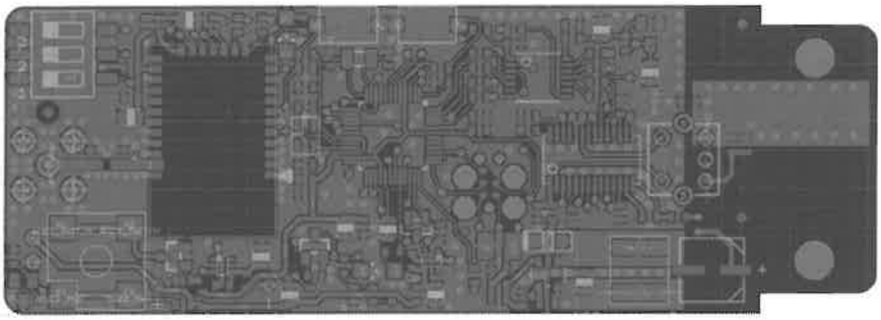


beware of common pitfalls:
- linear regulators
- antenna design
- VCC cut vs. extra sleep current



step 3: design

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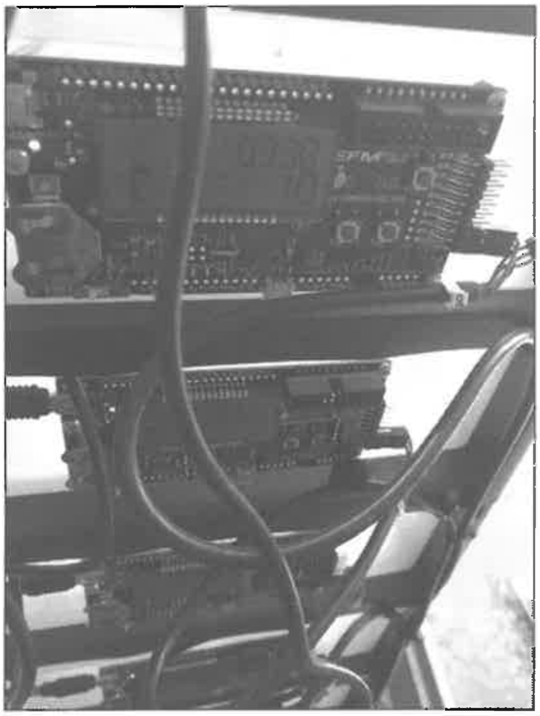
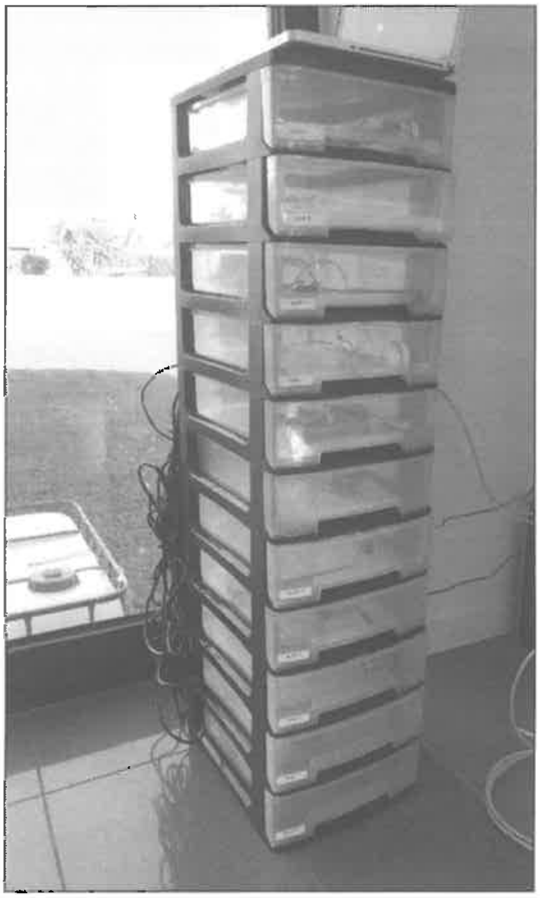
Power Tower





step 4: testing

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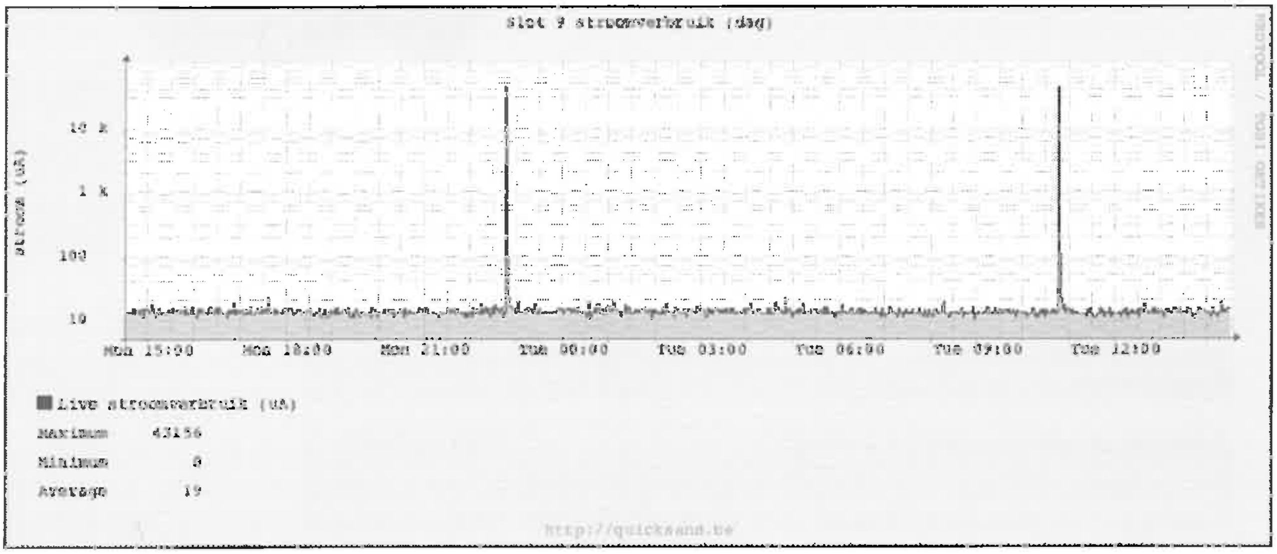

step 4: testing

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Revolution in RF land

Table 9. **Power consumption in transmission fc= 840-868 MHz**

Parameter	Test conditions	Min.	Typ.	Max.	Unit
Supply current	TX CW @ 14 dBm		20		mA
	TX CW @ 10 dBm[1]		11		
	TX CW @ 16 dBm in Boost [2]		27		

1. *SMPS output voltage 1.2 V, LDOs disable.*
2. *SMPS output voltage 1.8 V.*

revolution

QUICKSAND
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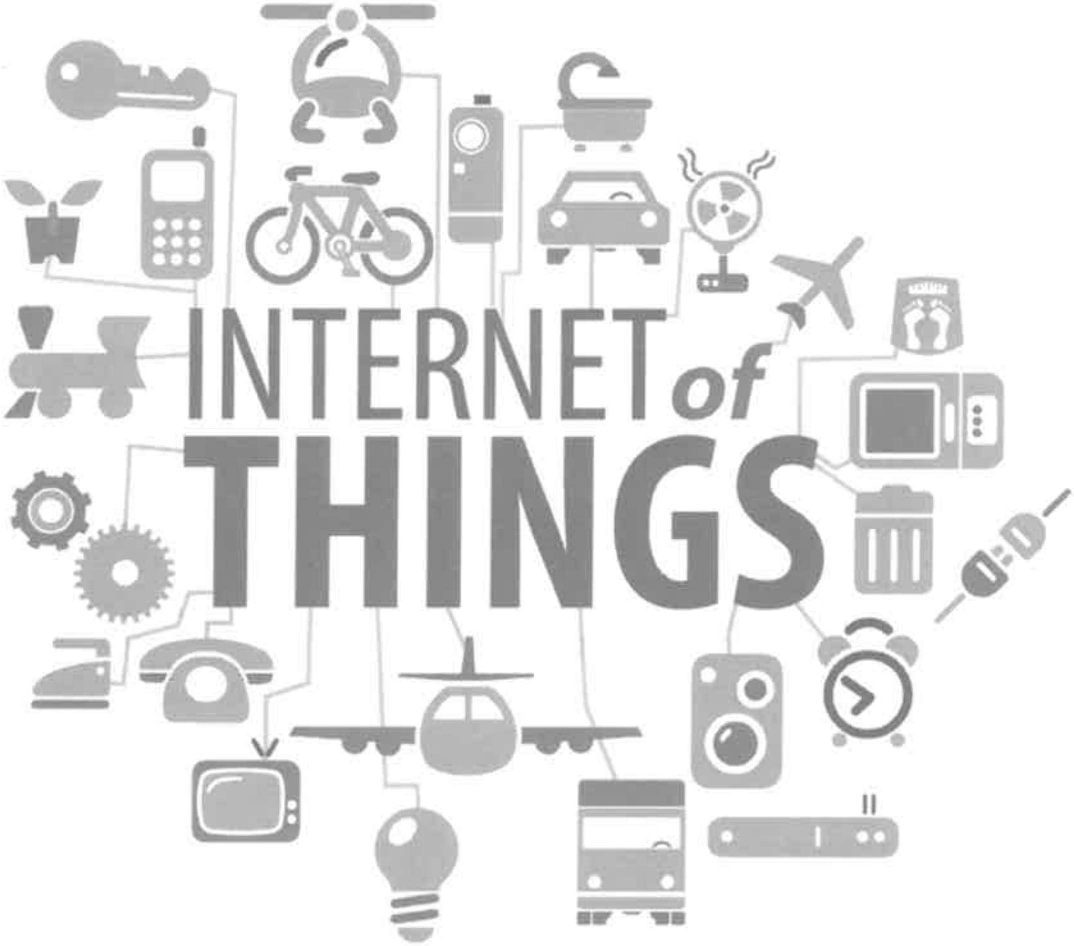
Revolution in RF land

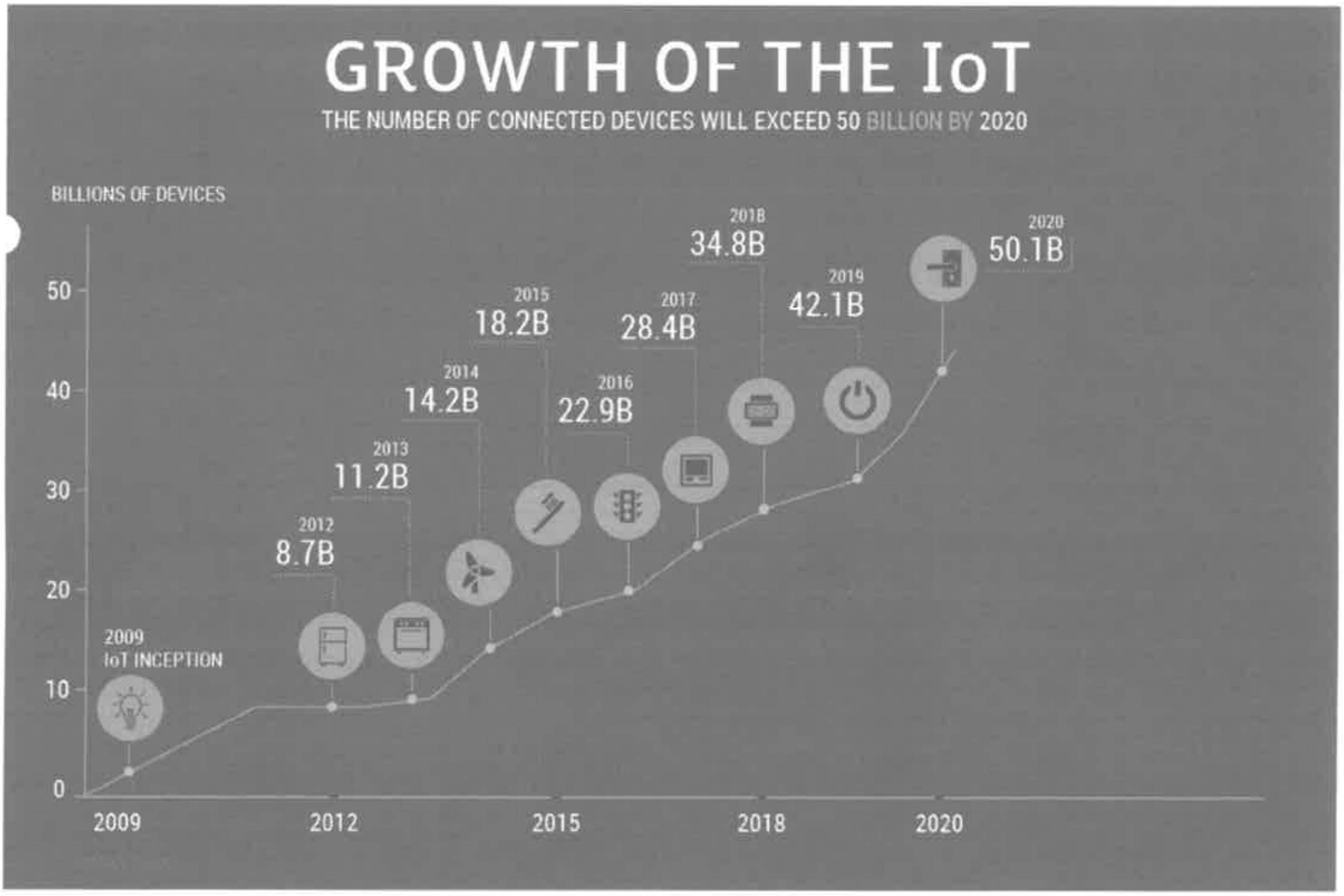
Component	Average current (month interval)		
CPU sleep current		4,00	uA
ultrasonic sensor		1,16	uA
SIGFOX communication		2,78	uA
CPU activity		1,85	uA
Peripherals/LDO		2,00	uA
Battery self-discharge		10,00	uA
total average		**21,79**	**uA**
Resulting system runtime on a battery of		1800	mAh cell
		9,67	years
		3442	days

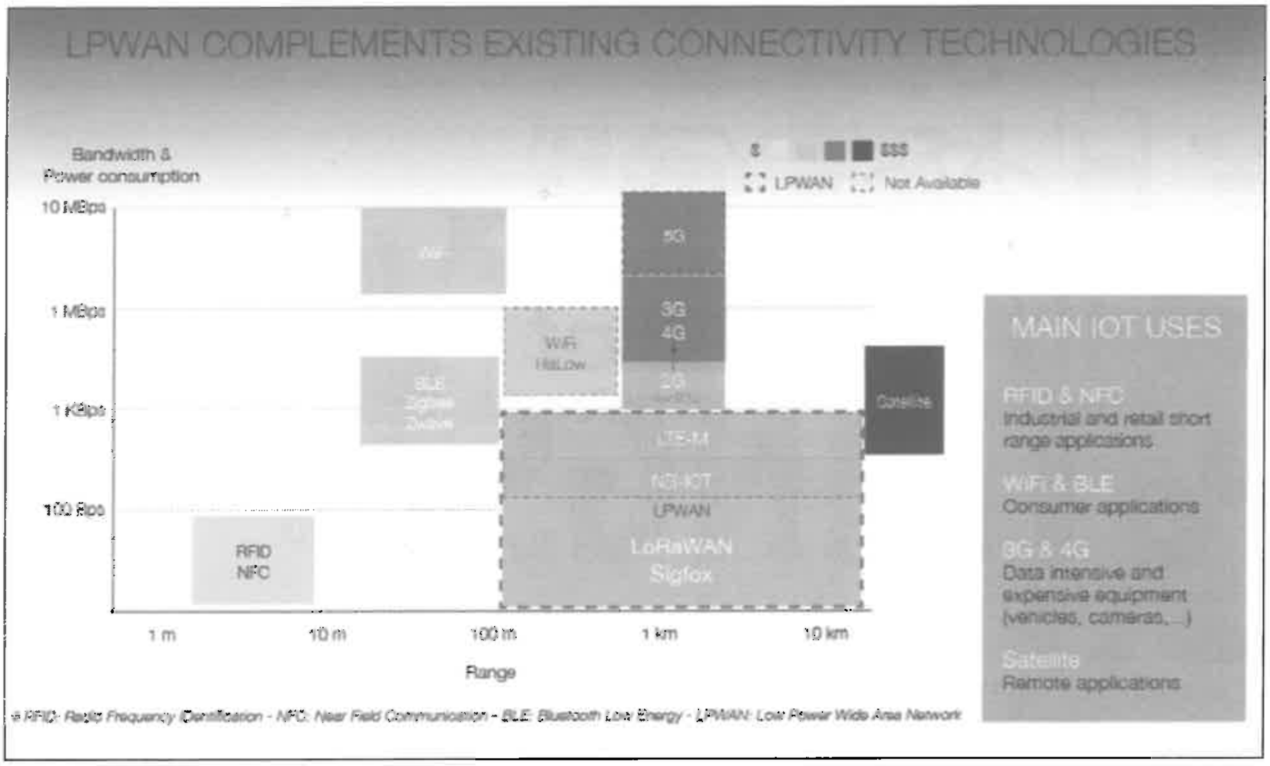
new power model

IoT challenges

LPWAN communication


INTERNET of
THINGS

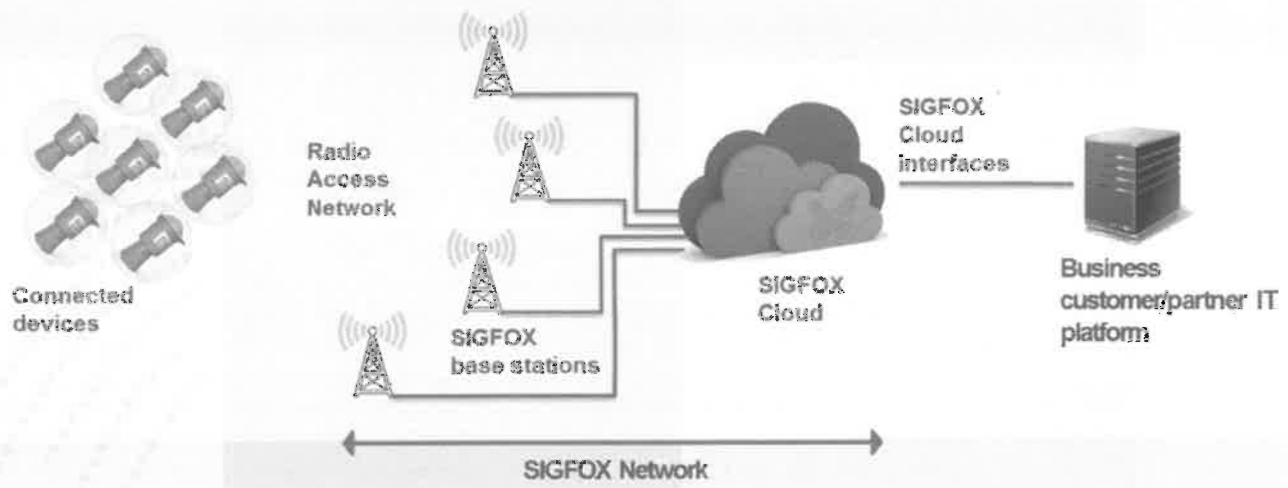

GROWTH OF THE IoT
THE NUMBER OF CONNECTED DEVICES WILL EXCEED 50 BILLION BY 2020
BILLIONS OF DEVICES
50
40
30
20
10
0
2009
IoT INCEPTION
2012
8.7B
2013
11.2B
2014
14.2B
2015
18.2B
2016
22.9B
2017
28.4B
2018
34.8B
2019
42.1B
2020
50.1B
2009
2012
2015
2018
2020



SIGFOX

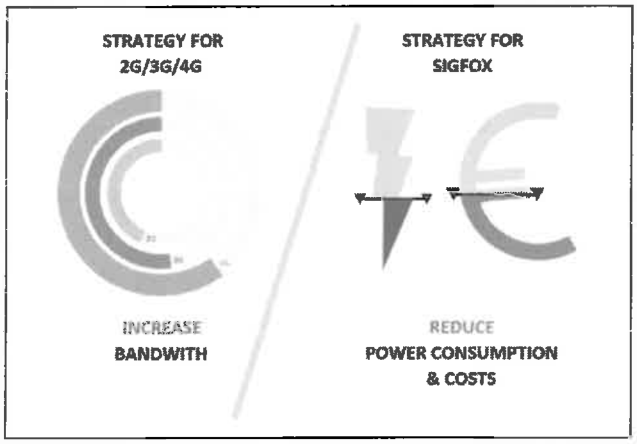
2.1- Network description

SIGFOX Network has a **star topology**: each of the base stations communicates with the SIGFOX Cloud via a **point-to-point link**



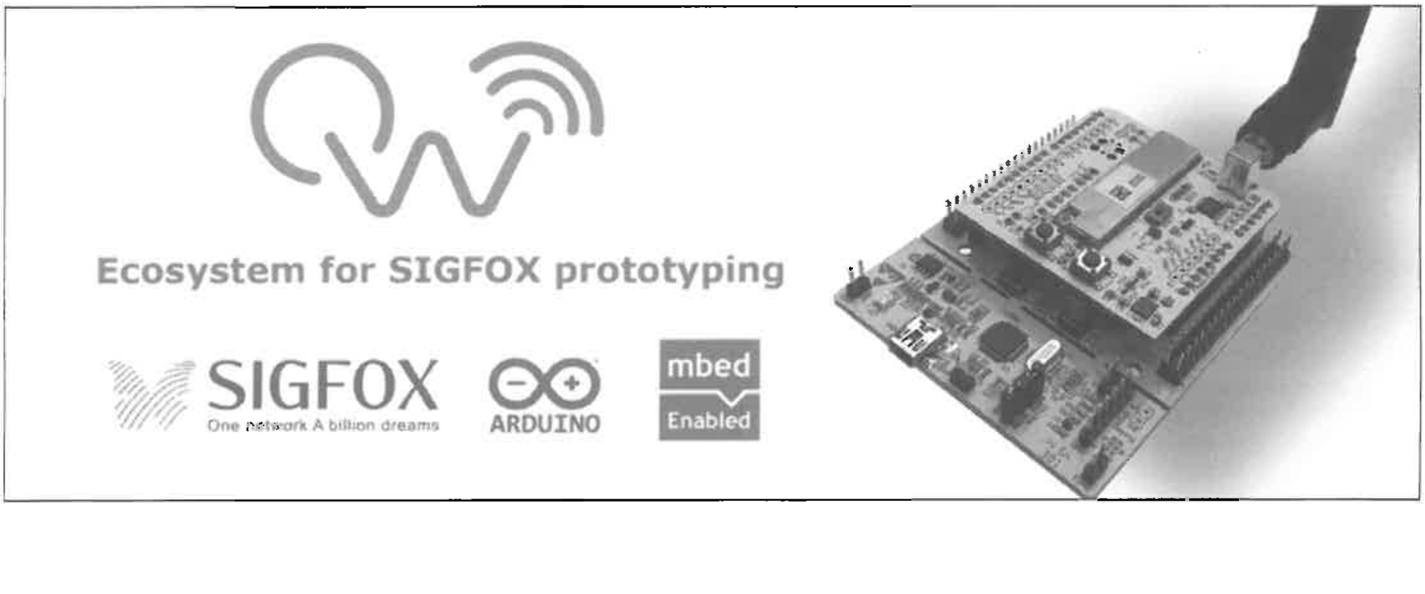
SIGFOX Support

5

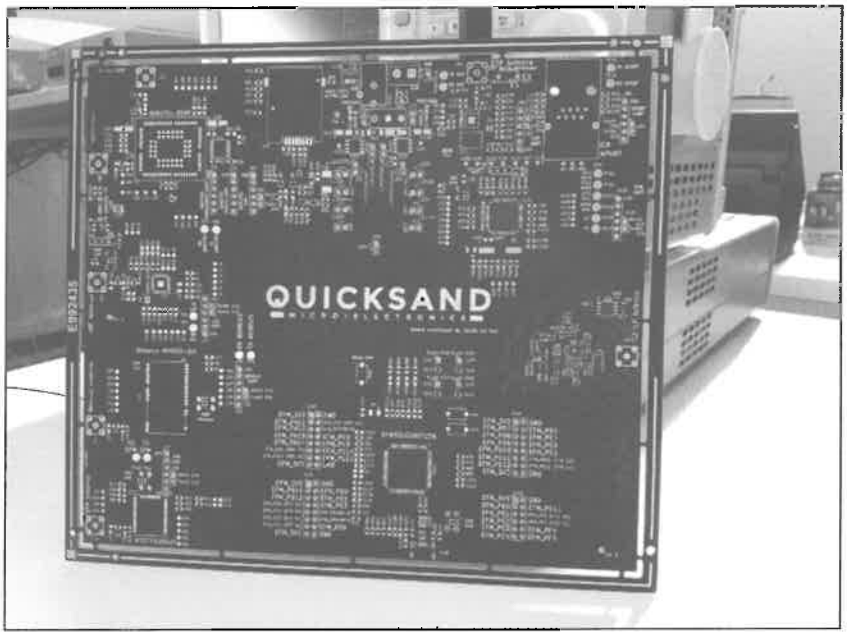


connectivity <> power consumption <> cost QUICKSAND MICRO-ELECTRONICS

- MBED compatible SIGFOX devkit
- comes with free subscription



case: IoT concentrator QUICKSAND MICRO-ELECTRONICS



SIGFOX

LoRa®

NB-IoT

Bluetooth®

case: IoT concentrator

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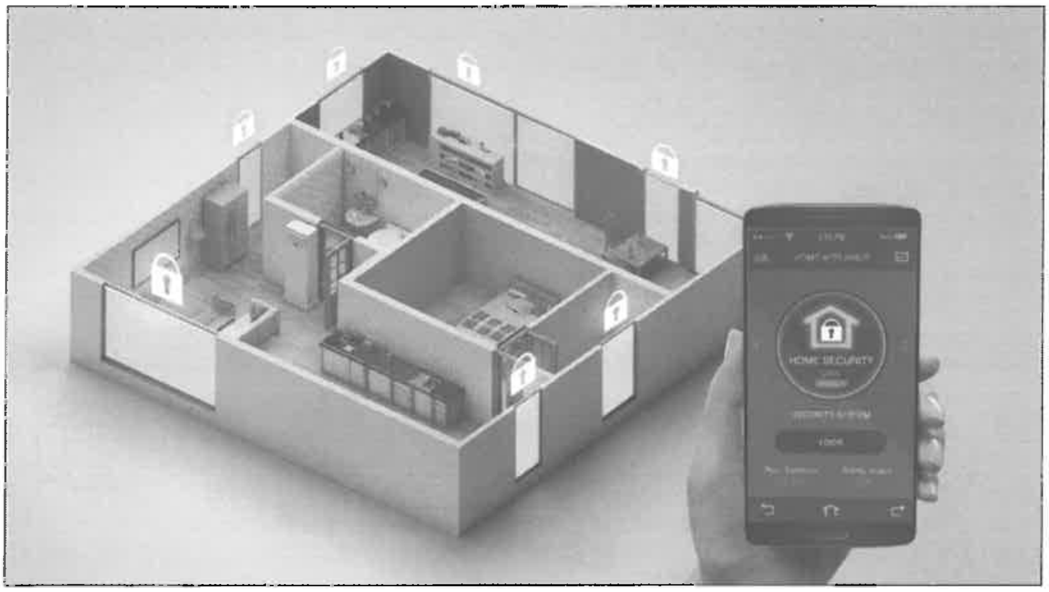
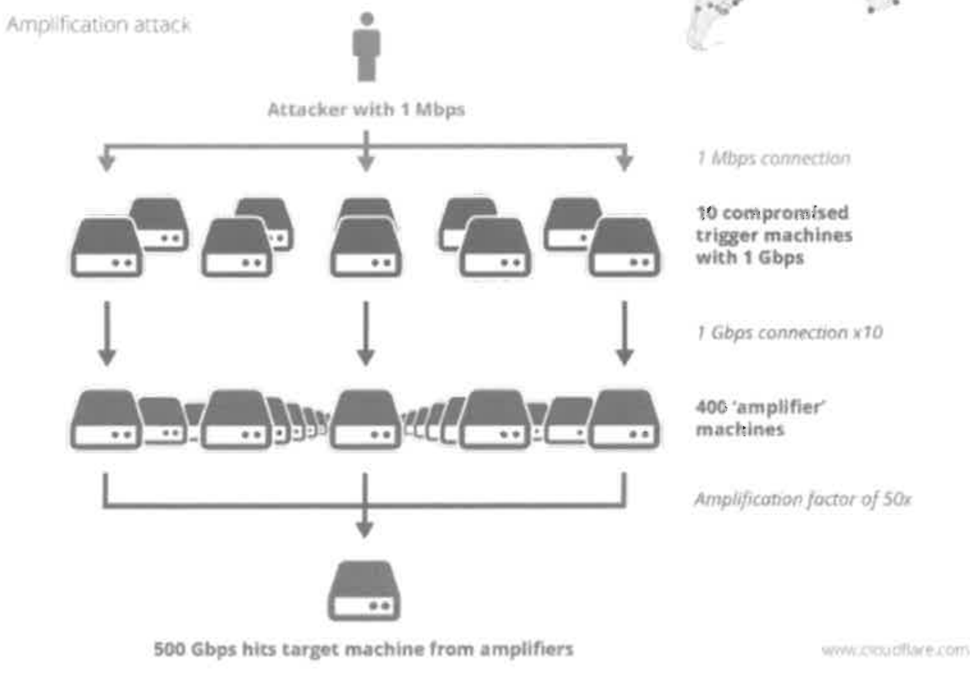
IoT challenges

security




MIRAI


Amplification attack
Attacker with 1 Mbps
1 Mbps connection
10 compromised trigger machines with 1 Gbps
1 Gbps connection x10
400 'amplifier' machines
Amplification factor of 50x
500 Gbps hits target machine from amplifiers
www.cloudflare.com

Use case

smart water valve

Use case: ultra-long lifetime smart sensors

Reliable communication

Easy installation

16 years
on a single
battery

Bidirectional

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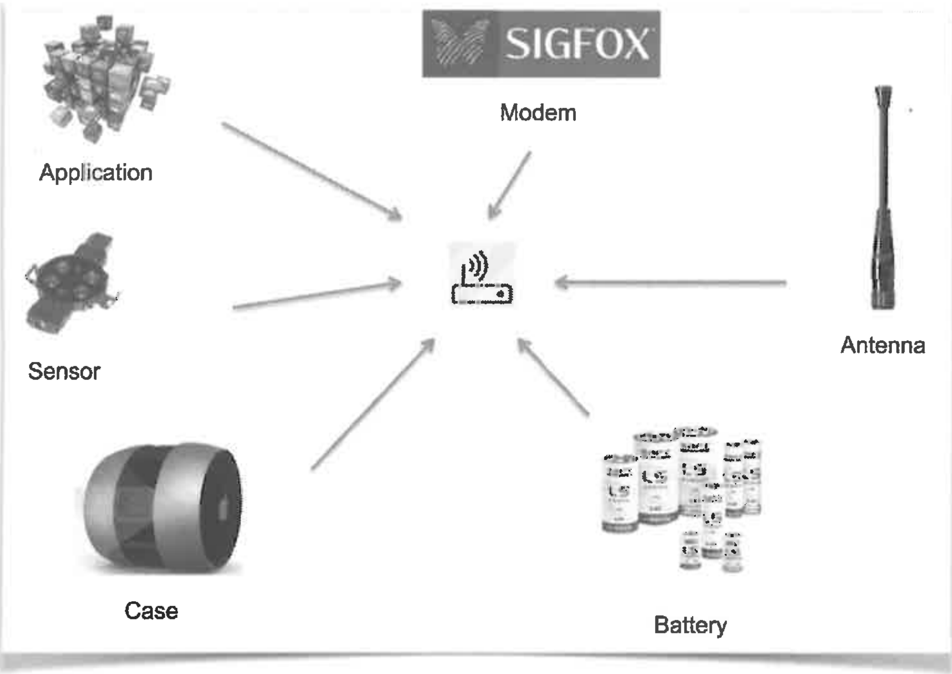
Step 1: feasibility study

define architecture, select components, calculate power budget



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Step 2: prototype

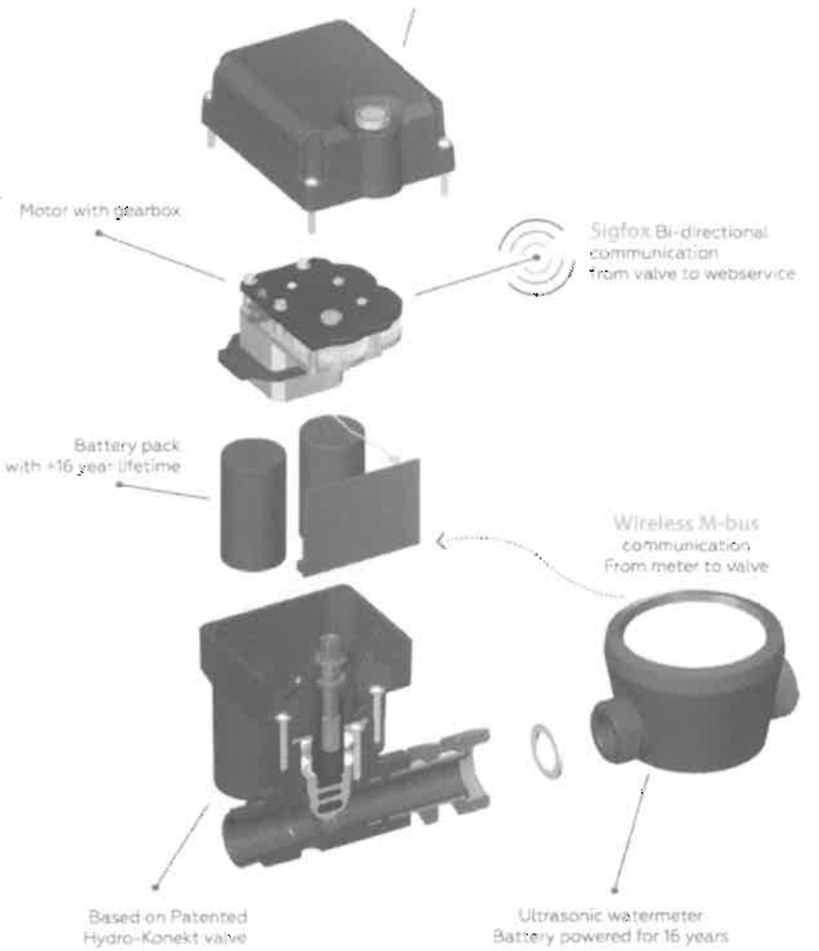
Component selection

Schematic design

Layout

Antenna matching

Firmware development



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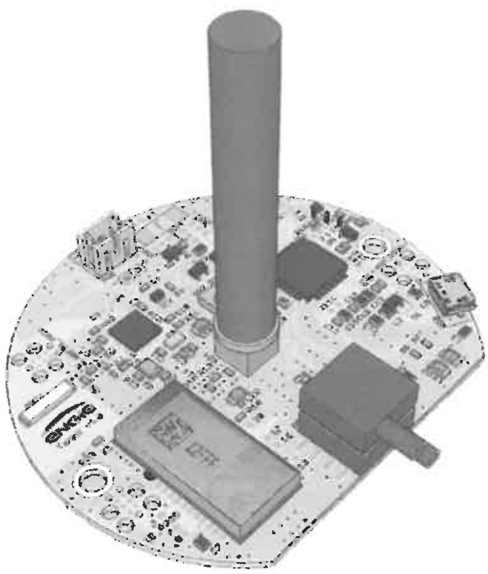
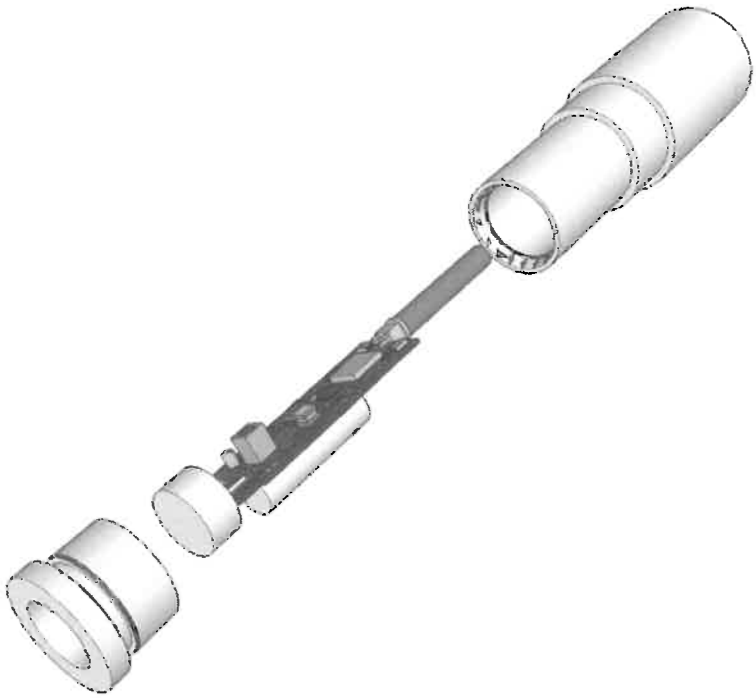
prototype iteration





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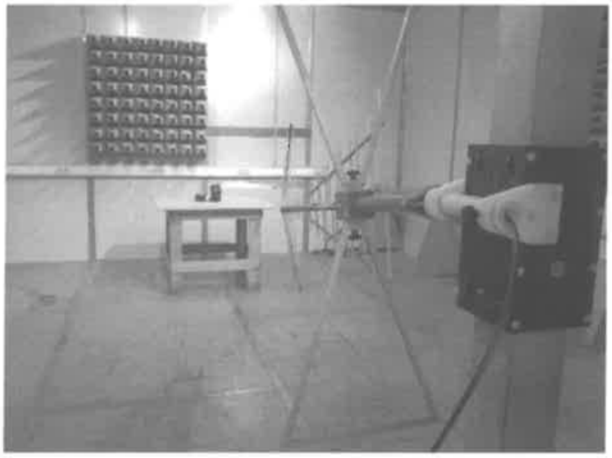
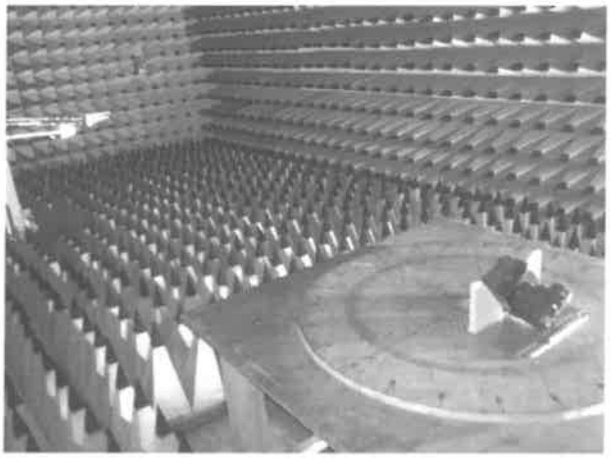
Step 3: prototype testing

- Firmware regression tests
- RF / EMC testing
- Field trial





smart valve field measurements

Step 4: A SIGFOX-enabled device needs to be certified before it is allowed on the network

- Depending on the selected path for integration, this is either a P1 or P2 certification program.

- Involves verification of the RF signal generation and the radio performance of the device.

	Uplink classes			
	Class 0u	Class 1u	Class 2u	Class 3u
radiated power	14dBm +/- 2dB	12dBm>P>7dBm	7dBm>P>0dBm	Below 0dBm

- Antenna performance is of key importance for the final network service quality!

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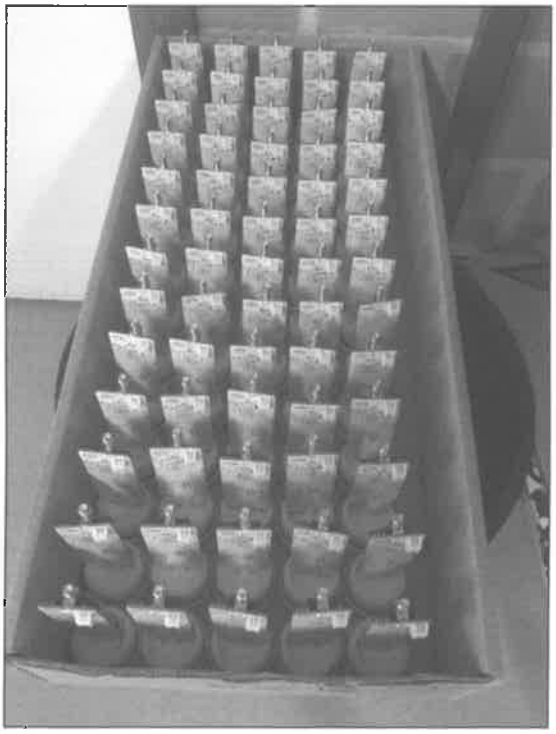
Step 5: upscaling



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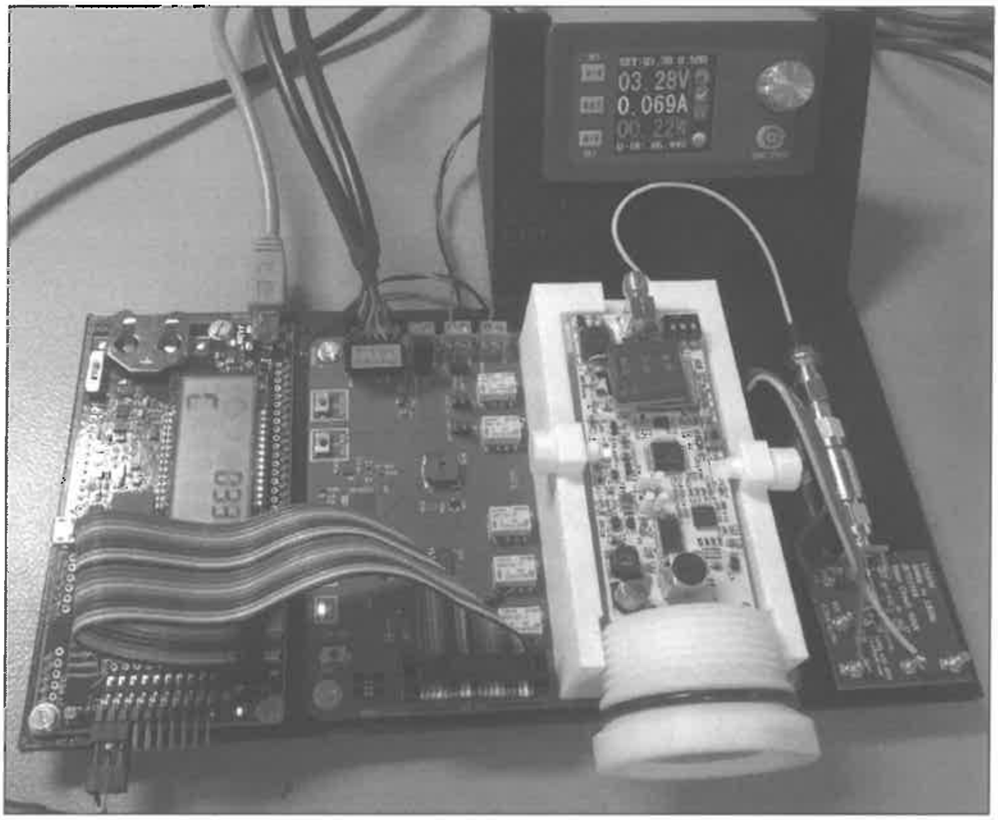
batch programming and testing



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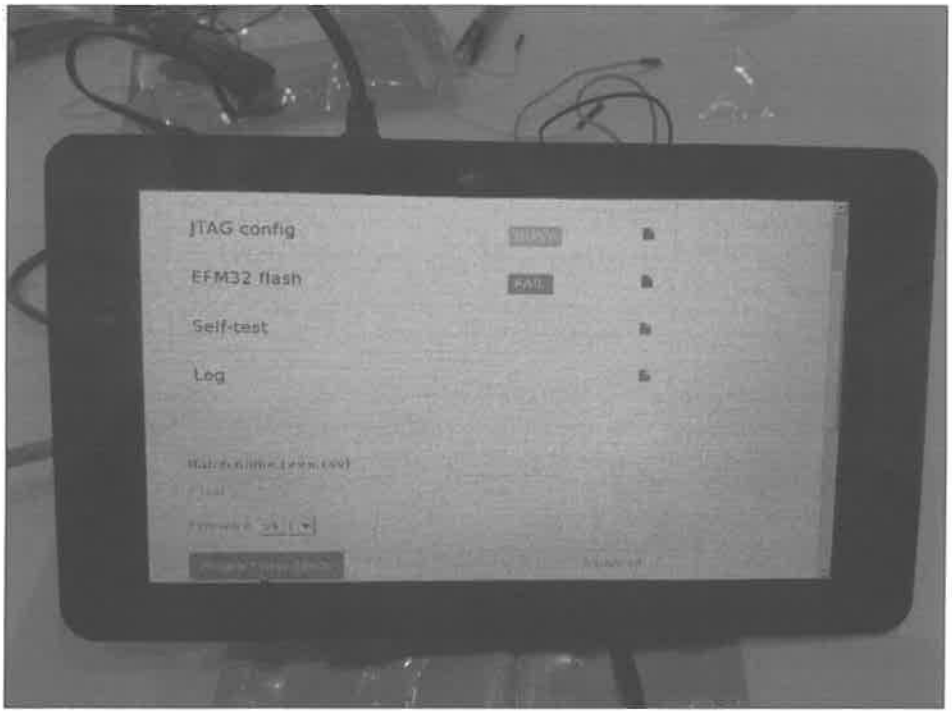
batch programming and testing



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step 5: deploy

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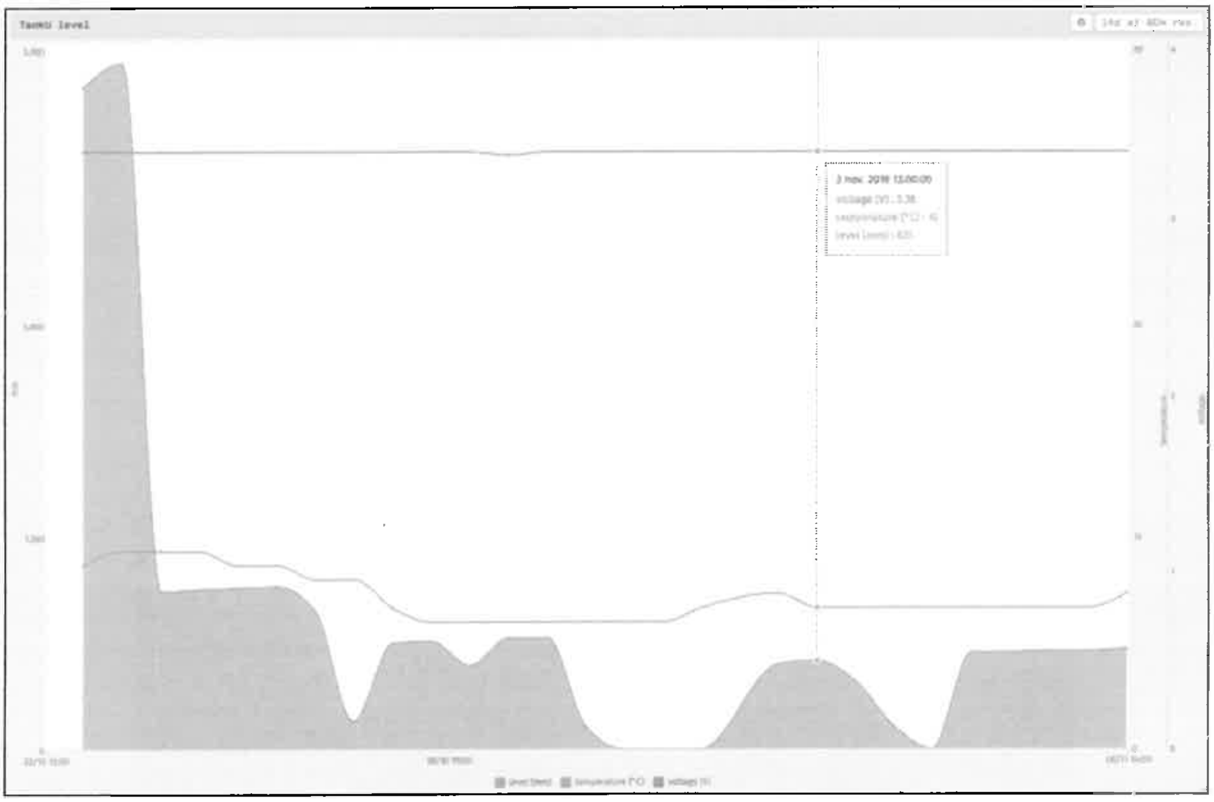
6. Monitoring



step 6: monitor

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Thank you

Q&A

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