IOT & CYBERSECURITY

THE INTERNET OF THINGS

ACADÉMIE MILITAIRE
SAINT-CYR COËTQUIDAN

COURSE OBJECTIVE

- Understand the concept of the Internet of Things
- Able to identify limitations and advantages of IoT devices
- Aware of the importance of connected “things”

PLAN

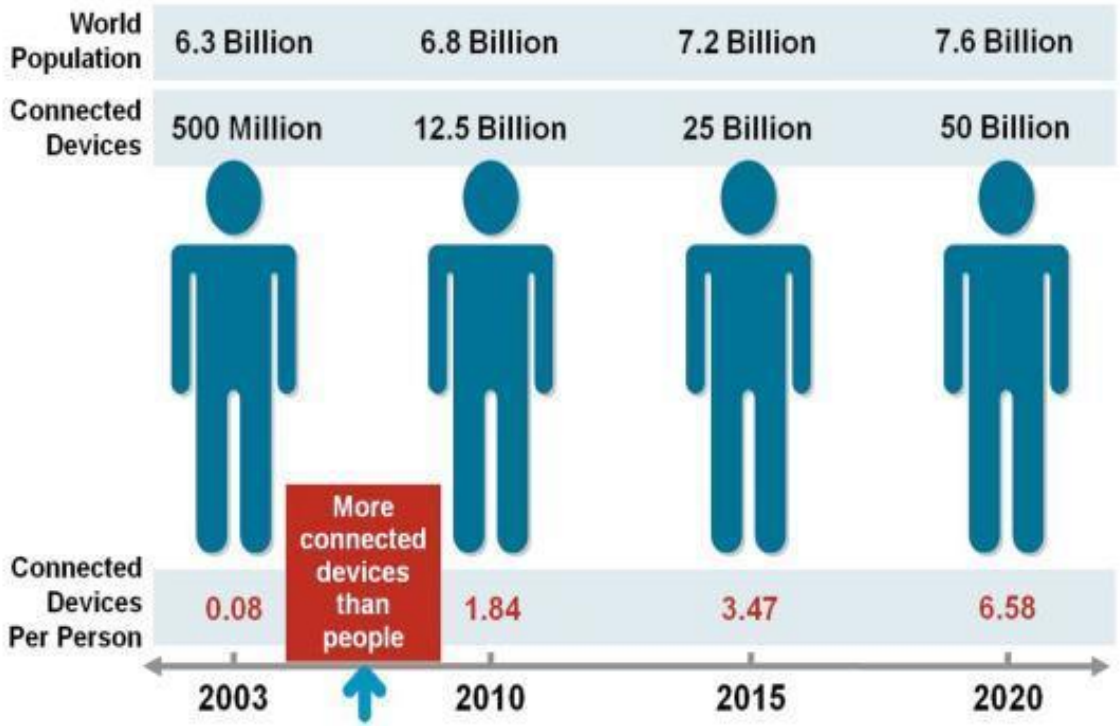
1. IoT concepts and market
2. Challenges and fundamentals
3. IoT architecture and systems
4. Technological solutions
5. Practical

I. IOT CONCEPTS AND MARKET

WHAT IS THE IOT?

- IoT → *Internet of Things*
  - Term coined in 1999 by Kevin Ashton – Describing RFID chips
  - Meaning "Internet connected to the physical world via ubiquitous sensors"

- Cisco's estimation → 2008 – 2009
  - More "things or objects" connected to the internet than people



Source: esferize, "*How has the Internet evolved*"

MULTIPLE DEFINITIONS

- ITU → "Global infrastructure for the information society enabling advanced services by interconnecting things based upon existing and evolving, interoperable information and communication technologies"
  - ITU-T Y.2060 – 2012
- IETF → "Network of physical objects or "things" embedded with electronics, software, sensors, actuators, and connectivity to enable objects to exchange data with the manufacturer, operator, and/or other connected devices"
- ISO/IEC → "An infrastructure of interconnected objects, people, systems and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react"
  - ISO/IEC JTC 1 – 2014

FROM MAN TO MACHINE

- Moving away from human control
  - **H2M** → *Human to Machine*
- Standard operating method for IT devices

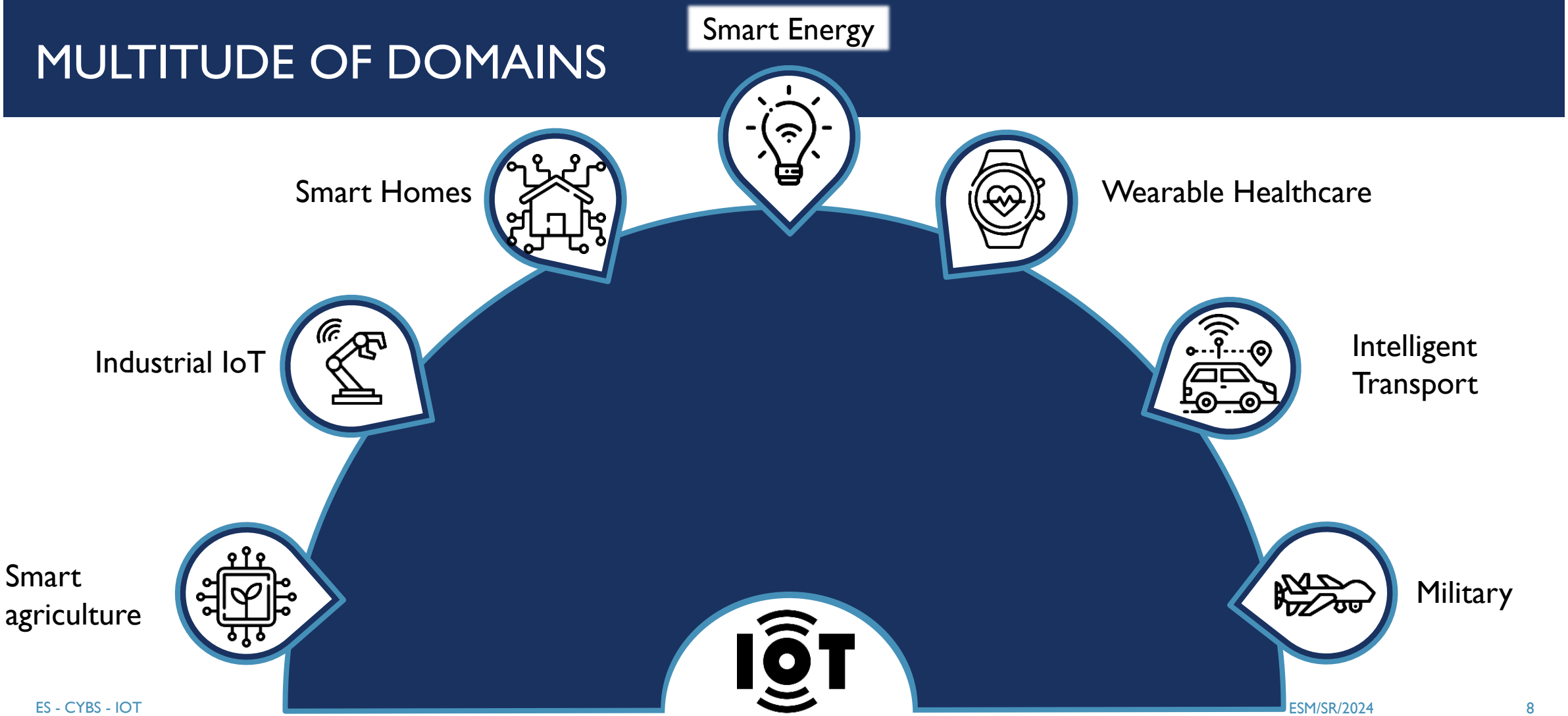
- Human input necessary for operations
  - Computers, Laptops, …
- Limited decision-based capabilities

- Machine interactions
  - **M2M** → *Machine to Machine*
- Next stage in IT evolution

- No human input at all
  - Traffic control, robotics, …
- Autonomous decision capabilities

- Next stage … **M2H** ?

MULTITUDE OF DOMAINS



ORIGINS

1982 – **Coke Machine**

- Carnegie Mellon University – Pennsylvania
- Inform admins when out of cans
- Connected to stock lights → stays on = empty
- Allows quick restocking
- Reduces unnecessary visits

1991 – **Trojan Room coffee pot**

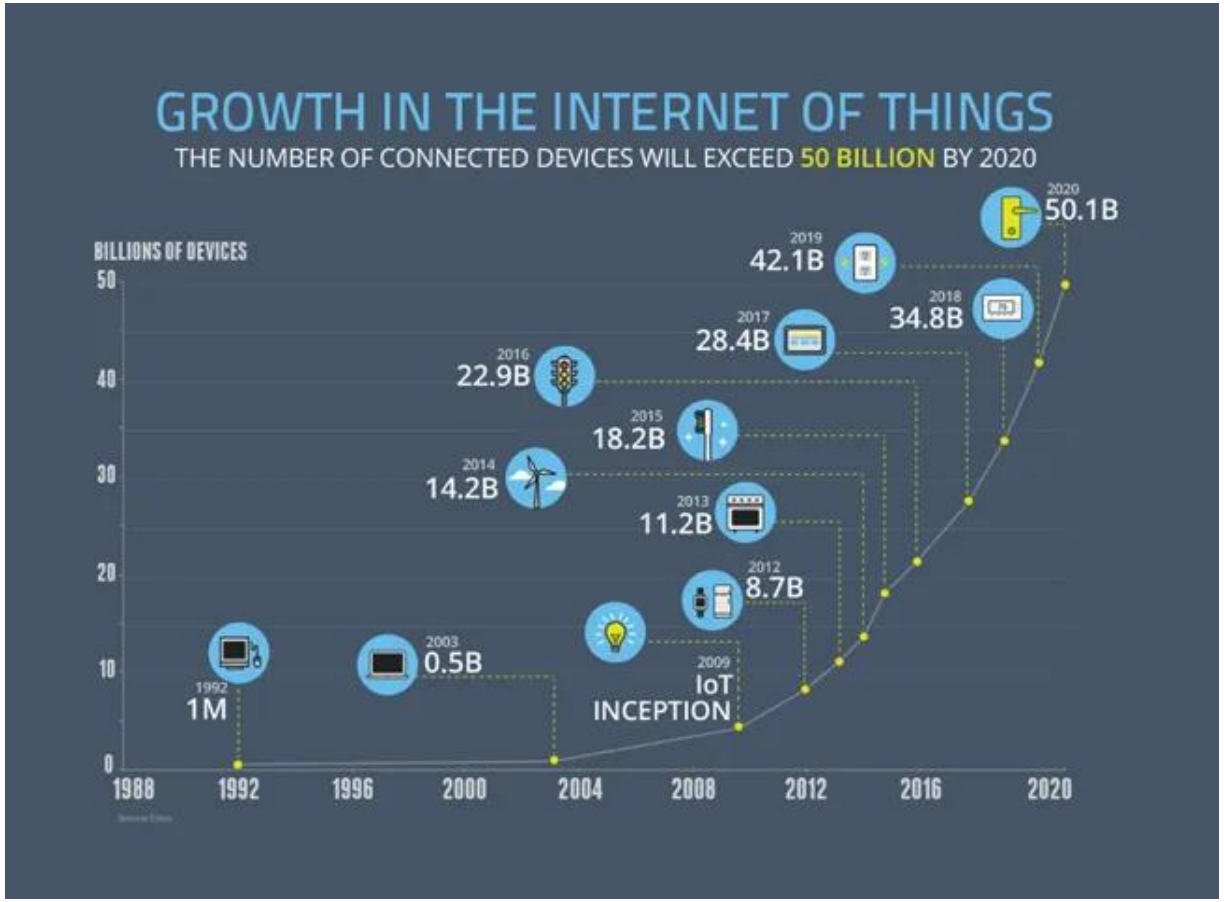
- University of Cambridge
- Camera setup informing all users of coffee level
- Avoid disappointment of finding empty machine
- → evolved to first webcam in 1993

ORIGINS

1995 – Telegarden

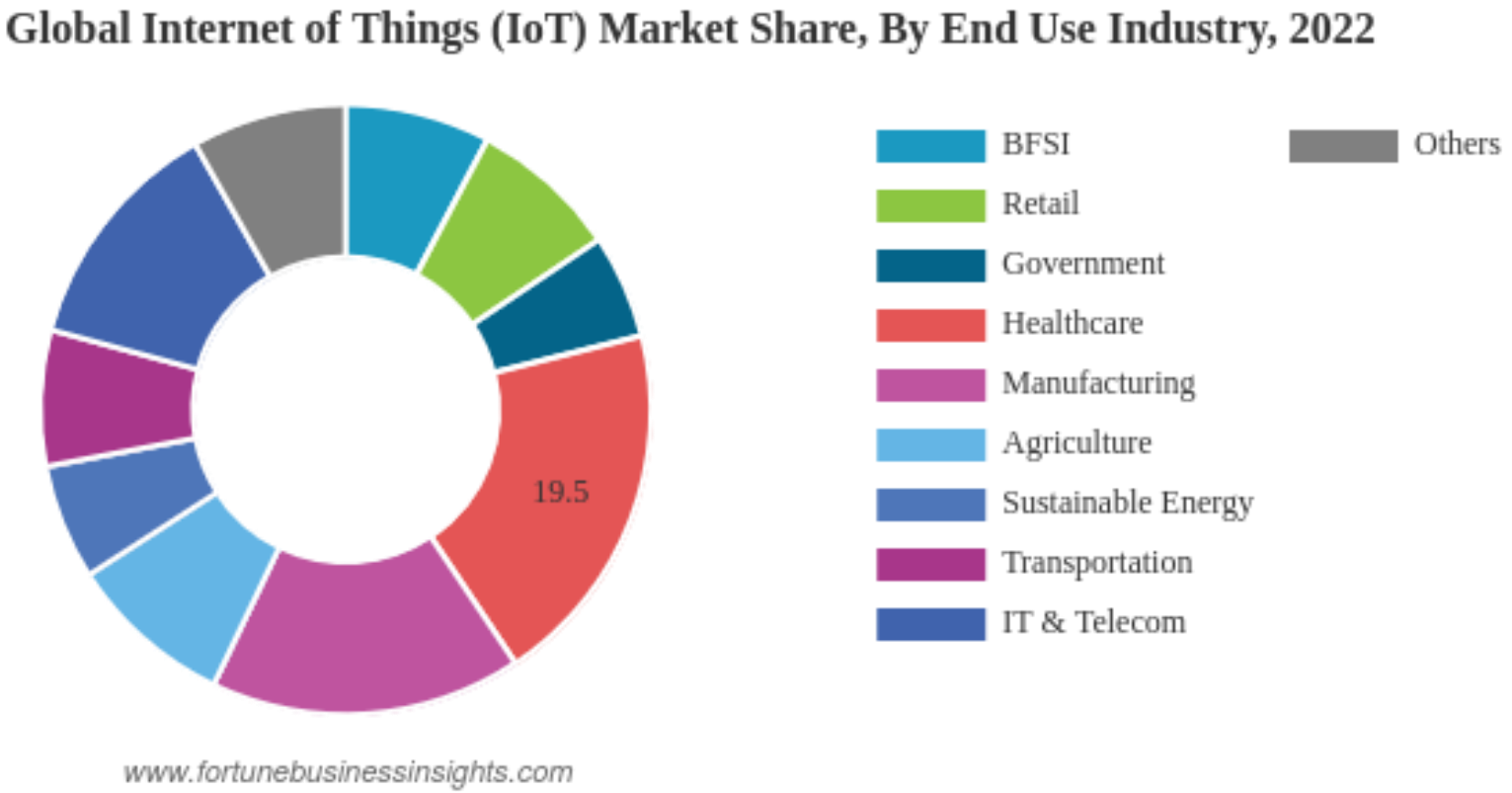
- University of Southern Carolina
- Telerobotic community garden
- Mixing agriculture, art and the Internet
- Allowed web users to view and interact
- Multiple interactions possible
  - Planting seedlings, water plants, monitor growth, …
- Over 9000 members in first year!

ESTIMATED MARKET GROWTH



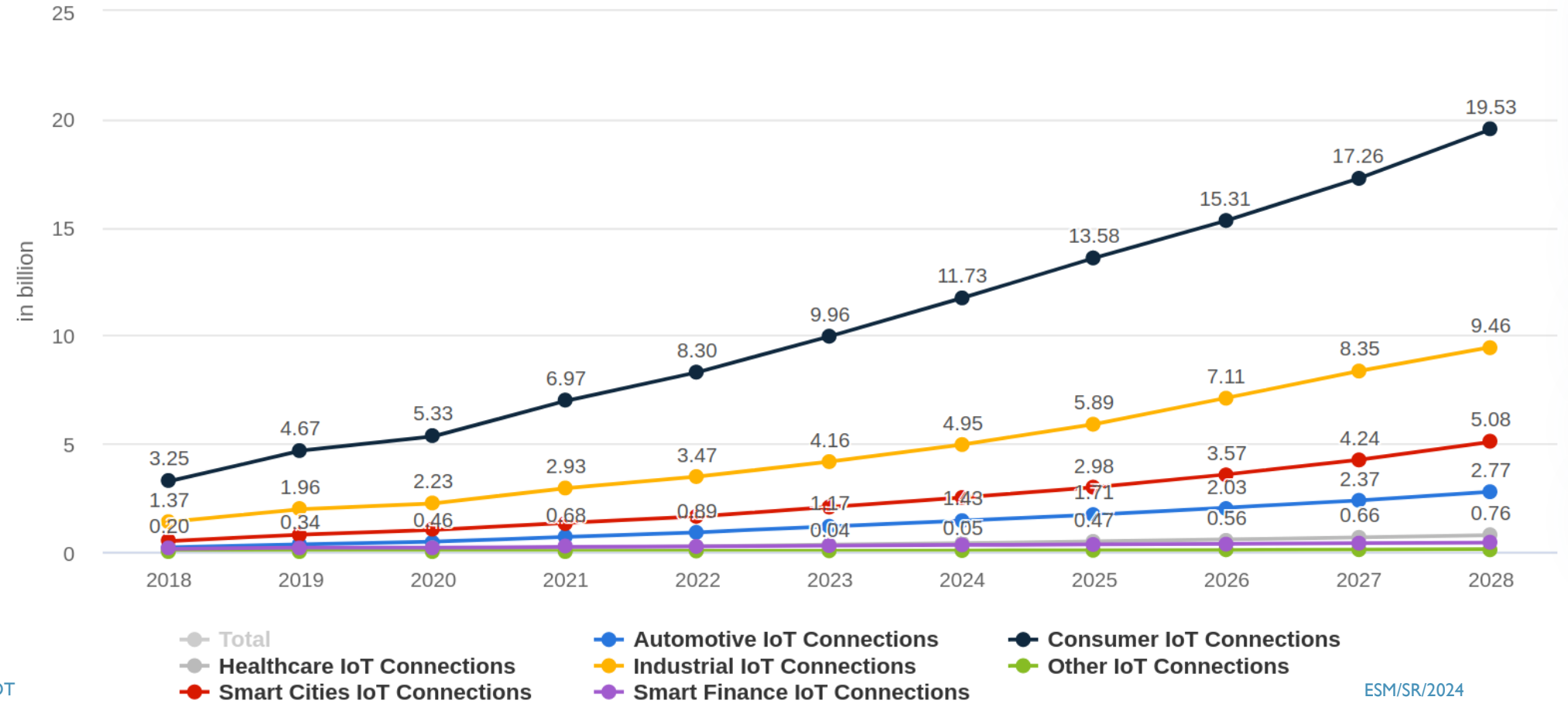
Source: Medium, "*Pros and Cons of Telecommunication and Working*", 30th January 2017

MARKET SHARE



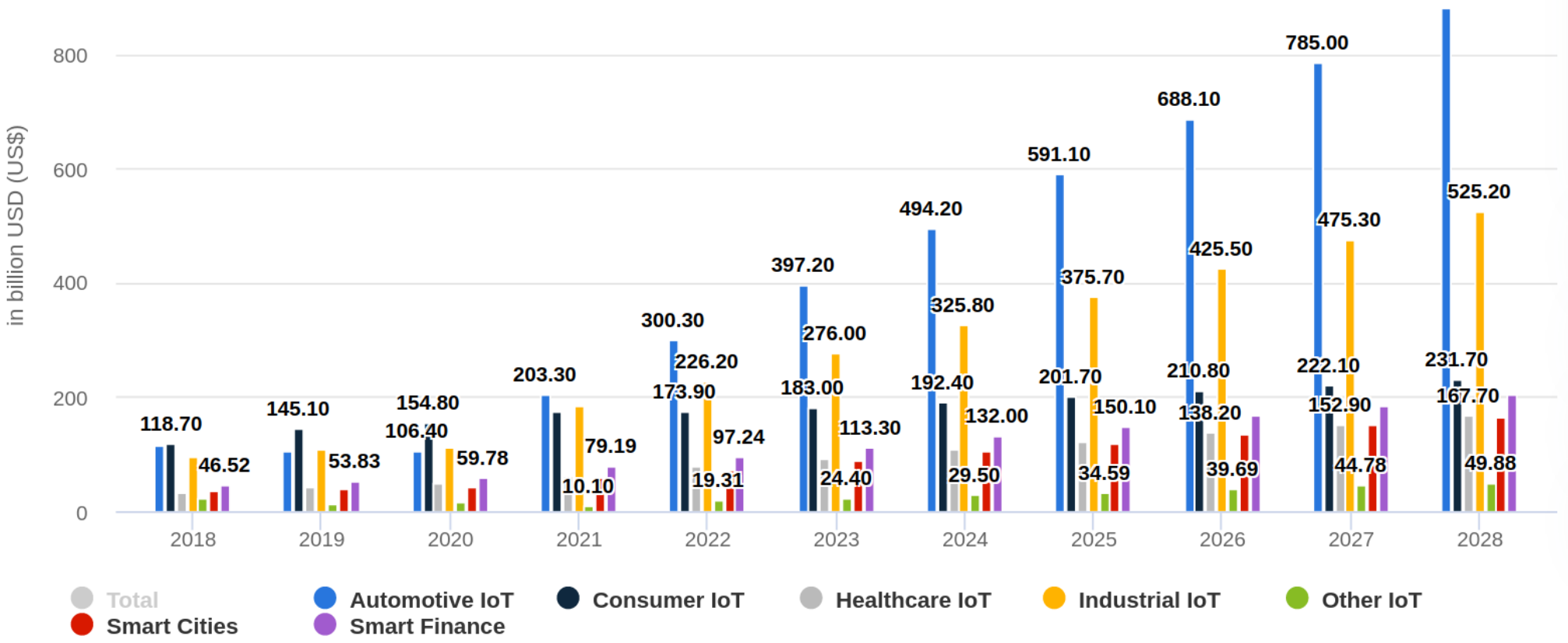
Source: Fortune Business Insights, *"Market Research Report"*, April 2023

IOT VOLUME



Source: Statista, "*Internet of Things – Worldwide*", September 2023

IOT REVENUE



Source: Statista, "*Internet of Things – Worldwide*", September 2023

Data shown is using current exchange rates and reflects market impacts of the Russia-Ukraine war

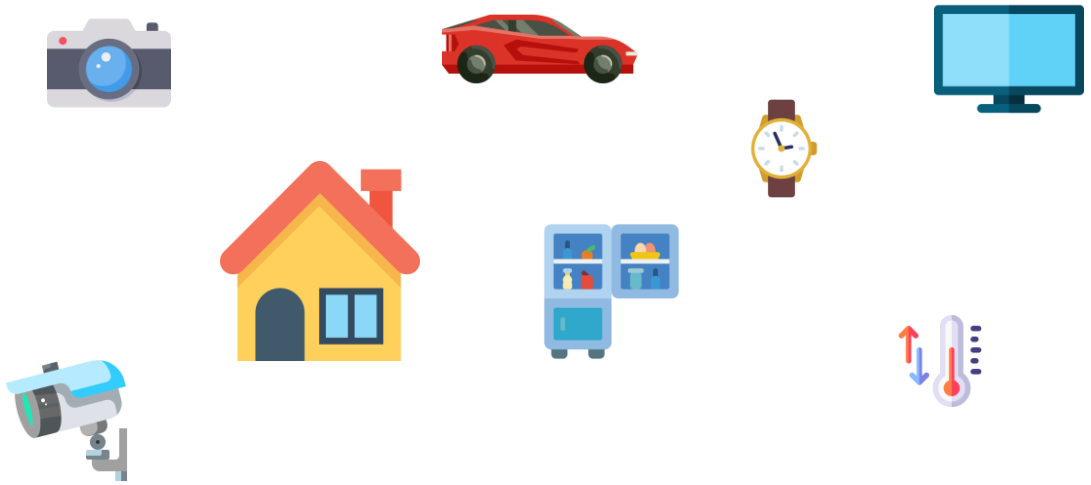
IOT IN 2023

Source: IoT Analytics, "*IoT 2023 in review: The 10 most relevant IoT developments of the year*", 11th January 2024

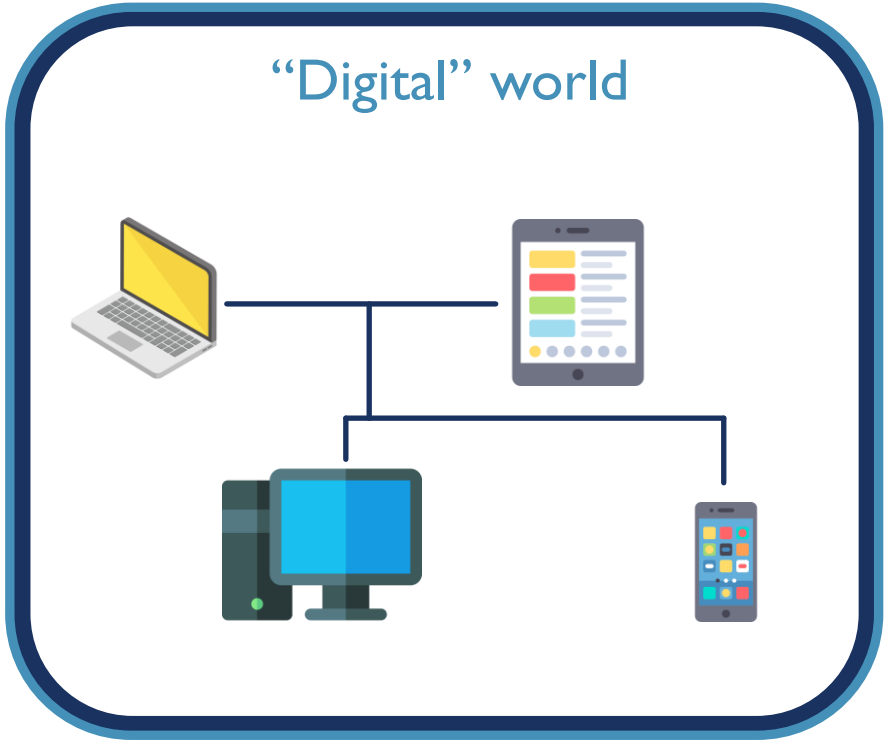
II. CHALLENGES AND FUNDAMENTALS

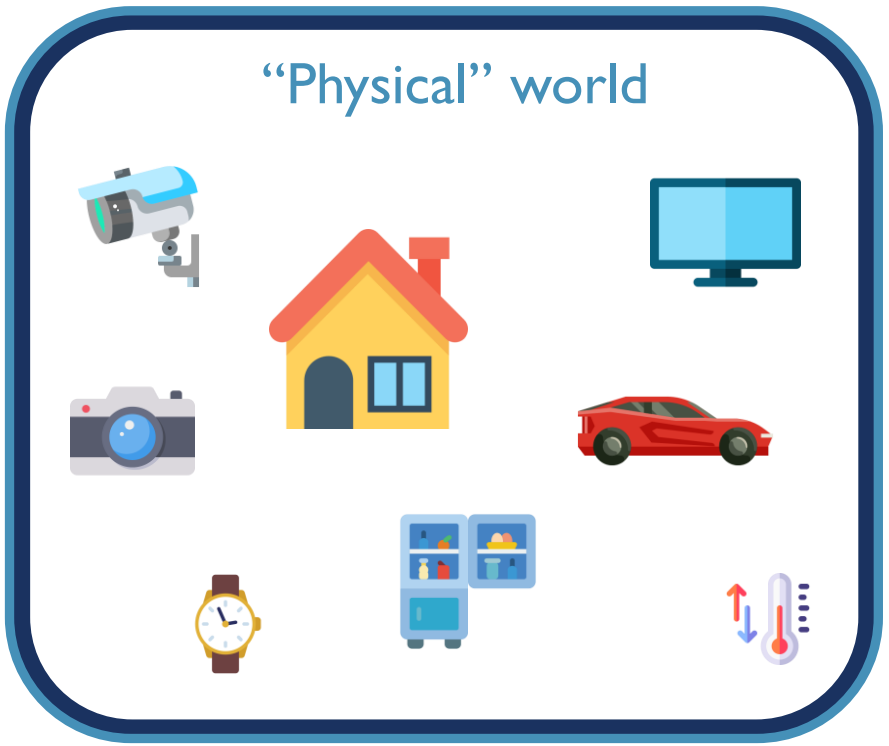
MAIN CONCEPT

- Devices whose primary functionality DOESN'T require Internet connectivity
- Internet provides extra functionalities to device and operators (professional and personal)

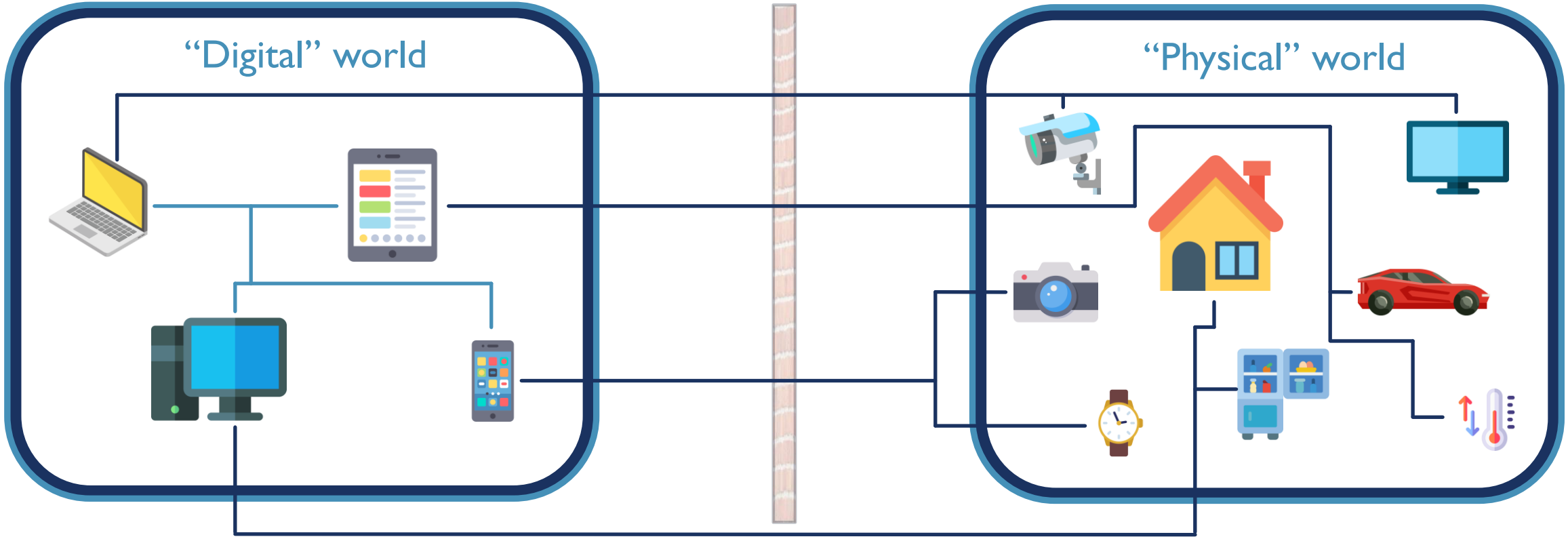


BEFORE THE IOT …





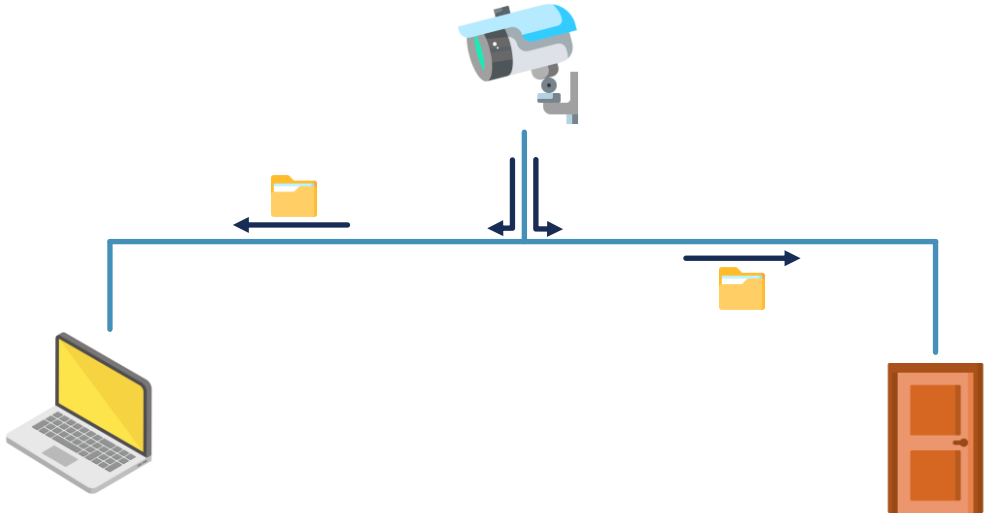
… NOW



FUNDAMENTALS

- Retrieve information from physical world
  - Sensors → 
- Action on physical world
  - Open doors → 
  - Start / heat a vehicle → 

- The information retrieved/ sent can originate from/travel to a user or other connected devices



COMMUNICATION

- More devices → difficulties communicating
- Not possible to wire everything

Wireless Networking

- Open to more large-scale inter-connected systems
  - Ex: Forest fire detection

- Multiple technologies exist

CHALLENGES

Interoperability

- Multiple technologies → not all compatible
- Fragmented standards
  - Low value but higher costs

→ Framework and standard convergence needed

Scalability

- Large quantities of devices → single network
- Data overload
  - Powerful analytics and large cloud storage

→ Scalable storage and computation systems

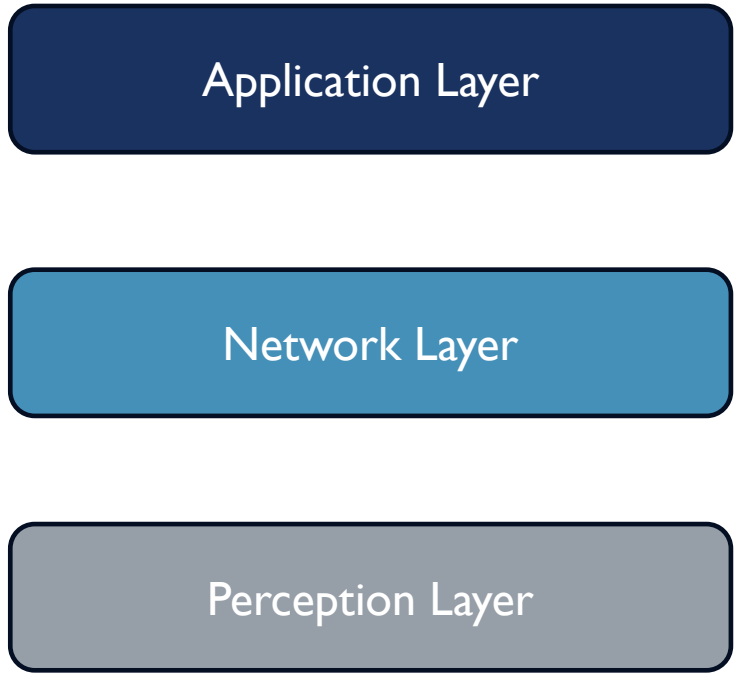
Security vulnerabilities

- Large "attack surface" → **Chapter 3**

III. IOT ARCHITECTURE AND SYSTEMS

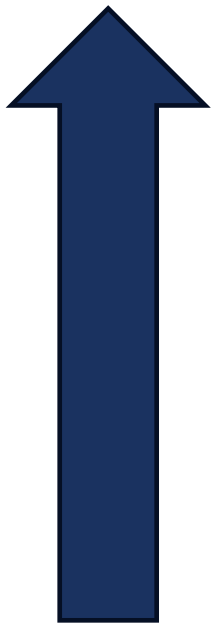
3-LAYER ARCHITECTURE

- Architecture evolves from system to system
- Most common is 3-layers
  - **Perception Layer**: Physical layer, interact with the environment
    - Sensors, actuators, …
  - **Network Layer**: Collects, transports and processes data
  - **Application Layer**: User oriented, providing applications and services



4-LAYER ARCHITECTURE

- Exists with 4-layers
  - Data processing put into own layer



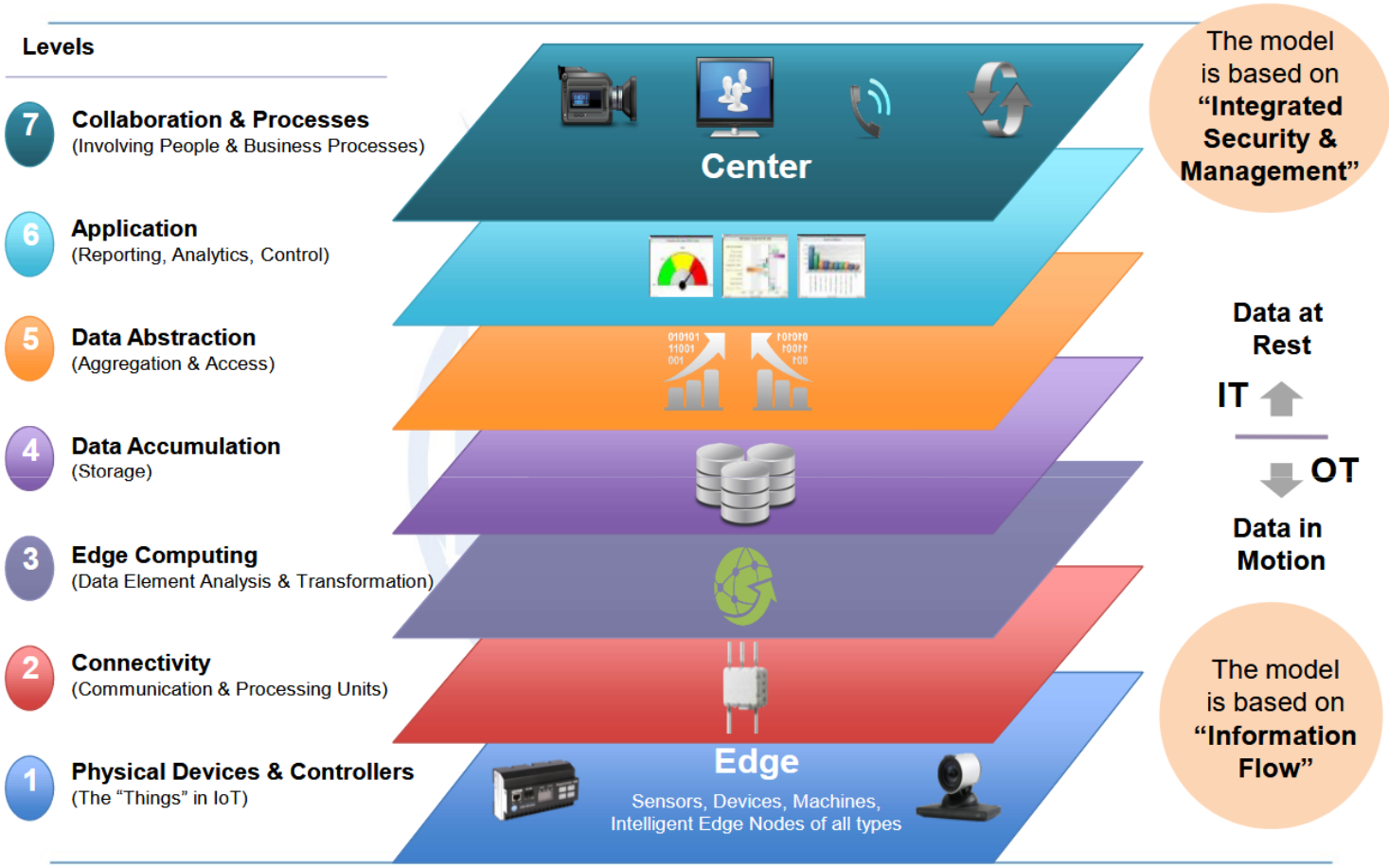
Application Layer

Information Processing Layer

Network Layer

Perception Layer

IOT REFERENCE MODEL



Source: ITU, "*IoT Standards, Part I: IoT Technology and Architecture*", September 2018

COMPONENTS

- Multi-layer approach
- Four general elements

ENVIRONMENTAL INTERACTION

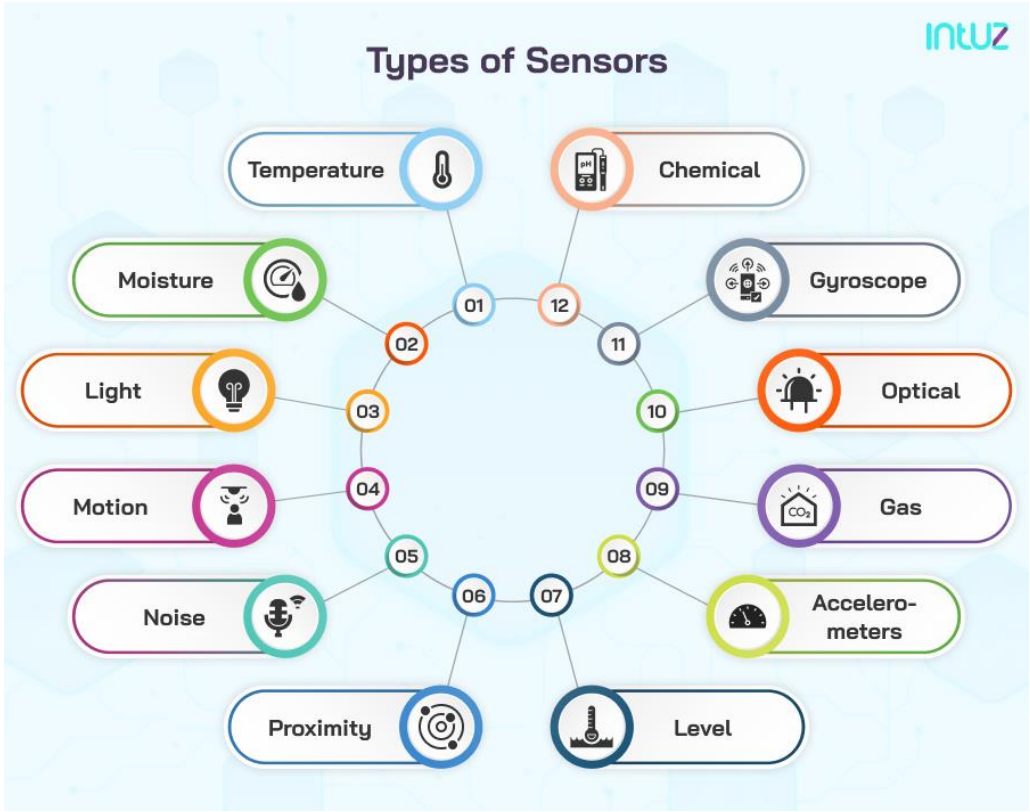
Sensors

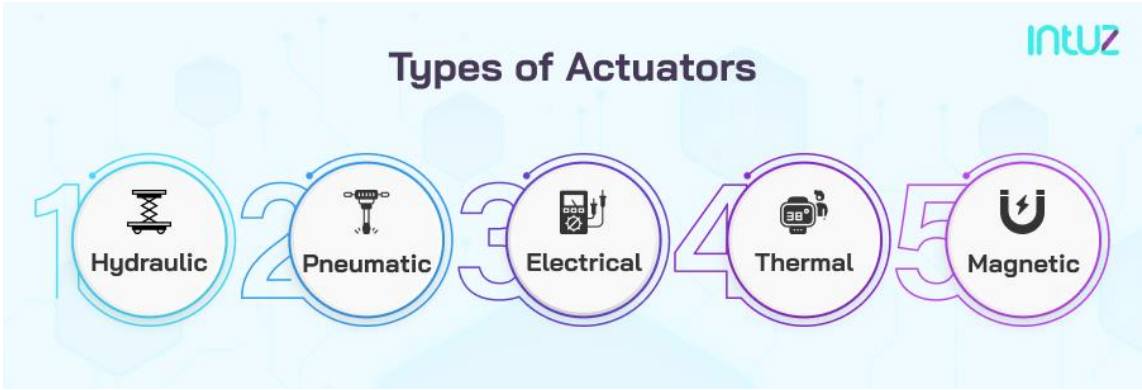
- Detect an event or external parameter
  - Motion in area
  - Temperature, humidity
- Small sized, cheap and low power consumption
- Convert physical notion into electrical current

Actuators

- Act upon the environment itself
  - Influence status of surrounding area
  - Ex: speaker …
- Larger than sensors and more power hungry
- Converts electrical current into physical movement / mechanical energy

SENSOR AND ACTUATOR EXAMPLES

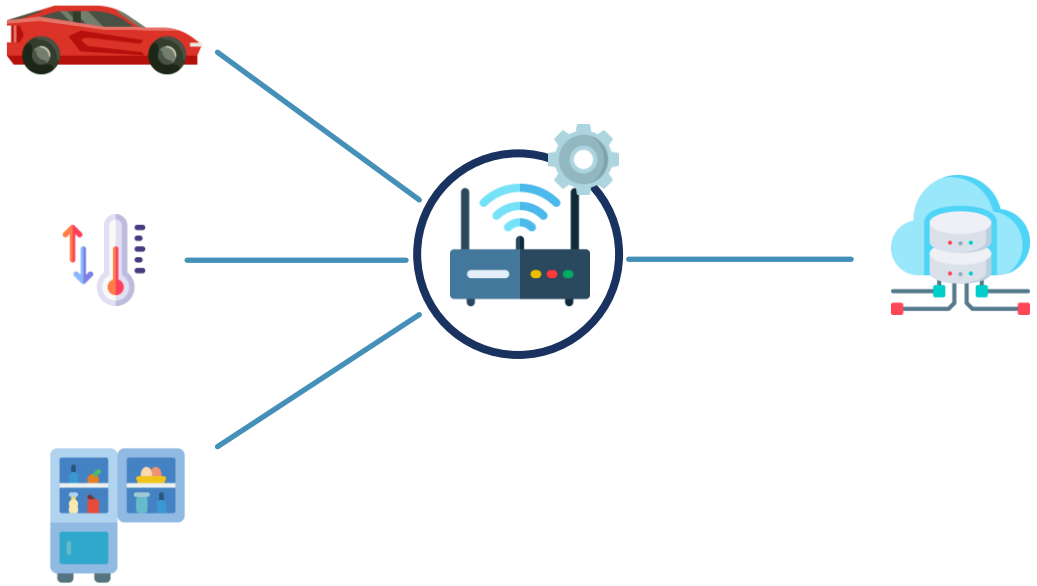




Source: DZone, "*Type of Sensors and Actuators in IoT*", 21st July 2022

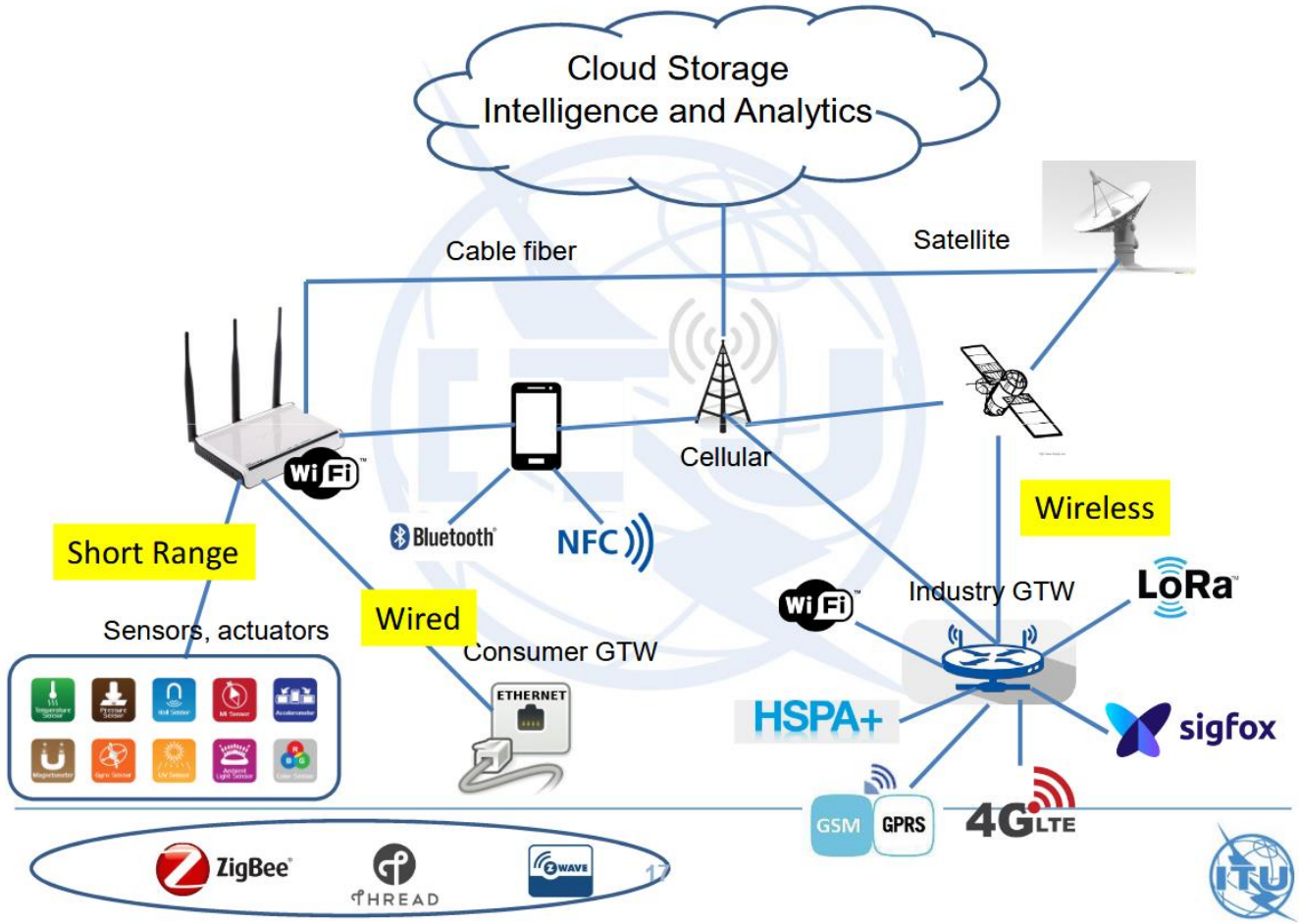
GATEWAY TO ANOTHER WORLD

- Bridge between two networks
  - IoT – Internet
- Combination of hardware and software
- Collects data from sensors before transmitting across internet
  - Can perform local processing



NETWORK ARCHITECTURE

Sensors / Actuators → Gateway → Network Infrastructure → Platforms



Source: ITU, "*IoT Standards, Part I: IoT Technology and Architecture*", September 2018

IOT PLATFORMS

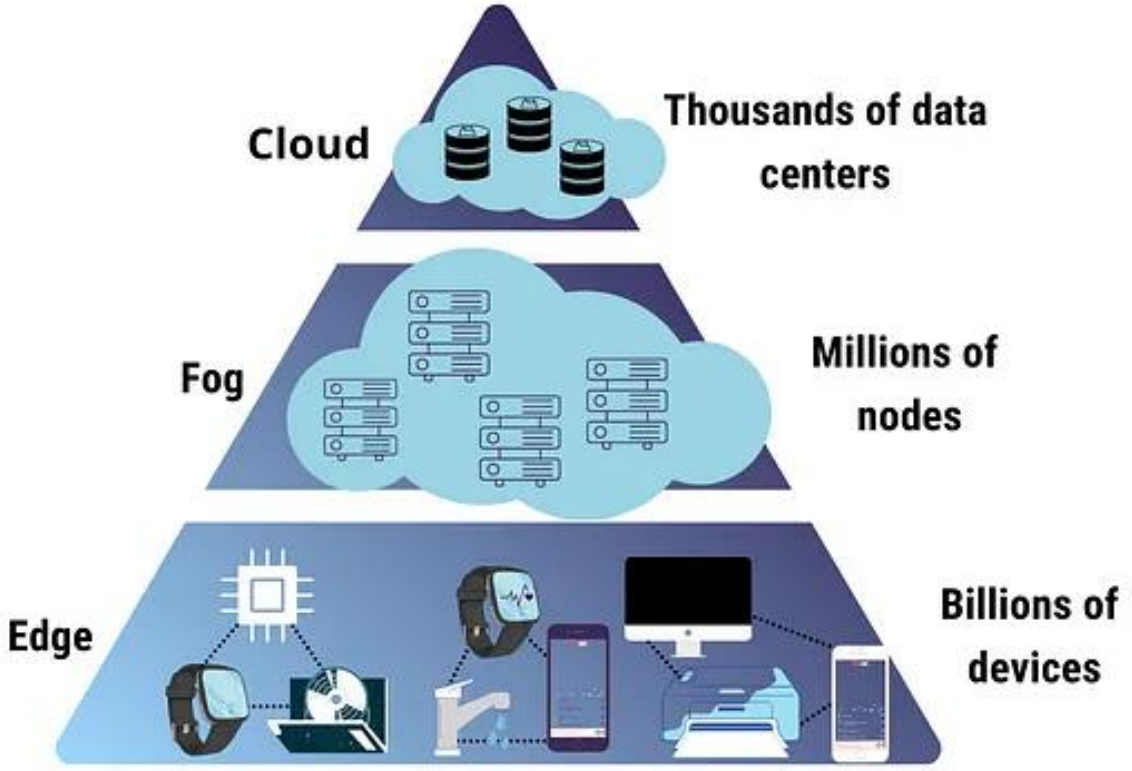
- Set of services for IoT data
  - Collection
  - Storage
  - Correlation
  - Analysis
  - Exploitation
- Cloud-based computing solutions

aws IoT
Bosch IoT Suite
Microsoft Azure IoT Platform
CISCO IoT
Ayla Networks
IBM Watson
Google Cloud
thingworx
IRI Voracity An Insatiable Appetite for Data
MindSphere

Source: ITU, "*IoT Standards, Part I: IoT Technology and Architecture*", September 2018

CLOUD COMPUTING

- Storing and retrieving of data over the internet
- Significant evolution for IoT solutions
- Two implementation possibilities:
  - **Edge Computing –** data processing is performed close to the source
    - Sensor / Gateway
  - **Fog Computing –** decentralised computation between cloud and edge
    - Distributed servers



Source: Medium, "*Edge Computing vs Fog Computing*", 8th December 2022

IOT PLATFORMS IN 2021

Sensors / Actuators → Gateway → Network Infrastructure → Platforms

IOT ANALYTICS

Your Global IoT Market Research Partner

The World's Biggest Corporations Are Using IoT Platforms

Industry	Corporation	Selected IoT platform vendor(s)
Retail	Walmart	Microsoft
Utilities	enel	C3.ai
Automotive	VW	aws, SIEMENS, Microsoft
Transportation / shipping	Port of Rotterdam	IBM, cisco
Glass manufacturing	LG CNS	Google Cloud
Food & beverage	Carlsberg	ptc, Microsoft
Shipping	Hapag-Lloyd	ERICSSON, Globe Tracker

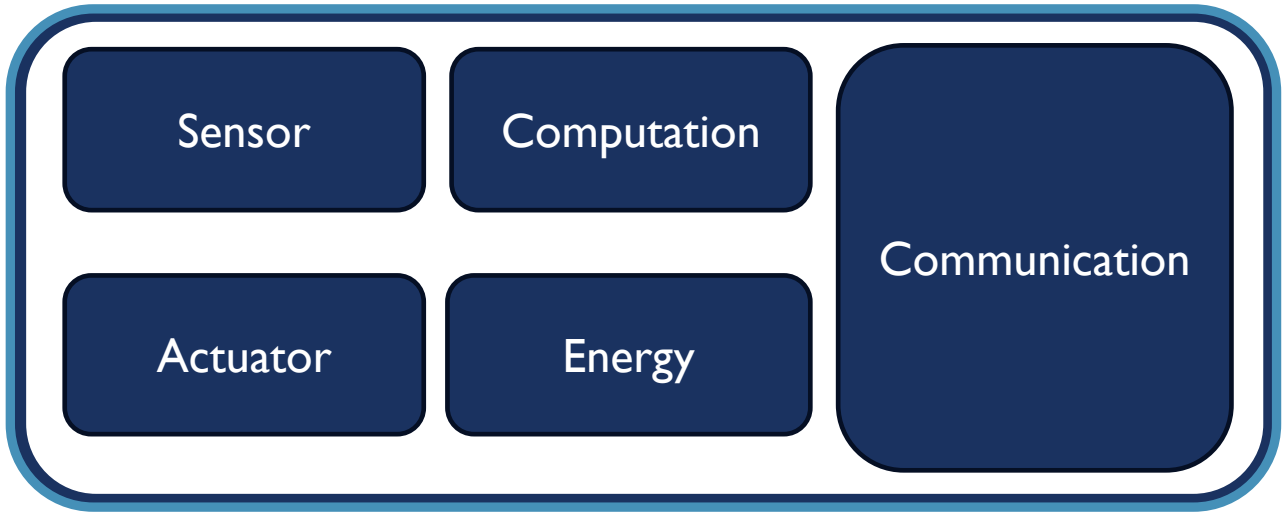
Note: Based on publicly information in May 2021. List is not exhaustive and subject to change.
Source: IoT Analytics Research 2021

Source: IoT Analytics, "*5 Things to Know About the IoT Platforms Market*", 8th June 2021

IV. TECHNOLOGICAL SOLUTIONS

GENERAL CHARACTERISTICS

- Interaction between the physical world and IT networks



GENERAL CHARACTERISTICS

- Interaction between the physical world and IT networks

Sensor	• Translate physical value into electrical signal
Actuator	• Modify the environment
Computation	• Local data analysis
Energy	• Power supply relative to the application
Communication	• Data transmission through specific or standard protocols, wired or wireless

GENERAL QUESTIONS

- Choosing a platform depends on the objective and intended use

- What data analysis is needed on the device ? → **Computing power**
- What needs to be stored on the device → **Memory**
- What interactions do I need with the world → **Sensors / Actuators**
- What use do I need and what power solution do I want → **Autonomie**
- What communication do I need and in what form → **Standard or dedicated protocols, wired / wireless, crypted traffic**
- How many devices do I need and what level of reliability do I want → **Cost**

TECHNOLOGICAL REVOLUTION

- Arrival of easy to access low-cost solutions
- Two main solutions

- Systems build around embedded OS
  - *Advantages* – Open, powerful, multiple programming languages
  - *Disadvantages* – Somewhat complex to use, long time to use, average reaction times, relatively high costs, more difficult to interface with other solutions
- Ex: Raspberry PI, Raspberry PI Zero

- Dedicated compact systems with proprietary software
  - Advantages – Very reactive, very low cost, more robust, easy interfacing, quick to use
  - Disadvantages – Less powerful, limited programming languages, lot less flexibility with software
- Ex: Arduino, ESP8266, ESP32, Raspberry PI Pico

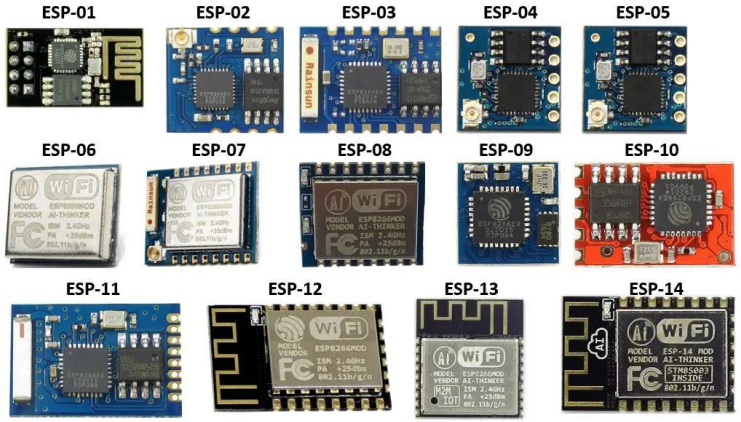
EXAMPLES

Arduino UNO Rev 3 ≈ 25€

Raspberry Pi 5 ≈ 70€

EVEN CHEAPER EXAMPLES …

Raspberry Pi Zero ≈ 15€

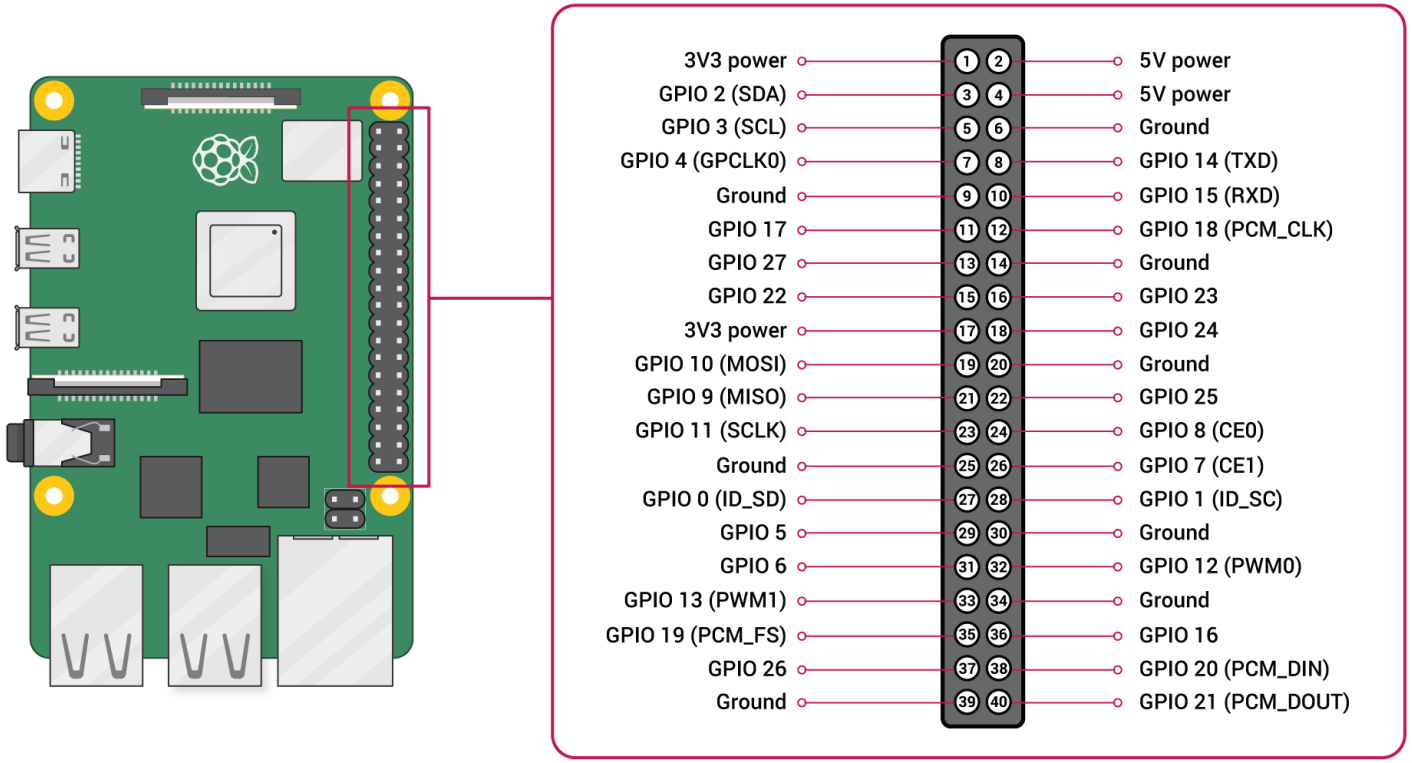


Espressif ESP 8266 ≈ 2€

RASPBERRY PI 5

Chipset	Broadcom BCM2712 SoC
CPU	2.4GHz quad-core 64-bit Arm Cortex-A76 CPU
RAM	4GB / 8GB 32-bit LPDDR4X
Storage	MicroSD card
Connections	2 × USB 3.0 ports, supporting simultaneous 5Gbps operation 2 × USB 2.0 ports 2 × 4-lane MIPI camera/display transceivers PCIe 2.0 x1 interface for fast peripherals Raspberry Pi standard 40-pin GPIO header
Power	600mA to 3A @ 5V
Networking	Dual-band 802.11ac Wi-Fi® Bluetooth 5.0 / Bluetooth Low Energy (BLE) Gigabit Ethernet, with PoE+ support

RASPBERRY PI 5



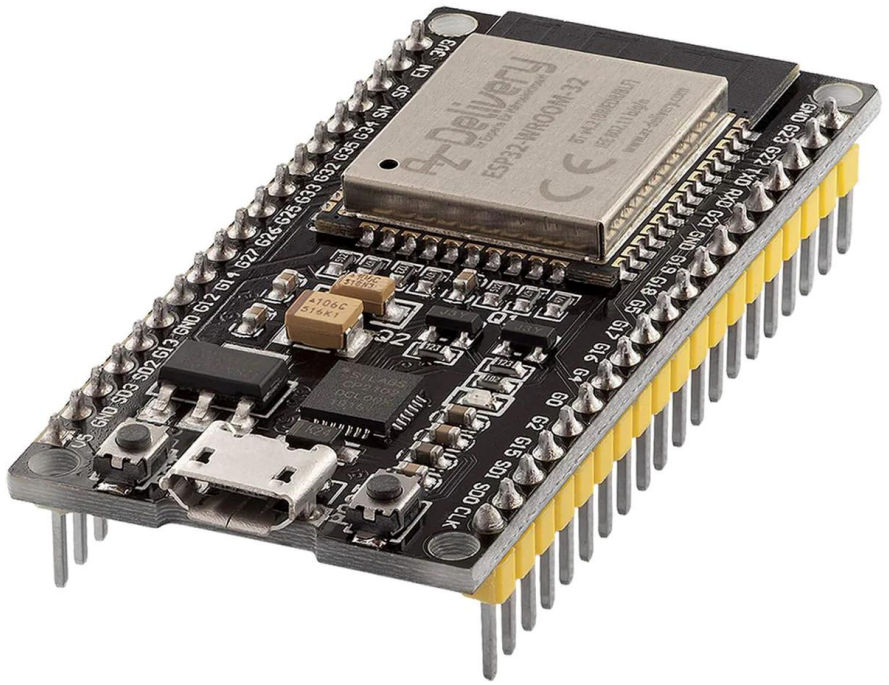
GPIO Pinout – General Purpose Input Output

RASPBERRY PI 5

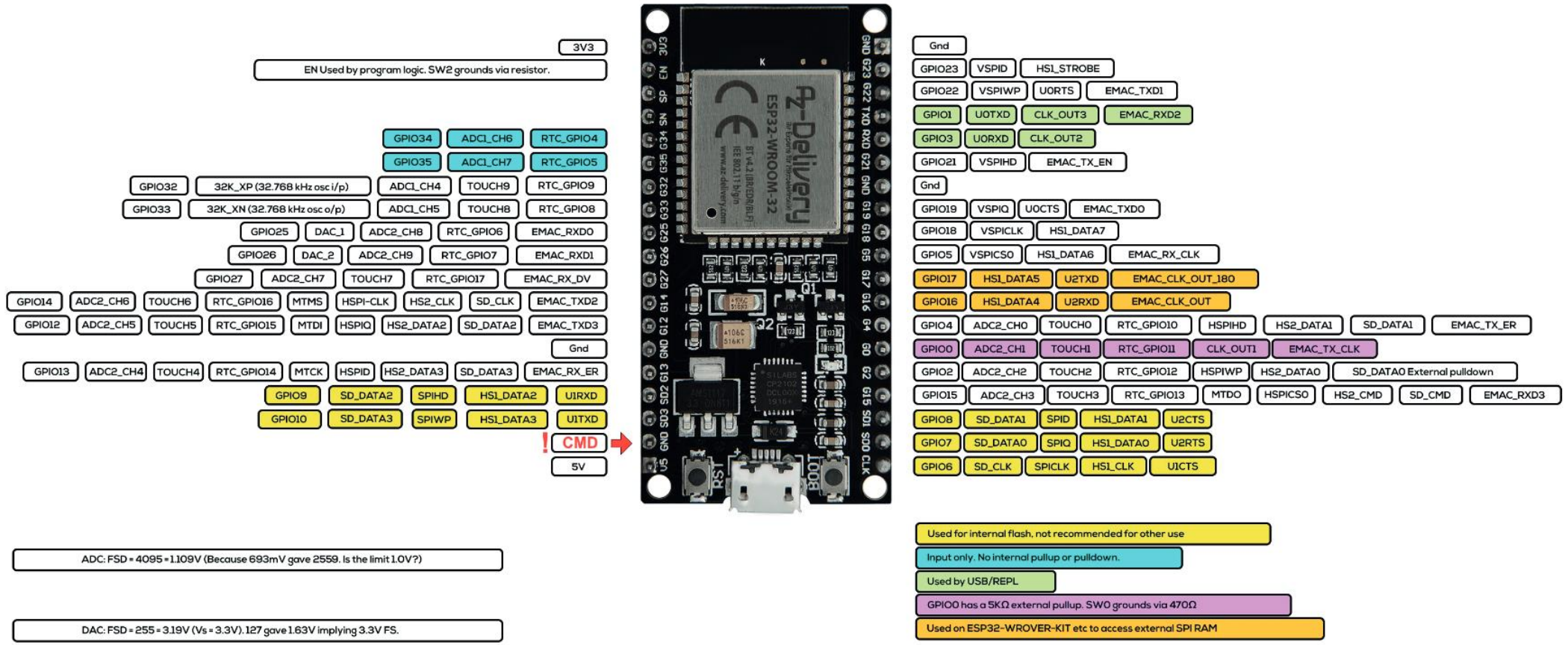
Powered by
Raspberry Pi OS

NODEMCU – ESP32

Chipset	ESP32-Wroom-32
CPU	240Mhz dual-core Tensilica LX6
RAM	512kb SRAM
Storage	4MB external flash
Connections	SPI, I2C, I2S, Can, Uart 34-pin GPIO header
Power	80mA to 600mA @ 3.3V via GPIO – down to 10 µA in deep sleep Can be powered by USB
Networking	802.11 b/g/n Wi-Fi® Bluetooth 4.2 / Bluetooth Low Energy (BLE)



NODEMCU – ESP32



RASPBERRY PI 5 VS NODEMCU – ESP32

	Raspberry Pi 5	NodeMCU – ESP32
Chipset	Broadcom BCM2712 SoC	ESP32-Wroom-32
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RAM	4GB / 8GB 32-bit LPDDR4X	512kb SRAM
Storage	MicroSD card	4MB external flash
Connections	2 × USB 3.0 ports, supporting simultaneous 5Gbps operation 2 × USB 2.0 ports 2 × 4-lane MIPI camera/display transceivers PCIe 2.0 x1 interface for fast peripherals Raspberry Pi standard 40-pin GPIO header	SPI, I2C, I2S, Can, Uart 34-pin GPIO header
Power	600mA to 3A @ 5V	80mA to 600mA @ 3.3V via GPIO – down to 10 µA in deep sleep Can be powered by USB
Networking	Dual-band 802.11ac Wi-Fi® Bluetooth 5.0 / Bluetooth Low Energy (BLE) Gigabit Ethernet, with PoE+ support	802.11 b/g/n Wi-Fi® Bluetooth 4.2 / Bluetooth Low Energy (BLE)

V. PRACTICAL

YOUR TIME TO SHINE

VI. PRACTICAL

- Hands on with IoT devices
- Challenge-based programming

- Coming soon!!