IoT Architecture Introduction

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2023 - 2024

Schedules

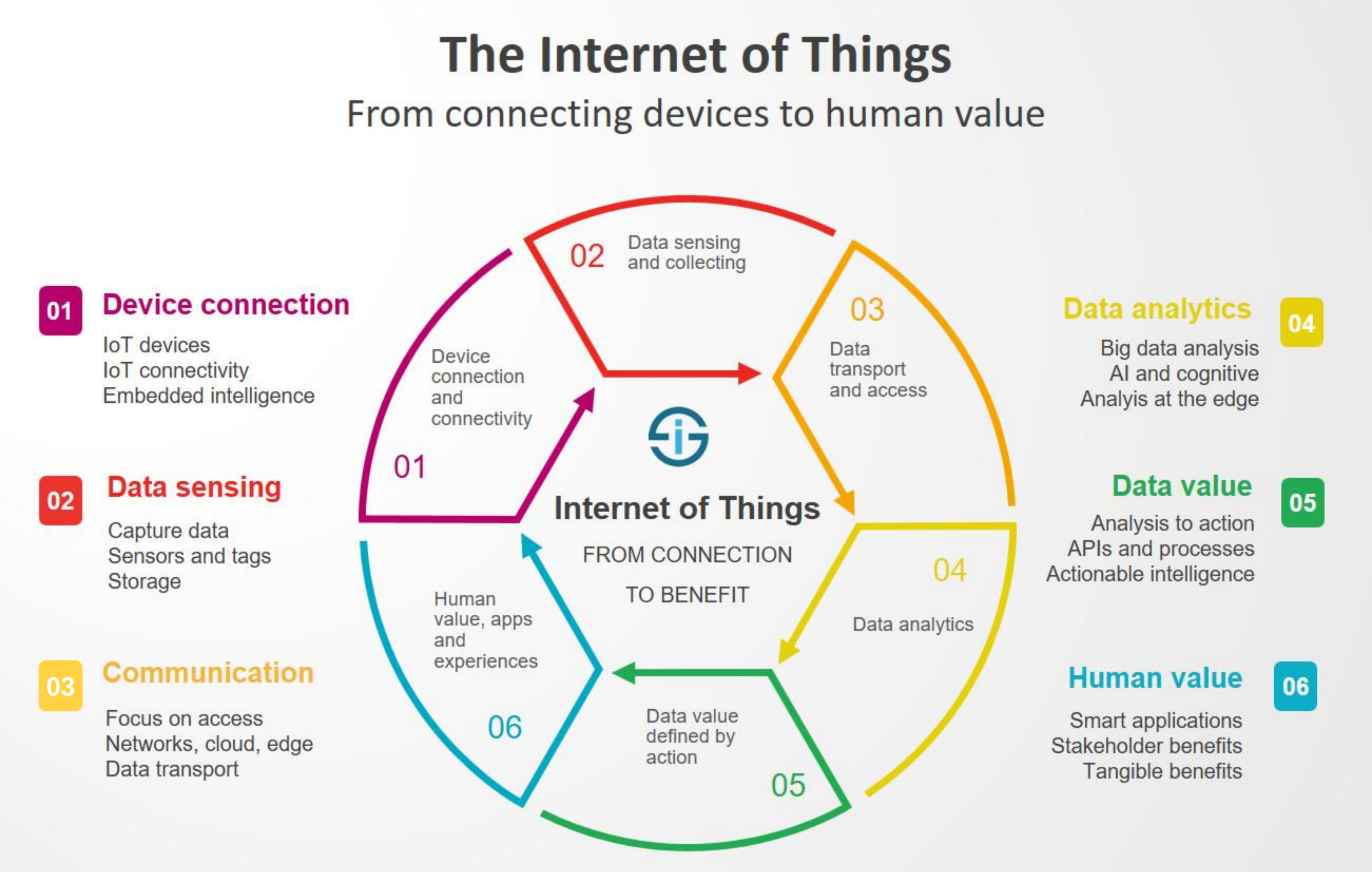
- Introduction of IoT Architecture
- Part 1 : short course + Sensors, Input/Output lab
- Part 2 : short course + Sensors, I2C lab
- Part 3 : short course + WiFi Networking lab
- Part 4 : short course + Broker & MQTT protocol lab
- Evaluation (2h): evaluation on sheet, not on the computer

Internet of Things (IoT)

- What is it ?
  - Paradigm refers to a system of end-devices
  - Interconnected with each other
  - Large data is being generated and transmitted across several devices
  - Equipped with computational capacity (smart objects)
  - Specific point is used to collect and to combine all data
  - Identifiable and enabled to transfer data over a network while requiring very little human intervention

- The term “Internet of Things” was first used in 1999 by Kevin Ashton
- Explain possible benefits of using RFID technology in goods management

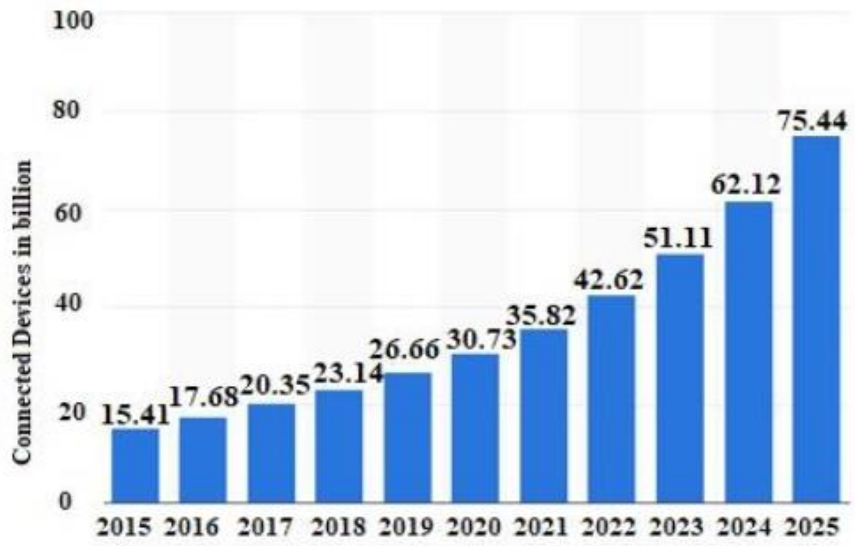
Internet of Things (IoT)
Connected objects to human value



INFOGRAPHICS: THE INTERNET OF THINGS - FROM CONNECTING DEVICES TO HUMAN VALUE, SOURCE: I-SCOOP

How many connected objects?

- Period between 2008–2009
  - number of connected objects exceeded the world population
- In 2017
  - About 20 billion connected objects
- In 2021
  - About 35 billion connected objects
  - Generates a market of about $500 billion
- In 2030
  - Connected objects will exceed 125 billion
- Became widespread in everyday life
  - Continuous technological developments
  - considerable investments by companies



Internet of Things (IoT) connected devices from 2015 to 2025 (in billions)

Reference: Alam, Tanweer. (2018). A Reliable Communication Framework and Its Use in Internet of Things (IoT).

IoT Layers

- There is no single consensus on architecture for IoT
- 5 IoT Layers define the fundamentals of almost every IoT system

To work at an edge or near the device to collect information

To cover all aspects of protecting the IoT architecture

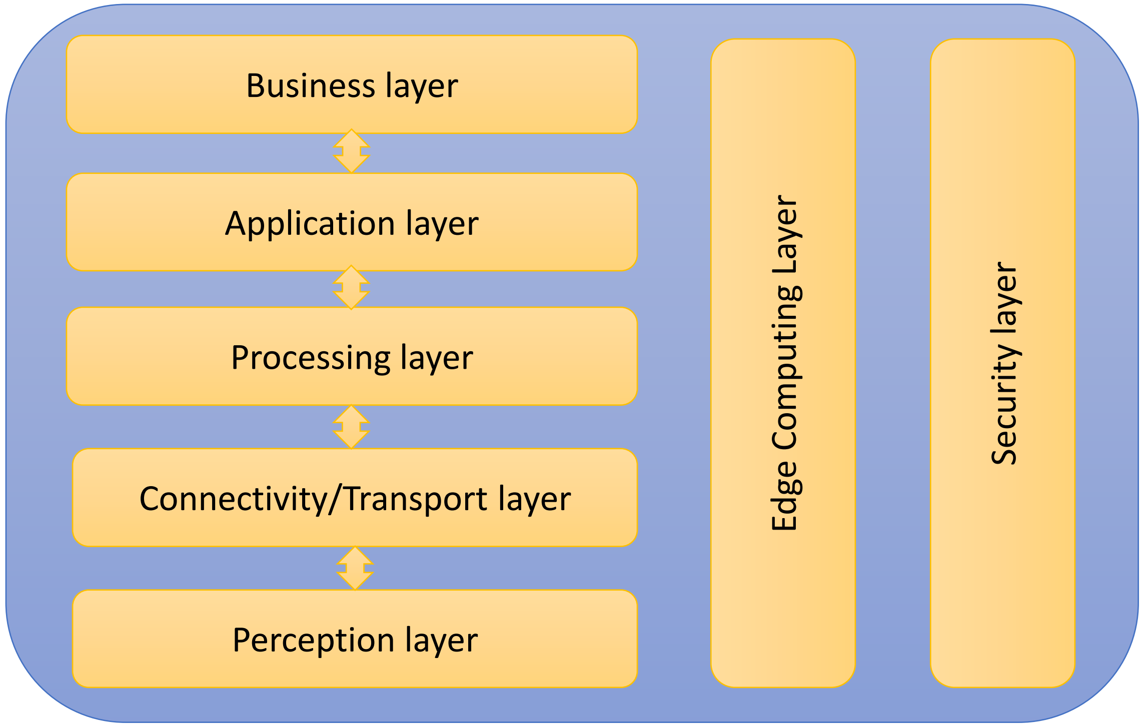
To derive information and decision-making analysis from data

To aid in the procedures of analytics, device control, and reporting to end-users

To control and to manage IoT levels to streamline data across the system

To allow transferring data from the devices to cloud and vice-versa
To deal with different aspects of gateways and networks

To manage smart devices across the system



1- Perception layer



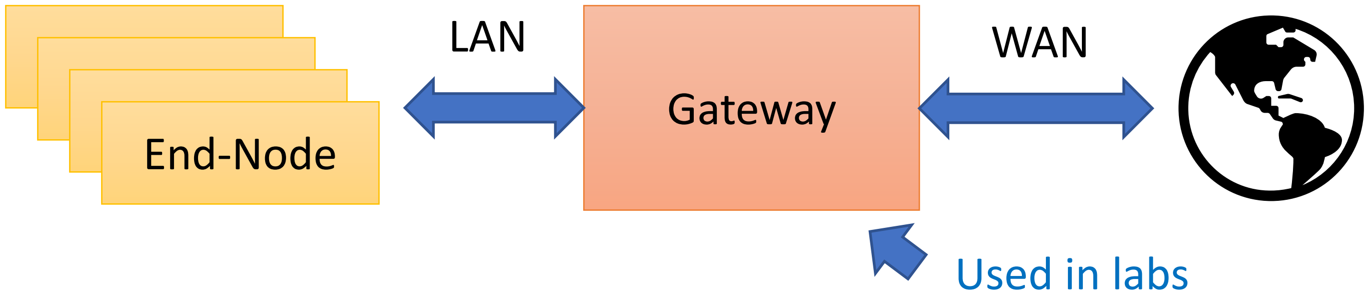

- Physical layer
- Sensors for sensing and gathering information about the environment
- The main function is to transform analog signals into the digital form and vice versa
- Sensors
  - Small devices or systems built to understand and detect the change in their environment and further streamline information to their system
  - Temperature sensors and thermostats, pressure sensors, light intensity detectors, proximity detection, RFID tags
- Actuators
  - To allow an electrical signal to be transformed into physical actions for a machine
- End Node = Sensors or Actuators





2- Connectivity/Transport layer (1)

- Also called *Network layer*
- Responsible for connecting to other smart things, network devices, and servers
- Focus on Communication, 2 cases:
  - Directly by either TCP or UDP/IP stack
  - Gateways act as a link between Local Area Network (LAN) and Wide Area Network (WAN)



2- Connectivity/Transport layer (2)
Some network technologies

- WiFi
  - Most popular and versatile technique used across data-driven technologies

Used in labs

- Ethernet
  - To support fixed or permanent devices such as video cameras, gaming consoles, and security installations

Used in labs

- Bluetooth
  - Widely used technology suited mainly for communication between devices within a short range
- NFC (Near Field Communications)
  - Communication between a very short distance of around 10 cm or less
- LPWAN (Low Power Wide Area Network)
  - Designed and built to match the IoT usage across long distances
  - Can last as much as 10 or more years while consuming low power
- ZigBee
  - Consumes low power and can offer small data-sharing ability
  - Capability to handle up to 65,000 nodes
- Cellular networks
  - Suited for communication on a global scale with more trust and reliability
  - LTE-M is Long Term Evolution for Machines (very high-speed exchange of data and smooth direct cloud communication)
  - NB-IoT (NarrowBand) offers small data exchange using low-frequency channels

2- Connectivity/Transport layer (3) Messaging protocols

- To allow seamless data sharing
- Data Distribution Service (DDS)
  - On top of transport layer in the OSI model
  - Machine-to-machine (M2M) real-time messaging framework
- Advanced Message Queuing Protocol (AMQP)
  - OSI layer: Application Layer
  - Server protocol for servers via peer-to-peer data exchange
- Constrained Application Protocol (CoAP)
  - OSI layer: Application Layer
  - Protocol for constrained devices that use low power and low memory, such as wireless sensors
- Message Queue Telemetry Transport (MQTT) ⇐ Used in labs
  - OSI layer: Application Layer
  - Messaging protocol standard for low-powered devices using TCP/IP for seamless data communication

3- Processing layer

- Also called *middleware Layer*
- To store, to analyze, and to processes huge amounts of data
- To manage and to provide a diverse set of services to the upper layers (databases, cloud computing, and big data processing)
- 2 main stages
- Data Accumulation
  - Every device sends lot of data streams across the IoT network
  - Separating the essential data from these large streams
- Data Abstraction
  - Selected data is taken out from the large data for application layer to optimize their business procedures
  - Collecting all the data from all IoT and non-IoT systems (CRM, ERP, & ERM)
  - Using data virtualization to make data accessible from a single location
  - Managing raw data in multiple forms
- Easy for using data for application and business layer !

Application & Business layers

- Application
  - Define various applications in which the IoT can be deployed
  - Smart homes, smart cities, and smart health
- Business
  - To manage the whole IoT system, including applications, business and profit models, and users’ privacy
  - Data is further processed and analyzed to gather business intelligence
  - Examples
    - Business decision-making softwares
    - Device control and monitoring services
    - Analytics solutions built with Machine Learning (ML) and Artificial Intelligence (AI)
    - Mobile Application for further interactions

Edge Computing Layer

- Situations
  - The size and numbers, latency for IoT framework becomes one of the major hurdles
  - Multiple devices tried connecting with the main center
    - Bottleneck problems
    - Delays for some procedures
- Edge Computing Layer
  - To process and analyze the information close to the source as much as possible
  - 5G networks offer systems to connect with more devices at a lower latency

Security Layer

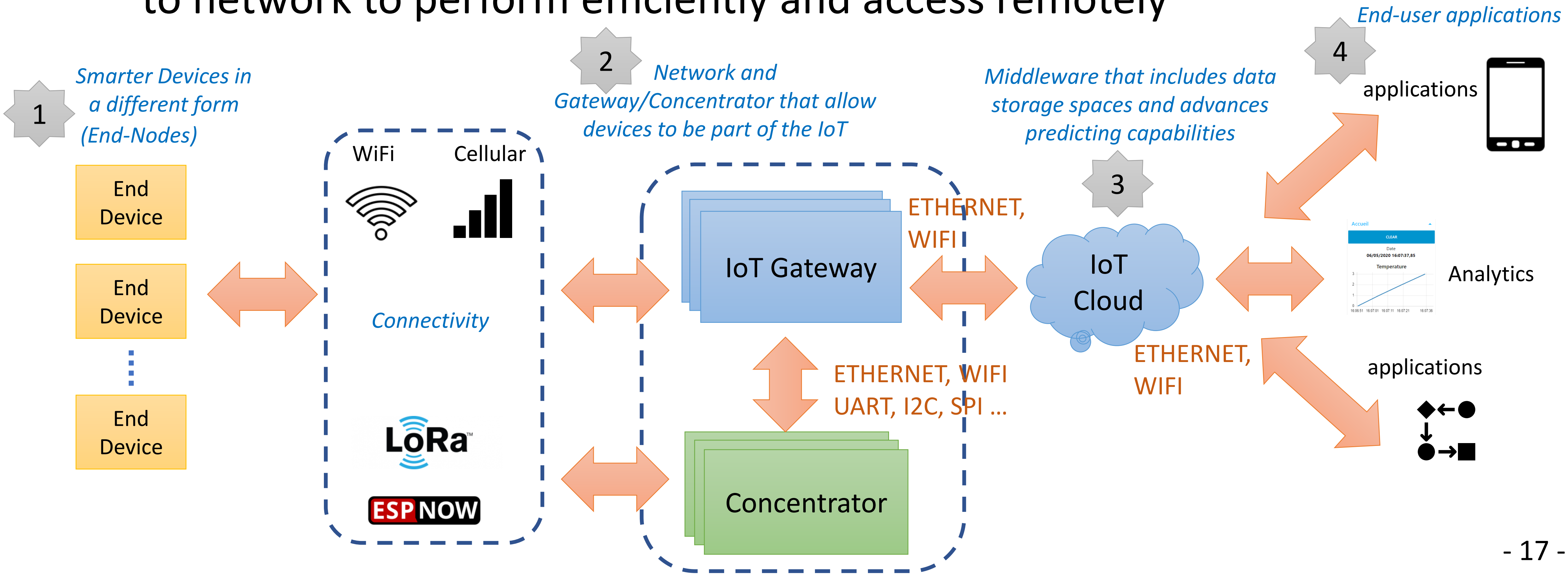
- Security is one of the main necessities of IoT architectures at each layer
- Device Security
  - Secure boot process to avoid any malicious code running on a device
  - Using Trusted Platform Module (TPM) chips in combination with cryptographic keys for devices endpoint protections
- Cloud Security
  - Multiple authorization factors and encryptions to avoid any data breach
  - Device identity management
- Connection Security
  - Must be encrypted from an end-to-end point
  - Messaging protocols such as DDS, AMQP, and MQTT are integrated to secure sensitive information from any breach
  - Use of TSL cryptographic protocol

Most Common IoT Architectures
Main challenges

- **Scalable**: to manage the increasing number of devices and services without degrading their performance
- **Interoperable**: devices from different vendors can cooperate to achieve common goals
- **Distributive**: to allow creating of a distributed environment in which, after being collected from different sources, data are processed by different entities in a distributed way
- **Able to operate with few resources:** since objects have little computing power
- **Secure**: not to allow unauthorized access

Internet of Things (IoT) Framework
Goal

- Transformation process of connecting our smart devices and objects to network to perform efficiently and access remotely

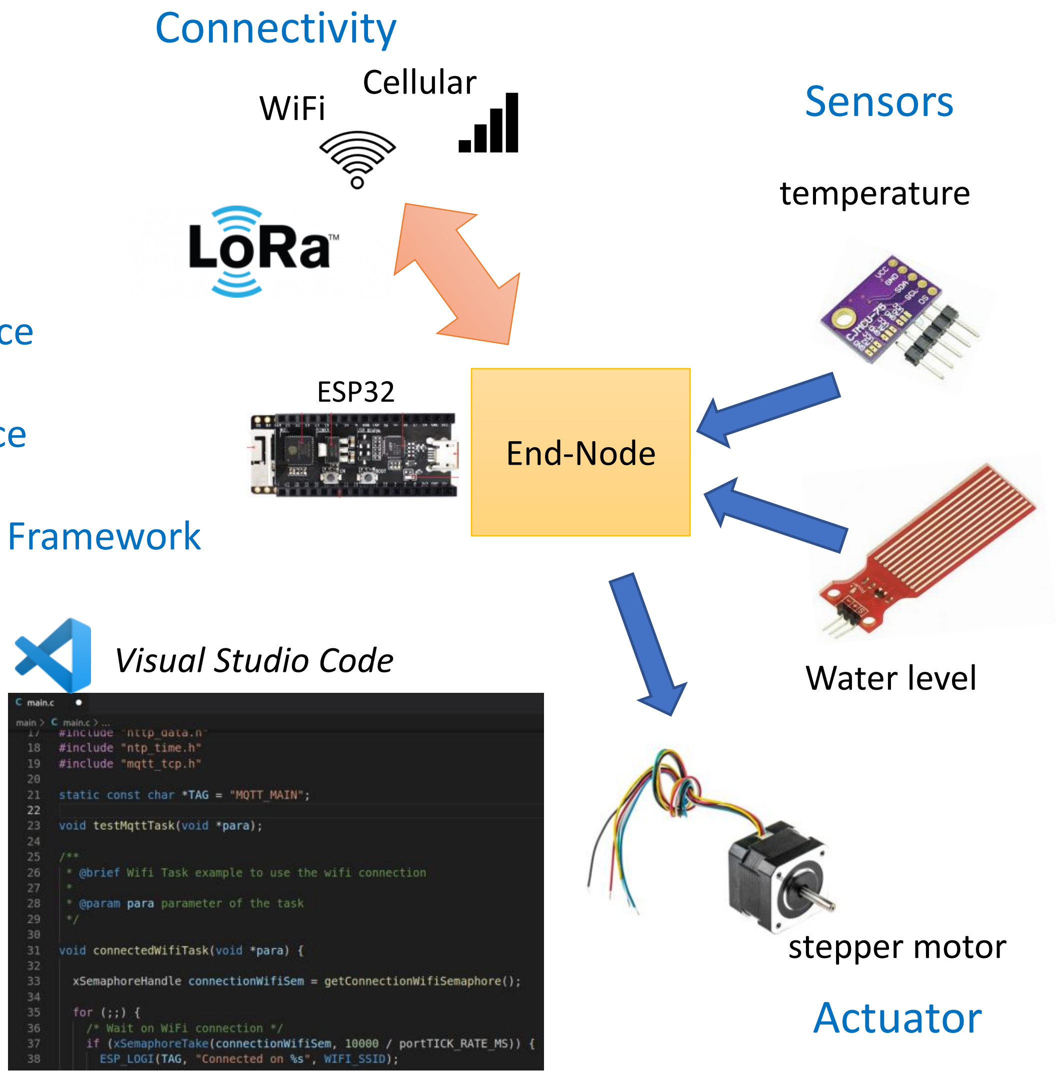


End-Device / End-Node

1

- Also called *End-node*
- Perception layer
- End-Node
  - Sensors
  - Actuators
  - Sensors + Actuators
- Hardware part
  - Knowledge on architecture
  - Micro-controllers
  - Sensor/Actuator behaviors
  - Communications (I2C, SPI, CAN, UART, ...)
- Software part
  - Write applications (C, C++, µPython …)
  - Configure the controller, sensors, actuators
  - Understand of how an API works inside the micro-controllers
- End-Node example
  - ESP32 board + sensors

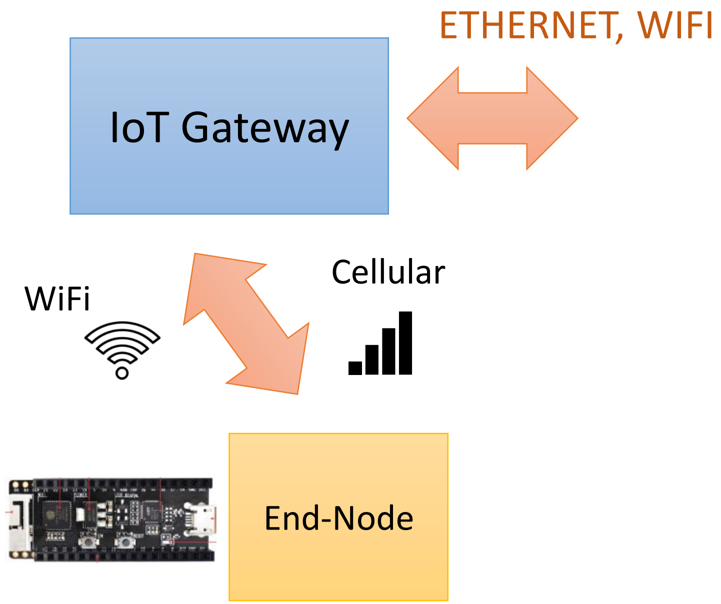
End-Node
=
Hardware Device
+
Software Device
+
Communication with IoT Framework

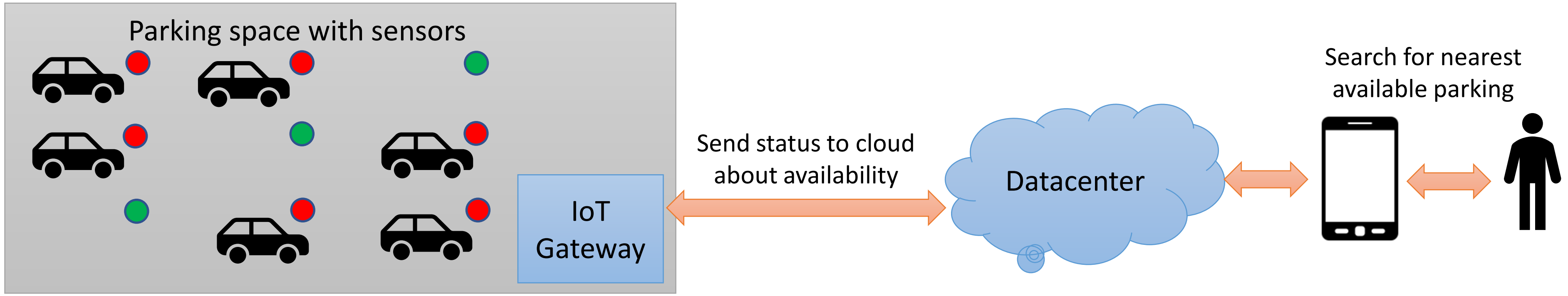


IoT Gateway

2

- To manage the bidirectional data traffic between different networks and protocols
- To translate different network protocols and make sure interoperability of the connected devices and sensors
- To perform preprocessing, filtering of the collected data from thousands of sensors locally before transmitting it to the next stage
- To offer certain level of security for the network and transmitted data with higher order encryption techniques





Concentrator & Bridge

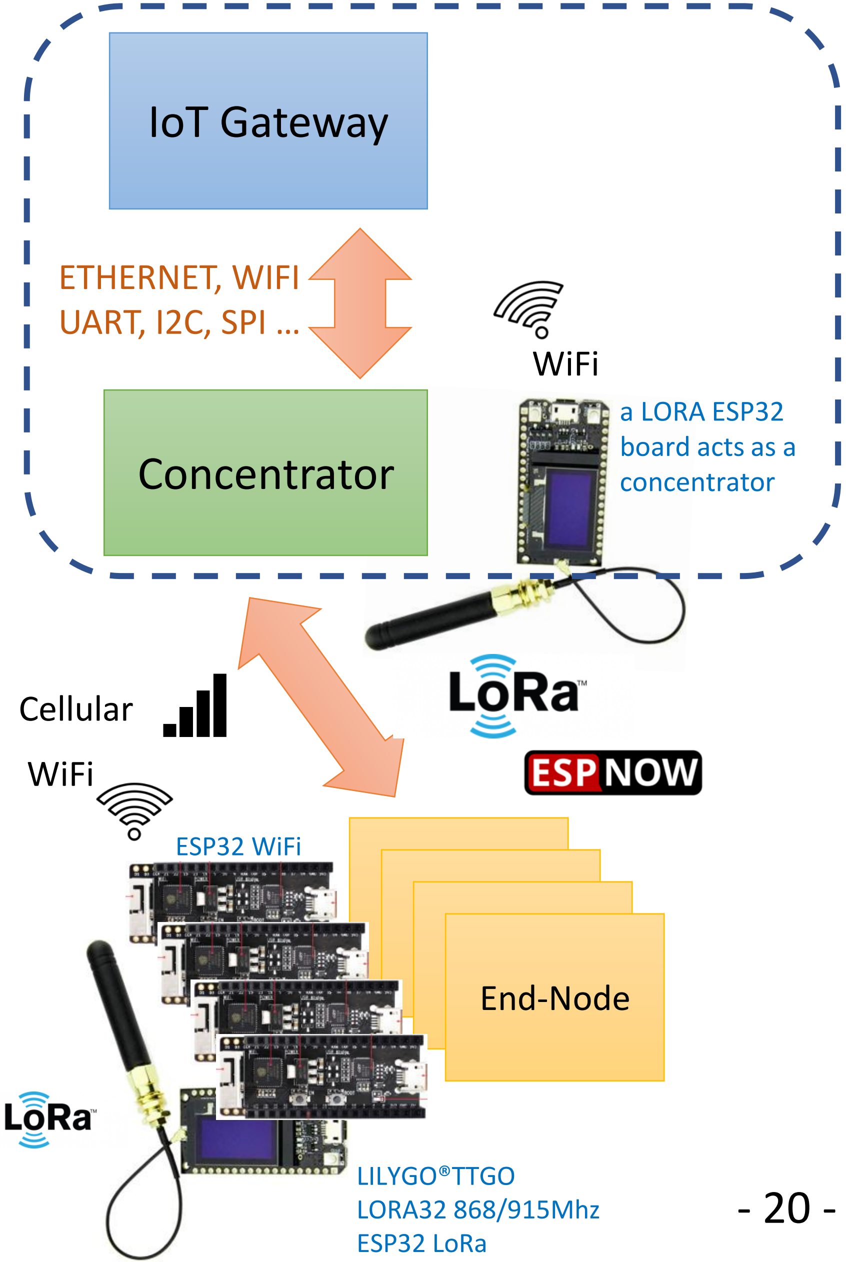
2

- Also called *IoT Edge Gateway*
- The Concentrator is the communication bridge between
  - Several End-Nodes
  - The IoT Gateway
- (1) Concentrator is a part of the IoT Gateway
  - Considering the Concentrator as the IoT Gateway (dotted line = IoT Gateway)
  - WiFi, 3/4/5G communications with End-Node (TCP/IP protocols)
  - Example: WISE-5231M-4GE Intelligent IoT Concentrator
- (2) Concentrator is not included in the IoT Gateway
  - Using I2C, SPI, UART local communication
  - LORA, ESP-NOW communications with End-Node
  - Example: iC880A-SPI LoRa® Concentrator

WISE-5231M-4GE Intelligent IoT Concentrator

https://www.measurementsystems.co.uk/wise-5231m-4ge--intelligent-iot-concentrator-4g

- Support Modbus TCP/RTU, SNMP, FTP and MQTT protocols
- Support 4G/3G wireless data communication
- Support Connection with IoT Cloud Platform (Microsoft Azure and IBM Bluemix)
- No more programming, Web pages provided for control logic editing

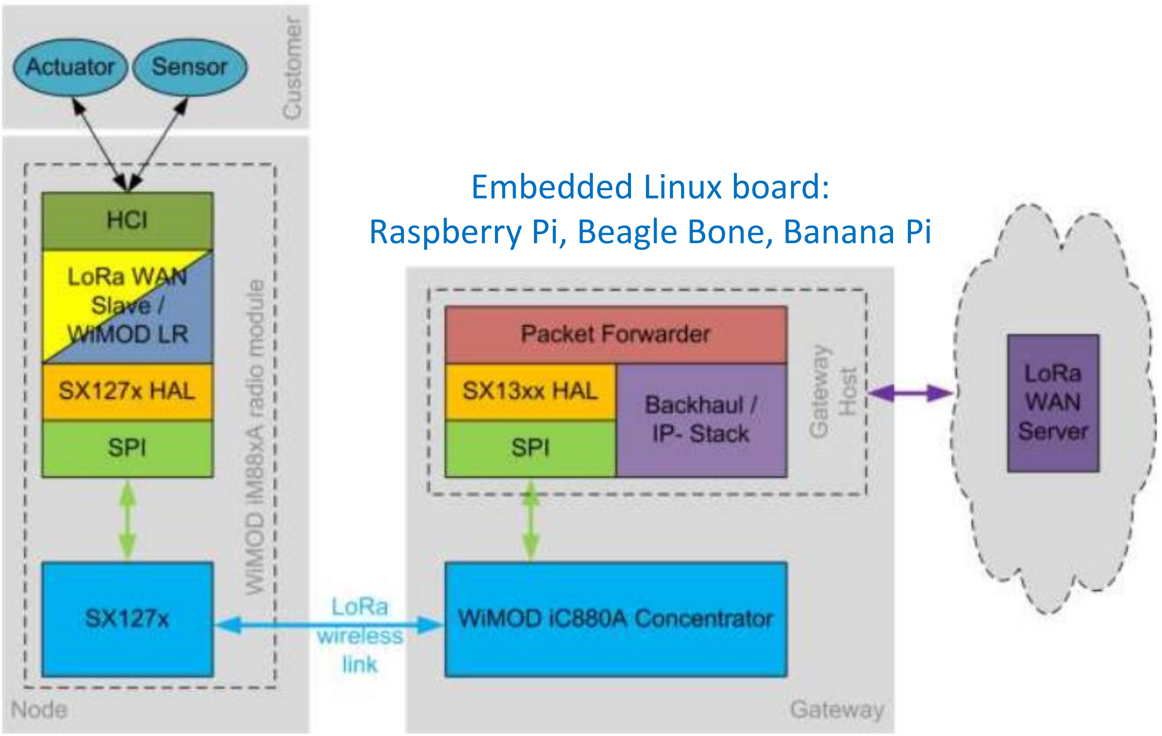


Concentrator & Bridge
Example - iC880A-SPI LoRa® Concentrator

2

- LoRaWAN® gateway
- To provide robust communication between a LoRa® gateway and a huge amount of LoRa® end-nodes
- To be able to receive up to 8 LoRa® packets simultaneously sent with different spreading factors and on different channels
- Embedded Linux boards

https://wireless-solutions.de/products/lora-solutions-by-imst/radio-modules/ic880a-spi/



IoT Cloud

3

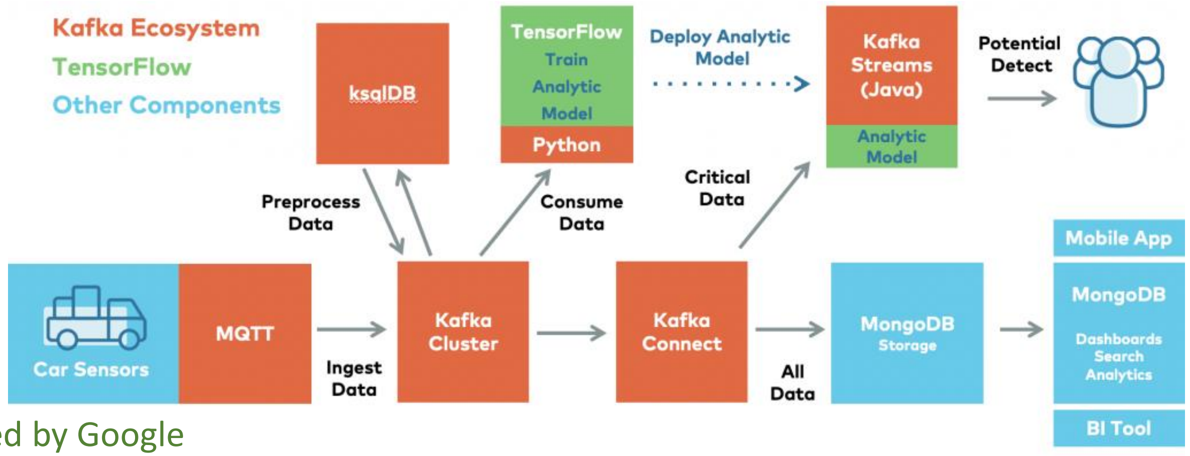
- Why?
  - IoT creates massive data from devices, applications and users
  - To manage data in an efficient way
- IoT cloud offers tools to collect, process, manage and store huge amount of data in real time
- IoT cloud is a sophisticated high-performance network of servers optimized to perform high speed data processing of billions of devices, traffic management and deliver accurate analytics
- Distributed database management systems are one of the most important components of IoT cloud

End-user applications
Analytics

4

- Smart analytics solutions are inevitable for IoT system for management and improvement of the entire system
- To help engineers to find out irregularities in the collected data
- To act fast to prevent an undesired scenario
- To make decisions for their future business opportunities
- Example: Apache Kafka
  - Pre-processing and filtering as well as intermediate storage
  - Kafka ecosystem processes analytical workloads
  - Mission-critical transactional data sets with zero downtime and zero data loss

https://www.confluent.io/fr-fr/blog/iot-streaming-use-cases-with-kafka-mqtt-confluent-and-waterstream/



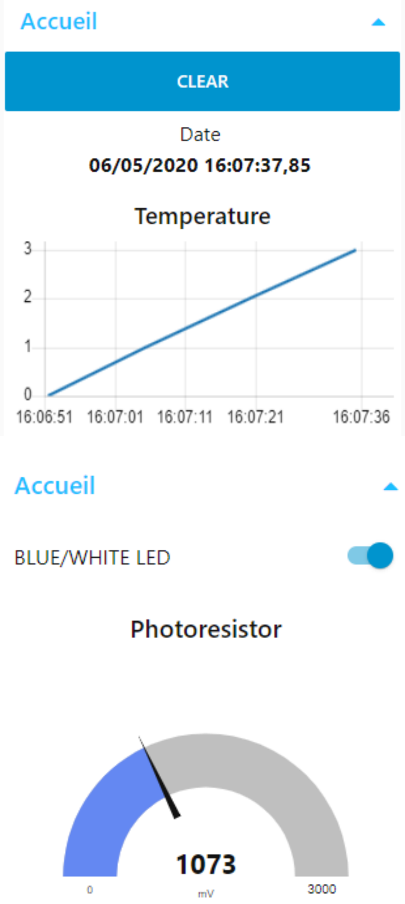
TensorFlow is an open-source Machine Learning (ML) tool developed by Google

End-user applications
User interface

4

- User interfaces are the visible, small part of the IoT system which can be accessible by users
- Must have well-designed user interface for a minimum effort for users and to encourage more interactions
- Example: Node-RED ⇦ Used in labs
  - Open-Source flow based on tool, IoT platform and Dashboard developed by IBM
  - To build easily applications by joining together black box functions (nodes) using a web interface
  - To build IoT and Home control dashboards and automations

Node-RED User Interface

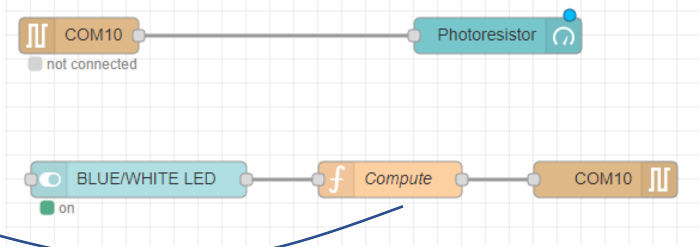


Function javascript

```
var led_state = msg.payload;
if (led_state === false)
    msg.payload = "WHITE:1000";
else
    msg.payload = "BLUE:500";

return msg;
```

Programming view



Cloud Frameworks

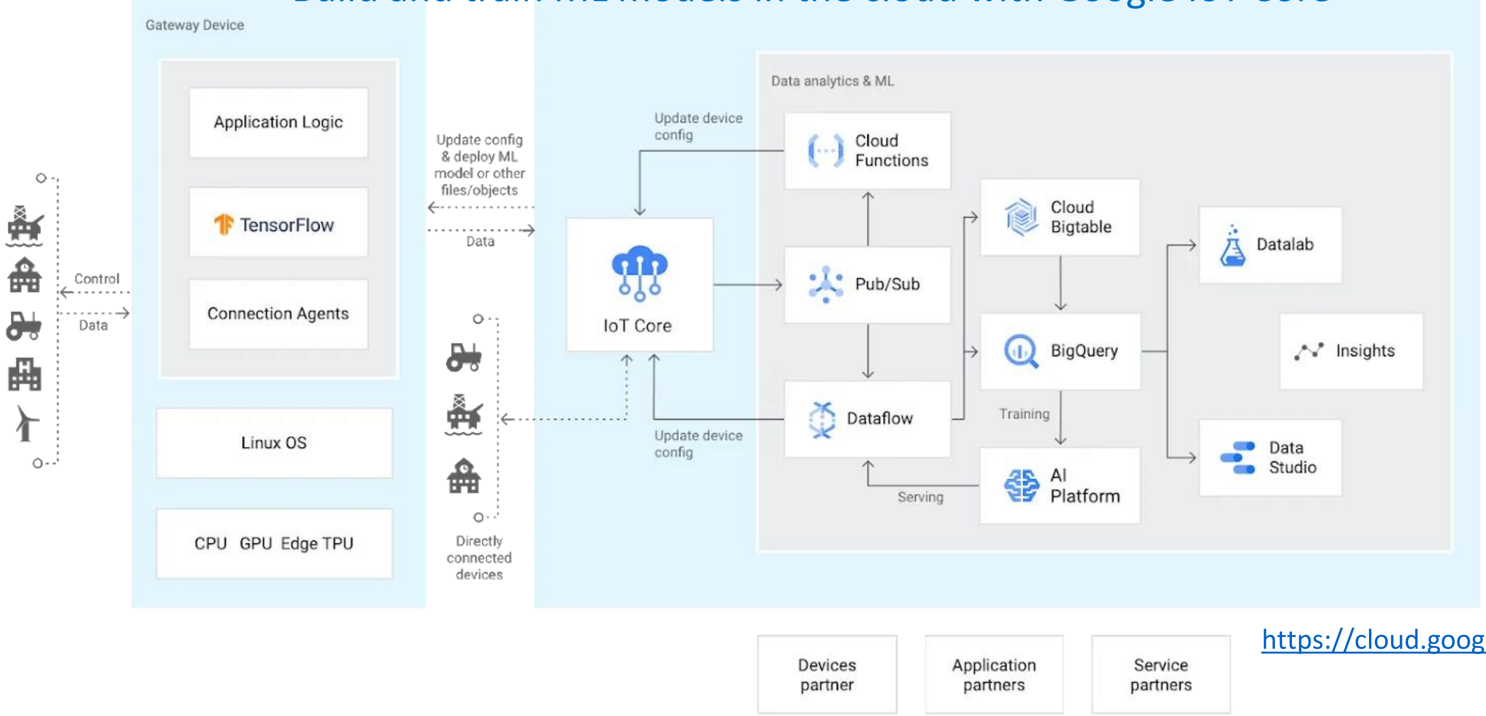
4

- AWS IoT (Amazon Web Services)
- Azure IoT (Microsoft)
- Google IoT Core (Google)

All frameworks are supported by ESP-IDF framework !

Build and train ML models in the cloud with Google IoT Core

End-Nodes
sensors
actuators



https://cloud.google.com/iot-core

Where using IoT Applications?

- Industrial IoT
  - Include various types of devices for industrial use
- Commercial IoT
  - IoT Healthcare, Smart City …
- Consumer IoT
  - smartphones, smart car, smartwatch …
- Current technologies can now be defined as mature
- Challenge: The miniaturization and integration of components/sensors/actuators
  - Can expand with the integration of silicon components into metallic or fabric materials
  - To quickly harvest the necessary energy from their environment
  - To withstand harsh conditions (humidity, temperature, shock and vibration …)
  - Need to be extremely reliable, and guarantee very high and consistent quality
  - Ability of smart devices to self-configure and organize themselves
- Challenge: Find standard protocols to identify objects uniquely, **MATTER**
  - founded by Google, Amazon and Apple, Zigbee Alliance
  - Old name: Connected Home over IP (CHIP)
  - Smart home interoperability protocol
  - Built upon Internet Protocol (IP)
  - Reference: https://github.com/project-chip/connectedhomeip
- Challenge: Critical field about security to find solutions to secure connected objects

References

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