Internet of Things

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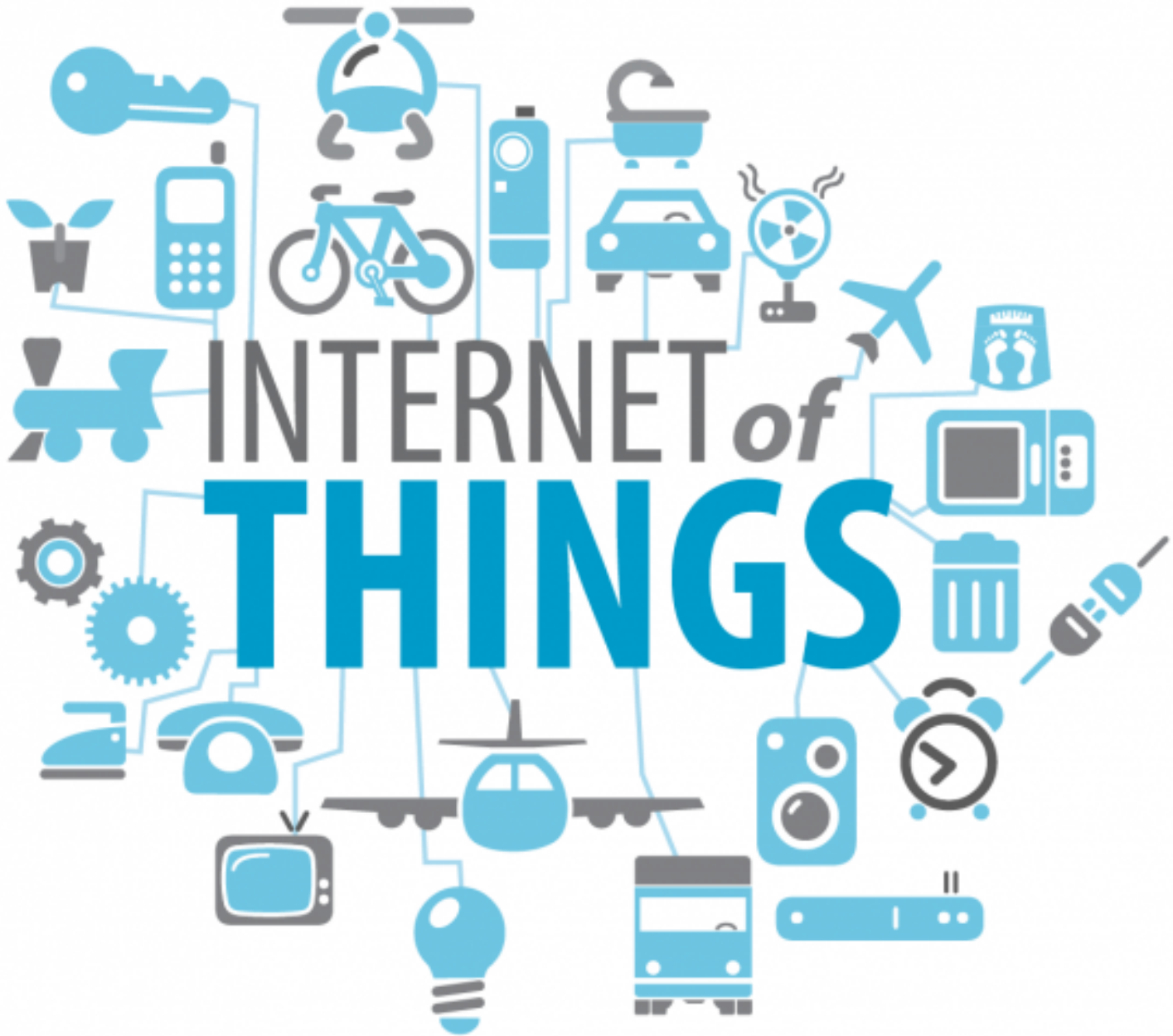
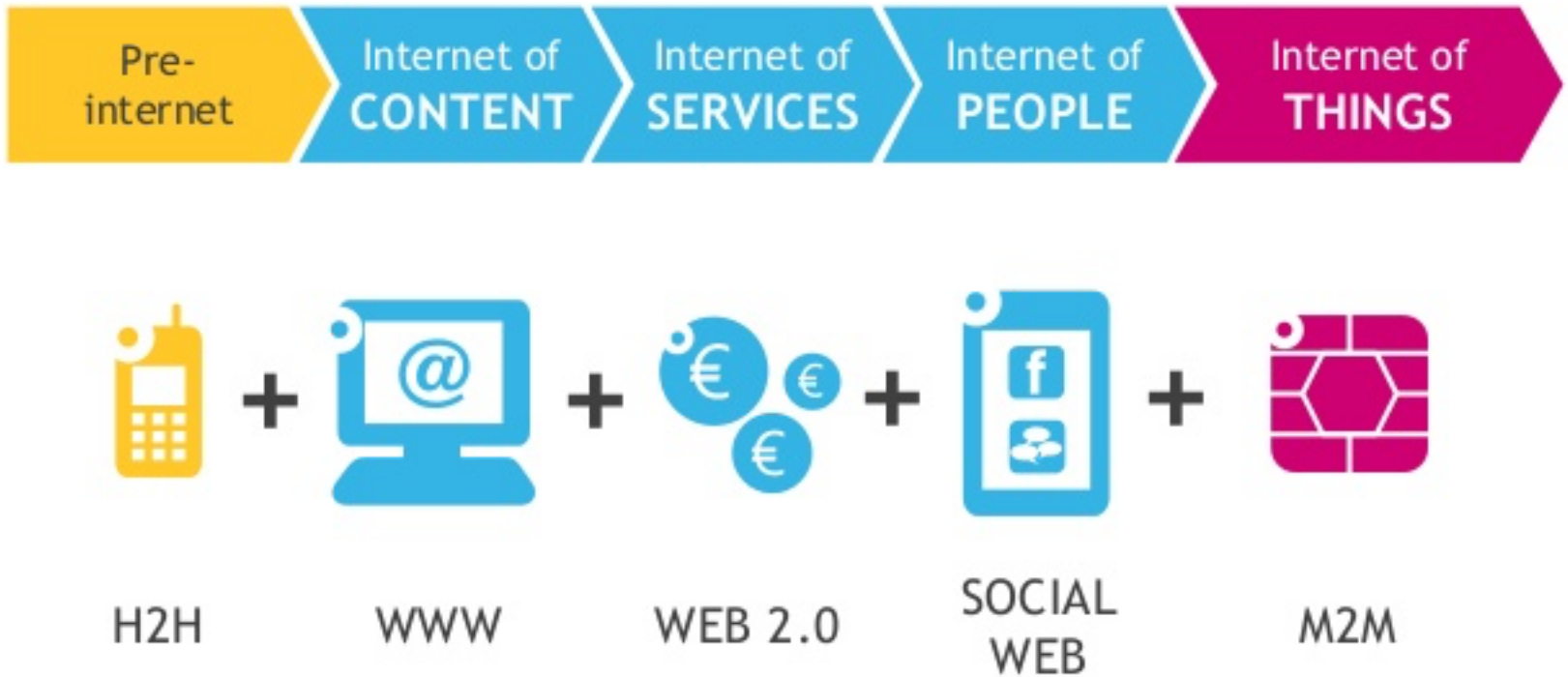

INTERNET of
THINGS

THE NEXT STEP IN INTERNET EVOLUTION




my devices
my profile
logout
reload dashboard
conserve energy
get help
symhome
energy management
GALTRONICS TELEMETRY
analyze my power bill
total $20.00
air conditioner $20.00
air conditioner 2 $0.00
water heater $0.00
May 1
other devices
whole home
back to my whole home
kilowatt-hours
2.6
1.7
0.9
12a 1a 2a 3a 4a 5a 6a 7a 8a 9a 10a 11a 12p 1p 2p 3p 4p 5p 6p 7p 8p 9p 10p 11p
back to days
energyDashboard
whole home $0.00
air conditioner $0.00
pool pump $0.00
refrigerator
stovetop
oven
microwave
dishwasher
water heater
compare to: yesterday prior week nothing
April 22, 2010 $0.78
type

January 2007

"There's no chance that the iPhone is going to get any significant market share."
Steve Ballmer, Microsoft CEO (April 2007)

2007

2009

2015

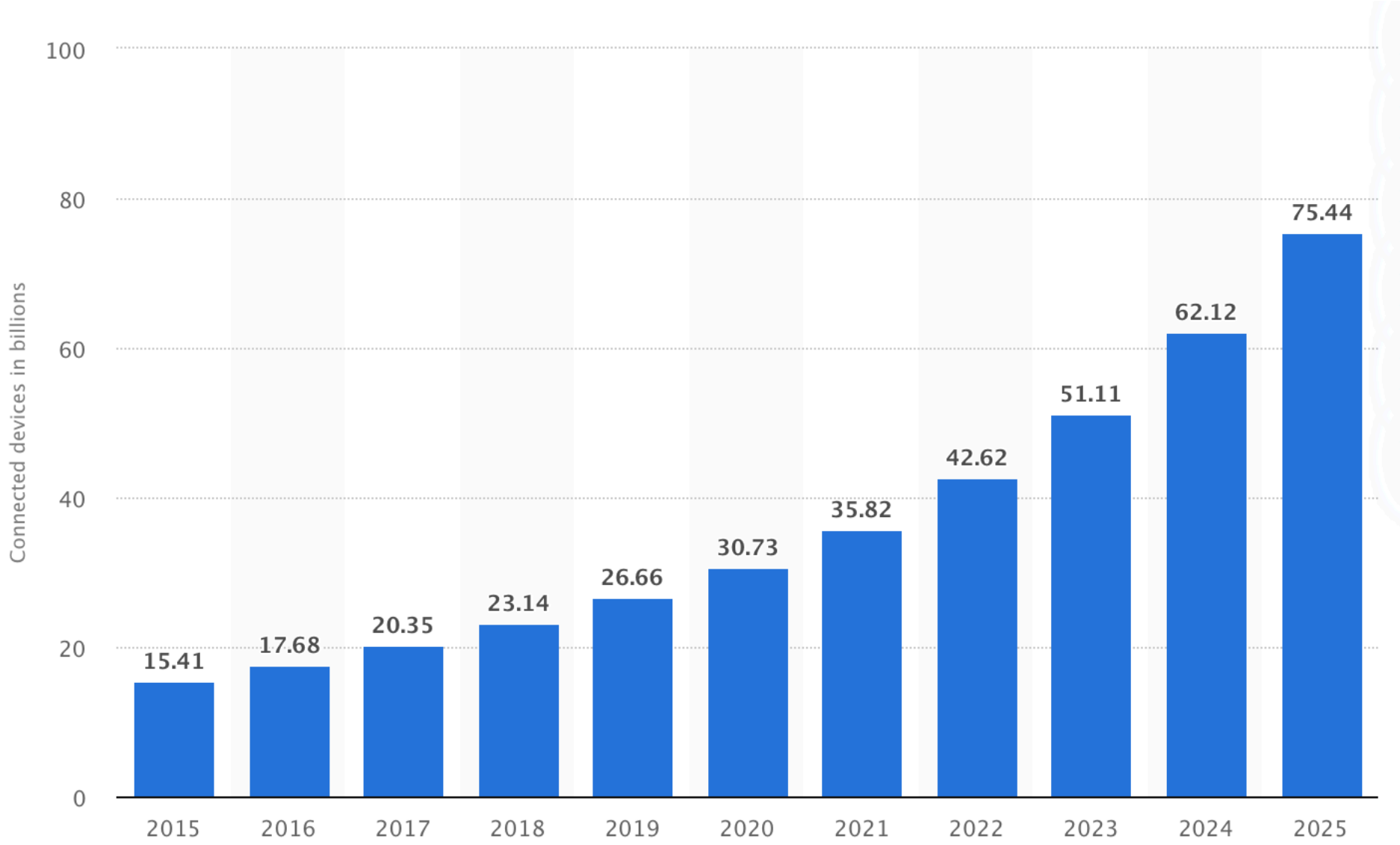

BEHMOR

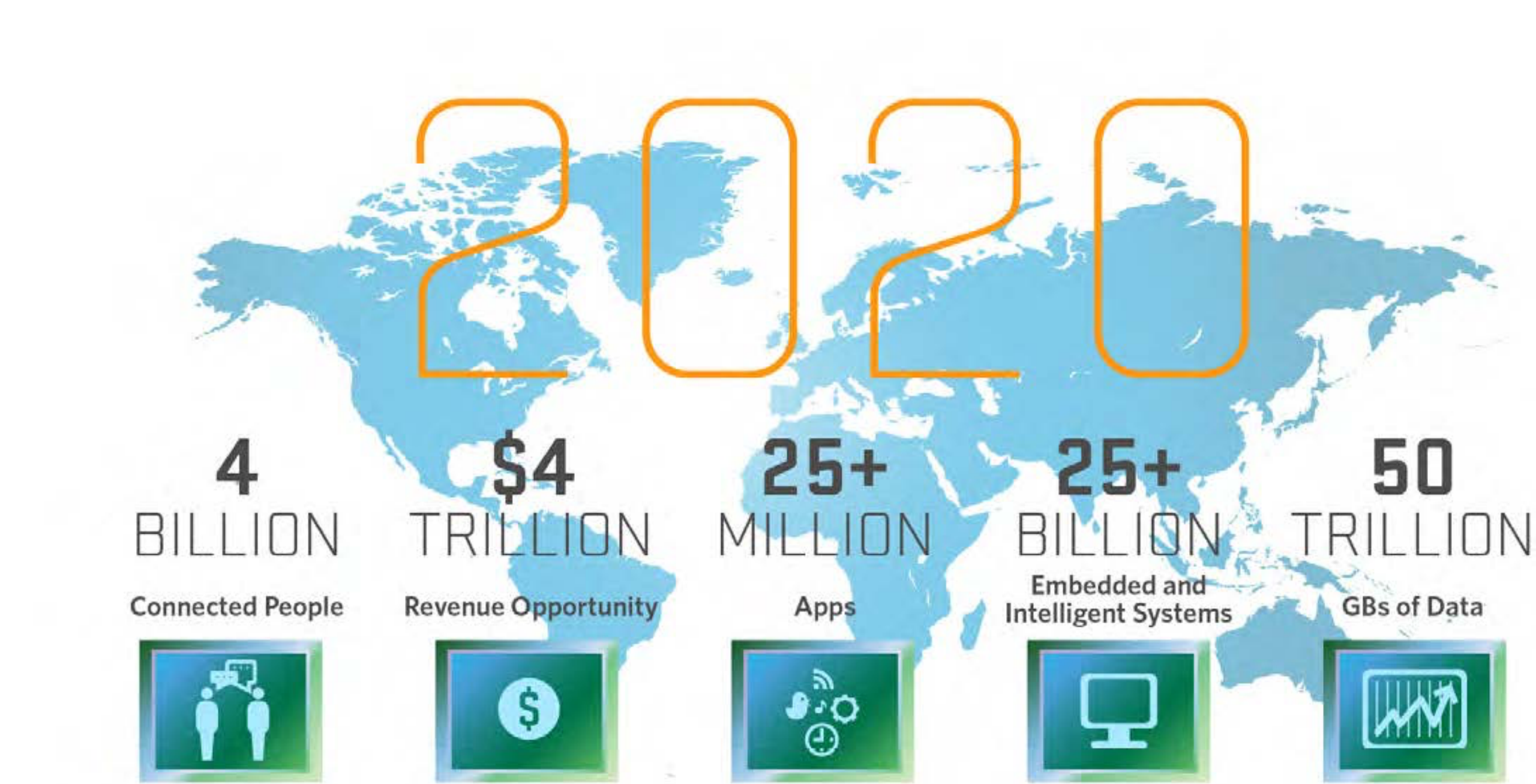

GeniCan


MOONPOOL
MY MENU
stir
0.61 fl. oz
Ramazzotti
1.21 fl. oz
Bianco
Vermouth
1.52 fl. oz
Old Tom Gin
Cocktail Shaker
1
SERVING
Pour
Perfect
SET
ON
OFF


SAMSUNG

IoT connected devices installed base worldwide from 2015 to 2025





Source: Mario Morales, IDC

Where?

Manufacturing

35% of manufacturers already use smart sensors, 10% plan to implement them within a year, and 8% plan to implement them within three years, according to PwC.

Transportation

Connected cars are a top IoT device. We estimate there will be over 220 million connected cars on the road by 2020.

Defense

We estimate spending on drones will reach $8.7 billion in 2020. In addition, 126,000 military robots will be shipped in 2020, according to Frost & Sullivan.

Agriculture

We estimate 75 million IoT devices will be shipped for agricultural uses in 2020, at a 20% CAGR. These devices are primary sensors placed in soil to track acidity levels, temperature, and variables that help farmers increase crop yields.

Oil, gas, and mining

We estimate 5.4 million IoT devices will be used on oil extraction sites by 2020. The devices will primarily be internet-connected sensors used to provide environmental metrics about extraction sites.

Insurance

74% of insurance executives said they believe the IoT will disrupt insurance within the next five years, and 74% plan to invest in developing and implementing IoT strategies by 2016, according to an SMA Research survey.

Connected Home

By 2030, we expect the majority of home devices shipped will be connected to the internet due to initiatives from device makers to connect everything they produce.

Food Services

We estimate 310 million IoT devices will be used by food services companies by 2020. The majority of these devices will be digital signs connected throughout grocery stores and fast-food companies.

Source: Business Insider, "The Internet of Things: 2015"

Where?

Infrastructure

We estimate municipalities worldwide will increase their spending on IoT systems at a 30% CAGR, from $36 billion in 2014 to $133 billion in 2019. This investment will generate$421 billion in economic value for cities worldwide in 2019.

Retail

Beacons, paired with mobile apps, are being used in stores to monitor customer behavior and push advertisements to customers. In the US, we estimate $44.4 billion will be generated from beacon-triggered messages.

Logistics

Tracking sensors placed on parcels and shipping containers will help reduce costs associated with lost or damaged goods. In addition, robots, such as the Amazon Kiva robot, help reduce labor costs in warehouses.

Banks

There are nearly 3 million ATMs installed globally in 2015, according the World Bank. Some teller-assist ATMs provide a live-stream video of a teller for added customer support.

Utilities

Energy companies throughout the world are trying to meet the rising demand in energy. To do this, they will be installing nearly 1 billion smart meters by 2020.

Hospitality

31% of hotels use next-generation door locks, 33% have room control devices, 16% have connected TVs, and 15% use beacons throughout the hotel, according to Hospitality Technology's 2015 Lodging Technology survey.

Healthcare

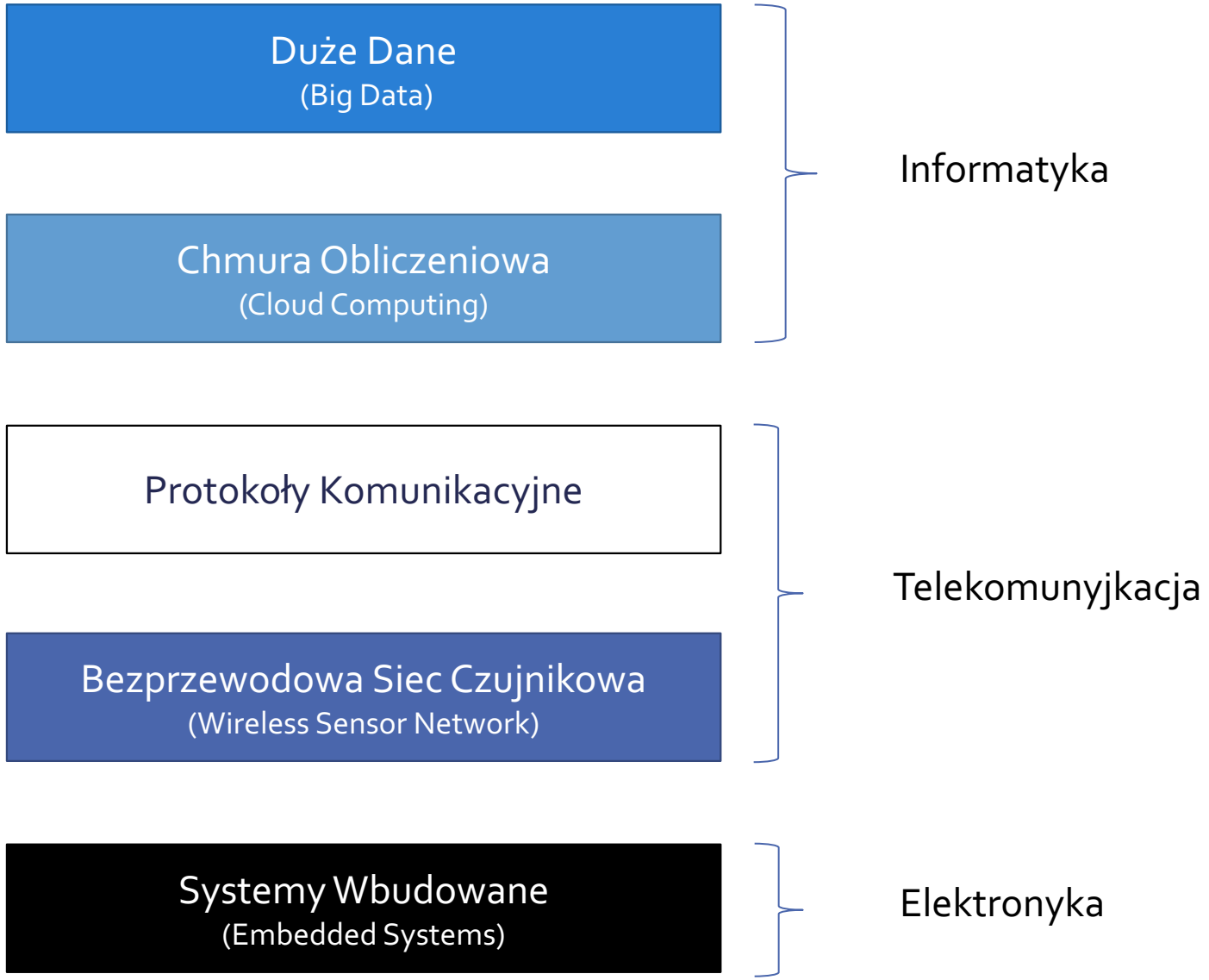
We estimate 646 million IoT devices will be used for healthcare by 2020. Connected healthcare devices can collect data, automate processes, and more. But these devices can also be hacked, thereby posing a threat to the patients who rely on them.

Smart Buildings

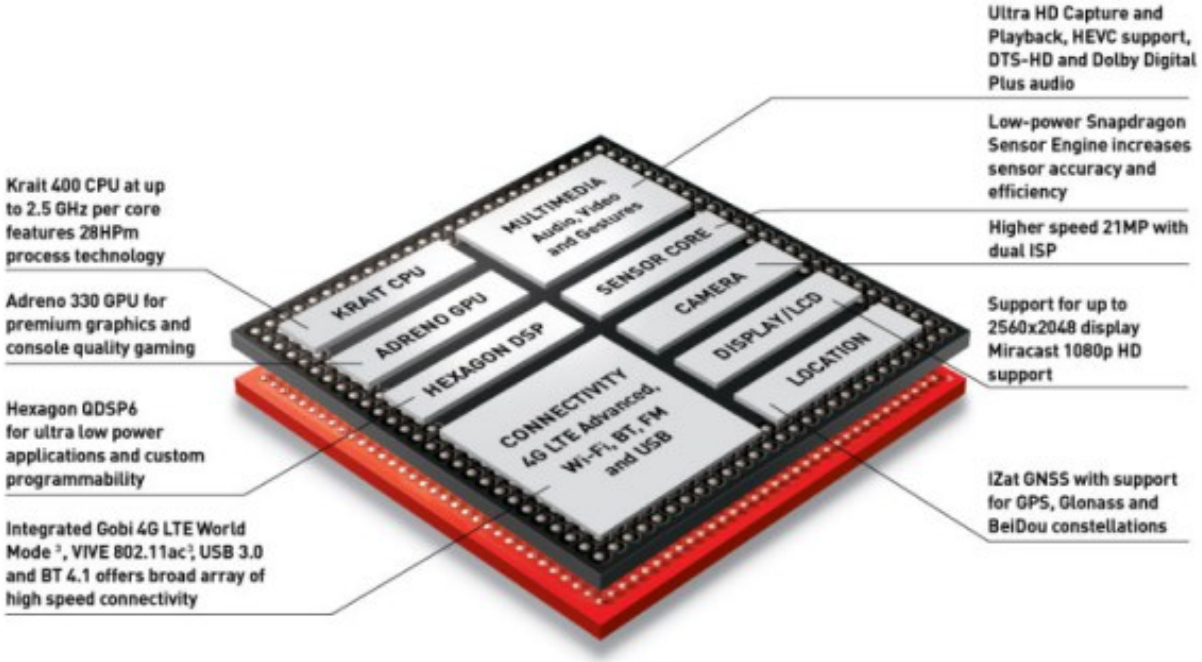
43% of building managers in the US believe the IoT will affect how they run their building within the next two to three years, according to a survey from Daintree Networks.

Source: Business Insider, "The Internet of Things: 2015"

IoT Supporting Technologies

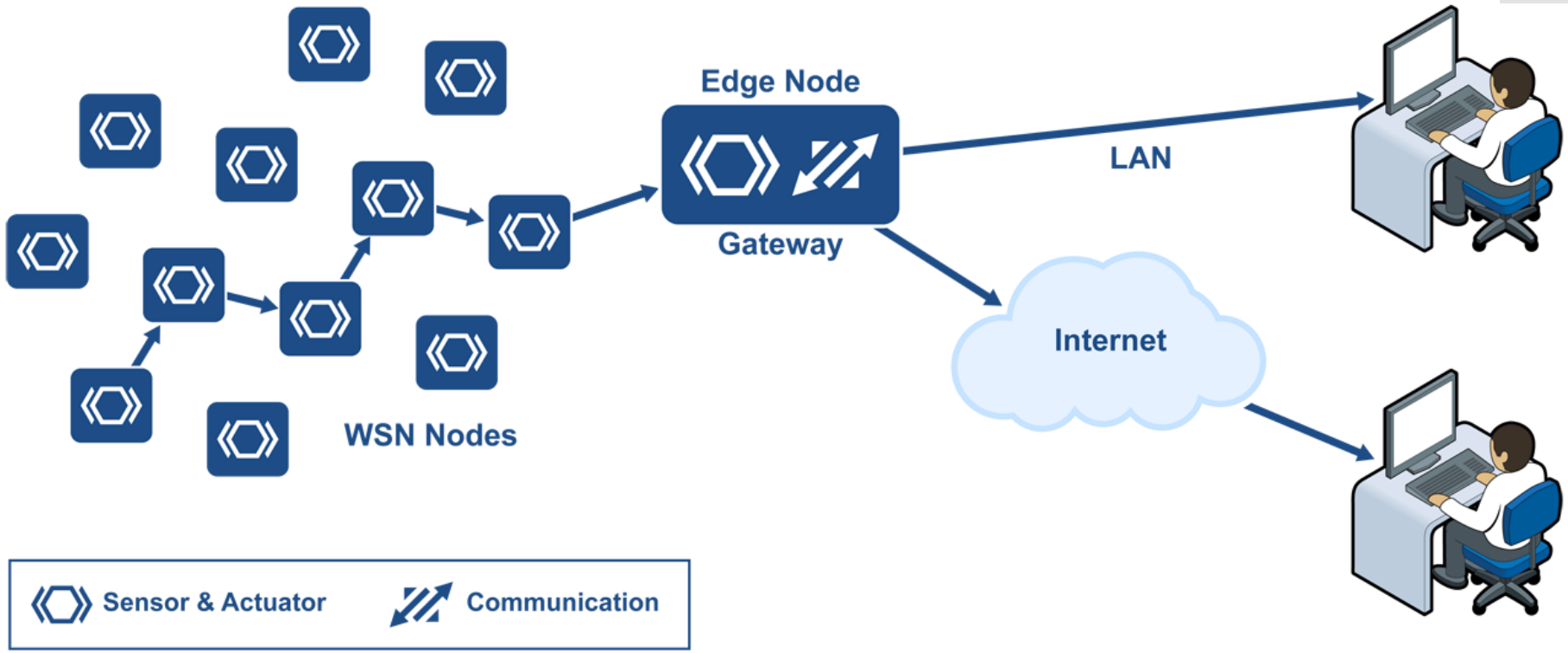


Embedded Systems

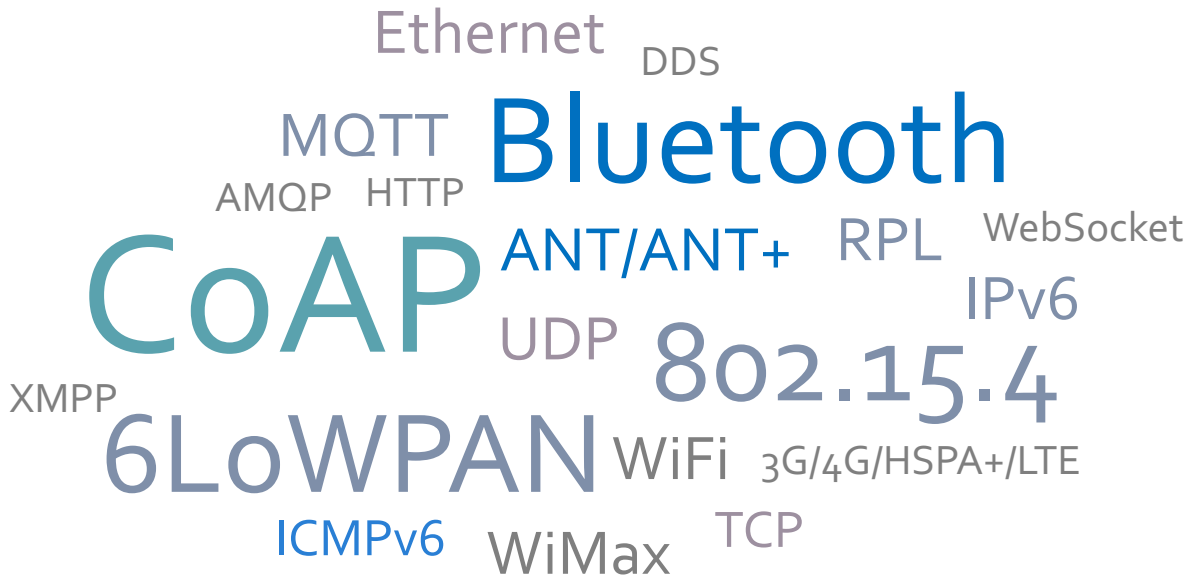


Vs.

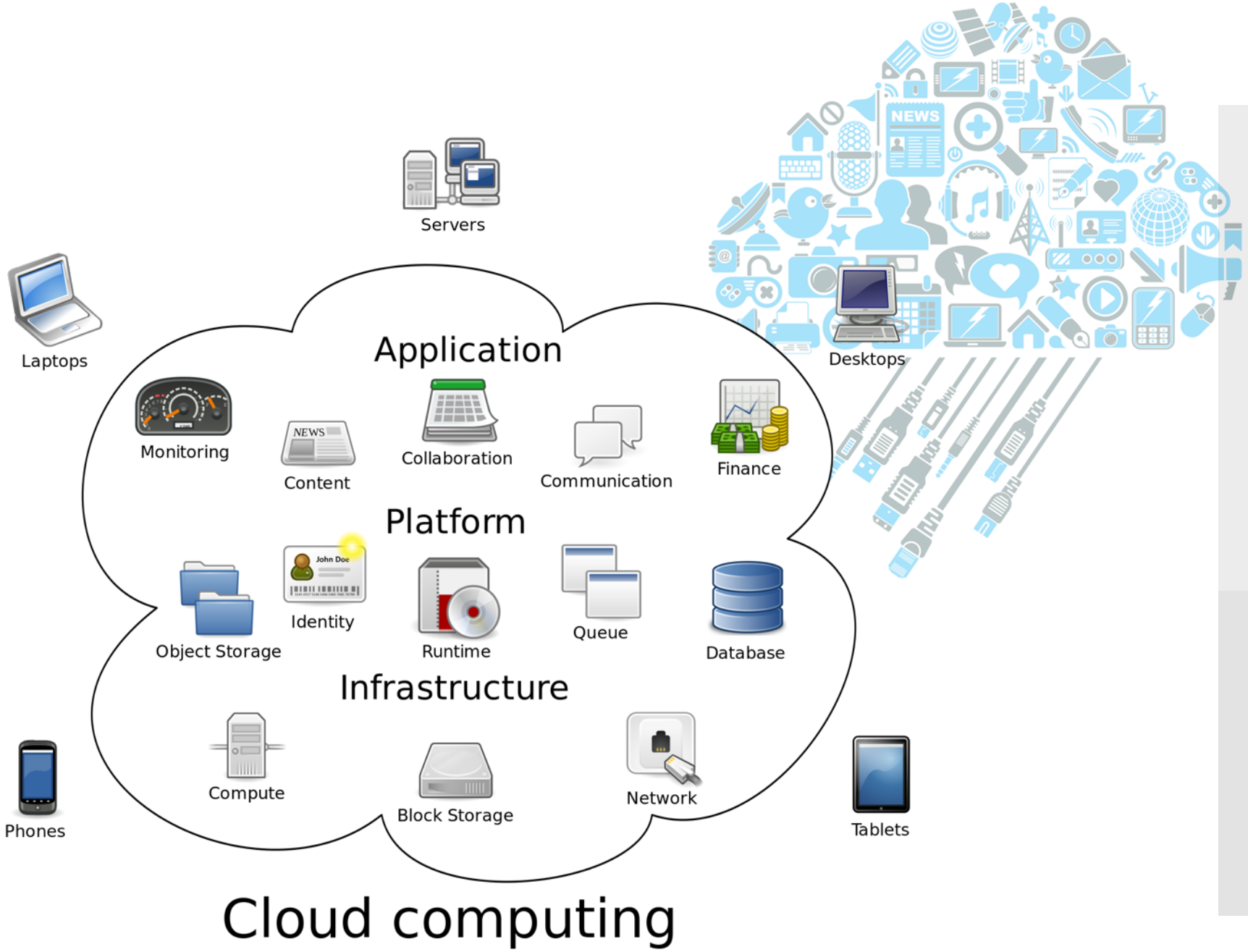
Wireless Sensor Networks



Communication Protocols



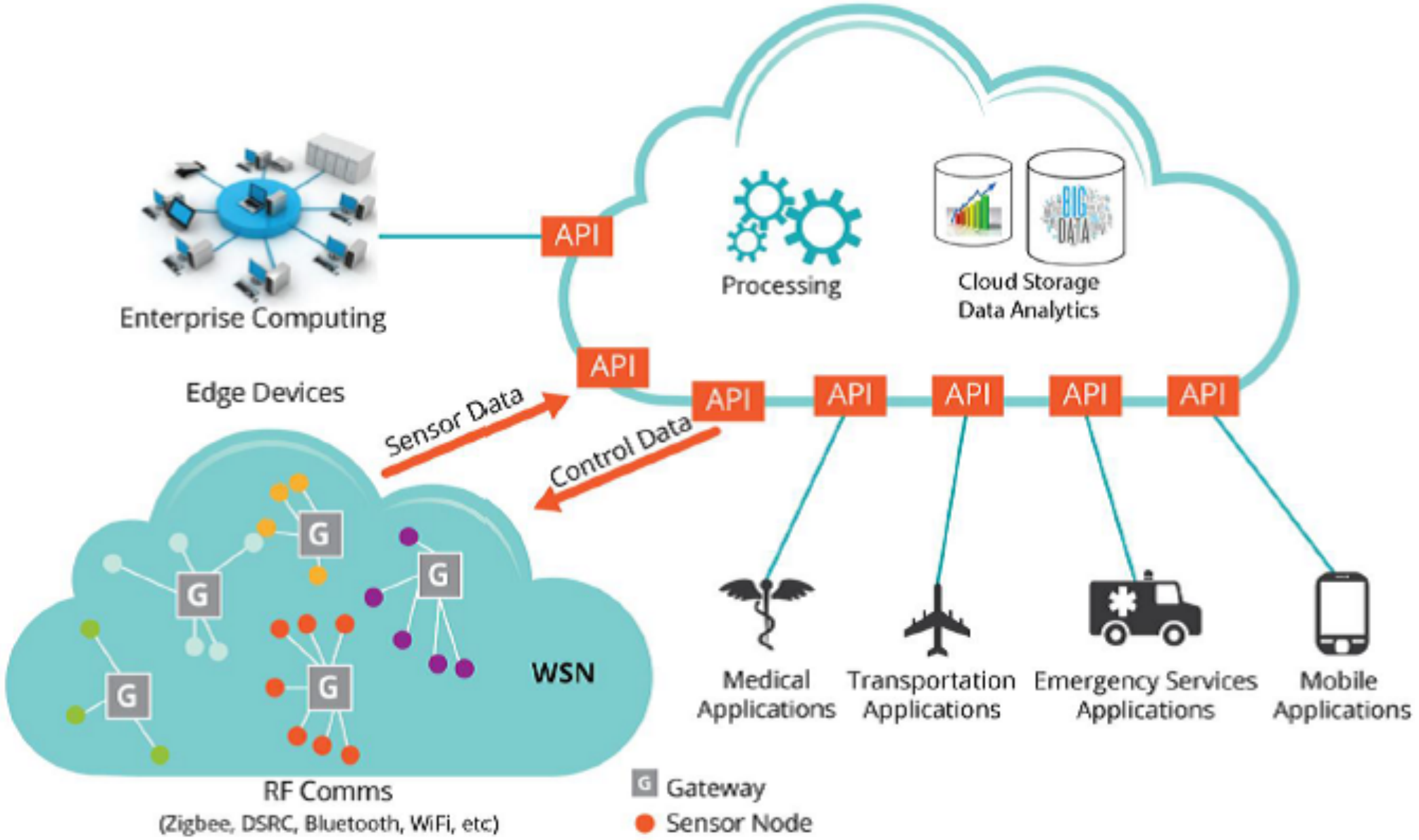
Cloud Computing



Big Data


BIG
DATA
ALSO
TOOLS
DISK
TARGET
APPLIED
SENSOR
EXAMPLES
SHARED
DEFINITION
CURRENT
MAY
MOVING
WITHIN
RECONSIDER
PRACTITIONERS
CAPTURE
ZETTABYTES
THOUGHT
INTERNET
BUSINESS
DISTRIBUTED
SETS
GENOMICS
DESCRIBING
RADIO-FREQUENCY
MANAGEMENT
TERABYTES
CASE
PETABYTES
INCLUDE
ELAPSED
SYSTEMS
TOLERABLE
ABILITY
STORAGE
SIZE
MPP
PARALLEL
SAN
QUALITIES
SINCE
MASSIVELY
GROW
EVERY
CONNECTOMICS
ORGANIZATIONS
SET
USE
RELATIONAL
LARGER
CONTINUES
SOCIAL
INDEXING
TENS
COMPLEX
CITATION
ANALYTICS
NOW
BIOLOGICAL
PROCESSING
UBIQUITOUS
CAPACITY
BURIED
WORLD'S
HUNDREDS
DESKTOP
RECORDS
NETWORKS
DATABASES
SEARCH
SOLID
TYPES
CURRENTLY
GARTNER
AMOUNT
WORKING
OPPORTUNITIES
DIFFICULTY

The Internet of Things



What's IoT?

„A **dynamic** global network infrastructure with **self-configuring** capabilities based on **standard and interoperable communication protocols** where *physical and virtual* "**things**" have **identities**, physical attributes, and virtual personalities, use intelligent interfaces, and are **seamlessly integrated** into the information network."

Chapter 2 in Internet of Things - Global Technological and Societal Trends, River Publishers, 2011, ISBN 978-87-92329-67-7.

Things Characteristics

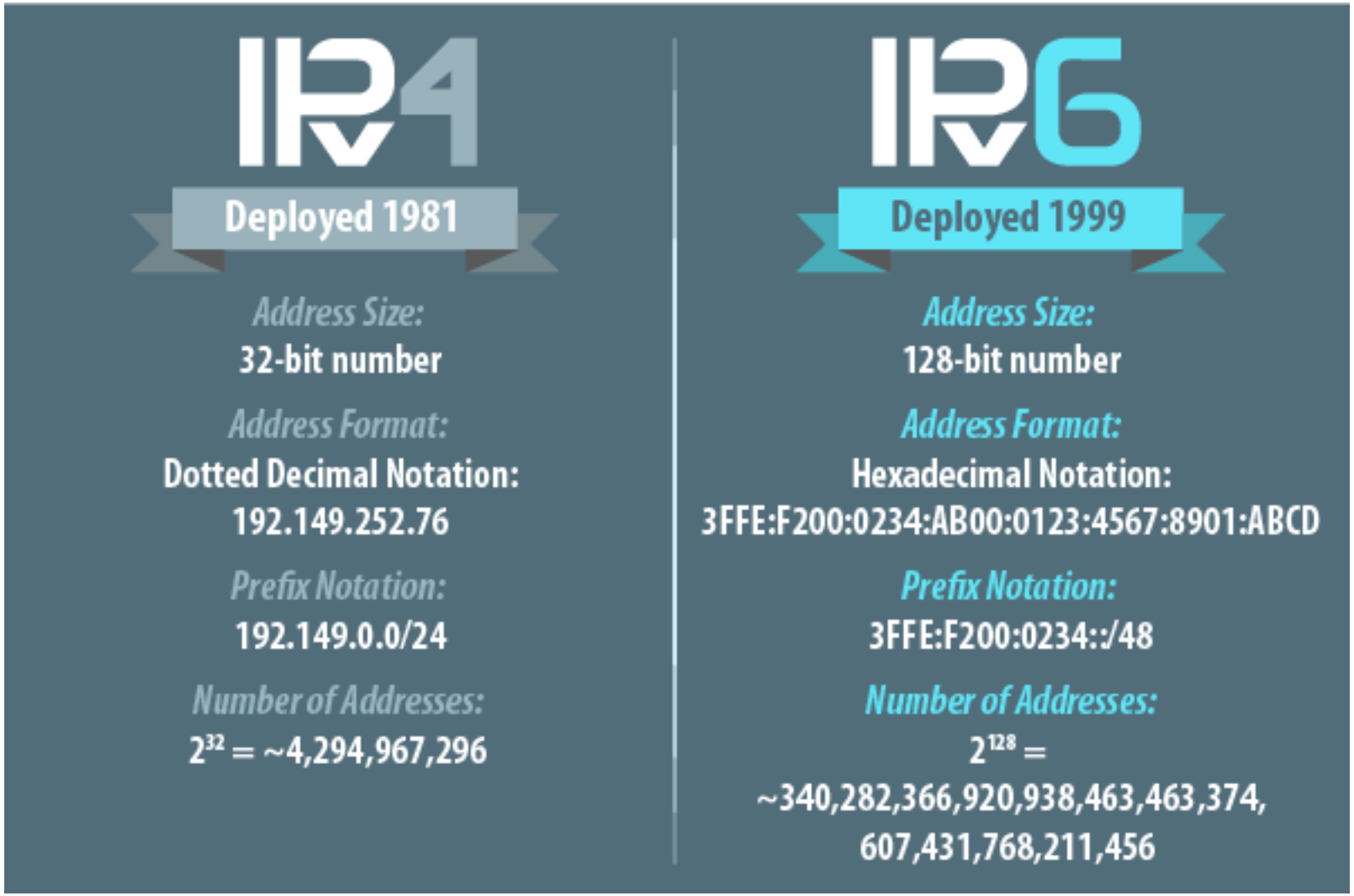
„A **dynamic** global network infrastructure with **self-configuring** capabilities based on **standard and interoperable communication protocols** where *physical and virtual* "**things**" have **identities**, physical attributes, and virtual personalities, use intelligent interfaces, and are **seamlessly integrated** into the information network."

- Dynamic
- Self-configuring
- Interoperable protocols
- Identities
- Integrated into the net

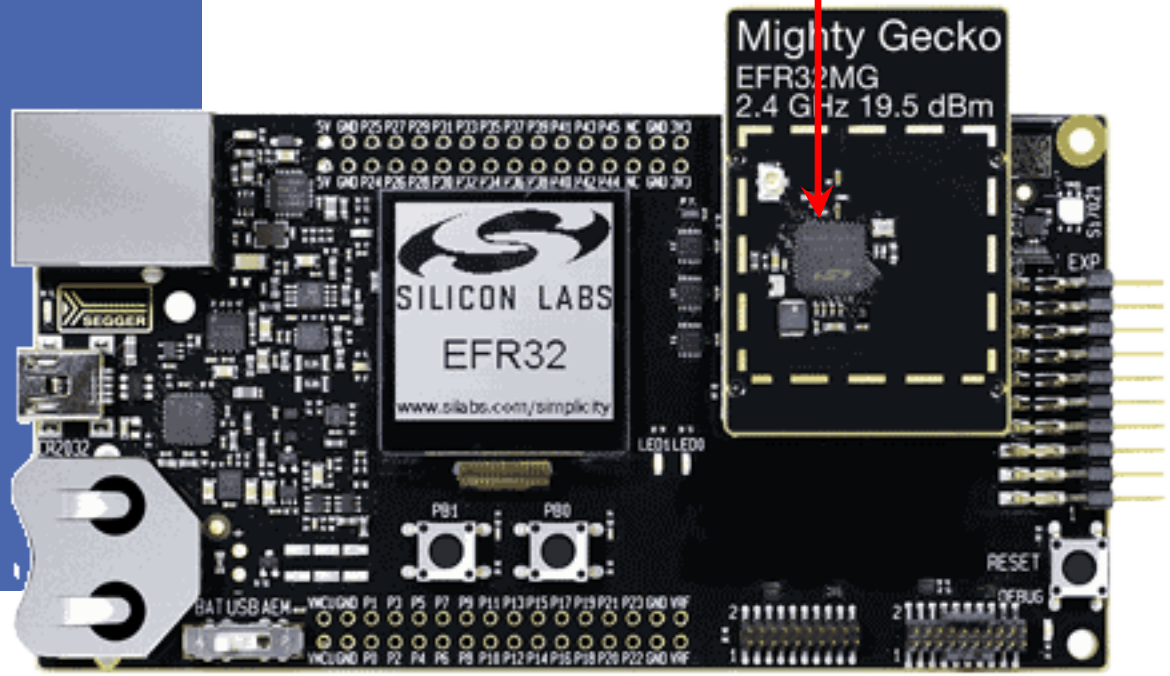
In concrete, a Thing usually has:

- Unique identities
- Sensors and actuators
- Capabilities for:
  - Exchange data and connect to other devices
  - Collect data
  - Process data or send data to be processed centralized
  - Perform tasks locally with some temporal and space constraints
    - Memory, processing capability, communication latencies, speeds and deadlines

Identities


IPv4
Deployed 1981
Address Size:
32-bit number
Address Format:
Dotted Decimal Notation:
192.149.252.76
Prefix Notation:
192.149.0.0/24
Number of Addresses:
2^{32} = ~4,294,967,296
IPv6
Deployed 1999
Address Size:
128-bit number
Address Format:
Hexadecimal Notation:
3FFE:F200:0234:AB00:0123:4567:8901:ABCD
Prefix Notation:
3FFE:F200:0234::/48
Number of Addresses:
2^{128} =
~340,282,366,920,938,463,463,374,
607,431,768,211,456

A “Thing”…



Kontroler:

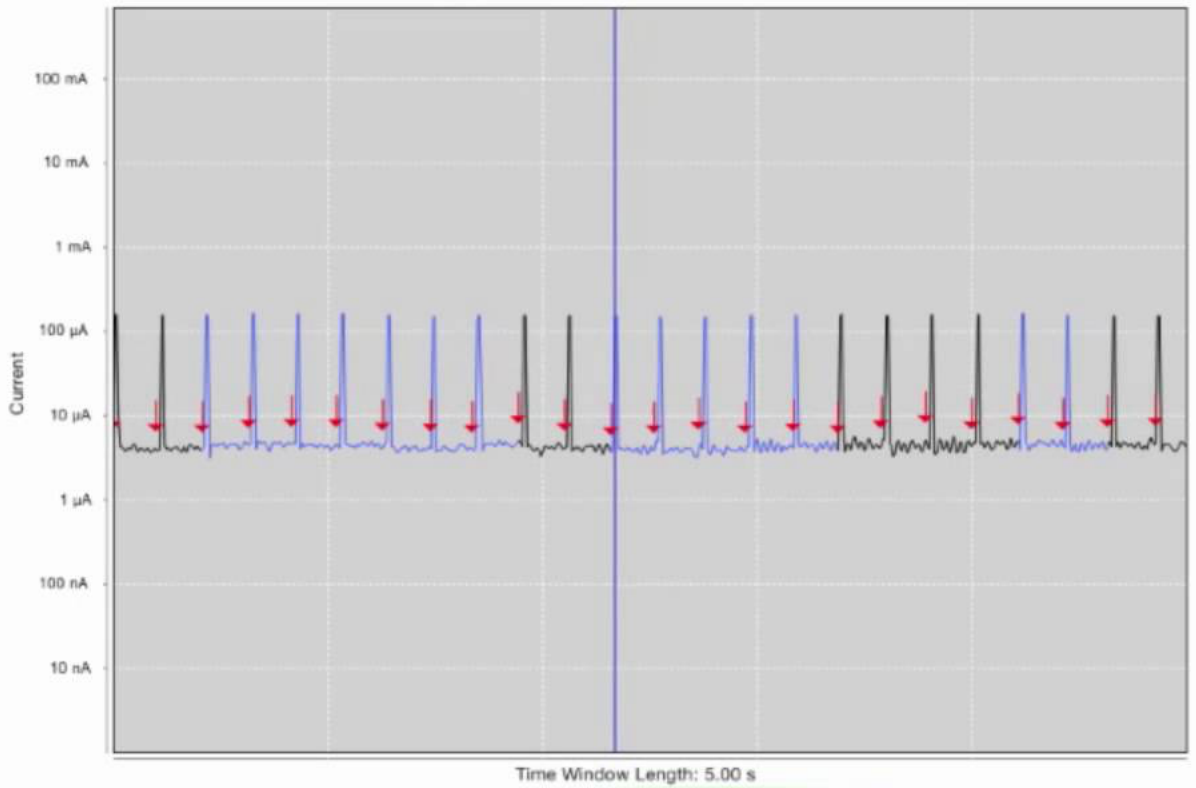
48MHz
256 KB ROM
32KB RAM
< 64 porty IO

Radio:

169MHz-2.4GHz
Tx up to +20dBm
Rx of -133 dBm

Current Graph

Profiling: /Applications/SimplicityStudio_v3/developer/sdks/efm32/v2/kits/EFM32WG_STK3800/examples/emlcd/bin/emlcd.out



Data

Selected Point

Current :	151.00 µA
Voltage :	3.31 V
Time :	10.54 s
PC :	199c
IRQ :	0

Selected Range

Avg. Current :	
Time Span :	
Energy :	

Counters

Avg. Current :	137.50 nA
Avg. Power :	454.68 mW
Total Energy :	98.10 µJ

Reset Counters

Energy Profile (live) | Energy Profile (range)

C	Function	Energy	Contribution (%)
	LCD_SyncBusyDelay	1.25 mJ	56.786%
	SegmentLCD_Write	417.66 µJ	18.96%
	SegmentLCD_Number	187.18 µJ	8.497%
	LCD_SegmentSet	149.16 µJ	6.771%
	<Unknown>	95.95 µJ	4.355%
	SegmentLCD_AlphaNumberOff	22.85 µJ	1.037%
	LCD_SegmentSetLow	21.90 µJ	0.994%
	RTC_Enable	21.68 µJ	0.984%
	EMU_Restore	18.12 µJ	0.822%
	LCD_SegmentSetHigh	17.41 µJ	0.79%

EFM32 Wonder Gecko Starter Kit Board (440(

segmentlcd.c

```
{
  int      data, length, index;
  uint16_t bitfield;
  uint32_t com, bit;
  int      i;

  length = strlen(string);
  index  = 0;

  /* If an update is in progress we must block, or there might
  LCD_SyncBusyDelay(0xFFFFFFFF);

  /* Freeze LCD to avoid partial updates */
  LCD_FreezeEnable(true);

  /* Turn all segments off */
  SegmentLCD_AlphaNumberOff();

  /* Fill out all characters on display */
  for (index = 0; index < 7; index++)
  {
    if (index < length)
    {
      data = (int) *string;
    }
    else           /* Padding with space */
    {
      data = 0x20; /* SPACE */
    }
    /* Defined letters currently starts at "SPACE" - ASCII 0x20
    data = data - 0x20;
    /* Get font for this letter */
    bitfield = EFM_Alphabet[data];

    for (i = 0; i < 14; i++)
    {
      bit = EFM_Display.Text[index].bit[i];
      com = EFM_Display.Text[index].com[i];

      if (bitfield & (1 << i))
      {
        /* Turn on segment */
        LCD_SegmentSet(com, bit, true);
      }
    }
    string++;
  }
  /* Enable update */
  LCD_FreezeEnable(false);
}
```

Outline | Call Hierarchy | Console

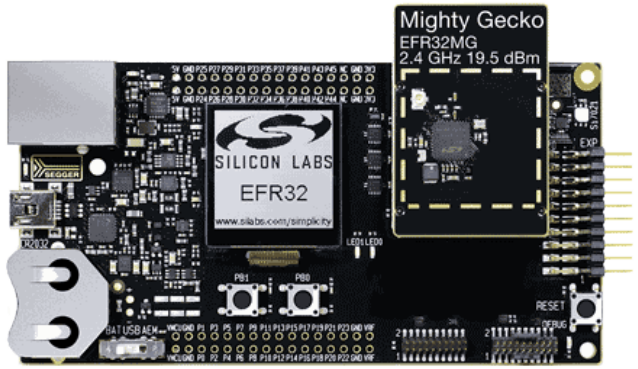
C/C++

Hardware specifications

48Mhz
256KB+32KB

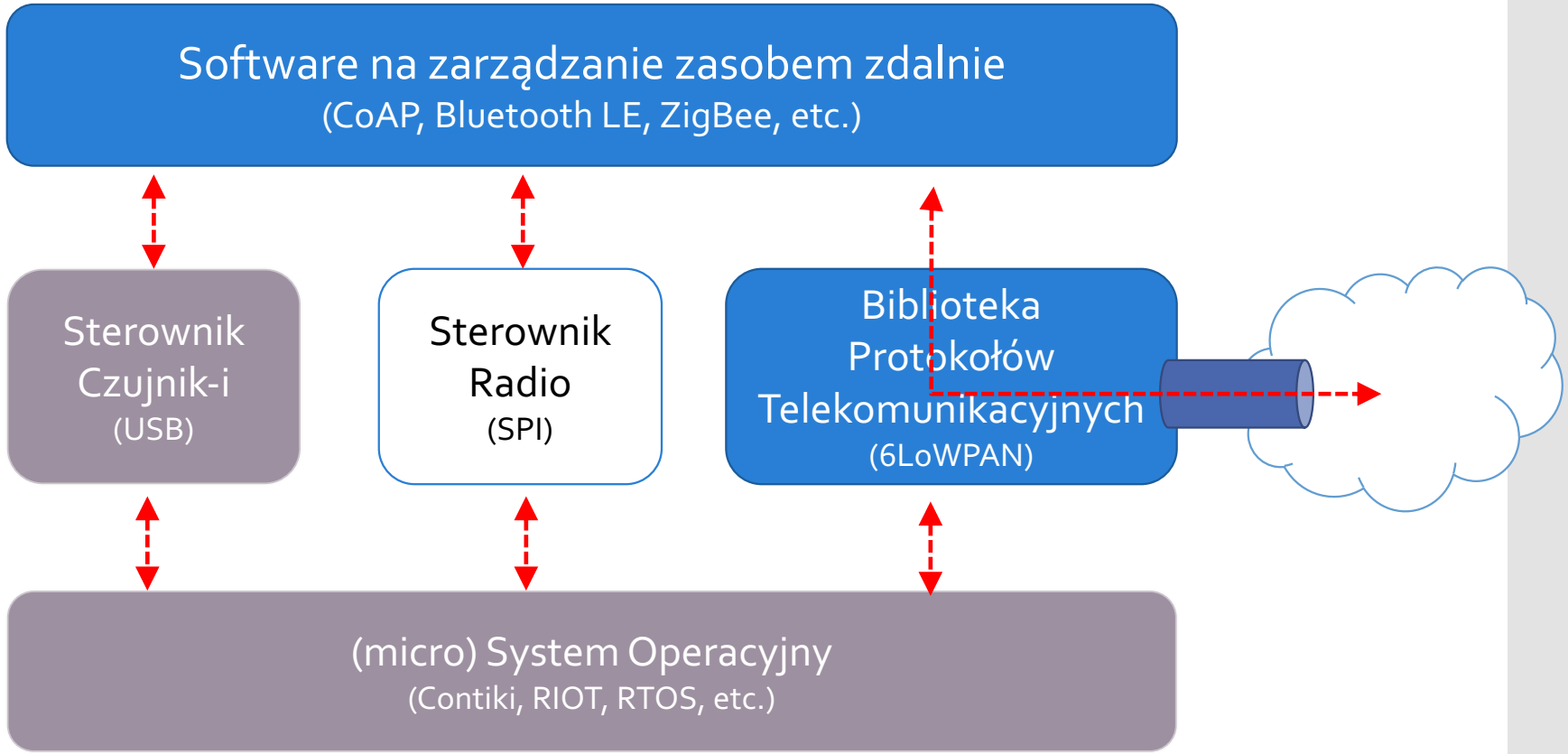
vs.

2.5GHz
32GB+2GB



IoT node

256KB ROM + 32KB RAM



Embedded Systems+ WSN + Tele

+

=

~ 2 years

1 packet/min

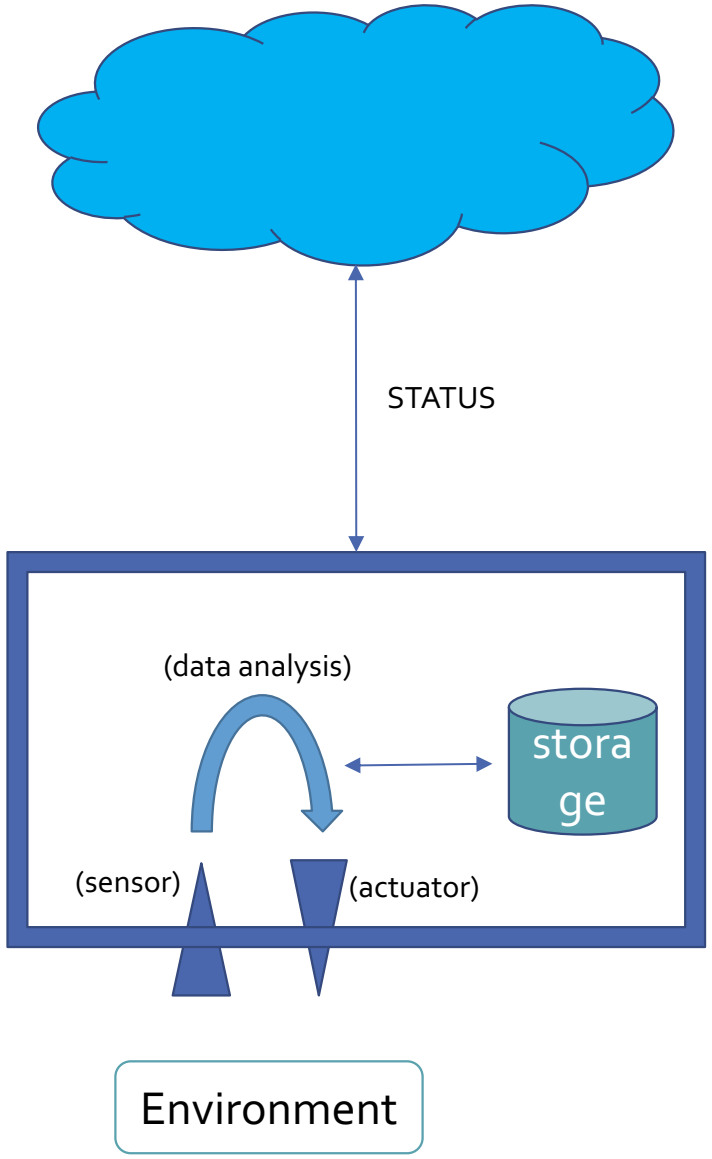
> 200 meters

IoT Levels and Deployment templates


TEMPERATURE
MOISTURE
PRESSURE
HEALTH
CONNECTIVITY

Smart irrigation

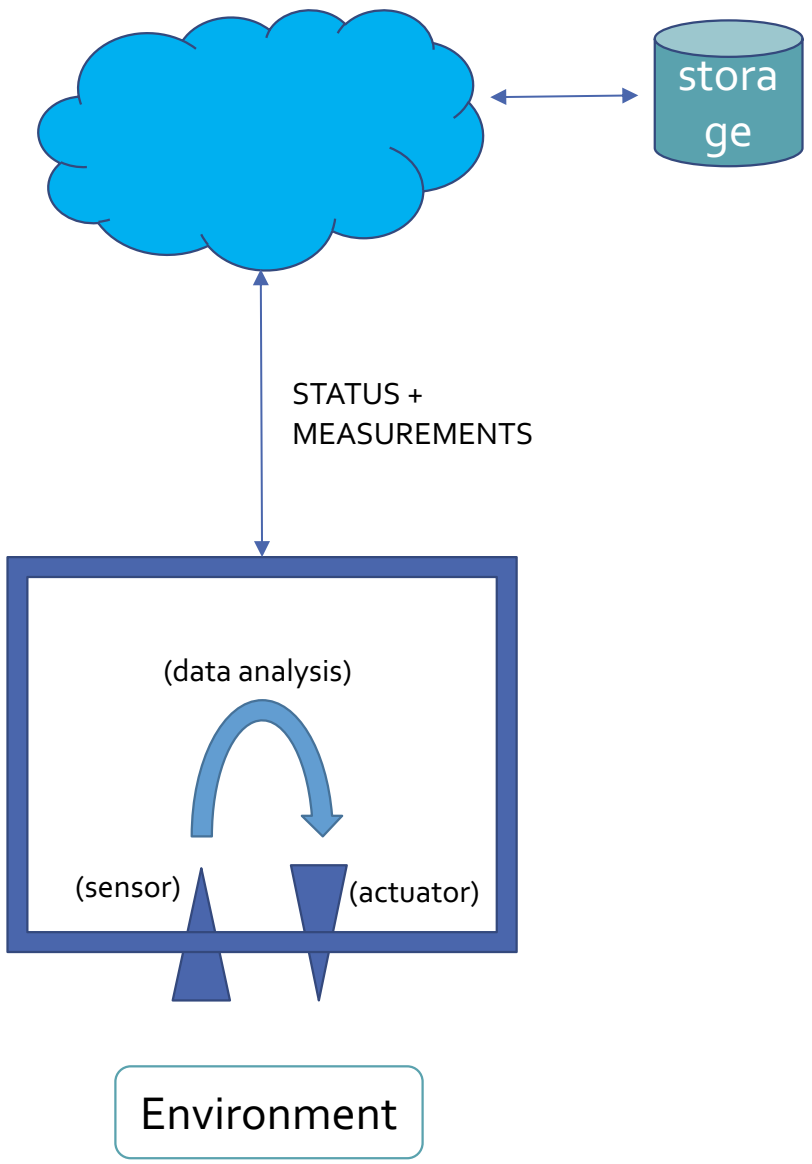
Level 1



- One node
- Simple data analysis: detects low humidity, open irrigation valves
  - Local analysis
- Reports state/status to the cloud
  - Local storage

Smart irrigation

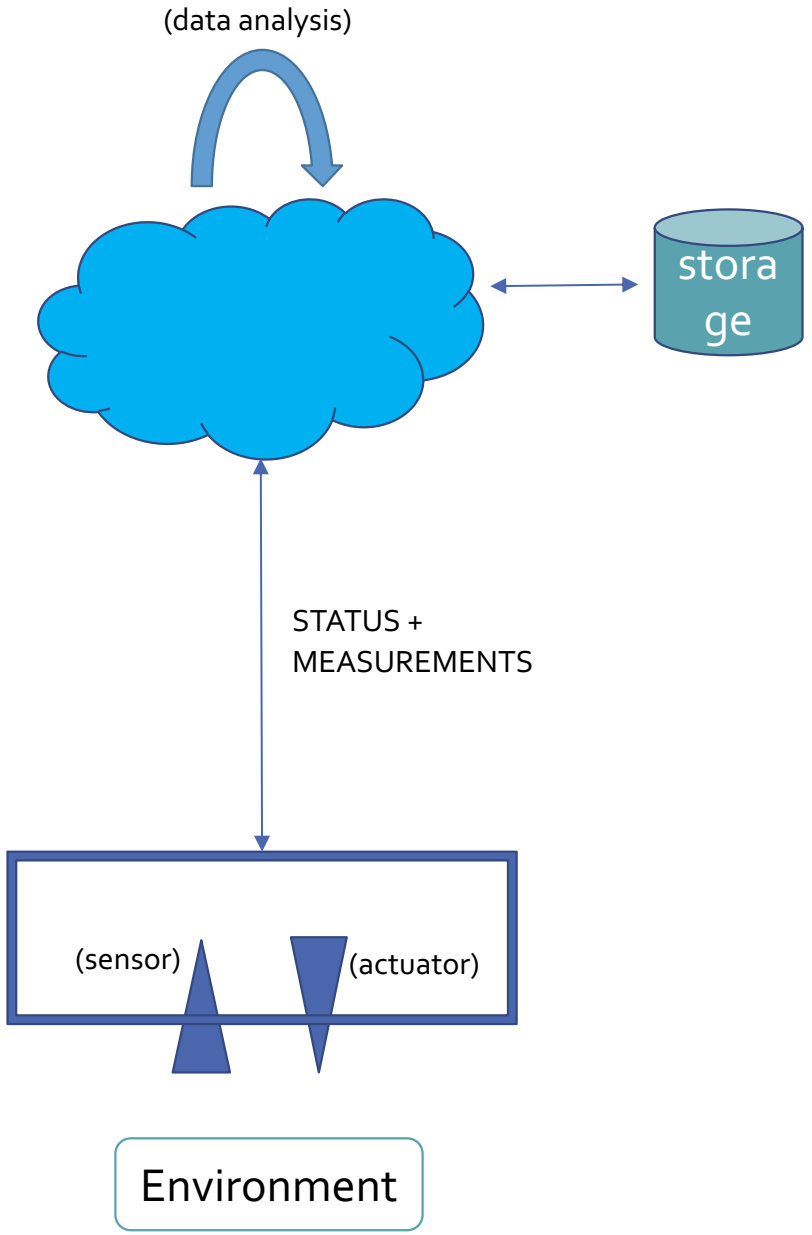
Level 2



- One node
- Simple data analysis: detects humidity, open irrigation valves
  - Local analysis
- Reports collected measurements and state/status to the cloud
  - Cloud storage

Smart irrigation

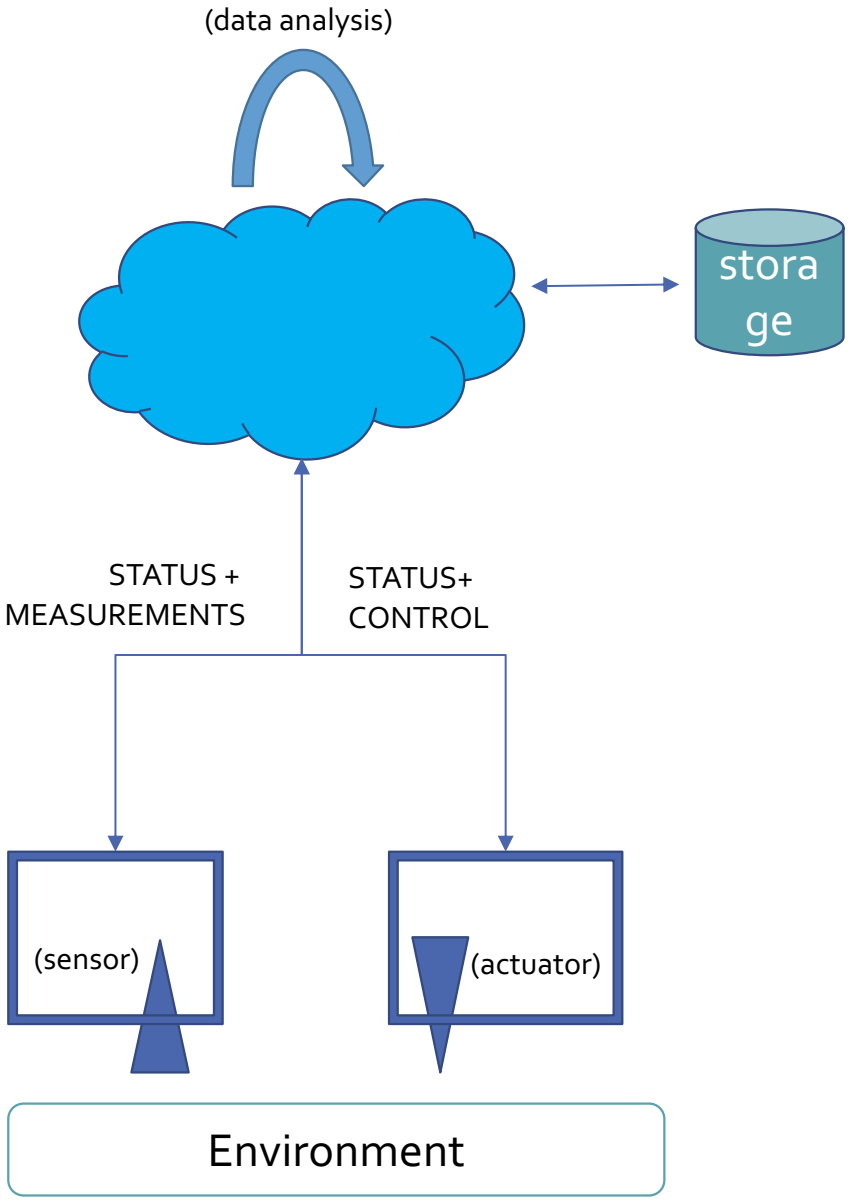
Level 3



- One node
- Complex data analysis: different sensors, different nutrients tanks
  - Cloud analysis
- Reports collected measurements and state/status to the cloud
  - Cloud storage

Smart irrigation

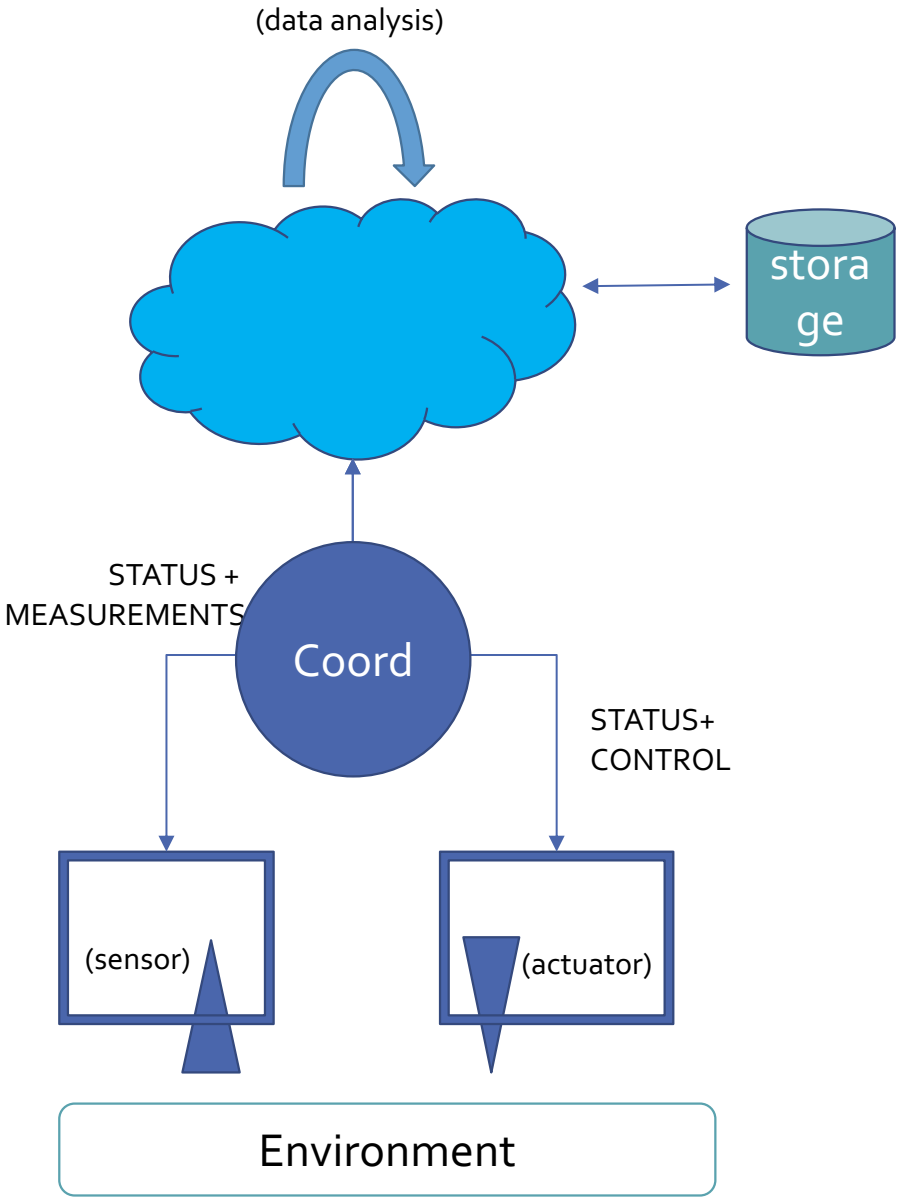
Level 4



- Several nodes:
  - Actuators and sensors separetely (Observers)
- Complex data analysis: different sensors, different nutrients tanks
  - Cloud analysis
- Reports collected measurements and state/status to the cloud
  - Cloud storage

Smart irrigation

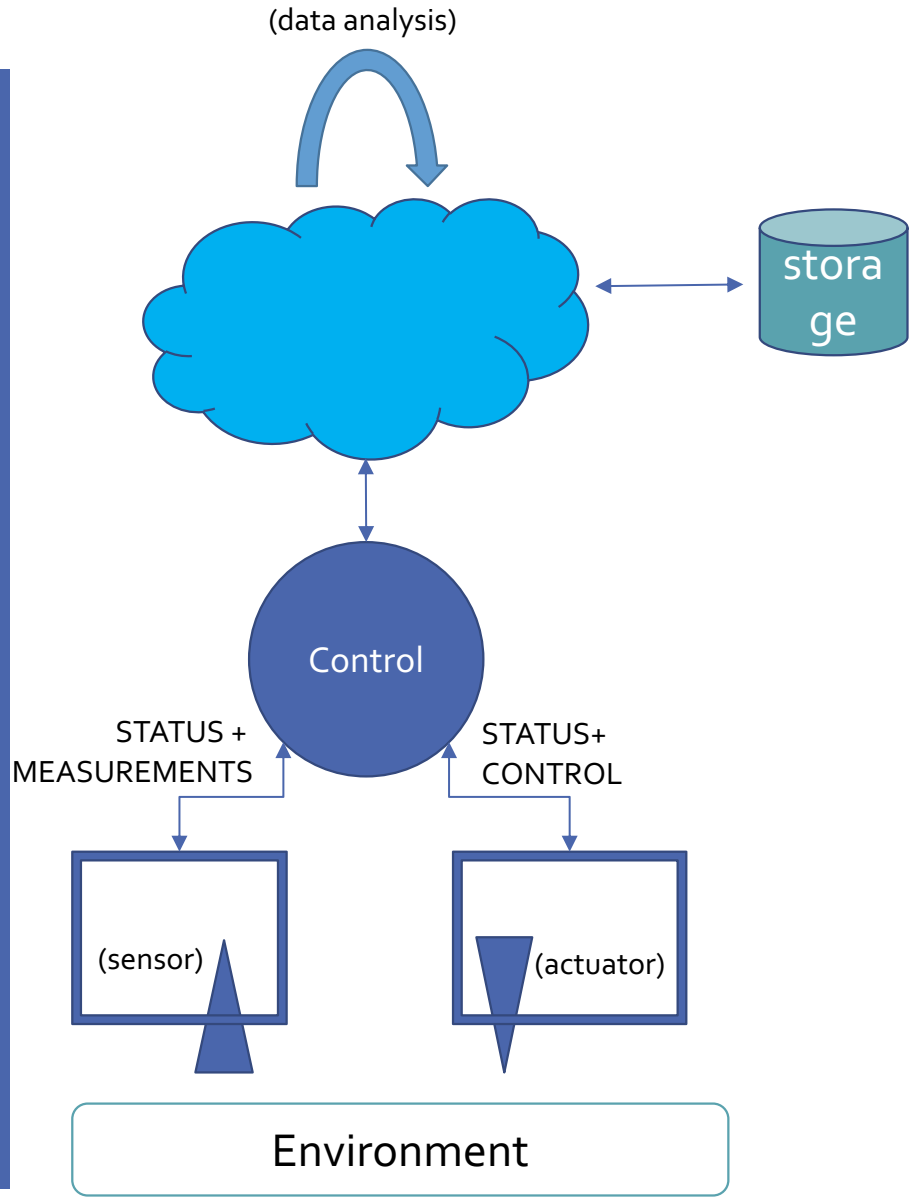
Level 5



- Several nodes:
  - Actuators and sensors separetely (Observers)
  - 1 coordinator (Gateway) – WSN-based
- Complex data analysis: different sensors, different nutrients tanks
  - Cloud analysis
- Reports collected measurements and state/status to the cloud
  - Cloud storage

Smart irrigation

Level 6



- Several nodes:
  - Actuators and sensors separetely (Observers)
  - 1 controller (Gateway) – WSN-based
- Complex data analysis: different sensors, different nutrients tanks
  - Cloud analysis
- Reports collected measurements and state/status to the cloud
  - Cloud storage

IoT levels

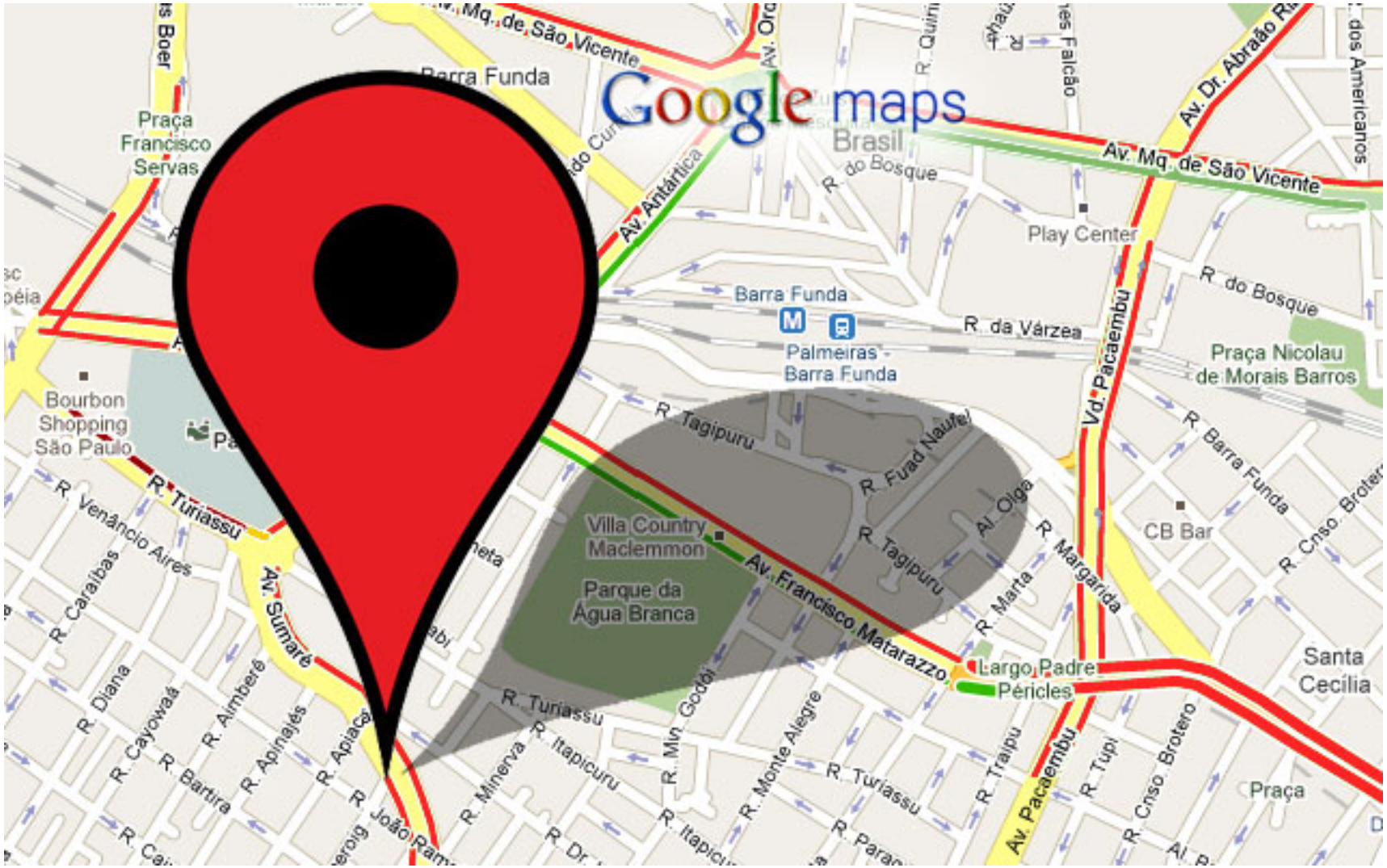
Summary

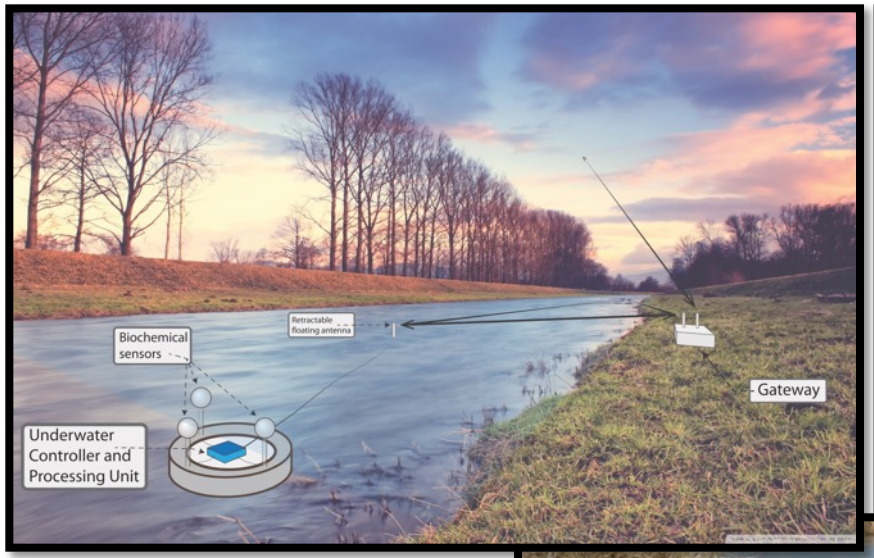
Feature	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Cloud Storage	-	YES	YES	YES	YES	YES
Cloud Analysis	-	-	YES	YES	YES	YES
Ext Observers	-	-	-	YES	YES	YES
Coordinator	-	-	-	-	YES	YES
Controller	-	-	-	-	-	YES

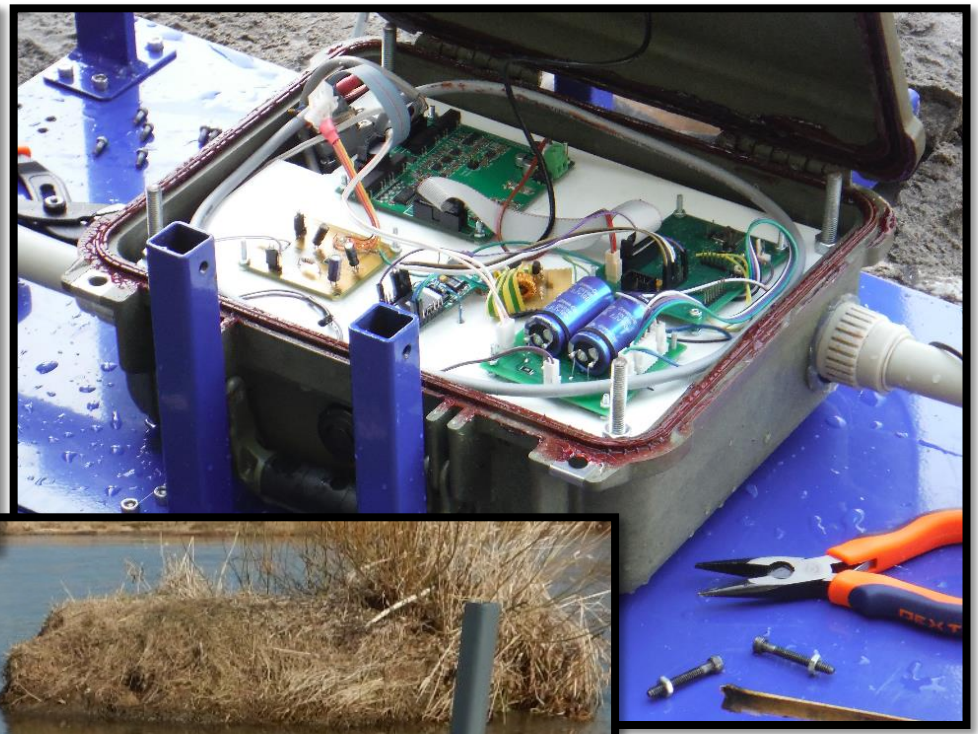
Examples

Two from PW + some others

Google Maps

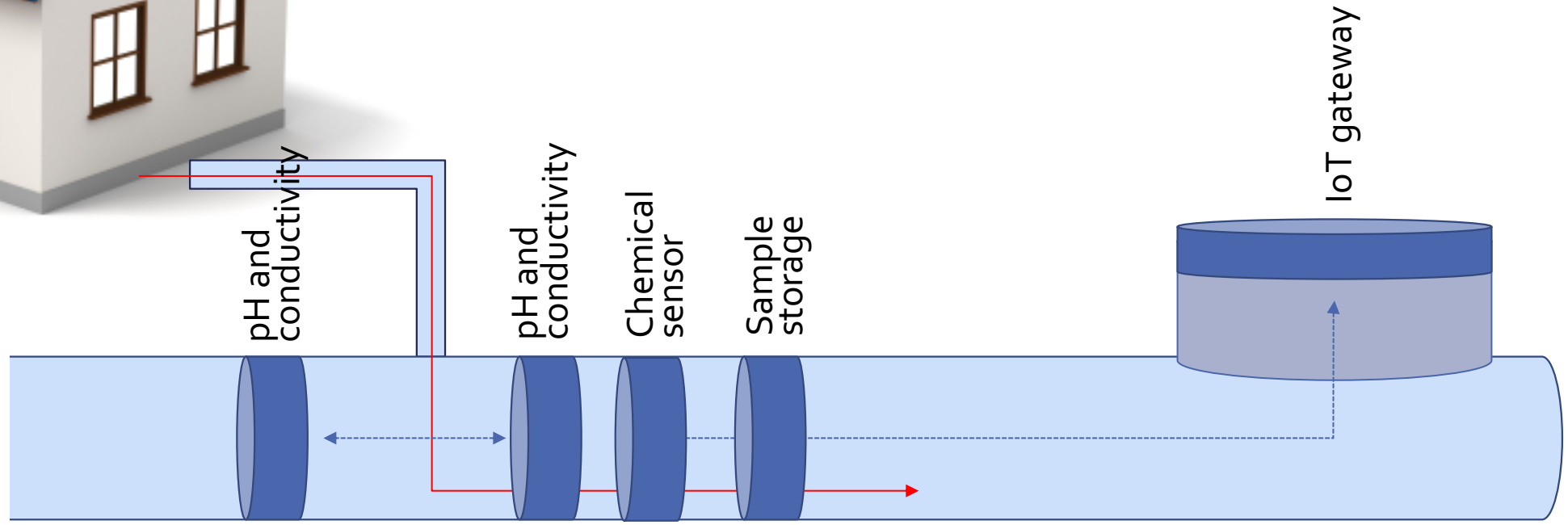

Google maps
Av. Mq. de São Vicente
Barra Funda
Praça Francisco Servas
Av. Antártica
Brasil
Play Center
Av. Dr. Abraão Ribeiro
Barra Funda
R. da Várzea
Palmeiras - Barra Funda
R. do Bosque
Praça Nicolau de Morais Barros
Vd. Pacaembu
Bourbon Shopping São Paulo
R. Tagipuru
R. Fuad Naufel
R. Barra Funda
R. Venâncio Aires
R. Turiassu
Villa Country Maclemmon
Av. Francisco Matarazzo
Al. Olga
R. Margarida
CB Bar
Av. Sumaré
Parque da Água Branca
R. Marta
Largo Padre Péricles
Santa Cecília
R. Caraíbas
R. Diana
R. Cayowaá
R. Bartira
R. Aimberé
R. Apinajés
R. Apiacás
R. Minerva
R. Itapicuru
R. Mvn. Godói
R. Monte Alegre
R. Turiassu
R. Traipu
Av. Pacaembu
R. Tupi
R. Cnso. Brotero
Praça





Goldfish FP7

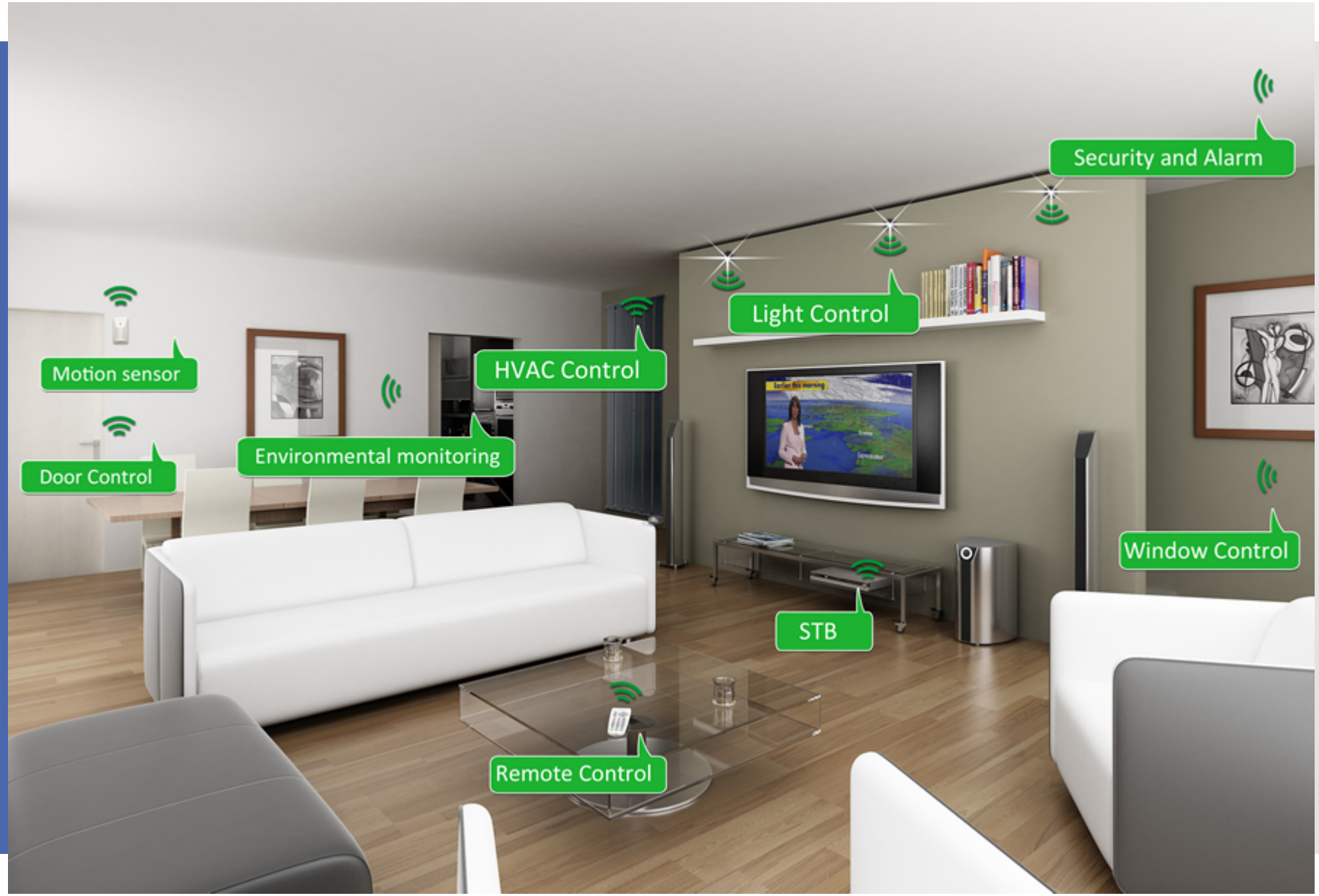
MICROMOLE



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653626

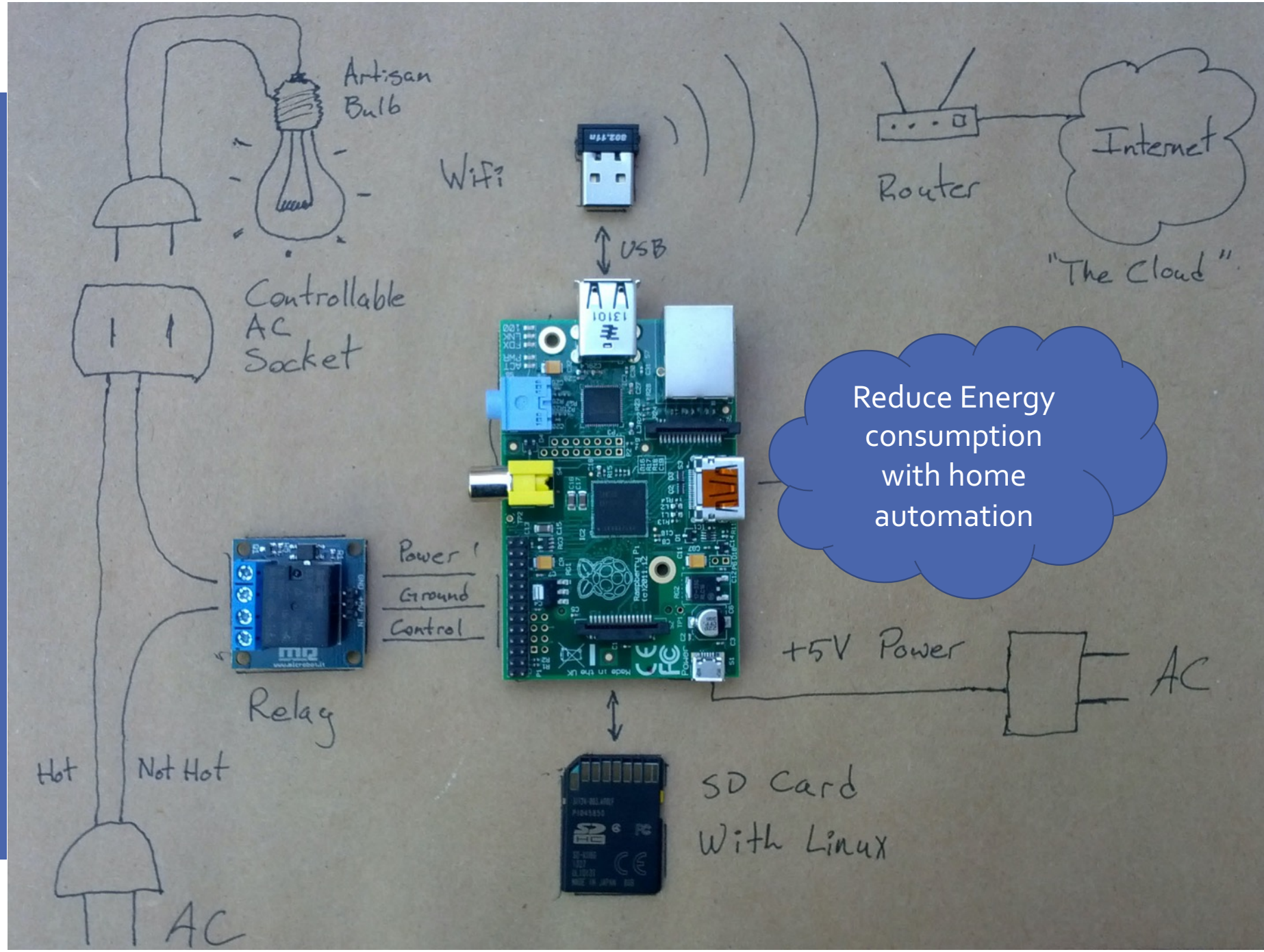
Air pollution

Wireless Sensor Networks and Hardware



A bad example

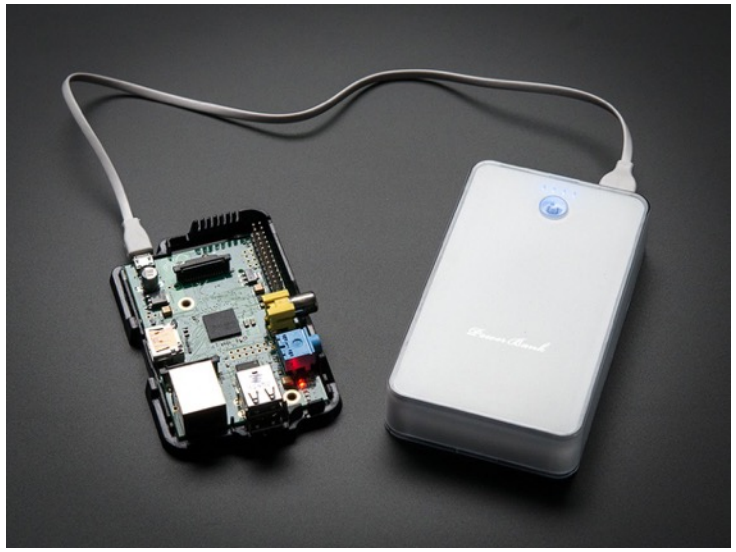
Remote bulb control



A bad example

Remote bulb control

Power Mgte



How often will I need to replace/recharge the battery?

Where can I connect it?
Do I have a plug nearby?

Even if so, what's the point?
Am I saving Energy with this system?

A bad example

Remote bulb control

- Wireless interface:
  - How many bytes do we need to transfer for switching on a bulb?
  - What is the WiFi speed?
  - What would be the overhead for transfering a small packet?
- Processor
  - How complex could be our controlling application at the Rpi? (memory/CPU cycles)
  - Can a delay of milliseconds be tolerable? Or is it microseconds justified?
- OS:
  - Can Linux be put into sleep?
  - If not, what's the boot time?
  - Can Linux put to sleep the WiFi independently?
  - Can we reduce the clock speed arbitrarely?

Hardware

	PC	Smartphone	Raspberry Pi
CPU	2.1-3.2 GHz	1.2-1.8GHz	900 MHz
Memory	16-32GB	8-16GB	512 MB
Wireless data rate	~ 1Mbps (BLE) > 11 Mbps (WiFi)		
Power consumption	300 watts	5-12 watts	1 watt (BLE) 2 watts (WiFi)
Battery	-	2000mAh	
Expected battery lifetime	-	1-2 days	4-6 days (if 2000mAh + WiFi)

Assume we deploy a 100 RPI… we'll have to replace 20 batteries a day!

Hardware




	PC	Smartphone	Raspberry Pi	Wireless sensor
CPU	2.1-3.2 GHz	1.2-1.8GHz	900 MHz	8-48MHz
Memory	16-32GB	8-16GB	512 MB	256 KB
Wireless data rate	> 11 Mbps (802.11)			20-250 Kbps
Power consumption	300 watts	5-12 watts	~ 2 watts	10 mW (on) 10uW (sleep)
Battery	-	2000mAh		750mAh
Expected battery lifetime	-	1-2 days	4-6 days (if 2000mAh)	4 years @ duty cycle 0.1%