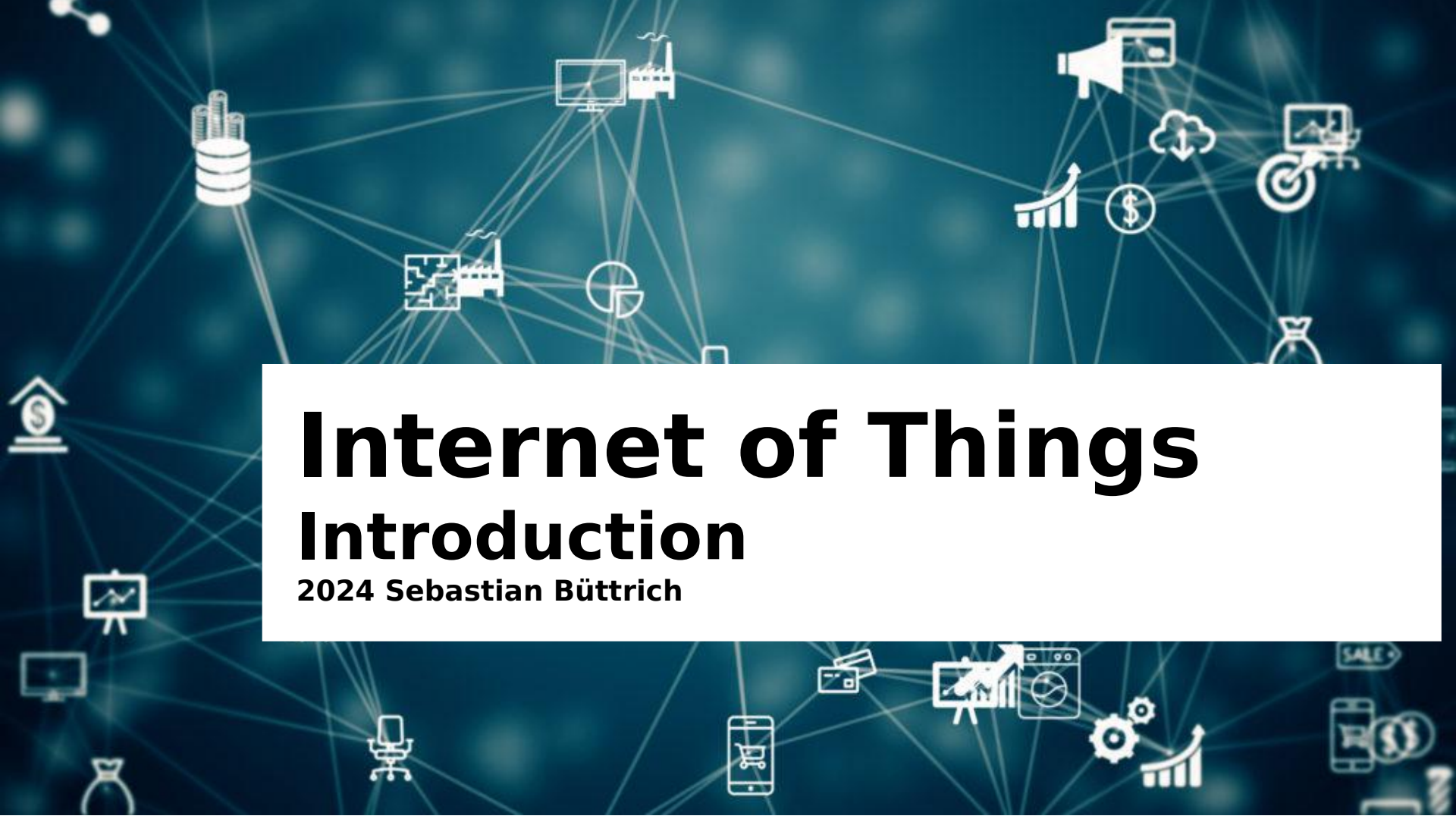


Internet of Things

Introduction

2024 Sebastian Büttrich

Scope of this Course

Lectures

- Intro / System design / Architecture
- Embedded systems & programming
- Sensing
- Networking I & II
  General → LPWANs
- Data stacks & analysis
- ML basics
  Edge computing, TinyML
- Energy
- Industry Guest Talks
- Security
- Societal/Ethics Issues
- Space & Satellite IoT

Exercises

- Hardware
- Embedded programming
- Networks
- Sensors
- Data backends
- Data Analytics / ML

Scope of this Course

Intended Learning Outcomes

- Describe the architecture of IoT systems
- Design, implement and evaluate networked embedded systems
- Evaluate and compare a range of IoT networking technologies
- Analyse the energy consumption of networked embedded systems
- Analyse security issues associated with IoT systems
- Design, implement and evaluate an IoT system
- Reason about the societal impact of IoT systems

Recent aspects

- IoT & Sustainability (”recent”)
- TinyML
- Space IoT

Warning & promise

IoT is physical computing and it is … well, physical.

It is not always binary, it is not always clean,
It s sometimes muddy or under water,
It gets stolen, and runs out of battery.

Warning
& promise

IoT is one of the most challenging areas of IT.

It is also one of the most interesting (i think).

We offer a variety of approaches – from low level to high level, physical to digital.

Skills
& Discussions

We aim at learning all the necessary skillsets, while also offering space for reflection on our data practices.

A bit of personal background

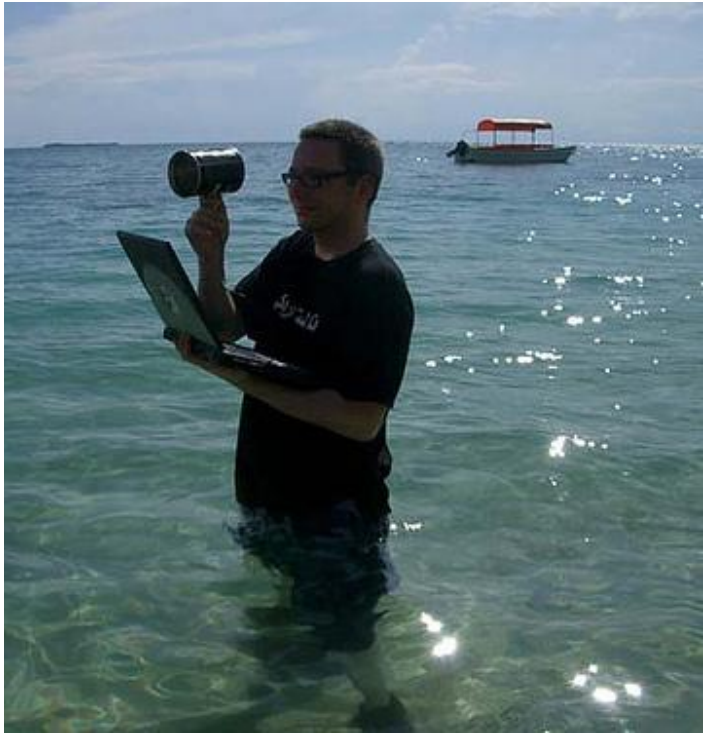
Sebastian Büttrich

PhD in Physics 1995

28 years professional in IT

20 years in global ICTs for development

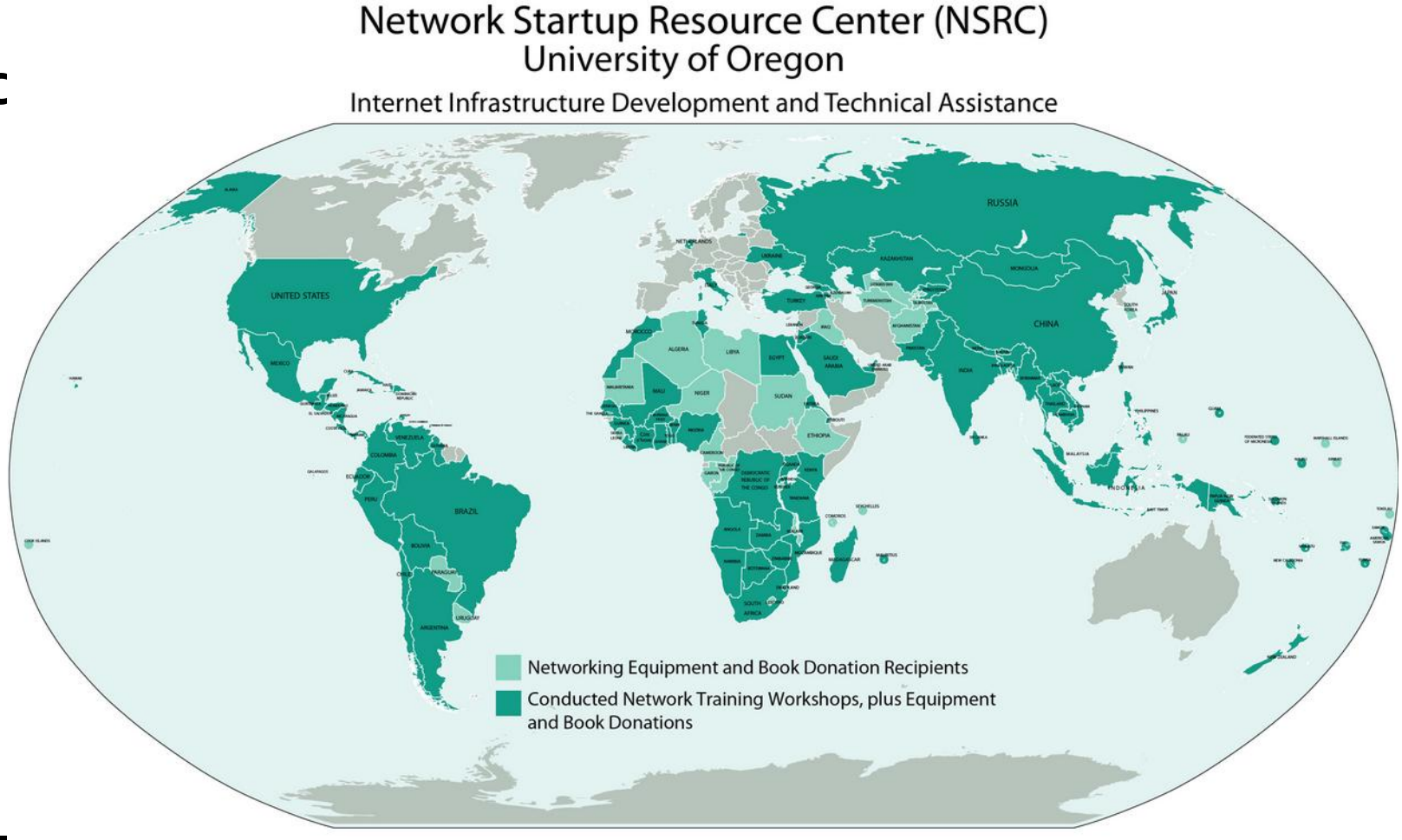
ITU since 2010, Research Lab Manager



A bit of personal background

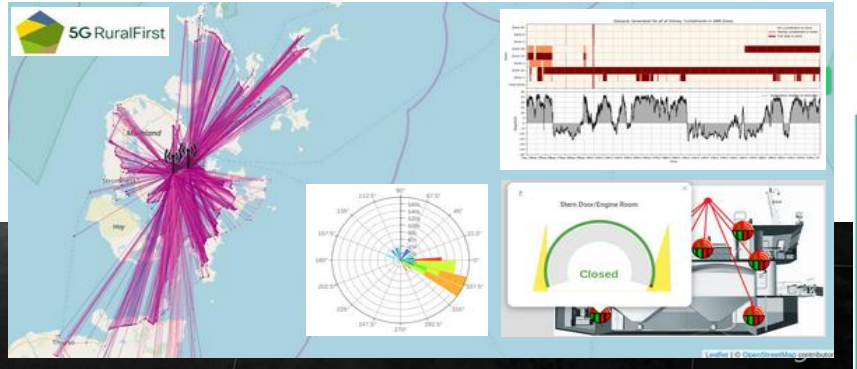
NSRC

ICTP



*From 1992 to March 2017, the NSRC has facilitated the distribution of more than 650 tons of network equipment and technical reference books to engineering and computer science departments, university libraries, teaching hospitals, research facilities, non-governmental organizations (NGOs), and Internet training facilities in more than 120 countries around the world. Contributing sponsors and supporters are acknowledged at https://nsrc.org/supporters.

IoT projects



infinit

Nyt projekt vil gøre intelligent måling af husholdningers ressourceforbrug tilgængeligt for flere

senti

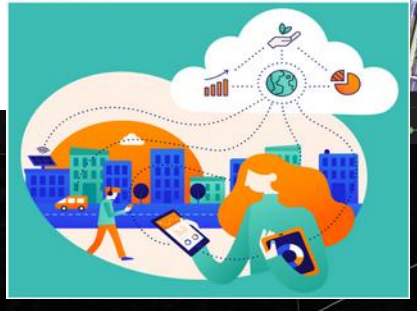
HOFOR

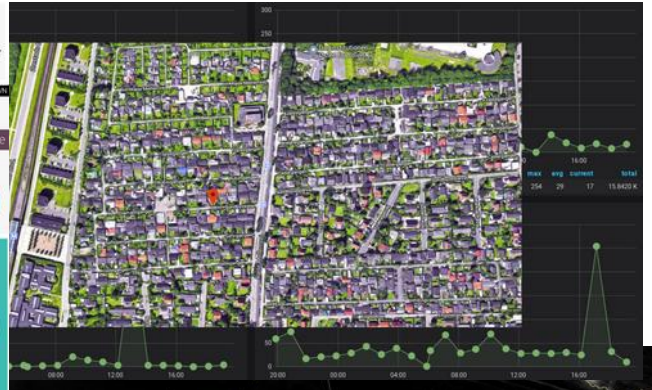
Nordic IoT Centre

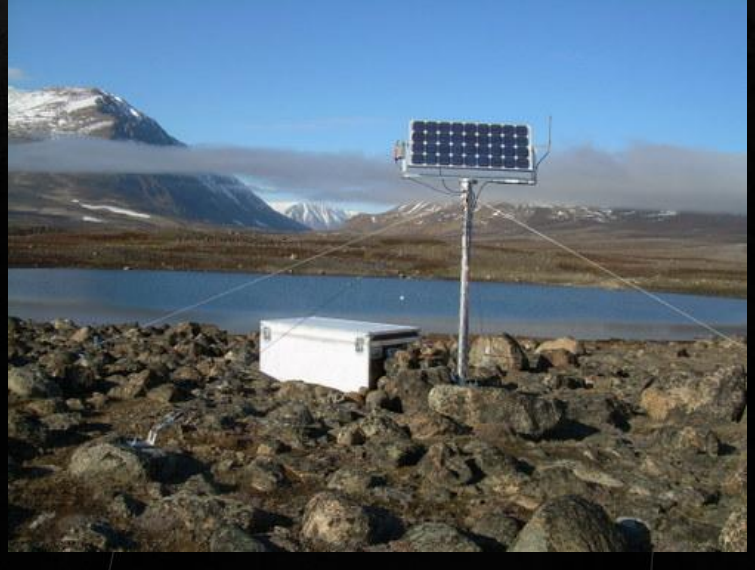
IndesmaTech

ØENS

HF Sundbyvester







Orkney

SEA-HAZEMON@TEIN Workshop on Internet of Things and Air Pollution Monitoring

16 - 20 September 2019, intERLab, AIT, Thailand

intERLab

TEIN CC

AsiaConnect

IoT

Internet of Things

Terminology / History

Terminology changes with time …

cultures change,
trends/hypes come and go …

IoT has a history and a pre-history

Ubiquitous computing, Pervasive Computing (1980s .. 90s ...)

- Focus on Interaction, applications, HCI

Wireless Sensor Networks, Cyber-Physical Systems (1990s … 2000s ...)

- Focus on System issues (hardware, OS, network, network embedded programming, network protocols, energy)

IoT – Internet of Things (2010s and on ….)

- Focus on back-end (cloud-based) data platforms, privacy, security, business models, societal issues.

Pre-History

"When wireless* is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole.....and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone. A man will be able to carry one in his vest pocket."

1926 - Nikola Tesla

History / Coke vending machine

1982
Coke vending machine
at Carnegie Mellon University
becoming the
first Internet-connected appliance

https://www.cs.cmu.edu/~coke/history_long.txt

The "Only" Coke Machine on the Internet

Hi, I'm the CMU CS Department Coke Machine. A lot of folks have written a quite a bit about me in the last couple of years, and most of them can tell you more about the history of me and my family than I can. Before I worked here, my Mom, and I think her Pop (heh heh :-) used to sell sodas to the folks in the Computer Science Department. In fact, my family has been here longer than most of the students, and even a lot of the faculty. We moved to the third floor of the computer science building (Wean Hall) in the 70's. I still sell Coke in bottles, but they're big 20 oz plastic things these days. They go for 50 cents each, which I guess isn't too bad considering inflation. And at least they don't break inside me any more like the glass ones used to. What a mess...

Tom Lane had the following to say about us:

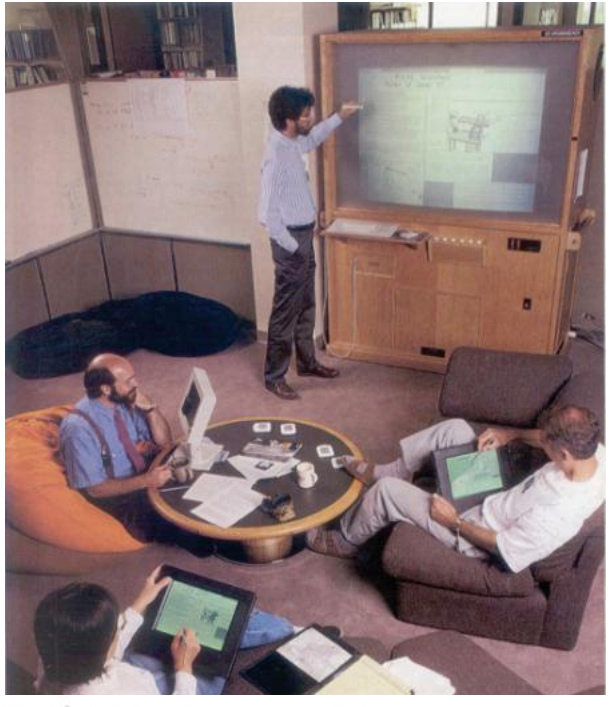
> Since time immemorial (well, maybe 1970) the Carnegie-Mellon CS
> department has maintained a departmental Coke machine which sells
> bottles of Coke for a dime or so less than other vending machines
> around campus. As no Real Programmer can function without caffeine,
> the machine is very popular. (I recall hearing that it had the highest
> sales volume of any Coke machine in the Pittsburgh area.) The machine
> is loaded on a rather erratic schedule by grad student volunteers.
>
> In the mid-seventies expansion of the department caused people's
> offices to be located ever further away from the main terminal room
> where the Coke machine stood. It got rather annoying to traipse down
> to the third floor only to find the machine empty - or worse, to shell
> out hard-earned cash to receive a recently loaded, still-warm Coke.
> One day a couple of people got together to devise a solution.
>
> They installed micro-switches in the Coke machine to sense how many
> bottles were present in each of its six columns of bottles. The
> switches were hooked up to CMUA, the PDP-10 that was then the main
> departmental computer. A server program was written to keep tabs on
> the Coke machine's state, including how long each bottle had been in
> the machine. When you ran the companion status inquiry program, you'd
> get a display that might look like this:
>
> EMPTY EMPTY 1h 3m
> COLD COLD 1h 4m
>

History / Mark Weiser’s Vision

1991
Mark Weiser's paper on ubiquitous computing, "The Computer of the 21st Century”
→ PerCom, UbiComp
Xerox PARC

”The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”

3 seminal papers:
The computing of the 21st Century;
Some Computer Science Issues in Ubiquitous Computing;
The Coming Age of Calm Technology.



Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence

by Mark Weiser

History / Smart Dust

The concepts for **Smart Dust** emerged from a workshop at RAND in **1992** and a series of DARPA ISAT studies in the mid-1990s due to the potential military applications of the technology.
The work was strongly influenced by work at UCLA and the University of Michigan during that period, as well as **science fiction** authors Stanislaw Lem (in novels The Invincible, in 1964 and Peace on Earth (novel), in 1985), Neal Stephenson and Vernor Vinge. The first public presentation of the concept by that name was at the American Vacuum Society meeting in Anaheim in 1996.

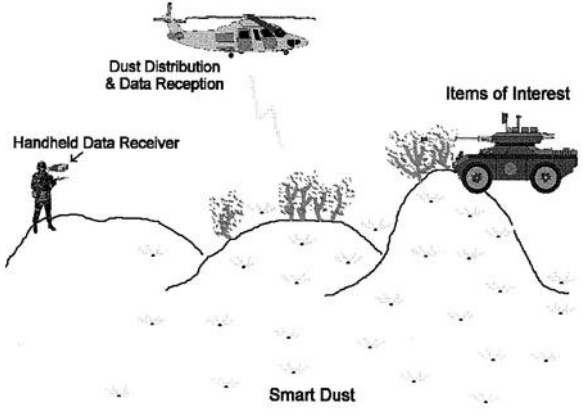


Figure 1: Primary deliverable: a battlefield sensor network. Thousands of sensor nodes covering square kilometers are delivered by autonomous helicopter. They track motion of vehicles for hours/days, and report information superimposed on live video when interrogated by hand-held receiver or helicopter borne receiver.

History / Smart Dust

A **Smart Dust research proposal** was presented to DARPA written by Kristofer S. J. Pister, Joe Kahn, and Bernhard Boser, all from the University of California, Berkeley, in 1997. The proposal, to build wireless sensor nodes with a volume of one cubic millimeter, was selected for **funding in 1998**. The project led to a working mote smaller than a grain of rice, and larger "COTS Dust" devices kicked off the TinyOS effort at Berkeley.

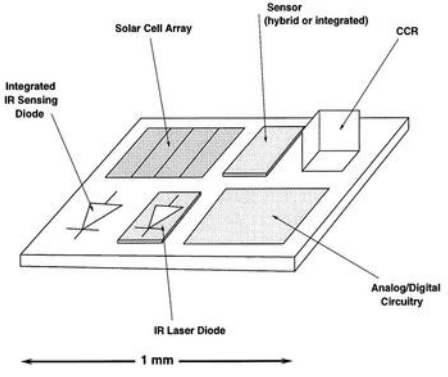


Figure 2: A solar powered dust mote is a completely autonomous sensing and bidirectional communication platform. Other versions will incorporate a cubic millimeter rechargeable thick film battery, and/or a zinc-air hearing aid battery.

https://people.eecs.berkeley.edu/~pister/SmartDust/
An interesting read – the forecast for 2010:
https://people.eecs.berkeley.edu/~pister/SmartDust/in2010

History / Smart Dust: Forecast 2010

Radios for $ 0.10

3 color laser projection systems, size of grain of rice, and < $1

Stealing cars, furniture, stereos, or other valuables will be unusual, because any of your valuables that leave your house will check in on their way out the door

Your house and office will be aware of your presence

A speck of dust on each of your fingernails will continuously transmit fingertip motion to your computer

You won't have to hunt for a parking space

[Warfare] will consist of firing up a web browser and proving your authorization.

No unanticipated illness.

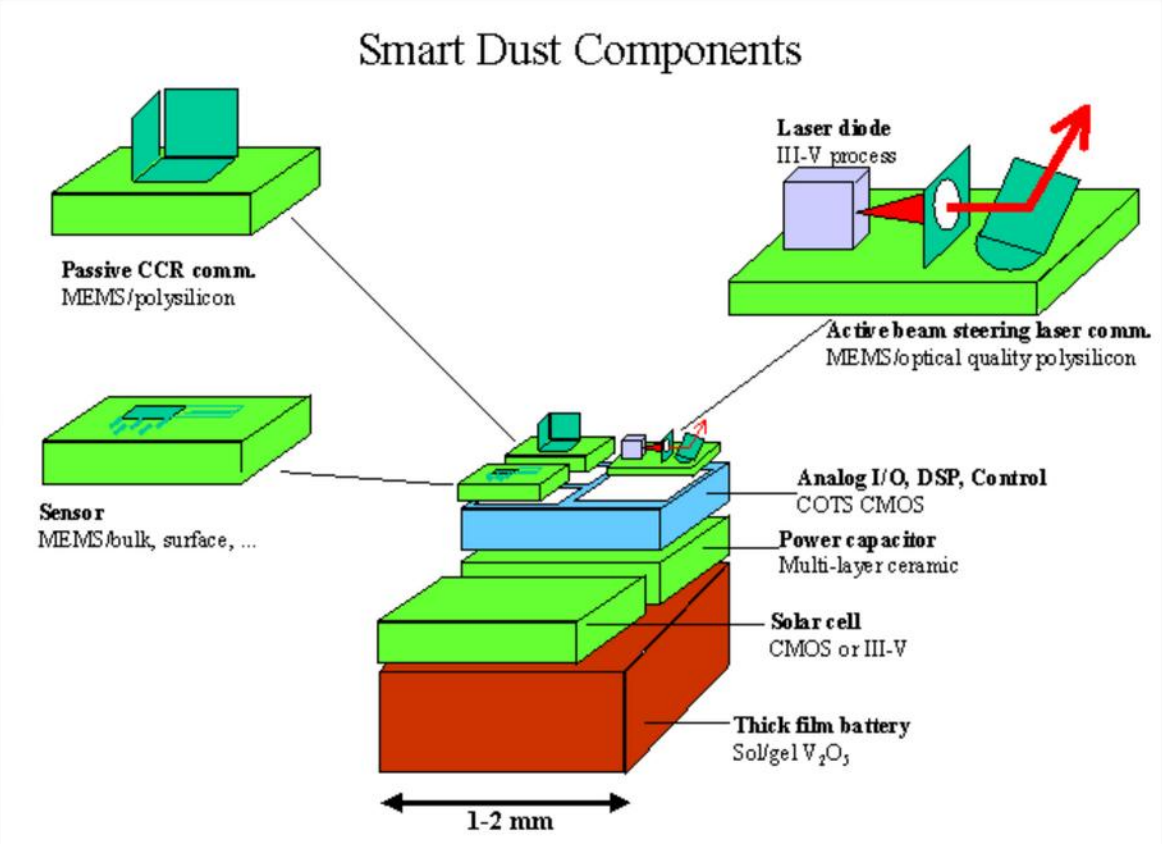
History / Smart Dust

History: SmartDust 1998 – 2001

"Goal: a cubic millimeter device
with a sensor, power supply, analog circuitry,
bidirectional optical communication, and a
programmable microprocessor.

Reached:
a (currently) non-functional mote with a volume
of about 100 cubic millimeters."

source: http://robotics.eecs.berkeley.edu/~pister/SmartDust/



History / 1990s - 2000s

1994, Reza Raji described the concept in IEEE Spectrum as "[moving] small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories".

1993 -1997, several companies proposed solutions like **Microsoft's at Work** or **Novell's NEST**.

Bill Joy (SUN) envisioned device-to-device communication as a part of his "Six Webs" framework, presented at the World Economic Forum at Davos in **1999**.

The **term "Internet of things"** was likely coined by **Kevin Ashton** of Procter & Gamble, later **MIT's Auto-ID Center**, in 1999 though he prefers the phrase "Internet for things". At that point **RFID** seen as essential to the Internet of things
Seen as "simply the point in time **when more 'things or objects' were connected to the Internet than people**", Cisco Systems estimated that the **IoT was "born" between 2008 and 2009**, with the things/people ratio growing from 0.08 in 2003 to 1.84 in 2010.

source: wikipedia

History / Term

> *The integration of people, processes and technology with connectable devices and sensors to enable remote monitoring, status, manipulation and evaluation of trends of such devices*

Peter T. Lewis, 1985

(disputed)

Zanzibar 2005

The days of the Cantenna

Wi-Fi
as
low cost
Infrastructure

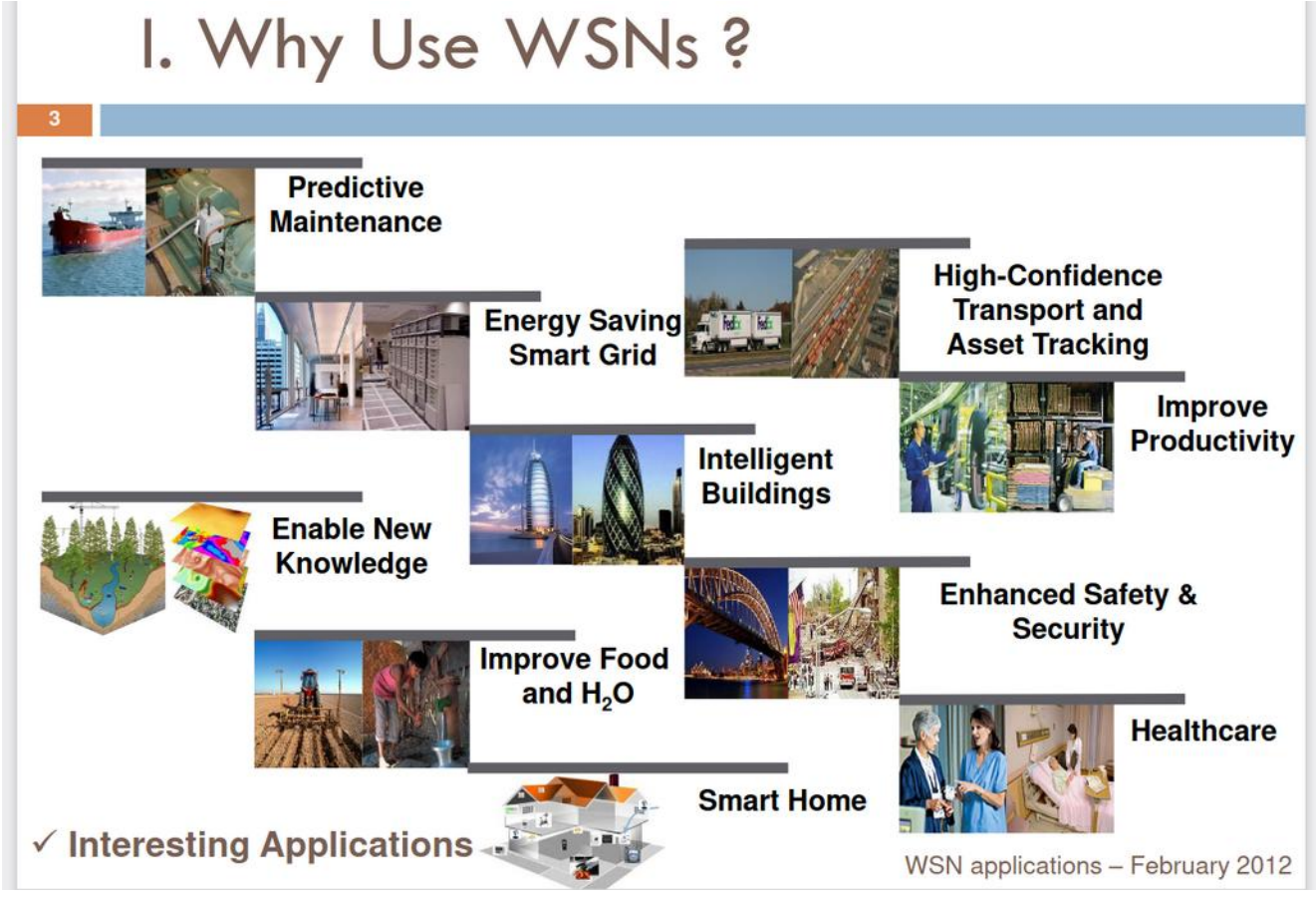
https://www.youtube.com/watch?v=rhzkMIHcS9I

ICTP Trieste 2005 -

Wireless Sensor Networks

2012 School

Antoine Bagula (UCT SA)



Around 2010, a comeback for IoT

ICTP Trieste 2005 -

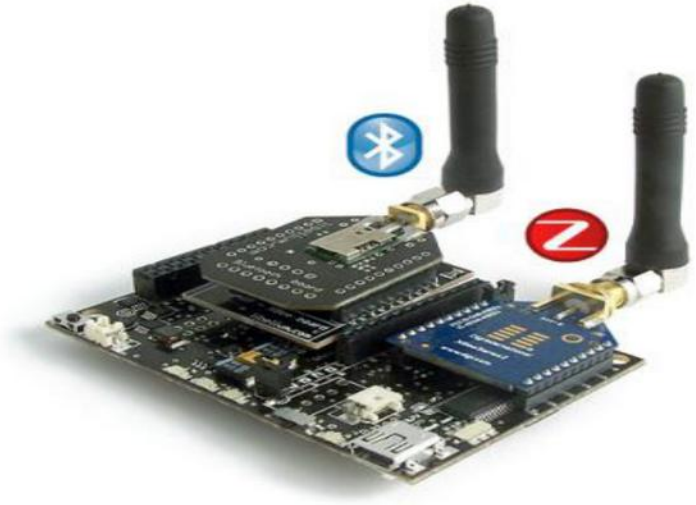
Wireless Sensor Networks

2012 School

Antoine Bagula
(University of the Western Cape, SA)

WSN application examples

52



Two different types of radio are connected at the same time: a **Bluetooth** radio is used as a sensor to make inquiries and detect nearby devices, while the **ZigBee** radio sends the information collected using its multi-hop capabilities.

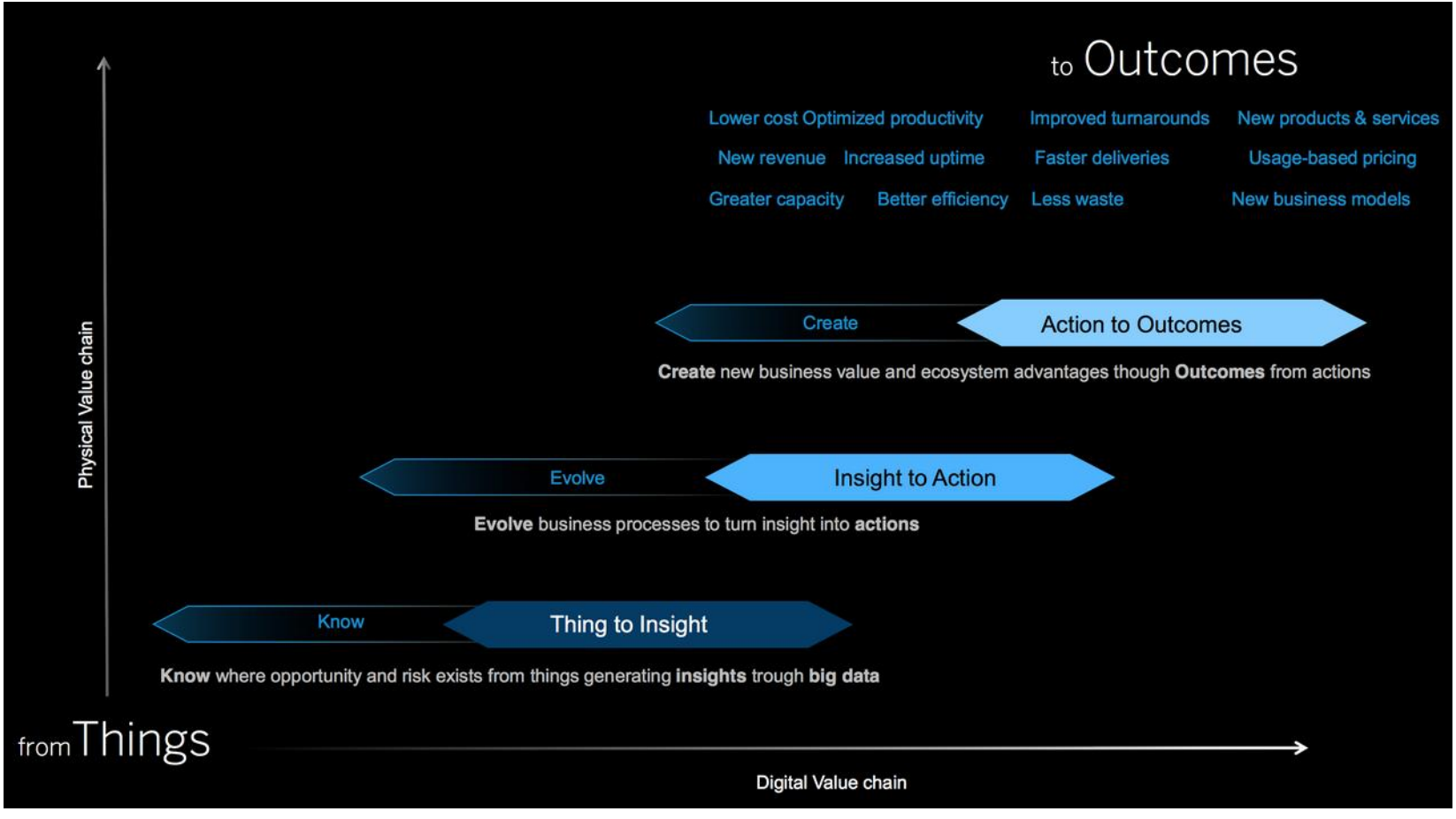
WSN applications – February 2012

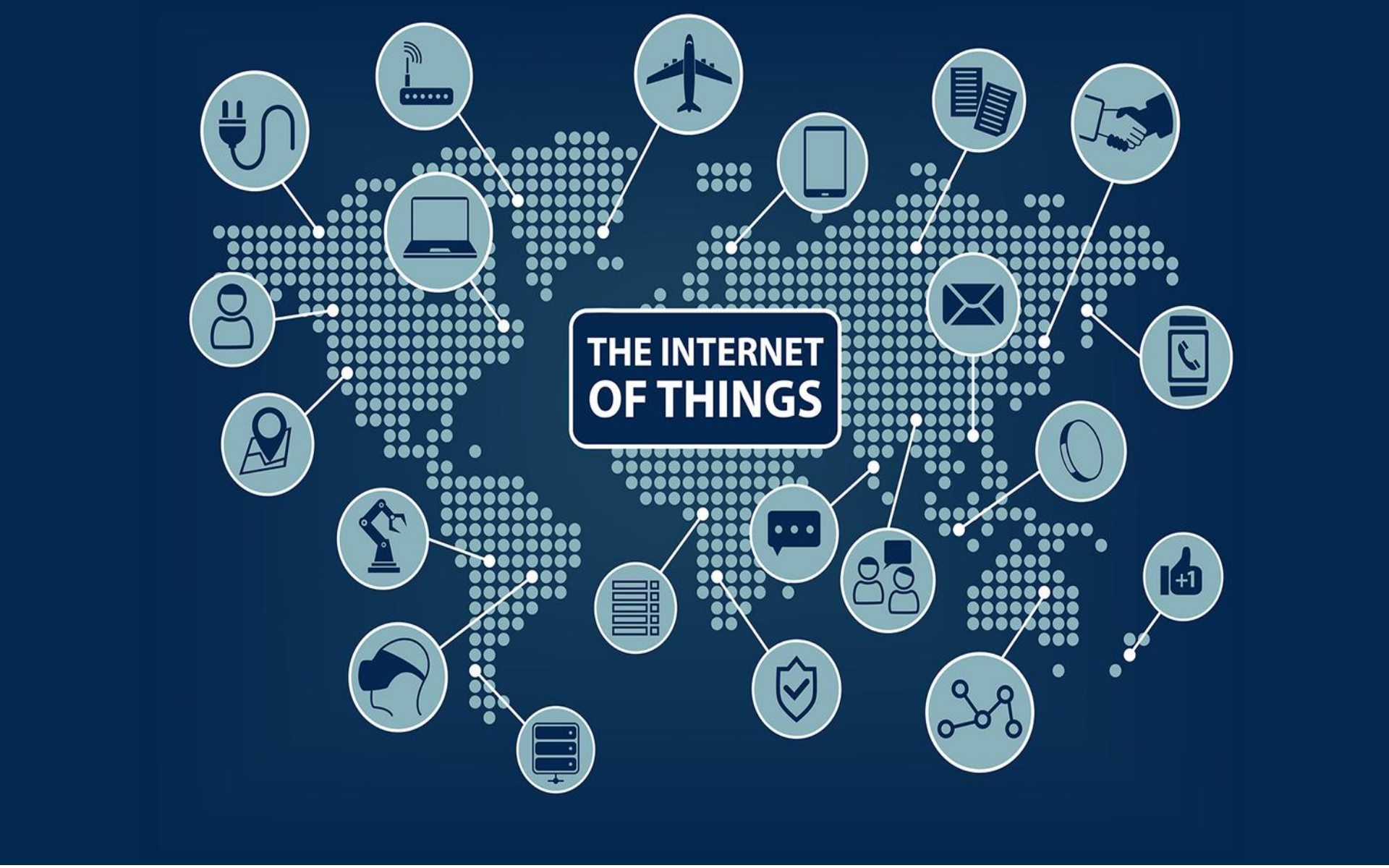
Different networks, similar approach

http://wireless.ictp.it/wp-content/uploads/2012/02/WSN-Applications.pdf

SAP Vision

Slide courtesy of Jesper Schleimann, SAP Nordic




THE INTERNET
OF THINGS
+1



THE INTERNET OF THINGS

the Internet of Things
CONNECT THE WORLD

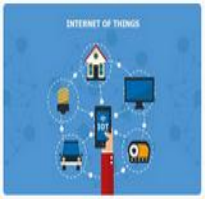
IOT

The Internet of Things (IoT)

INTERNET OF THINGS

The Internet of Things
From connecting devices to human value

INTERNET OF THINGS


INTERNET OF THINGS

INTERNET
OF THINGS

THE AGE OF
IOT

internet
of things


THE INTERNET OF THINGS


Internet of Things Uses By Industry


INTERNET
OF THINGS

IOT

INTERNET OF THINGS

IoT

INTERNET of THINGS

IOT
INTERNET OF THINGS

THE
INTERNET
OF THINGS

How Internet of Things (IoT) is
Changing the World?

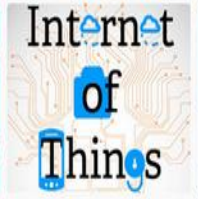
IOT


Internet Of Things (IoT)
Trends in 2018

Internet of Things
"Cloud"


INTERNET OF THINGS
IoT
edureka!

INTERNET
OF THINGS

INTERNET
OF THINGS

Internet
of
Things

IoT


Blockchain
and IoT


INTERNET of
THINGS

INTERNET
OF THINGS

INDUSTRIAL INTERNET OF THINGS

Internet Of Things Ecosystem
BI INTELLIGENCE

INTERNET
OF THINGS

The
INTERNET
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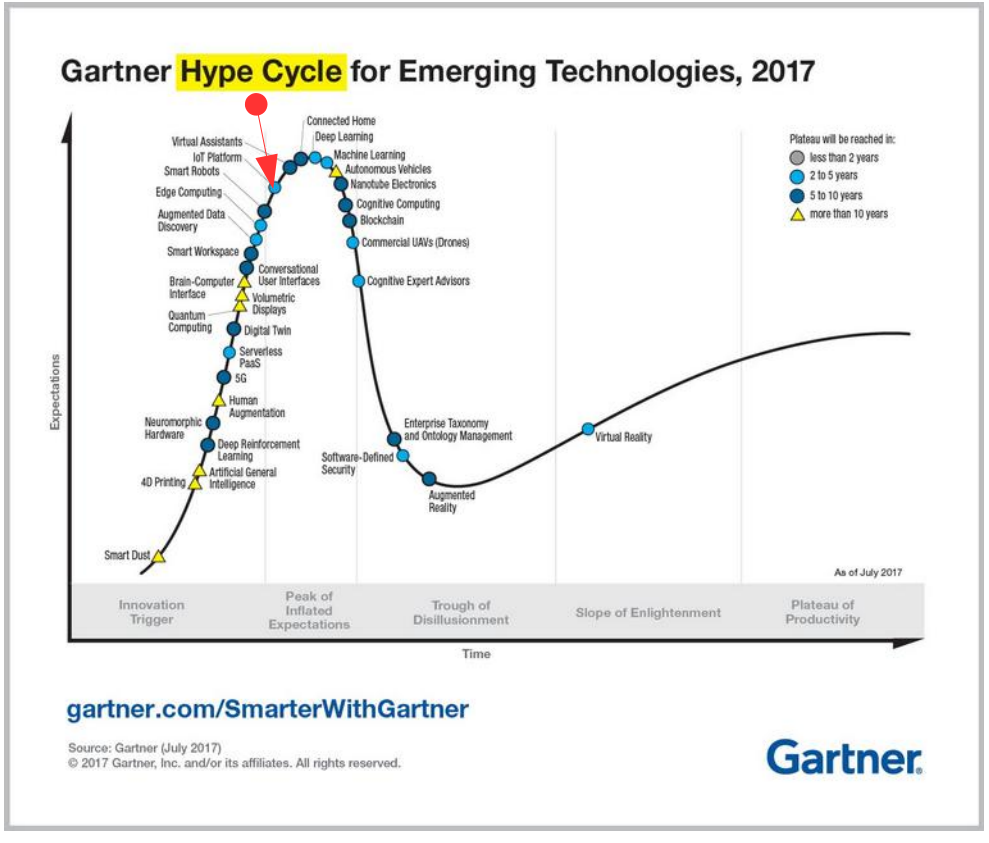
THE INTERNET
OF THINGS

INTERNET of
THINGS

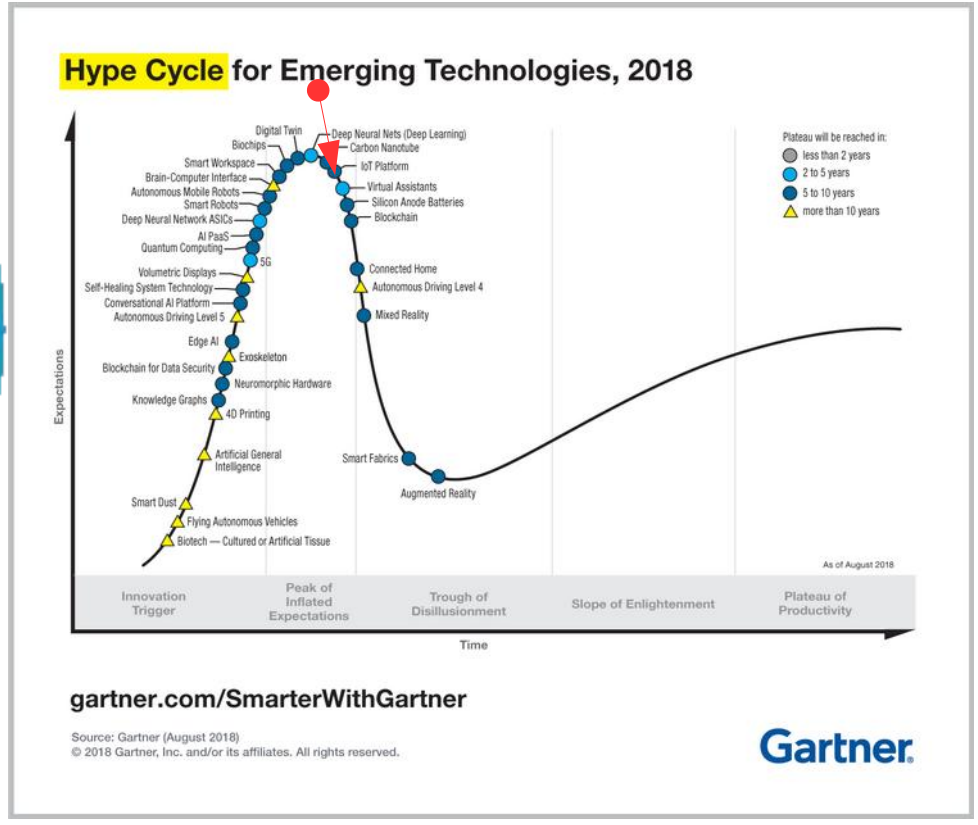
IOT

Internet of Things (IoT)

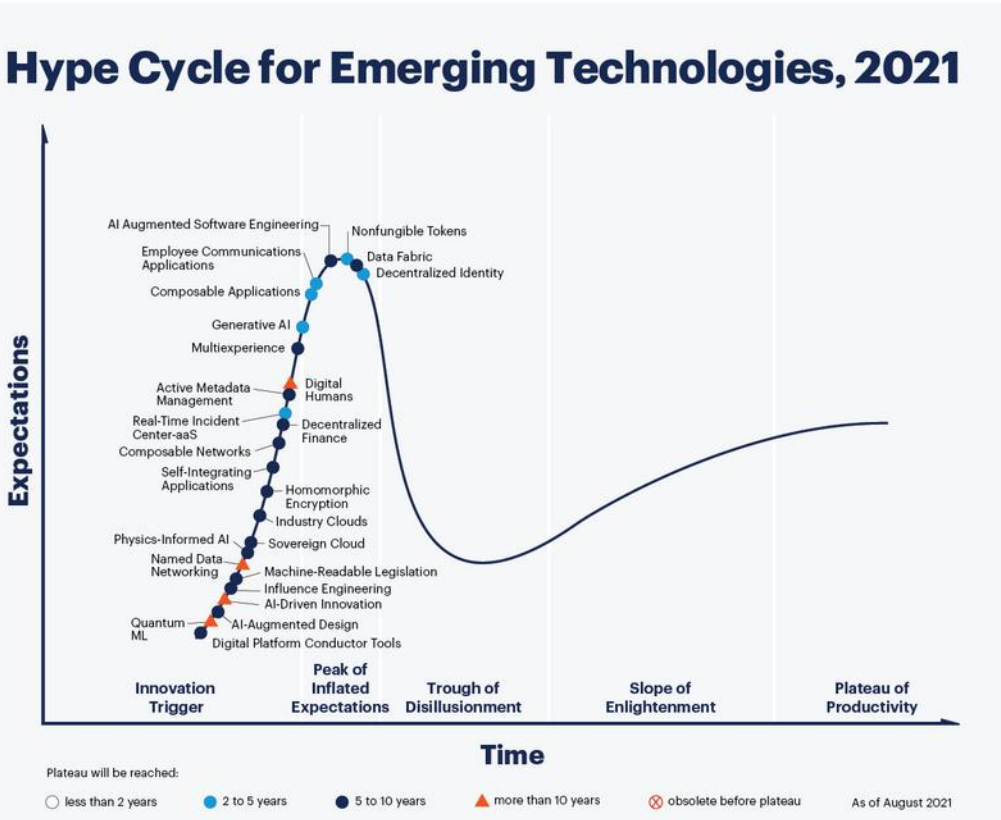
IoT Hype 2017



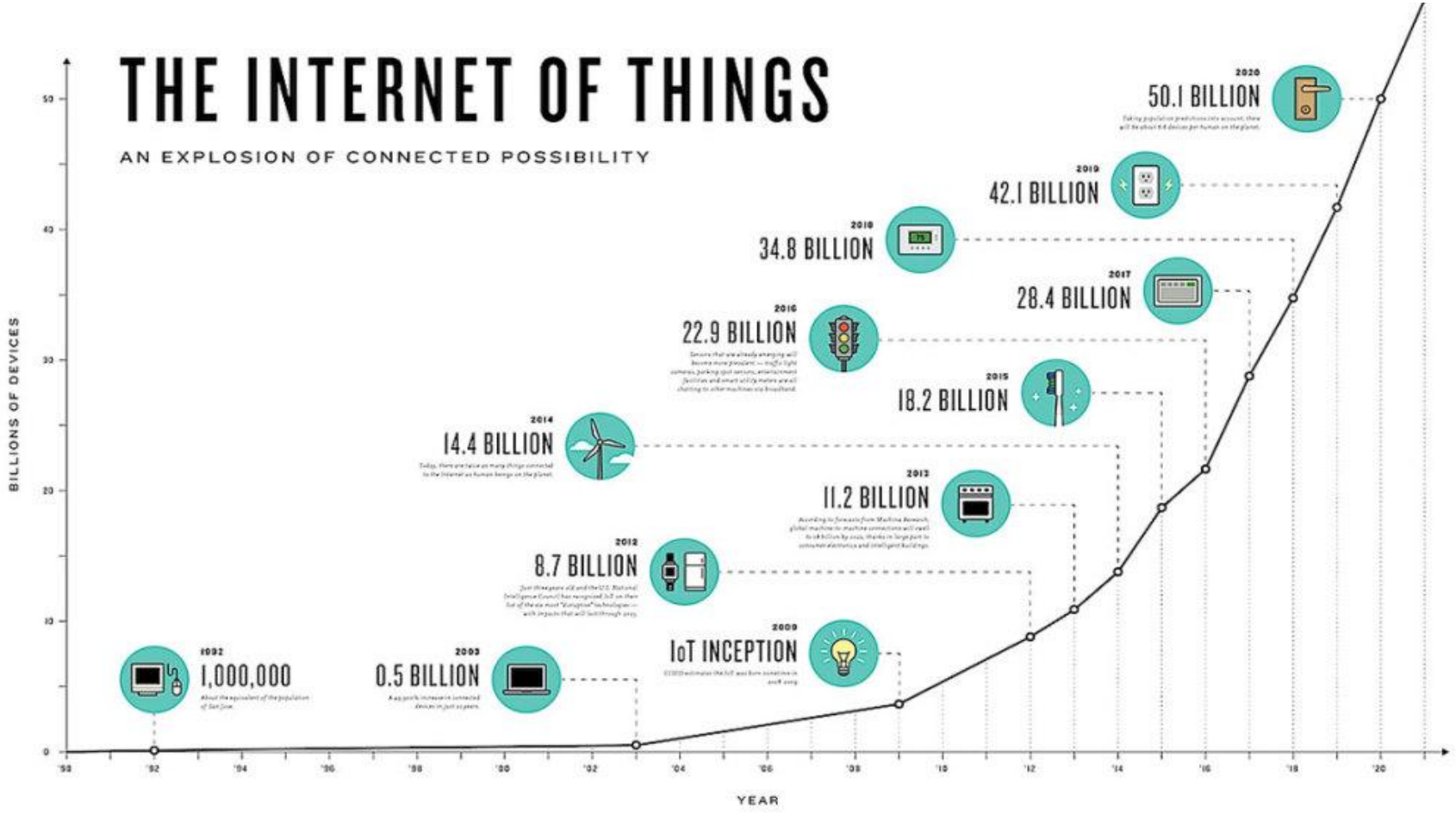
IoT Hype 2018



IoT Hype 2021 – gone ...



Number of things



Source:NCTA - https://www.ncta.com

On counting Things ...

A few things we have learnt about estimates:

They are always wrong.

People will gladly just forget them and make new ones.

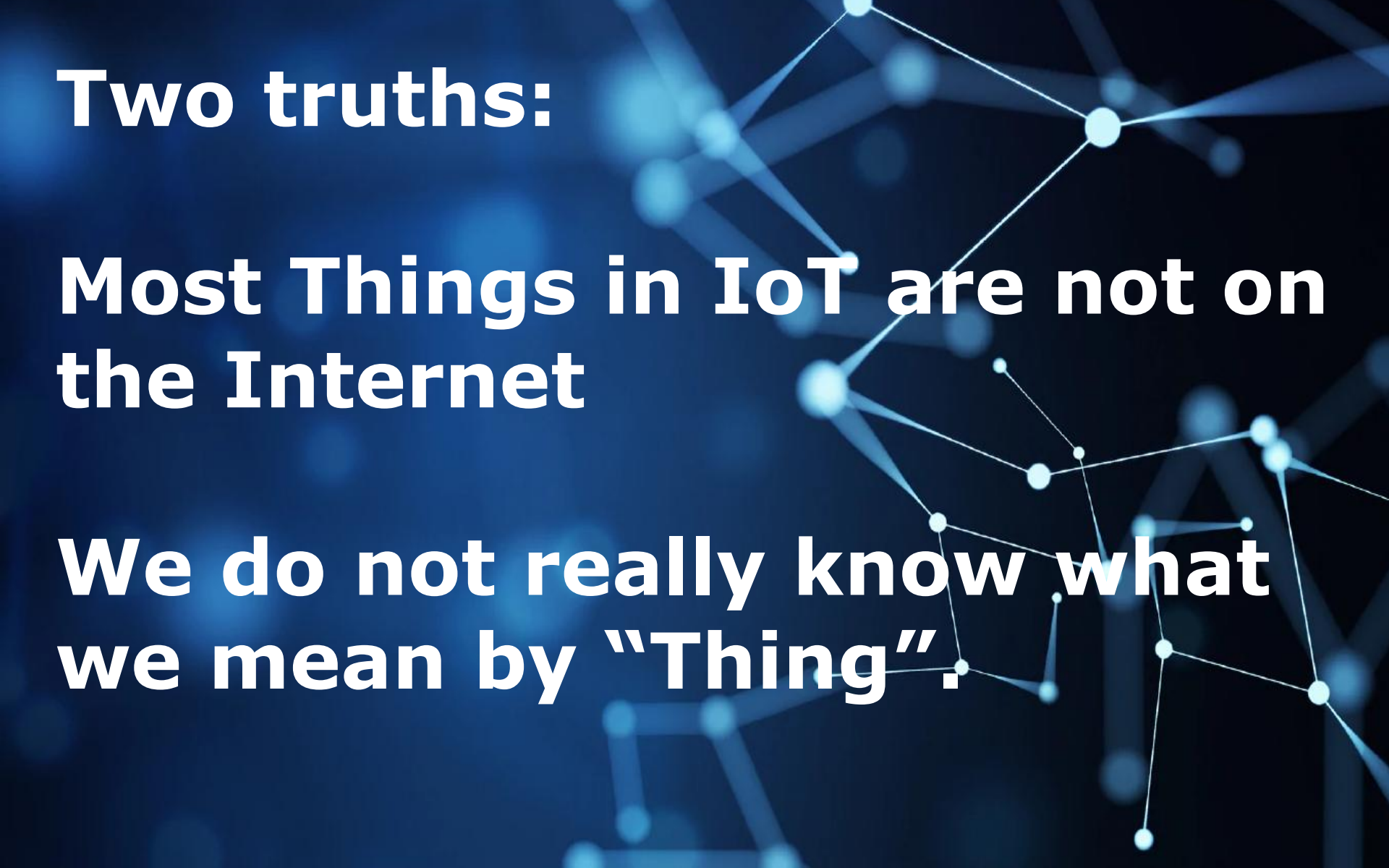
It is impossible to count the number of things on the net –
lacking a definition of both
”things” and ”being on the internet”.

Terms / IoT

ITU-T Y.2060 says:

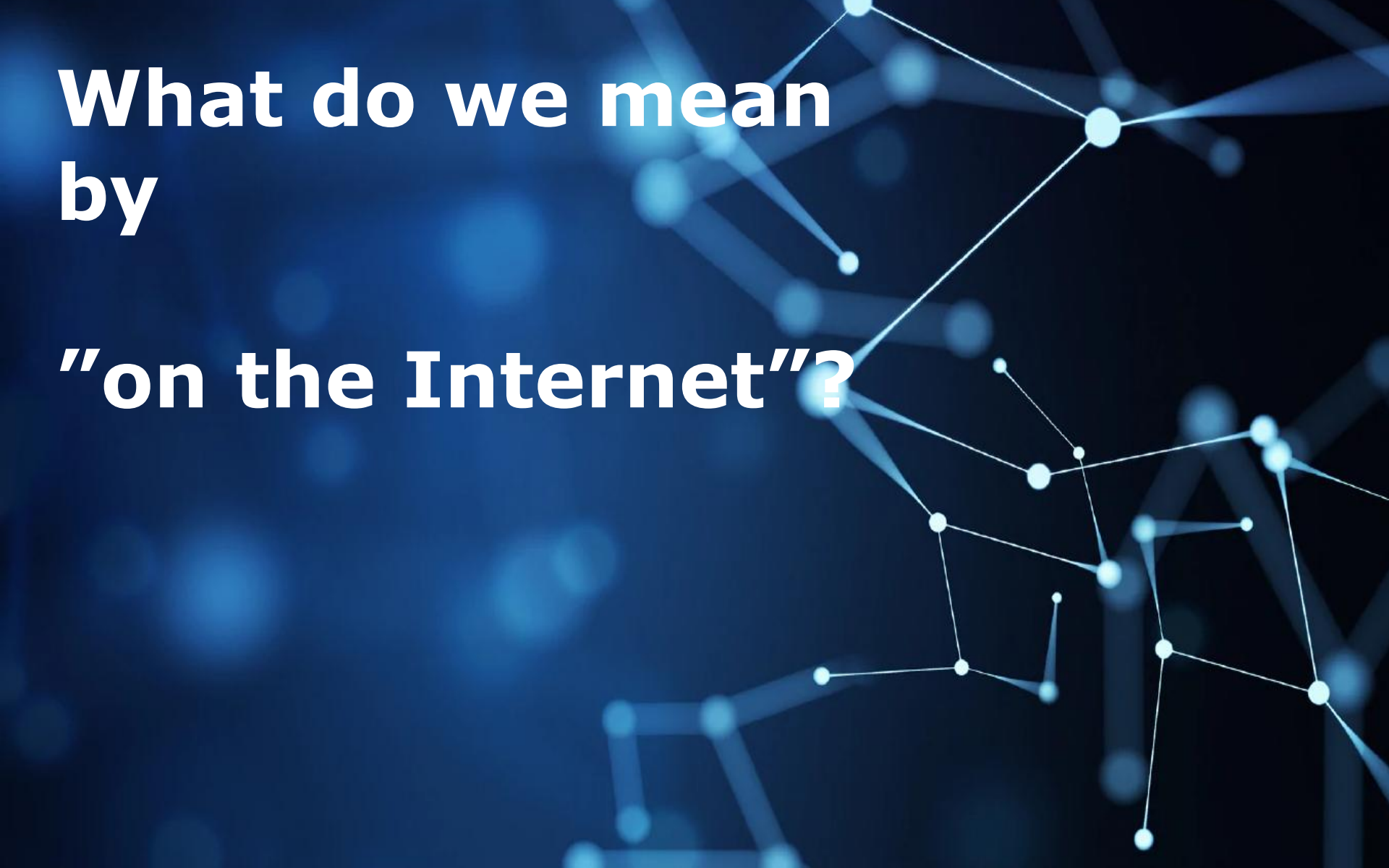
3.2.2 **Internet of things (IoT)**: A **global infrastructure** for the information society, enabling advanced **services** by **interconnecting (physical and virtual) things** based on existing and evolving interoperable information and **communication technologies.**

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.
NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.


Two truths:
Most Things in IoT are not on the Internet
We do not really know what we mean by “Thing”.

What do we mean by

”on the Internet”?



What do we mean by

”Thing”?

Terms / Things

ITU-T Y.2060 says:

3.2.3 thing:

With regard to the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.

This is a very very wide definition.

Terms / Devices

ITU-T Y.2060 says:

3.2.1 device: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, datacapture, data storage and data processing.

This, too, is a rather wide definition.

Terms / Things

Along which properties might we classify things?

Which might be relevant for IoT work?

…

Reminder: We have a bias in “Things”! Depending on our affiliations, interests, dislikes, …

Terms / Classification of Things

Along lines of e.g. ...

Mobility
Power
Size
Data rates
Autonomy
Human connection / Modality

Terms / How do we describe ...

Cars?

Webcams?

Mobile phones?

Along lines of e.g. ...

Mobility
Power
Size
Data rates
Autonomy
Human connection / Modality

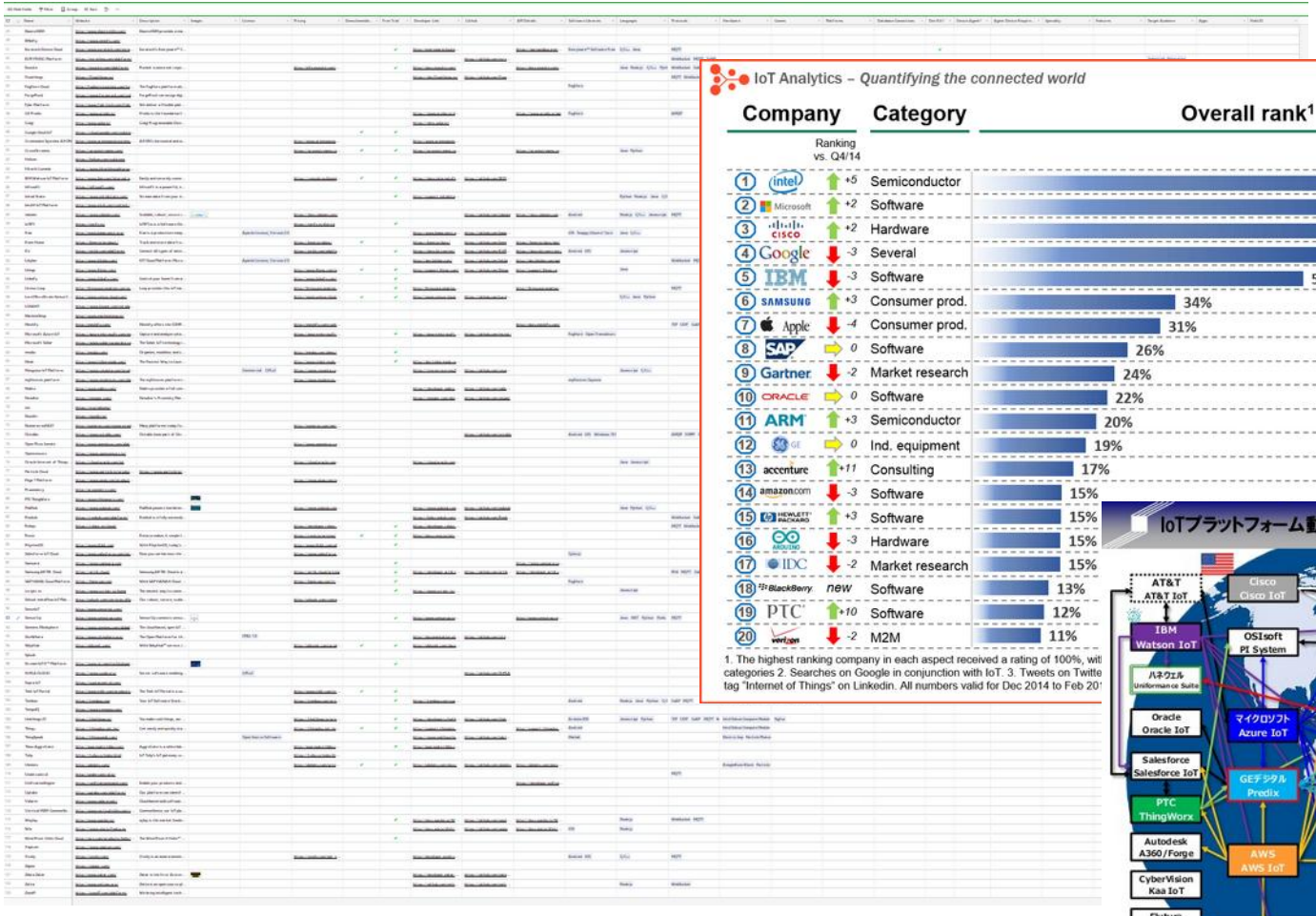
Terms / others

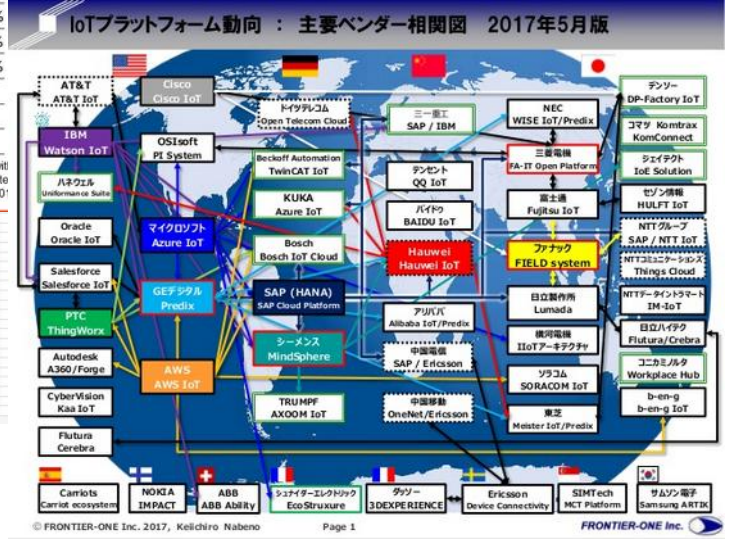
Lots of alternative names for “devices”:

Node
Mote
Dust mote

Sensor (no! - but people use it a lot!)

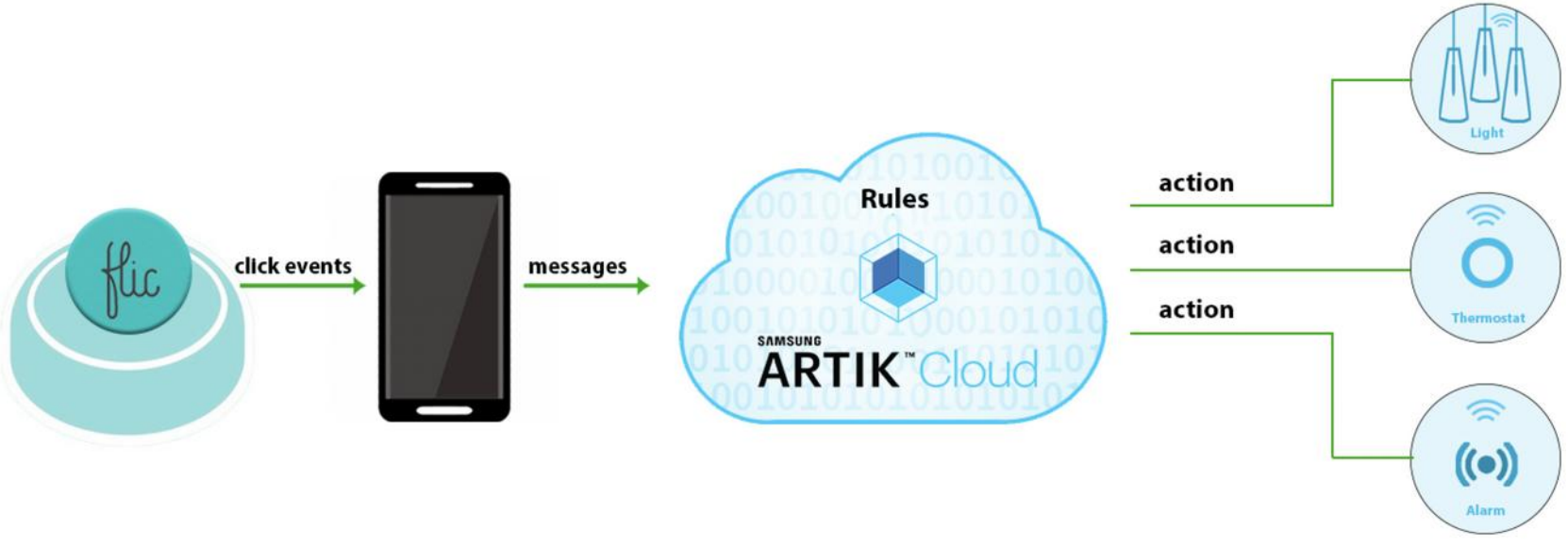
Here’s the top 100 IoT platforms … or so …

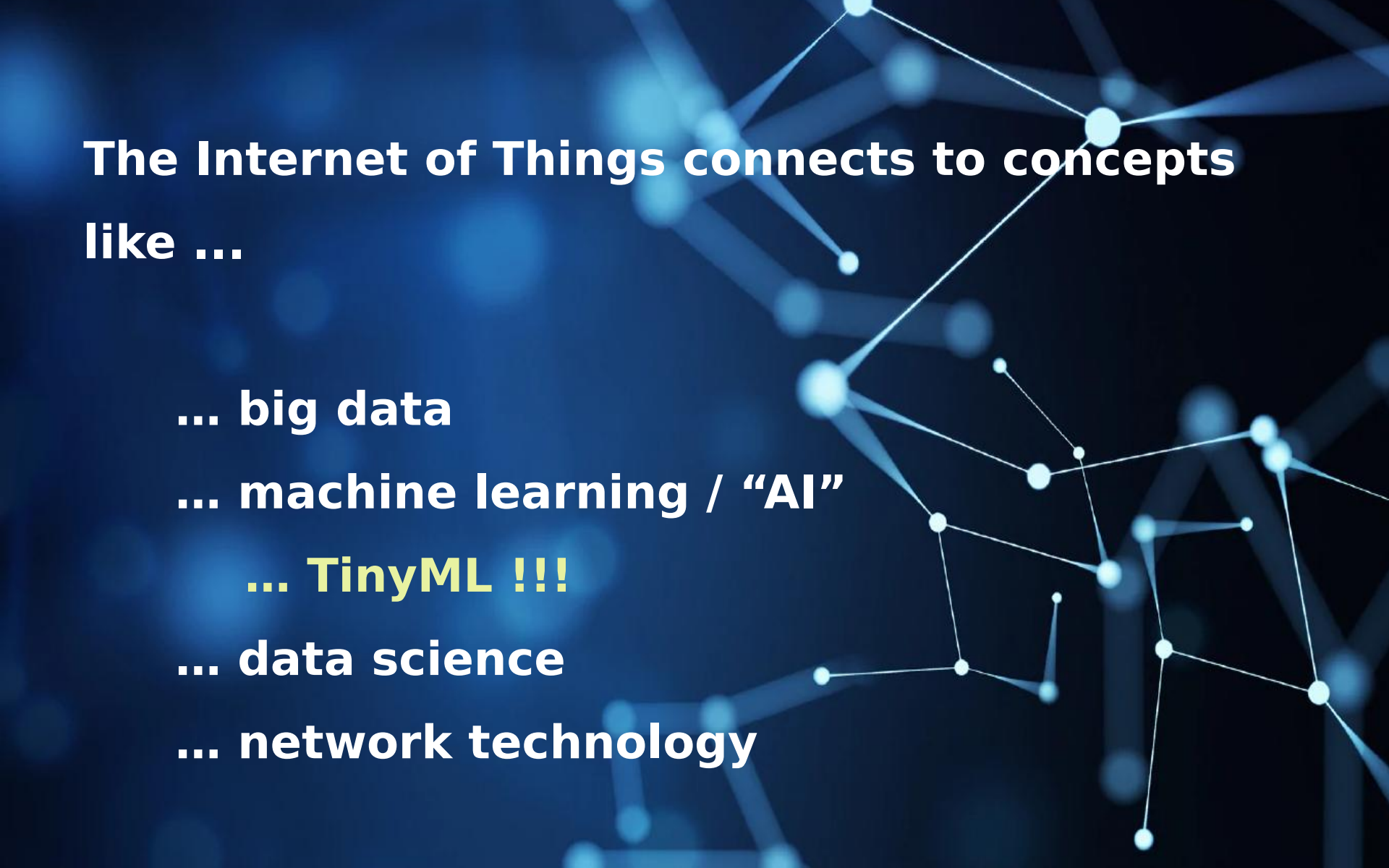




Commercial IoT platforms

Azure, IBM, Amazon AWS, Cisco, Intel, OVH...





The Internet of Things connects to concepts like ...

... big data

... machine learning / “AI”

... TinyML !!!

... data science

... network technology

Take-Aways

- **Definitions, Terms**
- **Some history**
  and an understanding of the various concepts
- **Classification of Things**

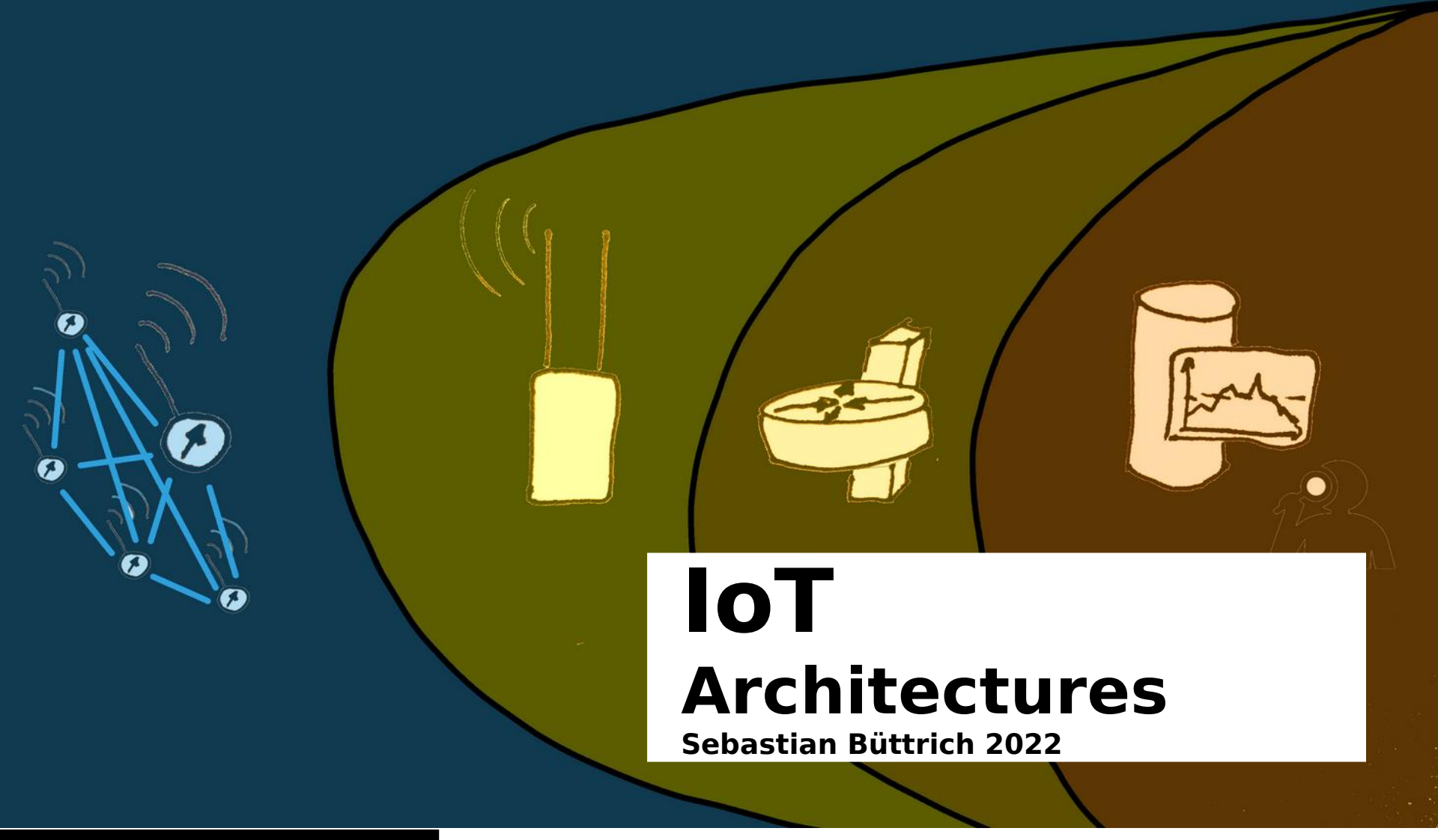
Terms / Things

Whiteboard interlude:

Write down keywords,
things that come to your mind when saying

Internet of Things:

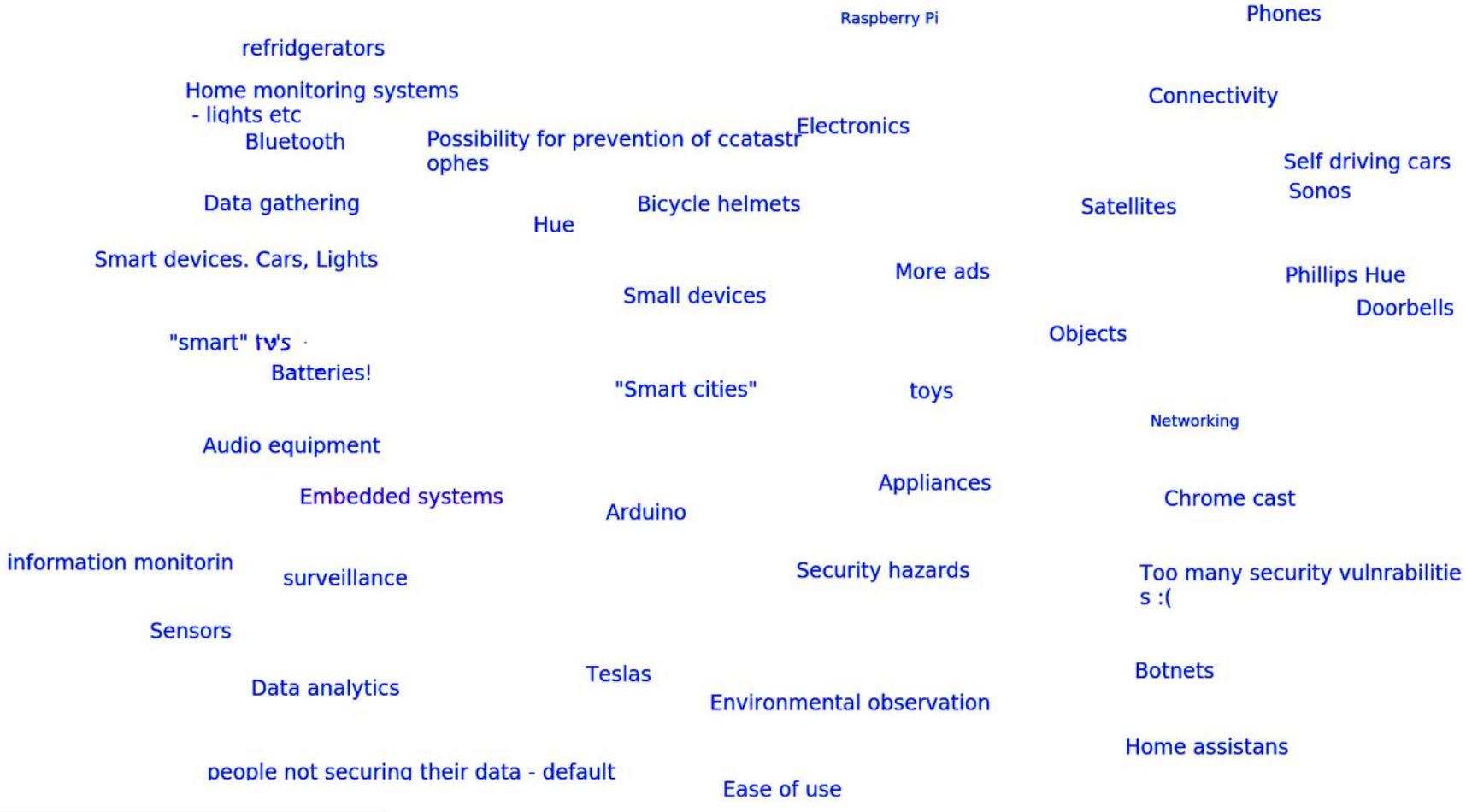
A Mindmap of IoT.



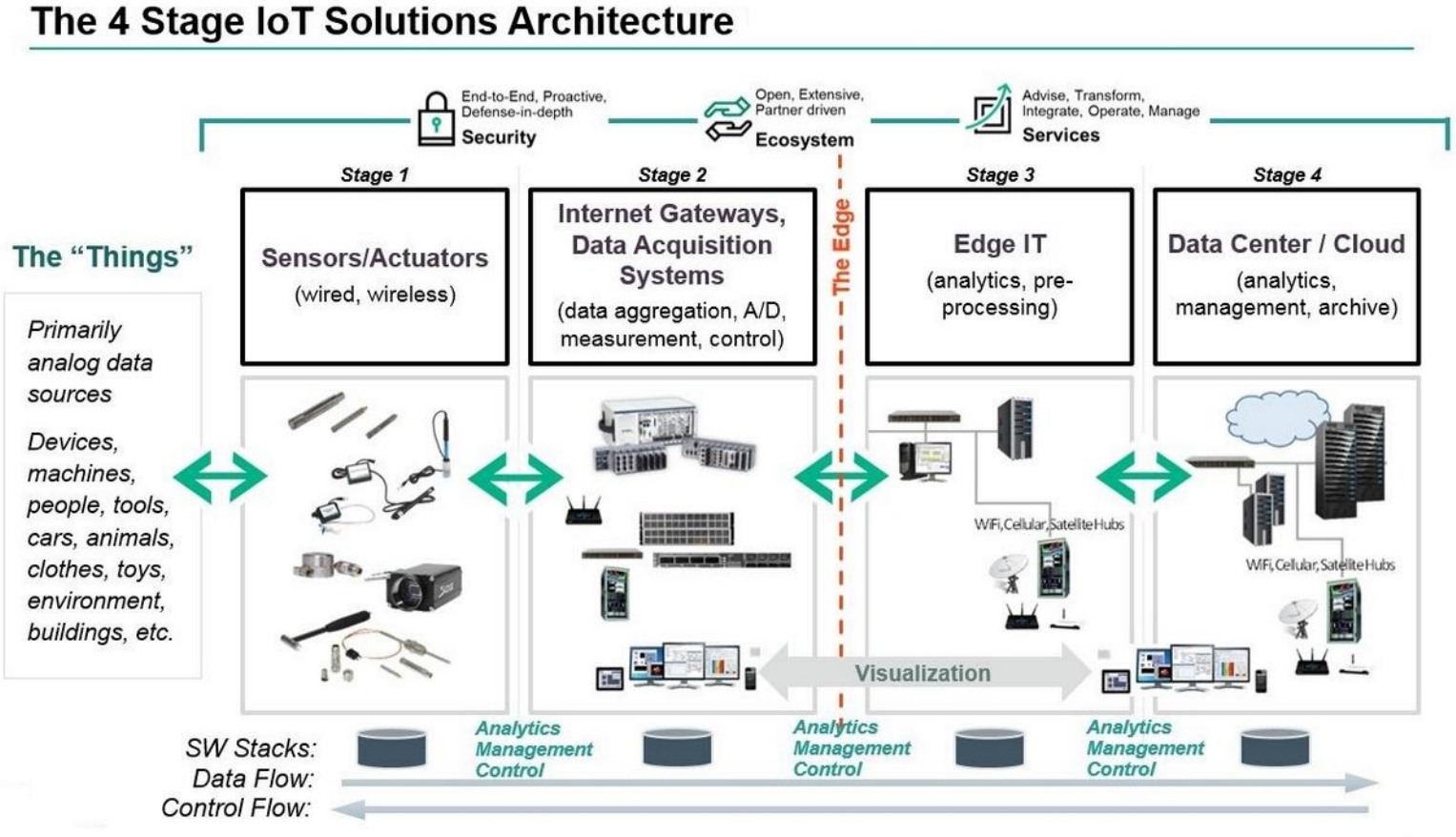
IoT Architectures

Sebastian Büttrich 2022

IoT / context

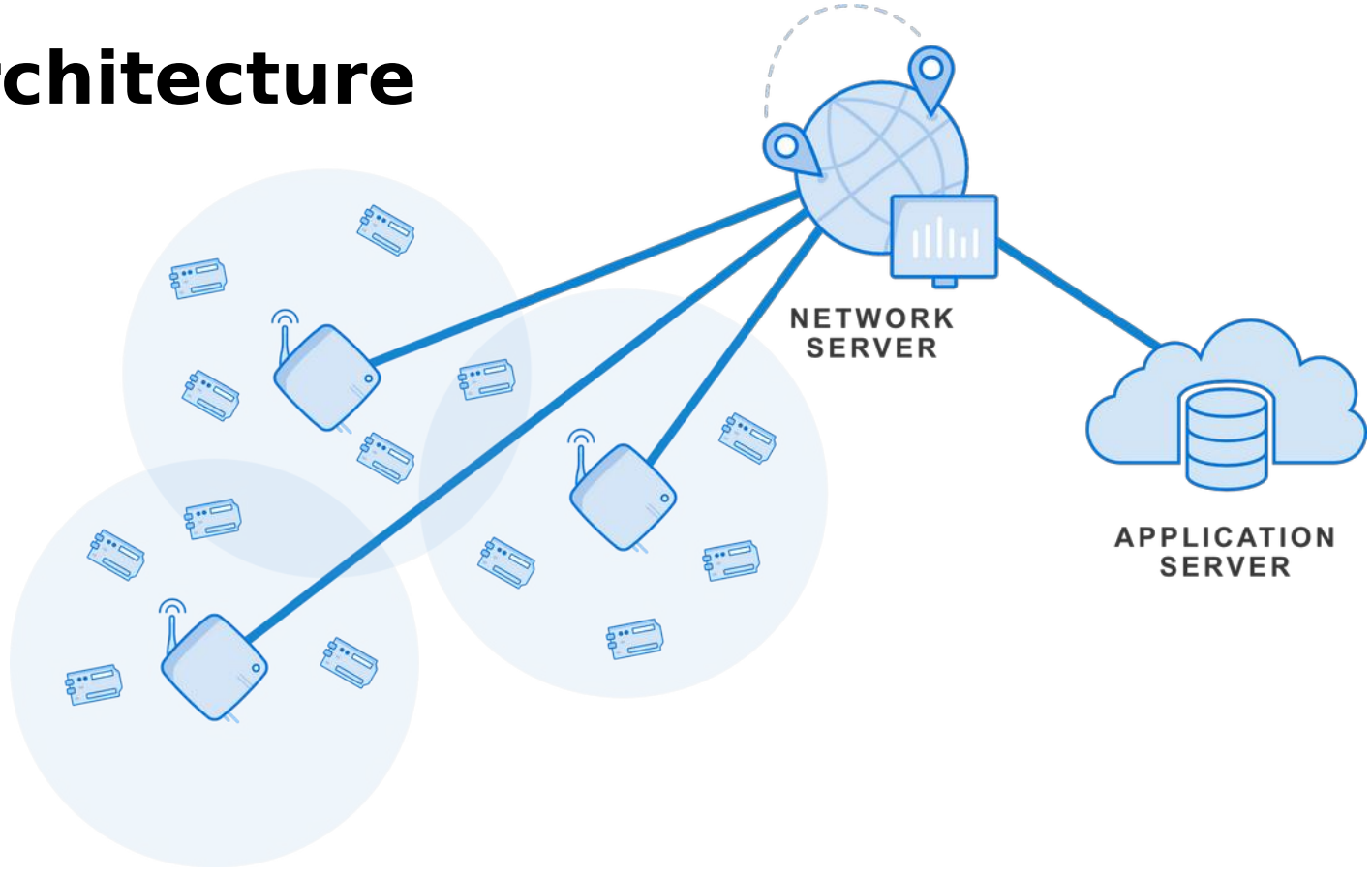

Raspberry Pi
Phones
refridgerators
Home monitoring systems - lights etc
Connectivity
Bluetooth
Possibility for prevention of ccatastr ophes
Electronics
Self driving cars
Sonos
Data gathering
Bicycle helmets
Satellites
Hue
Smart devices. Cars, Lights
More ads
Phillips Hue
Small devices
Doorbells
"smart" tv's
Objects
Batteries!
"Smart cities"
toys
Networking
Audio equipment
Appliances
Embedded systems
Chrome cast
Arduino
information monitorin
surveillance
Security hazards
Too many security vulnrabilitie s :(
Sensors
Botnets
Teslas
Data analytics
Environmental observation
Home assistans
people not securing their data - default
Ease of use

IoT Architecture / context

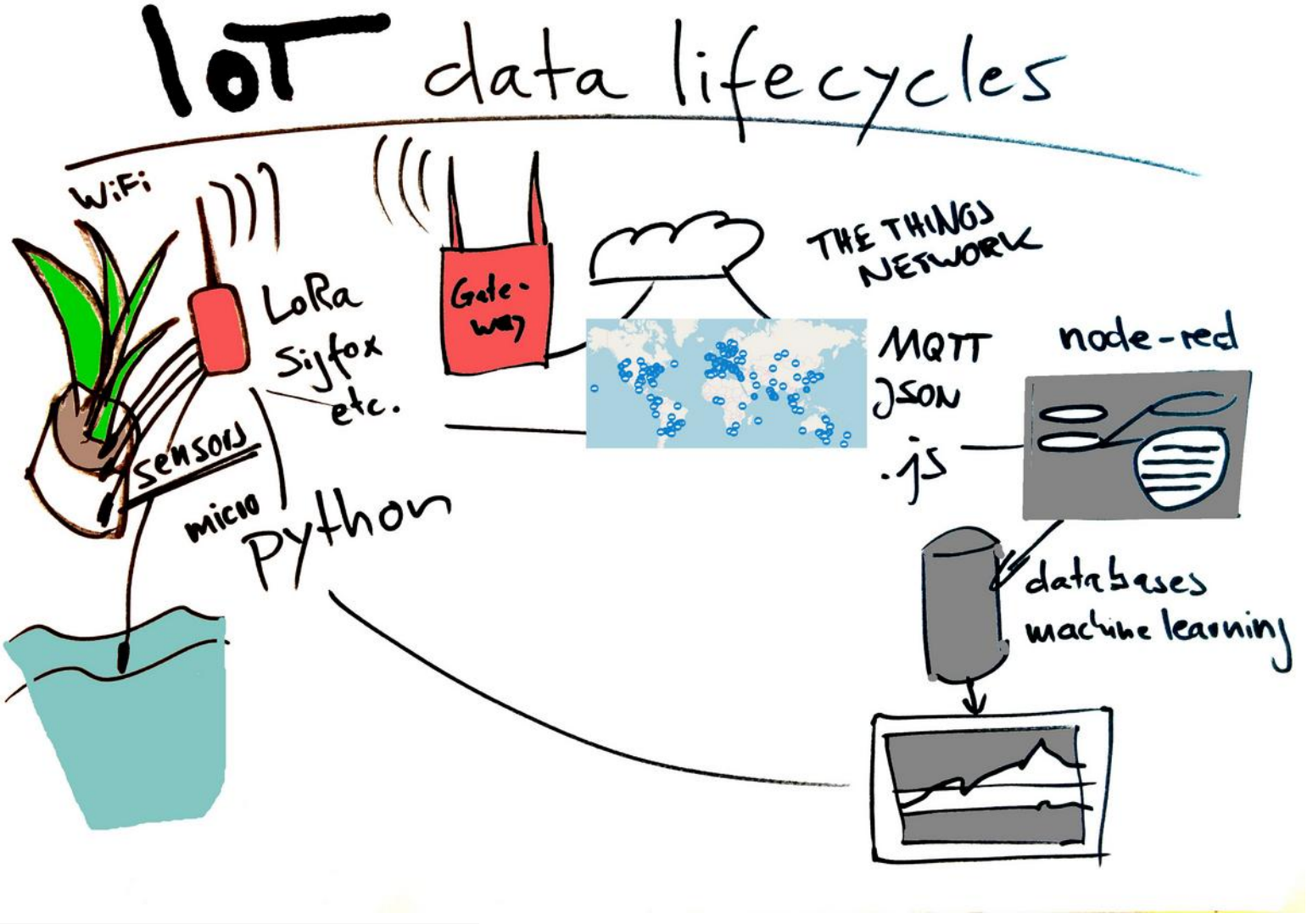


https://techbeacon.com/enterprise-it/4-stages-iot-architecture

IoT Architecture

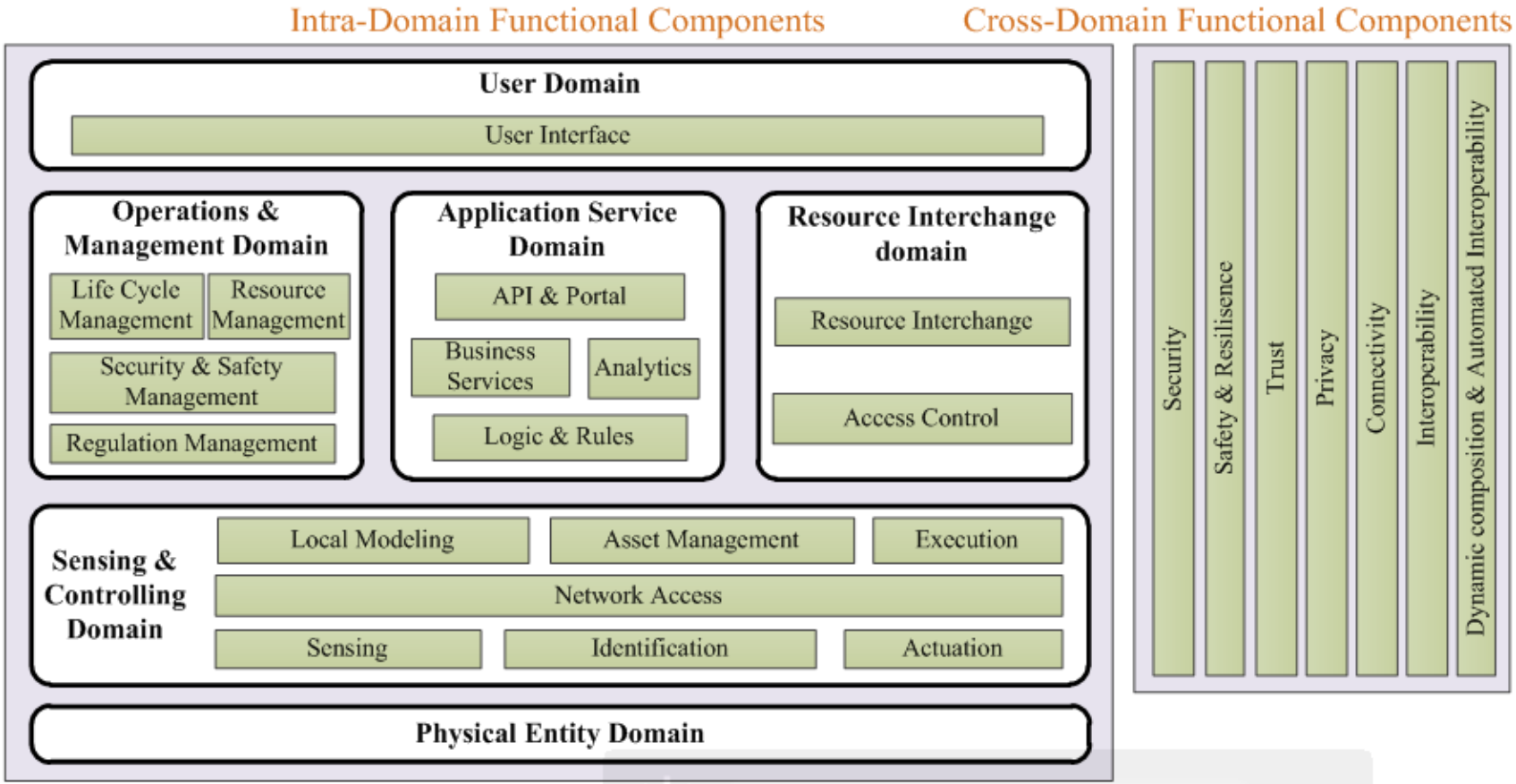


“Things” **Networks/Gateways** **Servers/Cloud**


IoT data lifecycles
Wi-Fi
LoRa
Sigfox
etc.
Gate-
way
THE THINGS NETWORK
MQTT
JSON
.js
node-red
Sensors
micro
Python
databases
machine learning

IoT Reference Architectures

Example: ISO/IEC CD 30141: Internet of Things Reference Architecture (IoT RA)



Importance of knowing where you are

Regardless of
whether you speak of
four or five tiers or layers or realms -

it is crucial in the design process

to know where you are operating!

What are your conditions, constraints, modes?

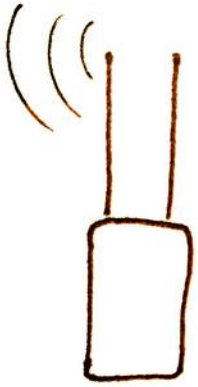
Architecture

Ambiguous term, could be

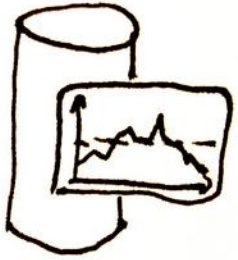
- **Overall IoT architecture –**
  - **framework for “the whole”**
- Software architecture, Stacks
- Hardware architecture

Bare minimum

Things
Devices
Nodes



Gateways
Concentrators
Aggregation

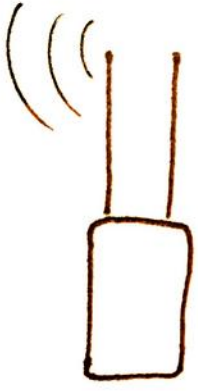


Data backends
Storage
Analytics

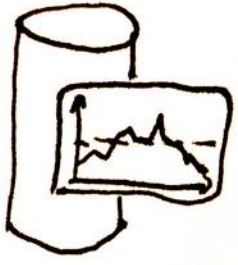
Something is missing

Management, Organization, Scale, Security, Access?

Things
Devices
Nodes

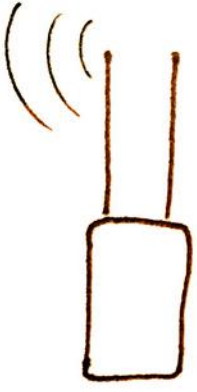


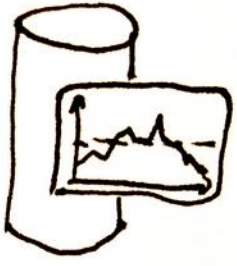
Gateways
Concentrators
Aggregation



Data backends
Storage
Analytics

Bare minimum





Things
Devices
Nodes

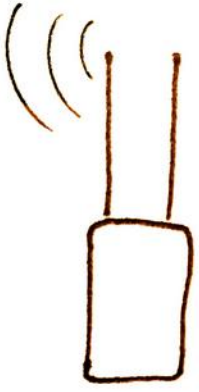
Gateways
Concentrators
Aggregation

Infrastructure Servers
Network servers
Identity
Provisioning
”Middleware”

Data backends
Storage
Analaytics

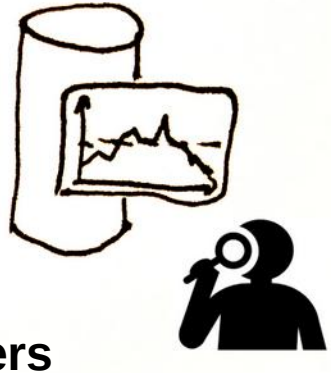
Another missing factor: the human

Things
Devices
Nodes



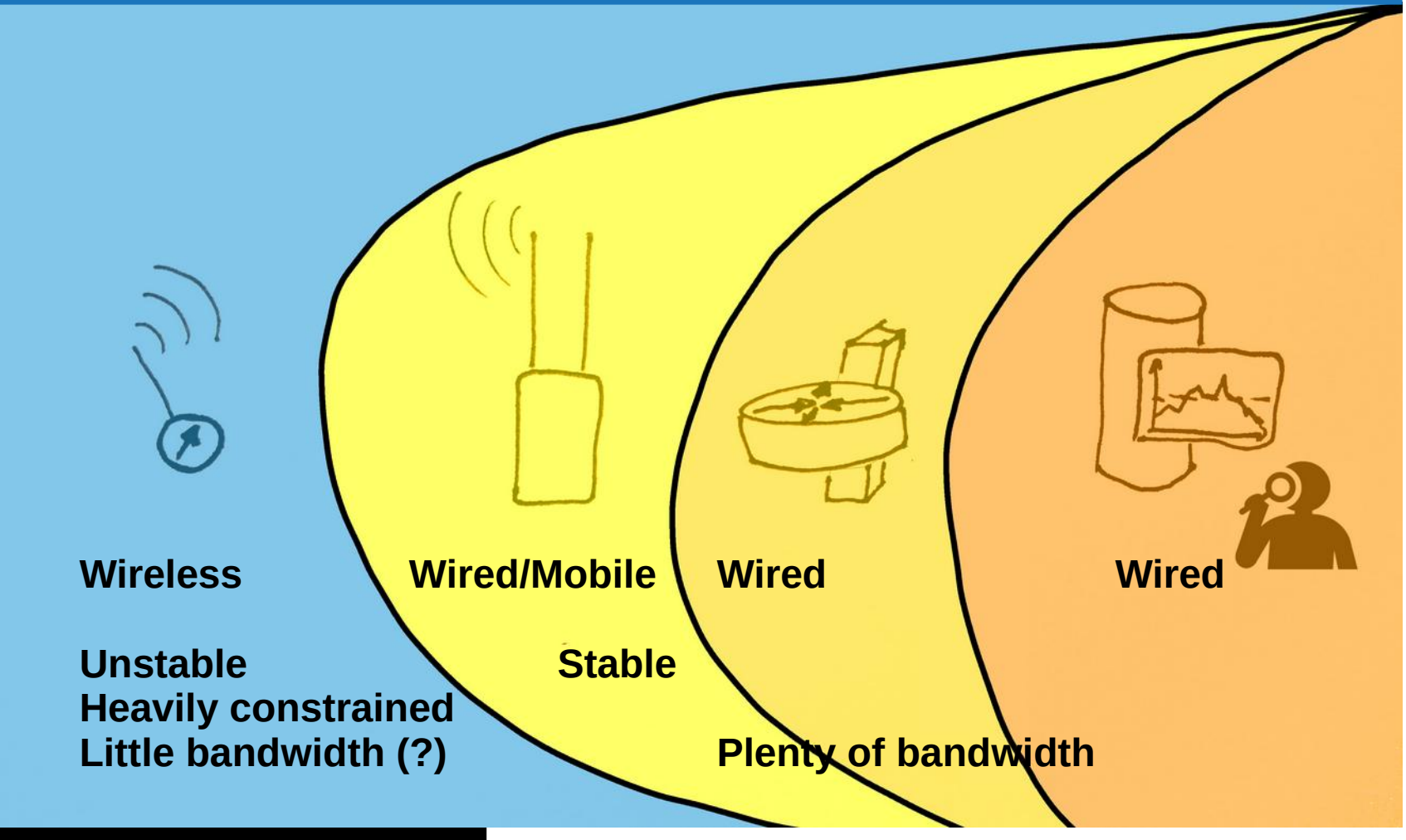
Gateways
Concentrators
Aggregation

Infrastructure Servers
Network servers
Identity
Provisioning
”Middleware”

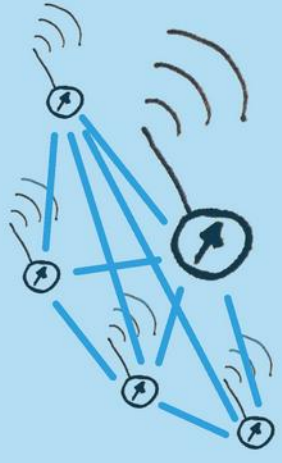


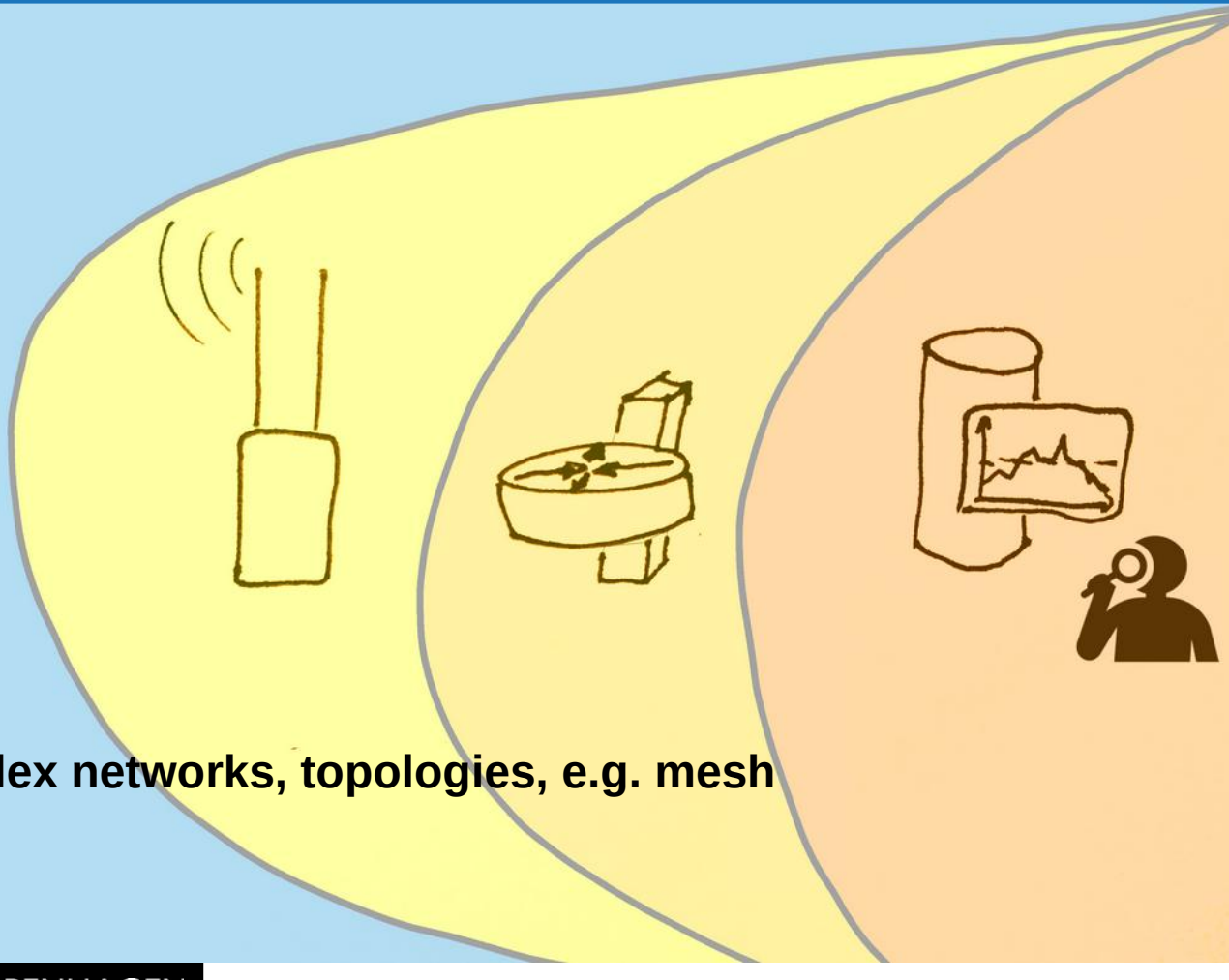
Data backends
Storage
Analytics

Network centric view



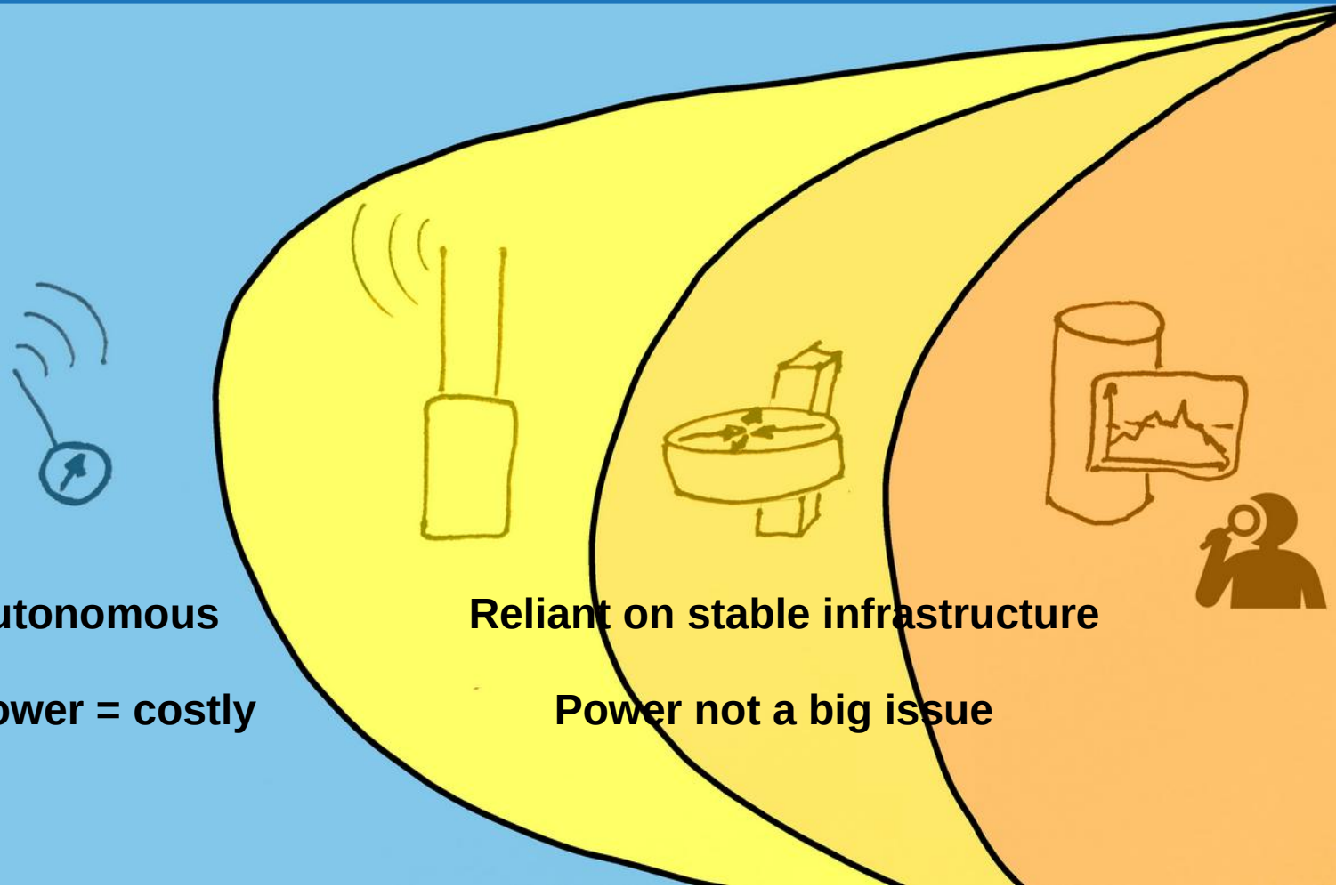
Things – complex networks





^^^ Complex networks, topologies, e.g. mesh

Power centric view



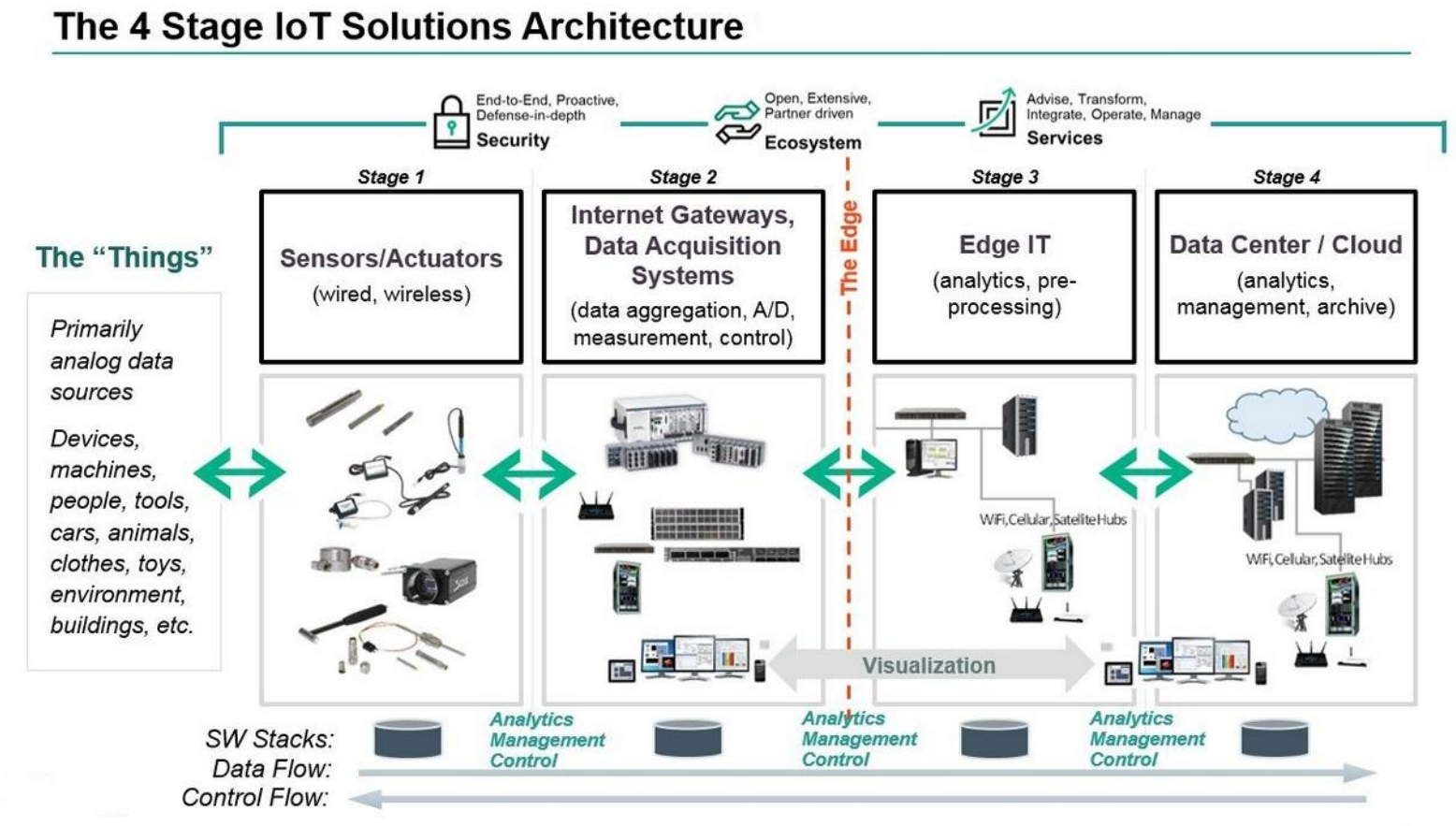
Autonomous

Power = costly

Reliant on stable infrastructure

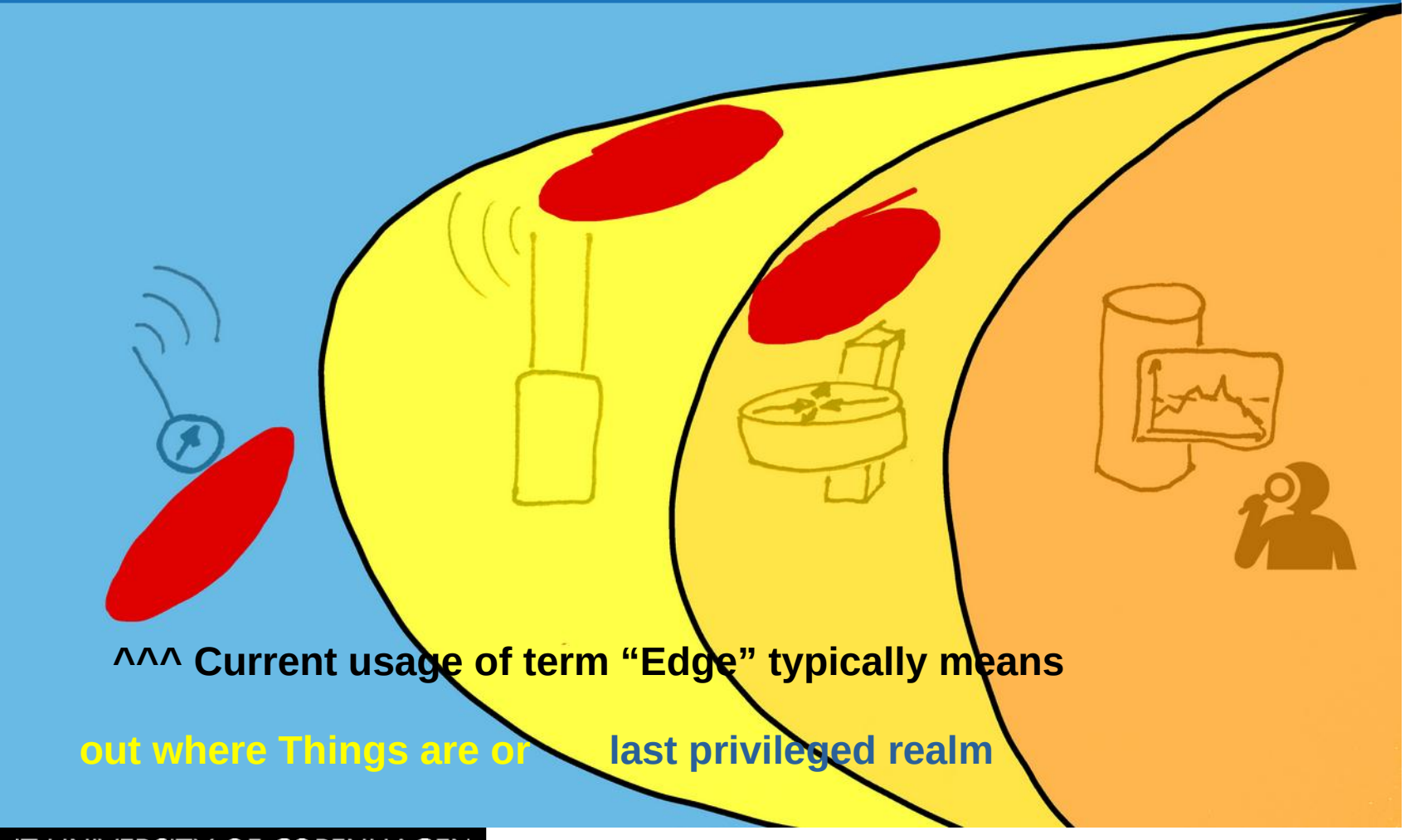
Power not a big issue

Where is the ”edge”?



The location of *Edge* depends on your viewpoint – the *Edge* of what?

Where is the ”edge”?



^^^ Current usage of term “Edge” typically means

out where Things are or last privileged realm

Advanced architectures: NebulaStream

TU Berlin, collab with DASYA ITU

Zeuch, S., Chaudhary, A., Del Monte, B., Gavriilidis, H., Giouroukis, D., Grulich, P. M., ... & Markl, V. (2019). The nebulastream platform: Data and application management for the internet of things. arXiv preprint arXiv:1910.07867.

https://www.nebula.stream/paper/zeuch_cidr20.pdf

Advanced architectures: NebulaStream

An example of a different terminology: fog, queries, engines ...

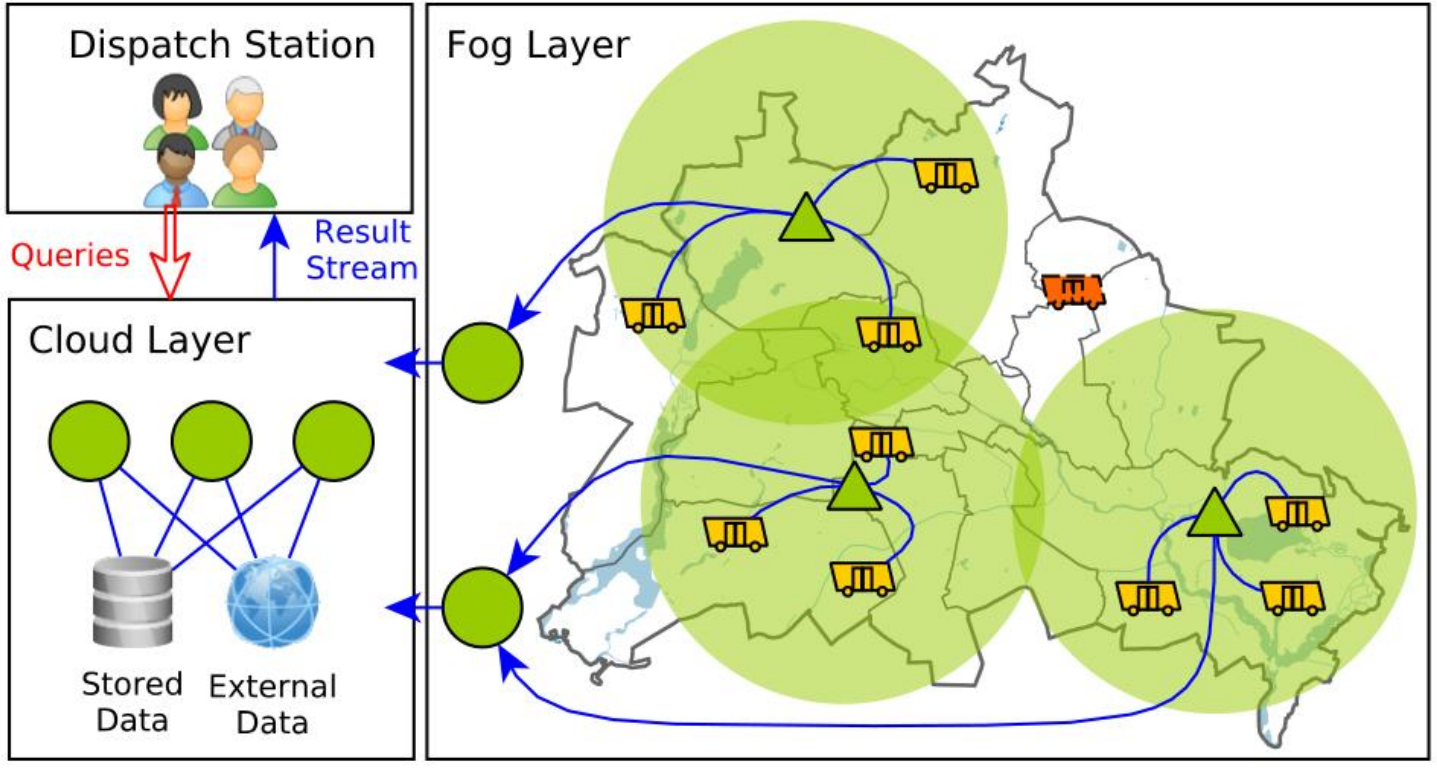


Figure 2: IoT application scenario.

An example of a different terminology: fog, queries, engines ...

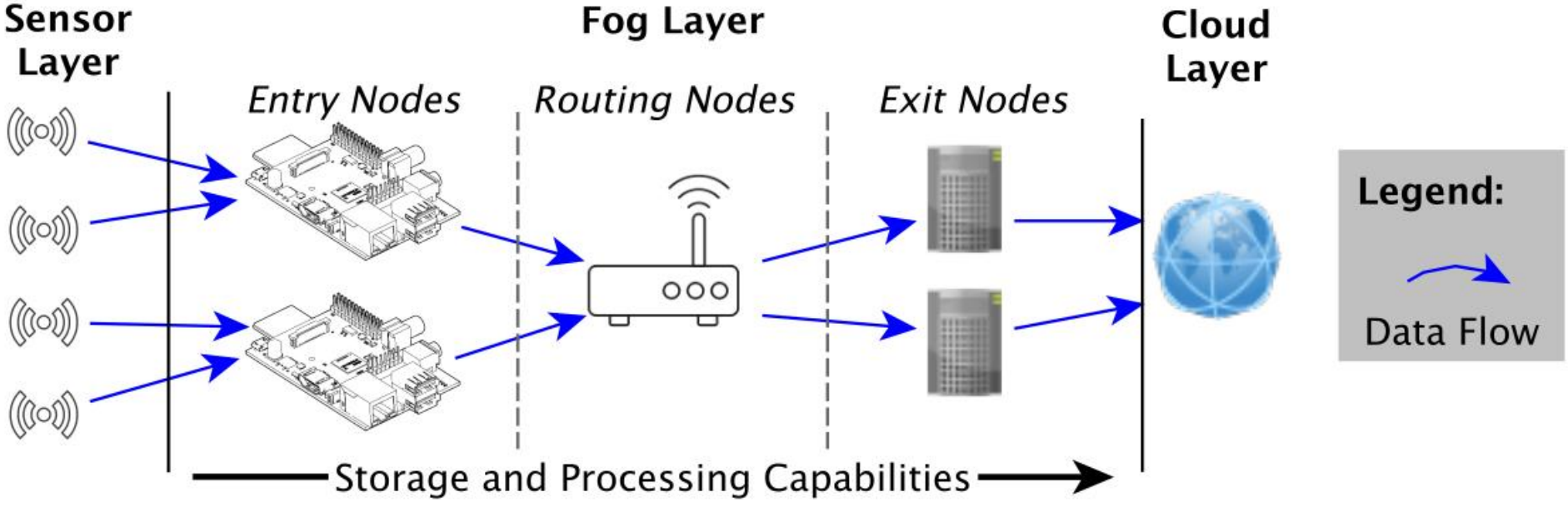


Figure 3: Multi-layer NES Topology.

Advanced architectures: NebulaStream

An example of a different terminology: fog, queries, engines ...

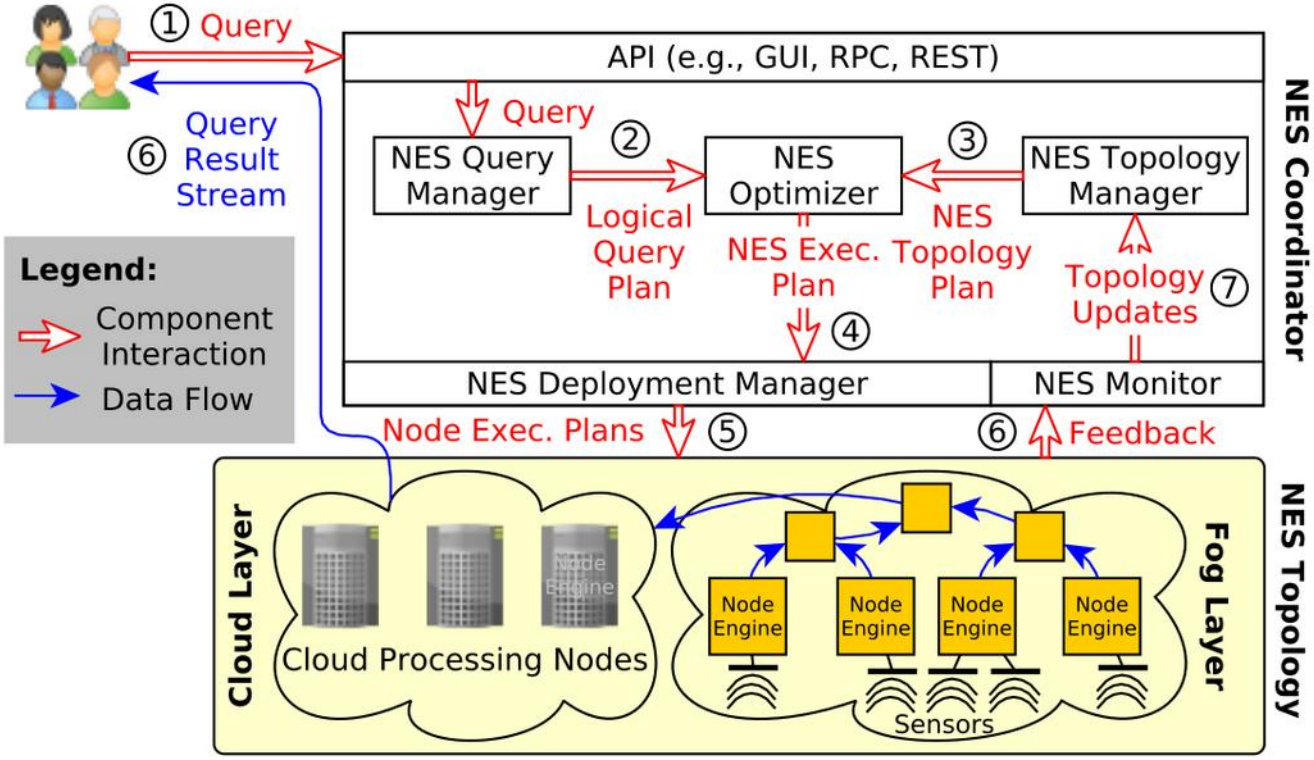
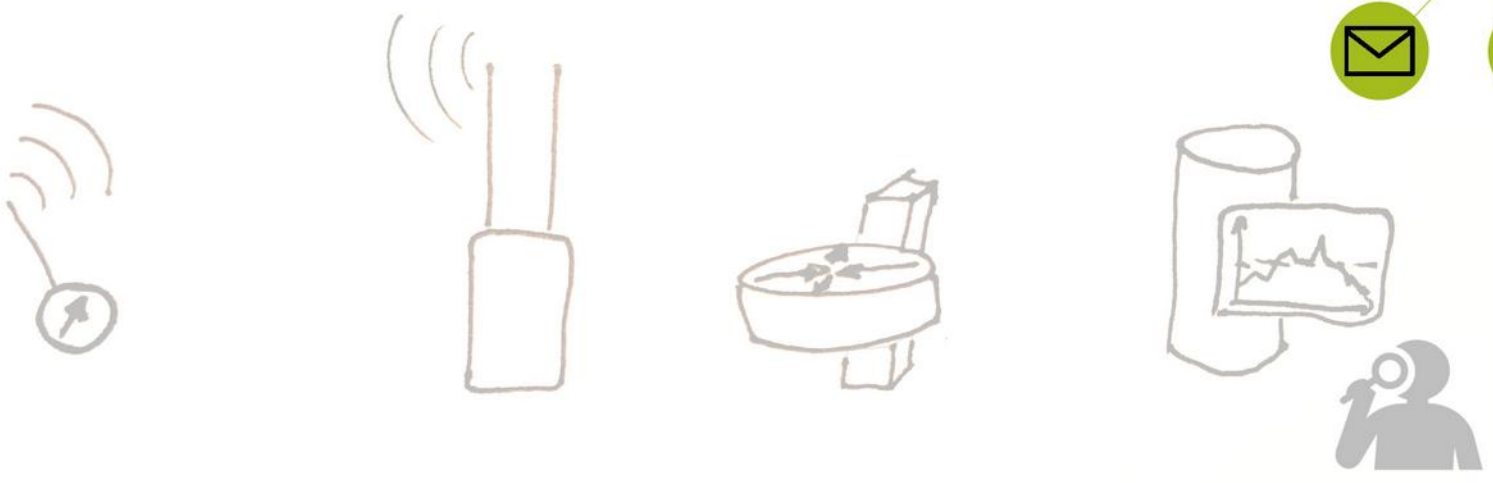


Figure 4: NES architecture overview.

Examples

Smart home

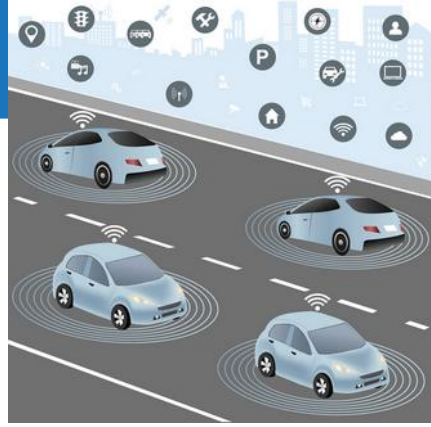


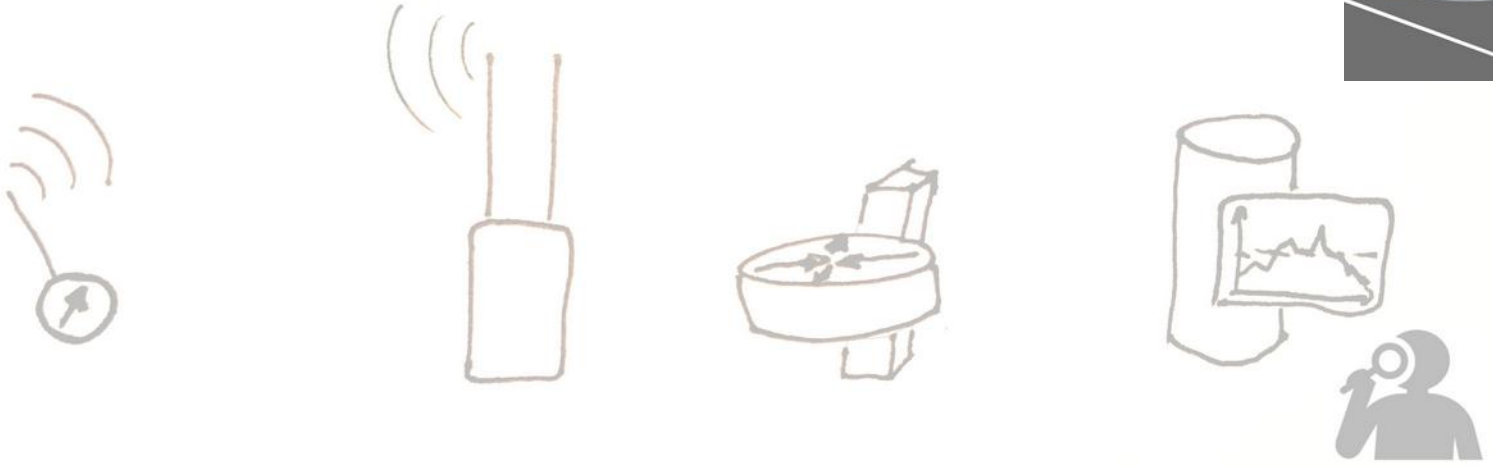
Home power Wi-Fi?
Bluetooth Local or Vendor clouds

https://commons.wikimedia.org/wiki/File:Hausautomation.jpg

Examples

Smart cars





Mobile
embedded SIM
or
phone?
Car-powered

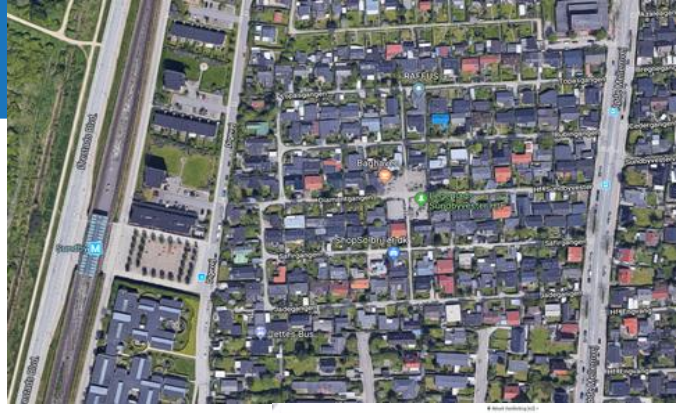
3G/4G/5G

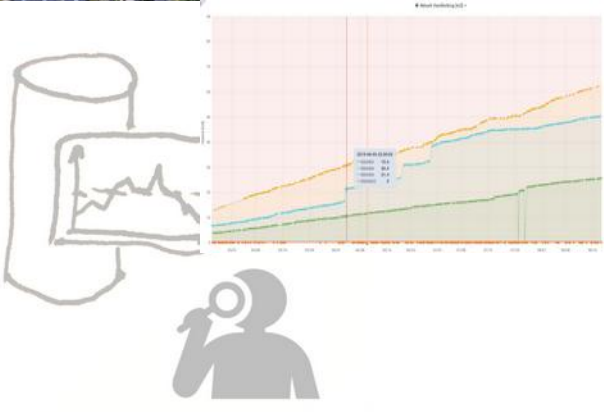
Vendor middleware and backends

https://commons.wikimedia.org/wiki/File:Hausautomation.jpg

Examples

Small smart city – Haveforening Sundbyvester





Battery-driven sensors
LoRaWAN

Local gateways

The Things Network

THE THINGS NETWORK COPENHAGEN

ITU
&
Commercial

Mana (2008/2011)

https://javigongon.files.wordpress.com/2011/12/mana.pdf

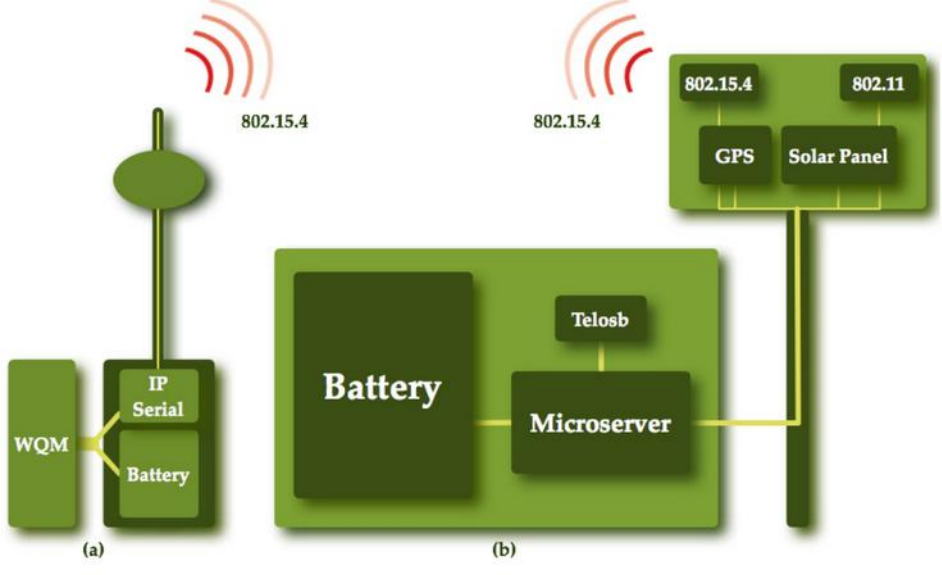


Figure 1: Schematics of the (a) Capoh Buoy and (b) Base Station

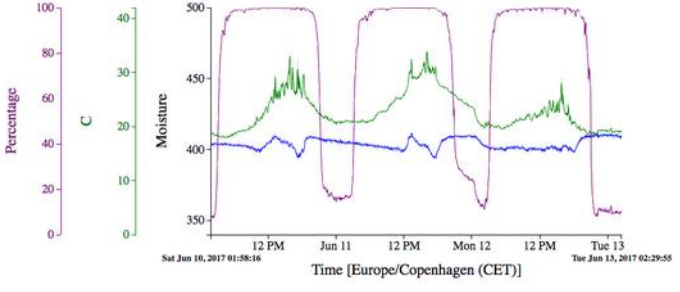
Student Projects: Urban Gardening

Watering System

Social Media

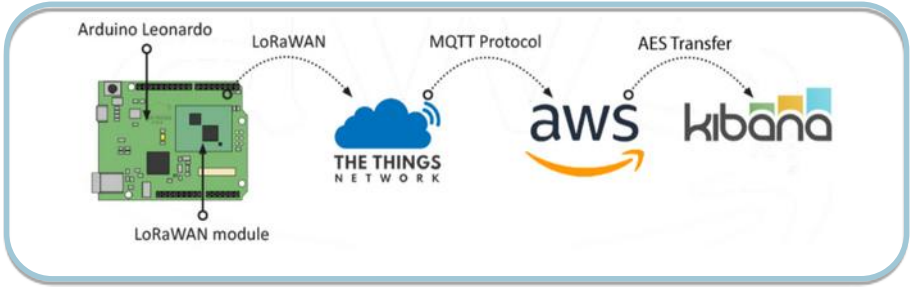
Instagram

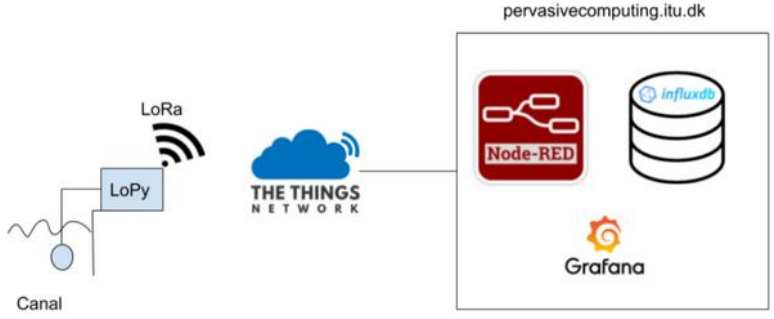
"Human-Plant Interaction"

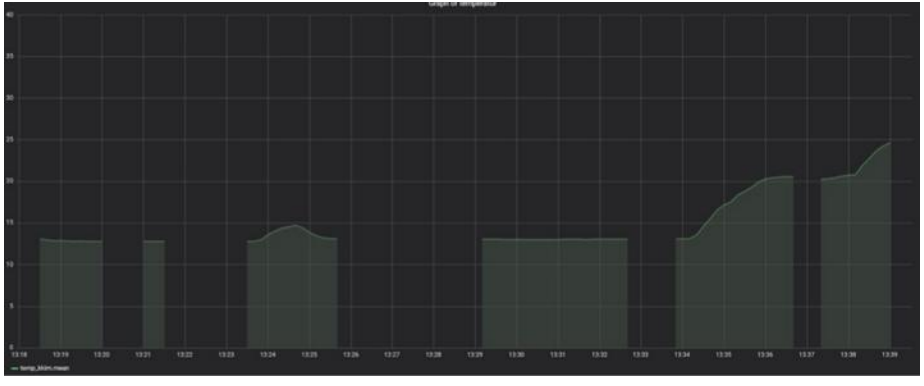


Data Analytics

Student Projects: ITU Canal Temperature







Hardware: node architectures

- Overview over IoT hardware (node) architectures
- Developed over the past ~10 years, this is already a historical overview
- With IoT Development and prototyping becoming mainstream, the field has been and is developing extremely fast
- Largely industry-driven
- We will talk about this in detail, in Lecture

  Embedded devices, systems and programming

New options for IoT platforms

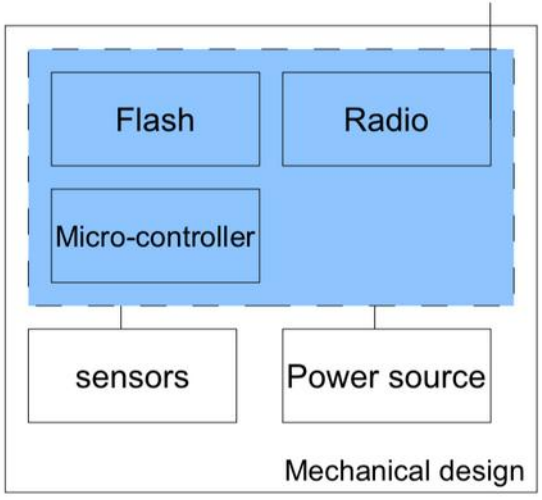
- Distinct differences between **prototyping/research** and **production/deployment** systems, but ...
- Proof that production/scalable IoT systems can be based on such prototyping platforms
- Popular affordable options: e.g.

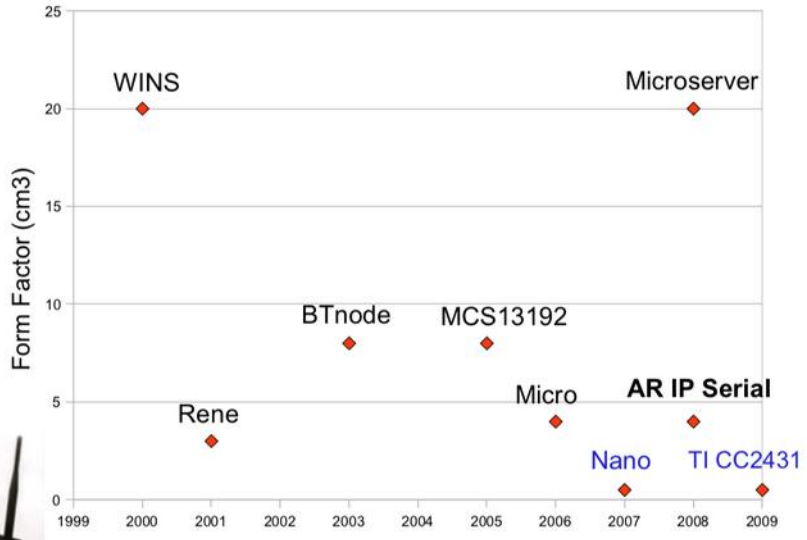
  Arduino (in many variations!)

  Raspberry Pi

  micropython devices
- **These all are relatively new (10 years) … a little look back in time ...**

Mote-Based Instrumentation



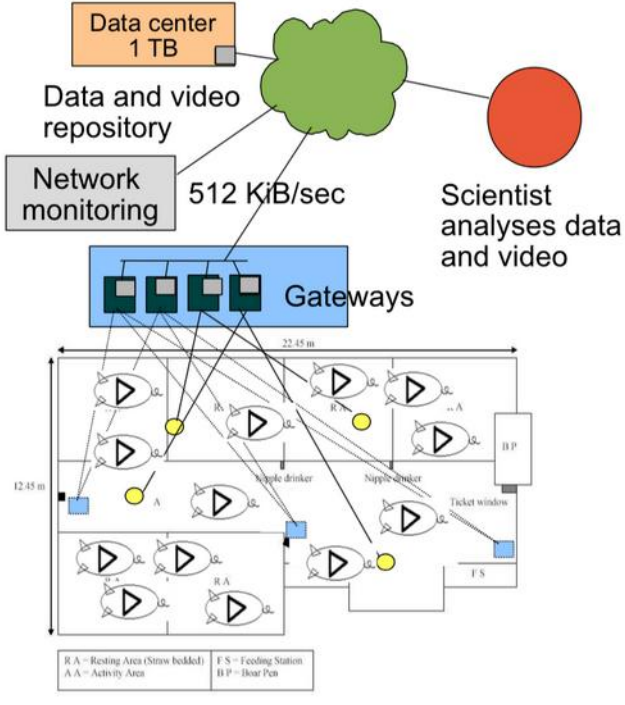


System challenges: (1) Prototyping tomorrow's platforms
(2) Exploring the boundaries of today's platforms

Hogthrob (2005/2008)

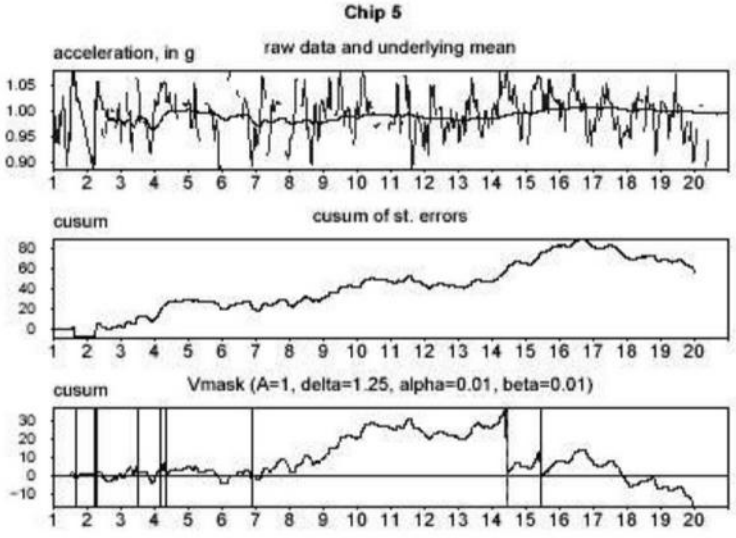
Deployment #2

- Approach:
  - Sensinode micro running TinyOS
    - 802.154 radio
    - 512 KiB flash
    - Accelerometer board
    - 2 NiMH cells (1.25V, 2400mA)
    - Compression
    - Control loops over sample, compress, store, send
  - Access points with external antennas



http://hogthrob.42.dk/thesis.pdf

Hogthrob (2005/2008)



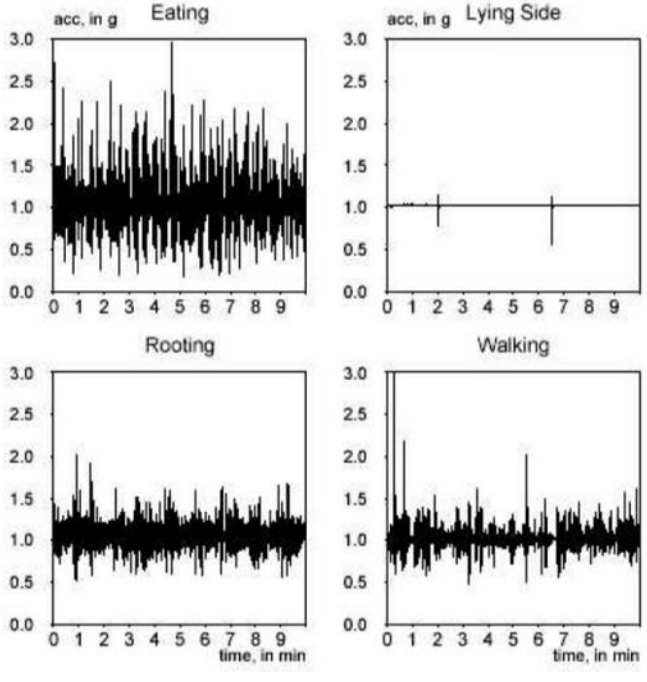


Figure courtesy of Cecile Cornou

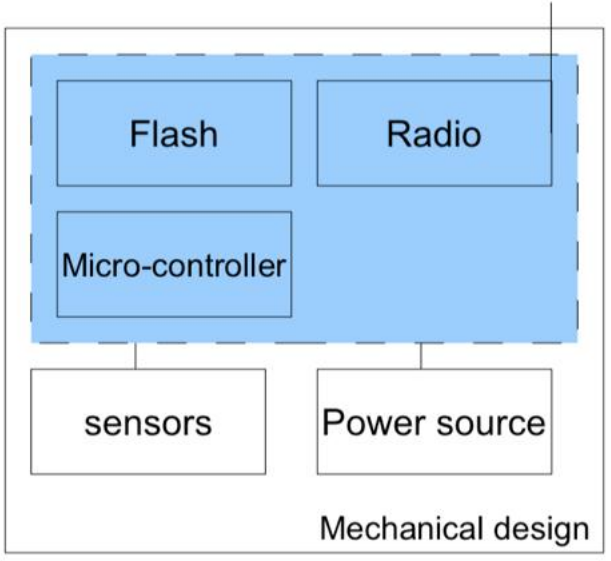
Arduinos

Much more than a hardware platform – an ecosystem of hardware, software … and a social movement

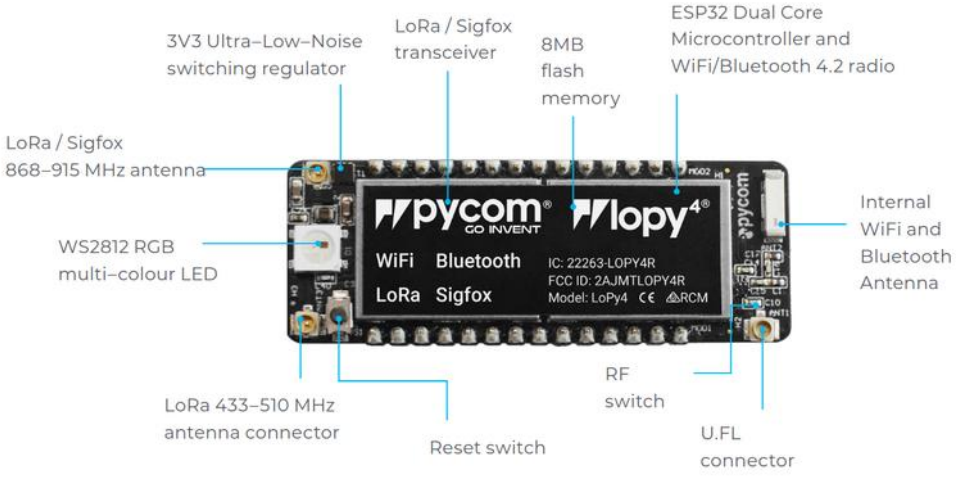
LoPy

(pycom was our platform of choice at ITU … **until 2023**

They went bankrupt in 2022 ...)



LoPy4 – some specs



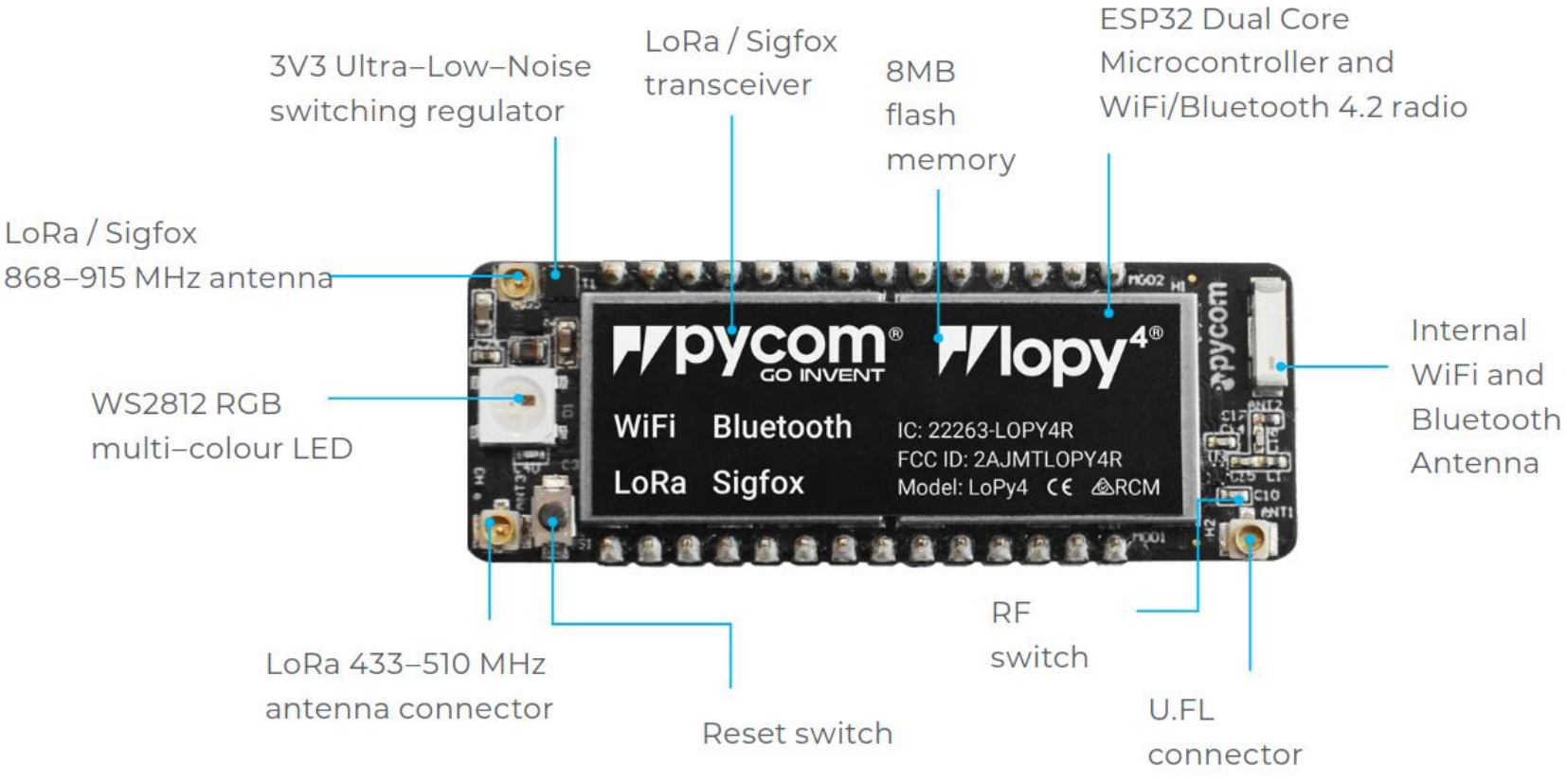
Four networks:
Wi-Fi
Bluetooth
LoRa
Sigfox (also bankrupt)
(+ LTE onboard: FiPy)

RAM: 4MB
Flash: 8 MB

lots of analog/digital I/O

https://docs.pycom.io/gitbook/assets/specsheets/Pycom_002_Specsheets_LoPy4_v2.pdf

LoPy4 – some specs



MCU: ESP32

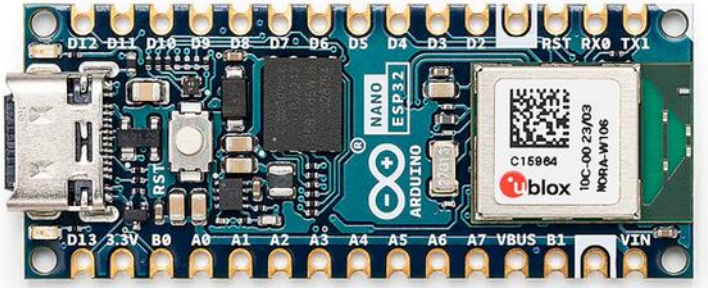
TTGO T-Beam & other ESP32 boards

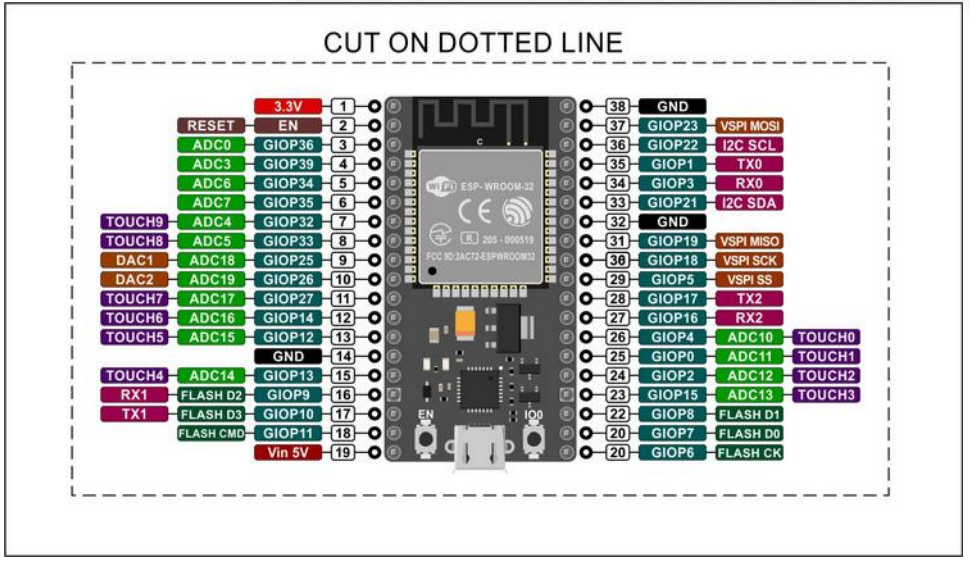
But there are many other ESP32 based boards:

Arduino Nano ESP32

Wroom

TTGO – T-Beam





TTGO T-Beam

Our current choice - TTGO – T-Beam

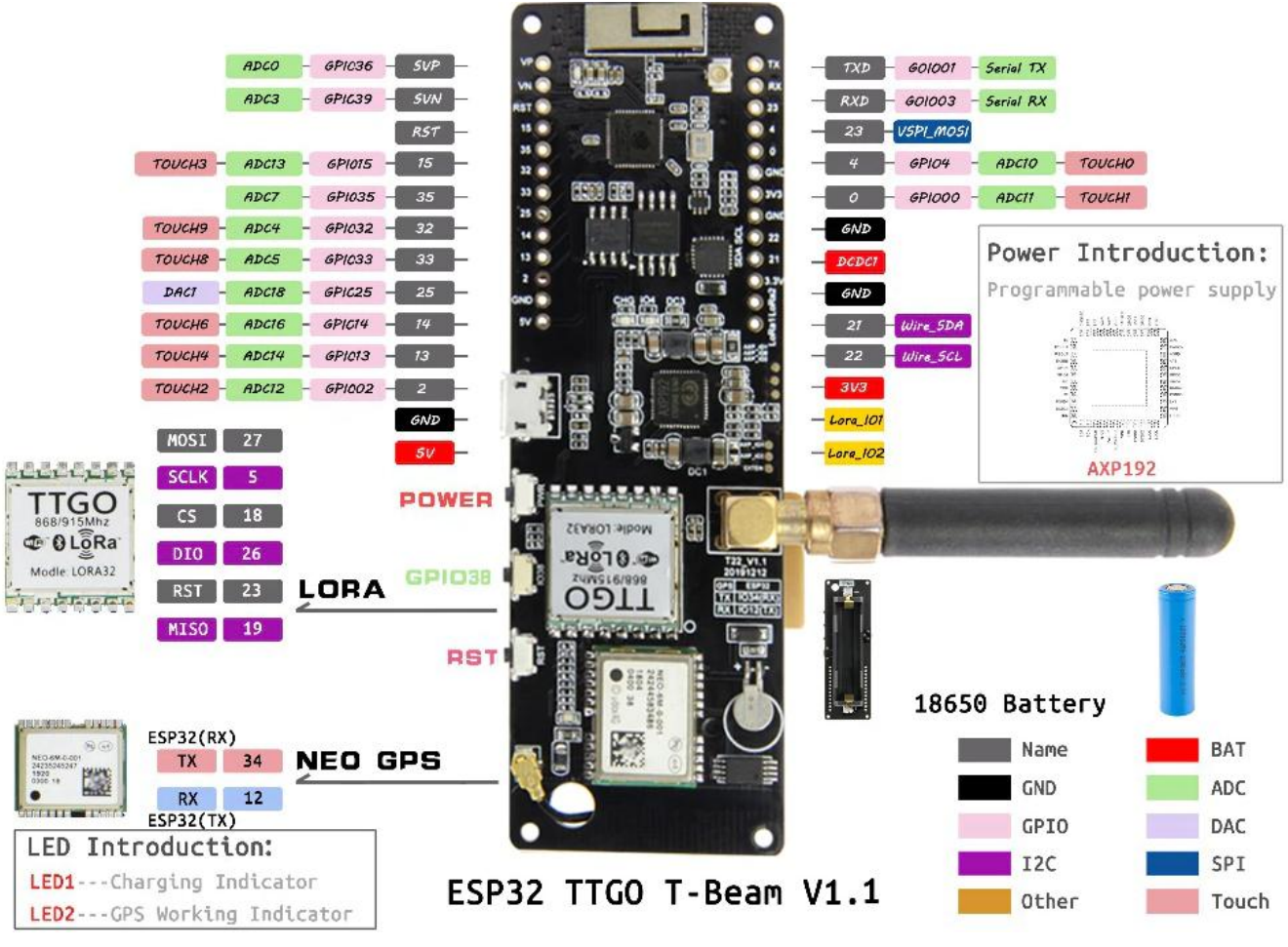
Reasons:

C/Arduino or micropython

Multi-network – Wi-Fi, Bluetooth, LoRa
Integrated GPS
Battery holder and charger
Screen option

Price

TTGO T-Beam


ADC0 GPIO36 SVP
ADC3 GPIO39 SVN
RST
TOUCH3 ADC13 GPIO15 15
ADC7 GPIO35 35
TOUCH9 ADC4 GPIO32 32
TOUCH8 ADC5 GPIO33 33
DAC1 ADC18 GPIO25 25
TOUCH6 ADC16 GPIO14 14
TOUCH4 ADC14 GPIO13 13
TOUCH2 ADC12 GPIO02 2
GND
5V
TXD GPIO01 Serial TX
RXD GPIO03 Serial RX
23 VSPI_MOSI
4 GPIO4 ADC10 TOUCH0
0 GPIO00 ADC11 TOUCH1
GND
DCDC1
GND
21 Wire_SDA
22 Wire_SCL
3V3
Lora_IO1
Lora_IO2
Power Introduction:
Programmable power supply
AXP192
MOSI 27
SCLK 5
CS 18
DIO 26
RST 23
MISO 19
LORA
POWER
GPIO38
RST
TTGO
868/915Mhz
LoRa
Modle LORA32
ESP32(RX)
TX 34
RX 12
ESP32(TX)
NEO GPS
18650 Battery
LED Introduction:
LED1---Charging Indicator
LED2---GPS Working Indicator
ESP32 TTGO T-Beam V1.1
Name
GND
GPIO
I2C
Other
BAT
ADC
DAC
SPI
Touch

Take-Aways

- **Ambiguity of terms – IoT, “Architecture” System, Software, Hardware, ...**
- **4-tier architectures (but it might be 3 or 5)**
- **Identify main elements and be aware of their constraints**
- **Discuss terms like thing, node, fog, edge, cloud, backend, application ...**