IT4735E

IoT and Applications

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Course Introduction

- IT4735E:IoT and Applications
- Credits: 2 (2-1-0-4)
- Evaluation:
  - Progress: 40%, Weekly exercises, Project exercises
  - Final-term: 60%,
    - Project exercises, presentation, oral exam (Q&A)
    - Final exam

Goal

- Overview of IoT
- Architecture, layered model, components of IoT system
- IoT technologies: devices and sensors, IoT communication standards, communication protocols for IoT applications, cloud platforms
- Programming for IoT devices and systems
- Security in IoT
- Design and build an IoT application system

Content

- Chapter 1. Overview of IoT
- Chapter 2. IoT Technologies
- Chapter 3. IoT Application and Programming
- Chapter 4. IoT Safety and Security
- Chapter 5. Designing and Building IoT Systems

Chapter 1. Overview of IoT

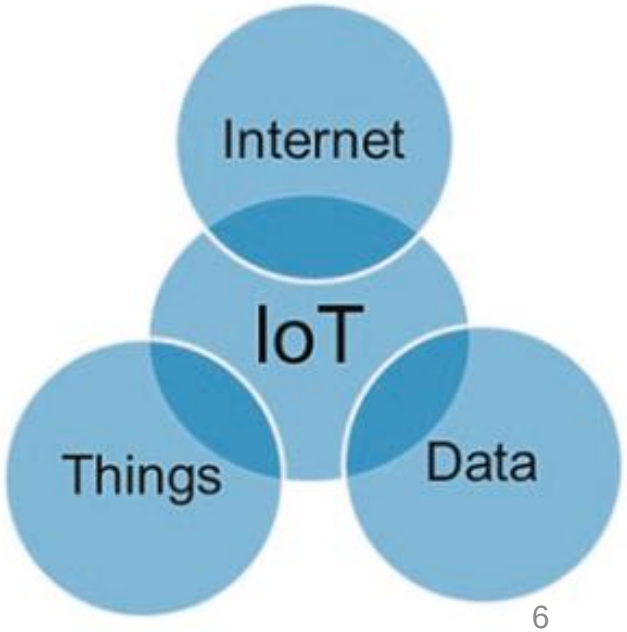
- 1.1. Overview of IoT
- 1.2. Evolution of IoT
- 1.3. Architecture of IoT System
- 1.4. IoT Technologies
- 1.5. IoT Applications
- 1.6. Challenges of IoT

1.1. Overview of IoT

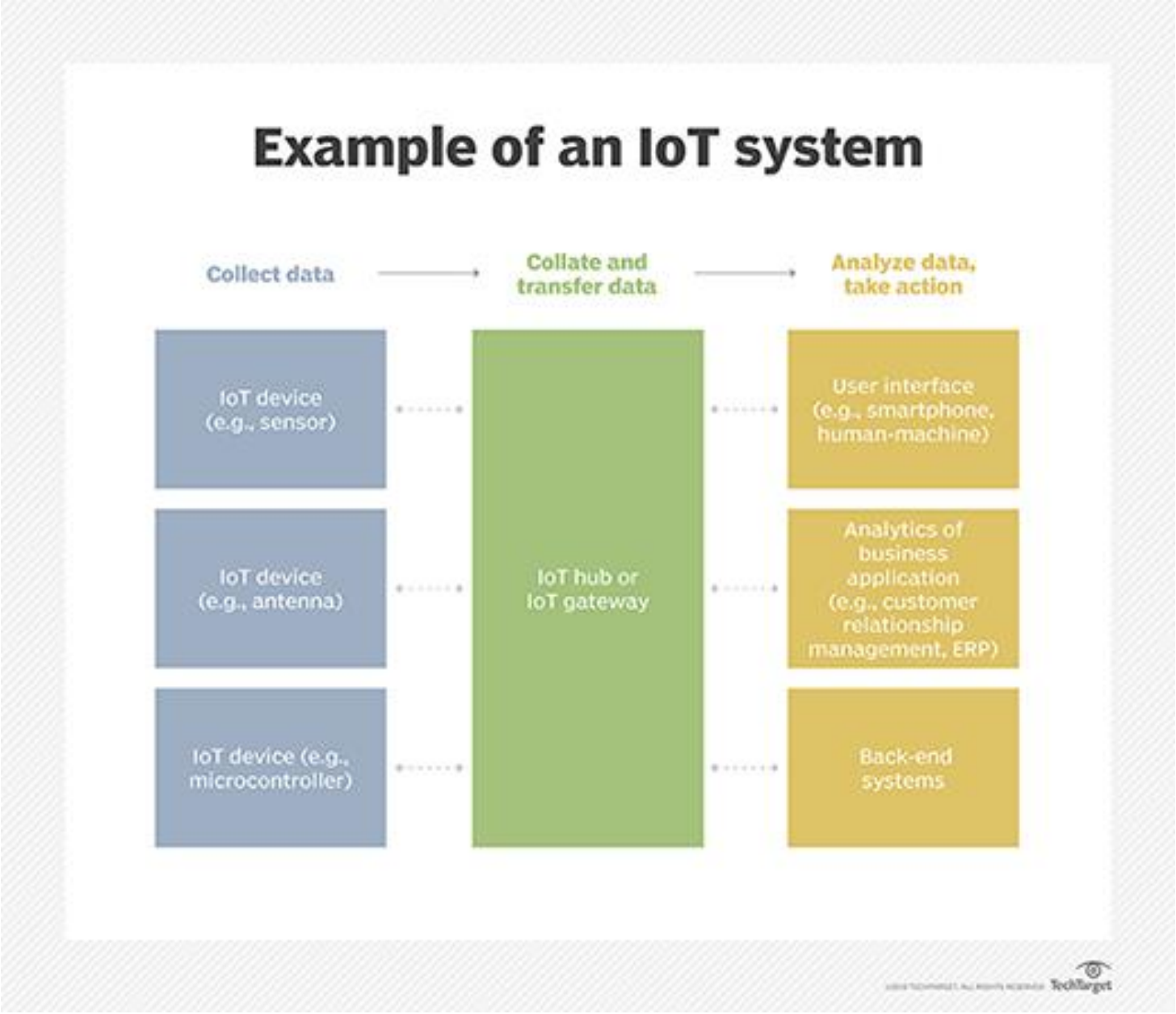
- **What is the Internet of Things (IoT) ?**
  - *IoT is the network of things, with clear element identification, embedded with software intelligence, sensors, and ubiquitous connectivity to the Internet*

    (Book: Internet of Things From Hype to Reality)
  - *Components:*
    - *Sensors*: to collect information
    - *Identifiers*: to identify the source of data (e.g., sensors, devices)
    - *Software*: to analyze data
    - *Internet connectivity*: to communicate and notify
- "Things" = "anything", "everything"
  - Home appliances, building, car, people, animals, trees, plants, ...

IoE = Internet of Everything (by Cisco)



1.1. Overview of IoT (Cont.)



1.1. Overview of IoT (cont.)

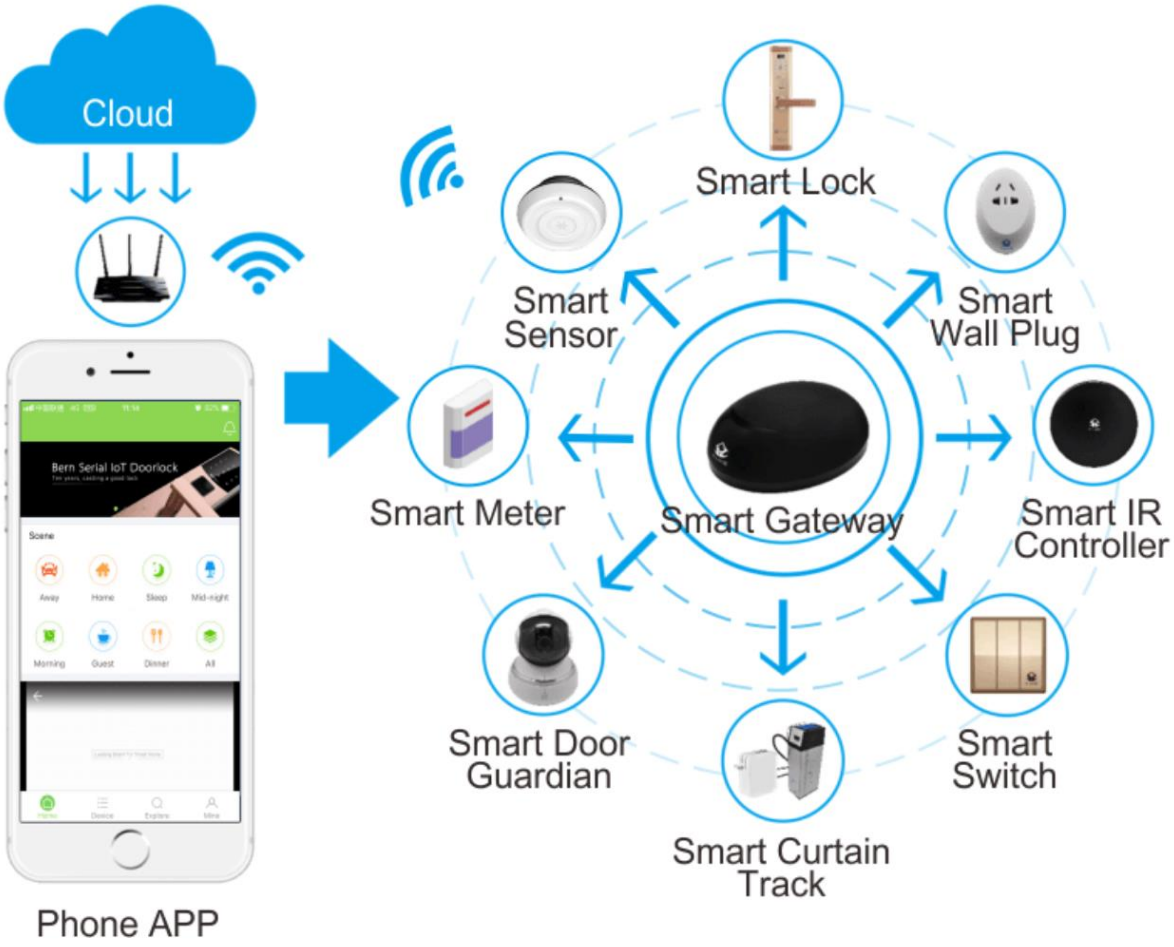
- **How does IoT works ?**
  - **IoT devices:** smart devices (that use embedded systems such as processors, sensors and communication hardware) to collect, send and act on data they acquire from their environments.
  - **IoT devices** share the sensor data they collect by connecting to an **IoT gateway**, which acts as a central hub where IoT devices can send data.
  - Before the data is shared, it can also be sent to an **edge device** where that data is analyzed locally. Analyzing data locally reduces the volume of data sent to the cloud, which minimizes bandwidth consumption.

1.1. Overview of IoT (cont.)

- **How does IoT works ?**
  - Sometimes, IoT devices communicate with other related devices and act on the information they get from one another.
  - The devices do most of the work without human intervention, although people can interact with the devices -- for example, to set them up, give them instructions or access the data.
  - The connectivity, networking and communication protocols used with these web-enabled devices largely depend on the specific IoT applications deployed.
  - **IoT can also use artificial intelligence** and machine learning to aid in making data collection processes easier and more dynamic.

1.1. Overview of IoT (cont.)

- An example of IoT smart home solution

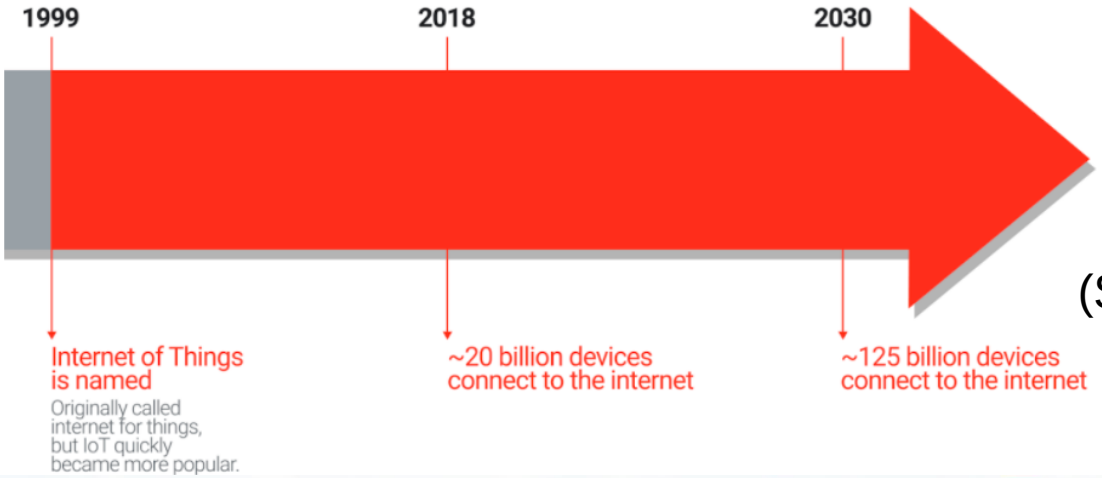


1.1. Overview of IoT (cont.)

- **Why is IoT important ?**
  - IoT helps people live and work smarter.
    - For example: IoT-embedded devices -- such as cars, smartwatches or thermostats -- improve people lives.
  - IoT is essential to business:
    - Real-time supervising of products/objects/system
    - Delivering insights into everything from the performance of machines to supply chain and logistics operations.
  - IoT enables machines to complete tedious tasks without human intervention.
    - automate processes, reduce labor costs, cut down on waste and improve service delivery.
    - less expensive to manufacture and deliver goods,
    - transparency into customer transactions.

1.2. Evolution of IoT

- The field of IoT has grown tremendously
- 1999: Kevin Ashton (Auto-ID Center, MIT) first mentioned the internet of things in a presentation about RFID

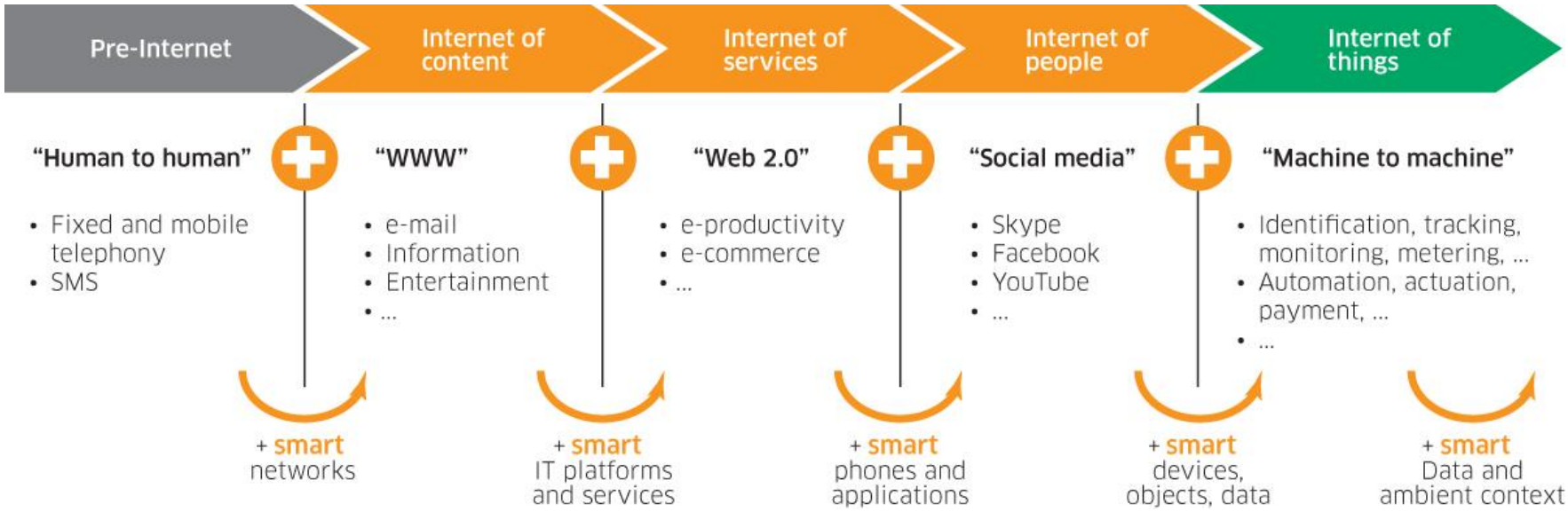


(Source: IHS)

1.2. Evolution of IoT (cont.)

- IoT has evolved from the convergence of:
  - Wireless technology
  - Microelectromechanical systems
  - Microservices
  - Internet
- M2M (machine to machine) communication, evolved to next level
- 2010: broader consumer use (smart phones, smart TV)
- 2020: cellular IoT (2G/3G/4G/5G. LoRaWAN, LTE)
- 2023: billions of internet-connected devices
  - **Digital twins:** virtual representation of a real-world entity or process

1.2. Evolution of IoT (cont.)



1. Pre-Internet: https://en.wikipedia.org/wiki/History_of_the_telephone

2. Internet of content (WWW, 1989, Tim Berners-Lee)
https://en.wikipedia.org/wiki/History_of_the_World_Wide_Web

3. Internet of services (Web 2.0, Yahoo, Amazon, … ~2000, dotcom companies)

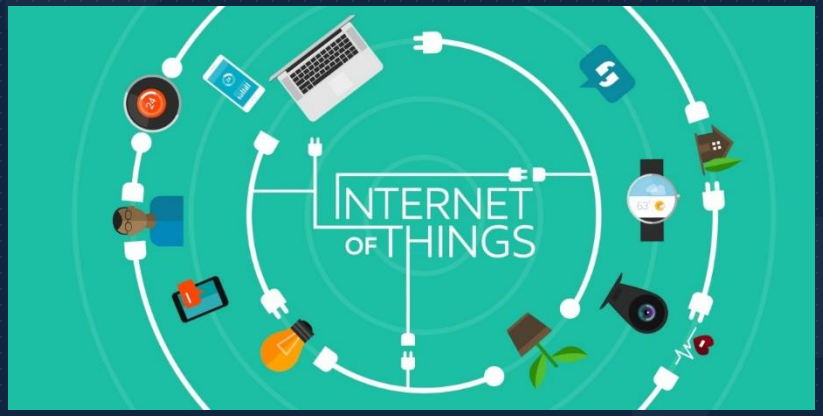
4. Internet of people (smart phones, social networks, iPhone1 2007)

Internet of Things named 1999 https://iot-analytics.com/internet-of-things-definition/

1.2. Evolution of IoT (cont.)

Idea: Move from Internet of People → Internet of Things

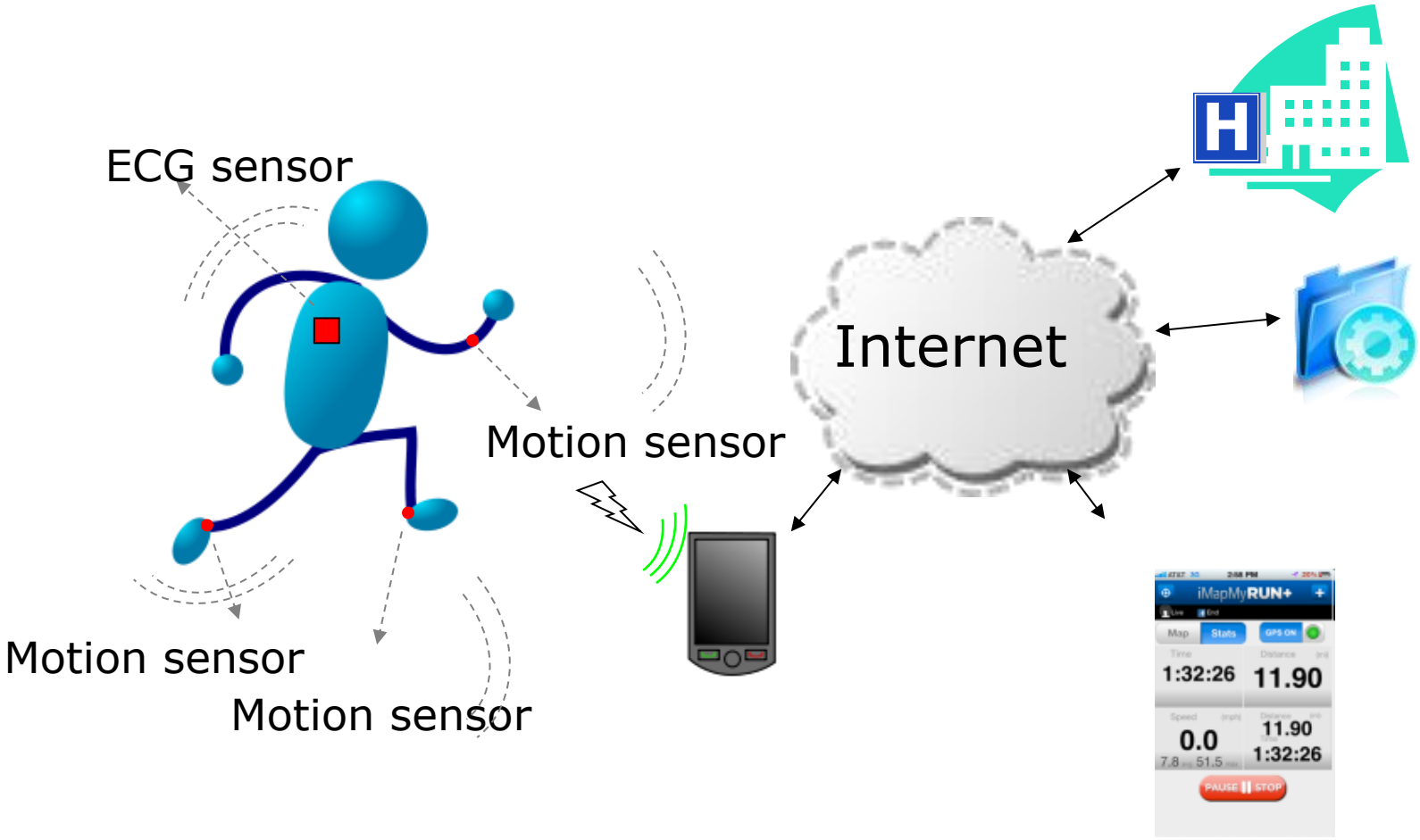
- Internet is present all over the world
- Initially, it was meant to connect human to human



- Internet of Things connects everything ("things") using existing infrastructure.

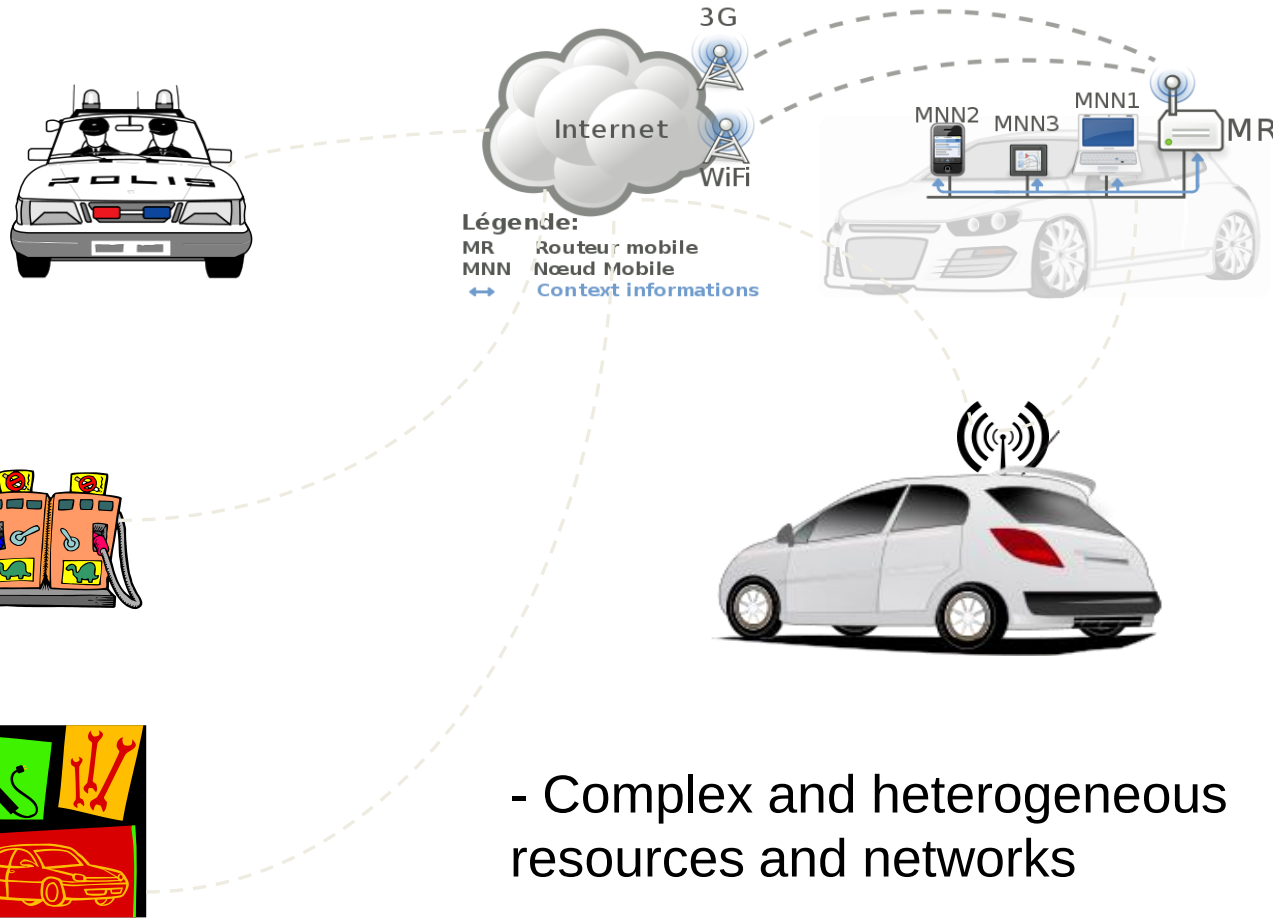
1.2. Evolution of IoT (cont.)

IoT: Human connecting with Things



1.2. Evolution of IoT (cont.)

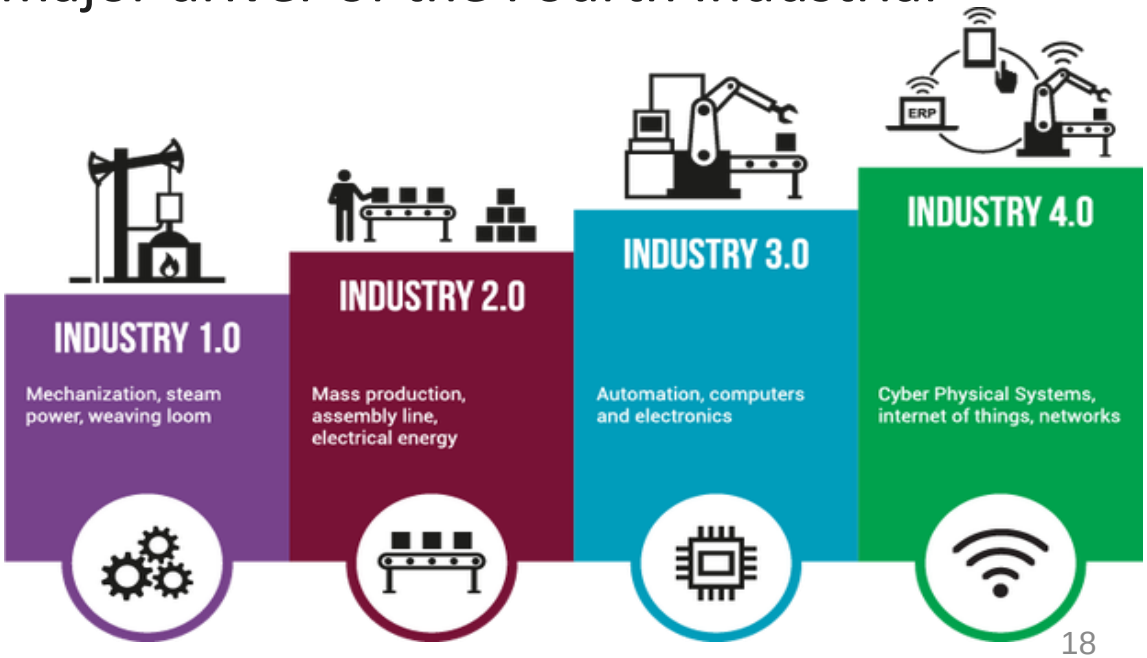
IoT: Things connecting with Things



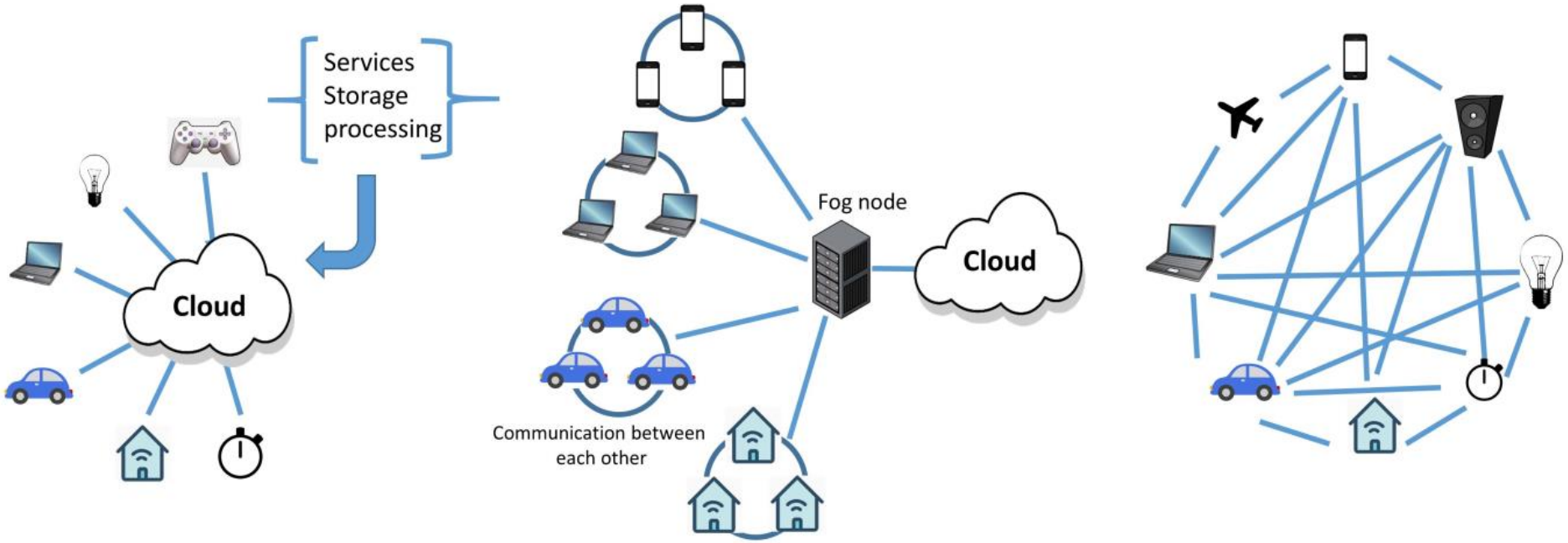
- Complex and heterogeneous resources and networks

4th IR and IoT

- The Fourth Industrial Revolution and IoT
  - 1st IR: transformed society with the introduction of machines and mechanized production.
  - 2nd IR: introduced electricity, which led to mass production.
  - 3rd IR: has been called the dawn of the information age.
  - 4th IR: as "the fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.“ (by *Klaus Schwab*)
- IoT is being called a major driver of the Fourth Industrial Revolution. Why?



1.3. Architecture of IoT system



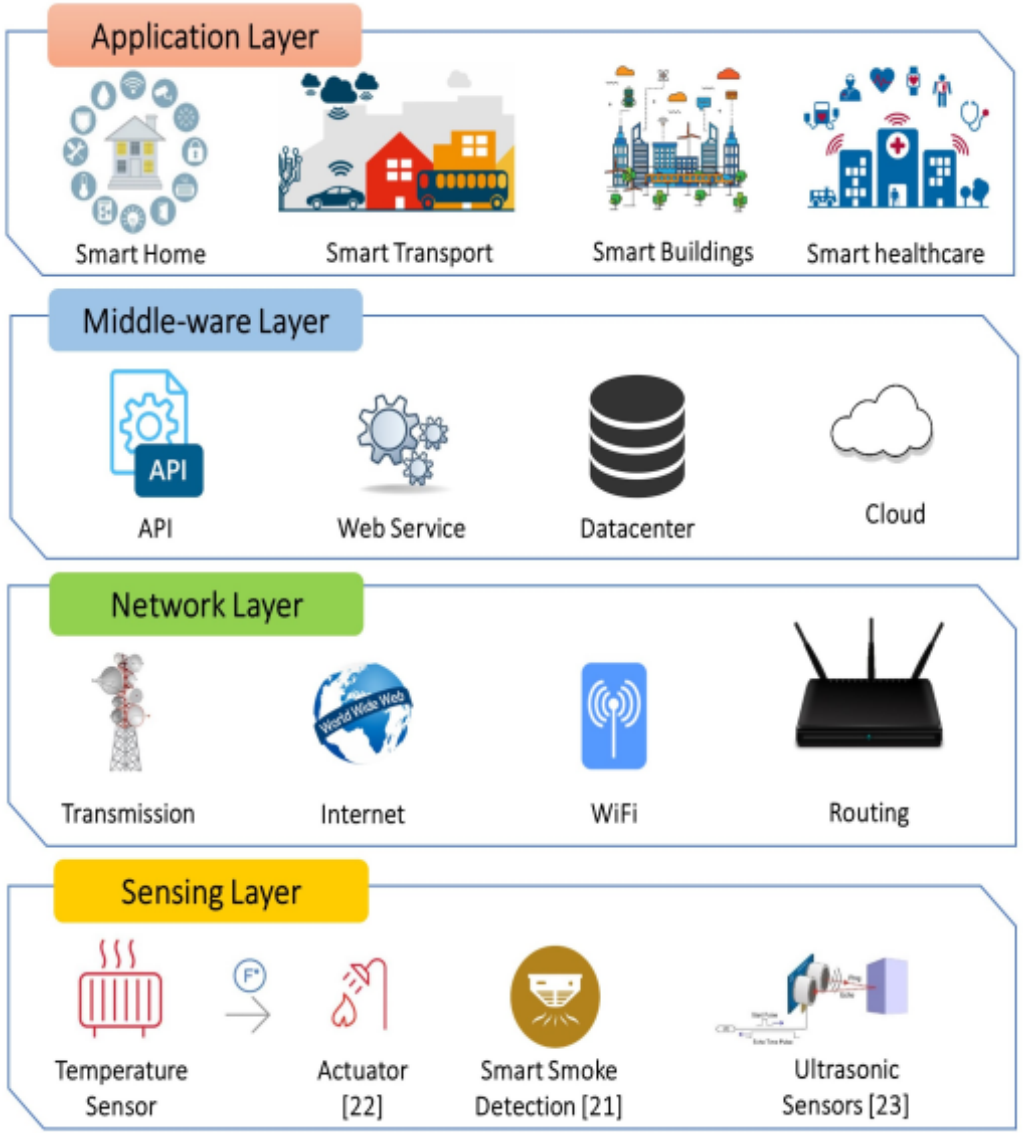
(1) (2) (3)

(1) Simple architecture: Devices connect directly to a server/cloud

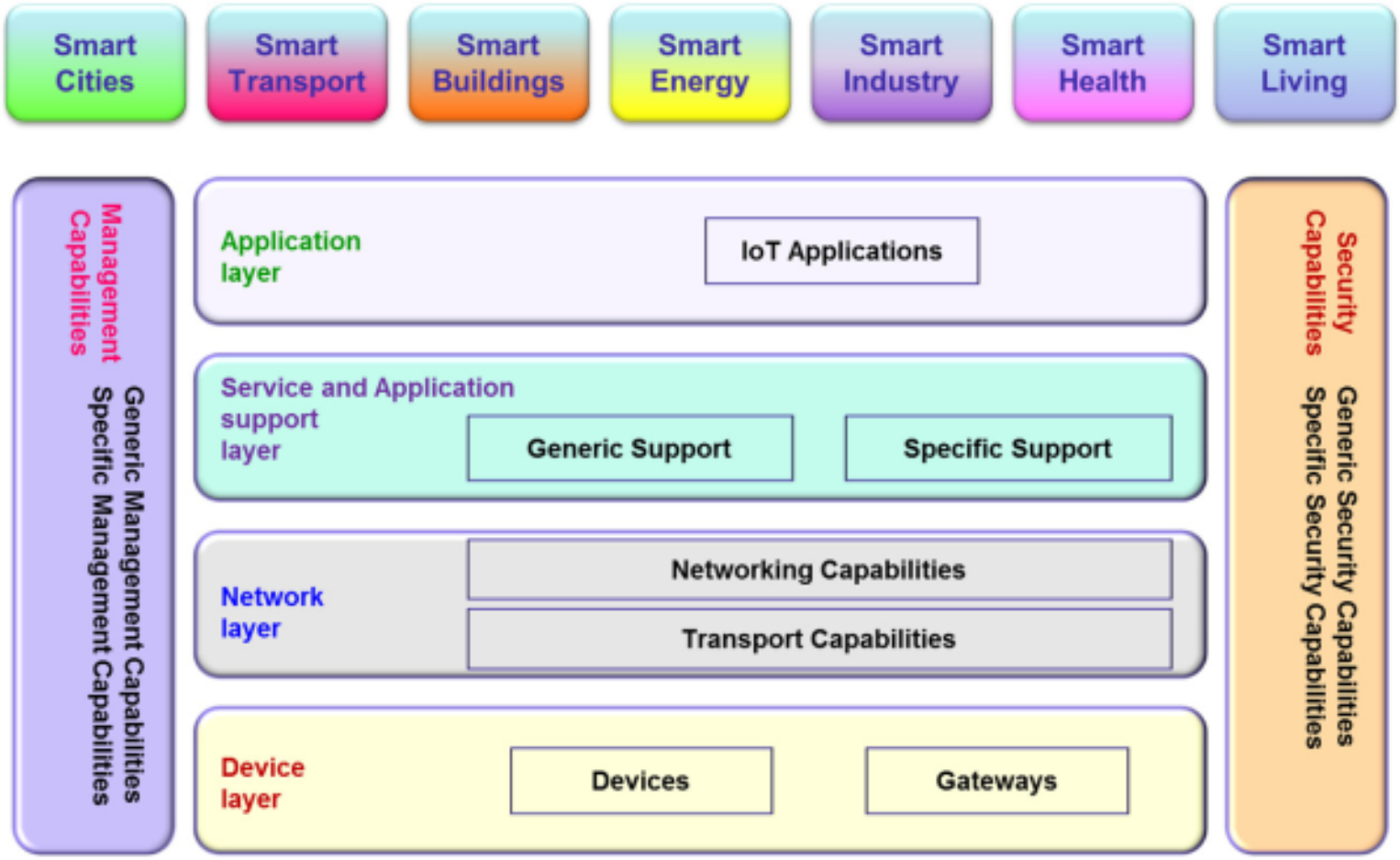
(2) Hierarchical Architecture: Devices connect through an intermediate layer (Fog/Edge node, gateway)

(3) Future Architecture: "Things" connect directly to other "Things"

1.3. Architecture of IoT system (cont.)



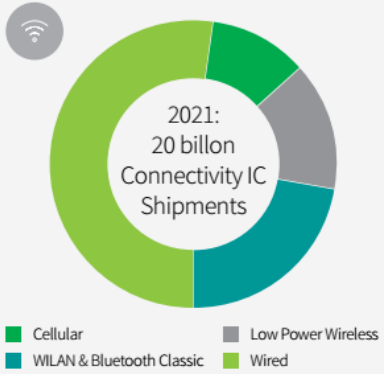
1.3. Architecture of IoT system (cont.)



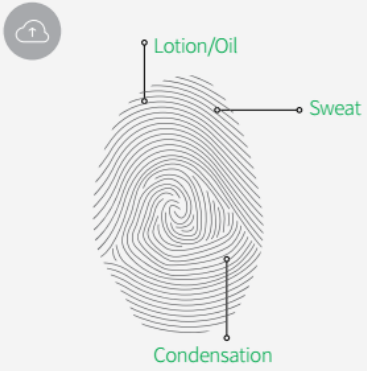
IoT Layered Architecture (Source: ITU-T)

The four fundamental “pillars” of IoT

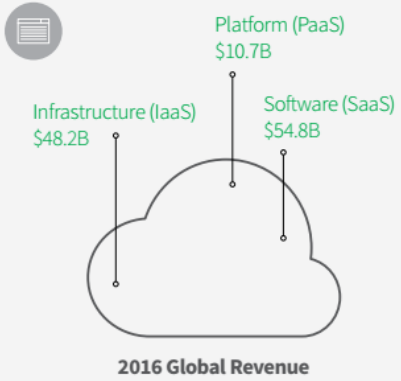
- **Connections**: Ability to connect devices and information
- **Collection:** Capability to gather data through increased connections of devices and information.
- **Computation:** capability enables the transformation of collected data into new functionalities
- **Creation:** Ability to generate new interactions, business models, and solutions



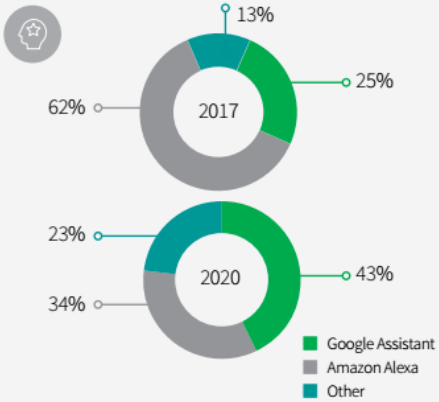
New 5G & NB-IoT capabilities shift demand for celluar activity



Emerging biometrics sensing technologies provide more convenient and stronger security



Cloud & XaaS driving new business models and cost efficiencies



Artificial Intelligence drives Google dominance in digital assistant market

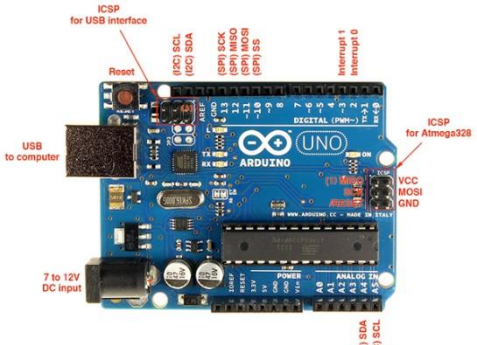
1.4. IoT technologies

- Hardware
- Communication
- Protocols
- Data Analytic
- Cloud Platforms

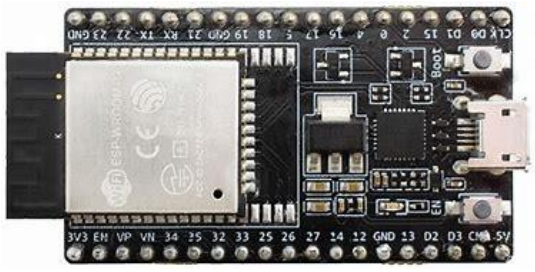
1.4.1. Hardware

Embedded Computers:

- Microcontrollers: 8-bit, 32-bit, without operating system
- Microcontrollers with simple operating system (e.g., FreeRTOS)
- High-performance 32-bit, 64-bit processors with operating systems (Raspbian, Embedded Linux, Ubuntu, Embedded Windows, ...)
- Architectures: AVR, Microchip, ARM, Intel, ...



Arduino Uno



ESP32


Raspberry Pi

Intel Galileo

1.4.2. Sensors

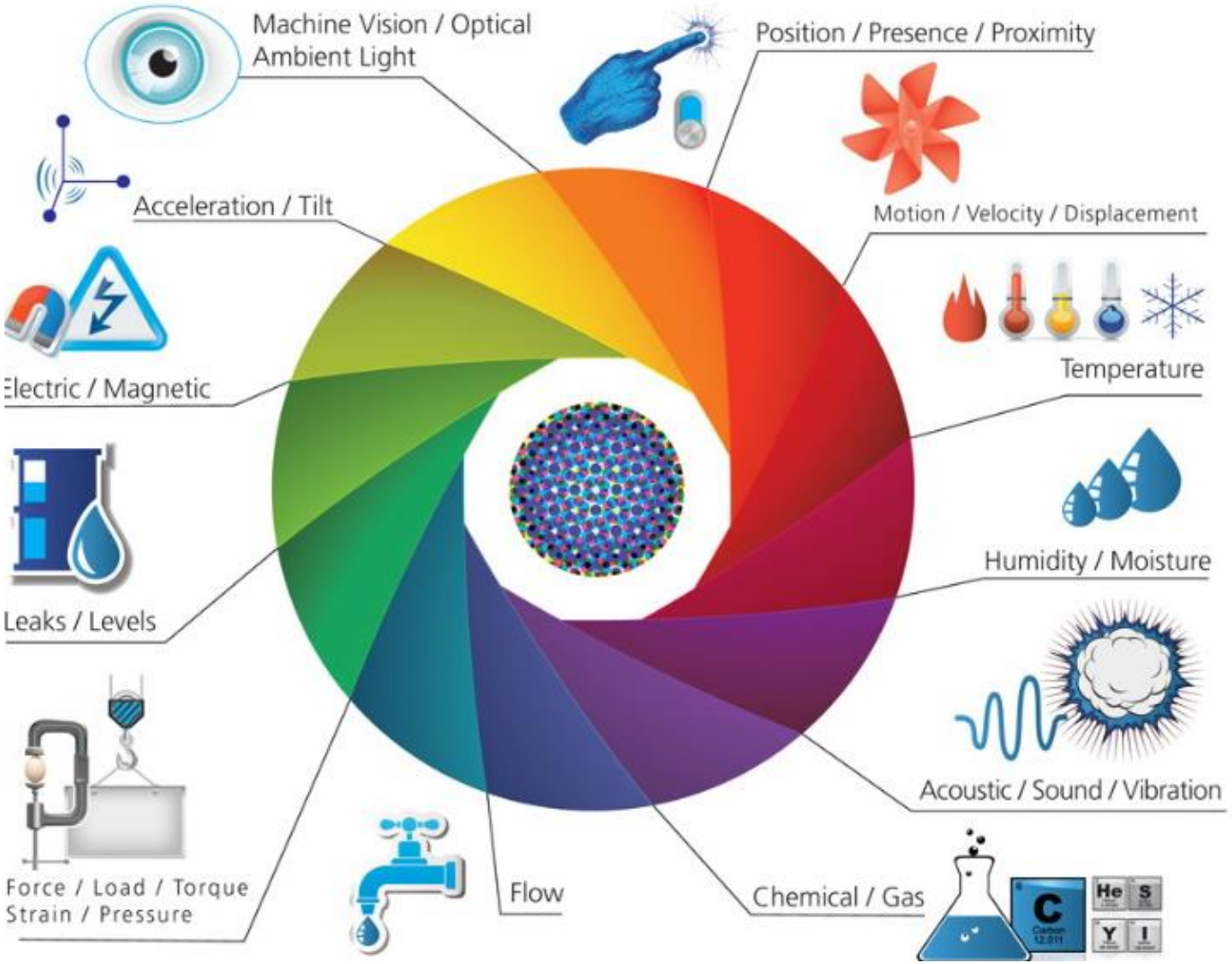
- Sensors can be considered the most crucial component in IoT devices
  - Analog or digital output.
- Sensor modules typically include:
  - Energy/power modules for supply and management of power
  - Sensing modules for data acquisition
  - Communication management component
  - Signal processing through communication management component (RF modules).
  - WiFi, ZigBee, Bluetooth, radio transceiver…

1.4.2. Sensors (cont.)

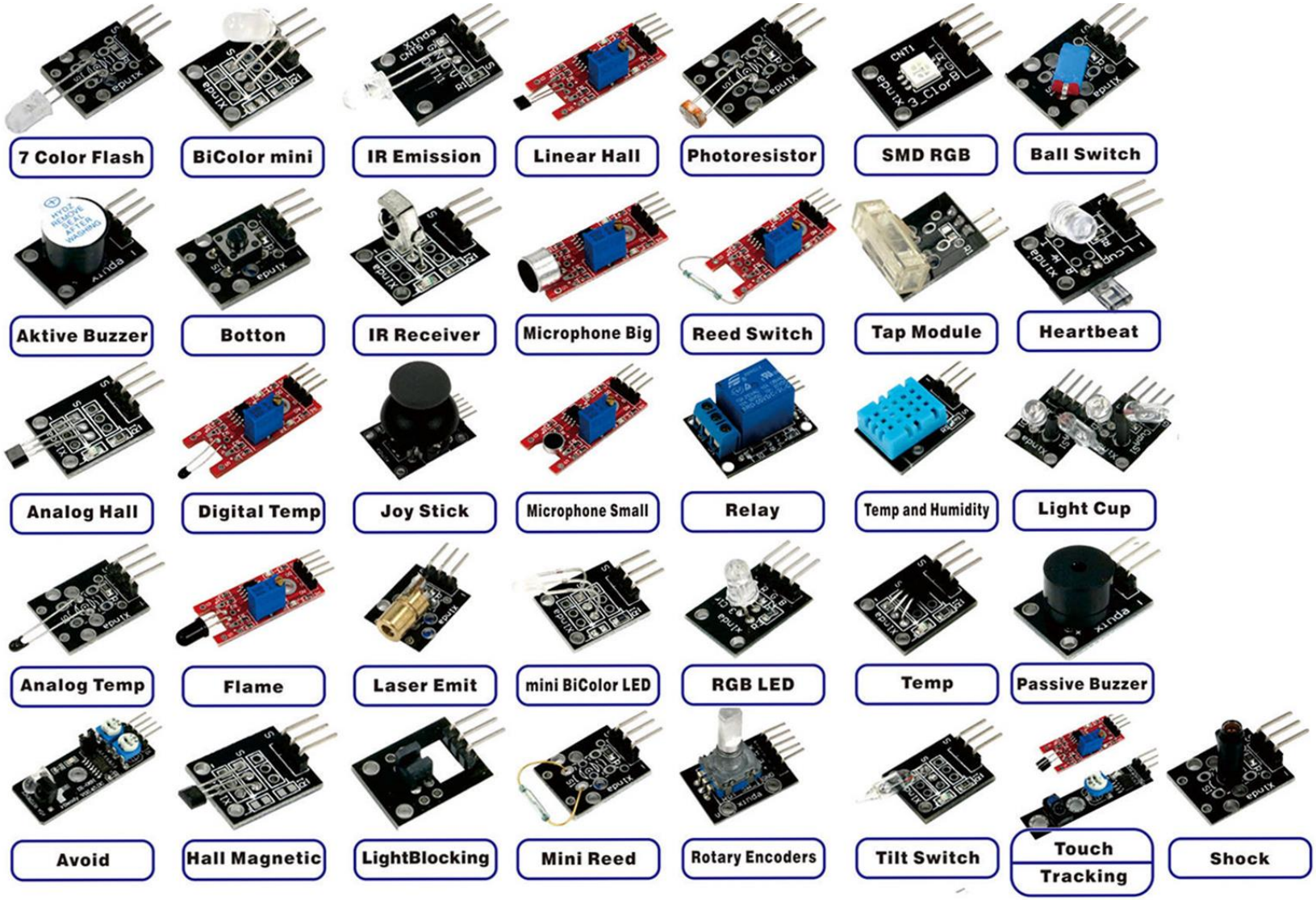
- There are many types of sensors:

Devices	
accelerometers	temperature sensors
magnetometers	proximity sensors
gyroscopes	image sensors
acoustic sensors	light sensors
pressure sensors	gas RFID sensors
humidity sensors	micro flow sensors

1.4.2. Sensors (cont.)



1.4.2. Sensors (Laboratory type)



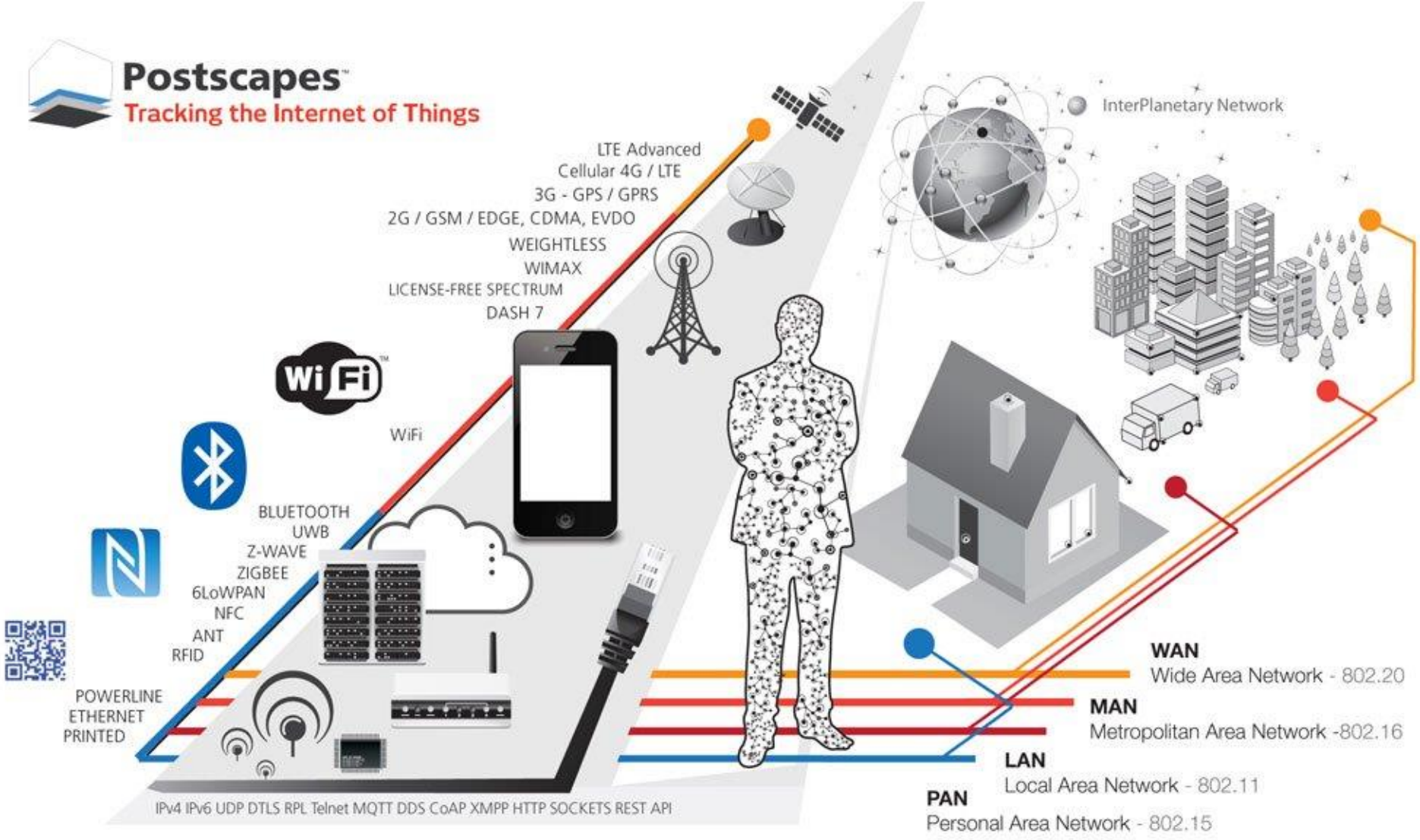
Wearables IoT

- **Head** – Helmets, glasses
- **Neck** – Jewelry, collars
- **Arm** – Watches, wristbands, rings
- **Torso** – Clothing, backpacks
- **Feet** – Socks, shoes

Wearables IoT

- https://www.sportswearable.net/fitness-and-sports-wearables-world-wide-market-analysis-forecasts-and-trends-through-2019-2025/

1.4.2. Communications



1.4.2. Communications (Cont.)

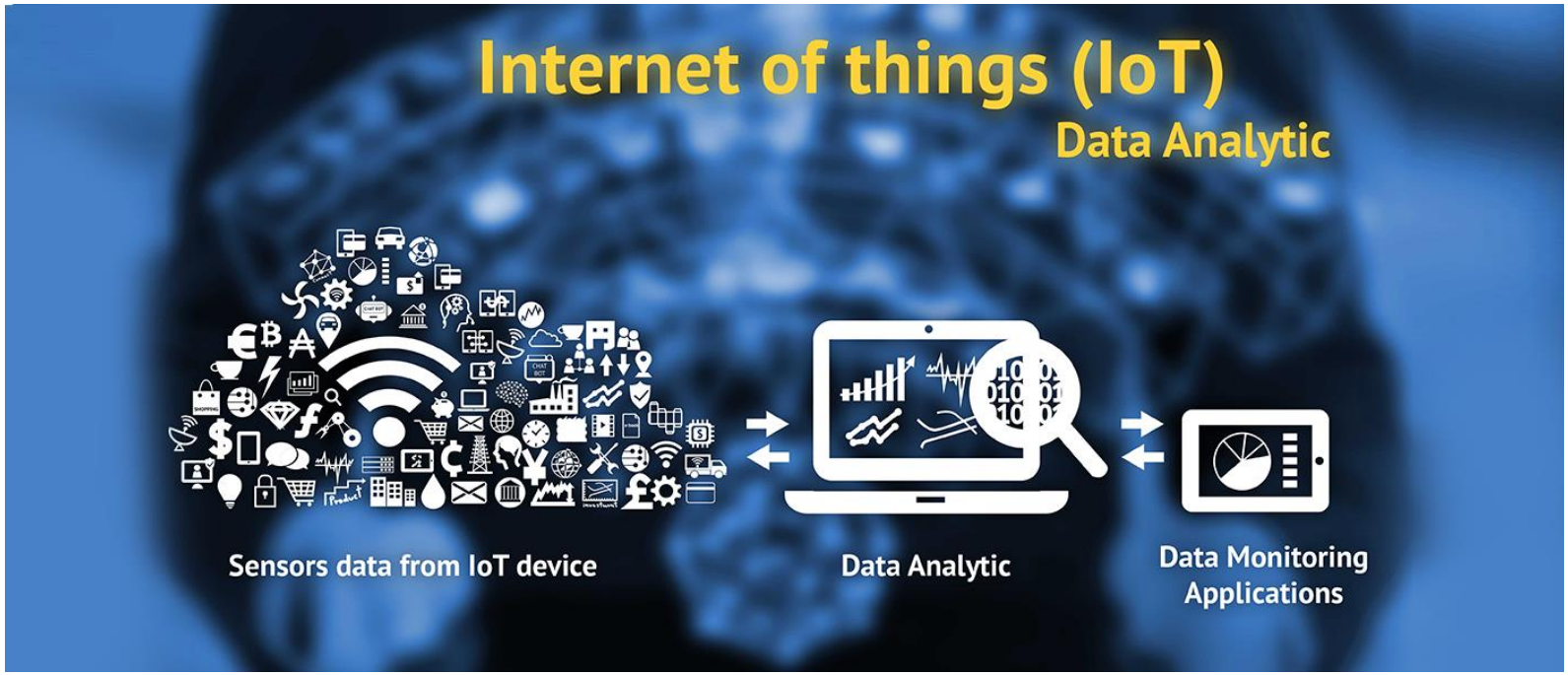
- Common communication standards for IoT:
  - NFC and RFID
  - Bluetooth
  - WiFi
  - GSM, 3G/4G/LTE, LTE-A

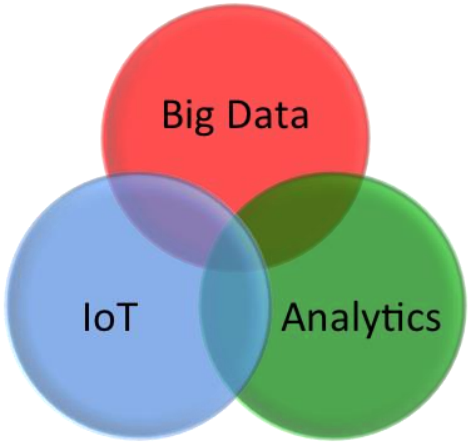
1.4.2. Communications (Cont.)

- Protocols for IoT applications:
  - HTTP (HyperText Transfer Protocol)
  - RESTful HTTP (Representational State Transfer)
  - MQTT (Message Queue Telemetry Transport)
  - AMQP (Advanced Message Queue Protocol)
  - CoAP (Constrained Application Protocol)
  - XMPP (Extensible Messaging and Presence Protocol)

https://www.postscapes.com/internet-of-things-technologies/

1.4.3. Data Analytic



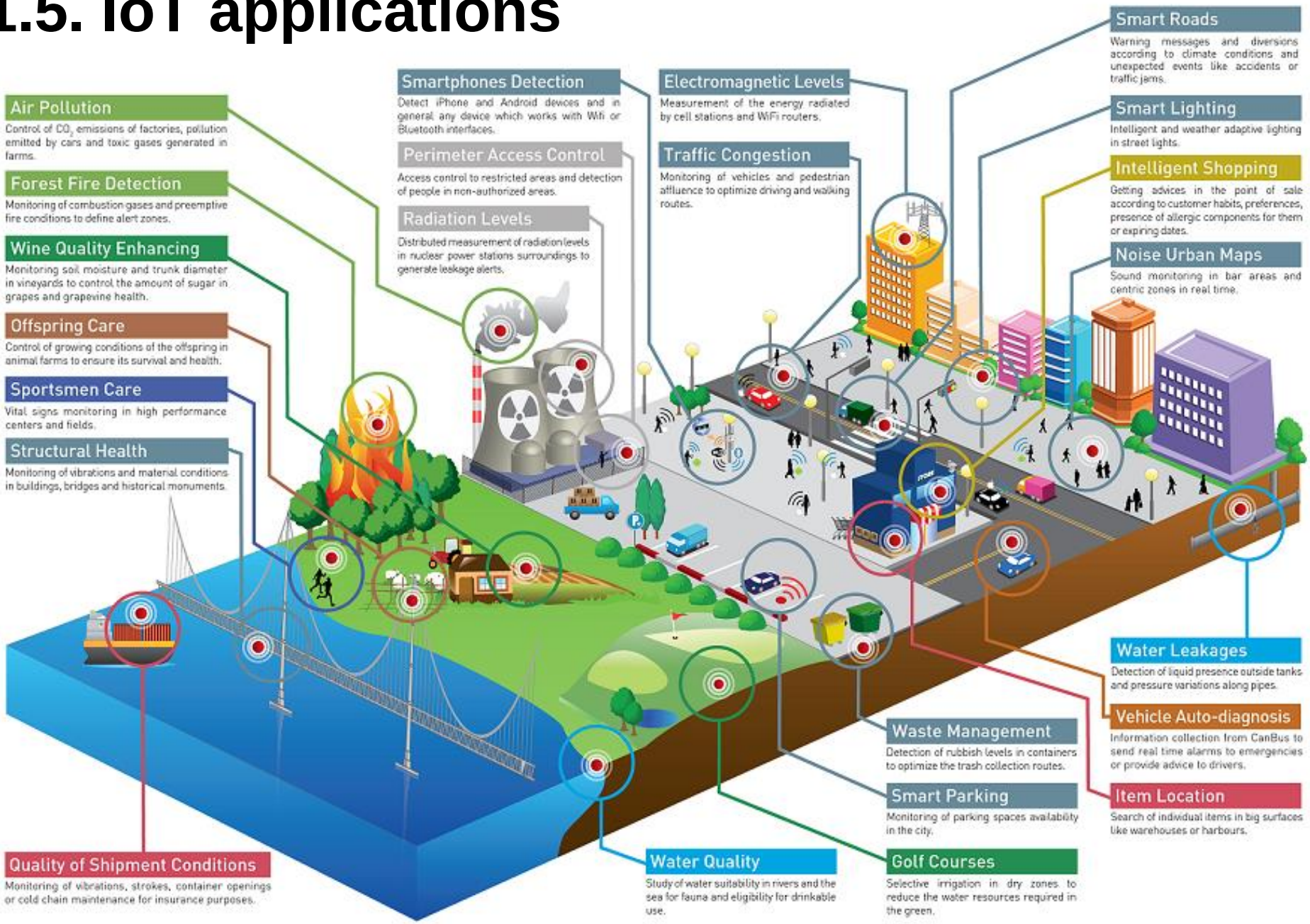


1.4.4. IoT Technologies: Cloud Platforms

- Some cloud service platforms in IoT:
  - IBM BlueMix
  - AWS IoT
  - Google Cloud IoT
  - Azure IoT

https://www.postscapes.com/internet-of-things-technologies/

1.5. IoT applications



1.5. IoT applications (cont.)

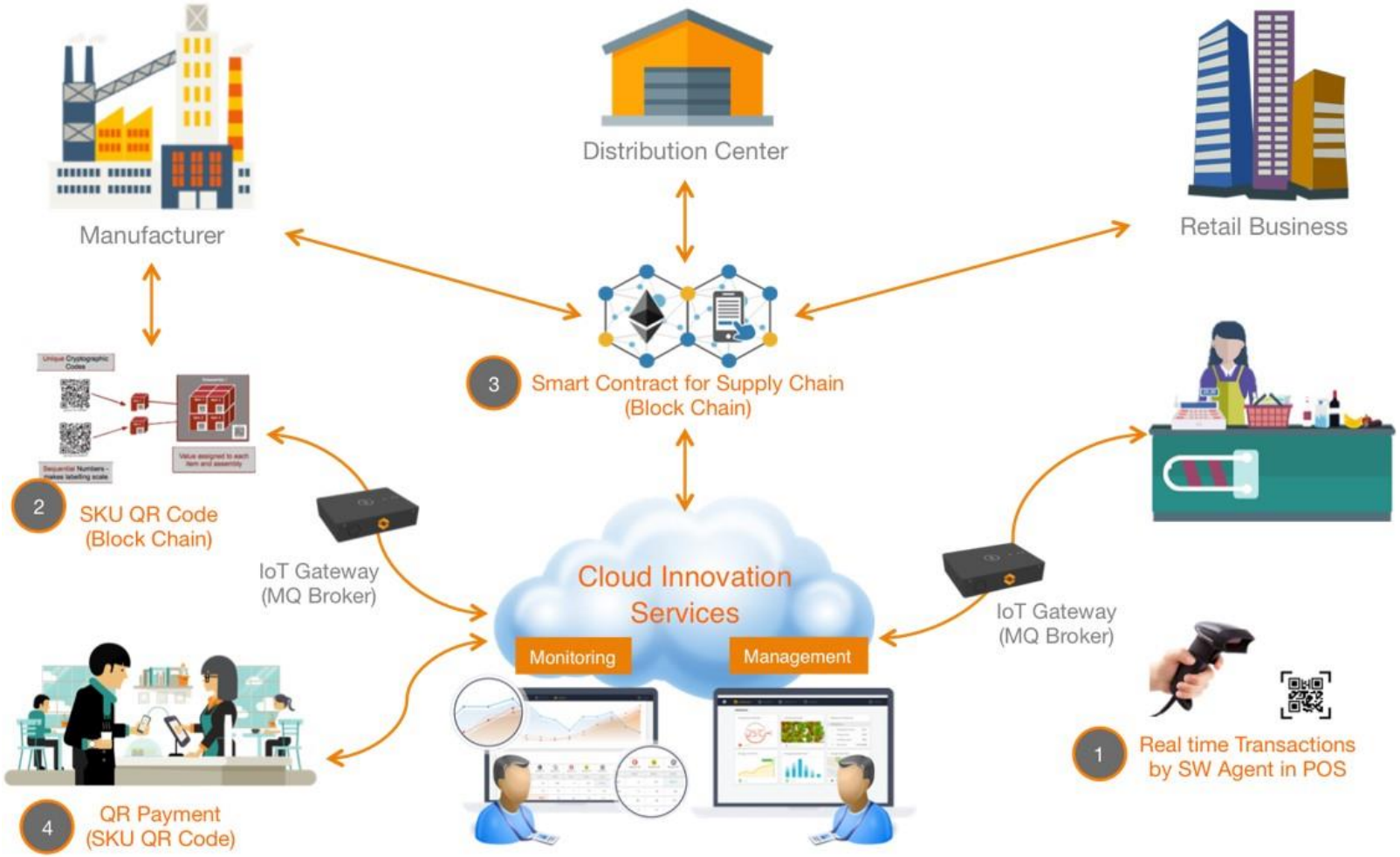
Top Industrial IoT Applications

- Healthcare
- Smart Retail
- Smart Building/Smart Home
- Smart Agriculture
- Smart Utilities (Power Energy, Water)

Healthcare

- One of the fastest sectors adopting the IoT
- A lot of sensors for tracking patients

Smart Retail

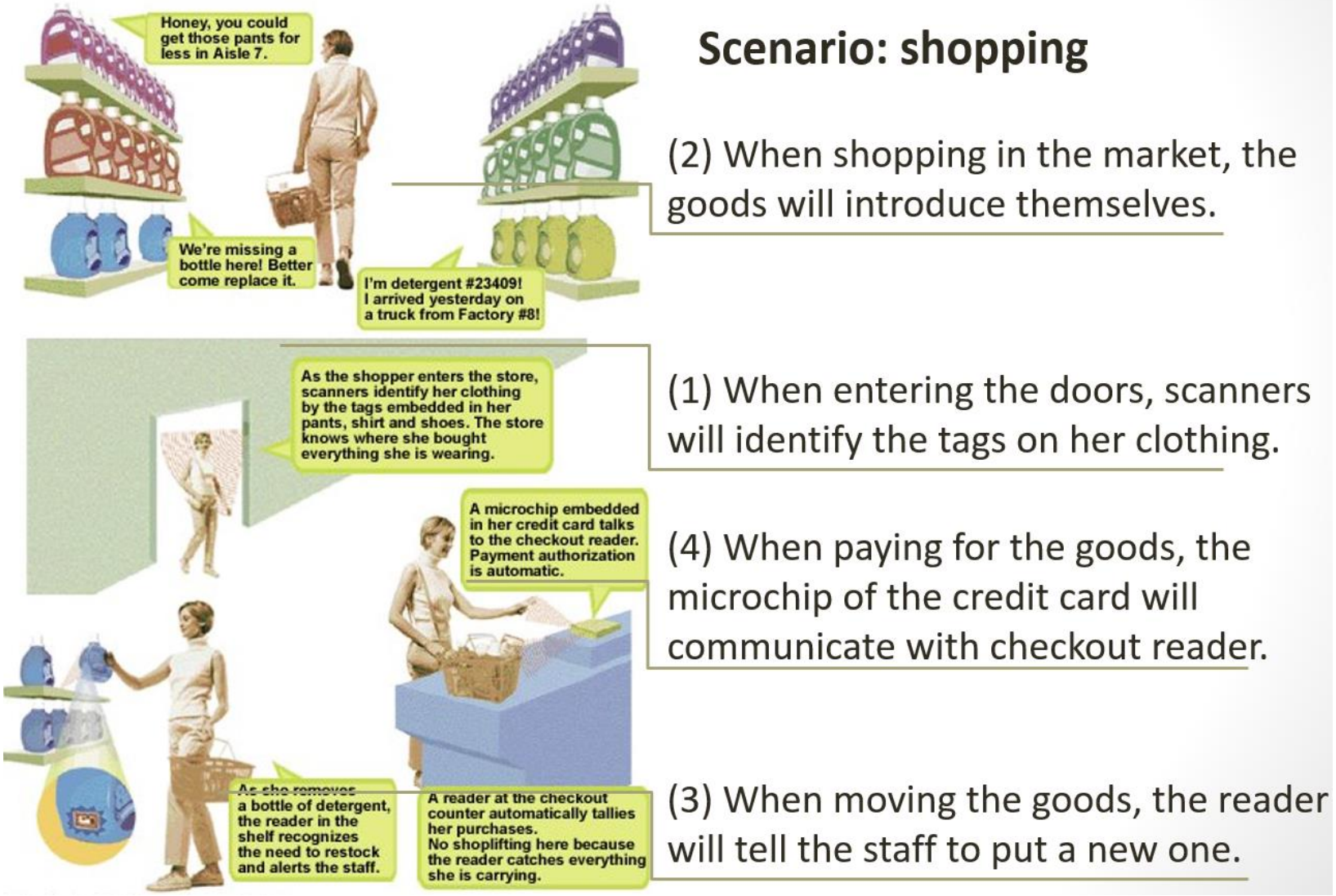


https://www.smartofthings.co.th/2018/08/27/smart-retail-solution/

Smart Retail

Amazon Go store

Smart Retail: Shopping



Scenario: shopping

(2) When shopping in the market, the goods will introduce themselves.

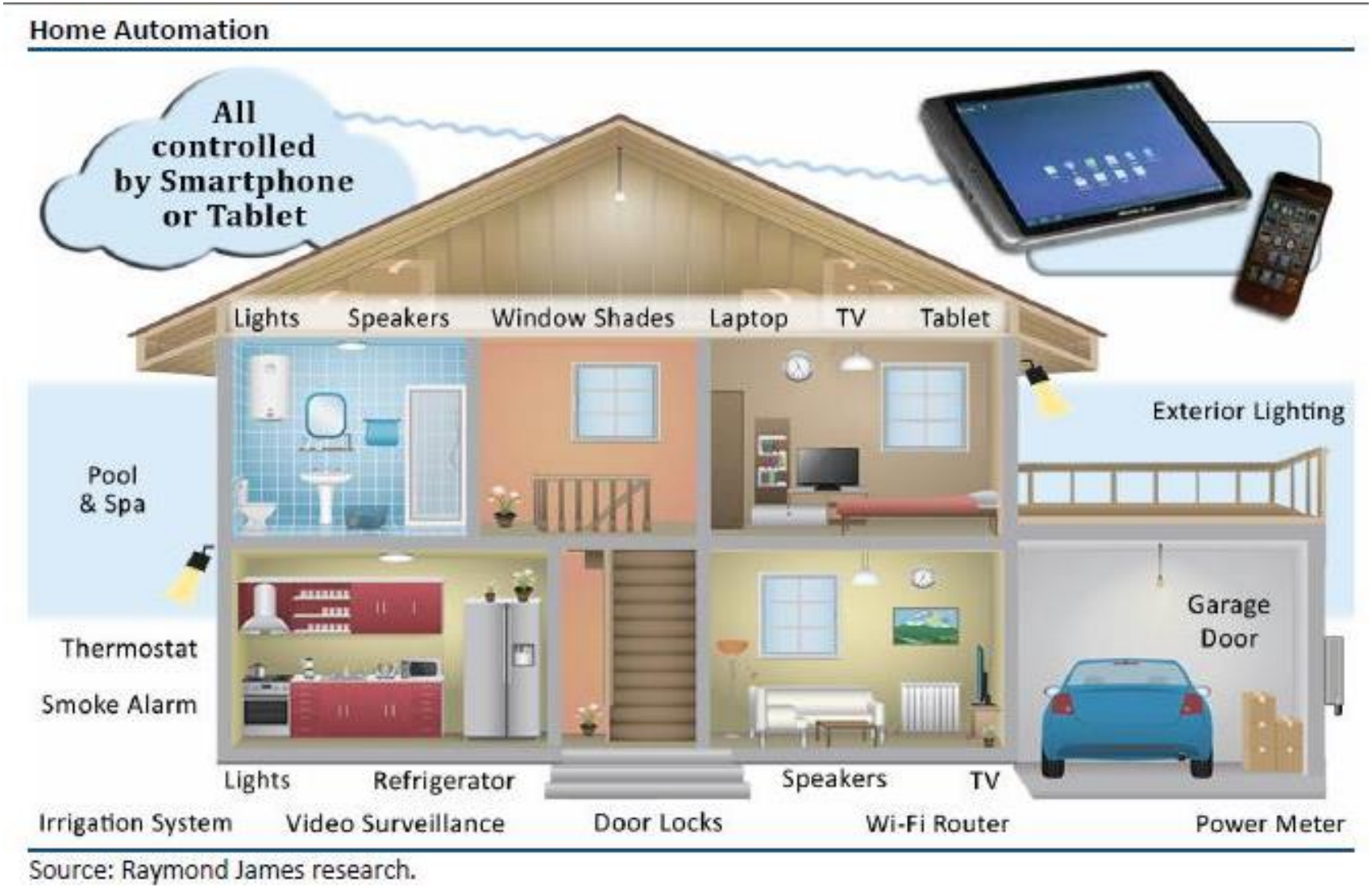
(1) When entering the doors, scanners will identify the tags on her clothing.

(4) When paying for the goods, the microchip of the credit card will communicate with checkout reader.

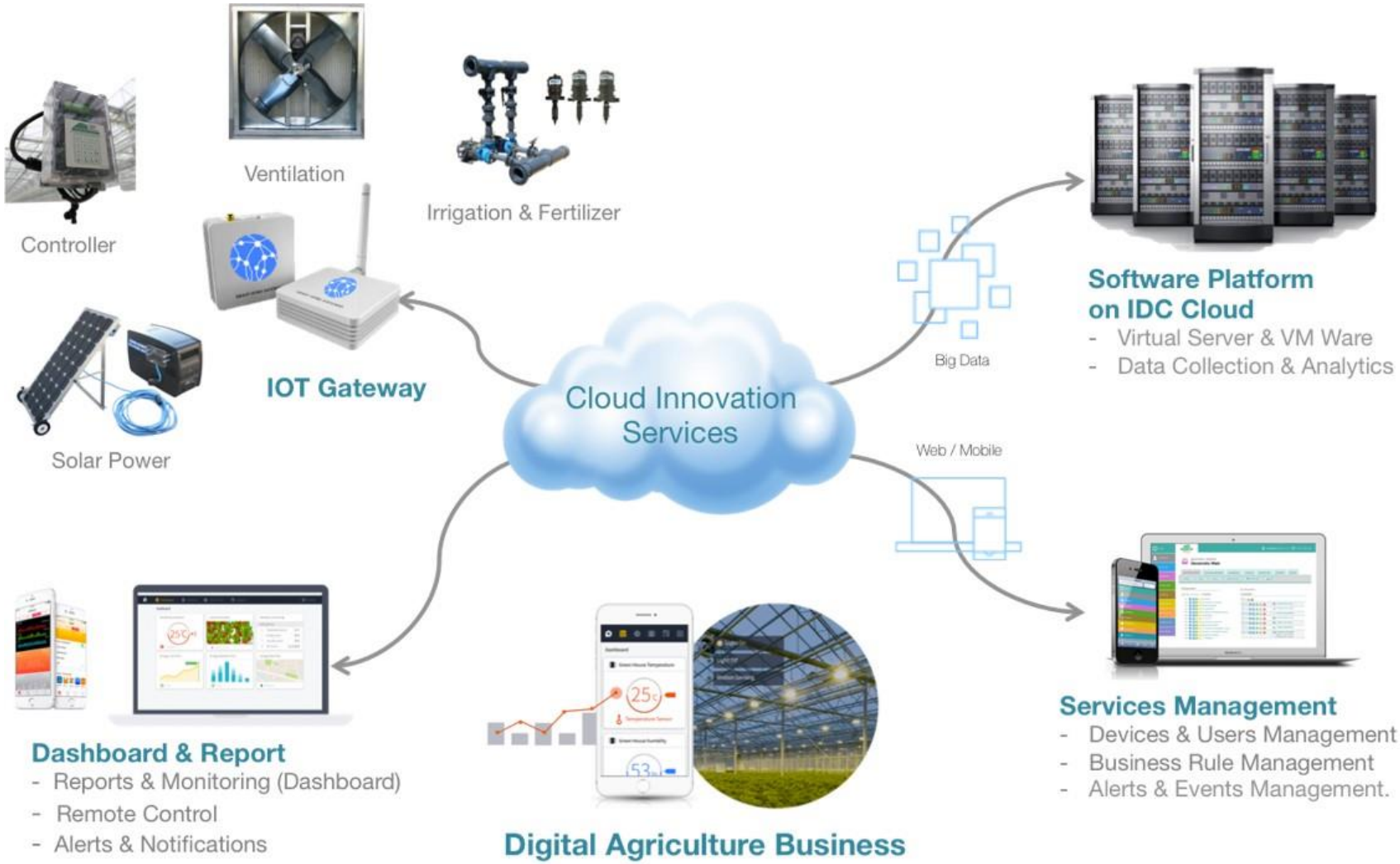
(3) When moving the goods, the reader will tell the staff to put a new one.

Smart Building

Smart Home


Home Automation
All controlled by Smartphone or Tablet
Lights
Speakers
Window Shades
Laptop
TV
Tablet
Exterior Lighting
Pool & Spa
Thermostat
Smoke Alarm
Garage Door
Lights
Refrigerator
Speakers
TV
Irrigation System
Video Surveillance
Door Locks
Wi-Fi Router
Power Meter
Source: Raymond James research.

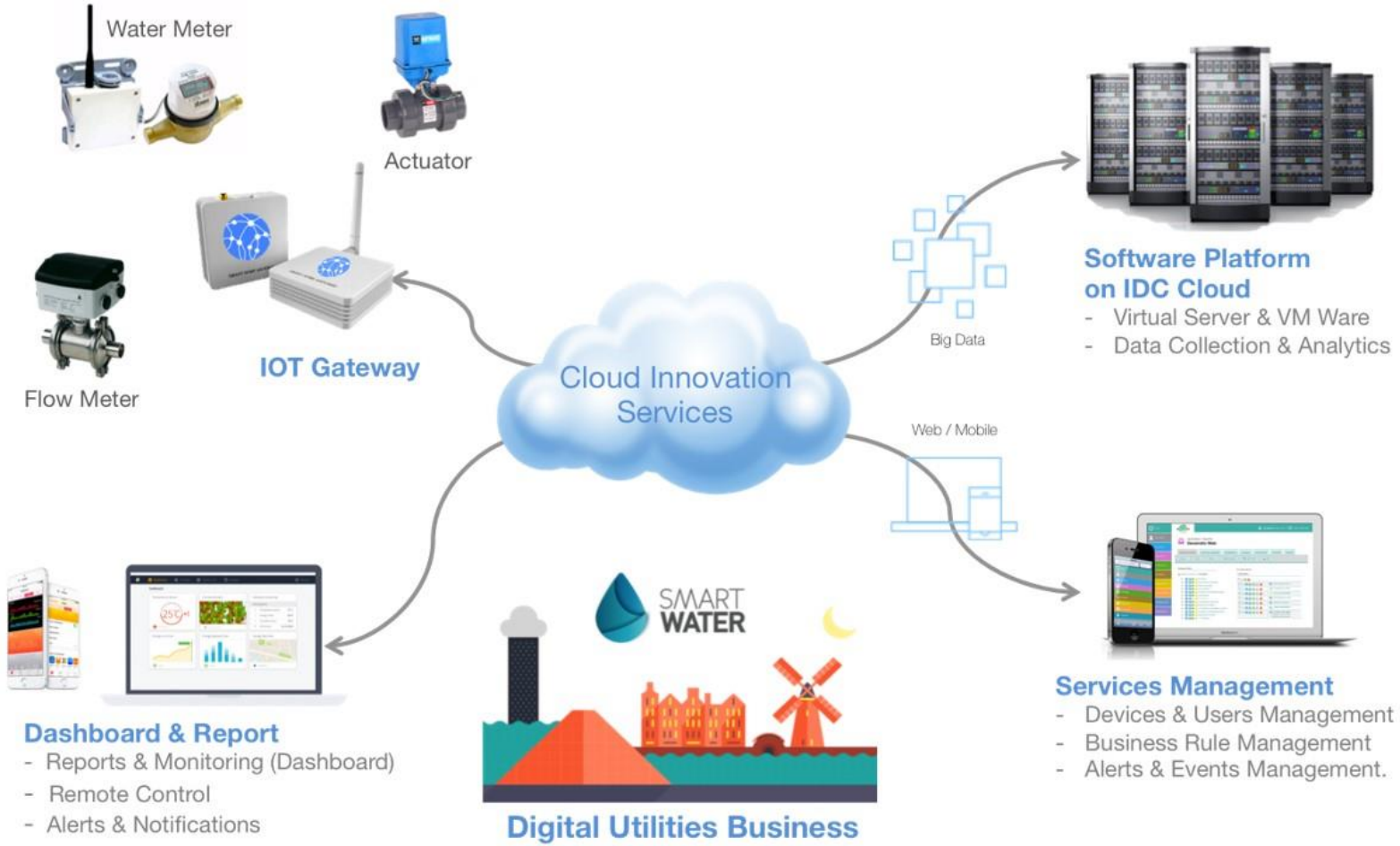
Smart Agriculture



https://www.smartofthings.co.th/2018/08/27/smart-agriculture-solution/

Smart Utilities

Electrical power, Water Supplying



https://www.smartofthings.co.th/2018/08/27/smart-utilities-solution/

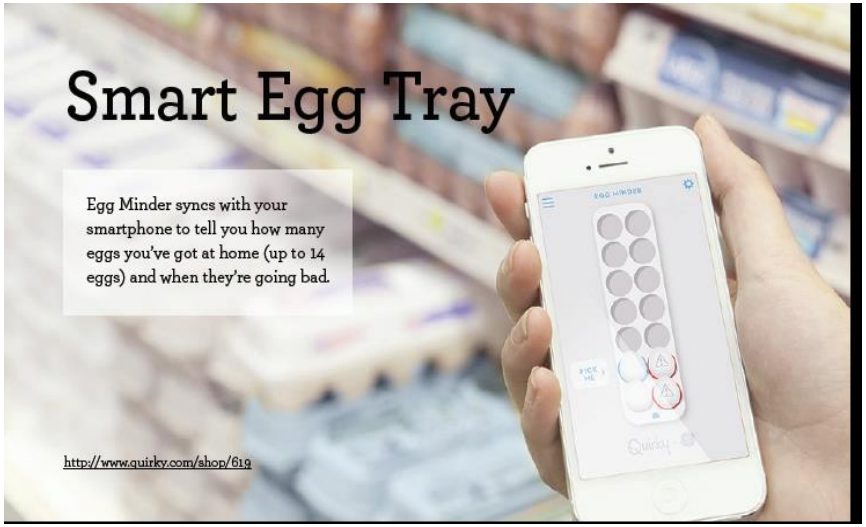
Transportation

Source: Raymond James research.

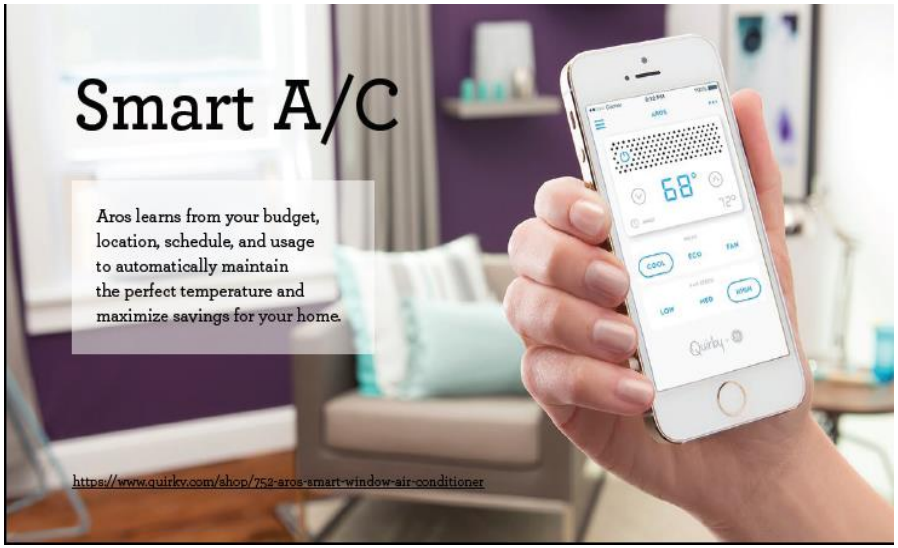
IoT – Manufacturing Applications

- Intelligent Product Enhancements
- Dynamic Response to Market Demands
- Lower Costs, Optimized Resource Use, Waste Reduction
- Improved Facility Safety
- Product Safety

Commercial products using IoT



Commercial products using IoT



Commercial products using IoT

Discussion

- What everyday activity can be changed by IoT?
- What existing process can be changed by IoT? Will this change lead to the greater good of society? Or to the individual?

1.6. Challenges of IoT

- Many different technologies
  - Advantages + Challenges?

- Challenges for governments in managing rapid technological advancements
  - Example: Uber, Grab

- Issue regarding privacy and security
  - Example: Facebook

- Lack of a central authority for governance and control.
  - Common issue with internet services

- Vulnerability to be attacked on the Internet:
  - Example: IP cameras

1.6. Challenges of IoT (cont.)

- **Connectivity problem**:
  - Currently, IoT relies on a server/client model for authentication and connecting devices within the network. This model can handle hundreds or thousands of devices. However, difficulties arise when the number of devices reaches millions or billions within the network
  - Without considering appropriate network throughput design, bottlenecks may occur during data exchange at the server
  - Tasks can be off-loaded to the edge devices for execution
  - IoT networks will require devices capable of data analysis, machine learning, and data collection.

1.6. Challenges of IoT (cont.)

- **Legacy infrastructure** – Issue of deployment on existing infrastructure:
  - IoT devices, existing network infrastructure, and new technologies being integrated (brownfied deployment)
  - Companies face the challenge of integrating new technology devices with existing network infrastructure.

1.6. Challenges of IoT (cont.)

- **Dealing with non-standard communication protocol**:
  - The connecting networks will need to cope with an unprecedented surge in data from devices and sensors
  - Controlling, processing, and storing data will increase in line with the rise in input data load. Additionally, data, as it increases in size and frequency, must remain readily available for data analysis.

1.6. Challenges of IoT (cont.)

- **IT/OT convergence**
  - The integration/convergence of Information Technology (IT) and Operational Technology (OT) in industrial Internet of Things (IIoT) applications. An example is in a power plant
  - IT focuses on data-centric operations, while OT is centered on monitoring events. IoT blurs this distinction by simultaneously monitoring devices and generating a large volume of data
  - Industrial enterprises will need to adjust their processes to accommodate IIoT devices and data

1.6. Challenges of IoT (cont.)

- **Get actionable intelligence from data**
  - The value of data increases when smart insights are derived from the augmented data
  - IoT analysis will need to work with unstructured data, large volumes of real-time data, and even outlier data.

Discussion

- Industry Transformations
  - IoT will cause the most transformation in non-technology-based industries.
- Give an example of a non-technology-based industry and explain how IoT will transform it.

Content

- Chapter 1. Overview of IoT
- Chapter 2. IoT Technologies
- Chapter 3. IoT Application and Programming
- Chapter 4. IoT Safety and Security
- Chapter 5. Designing and Building IoT Systems

Chapter 2. IoT Technologies

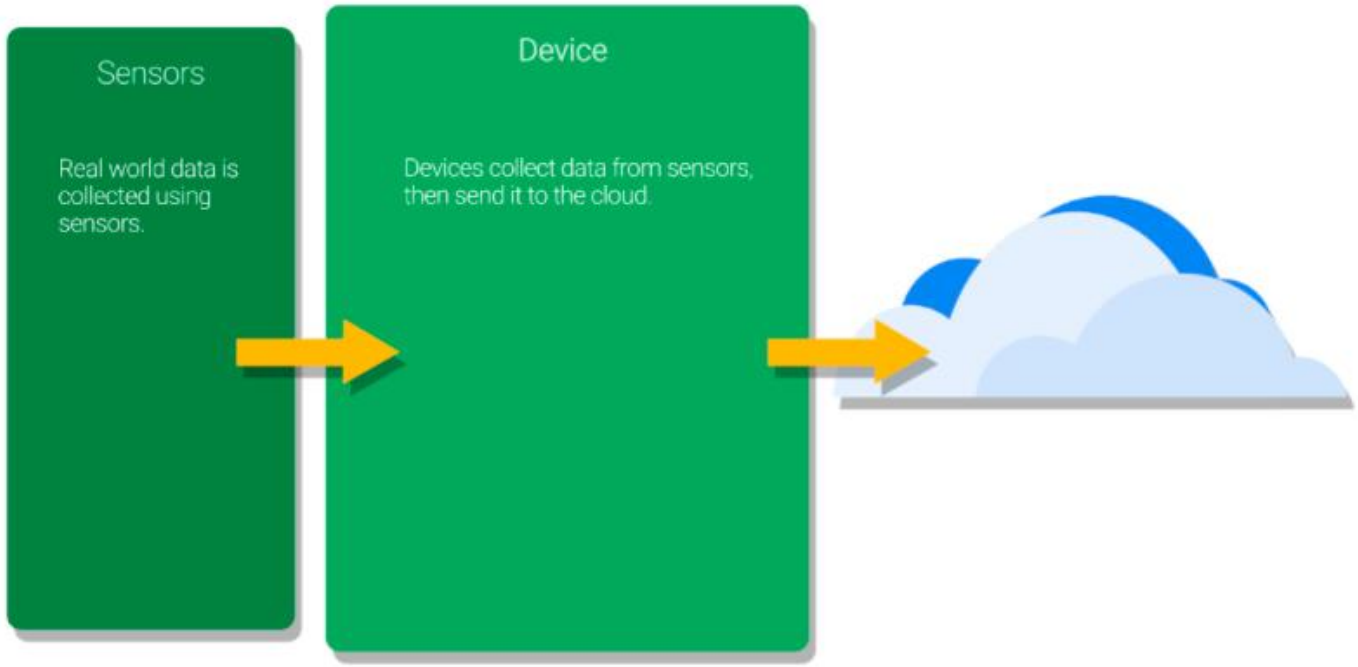
- 2.1. Sensors and devices
- 2.2. Some communication standards for IoT
- 2.3. Protocols for IoT applications
- 2.4. IoT cloud platform

2.1. Sensors and devices

- Sensor and devices:
  - Sensors and IoT devices are simply called devices with the implicit inclusion of sensors that are connected
  - In many situations, when referring to “devices” it can be understood as including both devices and sensors

Sensors and devices

- Sensors observe the changes around and send information about those changes to the device
- The devices collect data from the sensors and send it to the cloud/server



Sensors and devices

- The devices may be limited in computing resources (CPU, limited memory, ...)
- The devices can communicate privately without directly connecting to the cloud platform, for example through Bluetooth Low Energy (BLE)
- The devices can store, process and analyze data before sending it to the cloud

Types of Sensors

- According to the power supply requirement

Type	Definition	Example
passive	Does not require external power to operate. They respond to input from their environment.	A temperature sensor that changes resistance in response to temperature changes
active	Requires external power to operate.	A camera

- According to the type of signal

Type	Definition	Example
analog	Outputs an analog continuous signal	Accelerometers, temperature sensors
digital	The output is converted to discrete values (digital 1s and 0s) before transmitting to a device	Digital pressure sensor, digital temperature sensor

- According to the type of measuring device

Type	Definition	Example
chemical	Responds to chemical changes in its environment	Gas sensor
mechanical	Responds to physical changes in its environment	Microswitch
electrical	Responds to electrical changes in its environment	Optical sensor

Sensor selection

- Sensor selection needs to consider the importance of the factors and the priority level in the overall design
- **Durability:**
  - The durability of the sensor must be considered based on its operating environment.
  - Ensure that the device operates reliably for a significant period of time without having to incur repair or replacement costs.
  - Example: waterproof temperature sensor used for weather station

Sensor selection

- **Accuracy:**
  - The accuracy level must meet the demand (high accuracy comes with high cost)
  - Example: Measuring the temperature of a warehouse can accept an accuracy of +/-2 degrees. Measuring the temperature of a medical equipment system requires an accuracy of +/-0.2 degrees

Sensor selection

- **Versatility :**
  - The sensor can operate with the fluctuations of the surrounding environment
  - Example: The sensor for the weather station can work in summer and winter conditions. It is not feasible with the type of sensor that only works in indoor environments

Sensor selection

- **Power Consumption:**
  - Depending on the situation, some devices may require low power consumption, using energy-saving features
  - Example: sensors or devices using solar batteries need to design sleep mode to save energy, wake up when needed to collect and transmit data

Sensor selection

- **Consider the special environment:**
- Example: The sensor in monitoring water quality in aquaculture requires the sensor to be placed in a water environment (pH, DO, TDS, ...) different from the sensors based on sample analysis.

Sensor selection

- **Cost:**
  - IoT networks usually consist of hundreds, thousands of devices and sensors.
  - The design needs to consider the cost of installation, maintenance, replacement, etc.

IoT Devices

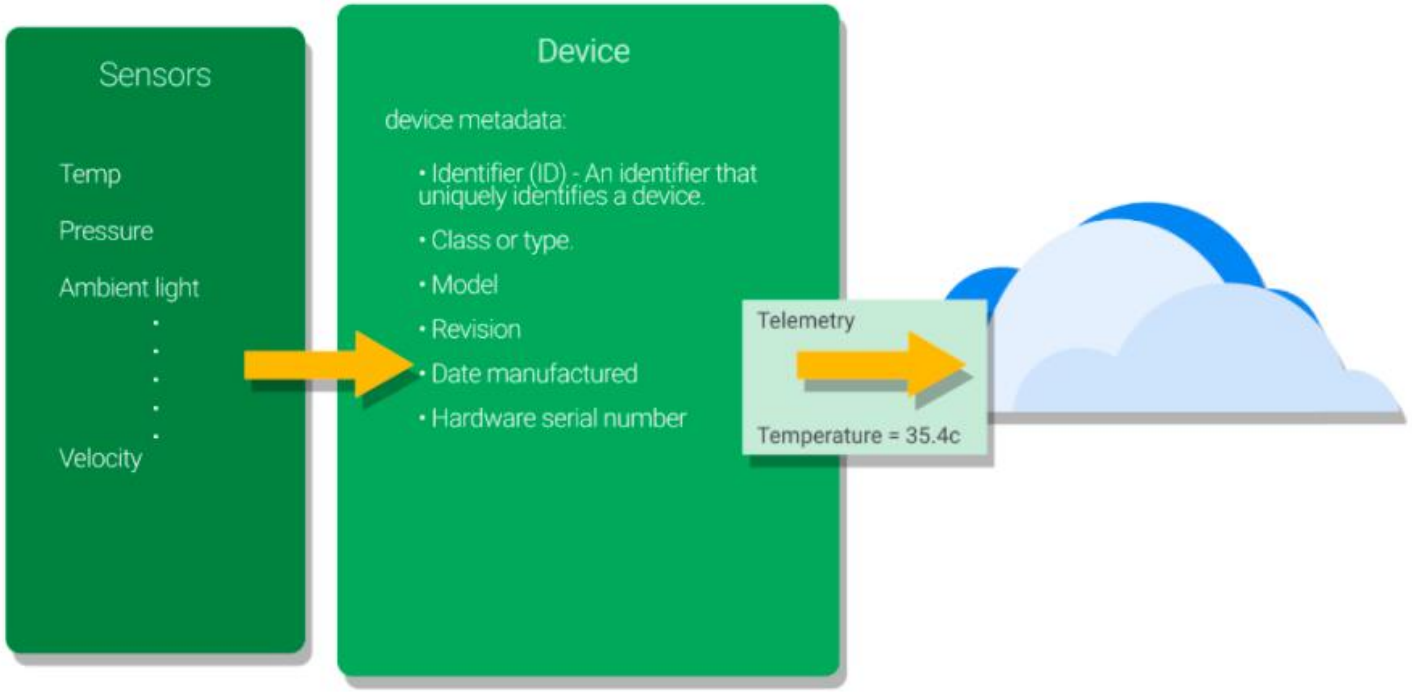
- A “Thing” in the “Internet of Things” is a processing unit that can connect to the internet to exchange data with the cloud
- The devices are often called "smart devices" or "connected devices”
- The device communicates with two types of data: telemetry (collected data) and state (device status)

Data type

- Each device can provide or use some types of data for different types of backend system
- **Device metadata:** Metadata contains descriptive information about the device (usually not changing much). For example
  - Identifier (ID) of device
  - Class or type of device
  - Model
  - Revision
  - Date manufactured
  - Hardware serial number

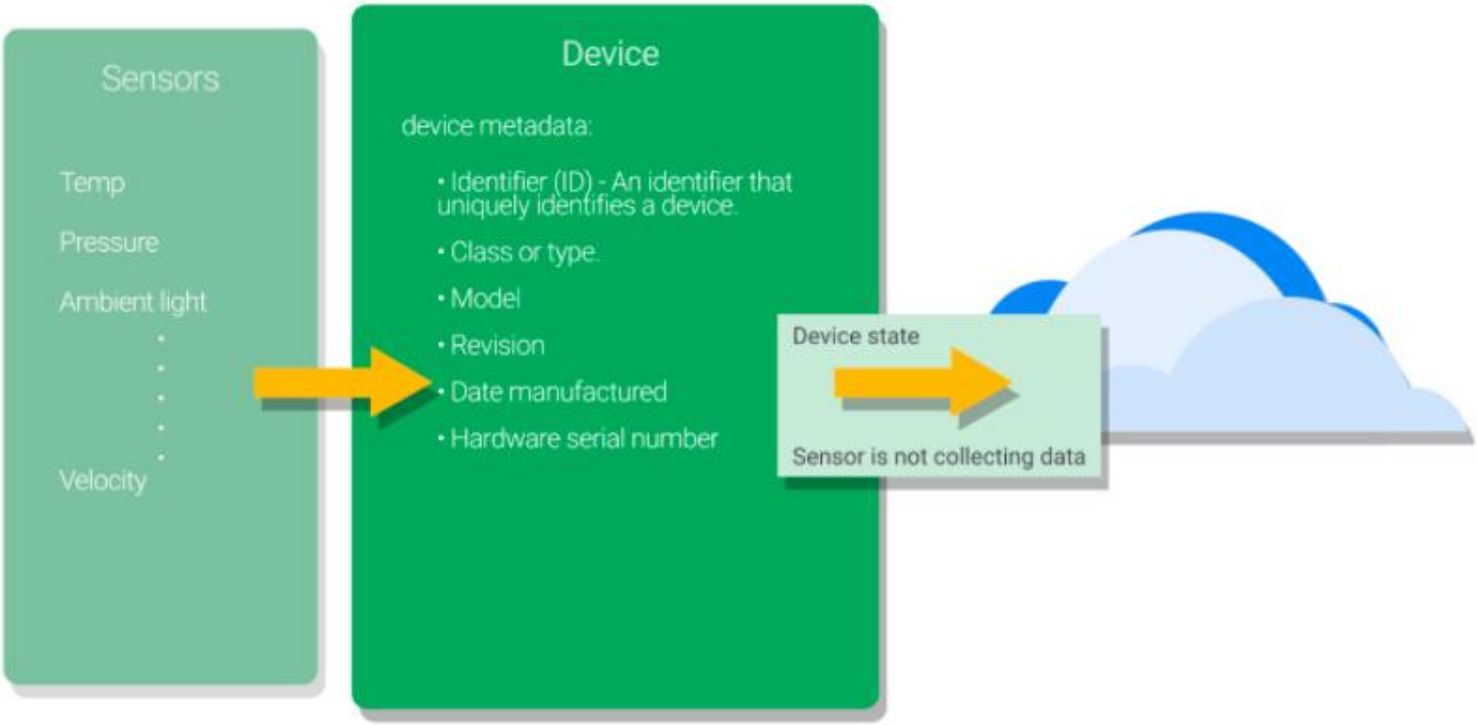
Data type

- **Telemetry**:
  - Data collected by the device through sensors is called telemetry.
  - It is read-only data (from the surrounding environment



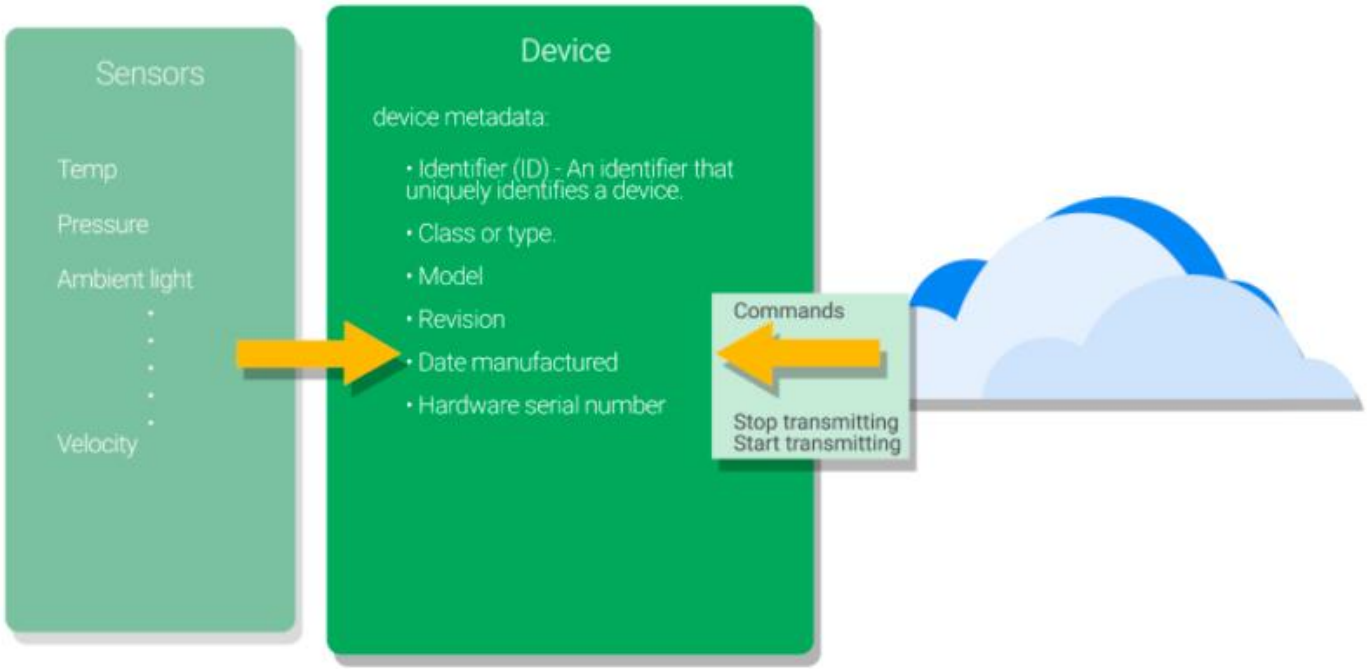
Data type

- **State information**:
  - Describes the current state of the device. It can be read/write, update (but less frequently)



Device Commands

- Commands: actions that are performed by the device.
- Examples:
  - Rotate 360 degrees to the right.
  - Turn on/off the light
  - Increase the data transmission frequency

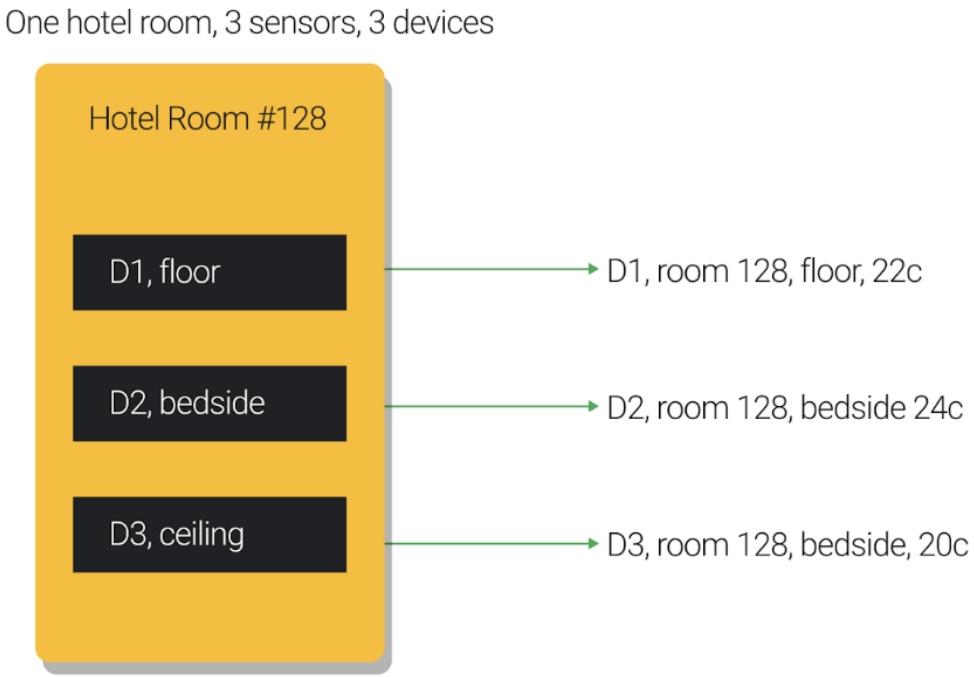


Definition of device in IoT system

- In the IoT system, the definition of a device can change depending on the project's needs.
- Each device can be considered as a separate entity, or a device can be responsible for a group of sensors.

Definition of device in IoT system - Example

- Monitoring the temperature of hotel rooms
- **Solution 1:** Each room has 3 sensors: one near the floor, one near the bed, and one near the ceiling

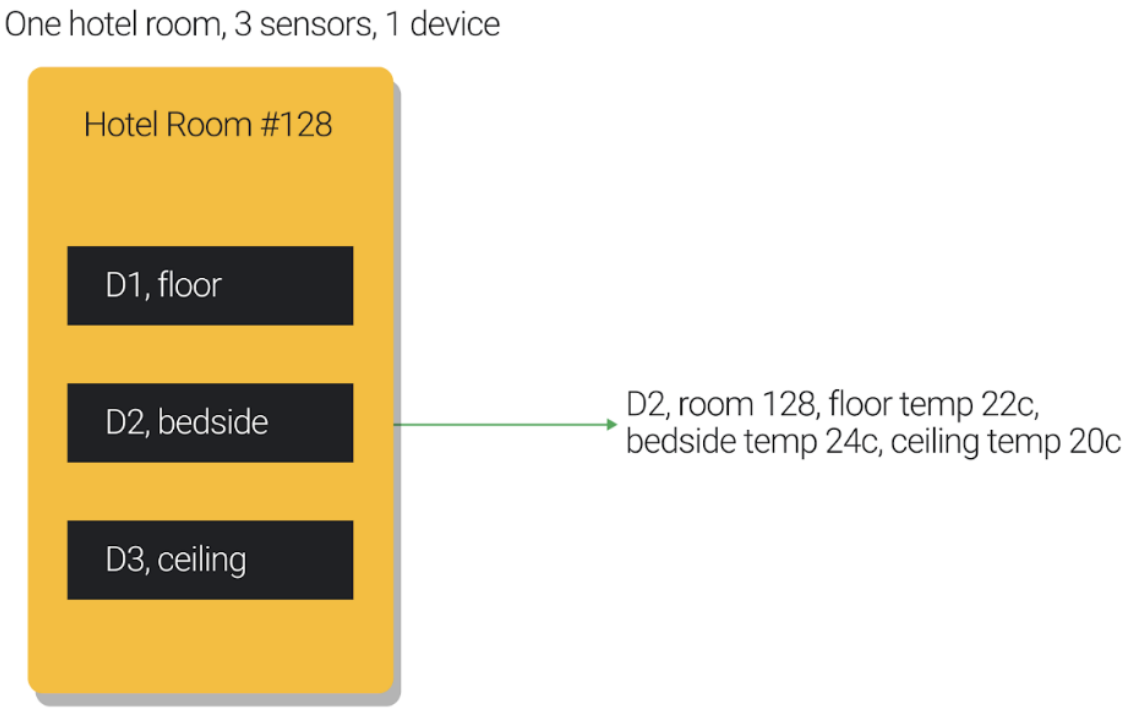


Definition of device in IoT system - Example

- **Solution 1:** Data is sent to the cloud as three different devices, each sending a temperature information to the cloud
  - {deviceID: "dh28dslkja", "location": "floor", "room": 128, "temp": 22 }
  - {deviceID: "8d3kiuhs8a", "location": "ceiling", "room": 128, "temp": 24 }
  - {deviceID: "kd8s8hh3o", "location": "bedside", "room": 128, "temp": 23 }

Definition of device in IoT system - Example

- **Solution 2:** Each room uses one device that is responsible for sending data from three sensors



Definition of device in IoT system - Example

- **Solution 2:** One device with three sensors transmits data to the cloud. The device can also process the data to find the average temperature..
  - {deviceID: "dh28dslkja", "room": 128, "temp_floor": 22, "temp_ceiling": 24, "temp_bedside": 23, "average_temp": 23 }

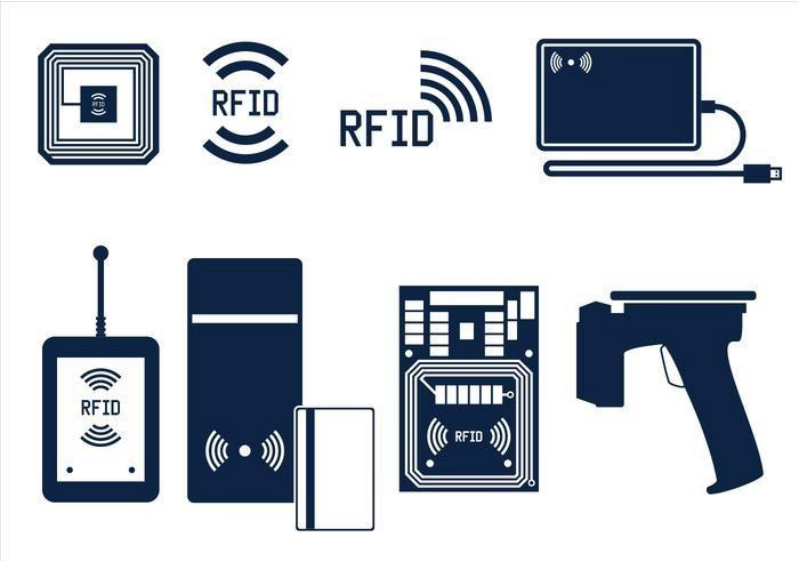
- The choice of solution depends on the intention of using the information at the present time and the potential in the future

2.2. Some communication standards for IoT

- Communication standards:
  - NFC and RFID
  - Bluetooth
  - WiFi
  - GSM, GPRS, 2G/3G/4G, LTE
  - ZigBee
  - 6LoWPAN
  - Thread

Some communication standards for IoT

- RFID (Radio-frequency identification)



https://www.youtube.com/watch?v=MAA9JpGraoU

Frequency: 120–150 kHz (LF), 13.56 MHz (HF), 433 MHz (UHF), 865-868 MHz (Europe)902-928 MHz (North America) UHF, 2450-5800 MHz (microwave), 3.1–10 GHz (microwave)
Range: 10cm to 200m
Examples: Road tolls, Building Access, Inventory

Some communication standards for IoT

- NFC (Near-Field Communications)

Frequency: 13.56 MHz
Range: < 0.2 m
Examples: Smart Wallets/Cards, Action Tags, Access Control

Some communication standards for IoT

- Bluetooth

Frequency: 2.4GHz
Range: 1-100m
Examples: Hands-free headsets, key dongles, fitness trackers

Some communication standards for IoT

- WiFi

Frequency: 2.4 GHz, 3.6 GHz and 4.9/5.0 GHz bands.
Range: Common range is up to 100m but can be extended.
Applications: Routers, Tablets, etc

More: https://www.postscapes.com/internet-of-things-technologies/

Some communication standards for IoT

- GSM (Global System for Mobile communications)

Frequency: Europe: 900MHz & 1.8GHz, US: 1.9GHz & 850MHz, Full List can be found here.
Data Rate: 9.6 kbps
Examples: Cell phones, M2M, smart meter, asset tracking

More: https://www.postscapes.com/internet-of-things-technologies/

Some communication standards for IoT

- ZigBee

- Standard: ZigBee 3.0 based on IEEE802.15.4
  - Frequency: 2.4GHz
  - Range: 10-100m
  - Data Rates: 250kbps

Some communication standards for IoT

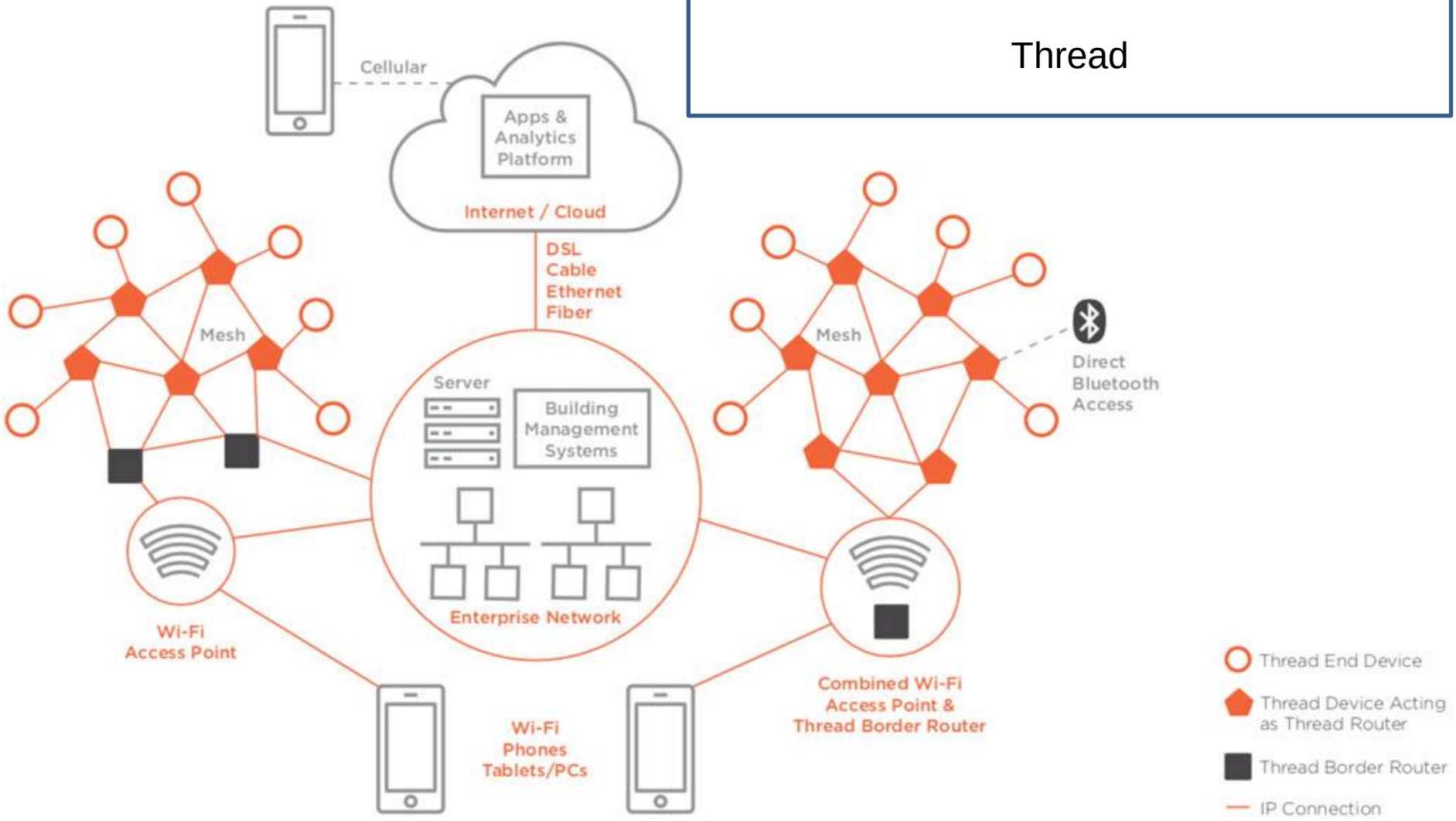
- **6LoWPAN**
- IPv6 protocol over low-power wireless PANs

Some communication standards for IoT

- Thread: A new IP protocol based on IPv6 platform designed for automation in smart homes and buildings
- Introduced in mid-2014 by Theard Group, Thread protocol follows different standards, such as IEEE802.15.4, IPv6 and 6LoWPAN, and offers an IP-based solution for IoT applications
- Standard: Theard, based on IEEE802.15.4 and 6LowPAN
- Frequency 2.4GHz
- Reference: https://smarthomekit.vn/thread-protocol/

Some communication standards for IoT

Thread



Some communication standards for IoT

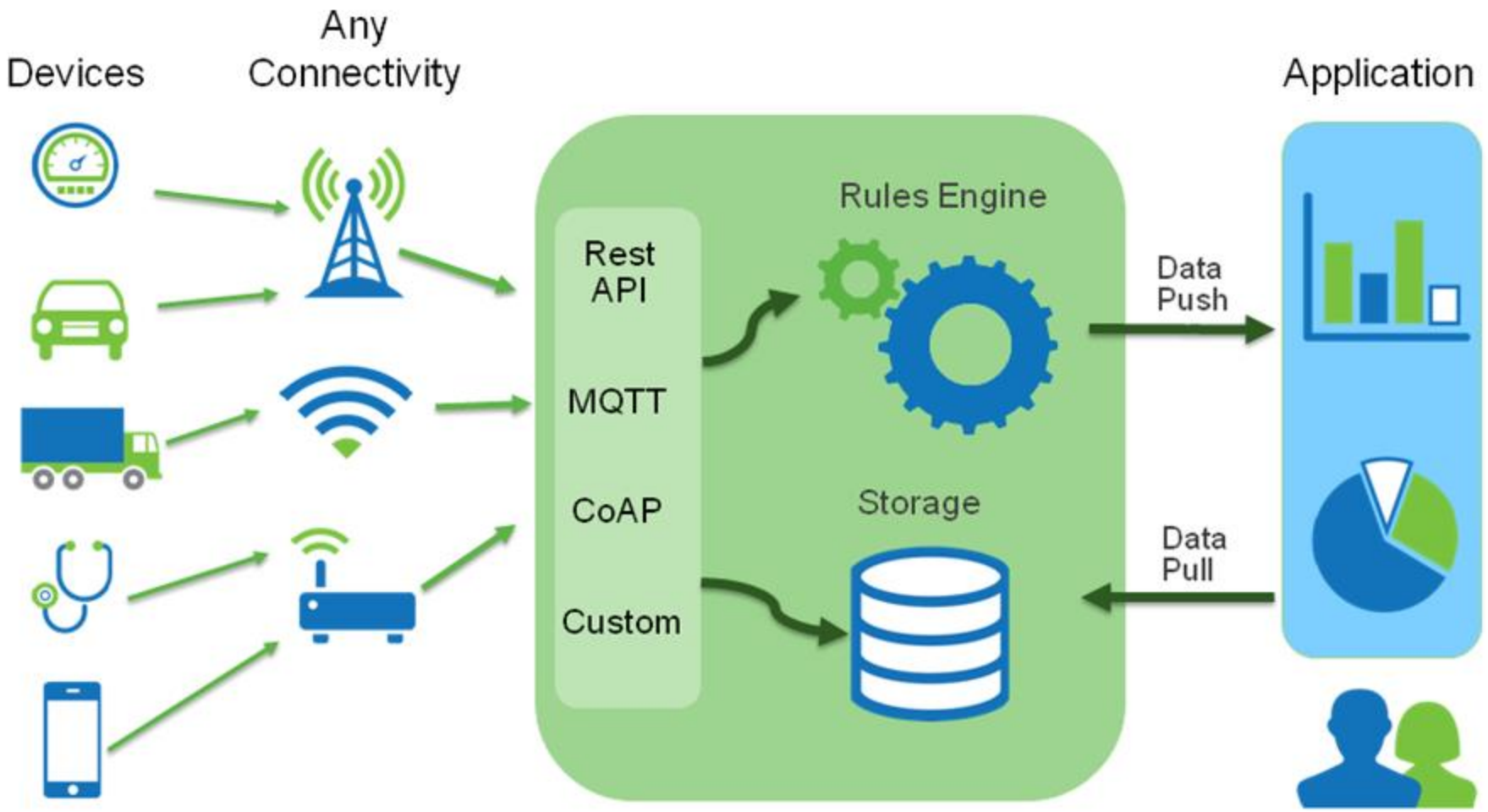
Additional:

- 3G
- 4G LTE
- ANT
- Dash7
- Ethernet
- GPRS
- PLC / Powerline
- QR Codes, EPC
- WiMax
- X-10
- 802.15.4
- Z-Wave
- Zigbee

Backbone: IPv4, IPv6, TCP/UDP

More: https://www.postscapes.com/internet-of-things-technologies/

2.3. Protocols for IoT applications



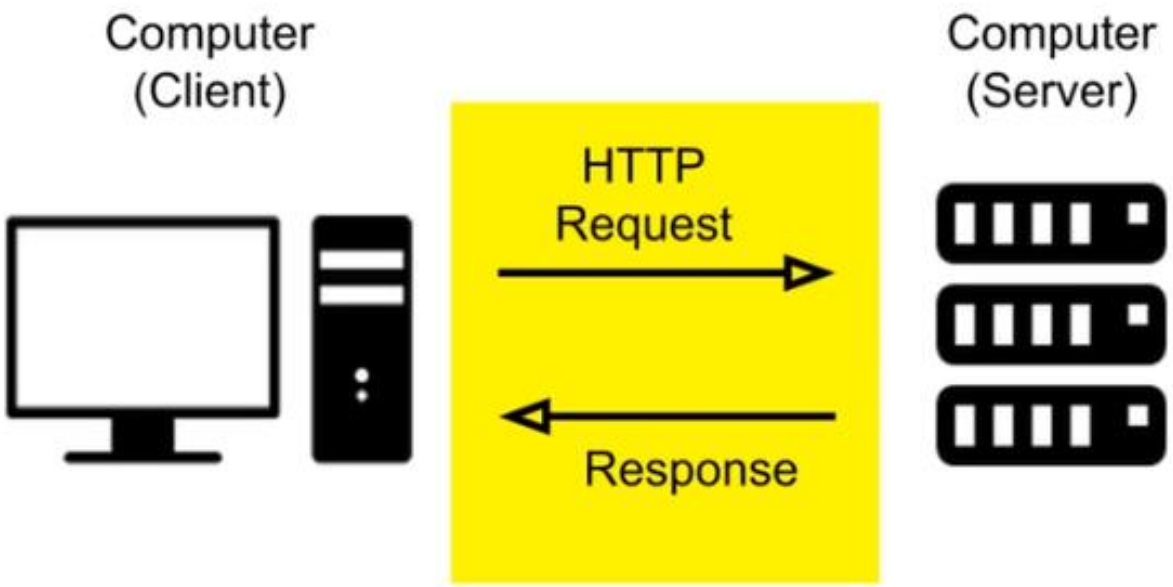
Protocols for IoT applications

- HTTP, HTTPS
- REST API HTTP (Representational State Transfer)
- MQTT (Message Queue Telemetry Transport)
- AMQP (Avanced Message Queue Protocol)

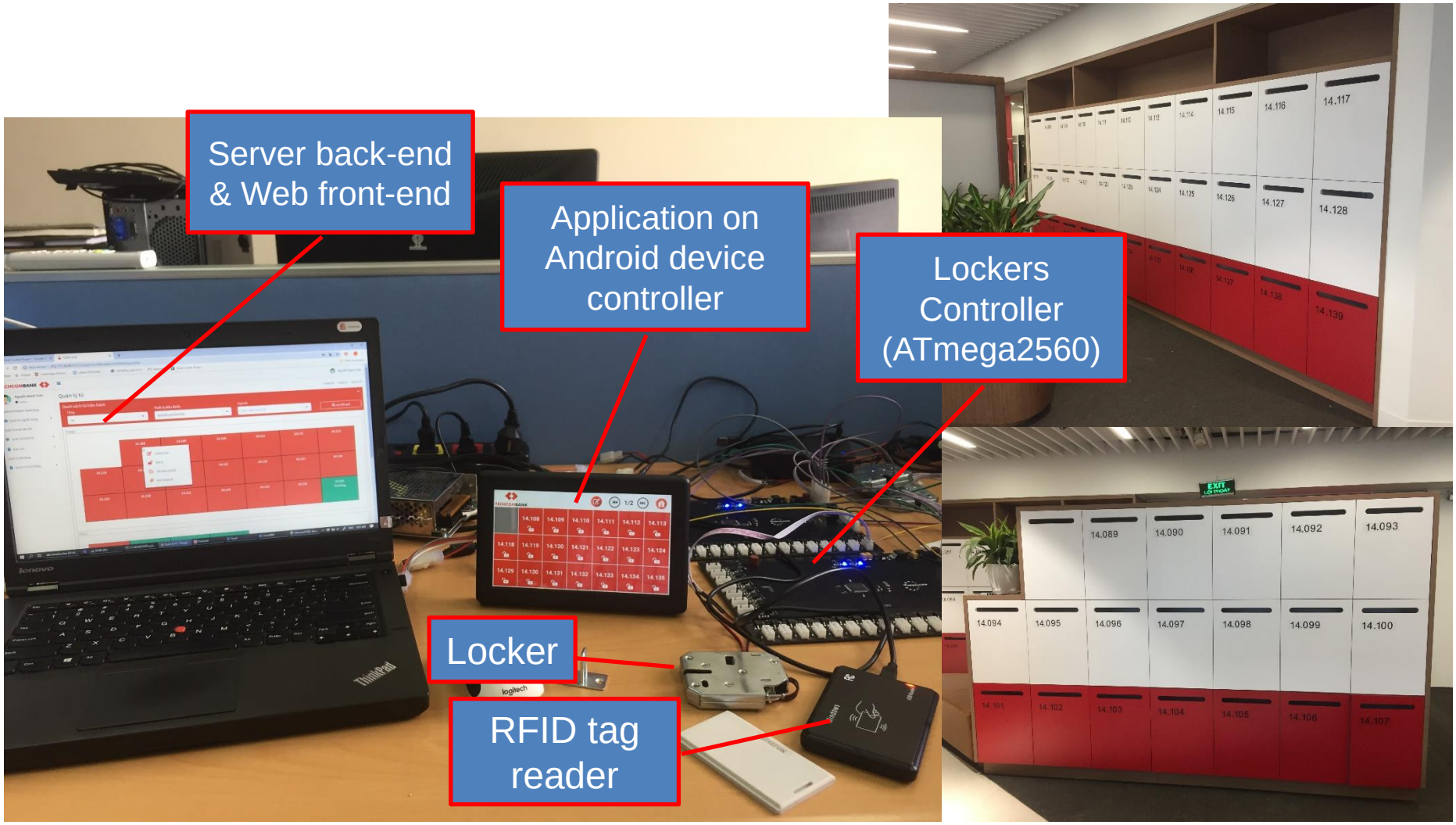
https://www.postscapes.com/internet-of-things-technologies/

2.3.1. HTTP

HTTP = HyperText Transfer Procol



Example of HTTP



Smart Locker system

Example of making an http request with Java (1)

- Using the HttpURLConnection library in Java to perform an http request to an http REST api
- **Step 1:** Create an *http connection*, set the properties for the *request*

```
public String requestUserInfor(String devId, String qrDevId, String
qrCode, int timeout){
    String result = "";
    try {
        String urlApi =
"https://203.171.20.94:8080/api/AccessControl/GetUserInfor";
        URL url = new URL(urlApi);
        HttpURLConnection conn = (HttpURLConnection)
url.openConnection();
        conn.setRequestMethod("POST");
        conn.setConnectTimeout(timeout);
        conn.setReadTimeout(timeout);
        conn.setRequestProperty("Content-Type", "application/json;
charset=utf-8");
```

Example of making an http request with Java (2)

- **Step 2:** Write the data to be sent to the output stream of the request. Data can be packaged using JSON

```
        ...
        OutputStream os = conn.getOutputStream();
        BufferedWriter writer = new BufferedWriter(new
OutputStreamWriter(os, "UTF-8"));
        JSONObject jsonObj = new JSONObject();
        try {
            jsonObj.accumulate("deviceId", devId);
            jsonObj.accumulate("qrCodeId", qrDevId);
            jsonObj.accumulate("qrCodeValue", qrCode);
        } catch (JSONException e) {
            e.printStackTrace();
        }

        writer.write(jsonObj.toString());
        writer.flush();
        writer.close();
        os.close();
        conn.connect();
```

Example of making an http request with Java (3)

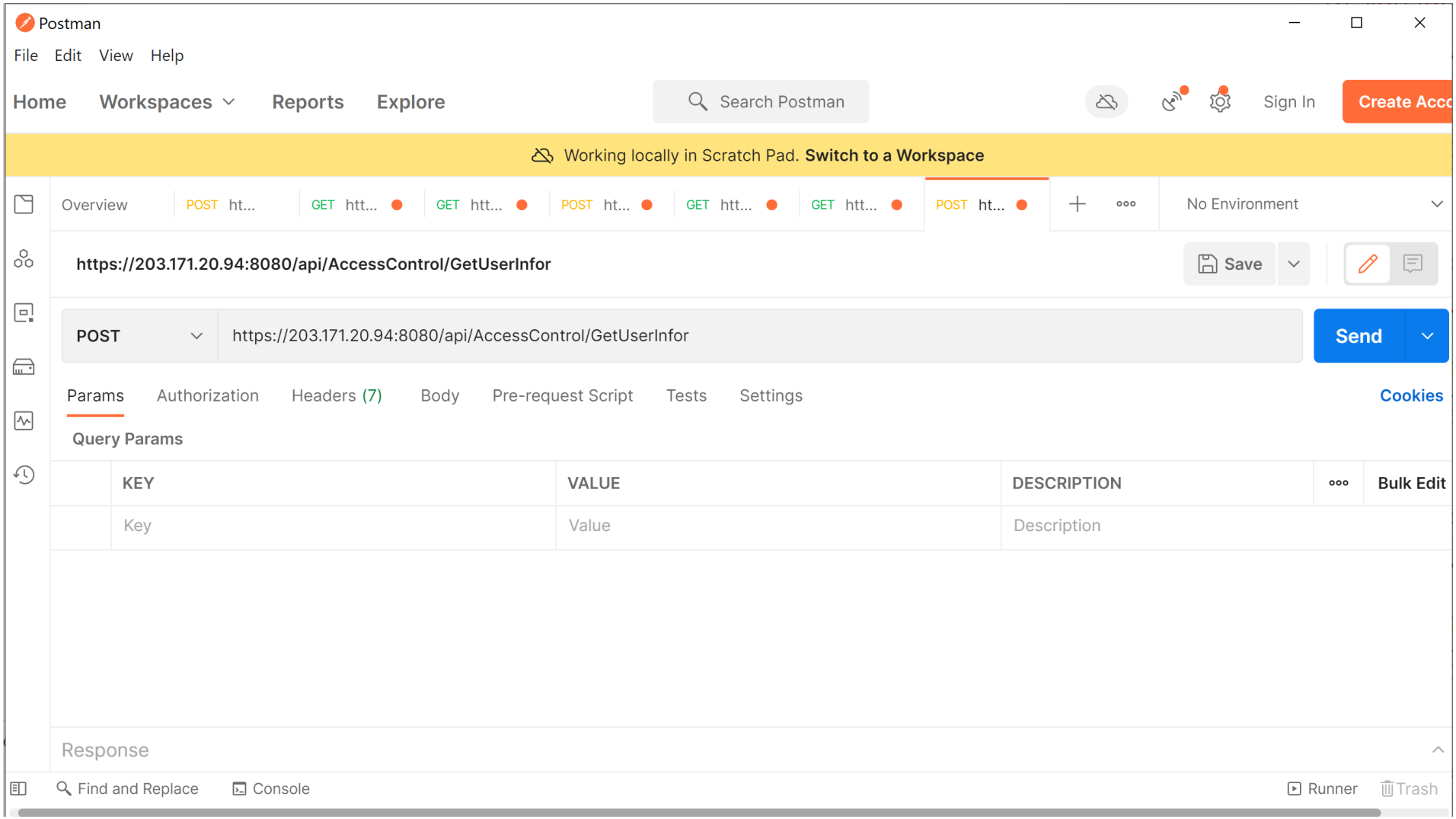
- **Step 3:** Receive http response from server. Check the return code and read data from the input stream of the http response

```
        ...
        StringBuffer sb = new StringBuffer();
        if (conn.getResponseCode() == HttpURLConnection.HTTP_OK) {
            InputStream in = conn.getInputStream();
            int chr;
            while ((chr = in.read()) != -1) {
                sb.append((char) chr);
            }
            in.close();
        } else {
            sb.append(conn.getResponseCode());
        }
        result = sb.toString();
        conn.disconnect();
    }
    catch(IOException e){
        e.printStackTrace();
    }
    return result;
}
```

Http Response code

- 200: OK
- 201: Created
- 204: No Content
- 401: Unauthorized
- 403: Forbidden
- 404: Not Found
- 408: Request Timeout
- 500: Internal Server Error
- 502: Bad Gateway
- 503: Service Unavailable

Use Postman


Postman
File Edit View Help
Home Workspaces Reports Explore
Search Postman
Sign In
Create Acc
Working locally in Scratch Pad. Switch to a Workspace
Overview
POST ht...
GET htt...
GET htt...
POST ht...
GET htt...
GET htt...
POST ht...
No Environment
https://203.171.20.94:8080/api/AccessControl/GetUserInfor
Save
POST
https://203.171.20.94:8080/api/AccessControl/GetUserInfor
Send
Params Authorization Headers (7) Body Pre-request Script Tests Settings
Cookies
Query Params
KEY VALUE DESCRIPTION Bulk Edit
Key Value Description
Response
Find and Replace Console Runner Trash

Example of making an http request with Python

```
import requests
URL = "https://maps.googleapis.com/maps/api/geocode/json"
location = "Hanoi University of Science and Technology"
PARAMS = {'address':location}
# sending get request and saving the response as response
object
r = requests.get(url = URL, params = PARAMS)
# extracting data in json format
data = r.json()

# extracting latitude, longitude and formatted address
# of the first matching location
latitude = data['results'][0]['geometry']['location']['lat']
longitude = data['results'][0]['geometry']['location']['lng']
formatted_address = data['results'][0]['formatted_address']
# printing the output
print("Latitude:%s\nLongitude:%s\nFormatted Address:%s"
   %(latitude, longitude,formatted_address))
```

Exercise 1

- HTTP request
  - Create API server
  - Request Body là json object


```
{"deviceId":"8a0fc66a61a959f6", "qrCodeId": "a652d57094b7590b0dea115b156c07098abdea87", "qrCodeValue":"P22498244182551944"}
```

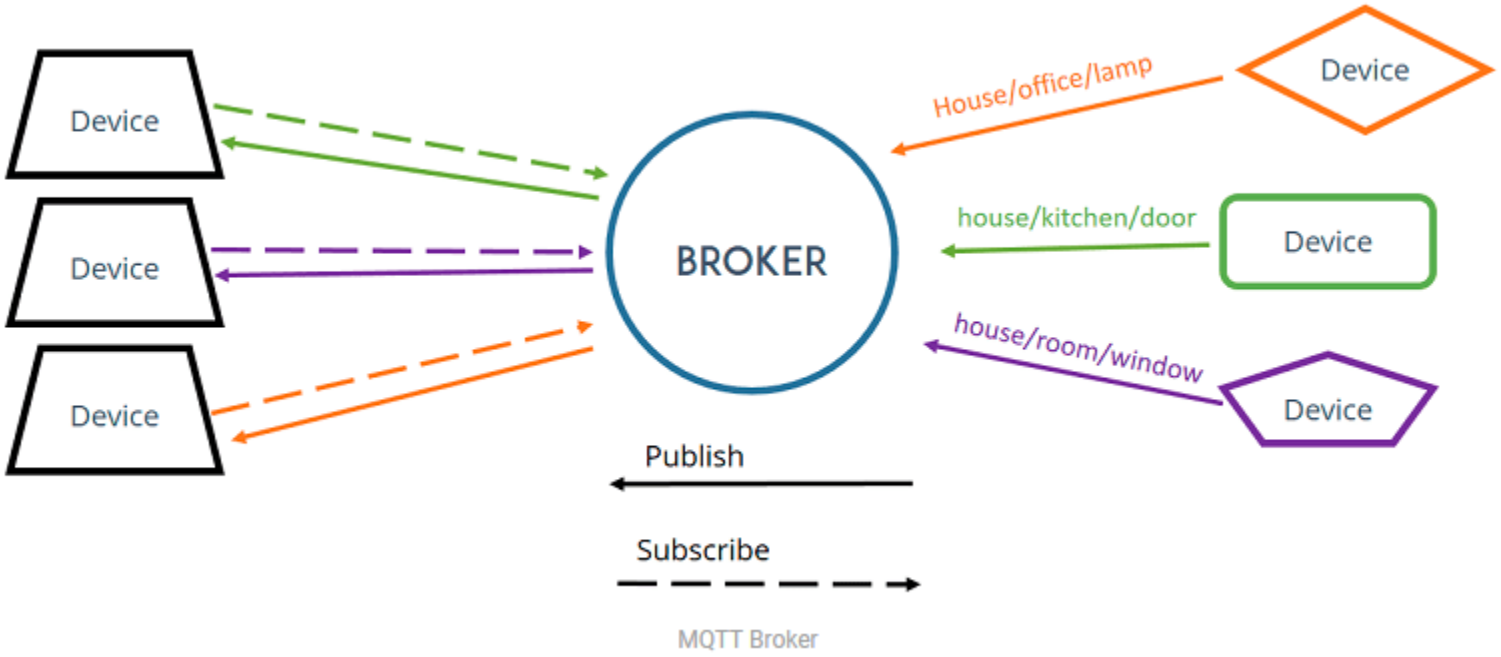

  - Using Postman for testing

2.3.2. MQTT Protocol

- **The Messaging and Data Exchange Protocol of the IoT**
- **MQTT** (Message Queuing Telemetry Transport):
  - Message-passing protocol based on the publish/subscribe model
  - Uses low bandwidth, high reliability and can operate in unstable network conditions.

MQTT protocol

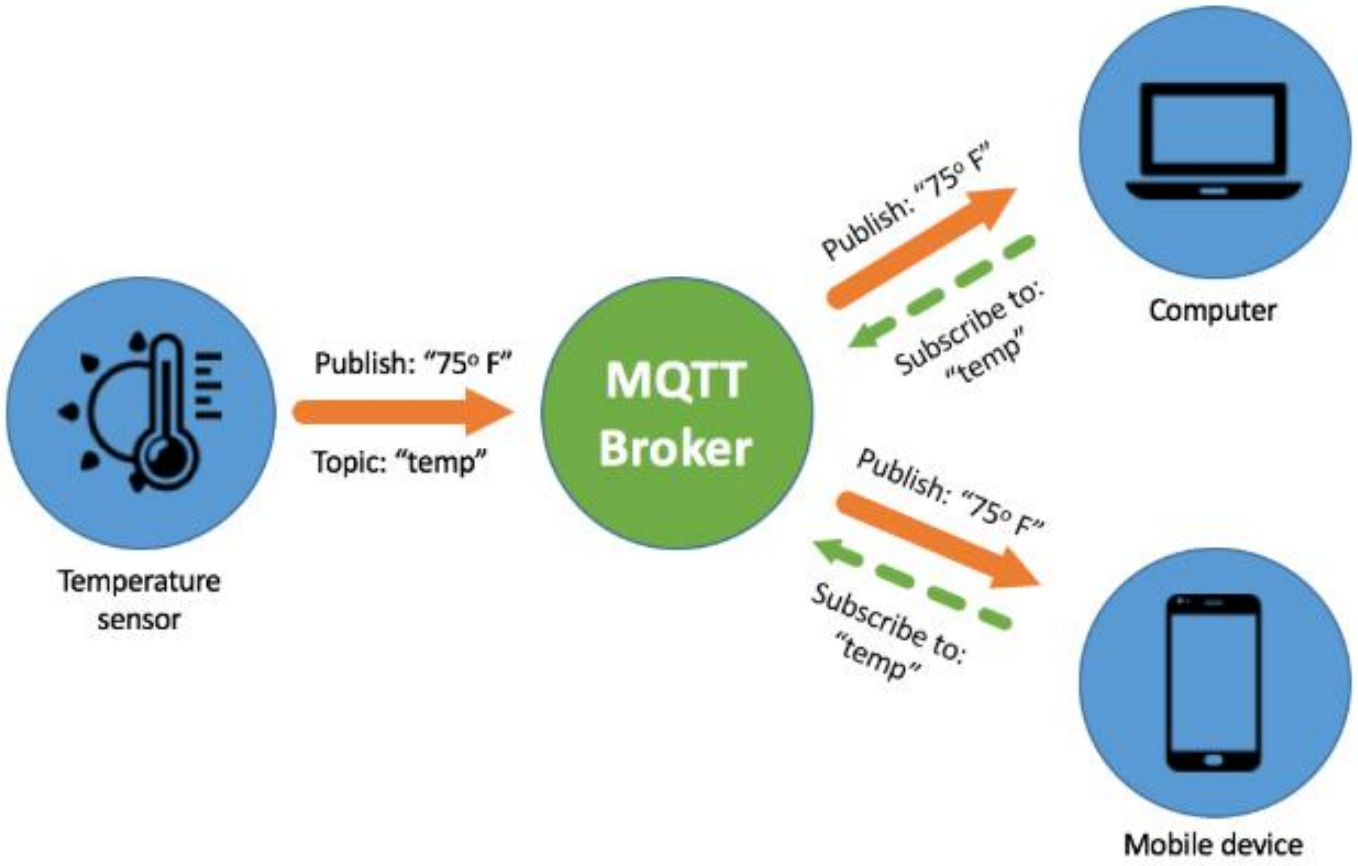
- The high-level architecture of MQTT consists of 2 main components:
  - Broker
  - Clients



MQTT Protocol

- **Publish/Subscribe:**
  - In a system using the MQTT protocol, many nodes (called mqtt clients - abbreviated as clients) connect to an MQTT server (called broker).
  - Each client will subscribe to a few channels (topics), for example “/client1/channel1”, “/client1/channel2”. This registration process is called “**subscribe**”. Each client will receive data when any other devices sends data to the registered channel.
  - When a client sends data to that channel, it is called “**publish**”.

MQTT Protocol



https://www.hivemq.com/mqtt-essentials/

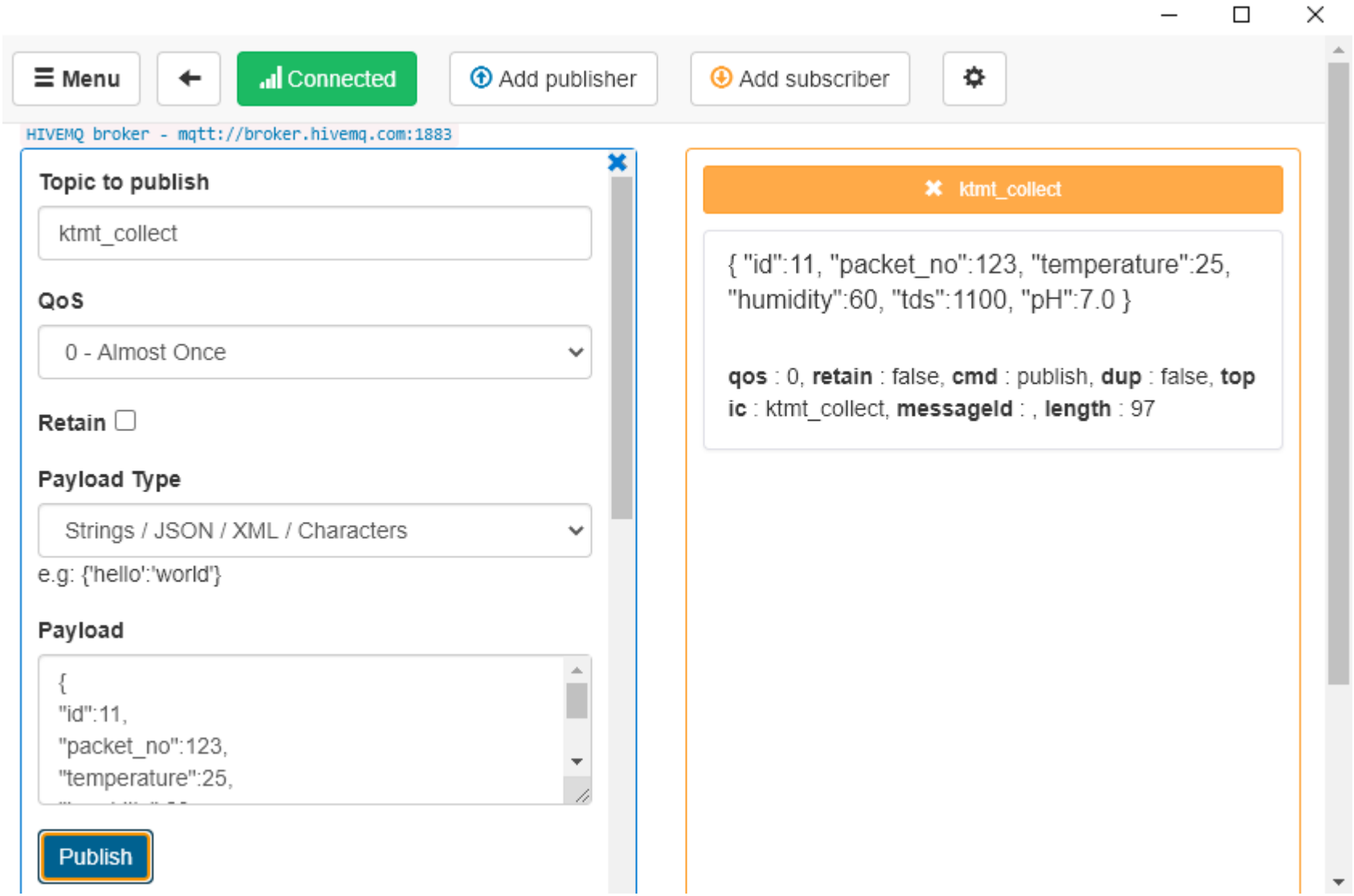
MQTT Protocol

- **QoS (Quality of Service):**
  - There are 3 QoS options when “publish” and “subscribe” :
  - **QoS0** Broker/client will send data exactly once, the sending process is confirmed by only TCP/IP protocol, (“fire and forget”)
  - **QoS1** Broker/client will send data with at least one confirmation from the other end, meaning there may be more than one confirmation of receiving data.
  - **QoS2** Broker/client ensures that when sending data, the receiver only receives exactly once, this process must go through 4 handshake steps.

MQTT Protocol

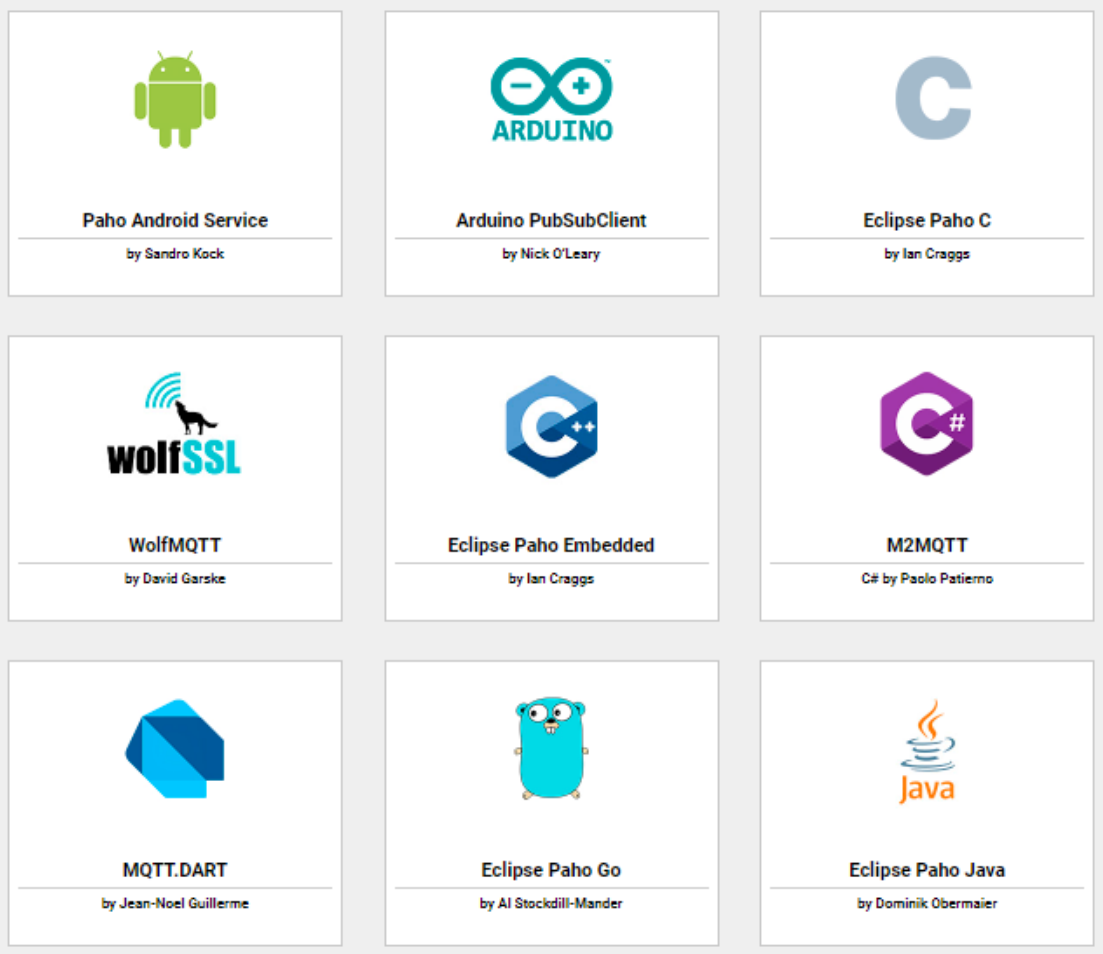
- Using the client tool: MQTTBox
  - https://www.hivemq.com/mqtt-toolbox/
  - Publish/Subscribe data

MQTT client tool: MQTTBox



MQTT client library

- MQTT client libraries for different platforms :
  - https://www.hivemq.com/mqtt-client-library-encyclopedia/



Example 1

- Publish/subscribe data using Paho mqtt client library for Java
- Paho mqtt client client
  - https://www.eclipse.org/paho/index.php?page=clients/java/index.php
- Using the Paho Java Client:
  - Using Maven dependency
  - Or add library .jar (Build Path >> Add External Archives):

Download library file: org.eclipse.paho.client.mqttv3-1.1.1.jar

Publish message

```
import org.eclipse.paho.client.mqttv3.MqttClient;
import org.eclipse.paho.client.mqttv3.MqttConnectOptions;
import org.eclipse.paho.client.mqttv3.MqttException;
import org.eclipse.paho.client.mqttv3.MqttMessage;
import org.eclipse.paho.client.mqttv3.persist.MemoryPersistence;
public class App {
public static void main(String[] args) {
    public static void main( String[] args ){
        System.out.println( "MQTT Demo!" );
        new App().doDemo();
    }
    public void doDemo() {
        String subTopic = "/ktmt/iot";
        String pubTopic = "/ktmt/iot";
        String content = "Hello World";
        int qos = 1;
        String broker = "tcp://broker.hivemq.com:1883";
        String clientId = "ID_OF_CLIENT";
        MemoryPersistence persistence = new MemoryPersistence();
        try {
            MqttClient client = new MqttClient(broker, clientId,
persistence);
```

```
        // MQTT connection option
        MqttConnectOptions connOpts = new MqttConnectOptions();
        // retain session
        connOpts.setCleanSession(true);
        // set callback
        client.setCallback(new OnMessageCallback());
        // establish a connection
        System.out.println("Connecting to broker: " + broker);
        client.connect(connOpts);
        System.out.println("Connected");
        // Subscribe
        client.subscribe(subTopic);
        // Required parameters for message publishing
        MqttMessage message = new MqttMessage(content.getBytes());
        message.setQos(qos);
        System.out.println("Publishing message: " + content);
        client.publish(pubTopic, message);
        System.out.println("Message published");
        client.disconnect();
        System.out.println("Disconnected");
        client.close();
        System.exit(0);
    }
    catch (MqttException me) {
         me.printStackTrace();
    }
}
```

Subscribe - Callback

```
public class OnMessageCallback implements MqttCallback {
    public void connectionLost(Throwable cause) {
        // After the connection is lost, it usually reconnects here
        System.out.println("disconnect, you can reconnect");
    }
    public void messageArrived(String topic, MqttMessage message)
throws Exception {
        // The messages obtained after subscribe will be executed here
        System.out.println("Received message topic:" + topic);
        System.out.println("Received message Qos:" + message.getQos());
        System.out.println("Received message content:" + new
            String(message.getPayload()));
    }
    public void deliveryComplete(IMqttDeliveryToken token) {
        System.out.println("deliveryComplete---------" +
    token.isComplete());
    }
}
```

Example 2:

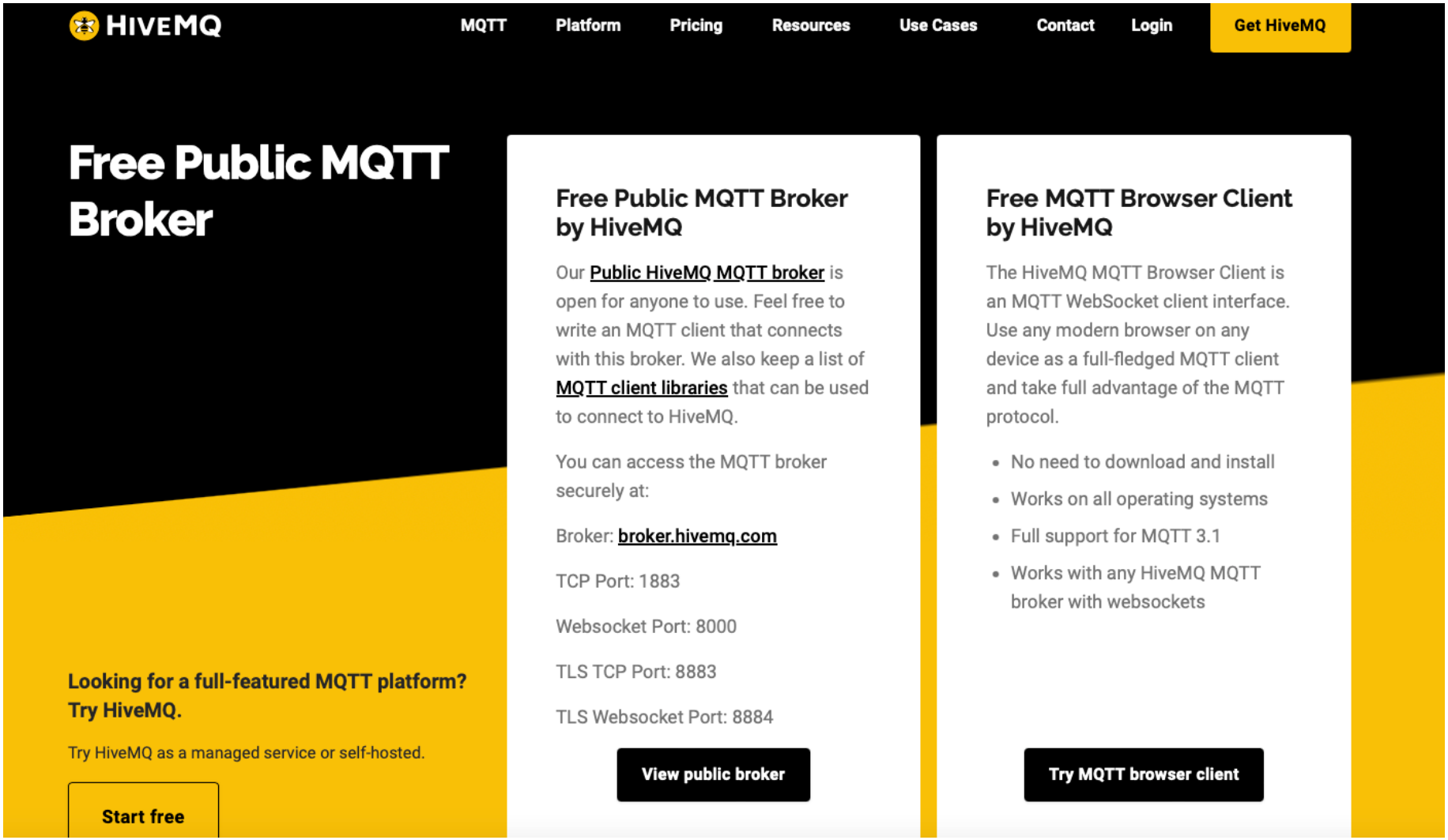
- Receive sensor data collected from devices sent up
- Refer to the source code:
  - https://github.com/hungpn37/iot_mqttdemo

Exercise 2

- Write a mqtt client program that performs:
  - Send (publish) data to mqtt broker
  - Receive (subscribe) data from mqtt broker
  - Pack data using JSON. For example: ":

    {"id":11, "packet_no":126, "temperature":30,
    "humidity":60, "tds":1100, "pH":5.0}
  - Use MQTTBox to illustrate sending and receiving
  - Example using mqtt broker:
    `tcp://broker.hivemq.com:1883`

Exercise 2


HIVEMQ
MQTT
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Use Cases
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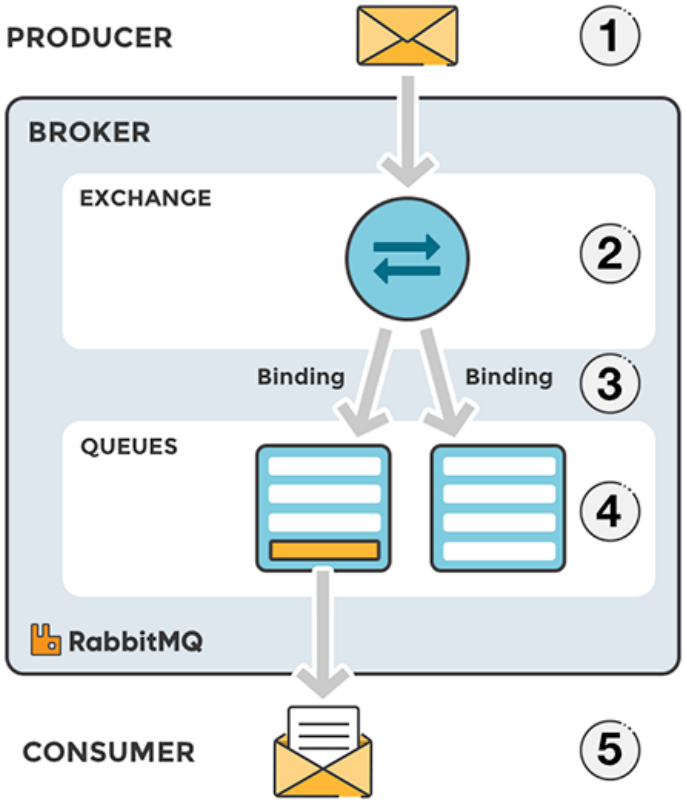
Free Public MQTT Broker
Looking for a full-featured MQTT platform? Try HiveMQ.
Try HiveMQ as a managed service or self-hosted.
Start free
Free Public MQTT Broker by HiveMQ
Our Public HiveMQ MQTT broker is open for anyone to use. Feel free to write an MQTT client that connects with this broker. We also keep a list of MQTT client libraries that can be used to connect to HiveMQ.
You can access the MQTT broker securely at:
Broker: broker.hivemq.com
TCP Port: 1883
Websocket Port: 8000
TLS TCP Port: 8883
TLS Websocket Port: 8884
View public broker
Free MQTT Browser Client by HiveMQ
The HiveMQ MQTT Browser Client is an MQTT WebSocket client interface. Use any modern browser on any device as a full-fledged MQTT client and take full advantage of the MQTT protocol.
No need to download and install
Works on all operating systems
Full support for MQTT 3.1
Works with any HiveMQ MQTT broker with websockets
Try MQTT browser client

2.3.3. AMQP protocol

- AMQP (Advanced Message Queue Protocol): The transmission protocol uses message queues
- RabbitMQ: A broker uses the AMQP protocol
- RabbitMQ broker acts as an intermediary to store and coordinate messages between the sender (producer) and the receiver (consumer)

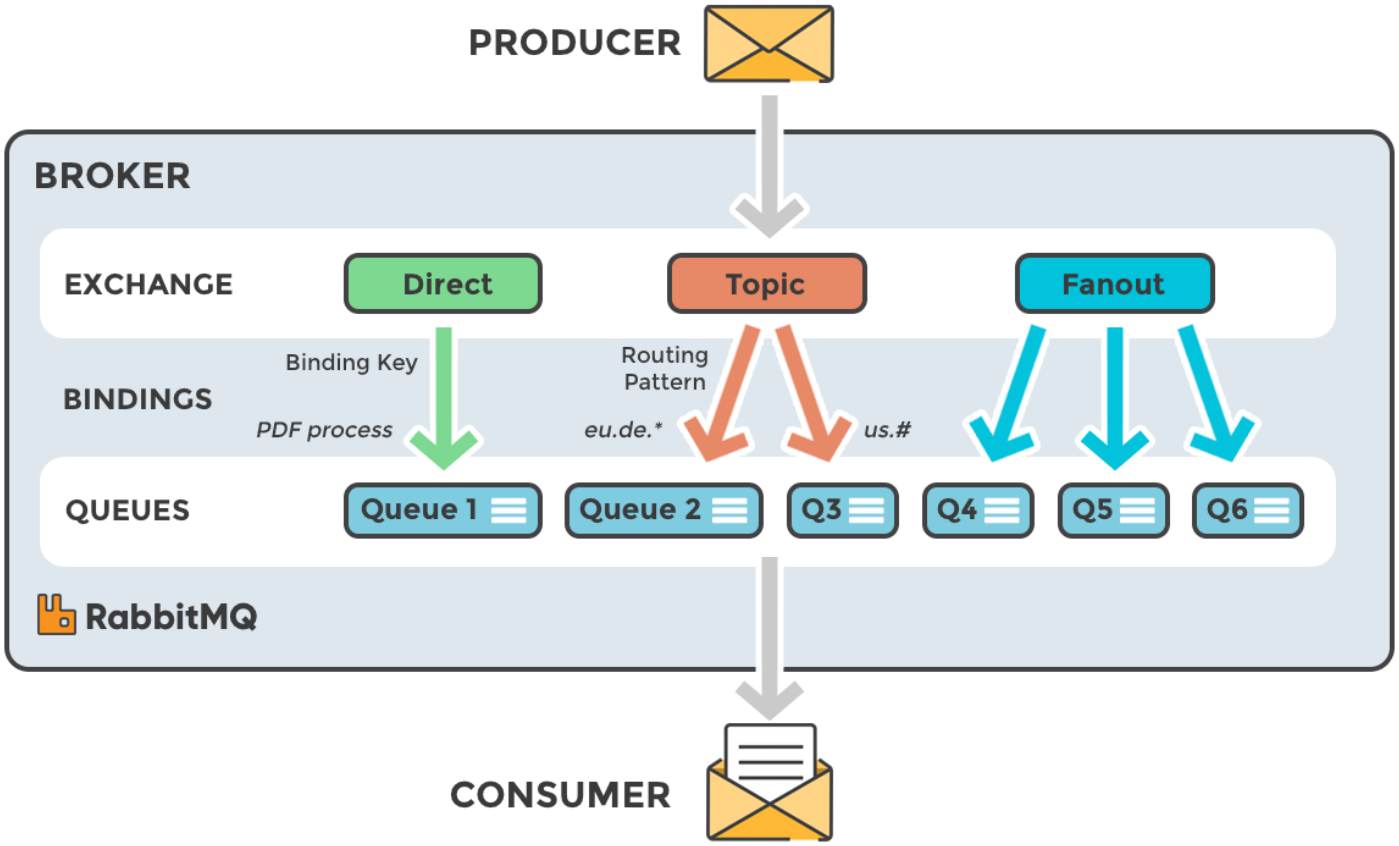
AMQP protocol

- RabbitMQ:
  - Flow of sending and receiving messages via RabbitMQ



AMQP protocol

- RabbitMQ:
  - Four Exchange types: direct, topic, fanout, headers

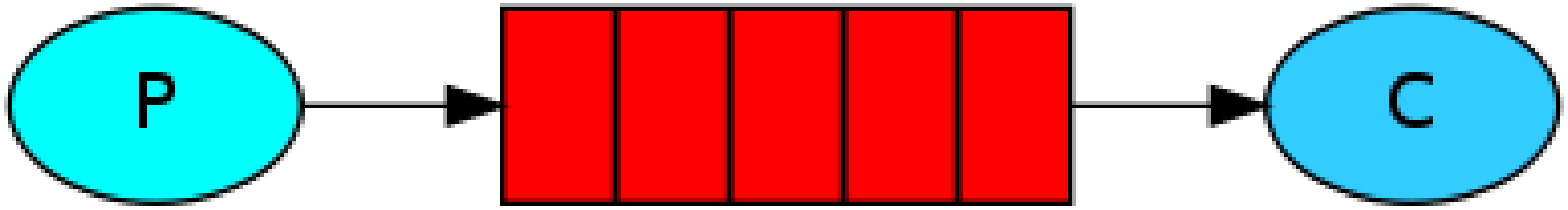


AMQP protocol

- Install RabbitMQ broker (server)
  - https://www.rabbitmq.com/download.html
  - https://www.rabbitmq.com/install-windows.html
- Administer the RabbitMQ broker using the tool:
  - https://www.rabbitmq.com/management.html
- RabbitMQ tutorials:
  - https://www.rabbitmq.com/getstarted.html

Tutorial 1

- Write a program to send and receive data via RabbitMQ
  - Install and use a RabbitMQ broker
  - Producer sends data (message)
  - Consumer receives data
  - Use default exchange (type: direct)



https://www.rabbitmq.com/tutorials/tutorial-one-java.html

Tutorial 1. Producer

Sender.java

```
import com.rabbitmq.client.Channel;
import com.rabbitmq.client.Connection;
import com.rabbitmq.client.ConnectionFactory;
import java.nio.charset.StandardCharsets;

public class send {
    private final static String QUEUE_NAME = “ktmt";
    public static void main(String[] argv) throws Exception {
        ConnectionFactory factory = new ConnectionFactory();
        factory.setHost(“localhost");
        factory.setUsername(“guest");
        factory.setPassword(“guest");
        try (Connection connection = factory.newConnection();
             Channel channel = connection.createChannel()) {
            channel.queueDeclare(QUEUE_NAME, false, false, false, null);
            String message = "Hello World! Publish message to broker";
            channel.basicPublish("", QUEUE_NAME, null,
                message.getBytes(StandardCharsets.UTF_8));
            System.out.println(" [x] Sent '" + message + "'");
        }
    }
}
```

Tutorial 1. Consumer

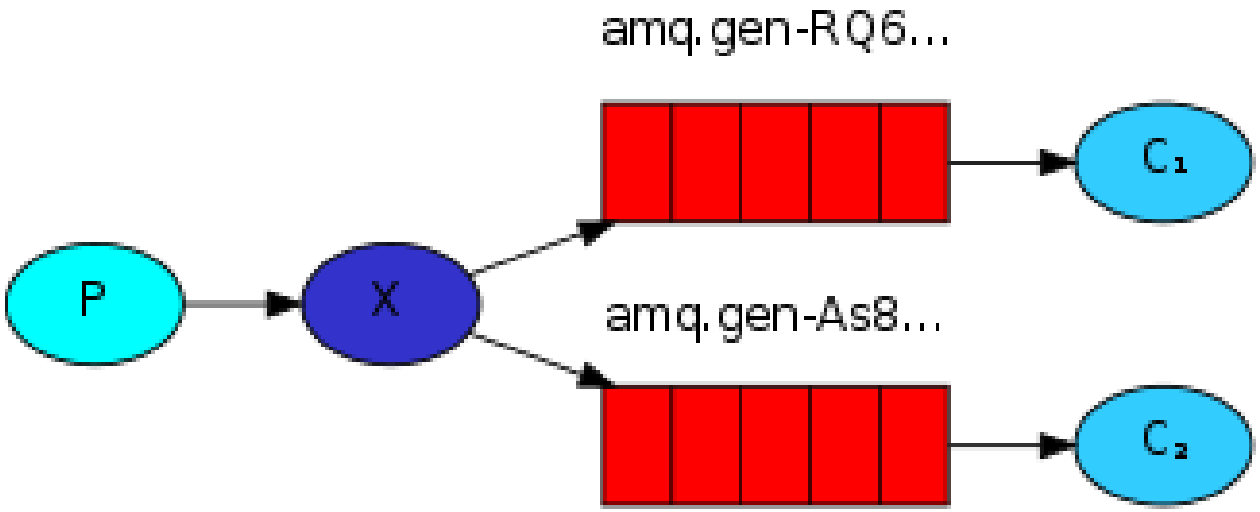
Recv.java

```
import com.rabbitmq.client.Channel;
import com.rabbitmq.client.Connection;
import com.rabbitmq.client.ConnectionFactory;
import com.rabbitmq.client.DeliverCallback;
public class Recv {
    private final static String QUEUE_NAME = “ktmt";
    public static void main(String[] argv) throws Exception {
        ConnectionFactory factory = new ConnectionFactory();
        factory.setHost(“localhost");
        factory.setUsername(“guest");
        factory.setPassword(“guest");
        Connection connection = factory.newConnection();
        Channel channel = connection.createChannel();
        channel.queueDeclare(QUEUE_NAME, false, false, false, null);
        System.out.println(" [*] Waiting for messages. To exit press CTRL+C");
        DeliverCallback deliverCallback = (consumerTag, delivery) -> {
            String message = new String(delivery.getBody(), "UTF-8");
            System.out.println(" [x] Received '" + message + "'");
        };
        channel.basicConsume(QUEUE_NAME, true, deliverCallback, consumerTag -> {
});
    }
}
```

Tutorial 3

- Improved Tutorial 1: a Producer sends messages to all consumers
  - Use exchange type = “fanout” (broadcast)

```
channel.exchangeDeclare(EXCHANGE_NAME, "fanout");
```



https://www.rabbitmq.com/tutorials/tutorial-three-java.html

Tutorial 4

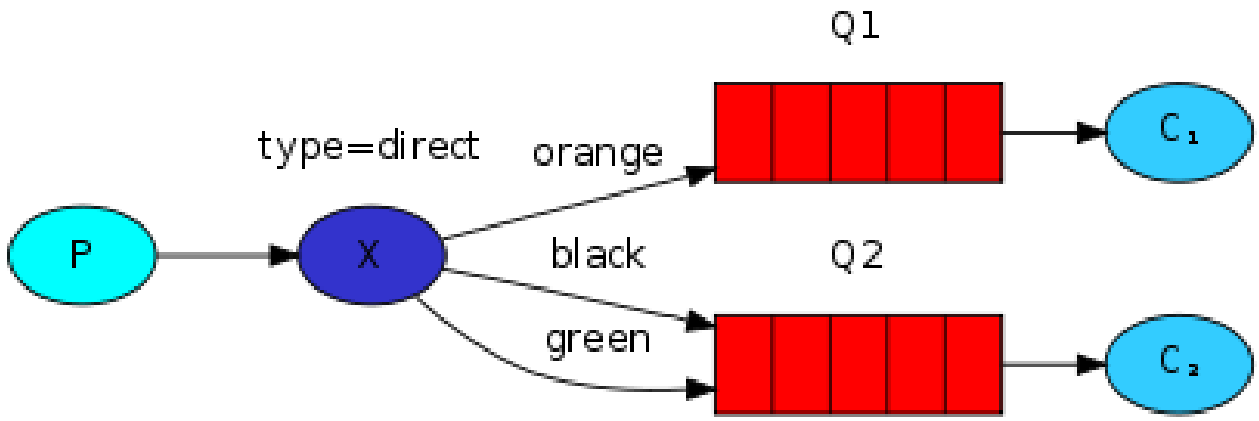
- Routing messages
- Select the message you want to receive (Receiving messages selectively)

Producer

```
channel.exchangeDeclare(EXCHANGE_NAME, "direct");
channel.basicPublish(EXCHANGE_NAME, “black”, null, message.getBytes());
```

Consumer

```
channel.queueBind(queueName, EXCHANGE_NAME, “black”);
```



https://www.rabbitmq.com/tutorials/tutorial-four-java.html

Tutorial 5

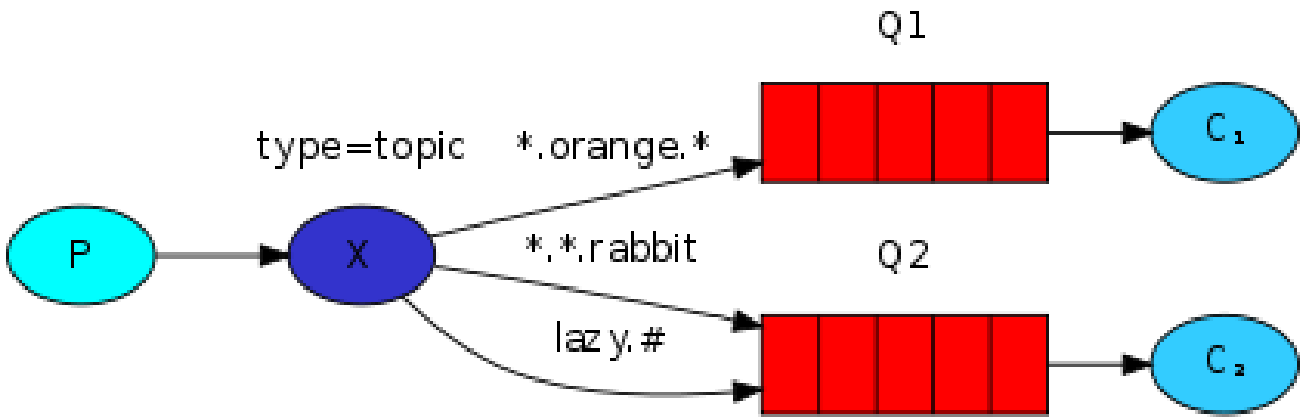
- Use exchange type = “topic”
- `routing_key` must be a list of words, delimited by dots.
  - *(star) can substitute for exactly one word.
  - #(hash) can substitute for zero or more words.

Producer

```
channel.basicPublish(EXCHANGE_NAME, routingKey, null, message.getBytes("UTF-8"));
```

Consumer

```
channel.queueBind(queueName, EXCHANGE_NAME, bindingKey);
```



https://www.rabbitmq.com/tutorials/tutorial-five-java.html

Exercise 3

- Write a program to send/receive data via RabbitMQ broker:
  - Send (publish) data to the RabbitMQ broker
  - Receive (subscribe) data from RabbitMQ broker
  - Packaging data using JSON. For example:

    {"id":11, "packet_no":126, "temperature":30,
    "humidity":60, "tds":1100, "pH":5.0}

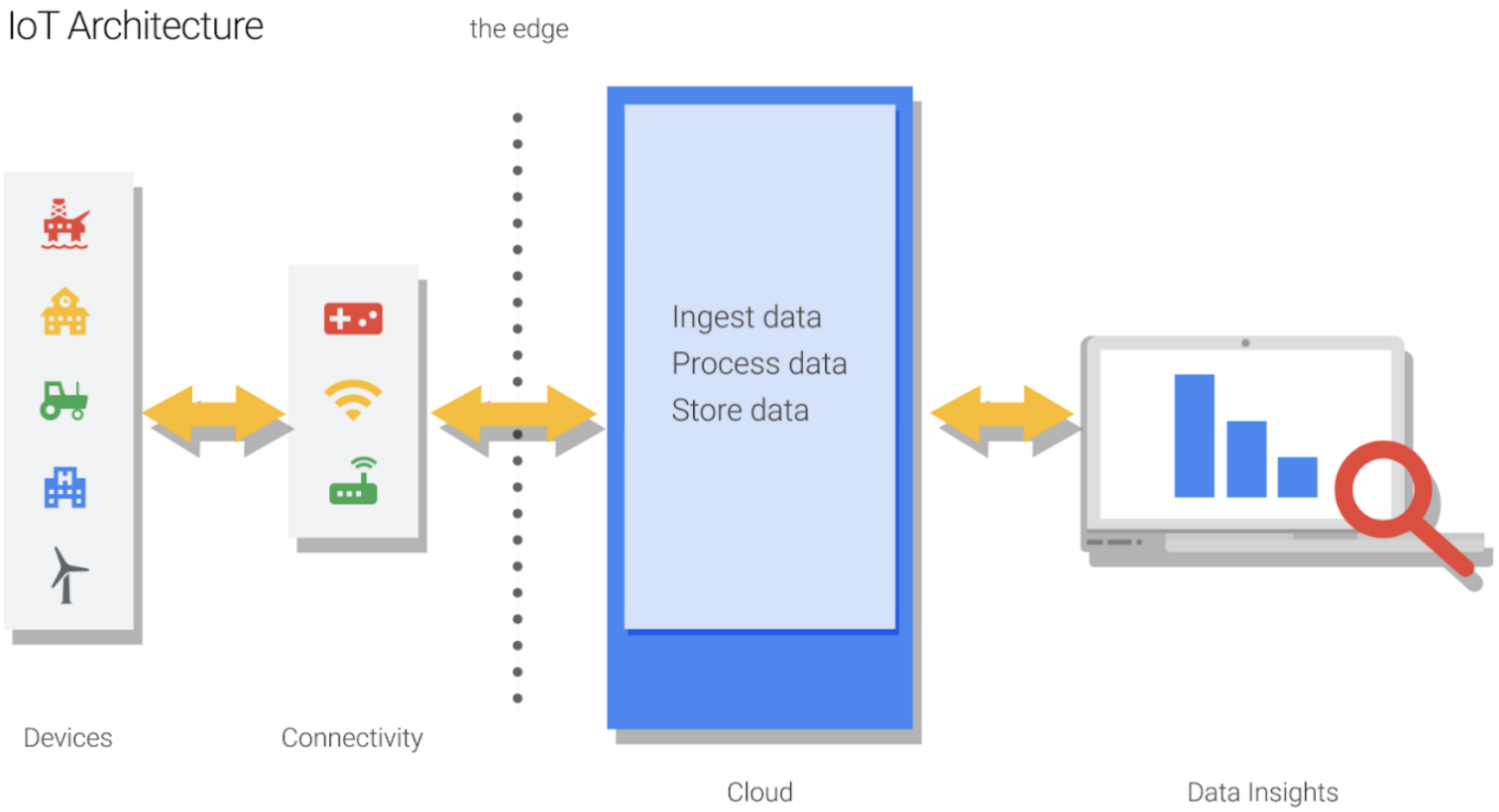
2.4. IoT Cloud Platform

- The architecture of IoT must have the ability to scale the connectivity of devices, gather data, process data, and store data.
- It should be capable of performing these tasks quickly while still conducting real-time data analysis.
- Sending large amounts of data to the cloud can slow down the processing process and may require additional bandwidth for data transmission

IoT Cloud Platform

- The popularity of distributed computing solutions, such as **fog or edge computing,** is on the rise.
- Edge computing involves performing computational tasks on nodes within the network, which are IoT devices located at the 'edge' of the network.
- This solution leads to the need for IoT devices to have the capability to locally process, clean, and analyze data. Only pre-processed data is then sent to the cloud.

IoT Cloud Platform



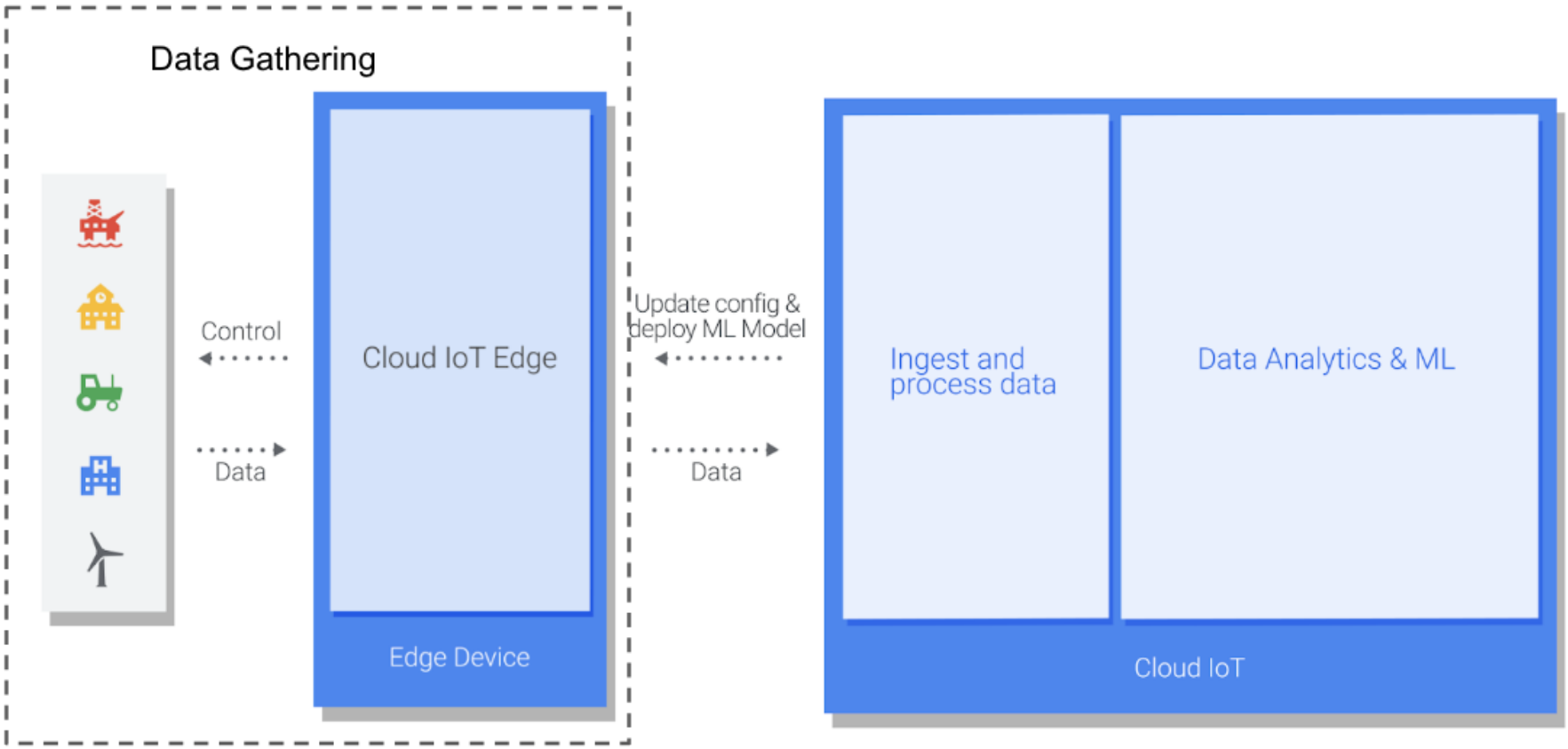
IoT Cloud Platforms

- Some IoT Cloud service platforms include:
  - IBM Watson IoT
  - AWS IoT
  - Google Cloud IoT
  - Microsoft Azure IoT

https://www.postscapes.com/internet-of-things-technologies/

Google Cloud IoT Architecture

Be capable of doing data import, process, storage, and analysis for hundreds of millions of events per hour from devices all over the world



Google Cloud IoT

- The Google Cloud IoT architecture is divided into four components:
  - data gathering
  - data ingest
  - data processing
  - data analysis

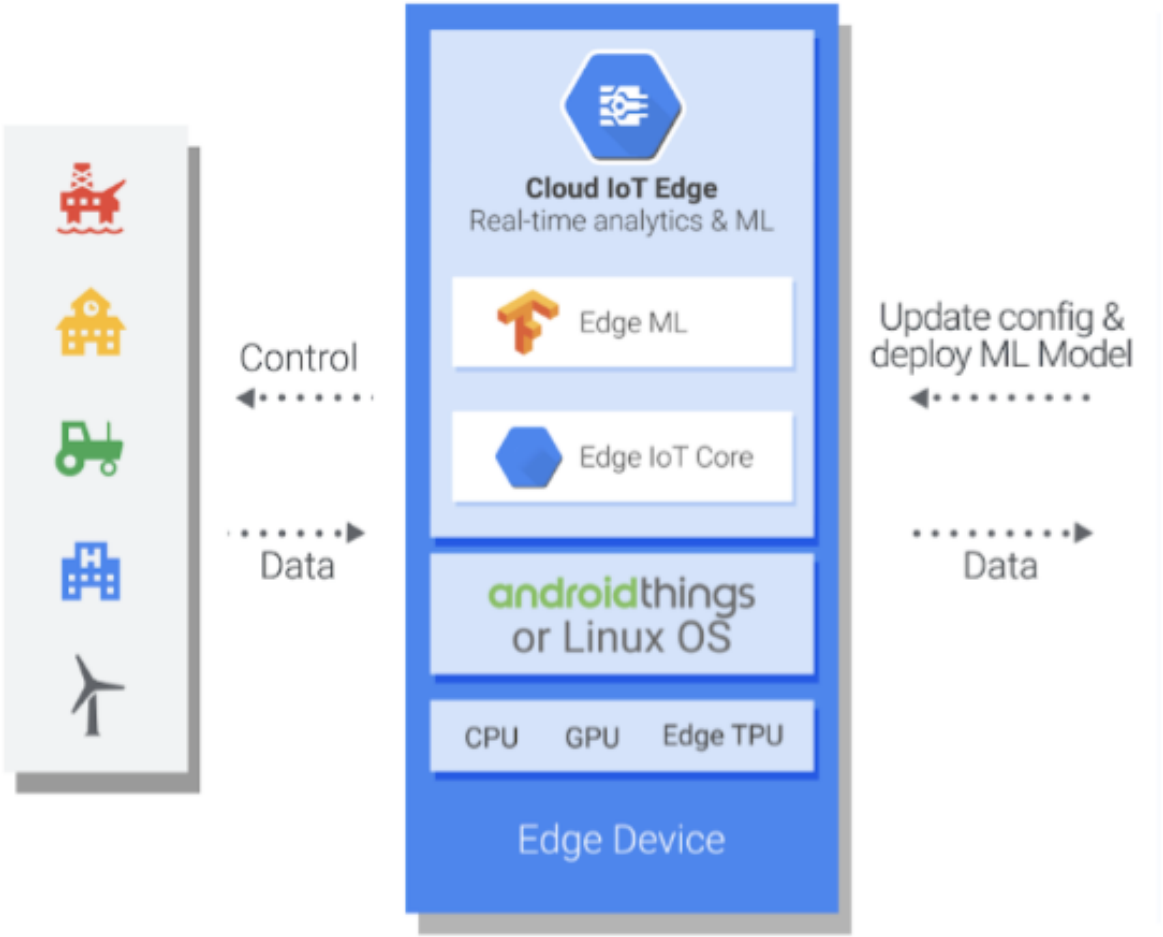
Google Cloud IoT

- Data Gathering (On-Device Data Collection):
  - Occurs on devices and sensors.
  - Sensors collect data from the environment and send it to the cloud, either directly or indirectly through an intermediary device.
  - Devices prepare the data for transmission to the cloud.

  Depending on the type of network connection, the preparation process may include data cleaning, preprocessing, analysis, or even utilizing machine learning

Google Cloud IoT

- Cloud IoT Edge:

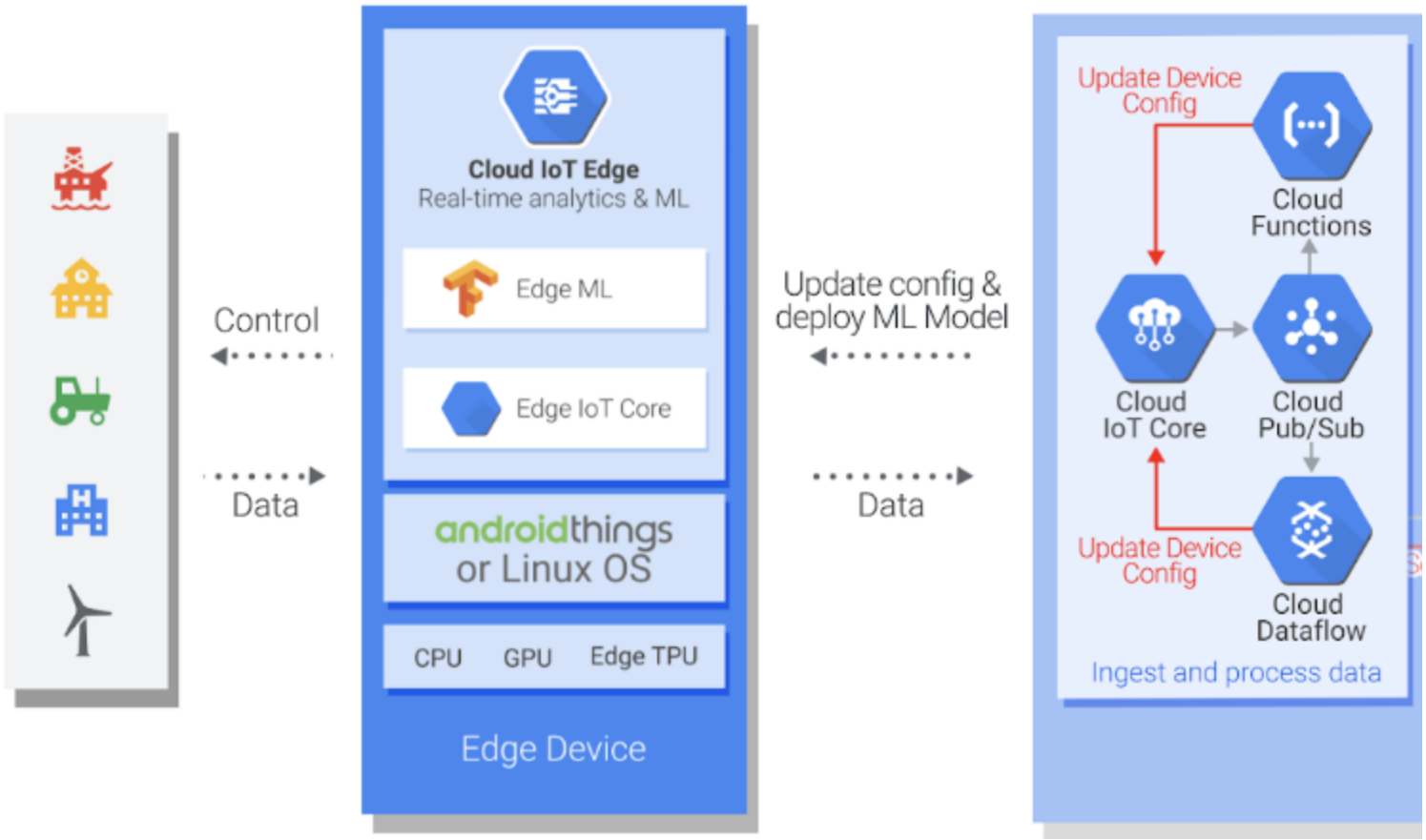


Google Cloud IoT

- Cloud IoT Edge:
  - In the Google Cloud IoT architecture, the data gathering phase can be performed on Cloud IoT Edge.
  - This component is a group of devices capable of conducting real-time analytics and machine learning. It enables the extension of data processing and ML operations to edge devices.
  - Cloud IoT Edge can utilize Android Things OS or Linux-based OS.
  - It consists of two components: Edge IoT Core and Edge ML

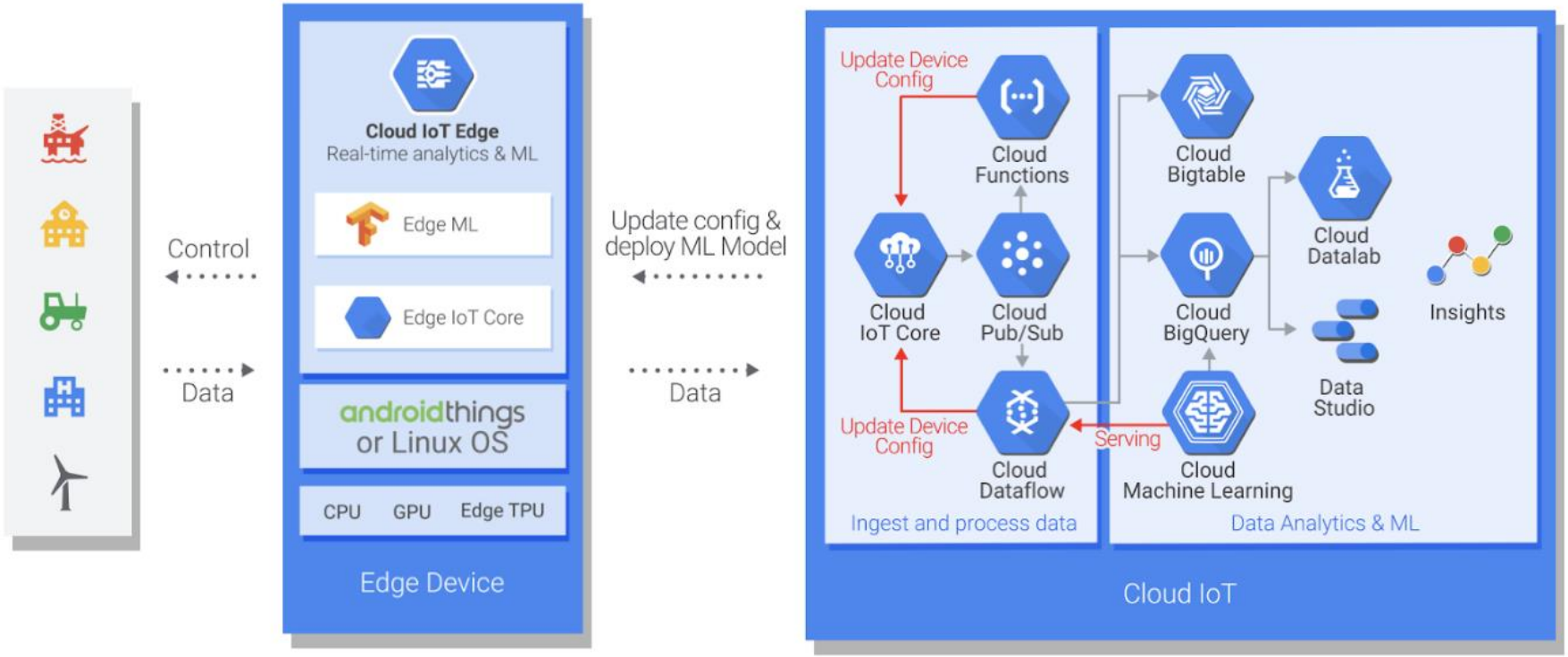
Google Cloud IoT

- Ingest and Process data:



Google Cloud IoT

- Data Analytics and ML:
  - It can be performed on the Edge or in the Cloud.
  - Google's Cloud IoT Core Data Analytics and ML are fully integrated with IoT data.



Content

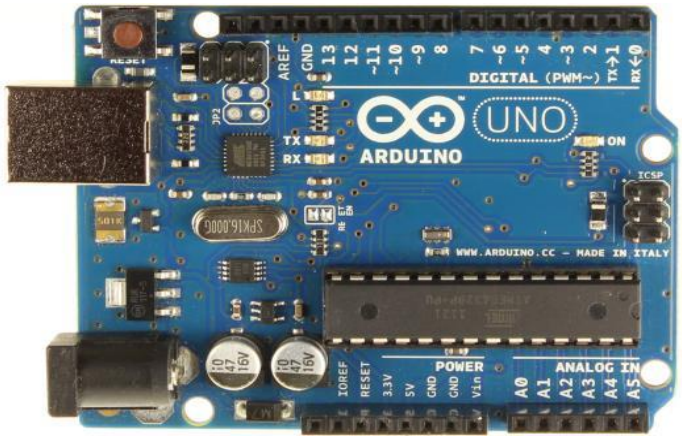
- Chapter 1. Overview of IoT
- Chapter 2. IoT Technologies
- Chapter 3. IoT Application and Programming
- Chapter 4. IoT Safety and Security
- Chapter 5. Designing and Building IoT Systems

Chapter 3. IoT Application and Programming

- 3.1. Programming for IoT devices
- 3.2. Building an IoT Server
- 3.3. Exploiting IoT Cloud Platform services

3.1. Programming for IoT devices

- Devices use microcontrollers
  - 8 bit-architecture, low performance, and do not use an operating system
  - Firmware programming, basic input-output operations using GPIO (General Purpose Input/Output), interfacing with peripherals (sensors, actuators) through common communication standards like UART, SPI, I2C
  - Examples: ATmega, PIC, AVR, Arduino



3.1. Programming for IoT devices

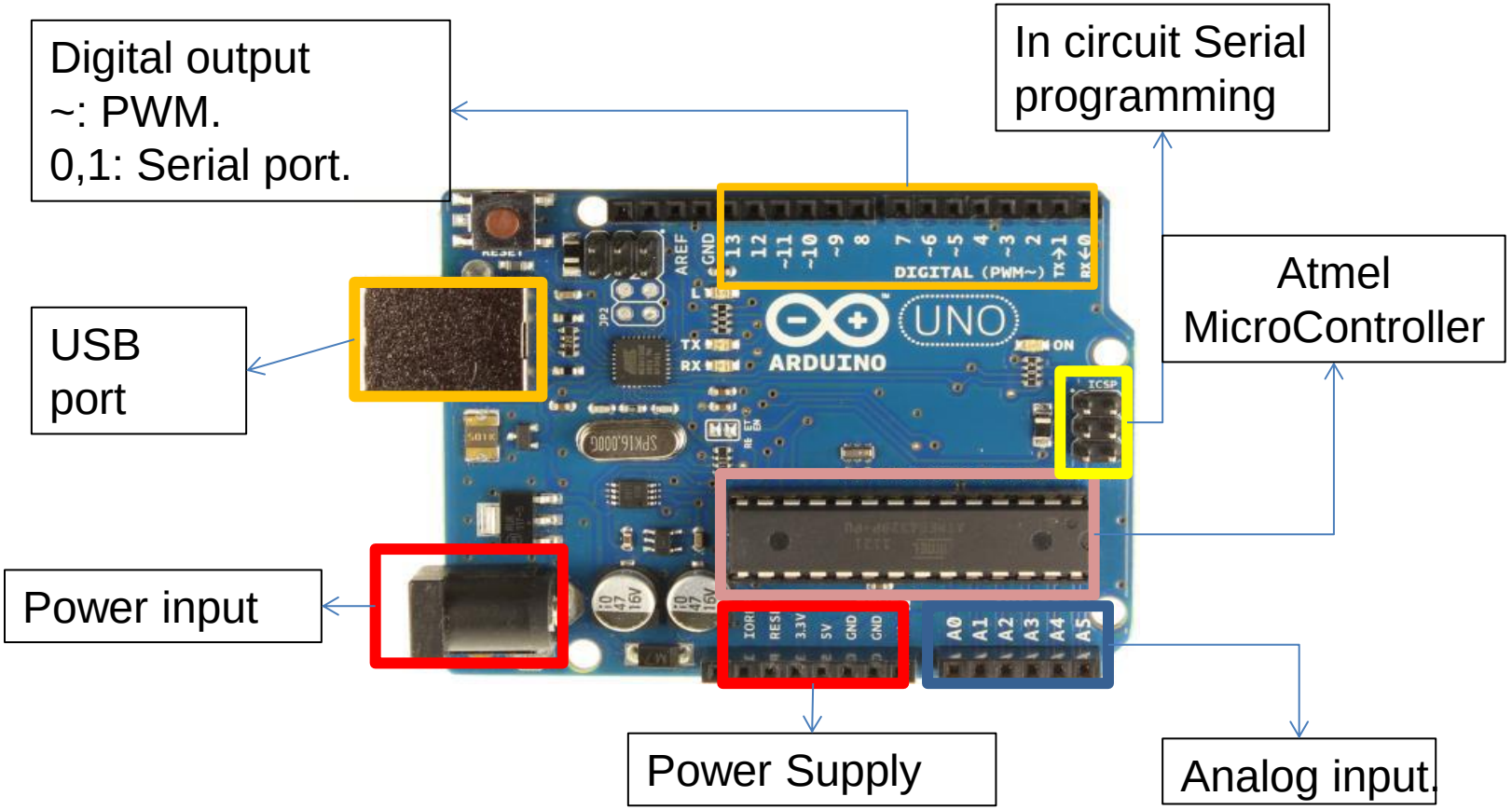
- Devices use 32-bit processors with moderate performance
  - Can use simple operating systems (FreeRTOS, TinyOS, uCLinux, …)
  - Perform basic input-output operations using GPIO, interface with peripherals using common communication standards like UART, SPI, I2C.
  - capability to connect with Wi-Fi, Bluetooth, GSM module
  - Examples: ESP8266, ESP32, Arduino Uno WiFi

3.1. Programming for IoT devices

- Devices use 32/64-bit processors with high performance.
  - Run operating systems such as Embedded Linux, Raspbian, Windows Embedded, Android, Ubuntu
  - Have connectivity options like Wi-Fi, Ethernet.
  - Peripheral communication: through drivers on the operating system.
  - Can use libraries on the operating system like Java, Python, .Net Framework, OpenCV
  - An example is the Raspberry Pi

3.1.1. Arduino programming

- Arduino Uno: Microchip ATmega328, no operating system used



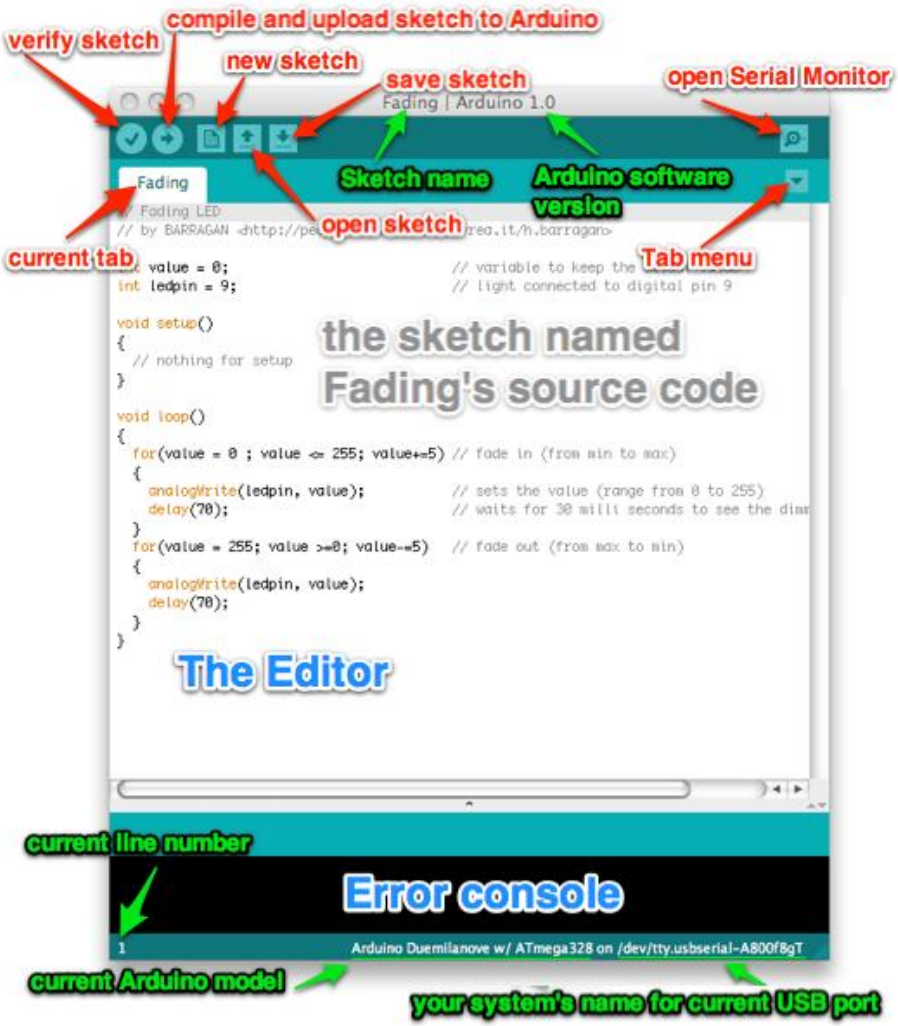
3.1.1. Arduino programming

- Install Arduino IDE
  - https://www.arduino.cc/en/guide/windows
- Code structure

```
void setup()
{
        //Used to indicate the initial values of system on starting.
}

void loop()
{
        Contains the statements that will run whenever the system
is powered after setup.
}
```

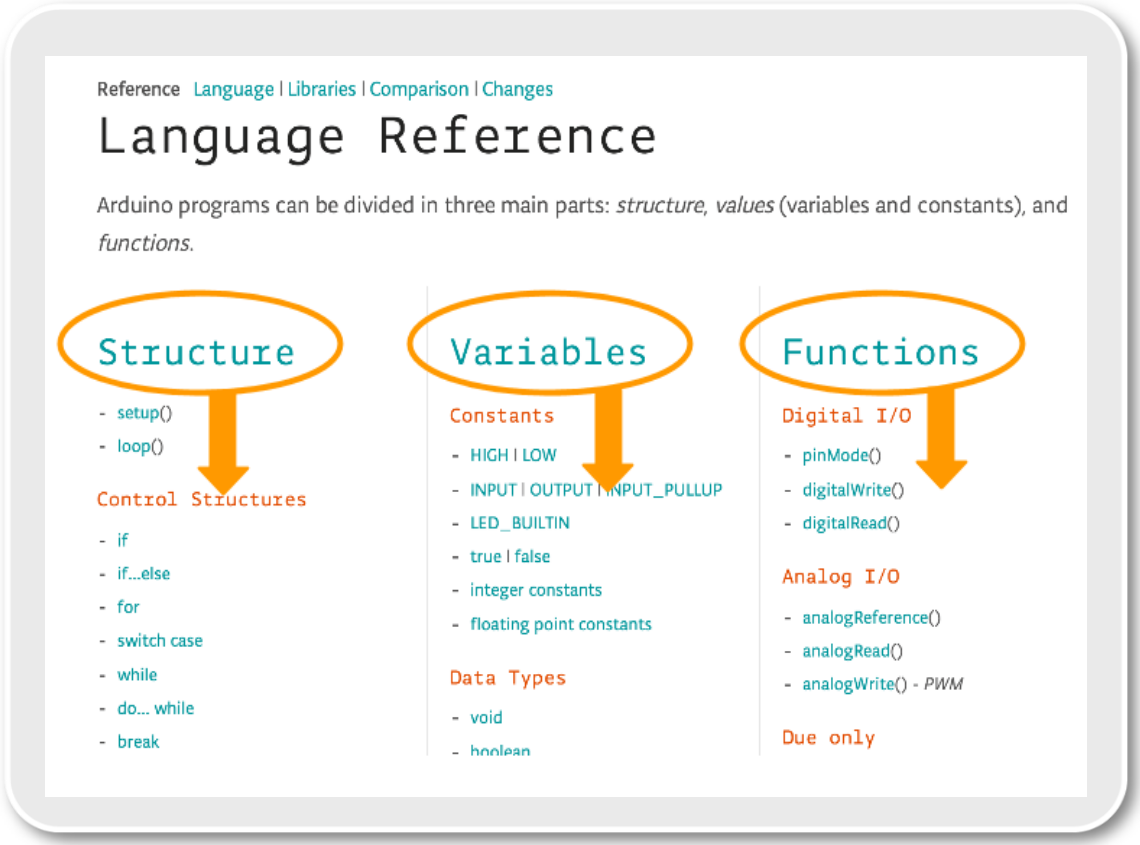
Arduino programming

- Program used to code and upload it to arduino boards (using PC)
- Editor (for code edit)
- Sketch (piece of program)



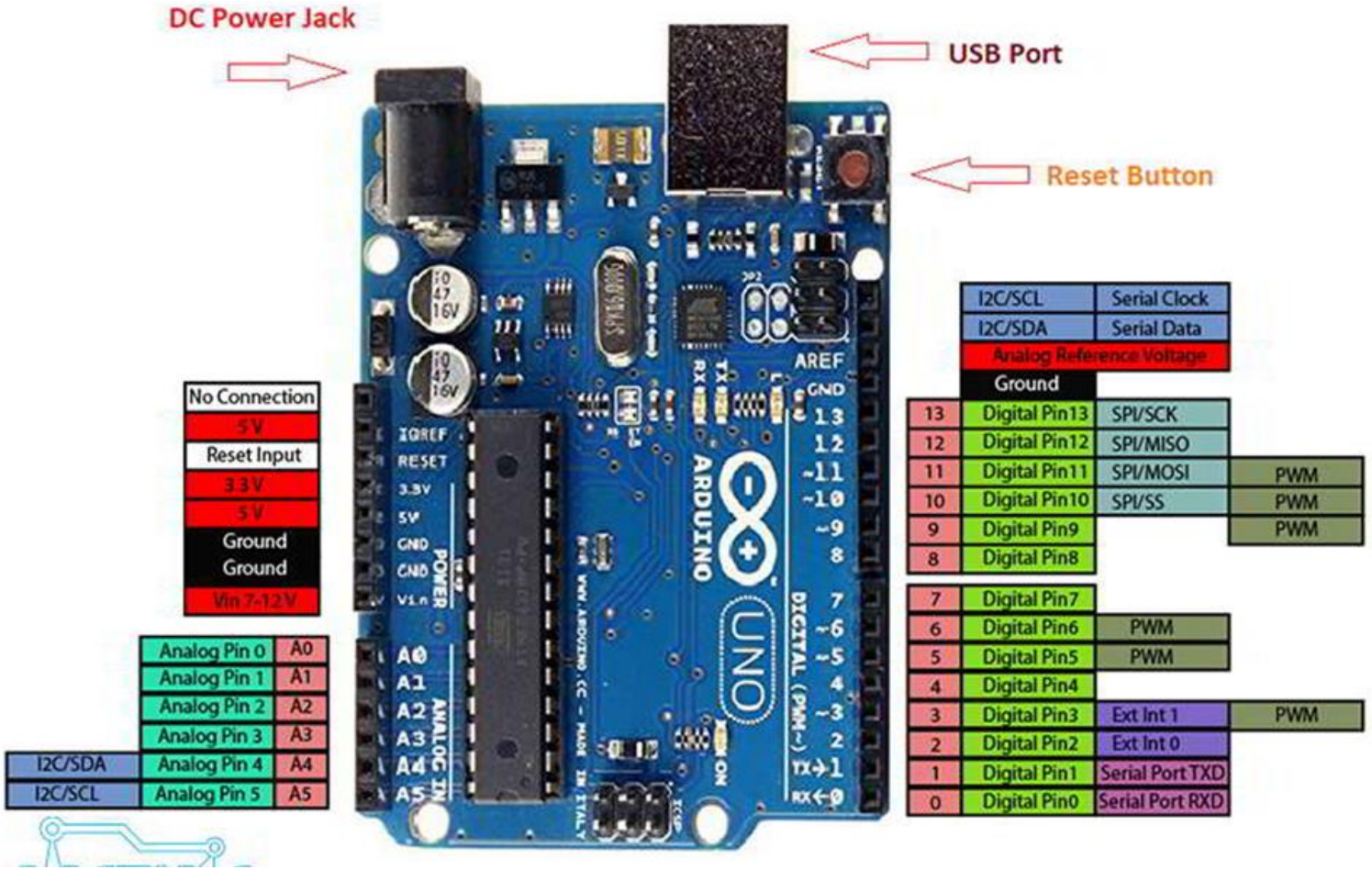
Arduino programming

- Document: Arduino References
- http://arduino.cc/en/Reference/HomePage



Peripheral communication

- GPIO, UART, I2C, SPI, ADC, PWM



Example 1: GPIO Communication - Output

- LED on/off trên pin 13

```
void setup() {
  // initialize digital pin 13 as an output.
  pinMode(13, OUTPUT);
}

void loop() {
  digitalWrite(13, HIGH);   // turn the LED on
  delay(1000);              // wait for a second
  digitalWrite(13, LOW);    // turn the LED off
  delay(1000);              // wait for a second
}
```

Example 1: GPIO Communication - Output

- Read state of the button on pin 2, and turn on/off on pin 13

```
const int buttonPin = 2;  // the number of the pushbutton pin
const int ledPin =  13;   // the number of the LED pin
int buttonState = 0;
void setup() {
    pinMode(ledPin, OUTPUT);
    pinMode(buttonPin, INPUT);
}
void loop() {
  // read the state of the pushbutton value:
  buttonState = digitalRead(buttonPin);
if (buttonState == HIGH) {
    digitalWrite(ledPin, HIGH);
  } else {
    digitalWrite(ledPin, LOW);
  }
  delay(100);
}
```

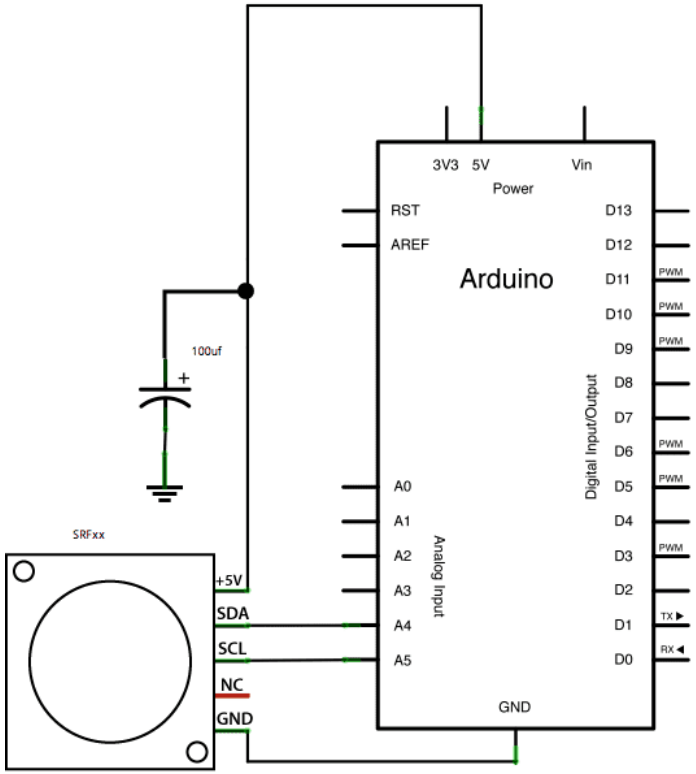
Example 2: UART communication

- Use Serial library of Arduino
  - https://www.arduino.cc/reference/en/language/functions/communication/serial/

```
int incomingByte = 0;
void setup() {
    // opens serial port, sets data rate to 9600 bps
    Serial.begin(9600);
}
void loop() {
    // send data only when you receive data:
    if (Serial.available() > 0) {
        // read the incoming byte:
        incomingByte = Serial.read();
        // say what you got:
        Serial.print("I received: ");
        Serial.println(incomingByte, DEC);
    }
}
```

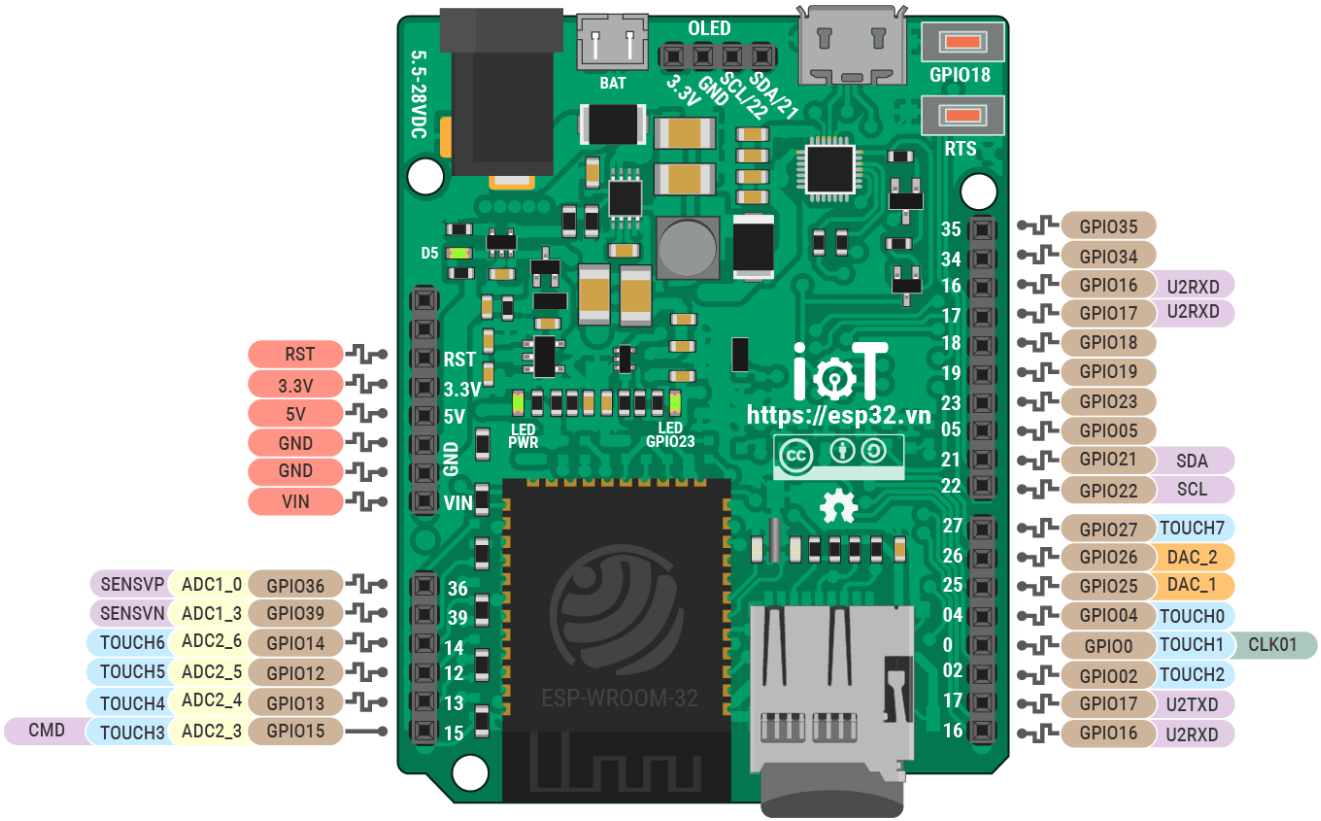
Example 3: I2C communication

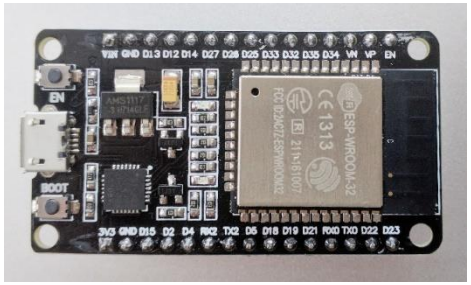
- Use Wire library
  - https://www.arduino.cc/en/Reference/Wire
- SRFxx Sonic Range Finder interface
  - https://www.arduino.cc/en/Tutorial/LibraryExamples/SFRRangerReader

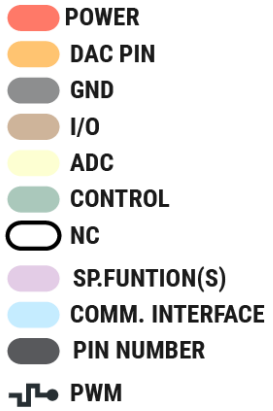


3.1.2. Programming ESP32/ESP8266 devices

- Programming with ESP32/ESP8266
  - https://esp32.vn/index.html
  - https://randomnerdtutorials.com/projects-esp32/





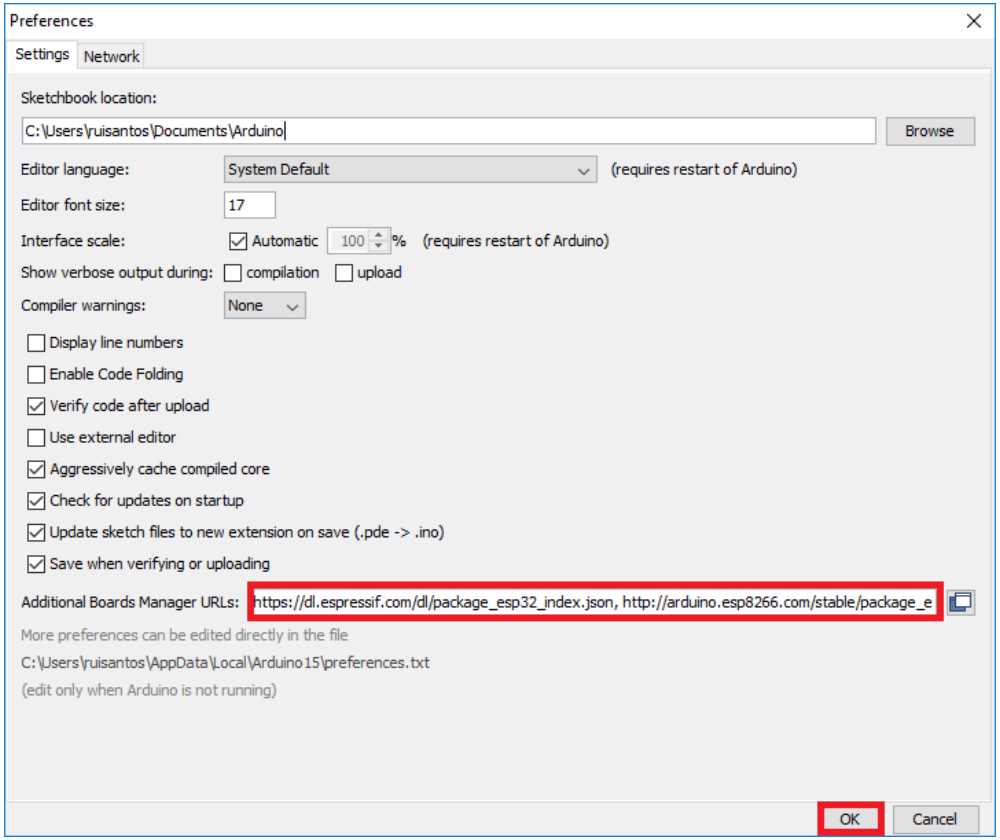


Programming ESP32/ESP8266 devices

- A. Setting up Arduino IDE for ESP32
- B. Connecting ESP32 to WiFi
- C. Communicating via HTTP with ESP32
- D. Communicating via MQTT with ESP32
- E. Programming multi-tasks with FreeRTOS

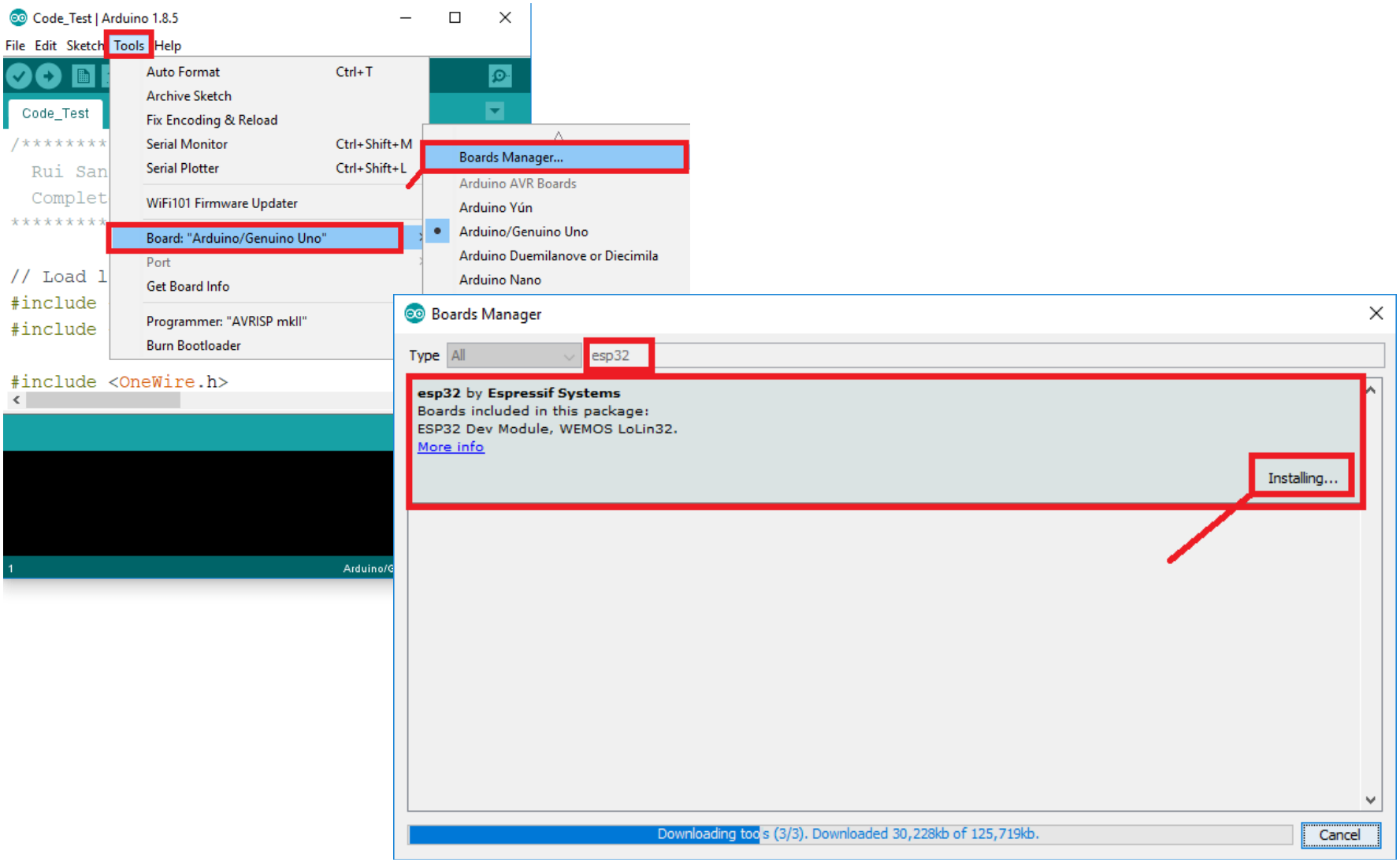
A. Setting up Arduino IDE for ESP32

- Installing the ESP32 Board Add-on on Arduino IDE:
  - 1) Open **File**> **Preferences**
  - 2) Enter https://dl.espressif.com/dl/package_esp32_index.json in "Additional Board Manager URLs" field



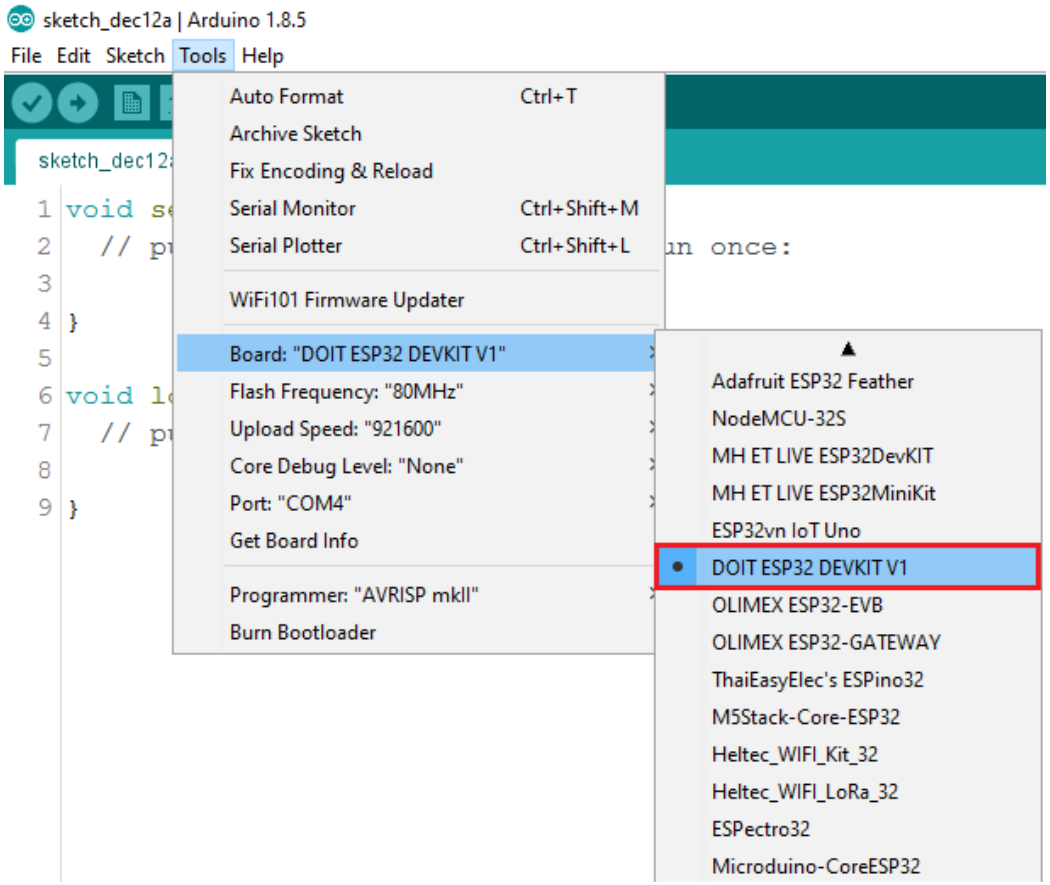
Setting up Arduino IDE for ESP32

3) Choose **Tools** > **Board** > **Boards Manager…**

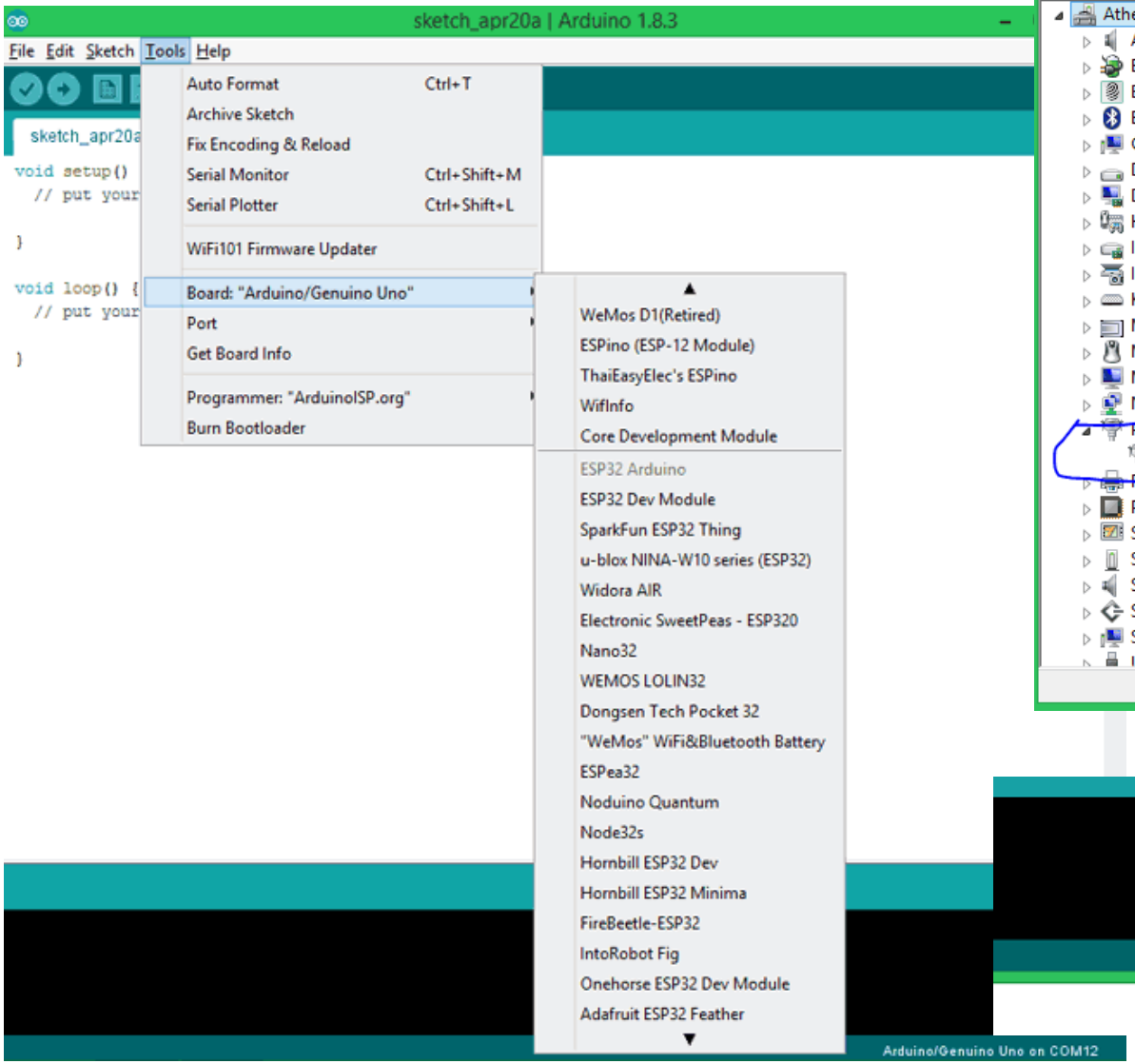


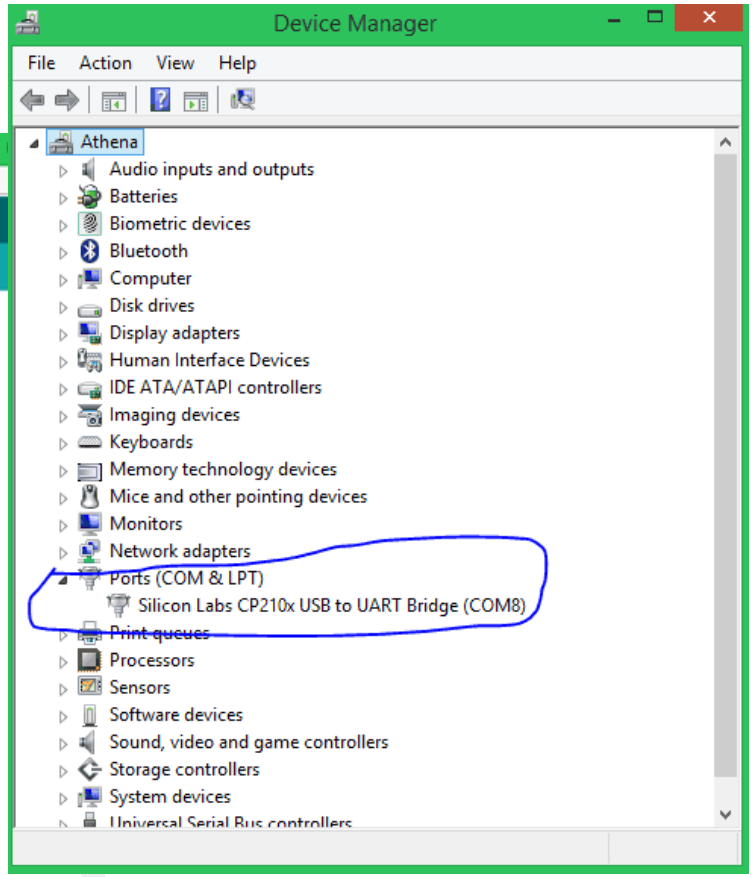
Setting up Arduino IDE for ESP32

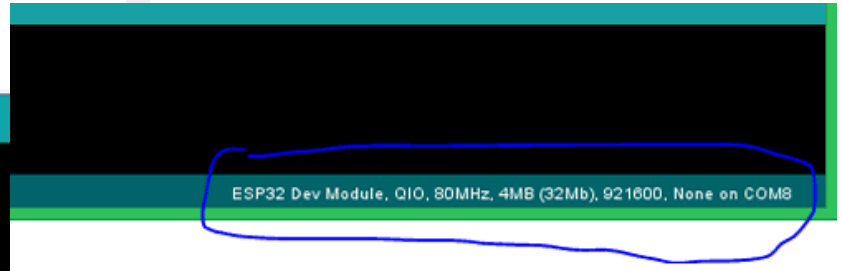
- Connect the ESP32 board to the computert
  - Select Board in **Tools** > **Board** menu (example: **DOIT ESP32 DEVKIT V1**)



Connect to the device



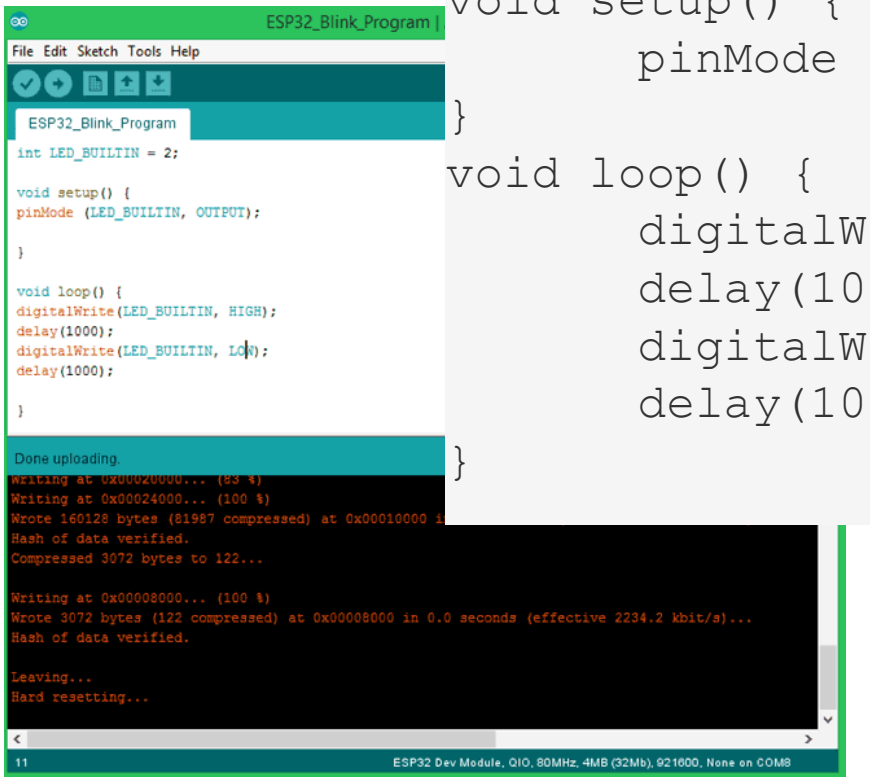


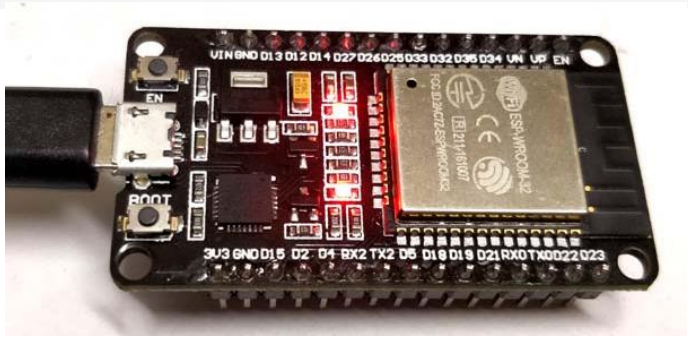


Upload the program to the device

- Upload the Blink Program. This program should blink the LED at an interval of 1 second.

```
int LED_BUILTIN = 2;
void setup() {
      pinMode (LED_BUILTIN, OUTPUT);
}
void loop() {
      digitalWrite(LED_BUILTIN,HIGH);
      delay(1000);
      digitalWrite(LED_BUILTIN,LOW);
      delay(1000);
}
```

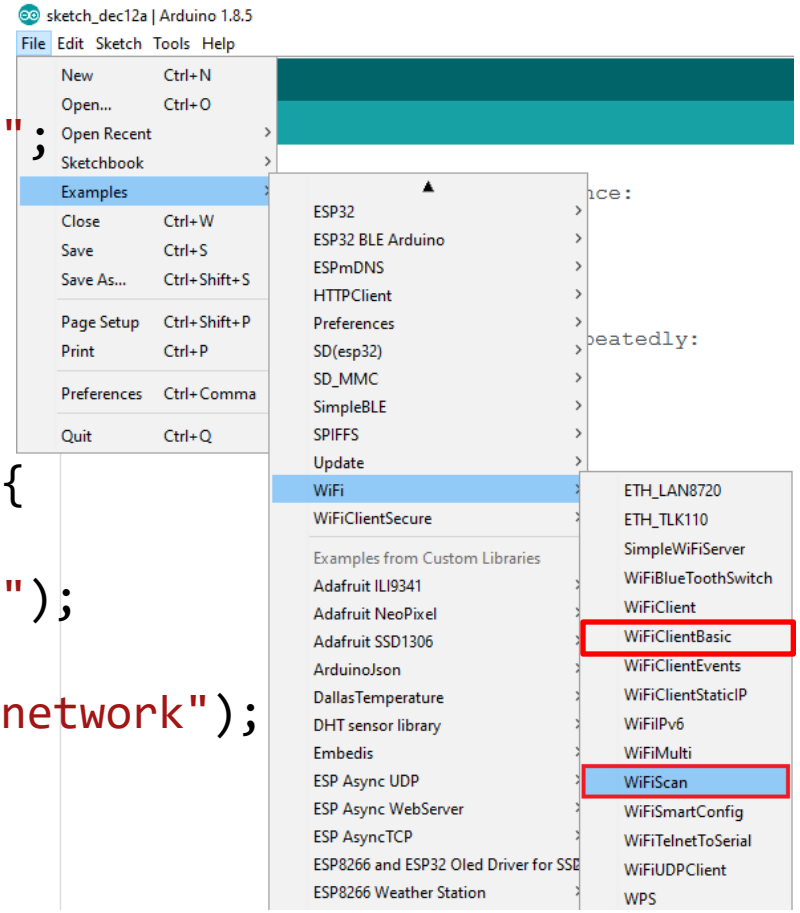




B. Connecting ESP32 to WiFi

Example 1: File > Examples > WiFi (ESP32) > WiFiClientBasic

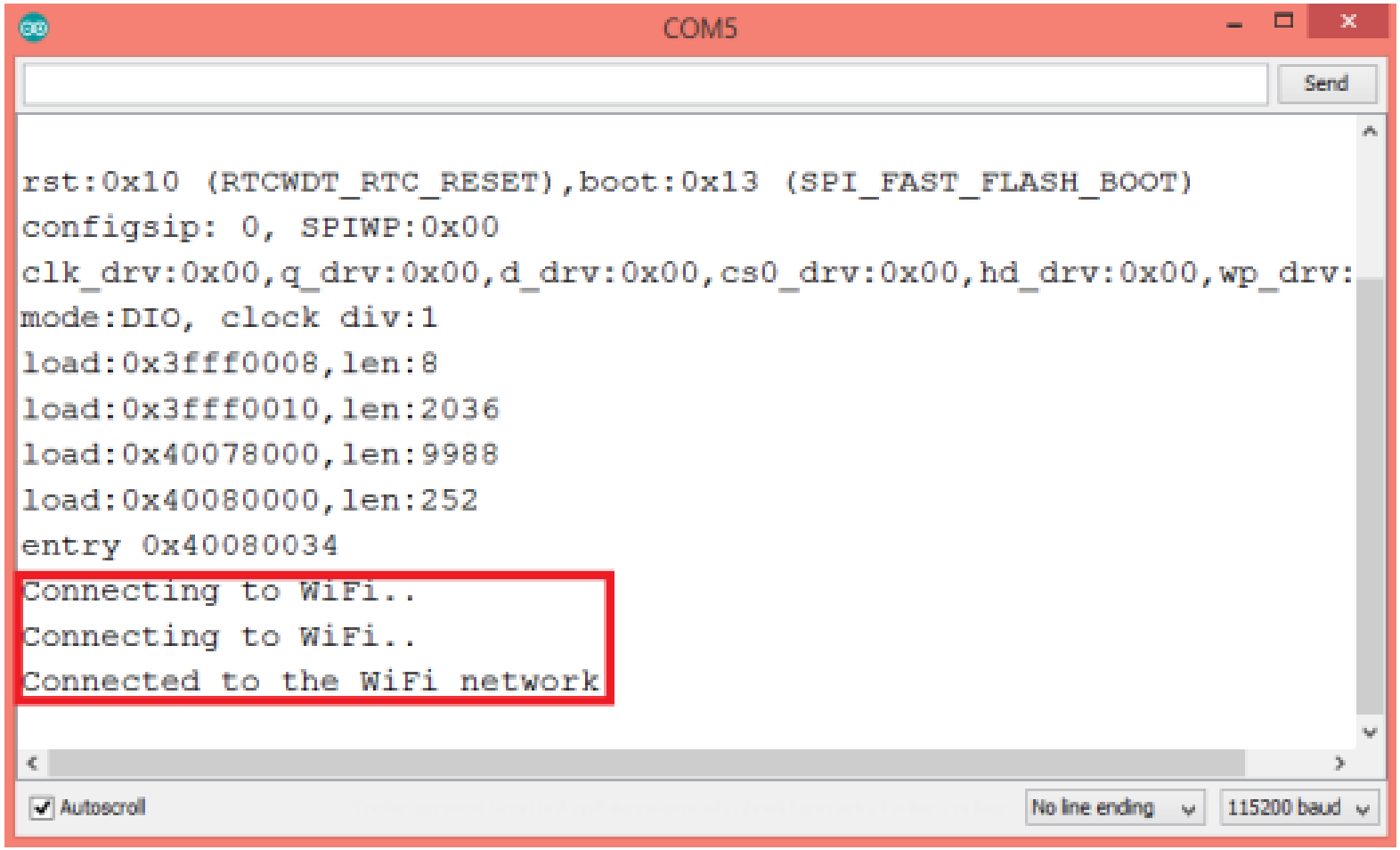
```
#include <WiFi.h>
const char* ssid = "yourNetworkName";
const char* password =  "yourNetworkPass";

void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.println("Connecting to WiFi..");
  }
  Serial.println("Connected to the WiFi network");
}

void loop() {
}
```



Example 2: File > Examples > WiFi (ESP32) > WiFiClient

Example of Wi-Fi connection

- Result: Write the log to the Serial port



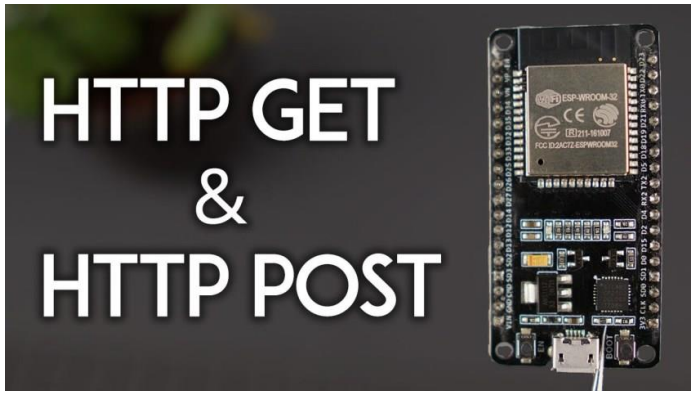
C. Communicating HTTP with ESP32

- HTTP request methods: GET vs. POST
- HTTP GET:
  - Used to request data/resources (get values from APIs)
  - Data is sent in the URL of the GET request
  - Example:

```
GET /update-sensor?temperature=value1
```

  - Or get JSON object:

```
GET /get-sensor
```



Communicating HTTP with ESP32

- HTTP POST:
  - Send data to the server to create/update resourcesD
  - Data is sent in the body of the POST request
  - Example:

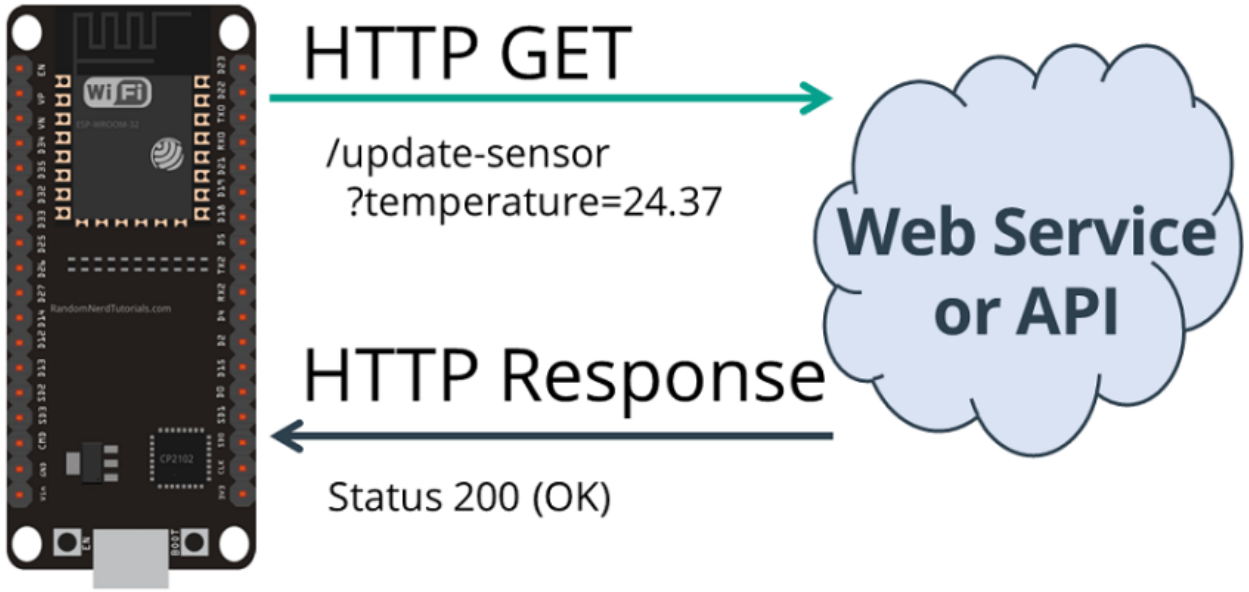
```
POST /update-sensor HTTP/1.1 Host: example.com
api_key=api&sensor_name=name&temperature=value1&humidity=value2&pressure=value3
Content-Type: application/x-www-form-urlencoded
```

  - Or use JSON object:

```
POST /update-sensor HTTP/1.1 Host: example.com {api_key: "api",
sensor_name: "name", temperature: value1, humidity: value2, pressure: value3}
Content-Type: application/json
```

ESP32 HTTP GET

- ESP32 sends data to the server using an HTTP GET request



https://randomnerdtutorials.com/esp32-http-get-post-arduino/

ESP32 HTTP GET – Example Code

Part 1. Connect WiFi

```
#include <WiFi.h>
#include <HTTPClient.h>
const char* ssid = “Soict";
const char* password = ”Soict1234";
String serverName = "https://postman-echo.com/get";
void setup()
{
    Serial.begin(115200);
    delay(10);
    // We start by connecting to a WiFi network
    WiFi.begin(ssid, password);
    Serial.print("Wait for WiFi... ");
    while (WiFi.status() != WL_CONNECTED) {
        Serial.println("Connecting to WiFi ...");
        delay(1000);
    }
    Serial.println("WiFi connected");
    Serial.println("IP address: ");
    Serial.println(WiFi.localIP());
    delay(500);
}
```

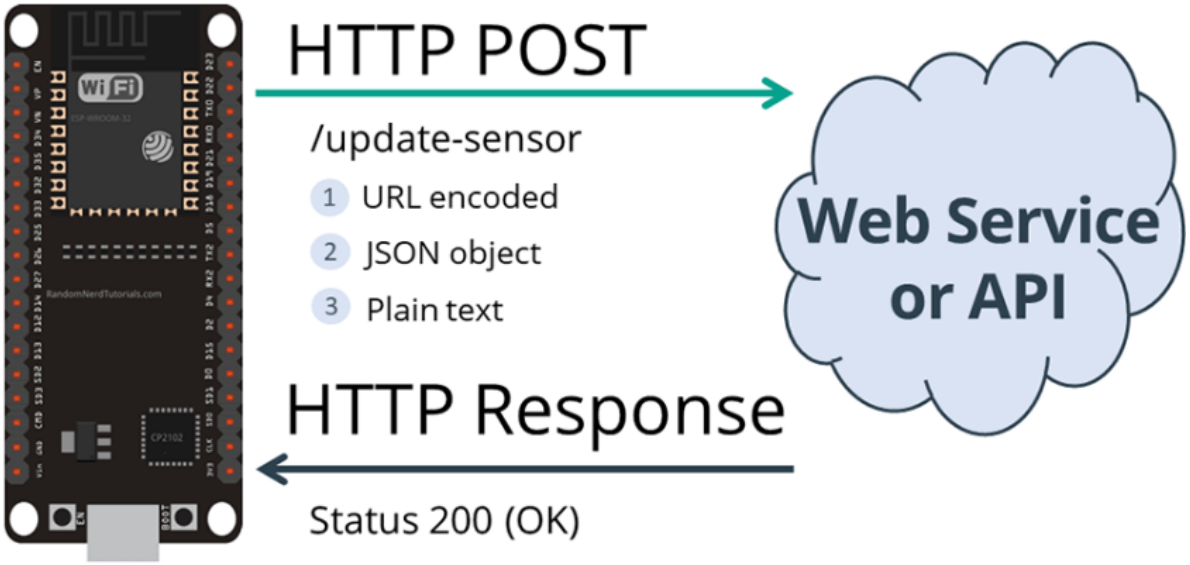
ESP32 HTTP GET – Example code

Part 2. Send http GET request

```
void loop()
{
    if (WiFi.status() == WL_CONNECTED) {
        HTTPClient http;
        String serverPath = serverName + "?temp1=24.7&temp2=30";
        // Your Domain name with URL path or IP address with path
        http.begin(serverPath.c_str()); // Send HTTP GET request
        int httpResponseCode = http.GET();
        if (httpResponseCode > 0) {
            Serial.print("HTTP Response code: ");
            Serial.println(httpResponseCode);
            String payload = http.getString();
            Serial.println(payload);
        }
        else {
            Serial.print("Error code: "); Serial.println(httpResponseCode);
        }
        http.end();
    }
    else {
        Serial.println("WiFi Disconnected");
    }
    delay(3000);
}
```

ESP32 HTTP POST

- Sending data using:
  - URL encoded (packaged in the URL)
  - JSON object (packaged in the request body)
  - Plain text



Code reference: https://randomnerdtutorials.com/esp32-http-get-post-arduino/

ESP32 HTTP POST

- POST data with URL encoded

POST /update-sensor HTTP/1.1 Host: 192.168.1.106:1880
api_key=tPmAT5Ab3j7F9&sensor=BME280&value1=24.25&value2=49.54
&value3=1005.14 Content-Type: application/x-www-form-urlencoded

```
// Your Domain name with URL path or IP address with path
http.begin(serverName);
// Specify content-type header
http.addHeader("Content-Type", "application/x-www-form-urlencoded");
// Data to send with HTTP POST
String httpRequestData =
"api_key=tPmAT5Ab3j7F9&sensor=BME280&value1=24.25&value2=49.54&value3
=1005.14";
// Send HTTP POST request
int httpResponseCode = http.POST(httpRequestData);
```

ESP32 HTTP POST

- Post JSON object

POST /update-sensor HTTP/1.1 Host: example.com {api_key: "tPmAT5Ab3j7F9", sensor_name: "BME280", temperature: 24.25; humidity: 49.54; pressure: 1005.14} Content-Type: application/json

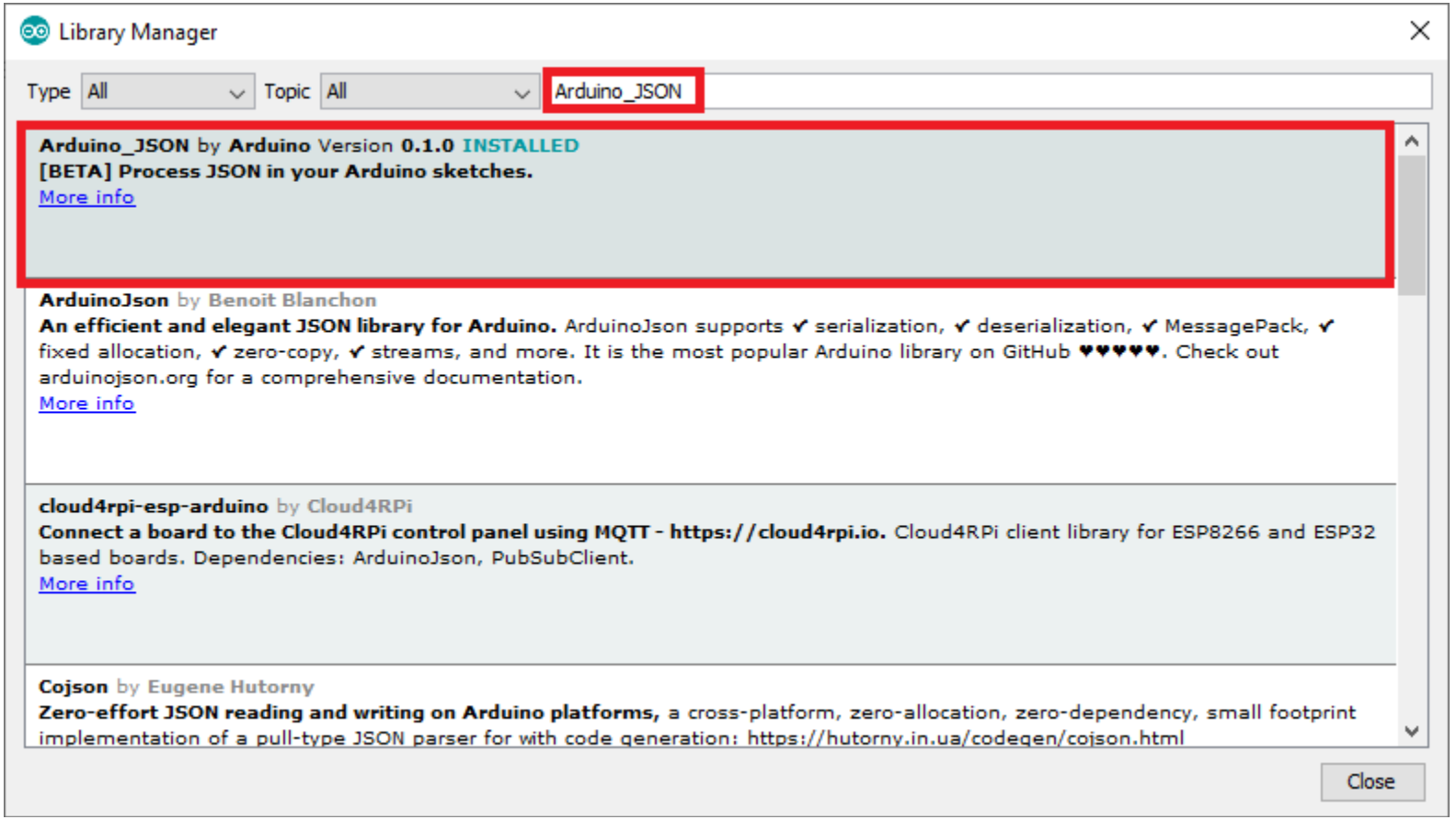
```
http.addHeader("Content-Type", "application/json");
int httpResponseCode =
http.POST("{\"api_key\":\"tPmAT5Ab3j7F9\",\"sensor\":\"BME280\",\"value1\"
:\"24.25\",\"value2\":\"49.54\",\"value3\":\"1005.14\"}");
```

- Post Plain Text

```
http.addHeader("Content-Type", "text/plain");
int httpResponseCode = http.POST("Hello, World!");
```

Use Arduino JSON library

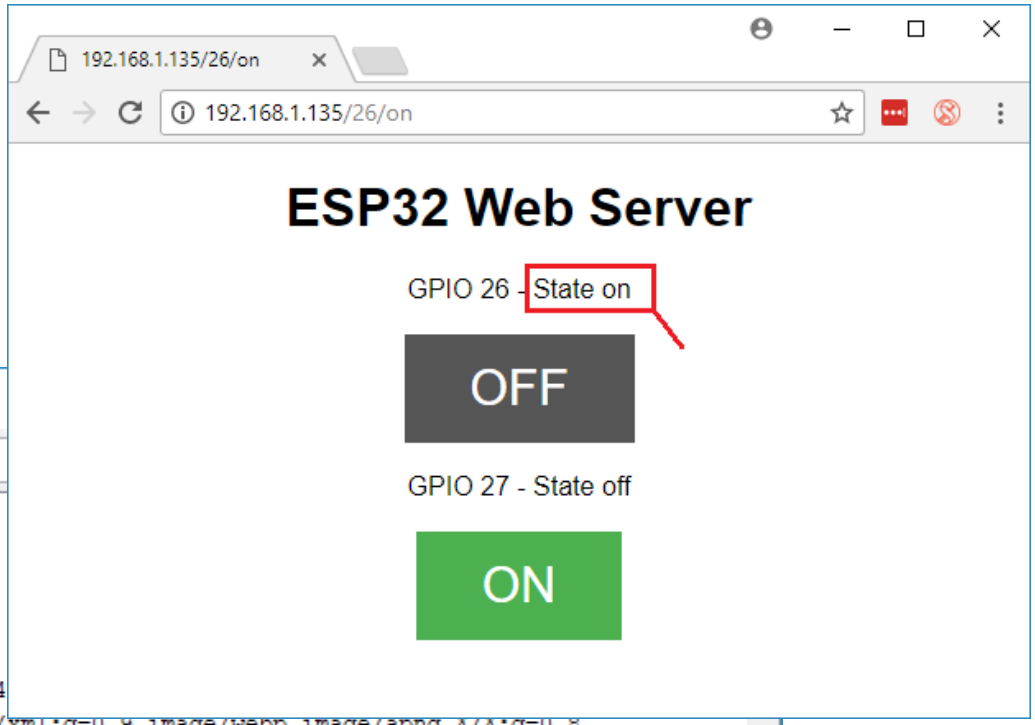
- Sketch > Include Library > Manage Libraries
- Add library using Arduino Library Manager

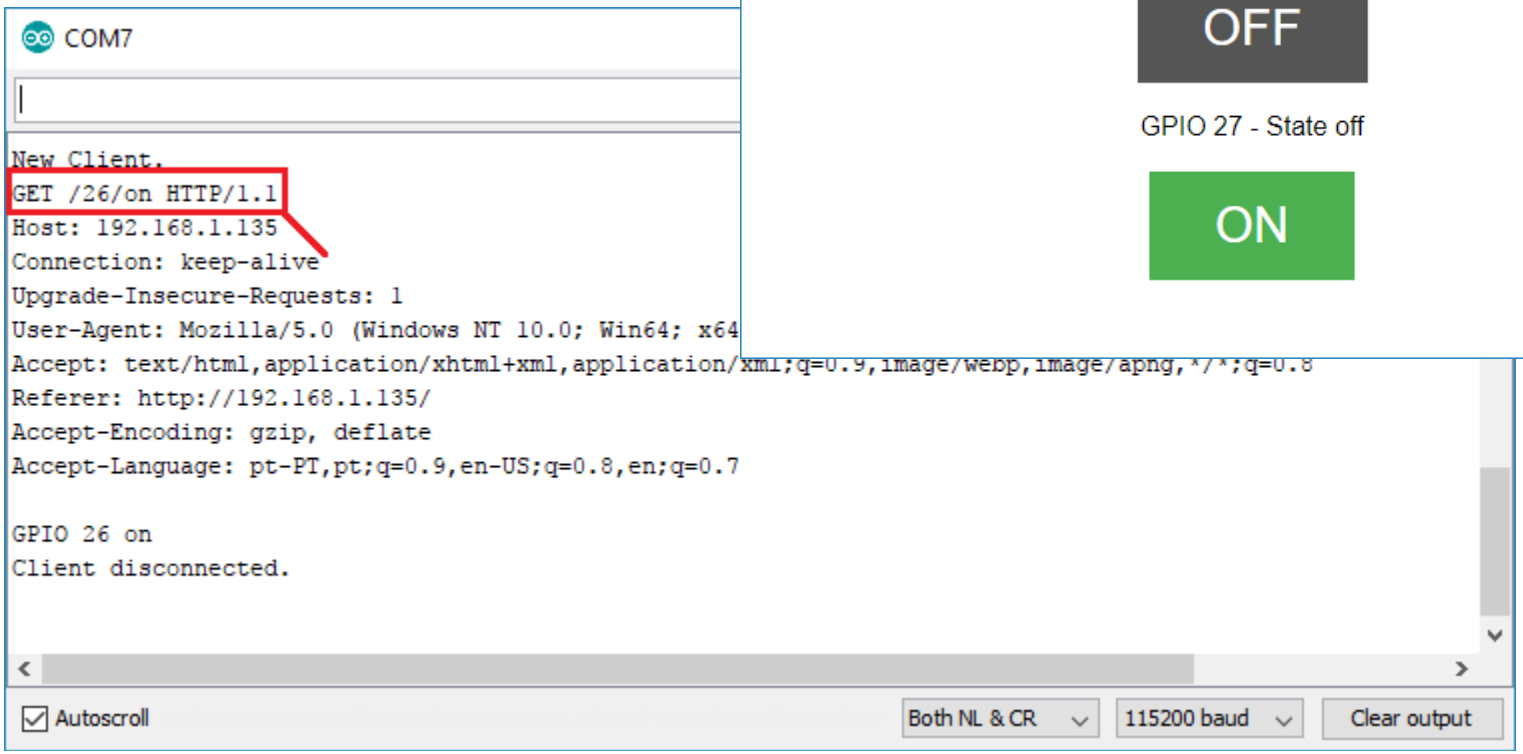


ESP32 Web server

- Build a simple web server on ESP32: control
- Example:
  - https://randomnerdtutorials.com/esp32-web-server-arduino-ide/

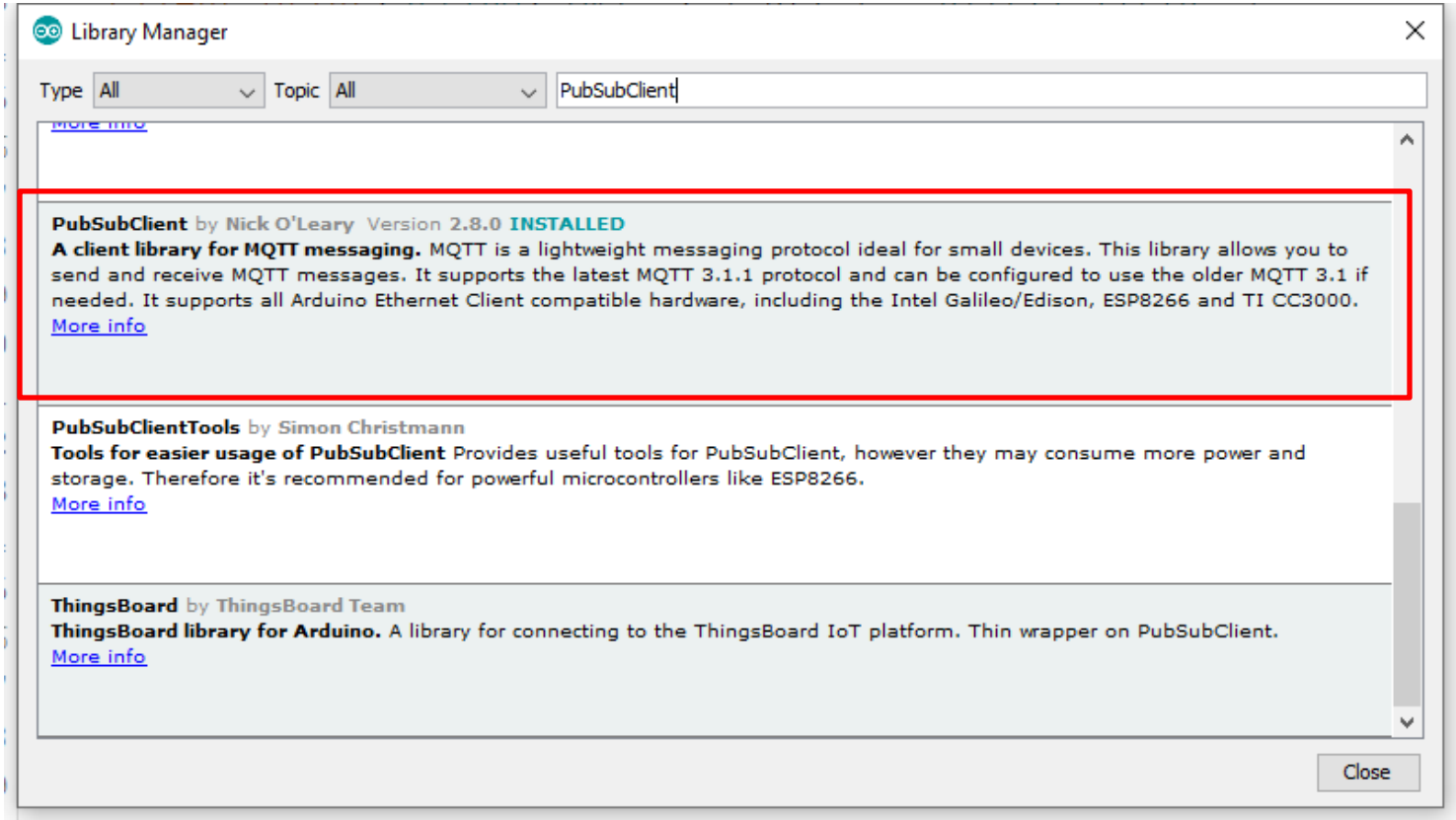
ESP32 Web server





D. Communicating via MQTT with ESP32

- Use the mqtt PubSubClient library for Arduino
  - https://www.arduinolibraries.info/libraries/pub-sub-client
  - https://github.com/knolleary/pubsubclient



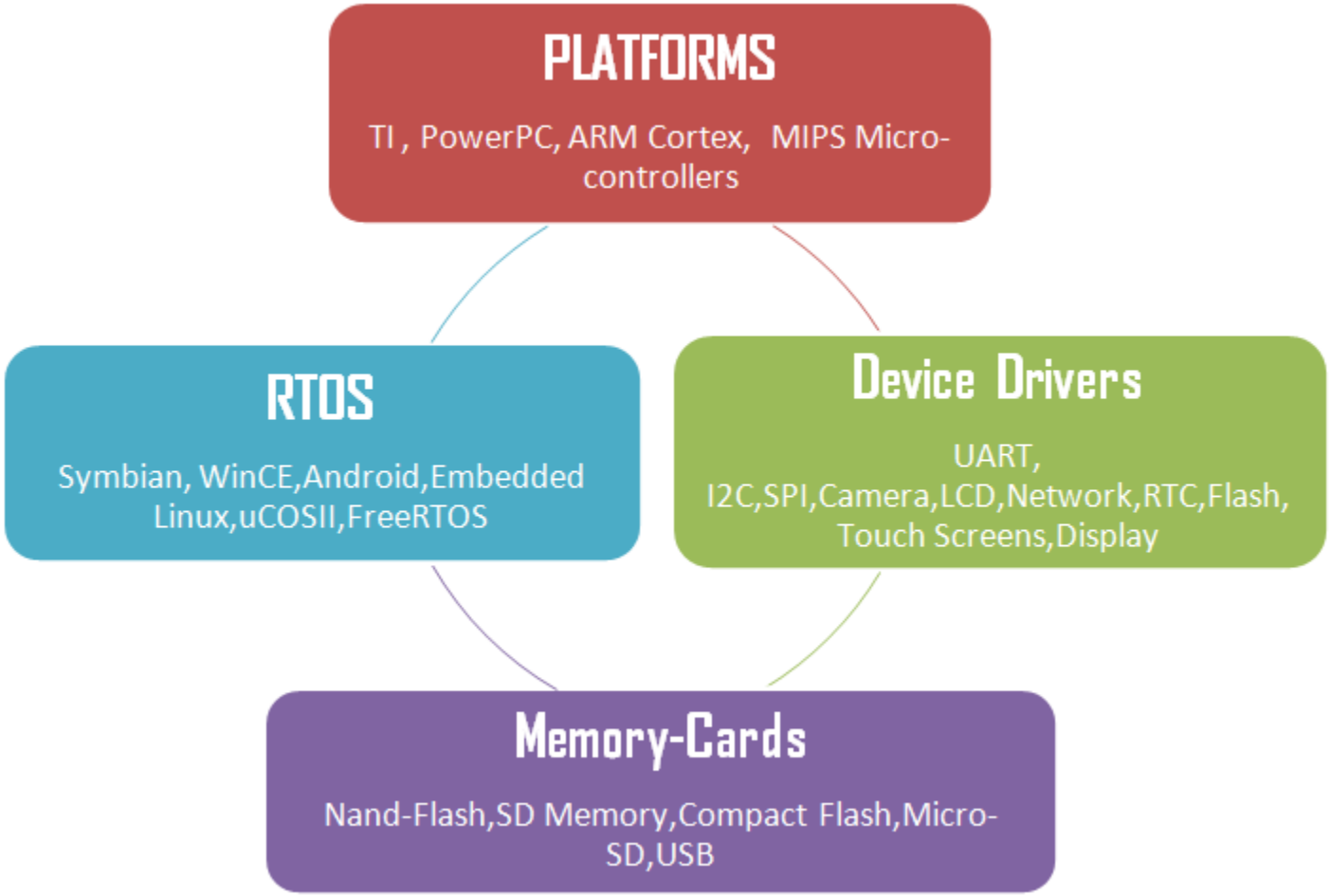
Communicating via MQTT with ESP32/ESP8266

- Refer:
  - https://github.com/knolleary/pubsubclient/blob/master/examples/mqtt_esp8266/mqtt_esp8266.ino

```
#include <ESP8266WiFi.h>          //Hoặc #include <WiFi.h>
#include <PubSubClient.h>
WiFiClient espClient;
PubSubClient client(espClient);
const char* mqtt_server = "broker.mqtt-dashboard.com";
void setup_wifi() { …}
void callback(char* topic, byte* payload, unsigned int length) { …}
void reconnect() { …}
void setup() {
      Serial.begin(115200);
      setup_wifi();
      client.setServer(mqtt_server, 1883);
      client.setCallback(callback);
}
void loop() { … }
```

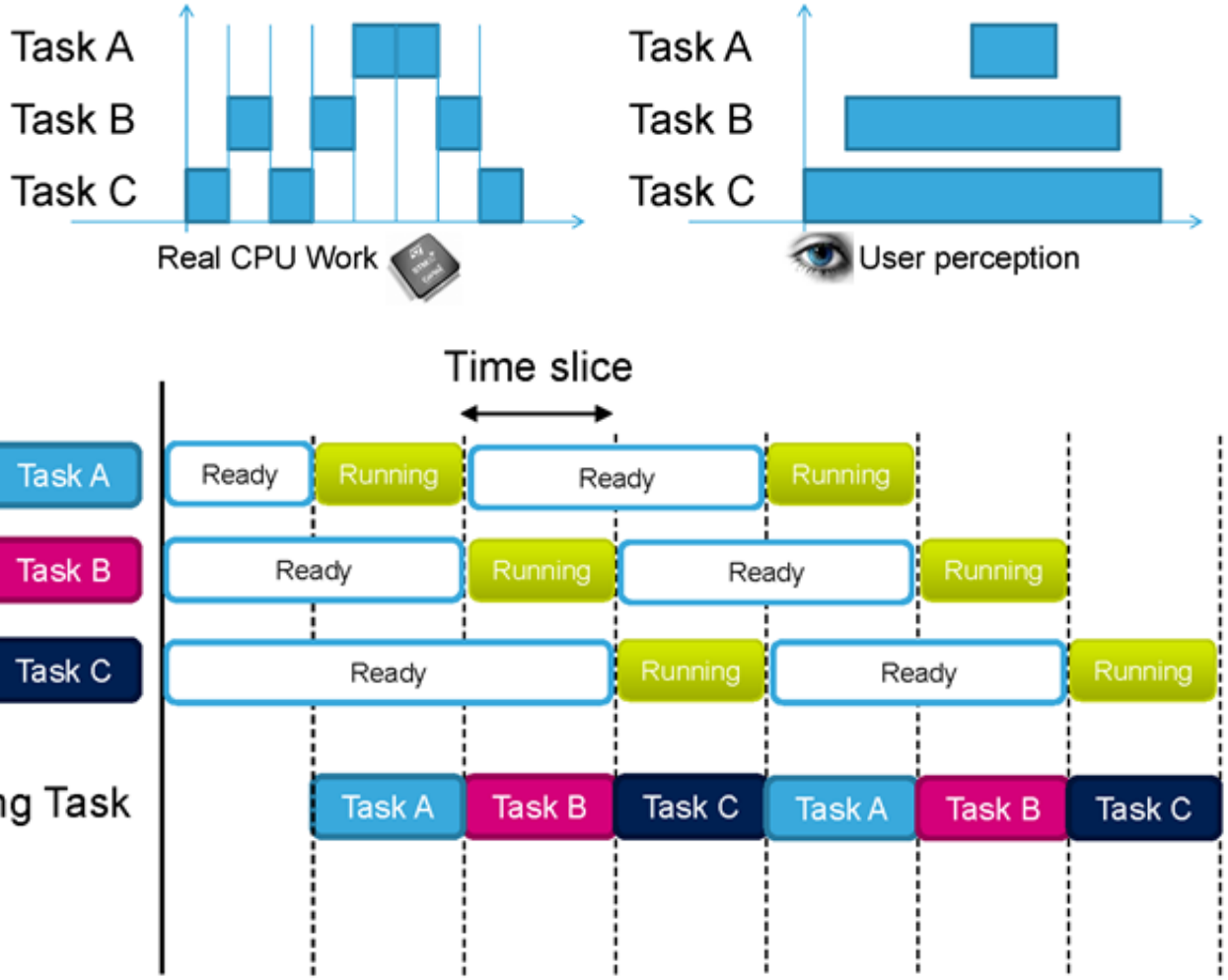
E. Programming multi-task with FreeRTOS

- RTOS = Real Time OS



E. Programming multi-task with FreeRTOS

- FreeRTOS multi-tasking



Programming multi-task with FreeRTOS

- Create a task

```
void toggleLED(void * parameter){
    for(;;){ // infinite loop
        // Turn the LED on
        digitalWrite(led1, HIGH);
        // Pause the task for 500ms
        vTaskDelay(500 / portTICK_PERIOD_MS);
        // Turn the LED off
        digitalWrite(led1, LOW);
        // Pause the task again for 500ms
        vTaskDelay(500 / portTICK_PERIOD_MS);
    }
}
```

Programming multi-task with FreeRTOS

- Create a task

```
void setup() {
xTaskCreate(
      toggleLED, // Function that should be called
      "Toggle LED", // Name of the task (for debugging)
      1000, // Stack size (bytes)
      NULL, // Parameter to pass
      1, // Task priority
      NULL// Task handle );
}
```

https://savjee.be/2020/01/multitasking-esp32-arduino-freertos/

https://savjee.be/2019/07/Home-Energy-Monitor-ESP32-CT-Sensor-Emonlib/

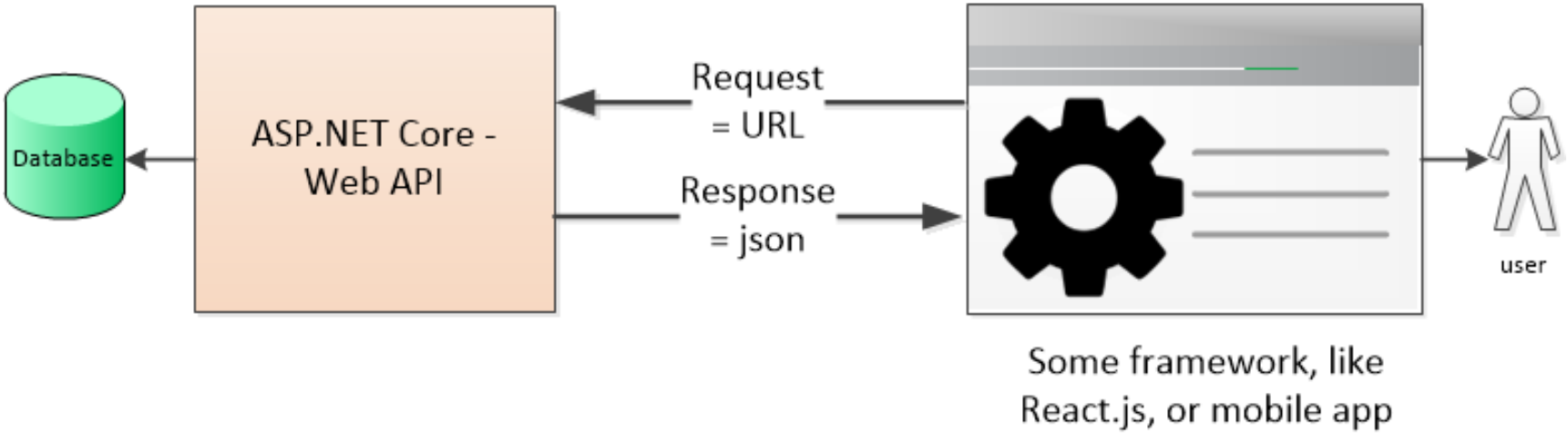
3.2. Building an IoT Server

3.2.1 .Net Core, Entity Framework

3.2.2. NodeJS, MongoDB

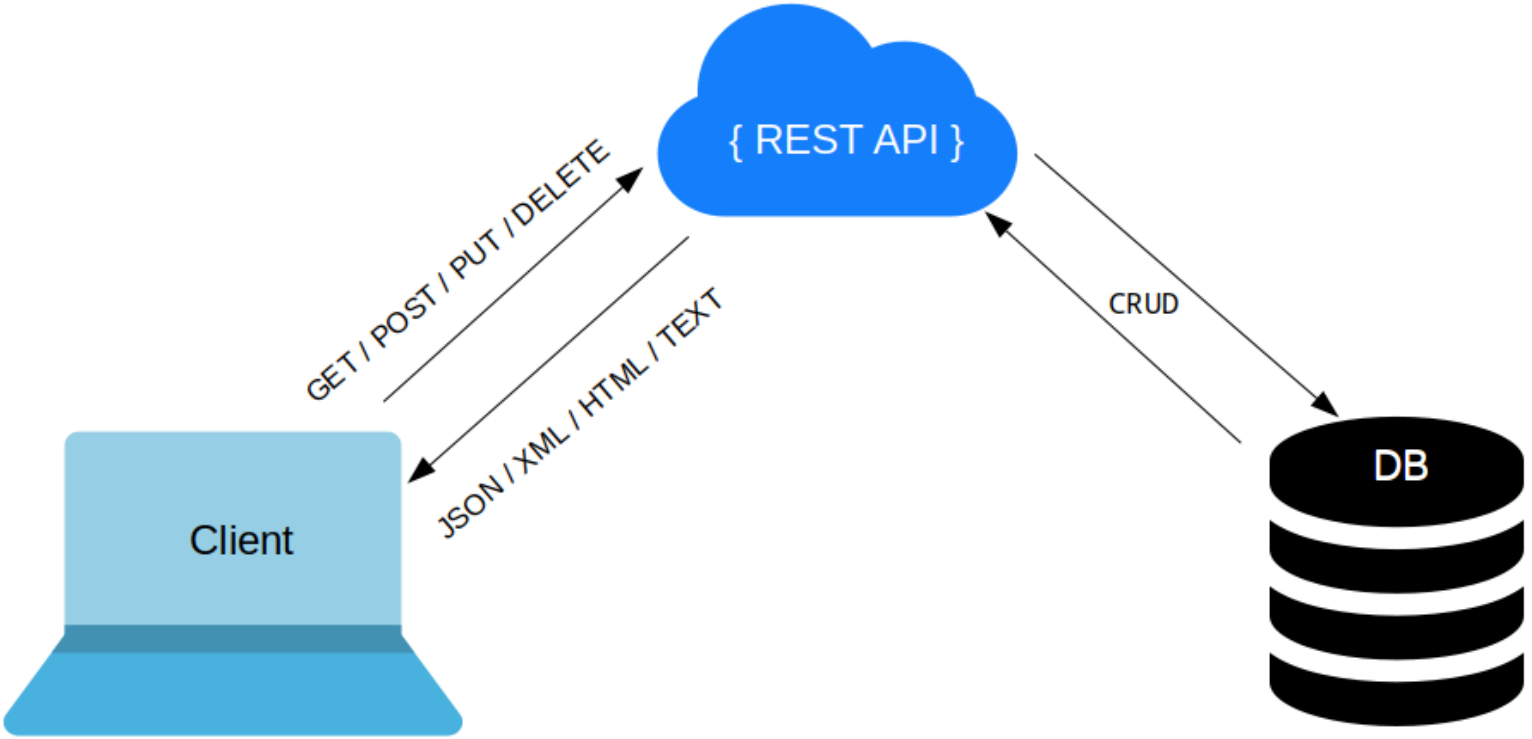
3.2.1. Building Web API with .NET Core

- Use ASP.NET Core and Entity Framework to build Web API for IoT application



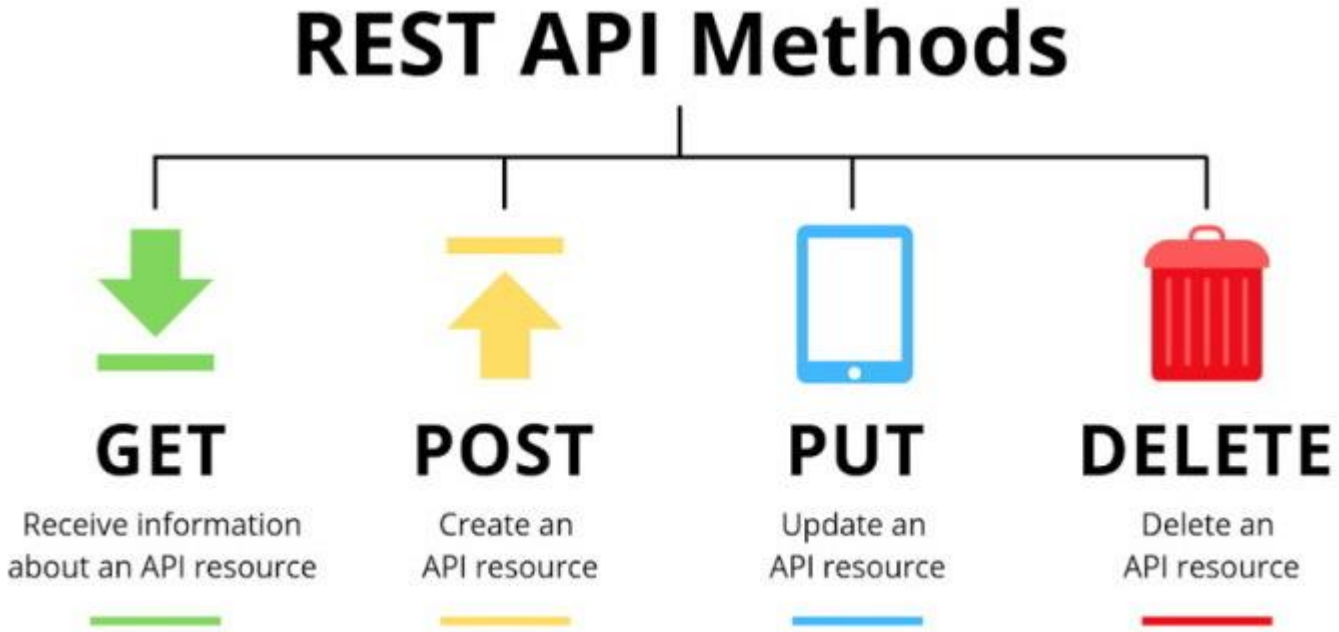
RESTful API

- REST = **RE**presentational **S**tate **T**ransfer: : Resource states are conveyed via HTTP.
- A standard used in Web API design



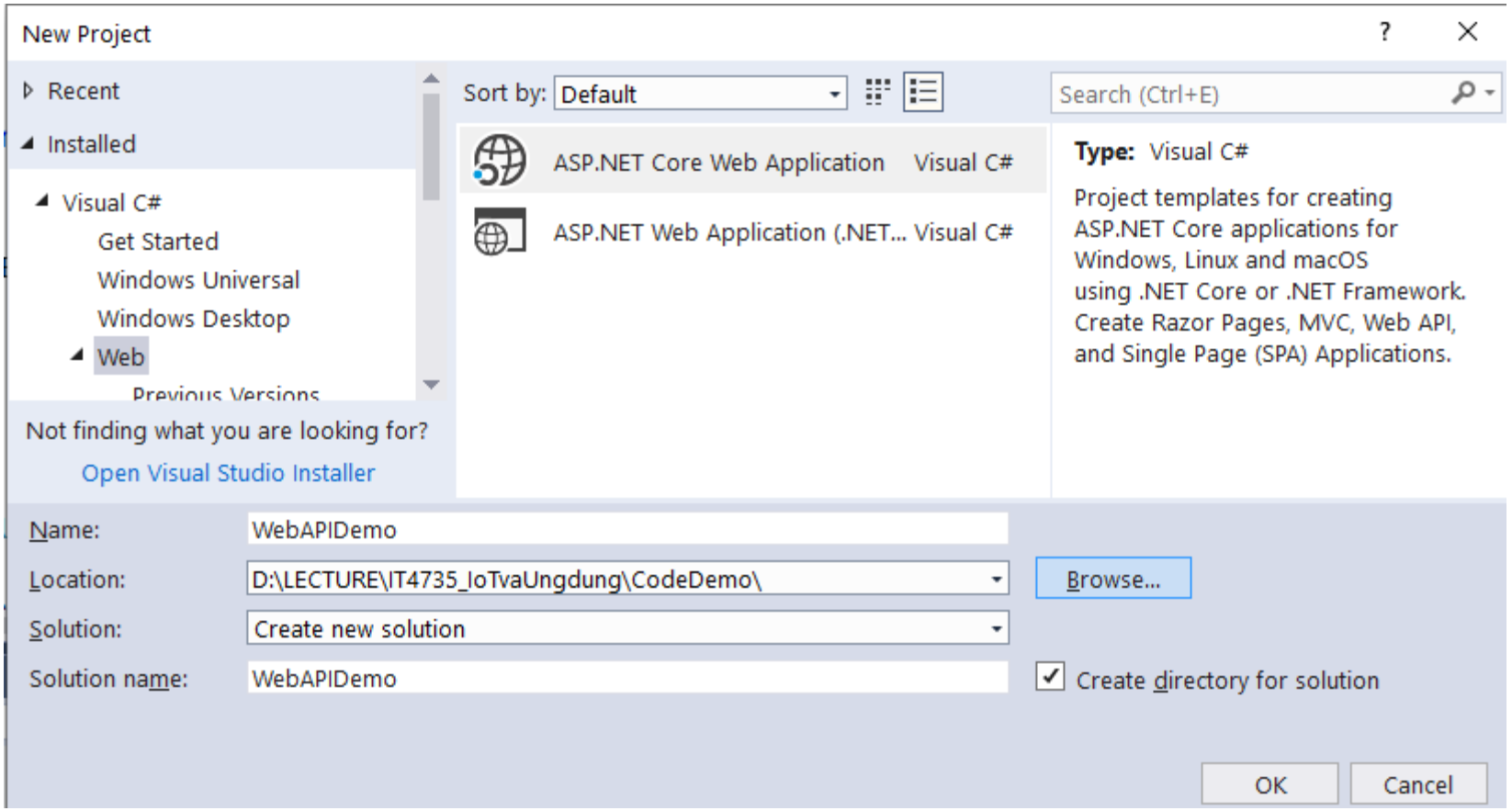
RESTful API

- Based on HTTP. Use HTTP methods:
  - GET: Retrieve (READ) specific resource information (by Id) or a list of resources.
  - POST: Create a new resource.
  - PUT: UPDATE information for a resource (by Id).
  - DELETE: DELETE) a resource by ID.



Create Web API project

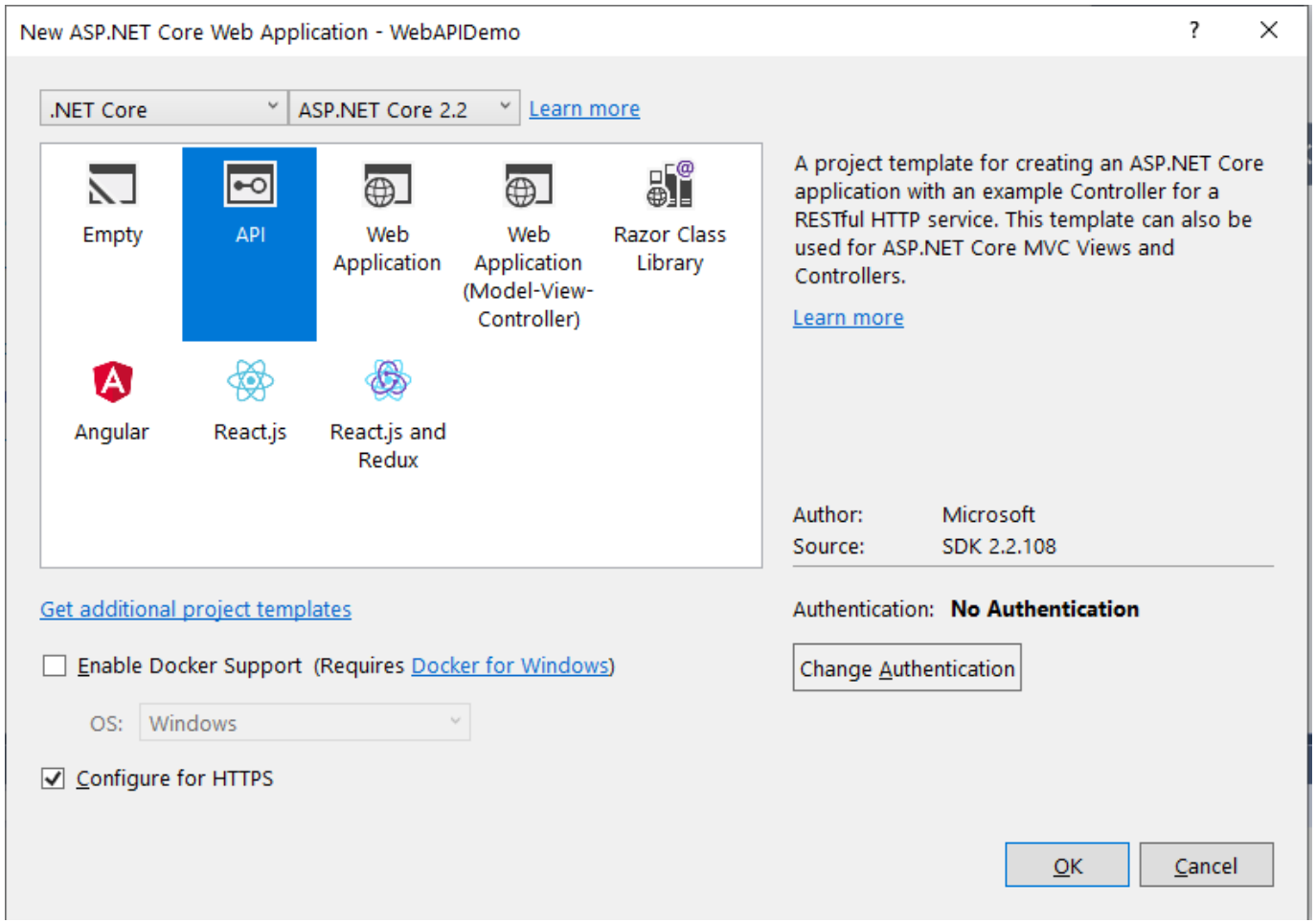
- Open File/New/Project in Visual Studio



https://medium.com/net-core/how-to-build-a-restful-api-with-asp-net-core-fb7dd8d3e5e3

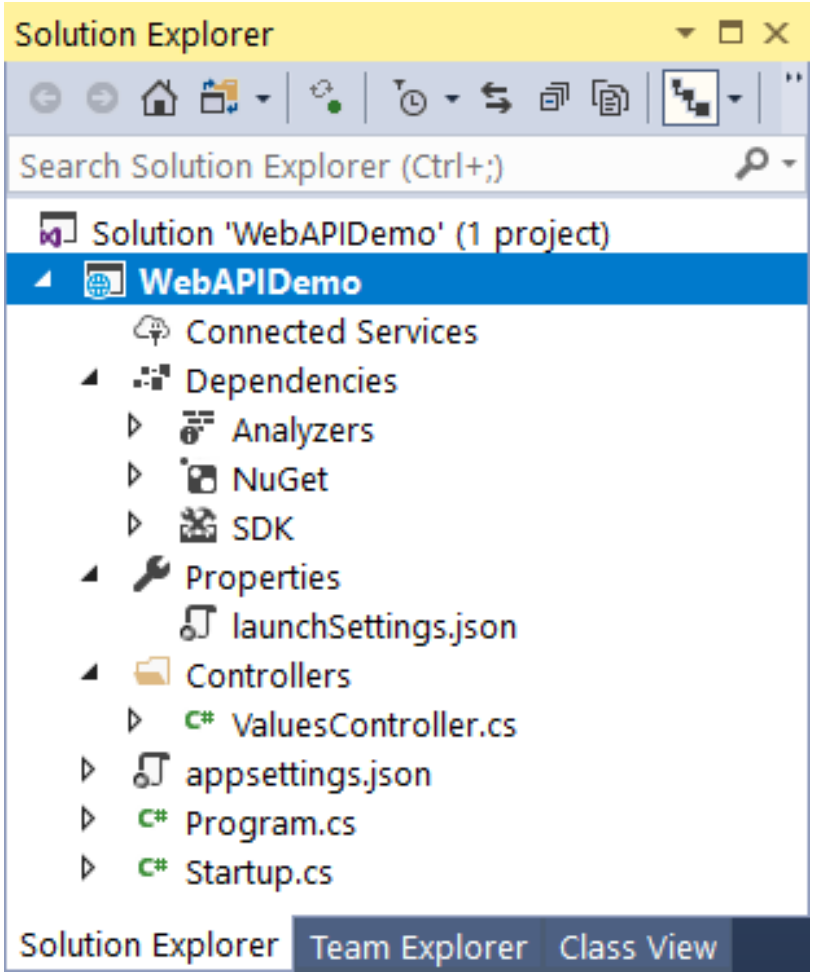
Create Web API project

- Select .NET Core, ASP.NET Core 2.2, API Project



Create Web API project

- Project WebAPIDemo



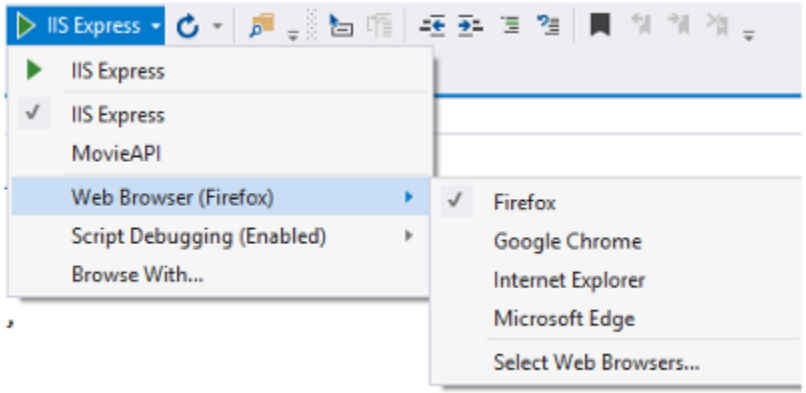
Create Web API project

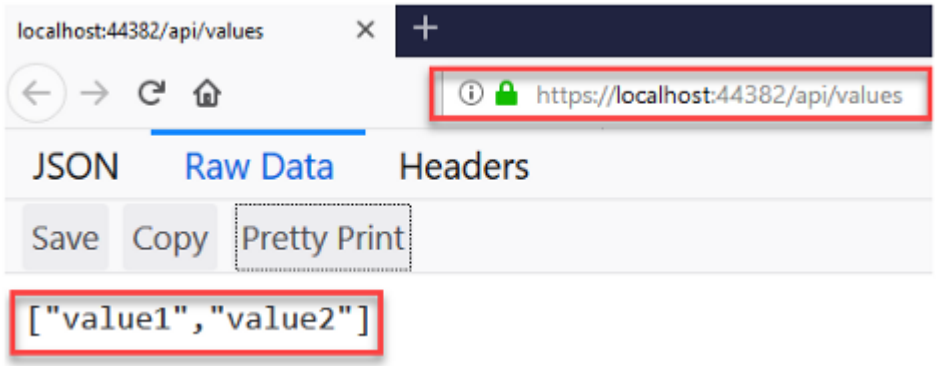
- MVC (Model-View-Controller) is added in Startup.cs

```
namespace WebAPIDemo
{
    2 references
    public class Startup
    {
        0 references | 0 exceptions
        public Startup(IConfiguration configuration)...
        1 reference | 0 exceptions
        public IConfiguration Configuration { get; }
        // This method gets called by the runtime. Use this method to add services to the container.
        0 references | 0 exceptions
        public void ConfigureServices(IServiceCollection services)
        {
            services.AddMvc().SetCompatibilityVersion(CompatibilityVersion.Version_2_2);
        }
        // This method gets called by the runtime. Use this method to configure the HTTP request pipeline.
        0 references | 0 exceptions
        public void Configure(IApplicationBuilder app, IHostingEnvironment env)
        {
            if (env.IsDevelopment())...
            else...
            app.UseHttpsRedirection();
            app.UseMvc();
        }
    }
}
```

Routing and URL paths

- Run app (Ctrl + F5), sử dụng IIS Express (MS webserver)
- Demo results on Web Browser





Routing and URL paths

- The default URL https://localhost:{port}/api/values is configured in the launchUrl in the file ***Properties\launchSettings.json***
- The values obtained in the browser are by default in the Get method of the ValuesController

launchSettings.json | Startup.cs | Program.cs

Schema: http://json.schemastore.org/launchsettings.json

```
{
  "$schema": "http://json.schemastore.org/launchsettings.json",
  "iisSettings": {
    "windowsAuthentication": false,
    "anonymousAuthentication": true,
    "iisExpress": {
      "applicationUrl": "http://localhost:54911",
      "sslPort": 44382
    }
  },
  "profiles": {
    "IIS Express": {
      "commandName": "IISExpress",
      "launchBrowser": true,
      "launchUrl": "api/values",
      "environmentVariables": {
        "ASPNETCORE_ENVIRONMENT": "Development"
      }
    },
    "MovieAPI": {
      "commandName": "Project",
      "launchBrowser": true,
      "launchUrl": "api/values",
      "applicationUrl": "https://localhost:5001;http://localhost:5000",
      "environmentVariables": {
        "ASPNETCORE_ENVIRONMENT": "Development"
      }
    }
  }
}
```

```
[Route("api/[controller]")]
[ApiController]
public class ValuesController : ControllerBase
{
    // GET api/values
    [HttpGet]
    public ActionResult<IEnumerable<string>> Get()
    {
        return new string[] { "value1", "value2" };
    }
```

Build a model

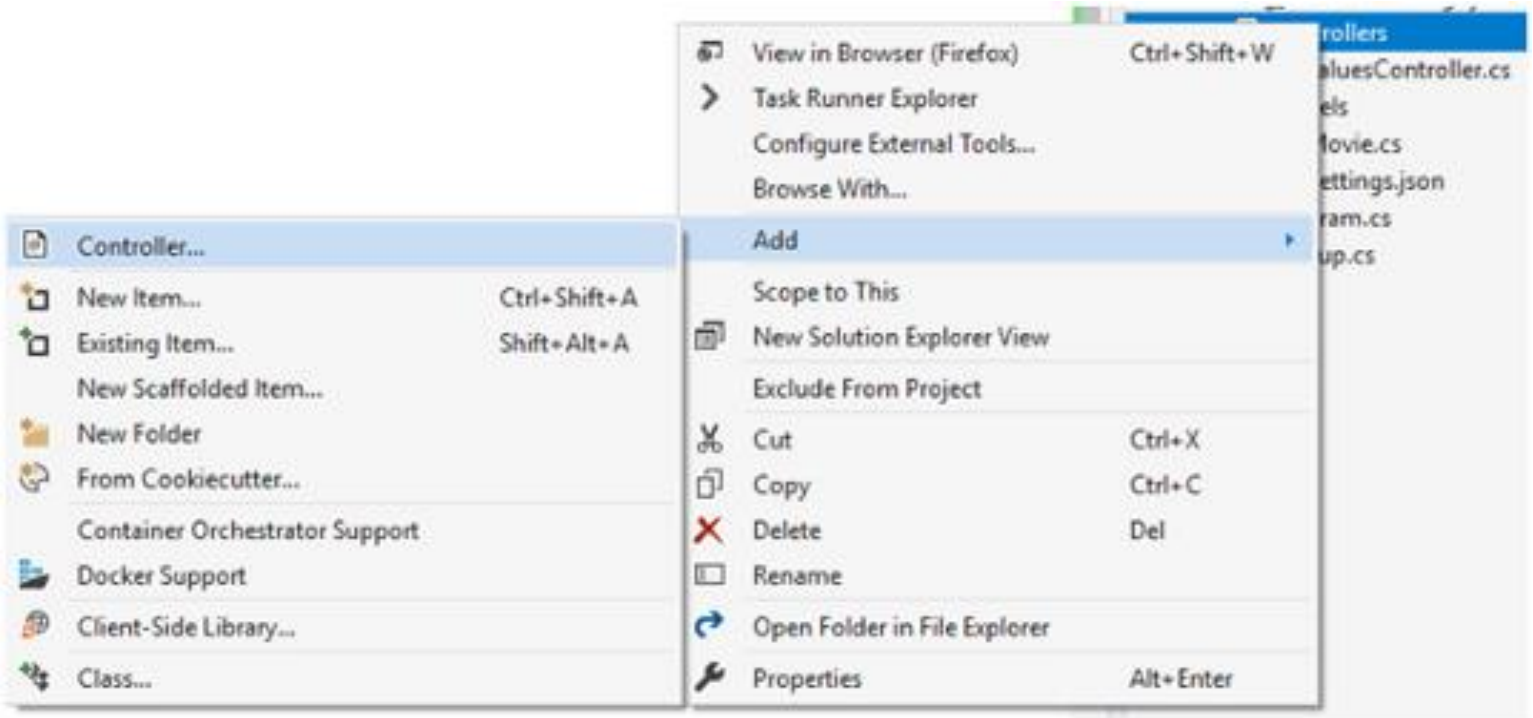
- Build data model class (**Model** in MVC architecture)
- In ***Solution Explorer***, right-click the project. Select ***Add*** > ***New Folder*** and name the folder ***Models***.
- Then right-click the ***Models*** folder and select ***Add->Class***. Name the class ***SensorData.cs*** and click Add.

Build a model

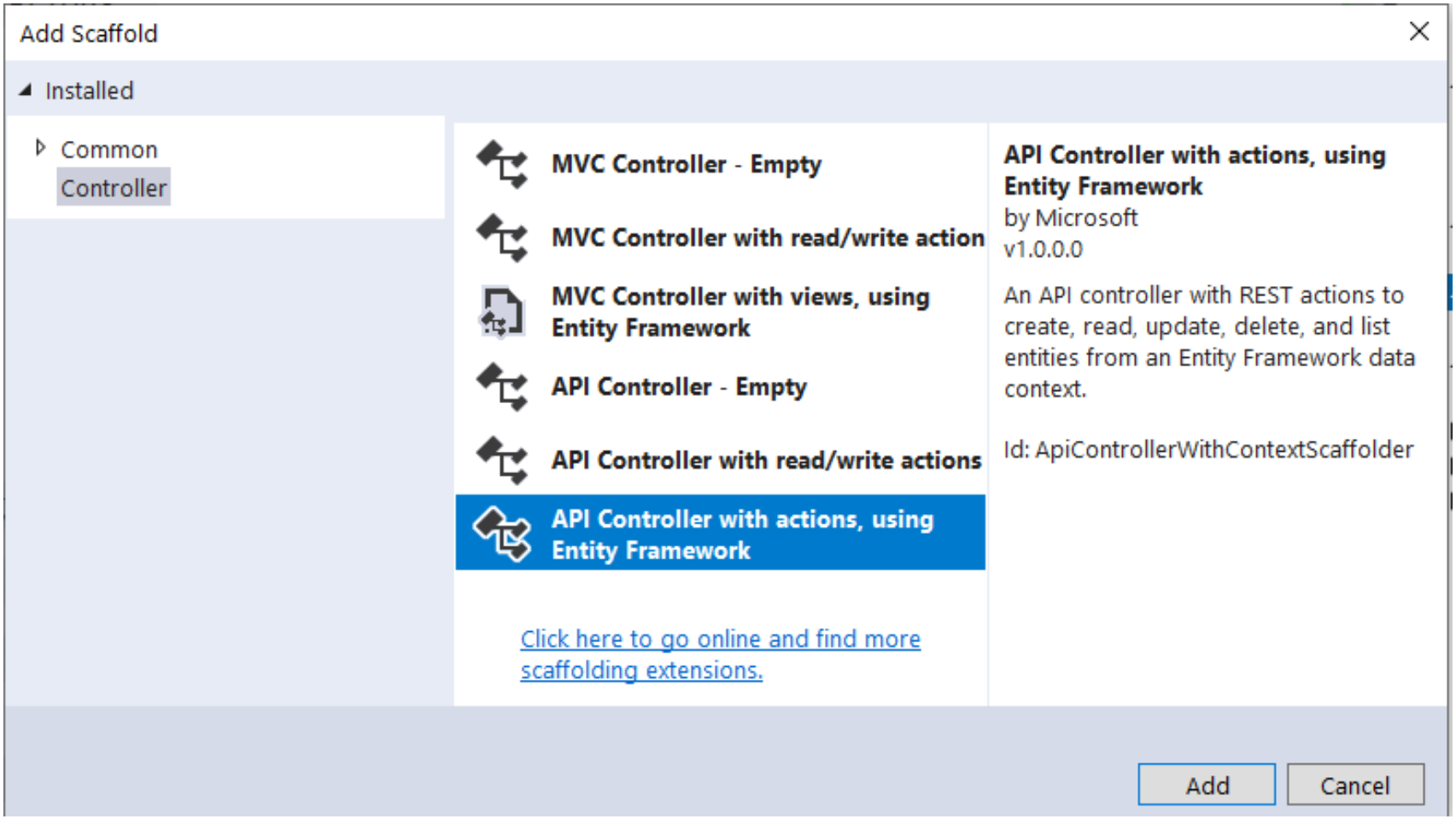
```
using System;
using System.Collections.Generic;
using System.ComponentModel.DataAnnotations;
using System.Linq;
using System.Threading.Tasks;

namespace WebAPIDemo.Models
{
    public class SensorData
    {
        public int Id { get; set; }
        [Required]  //Data Annotation
        [StringLength(60, MinimumLength = 3)]
        public string Name { get; set; }
        public float Value { get; set; }
        [DataType(DataType.Date)]
        public DateTime ReceiveTime { get; set; }
    }
}
```

Create a controller

- Create a controller (Controller component in MVC architecture), associated with the SensorData model
- Use Entity Framework Core (EF Core) to work with the database

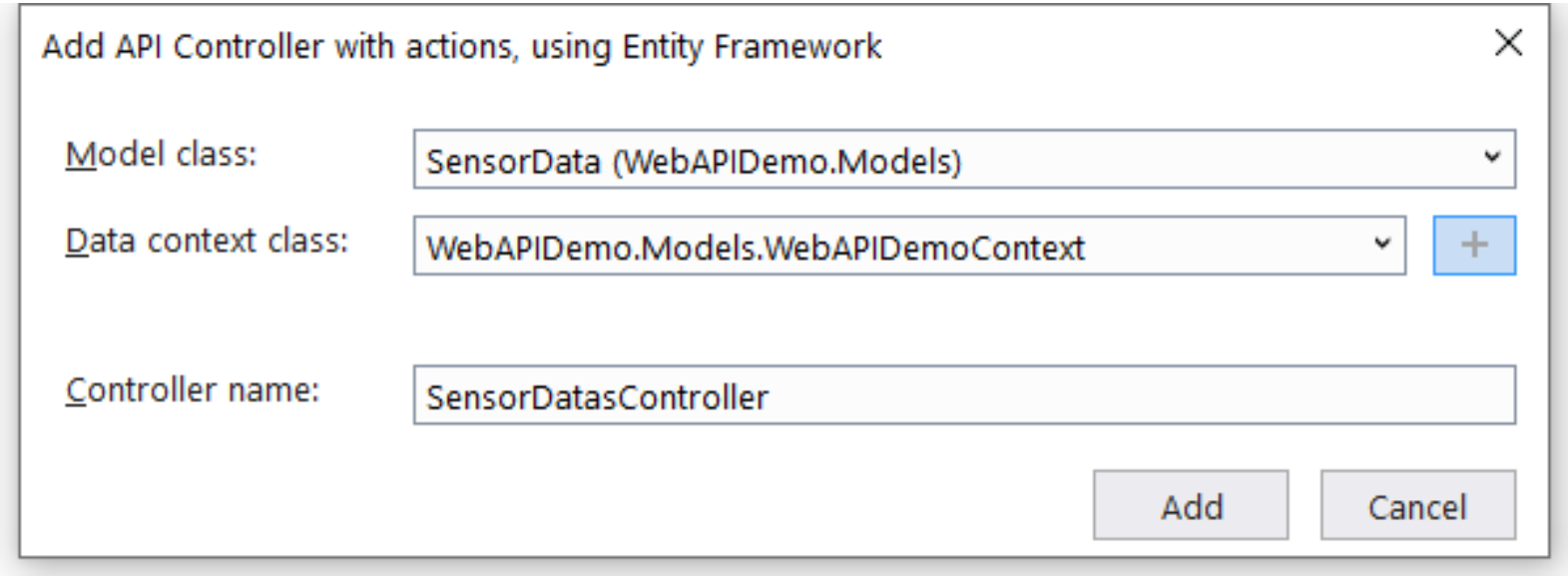


Create a controller



Create a controller

- ***scaffolding*** tool in .NET Core supports automatic code generation
- The automatic creation of the database context and **CRUD** (**C**reate, **R**ead, **U**pdate, and **D**elete) action methods is known as scaffolding.



Controller Class

- Example: SensorDatasController class with methods:
  - GetSensorData (GET method)
  - PostSensorData (POST method)
  - PutSensorData (PUT method)
  - DeleteSensorData (DELETE method)
- Controller class inherits from ControllerBase

```
public class SensorDatasController : ControllerBase
```

SensorDatasController.cs

```
namespace WebAPIDemo.Controllers
{
    [Route("api/[controller]")]
    [ApiController]
    1 reference | 0 requests
    public class SensorDatasController : ControllerBase
    {
        private readonly WebAPIDemoContext _context;
        0 references | 0 exceptions
        public SensorDatasController(WebAPIDemoContext context)...
        // GET: api/SensorDatas
        [HttpGet]
        0 references | 0 requests | 0 exceptions
        public async Task<ActionResult<IEnumerable<SensorData>>> GetSensorData()...
        // GET: api/SensorDatas/5
        [HttpGet("{id}")]
        0 references | 0 requests | 0 exceptions
        public async Task<ActionResult<SensorData>> GetSensorData(int id)...
        // PUT: api/SensorDatas/5
        [HttpPut("{id}")]
        0 references | 0 requests | 0 exceptions
        public async Task<IActionResult> PutSensorData(int id, SensorData sensorData)...
        // POST: api/SensorDatas
        [HttpPost]
        0 references | 0 requests | 0 exceptions
        public async Task<ActionResult<SensorData>> PostSensorData(SensorData sensorData)...
        // DELETE: api/SensorDatas/5
        [HttpDelete("{id}")]
        0 references | 0 requests | 0 exceptions
        public async Task<ActionResult<SensorData>> DeleteSensorData(int id)...
        1 reference | 0 exceptions
        private bool SensorDataExists(int id)...
    }
}
```

EF Core Database Context

- ***Data\WebAPIDemoContext.cs***
- ***WebAPIDemoContext*** kết nối với các chức năng của EF Core (Create, Read, Update, Delete, etc.) cho **SensorData** model
- ***WebAPIDemoContext*** kế thừa từ Microsoft.EntityFrameworkCore.DbContext.

```
using Microsoft.EntityFrameworkCore;
namespace WebAPIDemo.Models
{
    5 references
    public class WebAPIDemoContext : DbContext
    {
        0 references | 0 exceptions
        public WebAPIDemoContext (DbContextOptions<WebAPIDemoContext> options)...
        6 references | 0 exceptions
        public DbSet<WebAPIDemo.Models.SensorData> SensorData { get; set; }
    }
}
```

EF Core Database Context

- In Entity Framework terminology, an entity set typically corresponds to a database table and an entity corresponds to a row in the table.
- ASP.NET Core configuration system reads the connection string from the ***appsettings.json*** file:

```
{
  "Logging": {
    "LogLevel": {
      "Default": "Warning"
    }
  },
  "AllowedHosts": "*",
  "ConnectionStrings": {
    "WebAPIDemoContext": "Server=(localdb)\\mssqllocaldb;Database=WebAPIDemoContext-56113fd8-
  }
}
```

EF Core Database Context

- Register DB Context (WebAPIDemoContext) in Startup.cs

```
// This method gets called by the runtime. Use this method to add services to the container.
0 references | 0 exceptions
public void ConfigureServices(IServiceCollection services)
{
    services.AddMvc().SetCompatibilityVersion(CompatibilityVersion.Version_2_2);

    services.AddDbContext<WebAPIDemoContext>(options =>
            options.UseSqlServer(Configuration.GetConnectionString("WebAPIDemoContext")));
}
```

Inject the database context (WebAPIDemoContext) into the controller:

```
namespace WebAPIDemo.Controllers
{
    [Route("api/[controller]")]
    [ApiController]
    1 reference | 0 requests
    public class SensorDatasController : ControllerBase
    {
        private readonly WebAPIDemoContext _context;
        0 references | 0 exceptions
        public SensorDatasController(WebAPIDemoContext context)
        {
            _context = context;
        }
```

Create a database using Migrations

- Use Entity Framework code first
- Migrations tool create database that corresponds to the constructed data model (code first) and updates the database schema when there are changes in the data model.
- Execute the commands of the Migrations tool:
  - Open ***Tools -> NuGet Package Manager > Package Manager Console (PMC), execute command:***
  - **Add-Migration Initial (Create database)**
  - **Update-Database (Update database schema)**

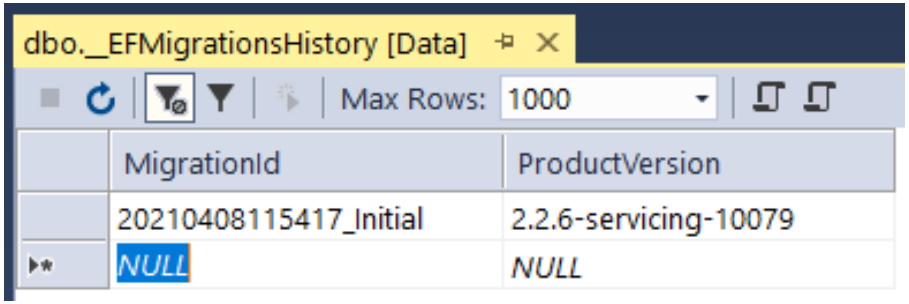
Create a database using Migrations

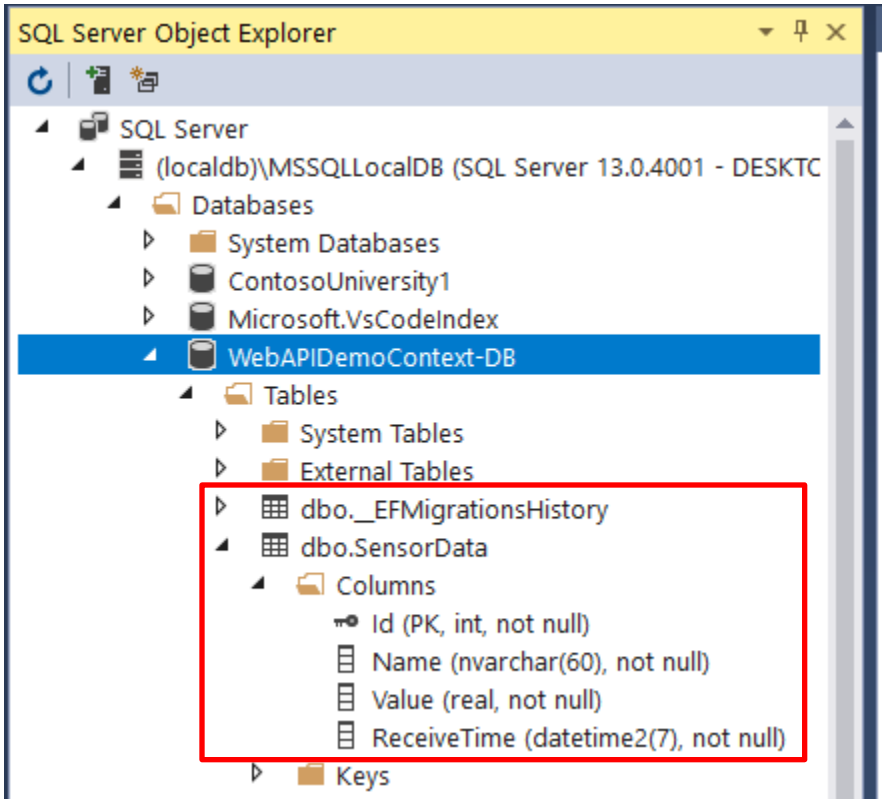
- Migration files are automatically generated in the Migration folder

```
namespace WebAPIDemo.Migrations
{
    1 reference
    public partial class Initial : Migration
    {
        0 references | 0 exceptions
        protected override void Up(MigrationBuilder migrationBuilder)
        {
            migrationBuilder.CreateTable(
                name: "SensorData",
                columns: table => new
                {
                    Id = table.Column<int>(nullable: false)
                        .Annotation("SqlServer:ValueGenerationStrategy", SqlServerValueGenerationStrategy.IdentityColumn),
                    Name = table.Column<string>(maxLength: 60, nullable: false),
                    Value = table.Column<float>(nullable: false),
                    ReceiveTime = table.Column<DateTime>(nullable: false)
                },
                constraints: table =>
                {
                    table.PrimaryKey("PK_SensorData", x => x.Id);
                });
        }
        0 references | 0 exceptions
        protected override void Down(MigrationBuilder migrationBuilder)
        {
            migrationBuilder.DropTable(
                name: "SensorData");
        }
    }
}
```

Create a database using Migrations

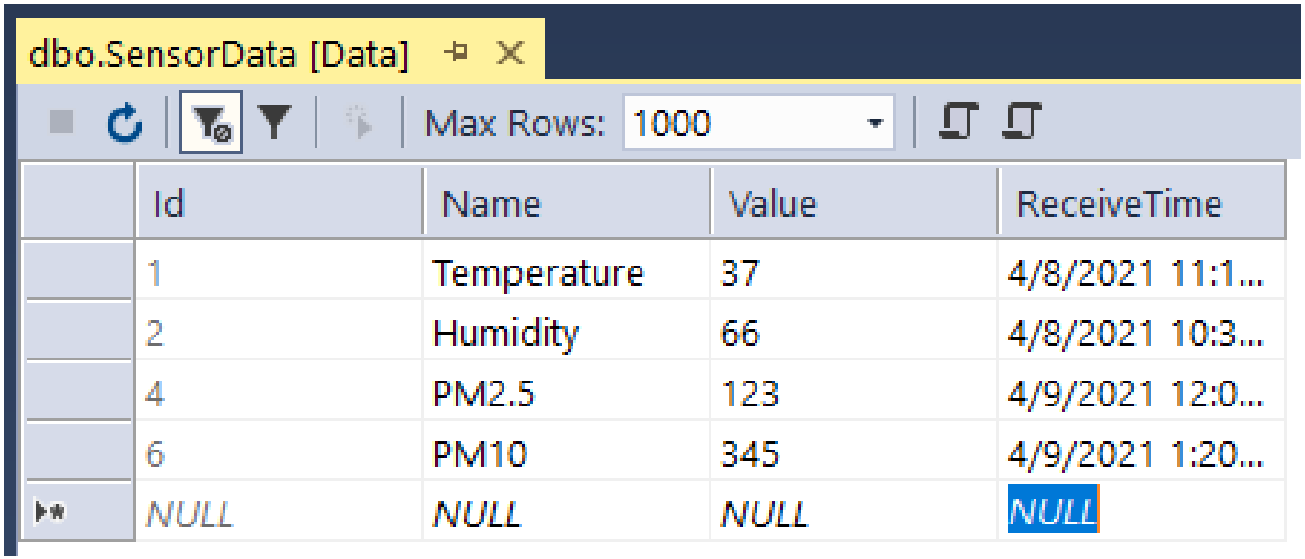
- Execute command **Update-Database** (in PMC)
- Up method in file ***Migrations/{time-stamp}_Initial.cs*** will be executed and will create a database
- Open SQL Server Object Explorer





Create a database

- Add data to the SensorData table
- **Open *SQL Server Object Explorer***, right-click on the SensorData table, select ***View Data*** to add a record.



	Id	Name	Value	ReceiveTime
	1	Temperature	37	4/8/2021 11:1...
	2	Humidity	66	4/8/2021 10:3...
	4	PM2.5	123	4/9/2021 12:0...
	6	PM10	345	4/9/2021 1:20...
▶*	*NULL*	*NULL*	*NULL*	*NULL*

GET method

- GetSensorData(): returns all records in the SensorData database.
- GetSensorData(int id): returns the corresponding record with the specified Id
- [HttpGet]: method handles HTTP GET requests

```
// GET: api/SensorDatas
[HttpGet]
0 references | 0 requests | 0 exceptions
public async Task<ActionResult<IEnumerable<SensorData>>> GetSensorData()
{
    return await _context.SensorData.ToListAsync();
}
// GET: api/SensorDatas/5
[HttpGet("{id}")]
0 references | 0 requests | 0 exceptions
public async Task<ActionResult<SensorData>> GetSensorData(int id)
{
    var sensorData = await _context.SensorData.FindAsync(id);

    if (sensorData == null)
    {
        return NotFound();
    }

    return sensorData;
}
```

GET method

- GET endpoints:
  - GET /api/SensorData
  - GET /api/SensorData/{id}
- Call HTTP GET request from browser:
  - https://localhost:{port}/api/SensorDatas
  - https://localhost:{port}/api/SensorDatas/2
- Return type **ActionResult<T> type**
  - .NET Core automatically serializes object to JSON and write it to the body of the response packet
  - Respone code: **200** (if there are no unhandled exceptions), otherwise, it returns a **5xx** error code

GET method

- Browser testing

localhost:44364/api/SensorDatas

```
// 20210409113750
// https://localhost:44364/api/SensorDatas

[
  {
    "id": 1,
    "name": "Temperature",
    "value": 37.0,
    "receiveTime": "2021-04-08T11:16:20"
  },
  {
    "id": 2,
    "name": "Humidity",
    "value": 66.0,
    "receiveTime": "2021-04-08T10:30:01"
  },
```

localhost:44364/api/SensorDatas/2

```
// 20210409113838
// https://localhost:44364/api/SensorDatas/2

{
  "id": 2,
  "name": "Humidity",
  "value": 66.0,
  "receiveTime": "2021-04-08T10:30:01"
}
```

GET method

- Default URL: Configure the launchUrl in the launchsettings.json file

launchSettings.json

Schema: http://json.schemastore.org/launchsettings.json

```
      "applicationUrl": "http://localhost:54420",
      "sslPort": 44364
    }
  },
  "profiles": {
    "IIS Express": {
      "commandName": "IISExpress",
      "launchBrowser": true,
      "launchUrl": "api/SensorDatas",
      "environmentVariables": {
        "ASPNETCORE_ENVIRONMENT": "Development"
      }
    },
    "WebAPIDemo": {
      "commandName": "Project",
      "launchBrowser": true,
      "launchUrl": "api/values",
      "applicationUrl": "https://localhost:5001;http://localhost:5000",
      "environmentVariables": {
        "ASPNETCORE_ENVIRONMENT": "Development"
      }
    }
  }
}
```

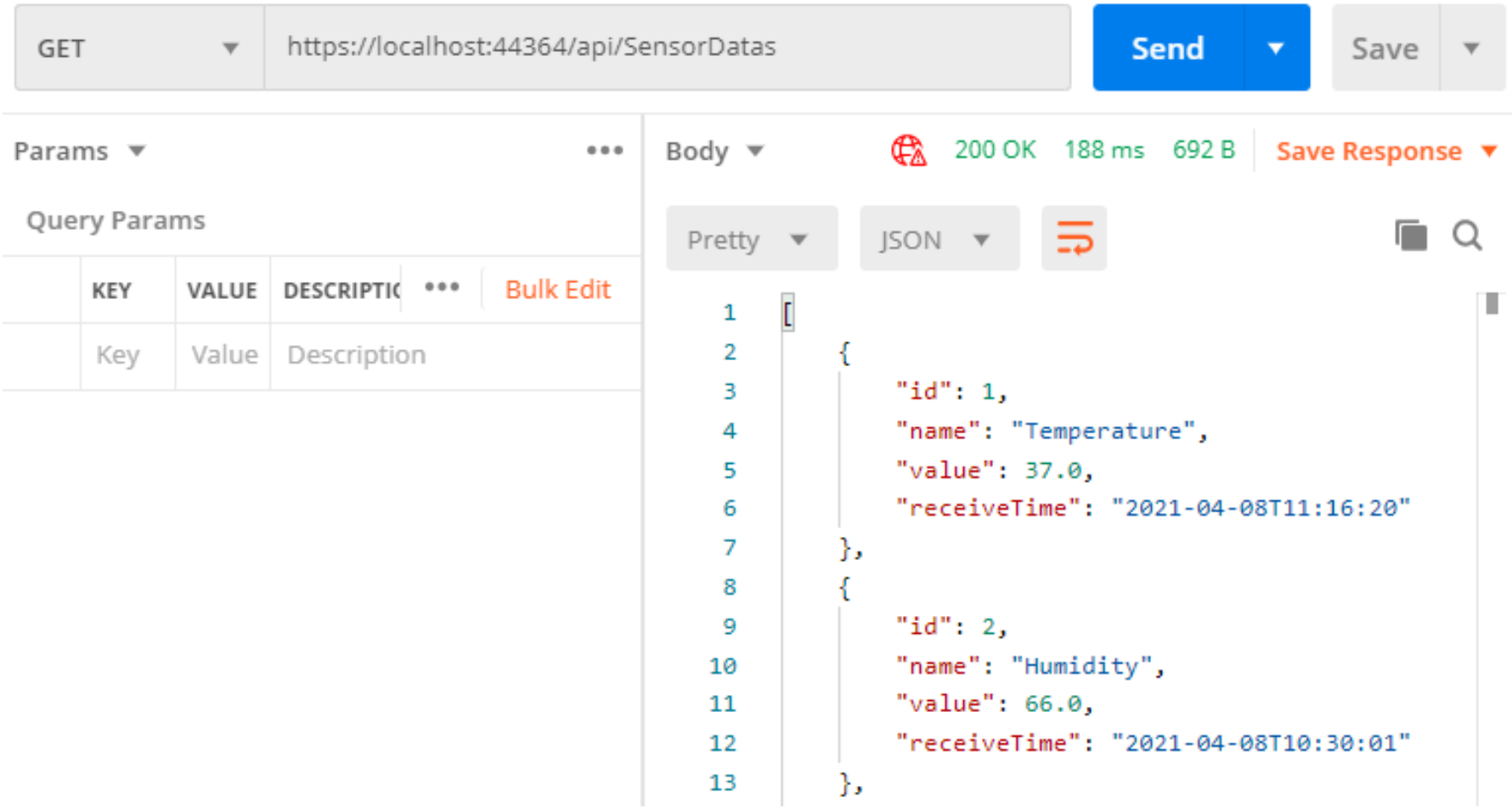
POST method

- PostSensorData() function creates a new record in the database
- Data (record) is sent in the body of the HTTP POST request
- CreatedAtAction() function:
  - Return HTTP status code 201 if successful

```
// POST: api/SensorDatas
[HttpPost]
0 references | 0 requests | 0 exceptions
public async Task<ActionResult<SensorData>> PostSensorData(SensorData sensorData)
{
    _context.SensorData.Add(sensorData);
    await _context.SaveChangesAsync();

    return CreatedAtAction("GetSensorData", new { id = sensorData.Id }, sensorData);
}
```

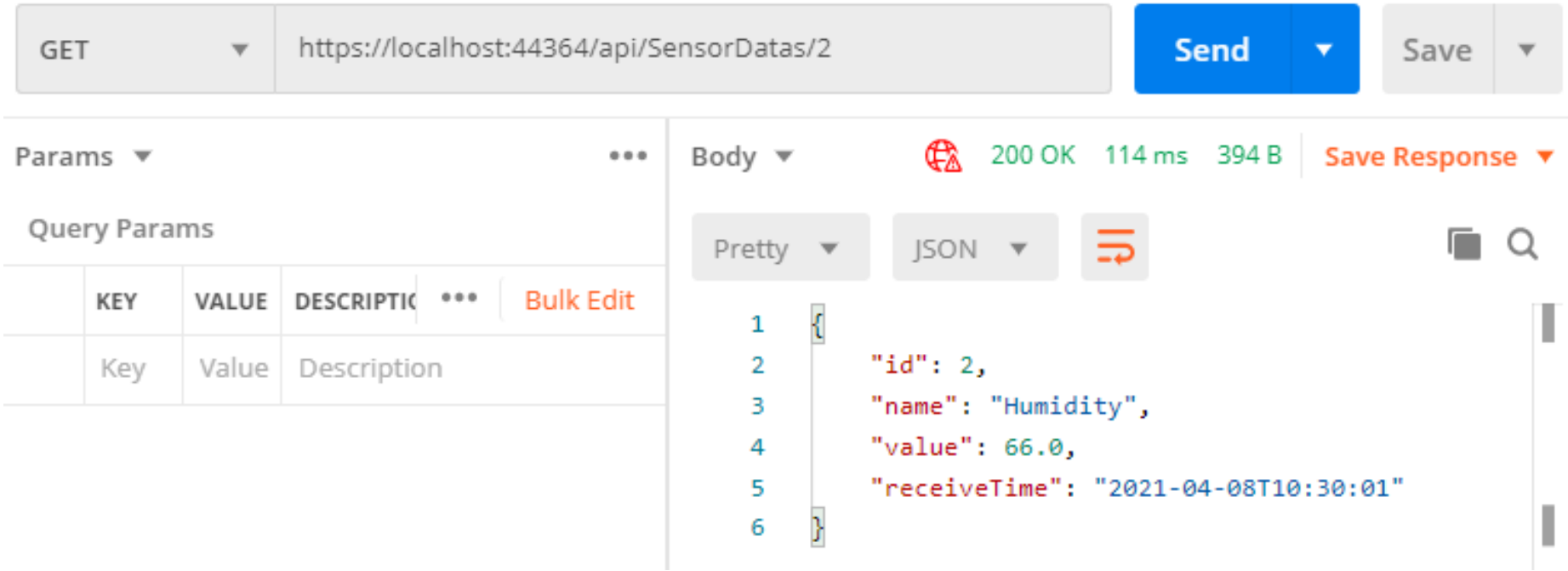
Testing using Postman

- GET method: get all resource



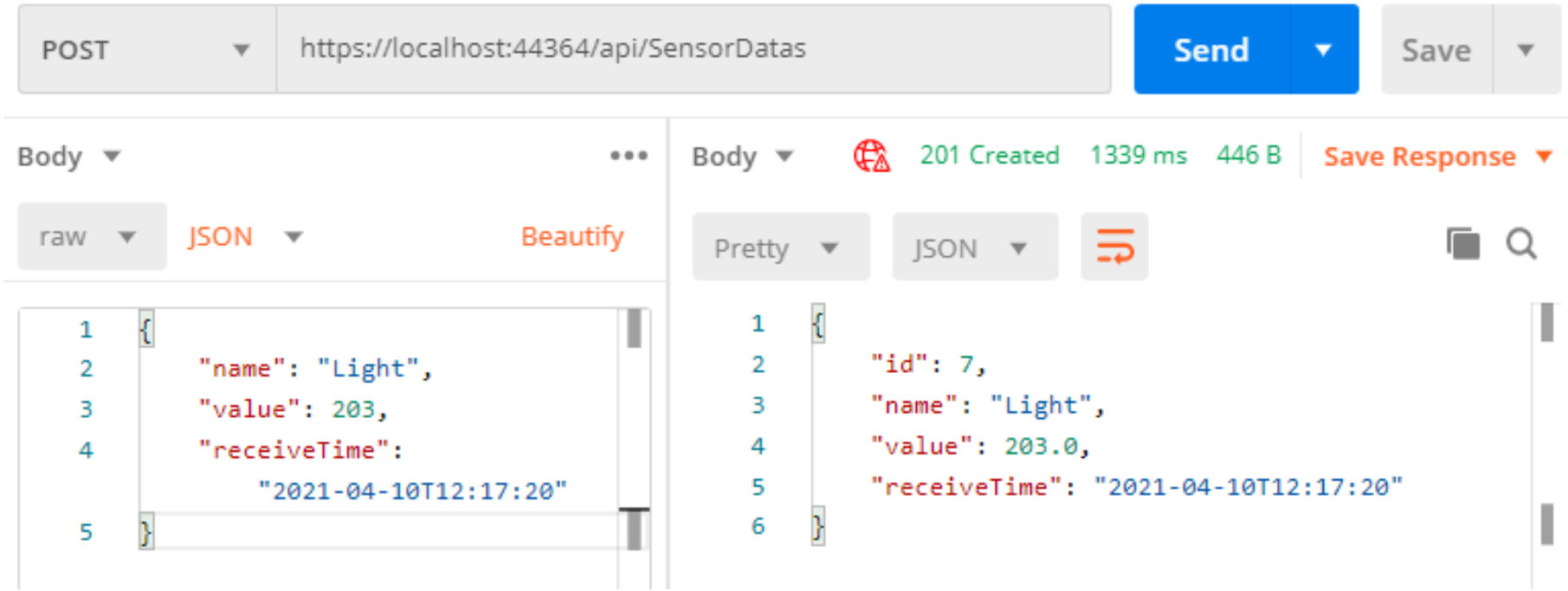
Testing using Postman

- GET method: get 1 resource by Id



Testing using Postman

- POST method



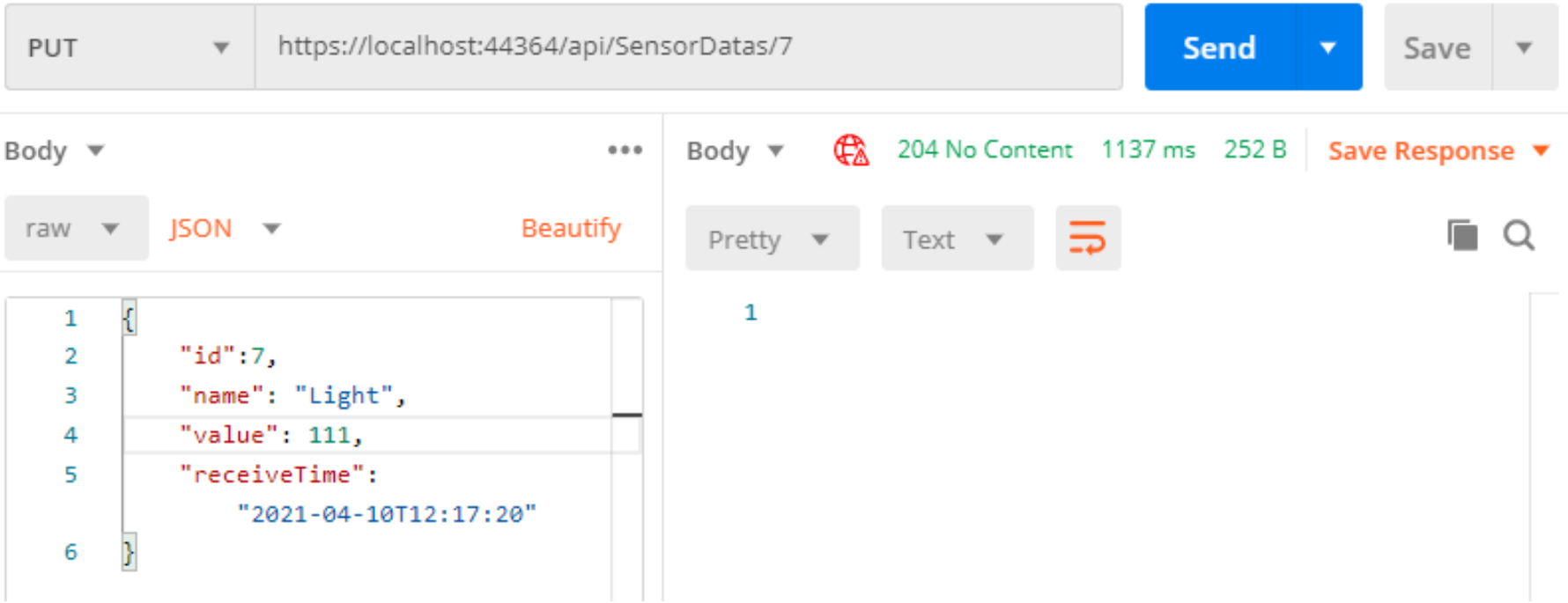
PUT method

- The PutSensorData() method updates a record

```
// PUT: api/SensorDatas/5
[HttpPut("{id}")]
0 references | 0 requests | 0 exceptions
public async Task<IActionResult> PutSensorData(int id, SensorData sensorData)
{
    if (id != sensorData.Id)
    {
        return BadRequest();
    }
    _context.Entry(sensorData).State = EntityState.Modified;
    try
    {
        await _context.SaveChangesAsync();
    }
    catch (DbUpdateConcurrencyException)
    {
        if (!SensorDataExists(id))
        {
            return NotFound();
        }
        else
        {
            throw;
        }
    }
    return NoContent();
}
```

PUT method

- Return code: HTTP 204 (No Content)



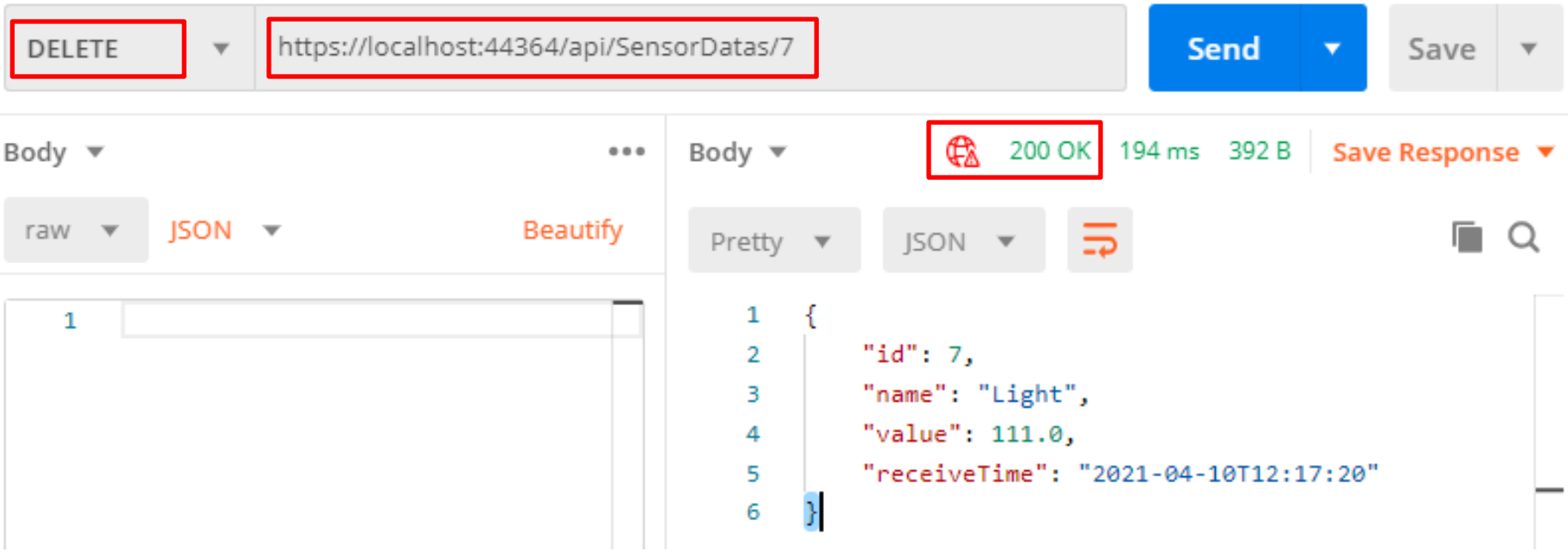
DELETE method

- Delete a record (by Id)

```
// DELETE: api/SensorDatas/5
[HttpDelete("{id}")]
0 references | 0 requests | 0 exceptions
public async Task<ActionResult<SensorData>> DeleteSensorData(int id)
{
    var sensorData = await _context.SensorData.FindAsync(id);
    if (sensorData == null)
    {
        return NotFound();
    }

    _context.SensorData.Remove(sensorData);
    await _context.SaveChangesAsync();

    return sensorData;
}
```

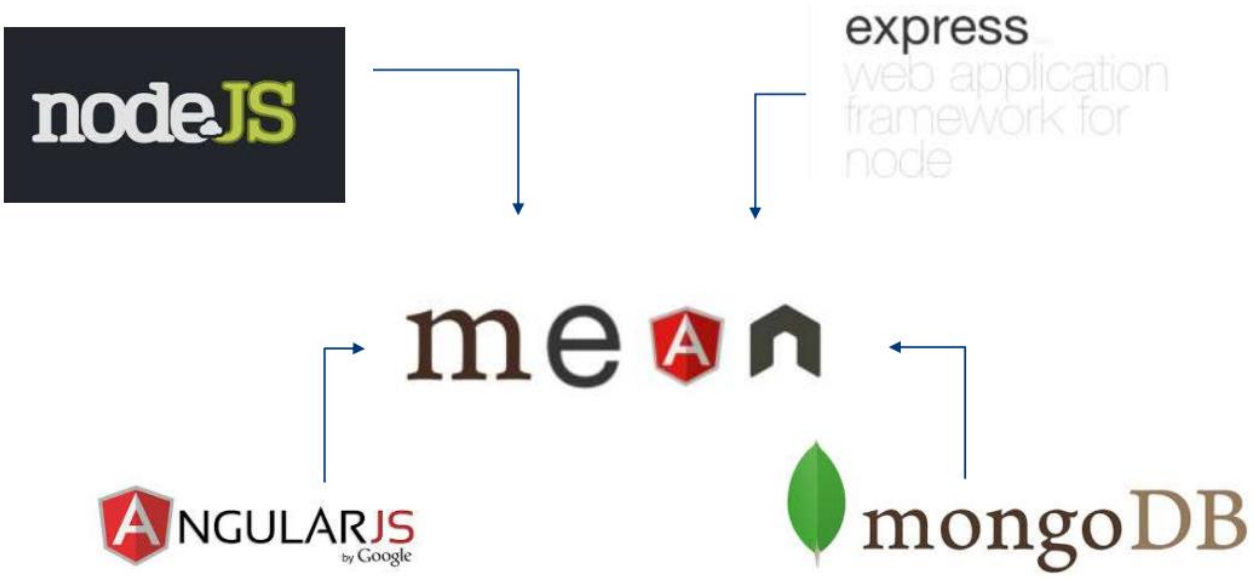
DELETE method

- Delete a record (by Id)
- Rerun code HTTP OK 200 (successful)



3.2.2. NodeJS, MongoDB techologie

- MEAN stack (mongoDB, ExpressJS, AngularJS, NodeJS)



https://www.tutorialspoint.com/nodejs/nodejs_restful_api.htm

https://blog.postman.com/how-to-create-a-rest-api-with-node-js-and-express/

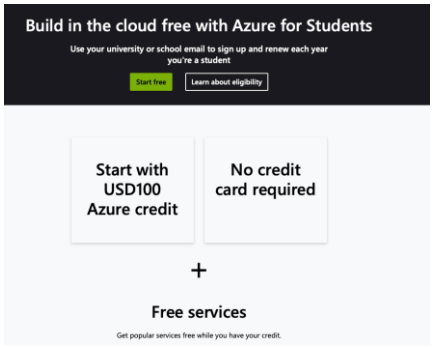
https://www.youtube.com/watch?v=RfHBm5yRxuw

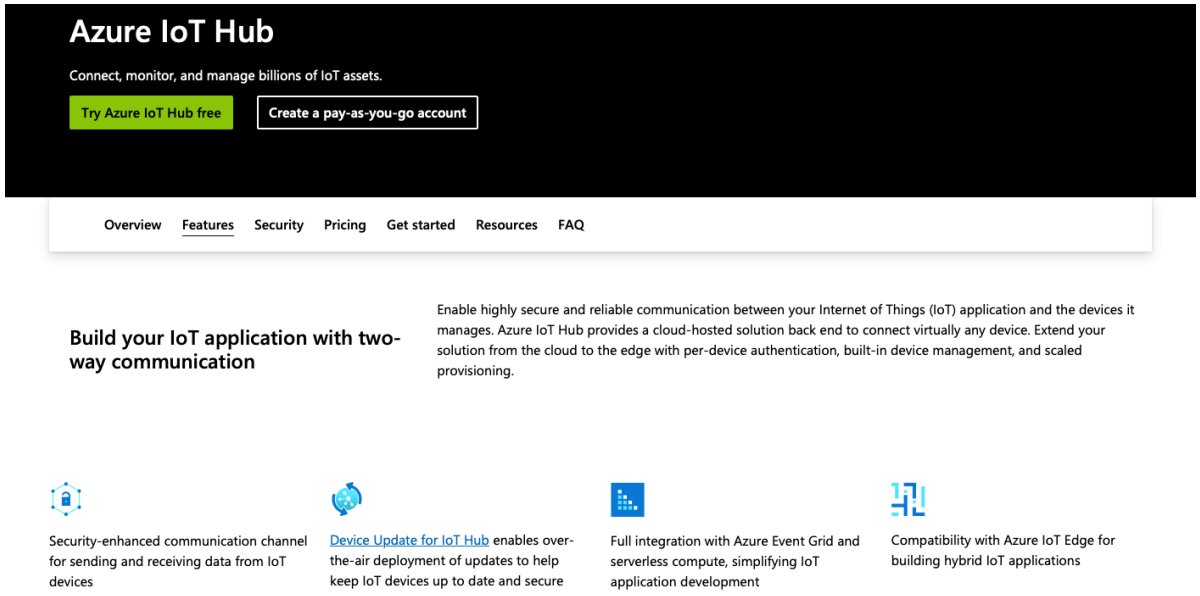
3.3. Using IoT Cloud

- IoT Cloud services:
  - Collecting, Ingesting data
  - Cloud Storage, Database
  - Data Representation
  - Dashboard
- Some IoT Cloud service platforms:
  - IBM BlueMix
  - AWS IoT
  - Google Cloud IoT
  - Azure IoT

3.3.1. Using Azure IoT hub

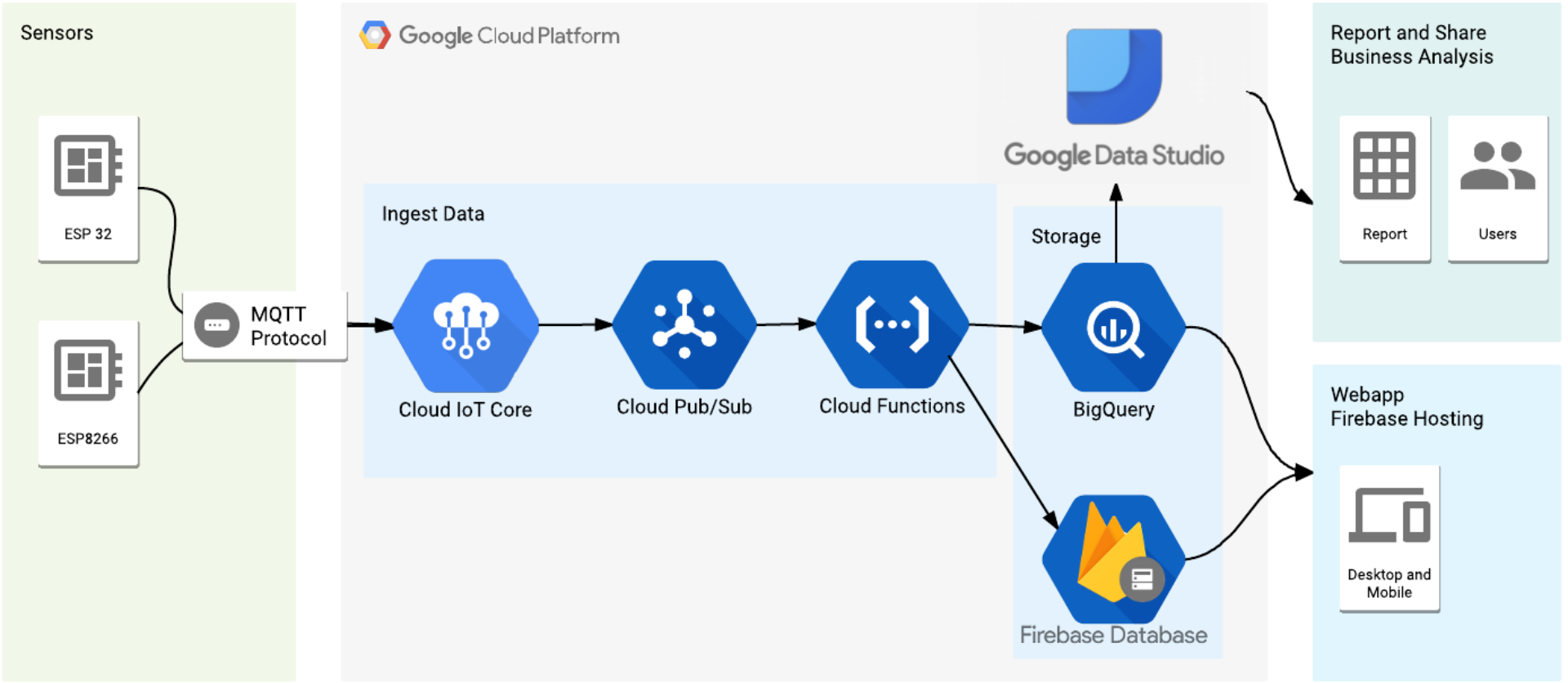
- https://sstechsolutioncom.wordpress.com/iot/iot-hub-esp32-dht11/





3.3.2. Using Google Cloud IoT

- A tutorial: https://medium.com/google-cloud/build-a-weather-station-using-google-cloud-iot-core-and-mongooseos-7a78b69822c5



Content

- Chapter 1. Overview of IoT
- Chapter 2. IoT Technologies
- Chapter 3. IoT Application and Programming
- Chapter 4. IoT Safety and Security
- Chapter 5. Designing and Building IoT Systems

Chapter 4. IoT Safety and Security

- 4.1. Overview of IoT Security
- 4.2. Types of Attacks on IoT Infrastructure
- 4.3. The Security Vulnerabilities of IoT

4.1. Overview of IoT Security

- Issues in IoT Security:
  - Initial design for proprietary communication networks, later transitioning to IP and the Internet.
  - Firmware updates for IoT devices are challenging
  - Starting from basic security requirements, more complex security flaws have emerged.
  - Poor security in devices due to the utilization of inadequate initial designs in practical applications

Overview of IoT Security

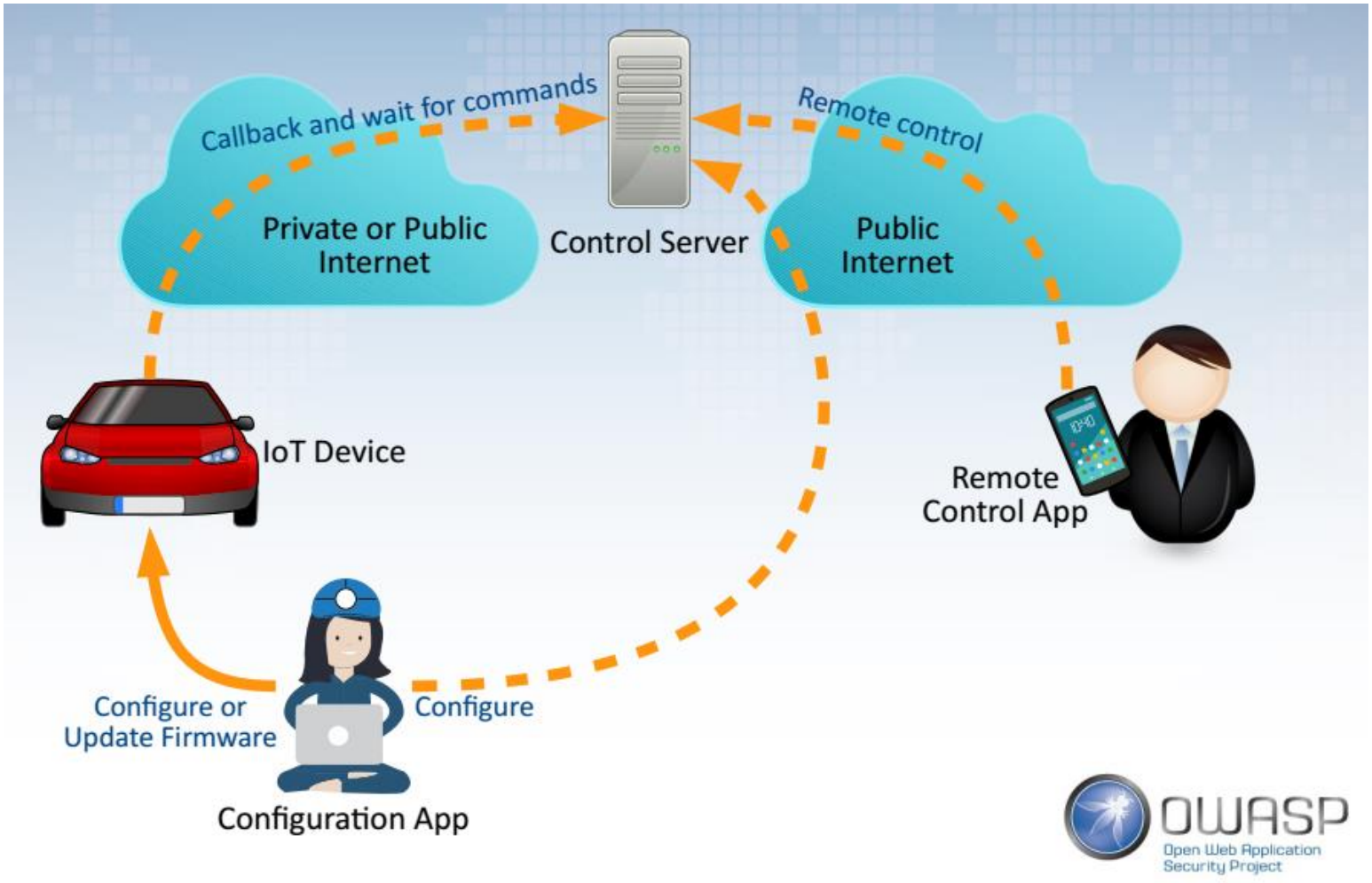
- Classification of Risks in IoT Security:
  - **Capture:** Risks associated with 'capturing' (collecting, stealing) data from the system
  - **Disrupt:** Risks related to denial-of-service attacks, destruction, or interruption of the system
  - **Manipulate:** Risks associated with interference/change (manipulating) data and identity

Overview of IoT Security

- Security Requirements for IoT:
  - Confidentiality:
    - Data transmitted can only be read by the intended recipient.
  - Availability :
    - Communication between transmitting and receiving devices is always available
  - Integrity
    - Received data is not tampered with during transmission, ensuring the accuracy and completeness of the data.
  - Authenticity
    - The sender can always verify the sent data
    - Data can only be accessed by authorized recipients

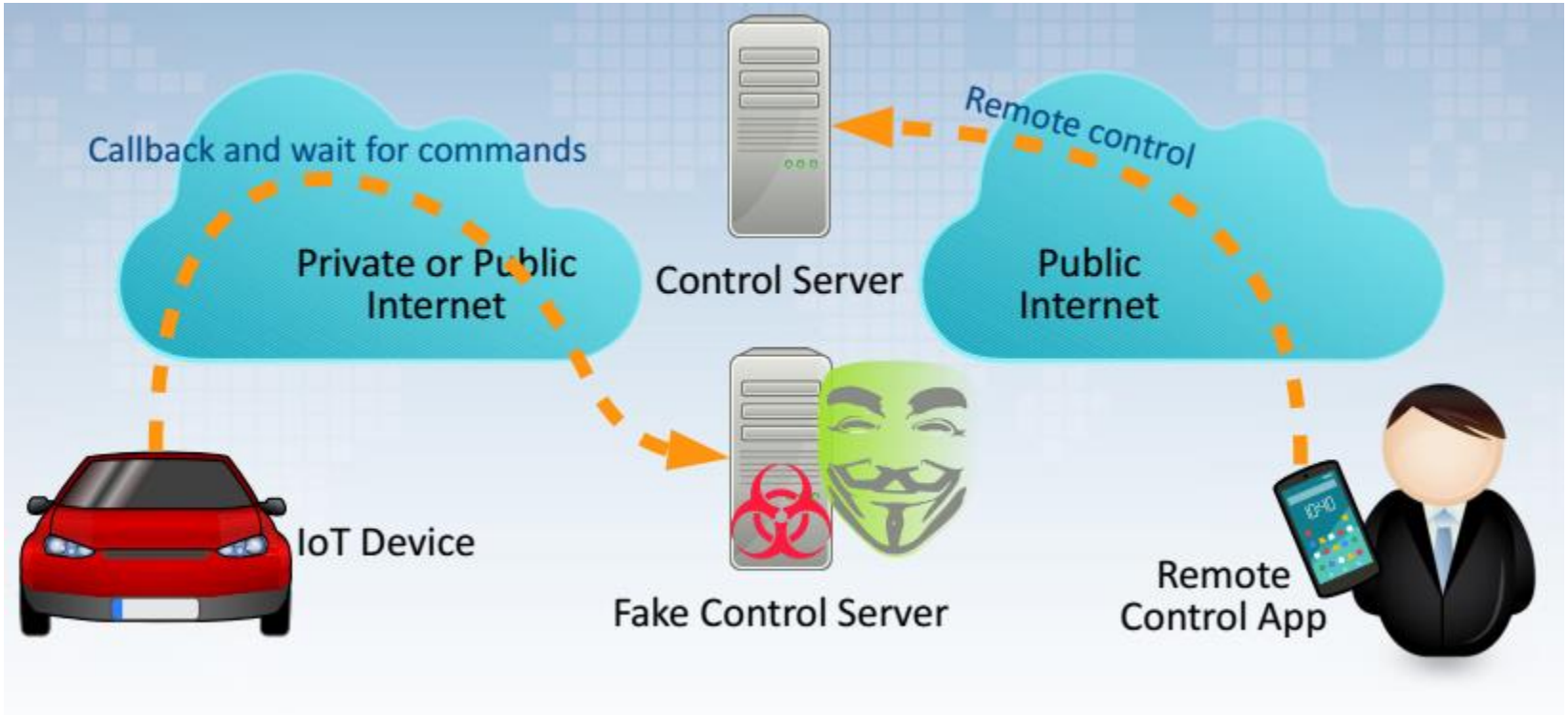
4.2. Types of Attacks on IoT Infrastructure

- Common IoT Infrastructure



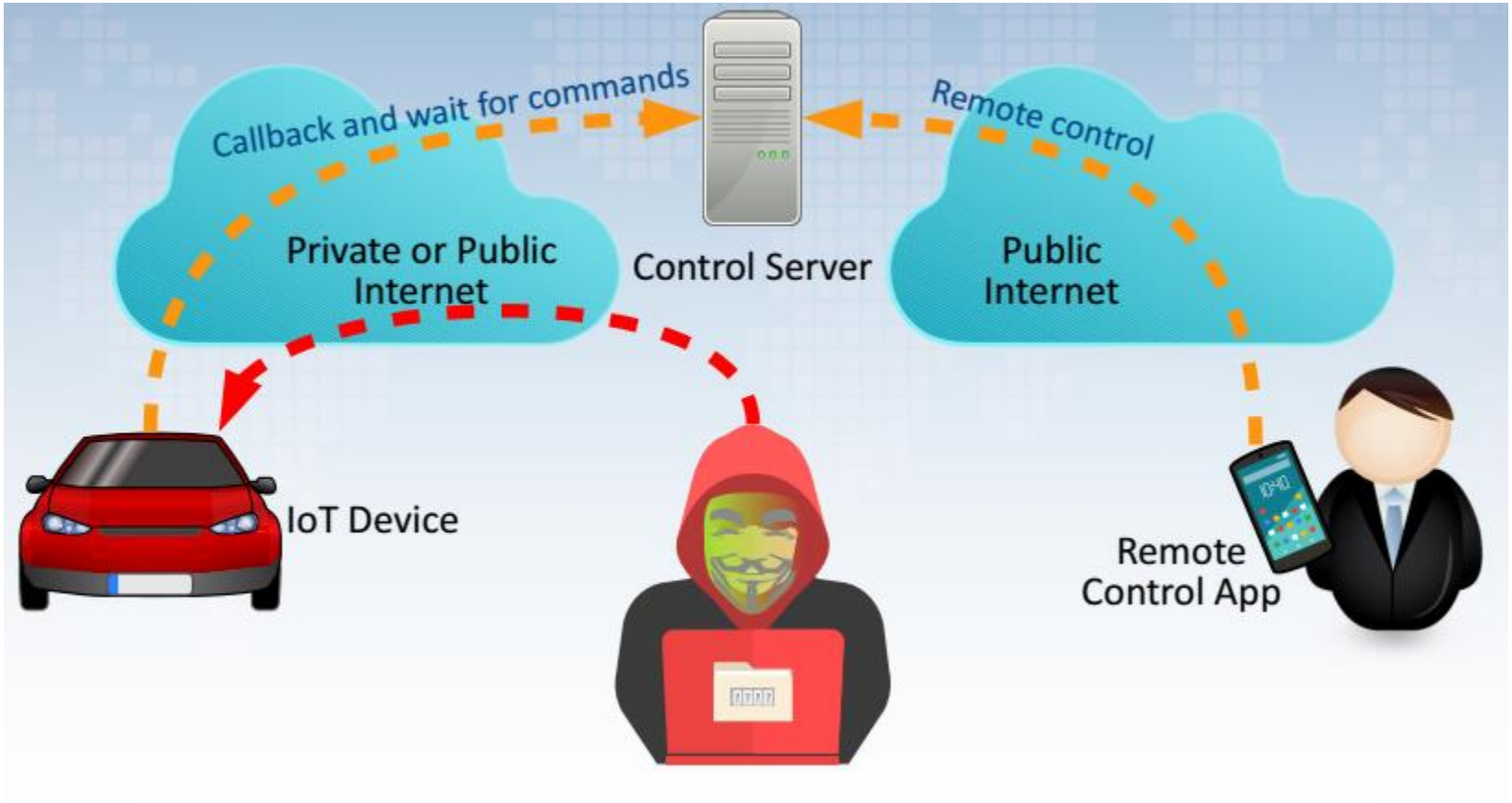
Types of Attacks on IoT Infrastructure

- Fake Control Server



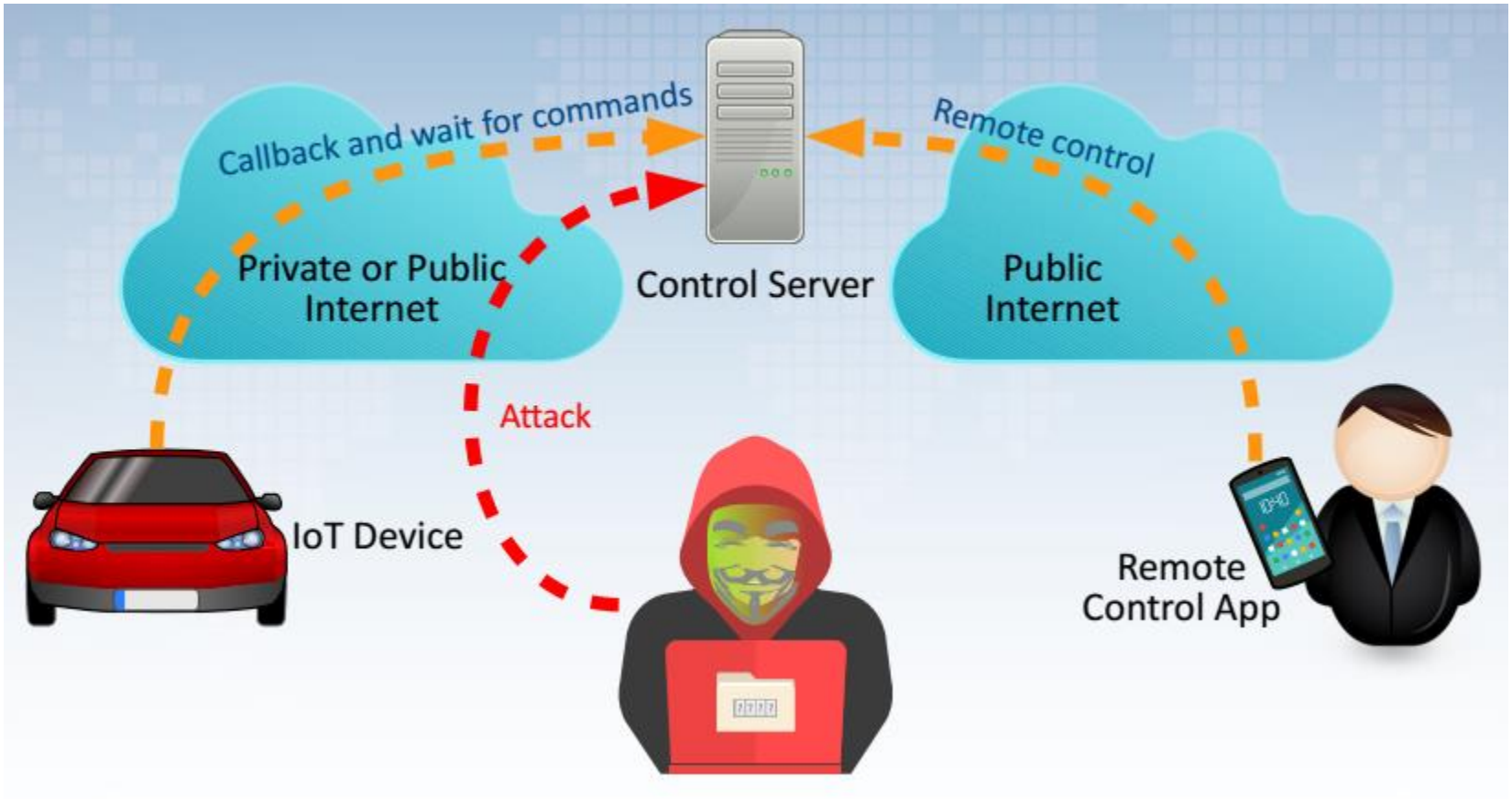
Types of Attacks on IoT Infrastructure

- Attack on device open ports



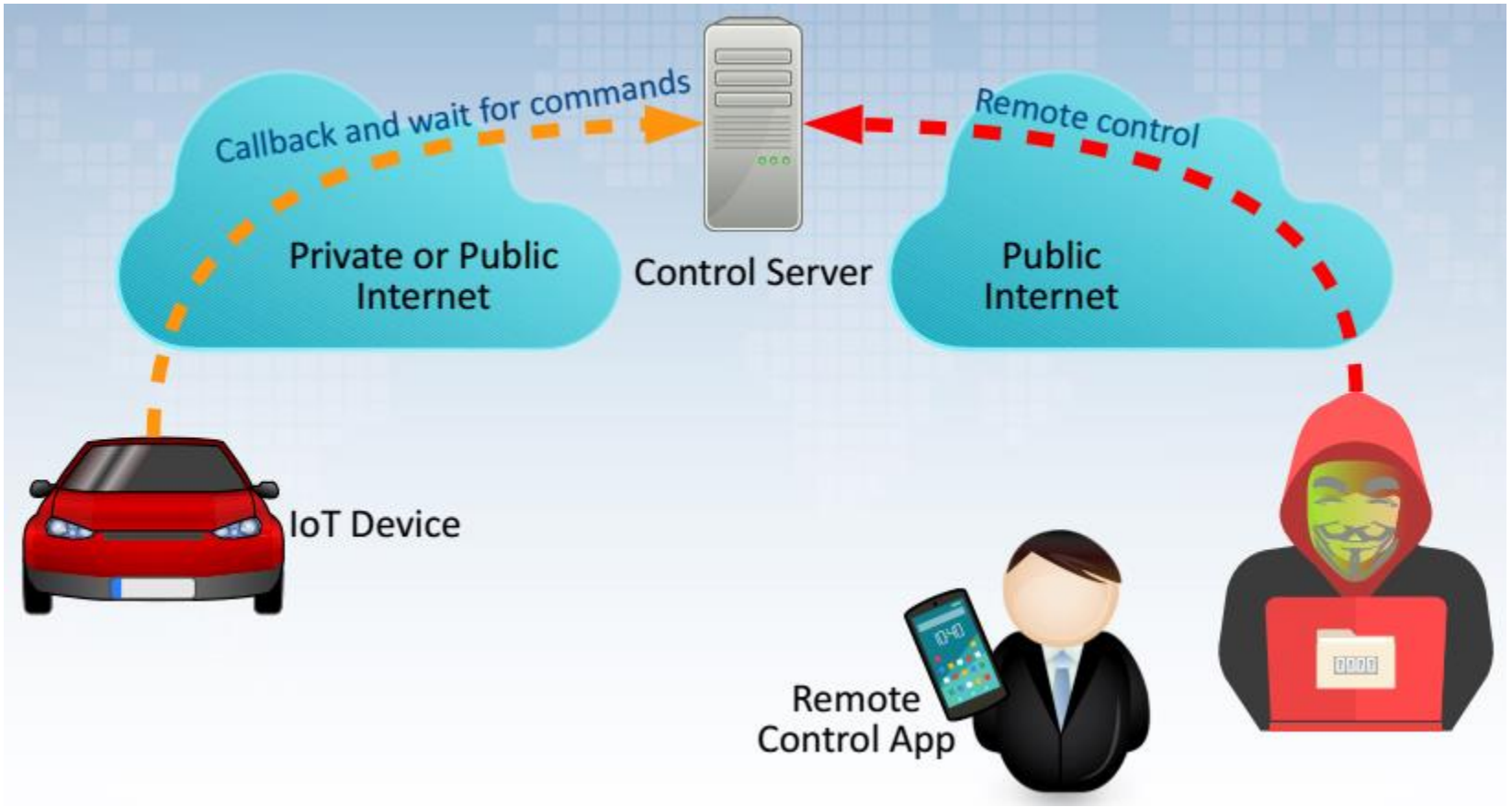
Types of Attacks on IoT Infrastructure

- Attack on server open ports



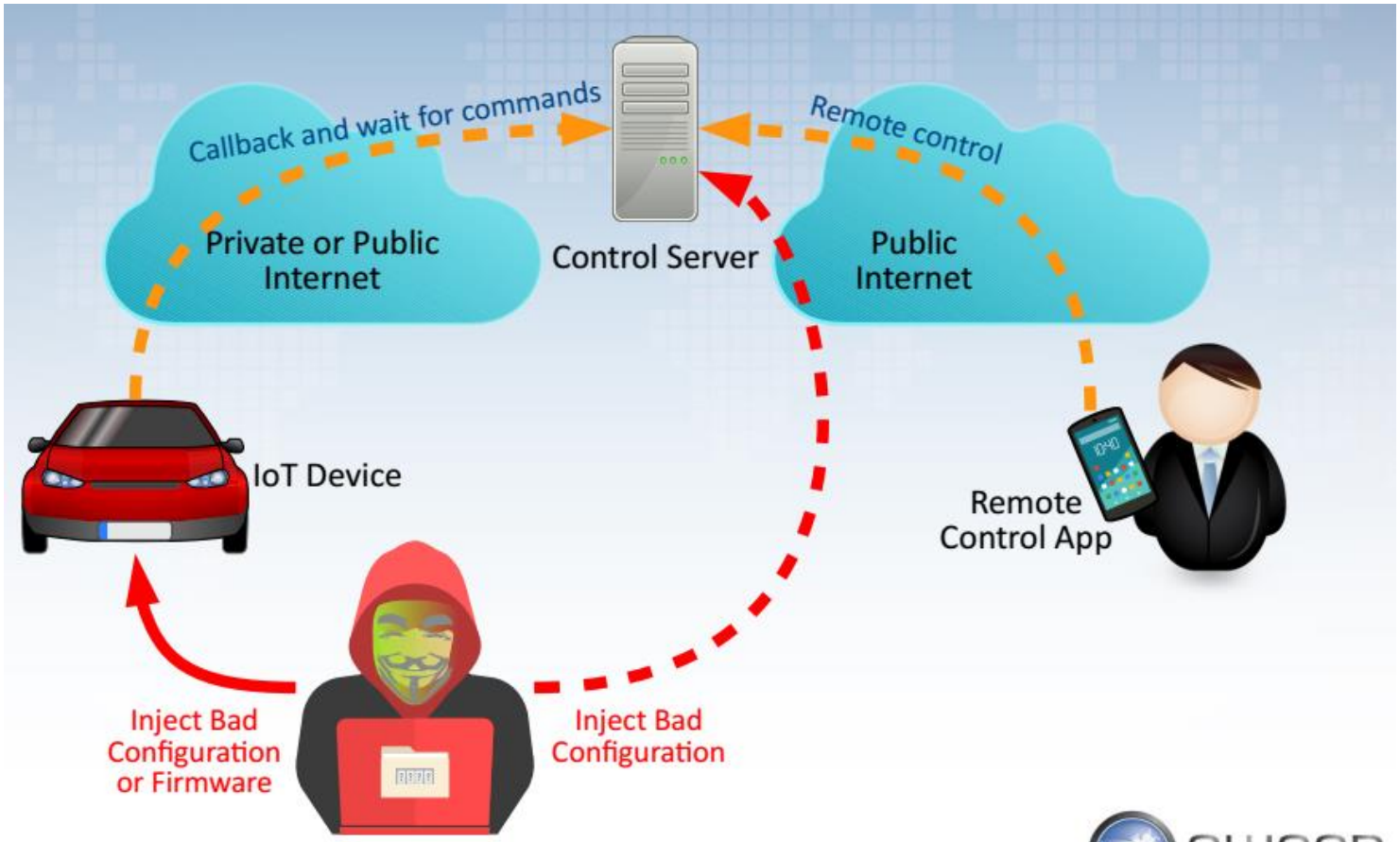
Types of Attacks on IoT Infrastructure

- Steal Credential



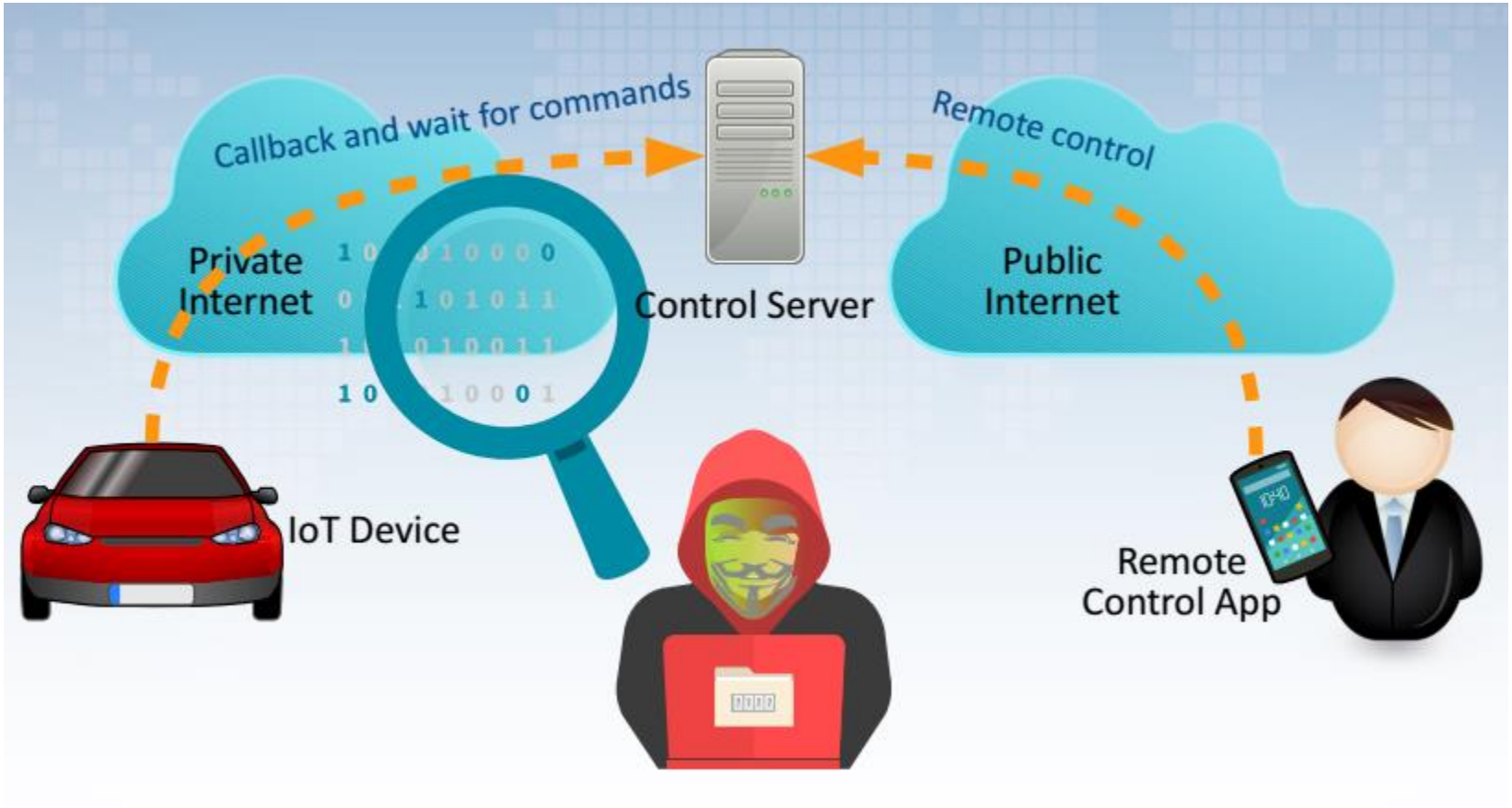
Types of Attacks on IoT Infrastructure

- Inject bad configuration or firmware



Types of Attacks on IoT Infrastructure

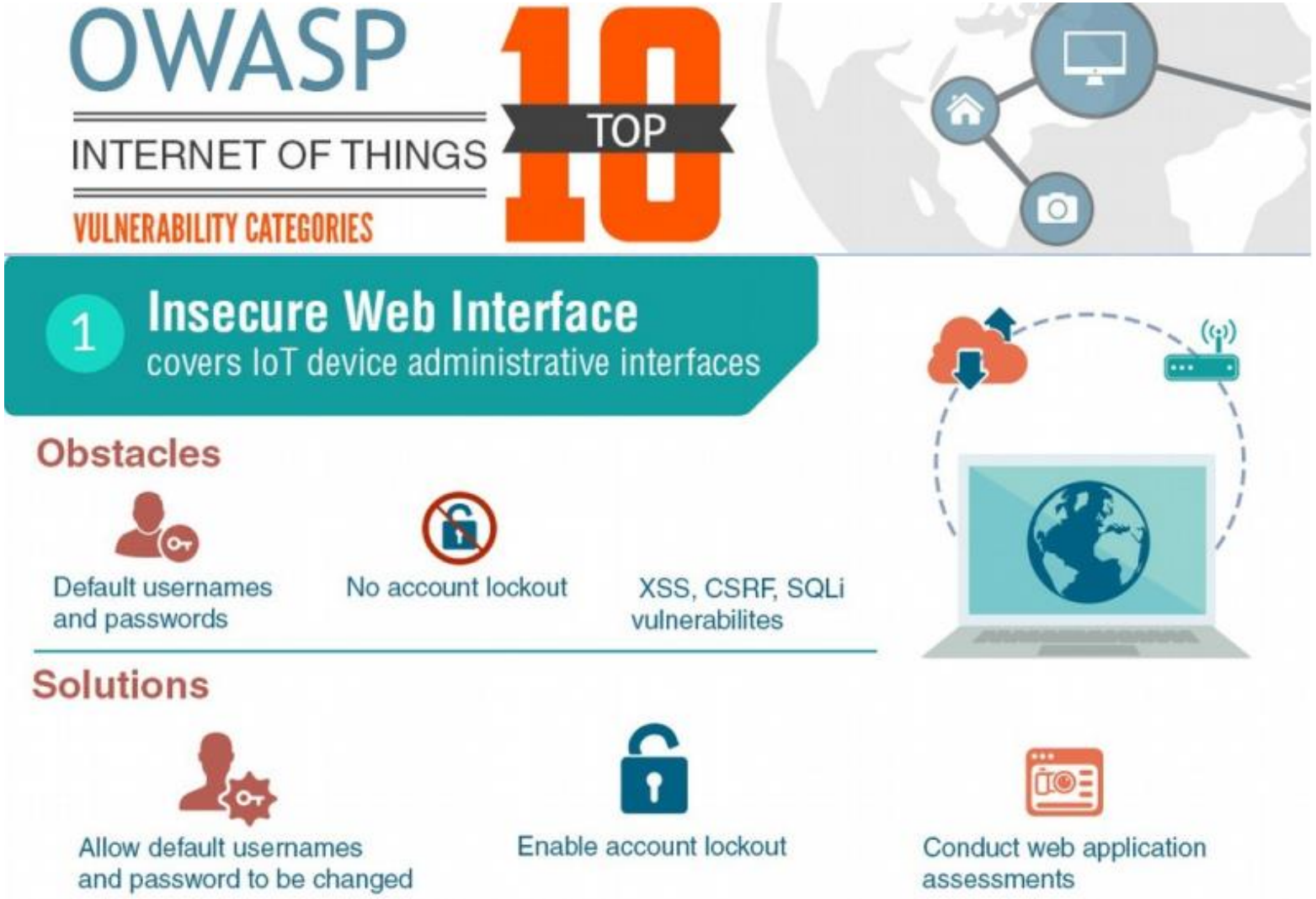
- Sniff data on private network



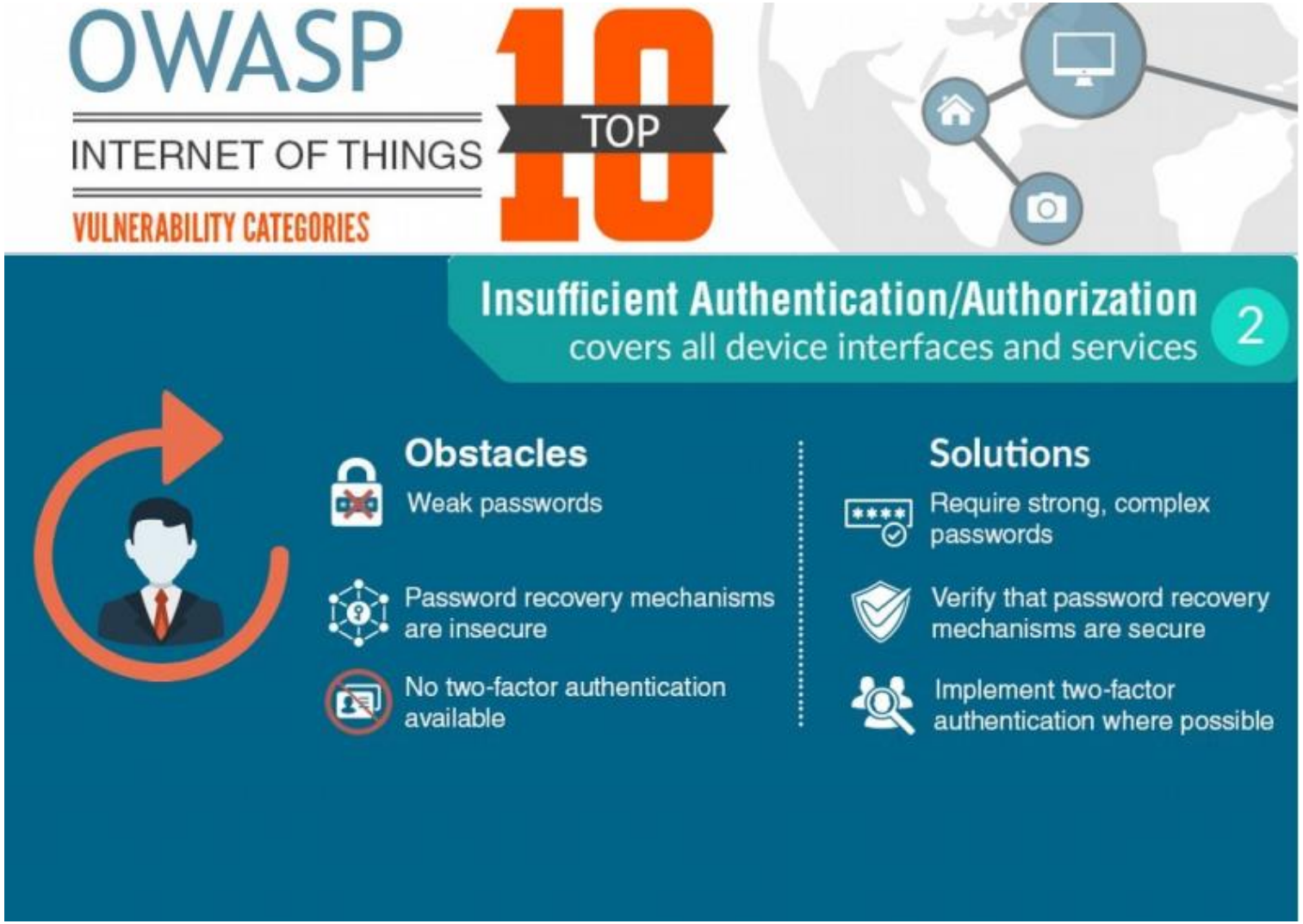
4.3. The Security Vulnerabilities of IoT

- I1. Insecure Web Interface
- I2. Insufficient Authentication
- I3. Insecure Network Services
- I4. Lack of Transport Encryption/Integrity Verification
- I5. Privacy Concerns
- I6. Insecure Cloud Interface
- I7. Insecure Mobile
- I8. Insufficient Security Configurability
- I9. Insecure Software/Firmware
- I10. Poor Physical Security

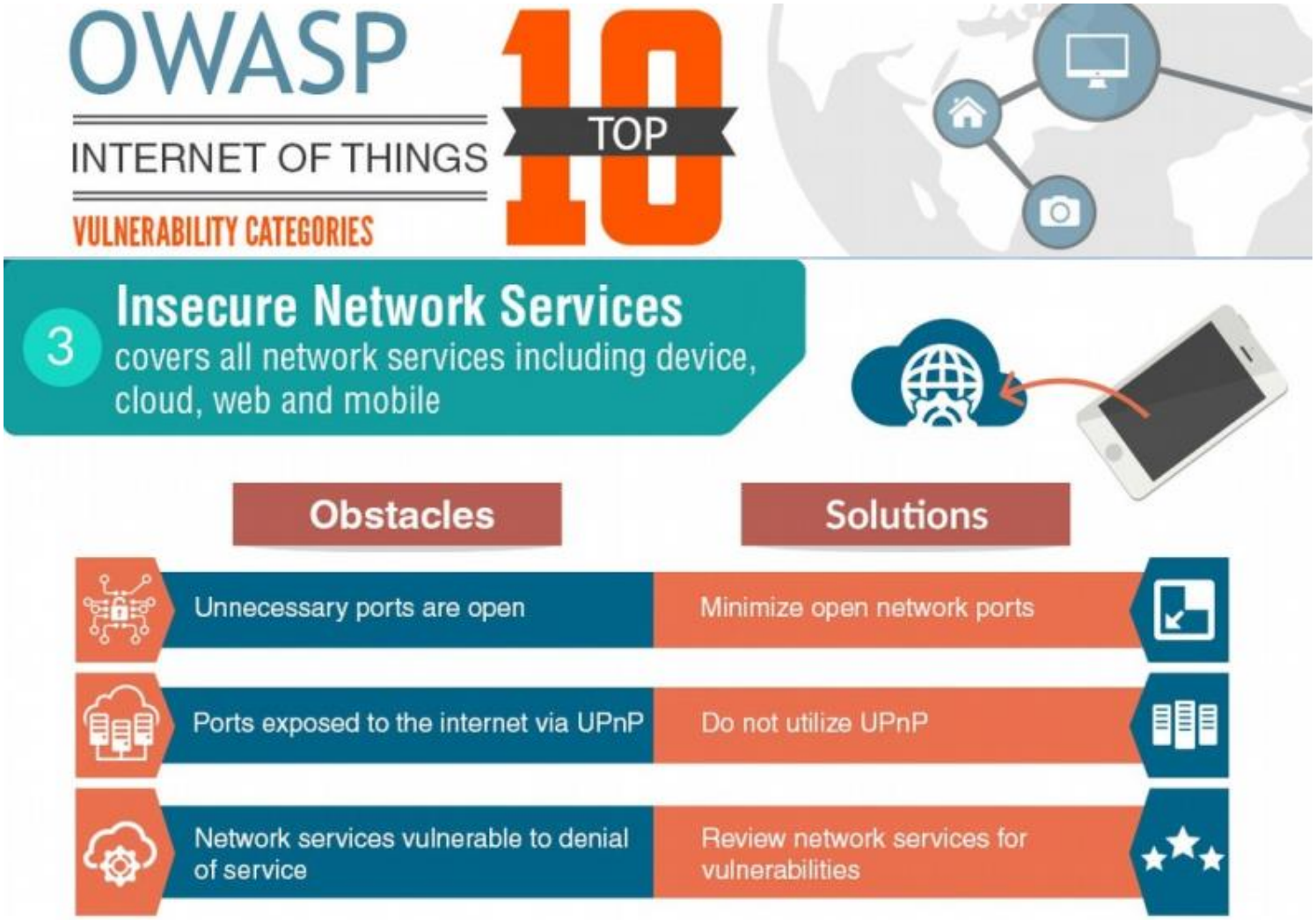
1. Insecure Web Interface



2. Insufficient Authentication/Authorization



3. Insecure Network Services



4. Lack of Transport Encryption/Integrity Verification

5. Privacy Concerns

OWASP TOP 10
INTERNET OF THINGS
VULNERABILITY CATEGORIES

5 Privacy Concerns
covers all components of IoT solution

Obstacles

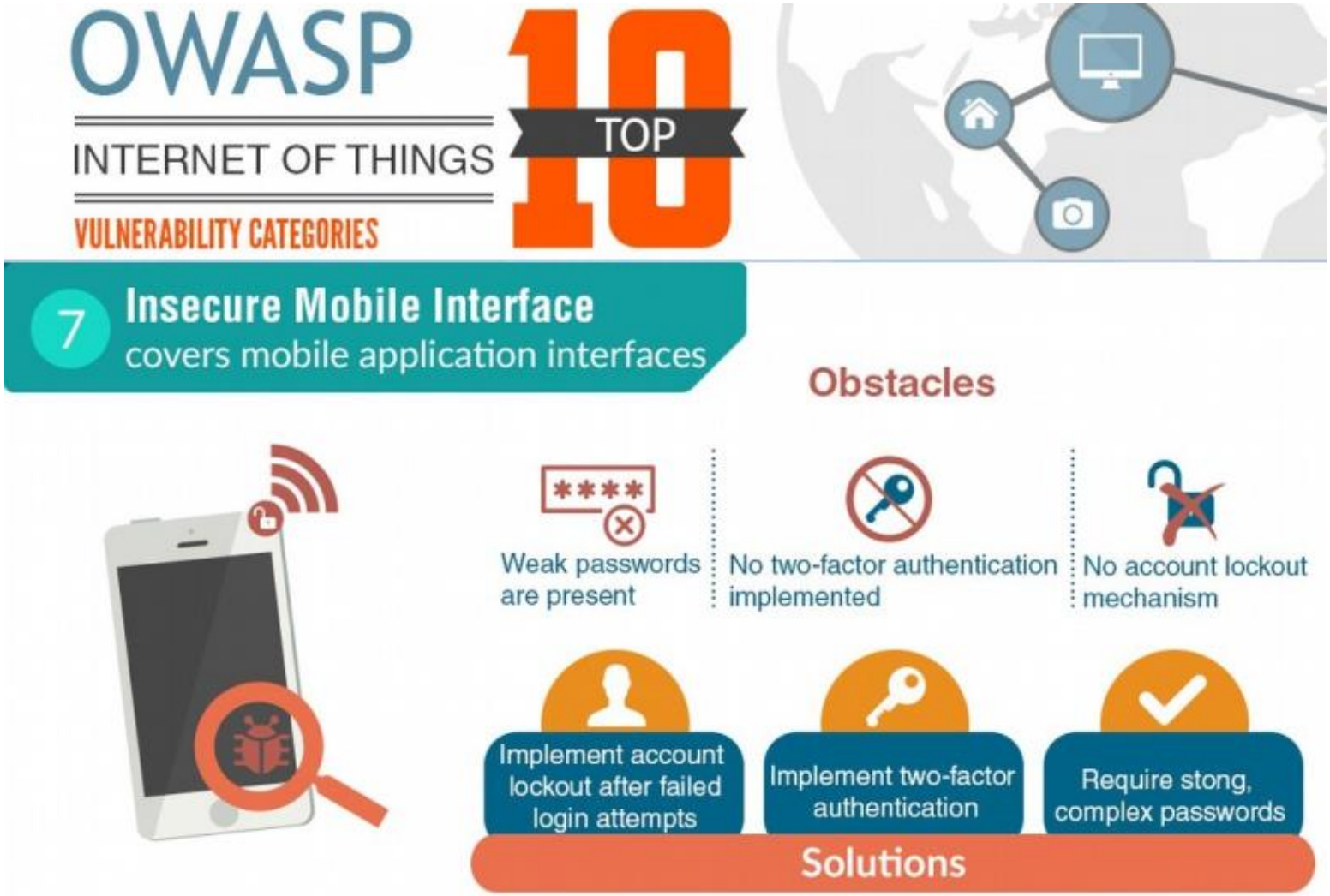
- Too much personal information is collected
- Collected information is not properly protected
- End user is not given a choice to allow collection of certain types of data

Solutions

- Minimize data collection
- Anonymize collected data
- Give end users the ability to decide what data is collected

6. Insecure Cloud Interface

7. Insecure Mobile Interface



8. Insufficient Security Configurability

9. Insecure Software/Firmware

10. Poor Physical Security

Content

- Chapter 1. Overview of IoT
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Chapter 5. Designing and Building IoT Systems

- Project-Based Learning:
  - Learning Based on Solving a Specific IoT Problem/Project
- Skills:
  - Finding the problems
  - System design and Analysis
  - Implementing, Programming
  - Presentation, Report
  - Teamwork

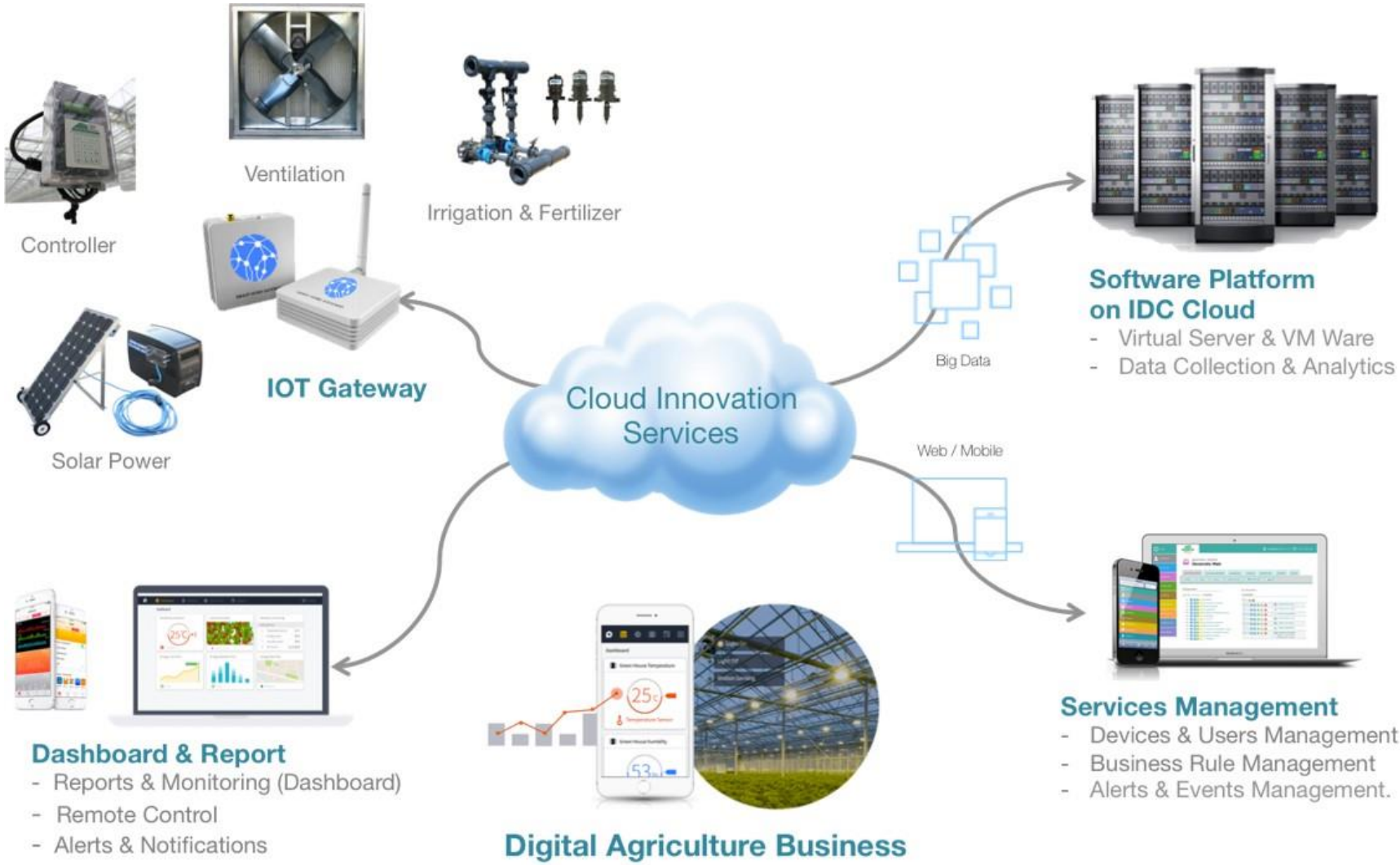
The process of conducting IoT project

- Form a team: 3-4 members
- Define the IoT application problem
- Analyze and design the IoT system:
  - Design the overall architecture of the system
  - Design the detailed components of the system
  - Select hardware devices: embedded computers, sensors
  - Choose IoT software/solution
- Build the system:
  - Program and deploy the system components
  - Apply IoT solutions, services, and technologies
- Presentation and report

Topics of IoT applications

- P1. Smart Agriculture:
  - IoT applications in Smart Agriculture

P1. Smart Agriculture



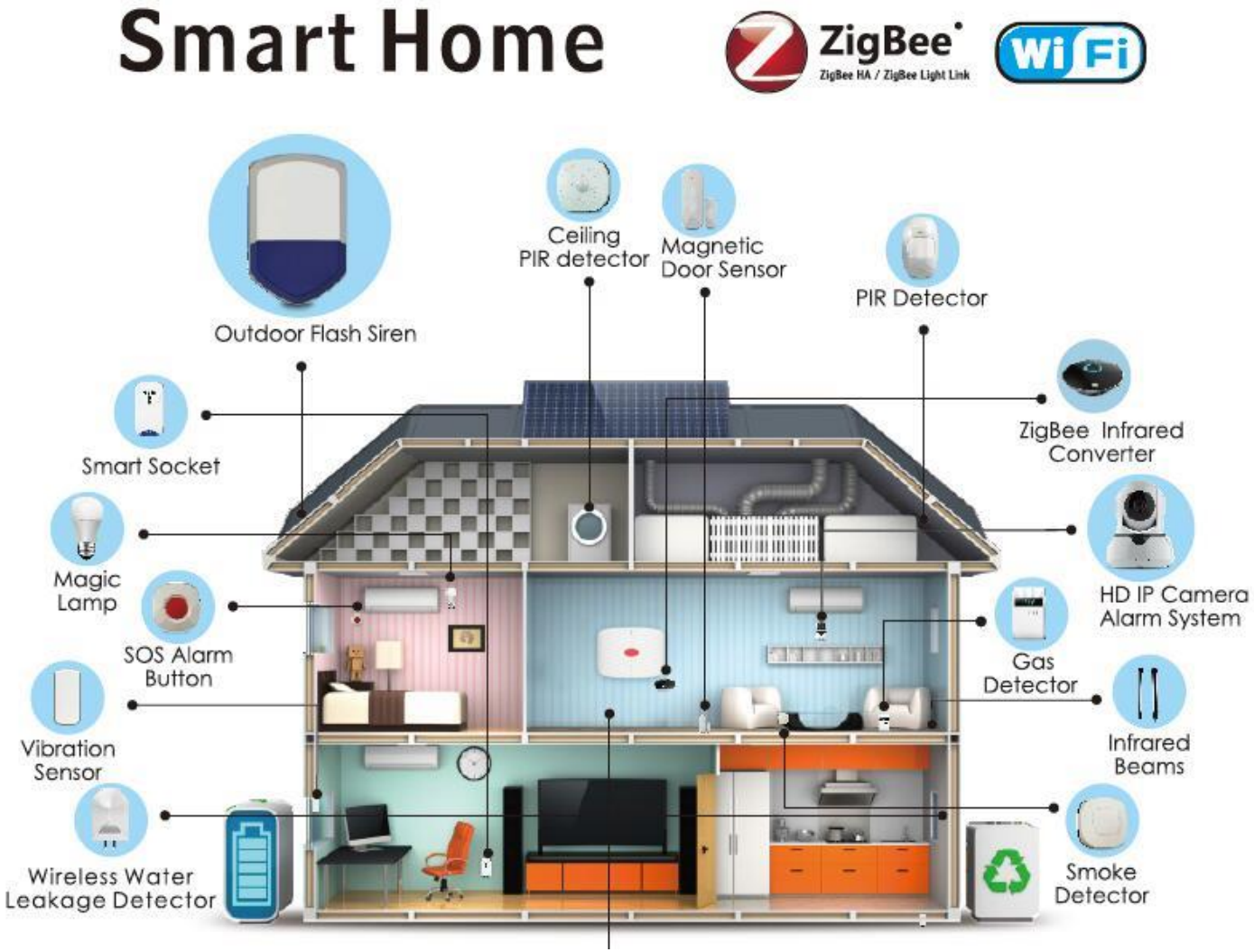
https://www.smartofthings.co.th/2018/08/27/smart-agriculture-solution/

P2. Smart Home

- IoT applications in smart home:
  - Remote Device Control (Mobile App)
  - Voice-Controlled (Google assistant)
  - Remote Monitoring

P2. Smart Home

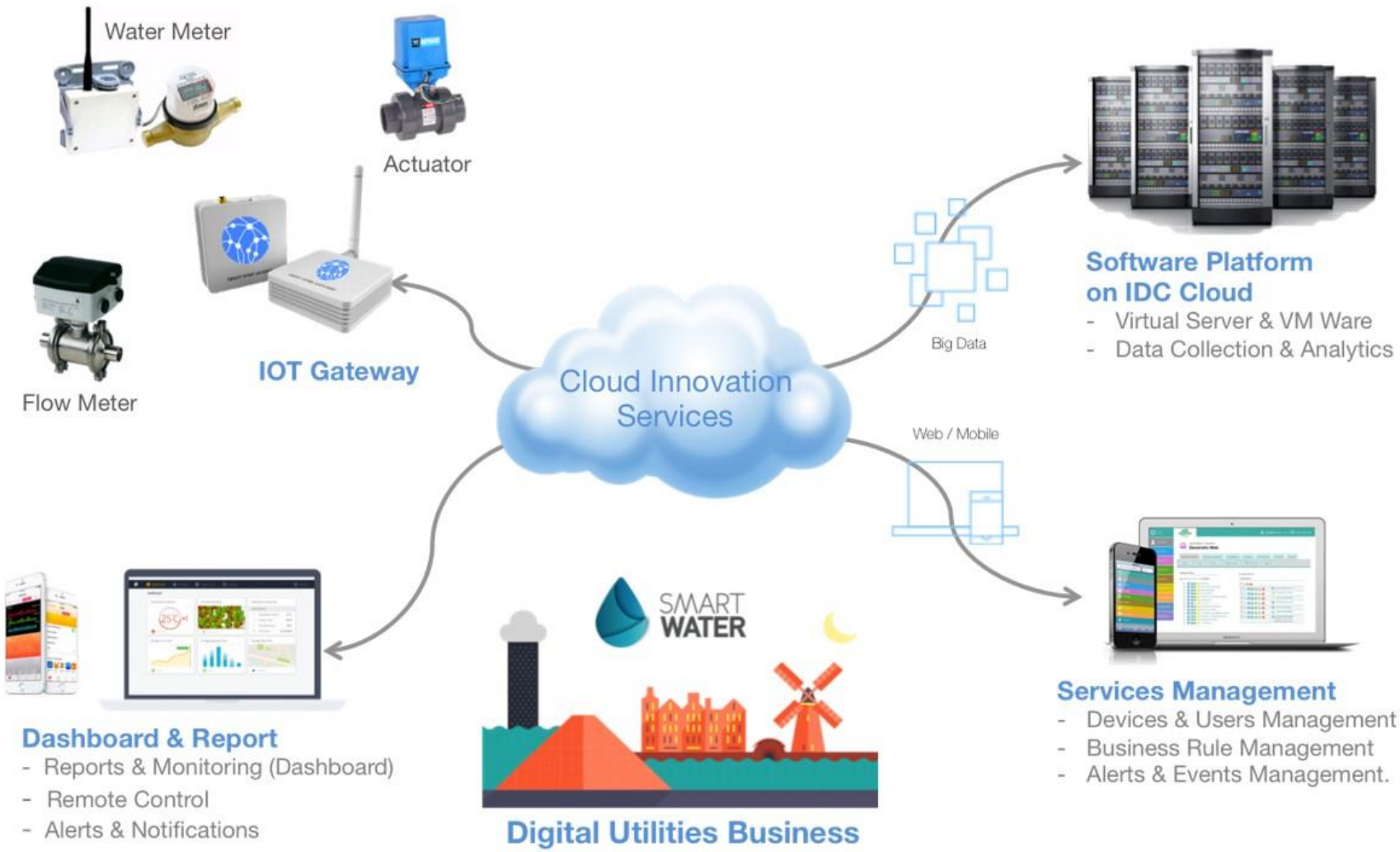
- Example:



Topic of IoT applications

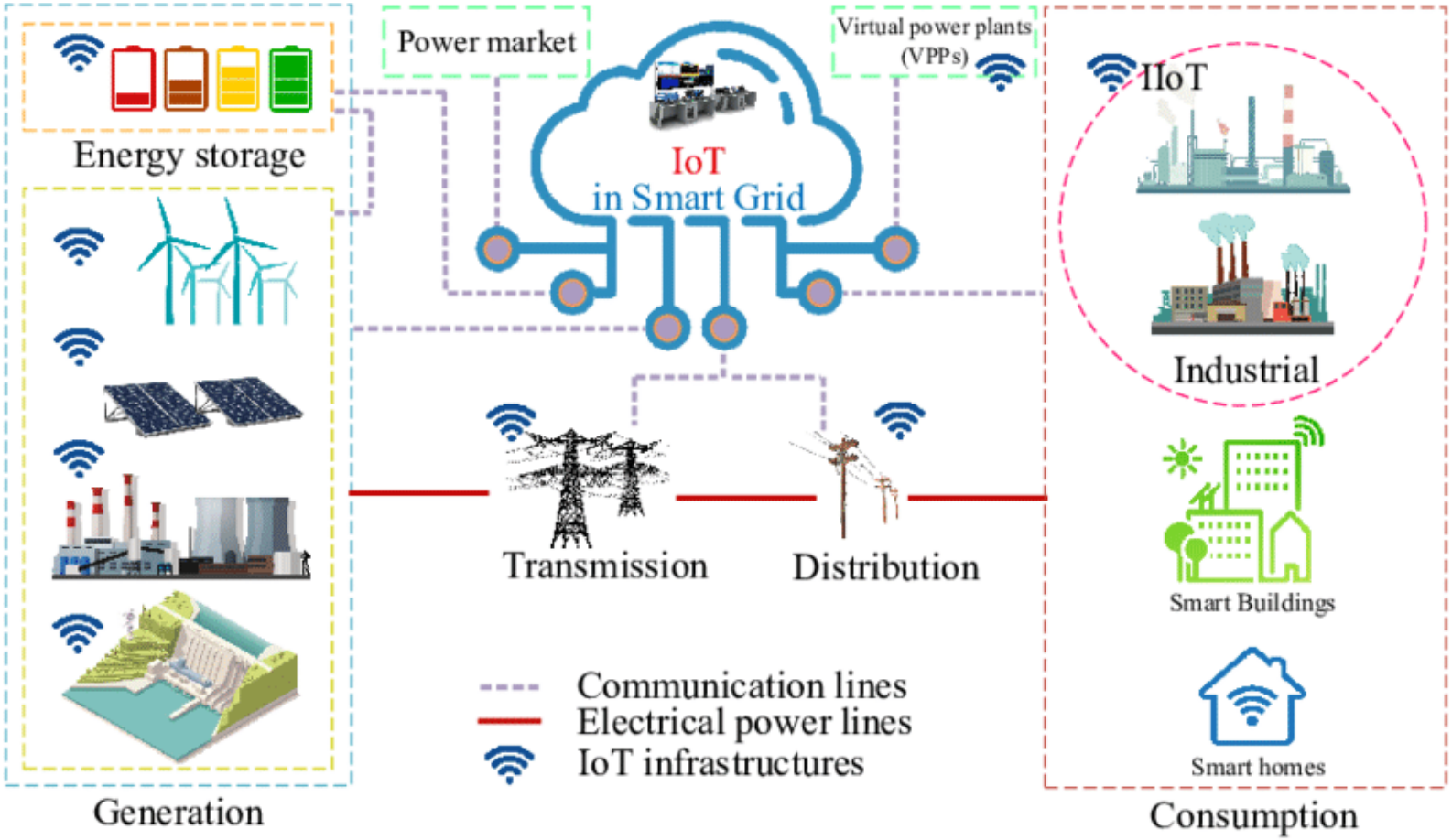
- P3. Smart Water Supply Monitoring:
  - IoT applications in smart water supply/monitoring
- P4. Smart Electrical Power Monitoring:
  - IoT Applications in Smart Power Distribution Monitoring

Smart Utitlies (Electrical power, Water)



https://www.smartofthings.co.th/2018/08/27/smart-utilities-solution/

IoT for Smart Grids



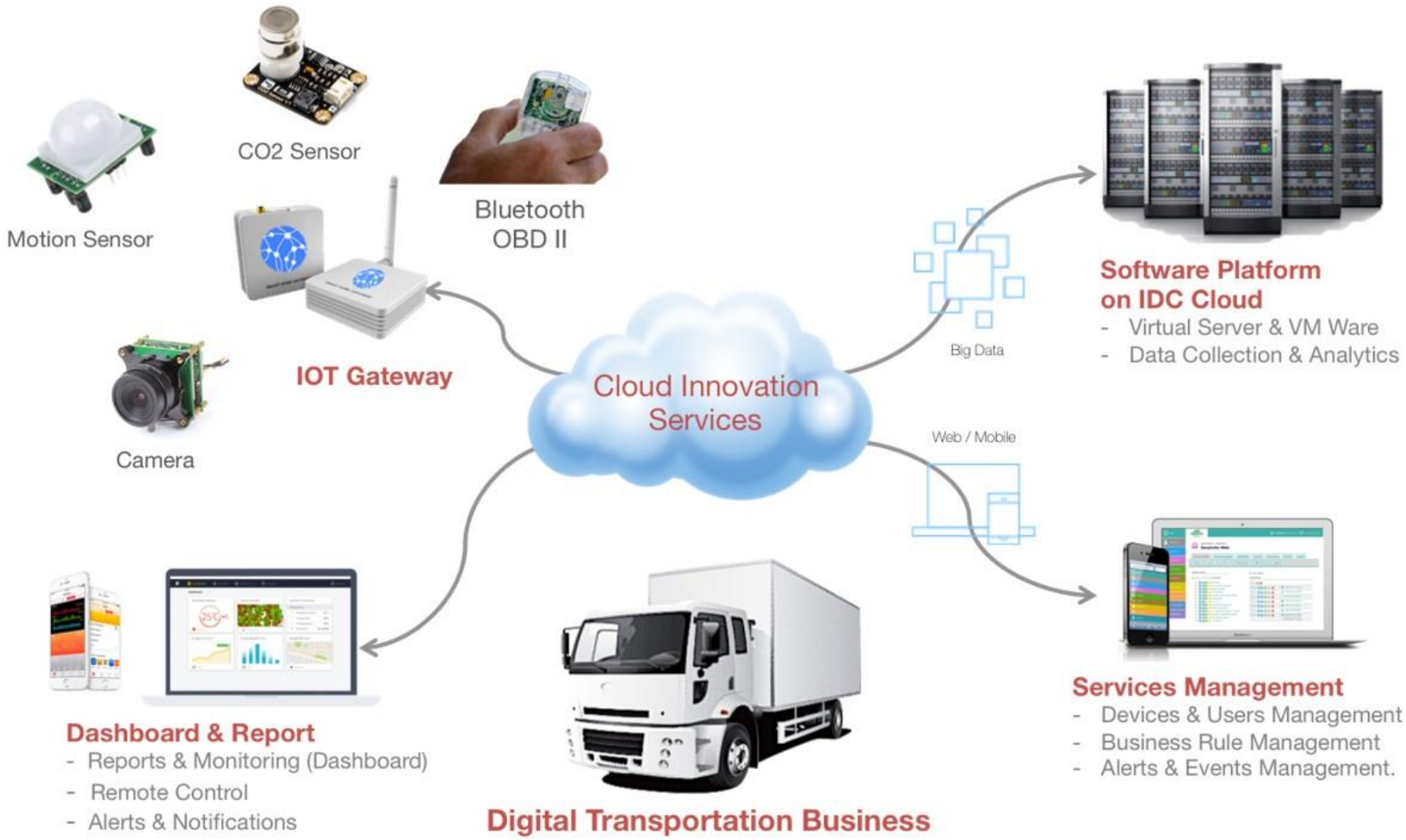
The paradigm of IoT in smart electrical grids

https://www.researchgate.net/publication/331103655_IoT_Architecture_for_Smart_Grids

Topics for IoT applications

- P5. Smart Transportation:
  - IoT Applications in Smart Transportation Monitoring

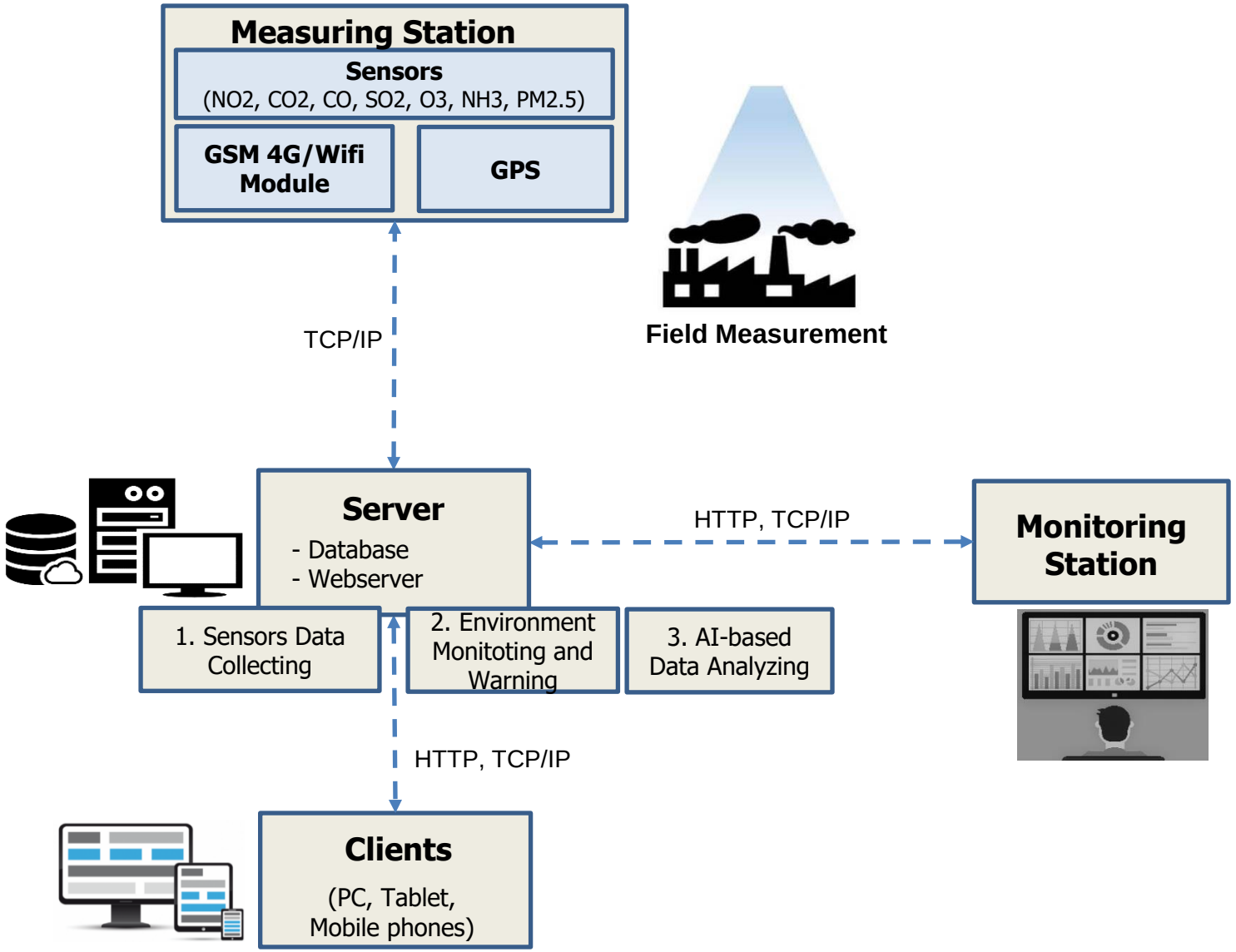
P5. Smart Transportation



Topics for IoT applications

- 6. Smart Air Quality Monitoring:
  - IoT Applications in Air Quality Monitoring

P6. Smart Air Quality Monitoring

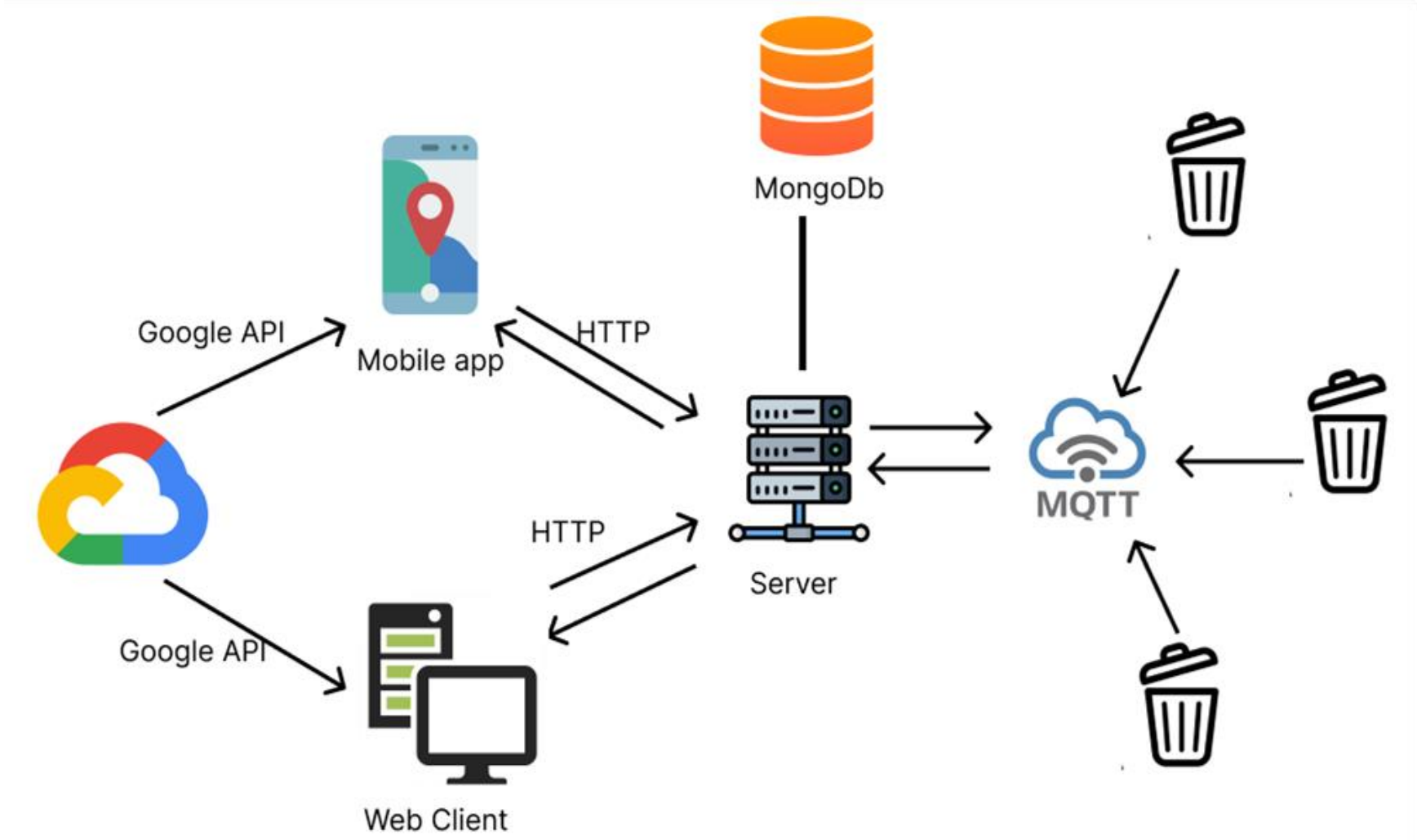


Topics for IoT applications

- 7. Smart Gabaging:
  - IoT Applications in Smart Waste Collection
  - Read: https://www.instructables.com/id/Smart-Garbage-Monitoring-System-Using-Internet-of-/
- 8. Smart Parking:
  - IoT Applications in Smart Parking
- 9. Smart Health Monitoring:
  - IoT Applications in Smart Health Monitoring10. S
- 10. Smart Robotic Warehouse:
  - IoT Applications in Smart Warehousing

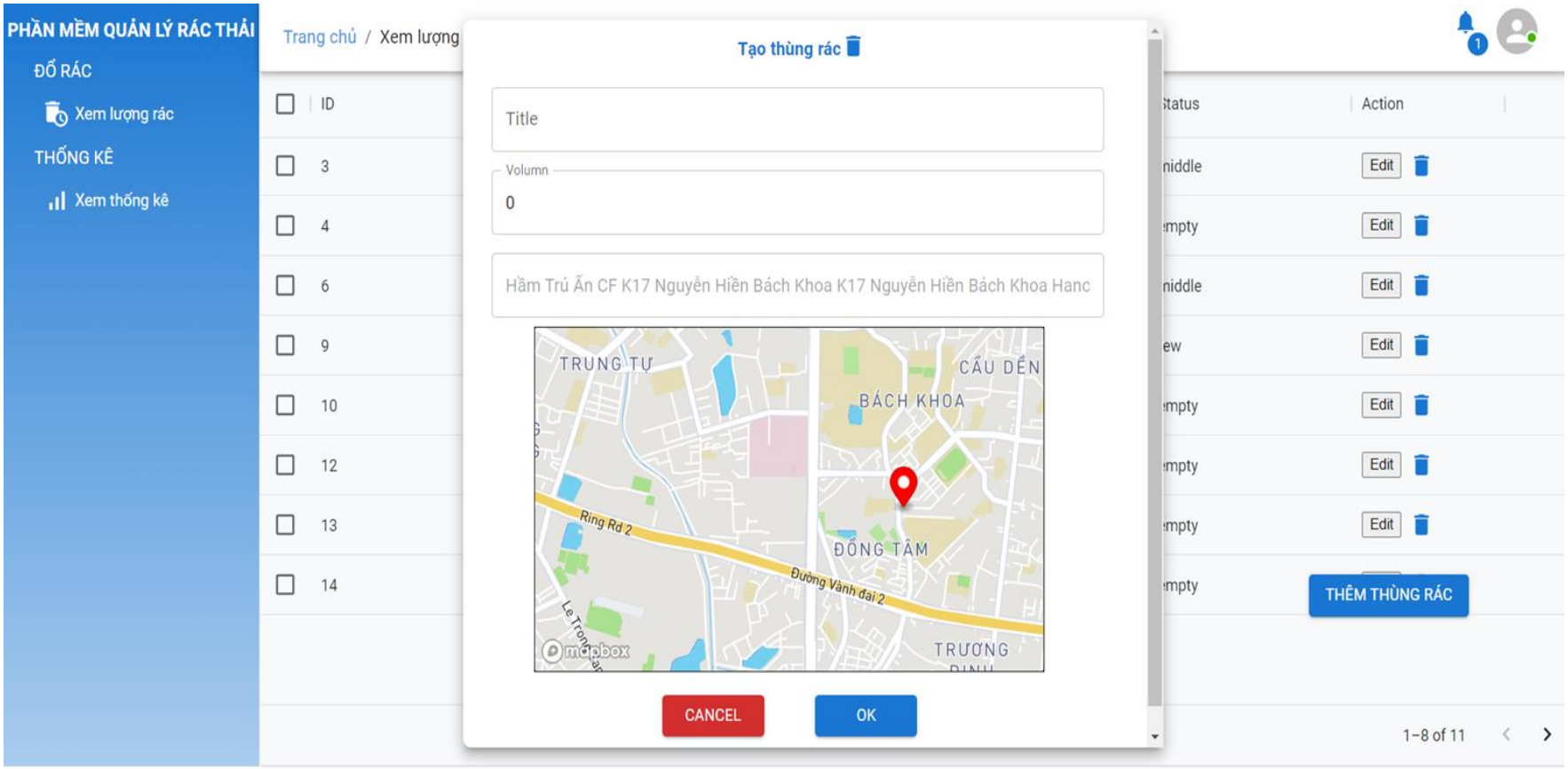
Project 1: Smart Gabage

- Overview



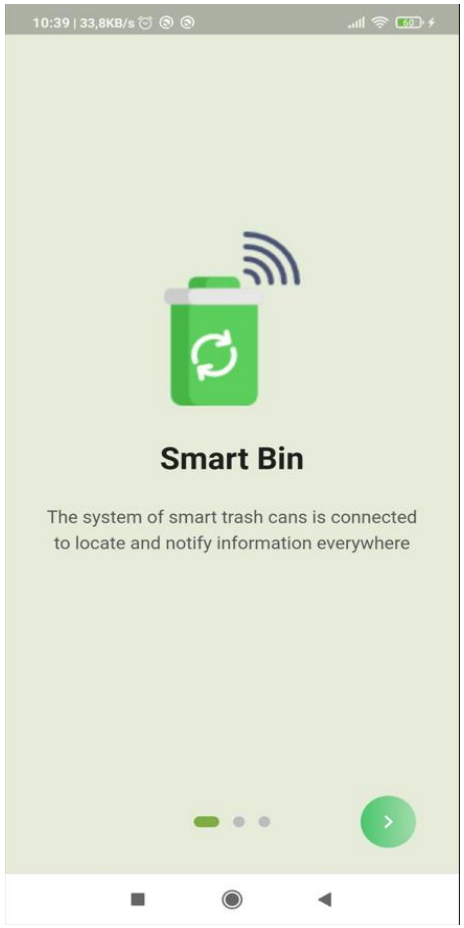
Project 1: Smart Gabage

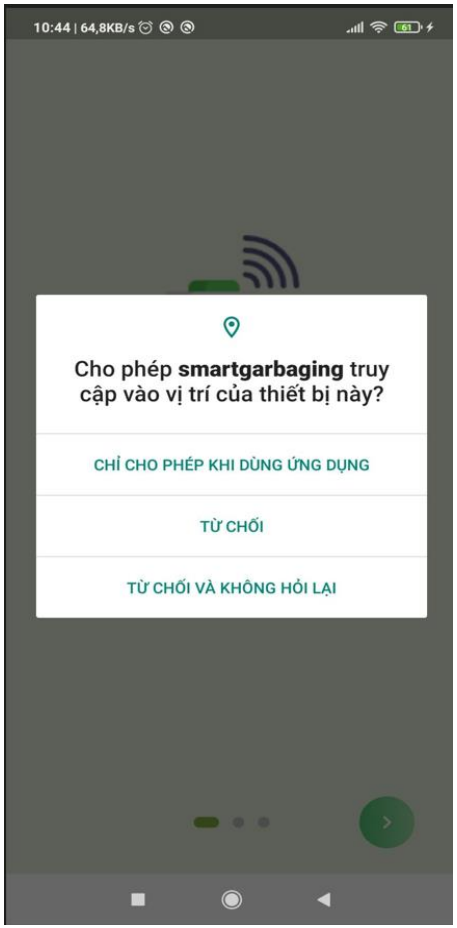
- Web App for Waste Bin Management: Add/Edit Bins

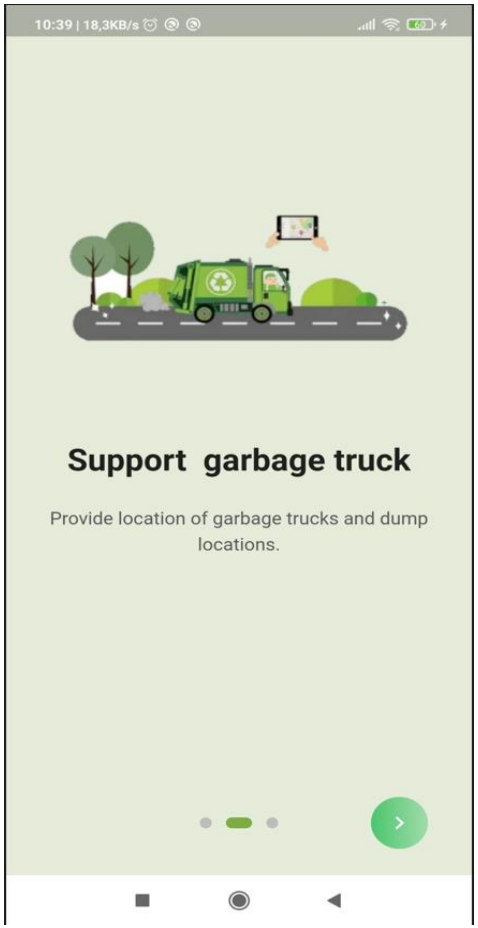


Project 1: Smart Gabage

- Mobile app

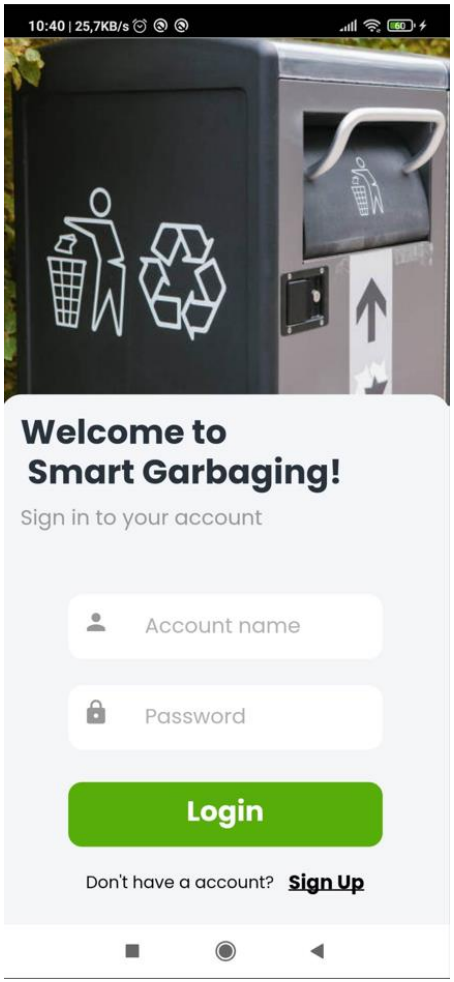


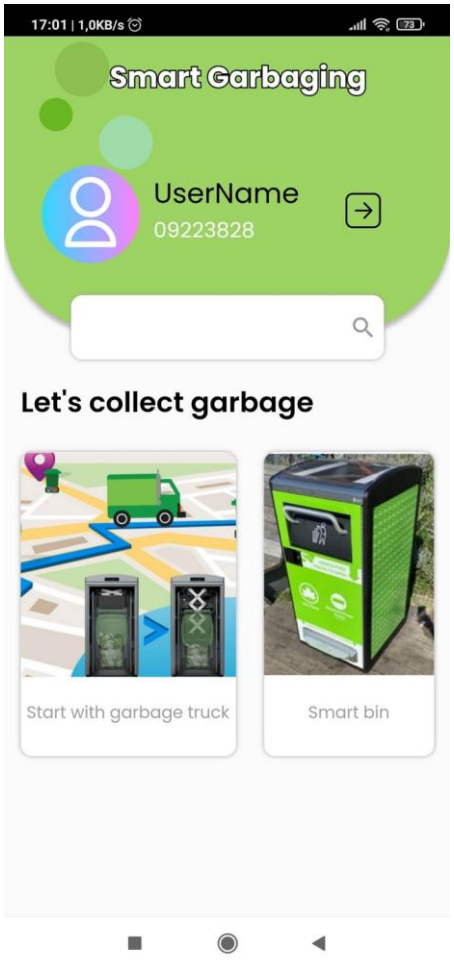


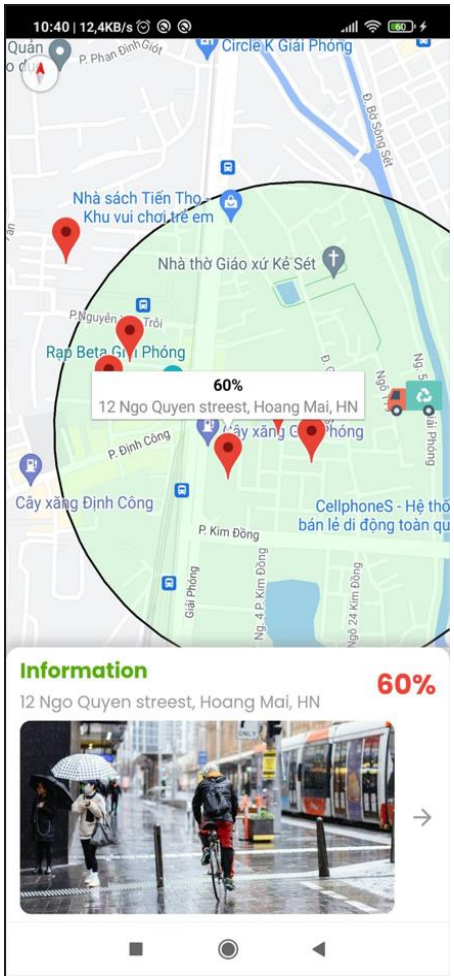


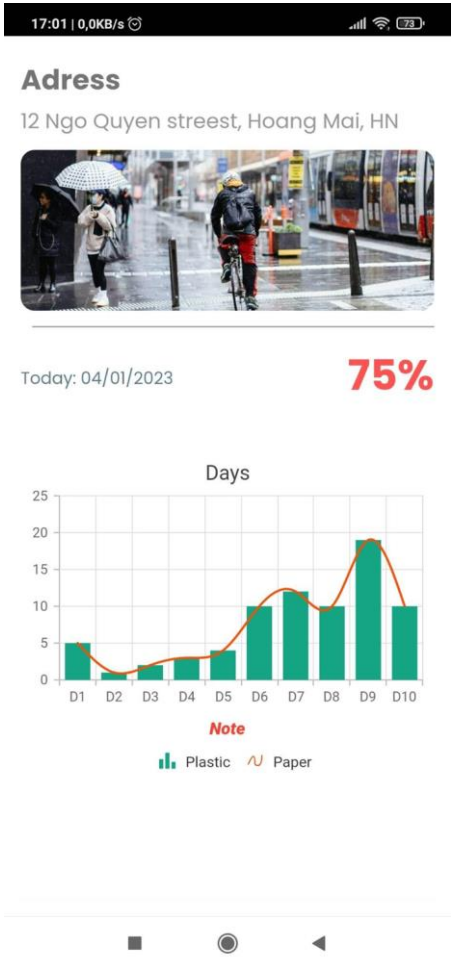
Project 1: Smart Gabage

- Mobile app



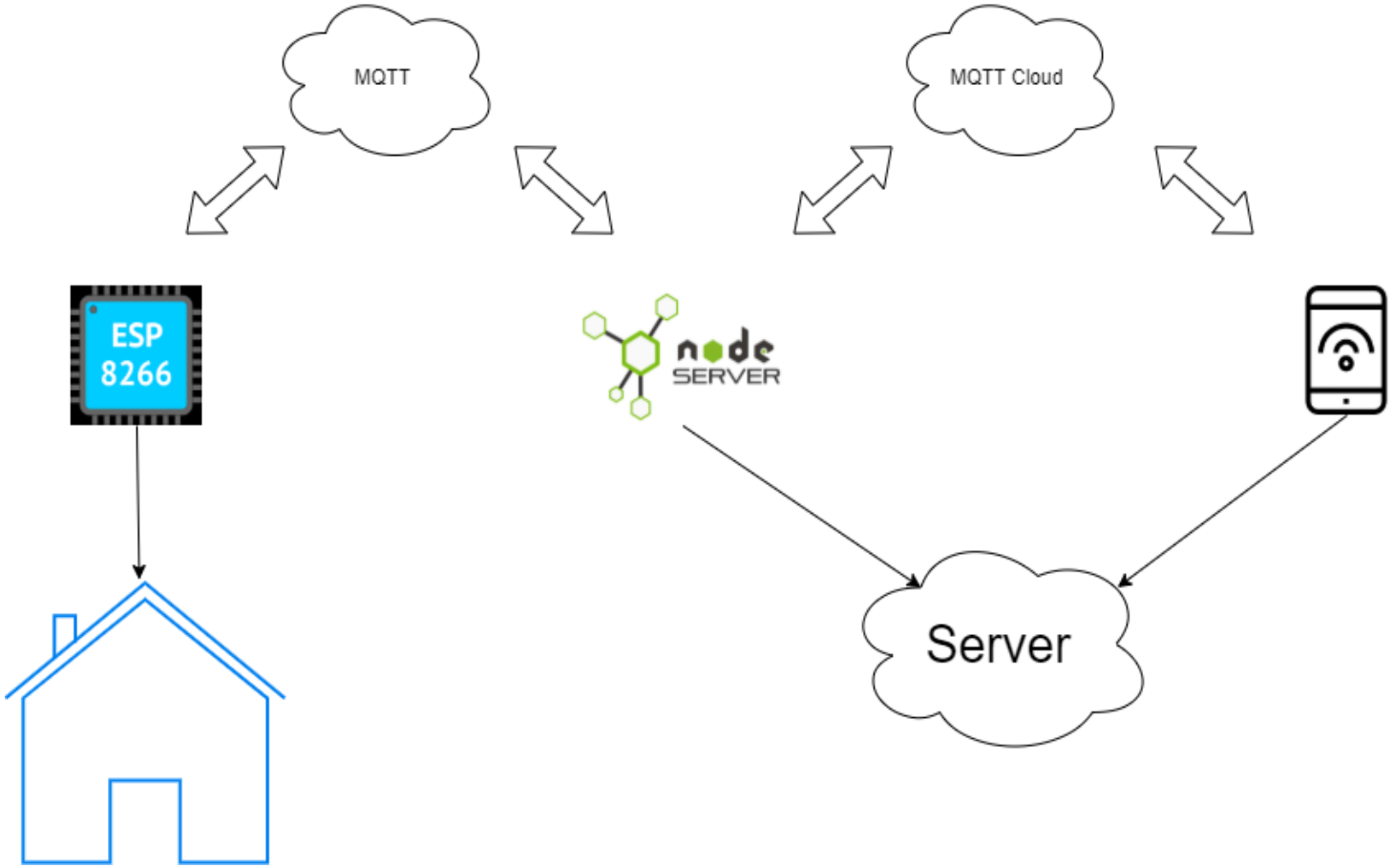






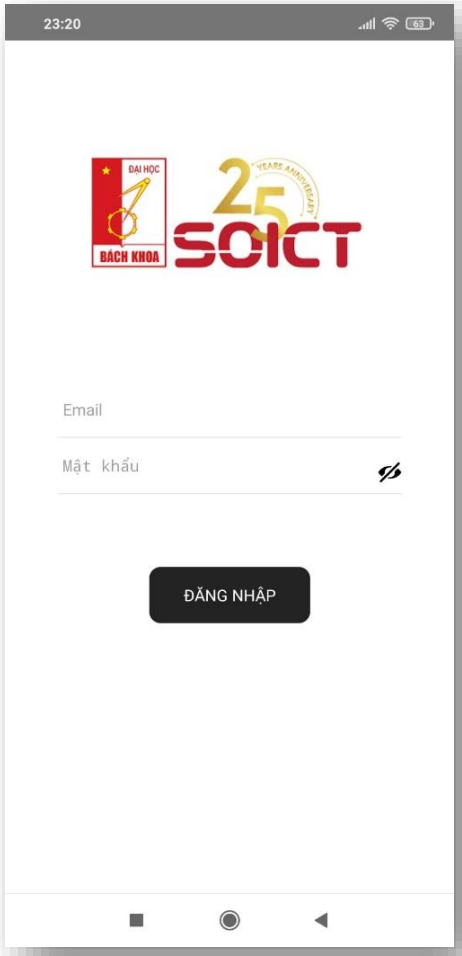
Project 2. Smart Home

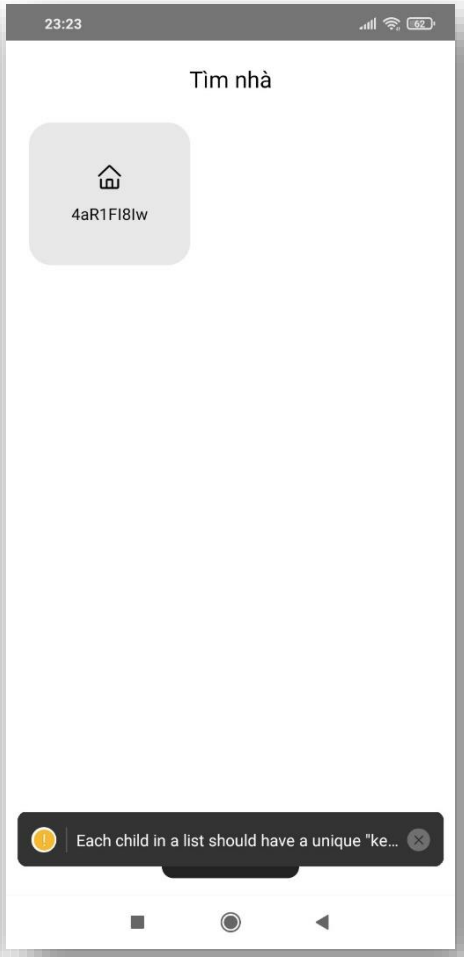
- Overview:



Project 2. Smart home

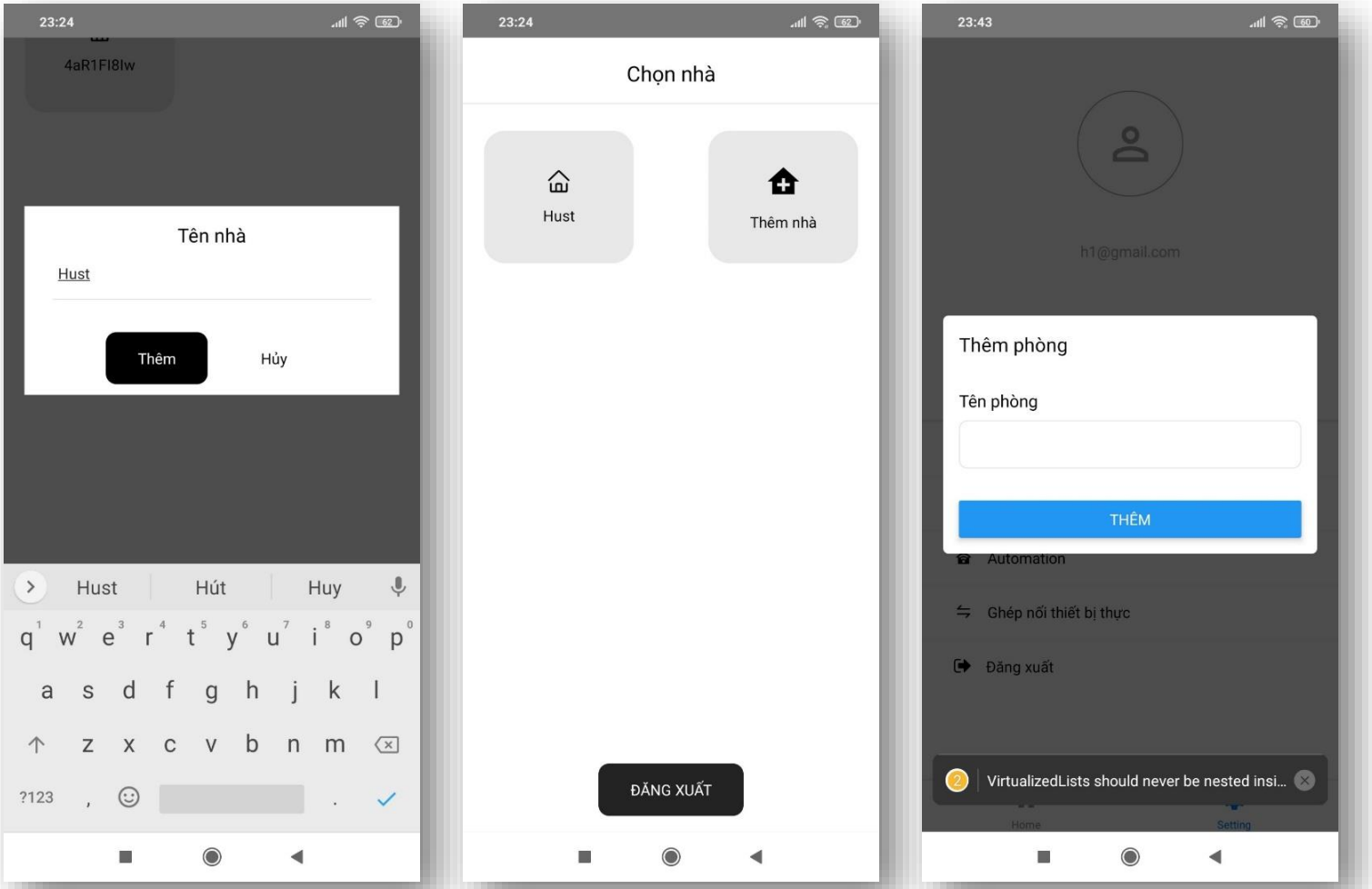
- Mobile app:
  - Home/Rooms Management (Add/Edit)





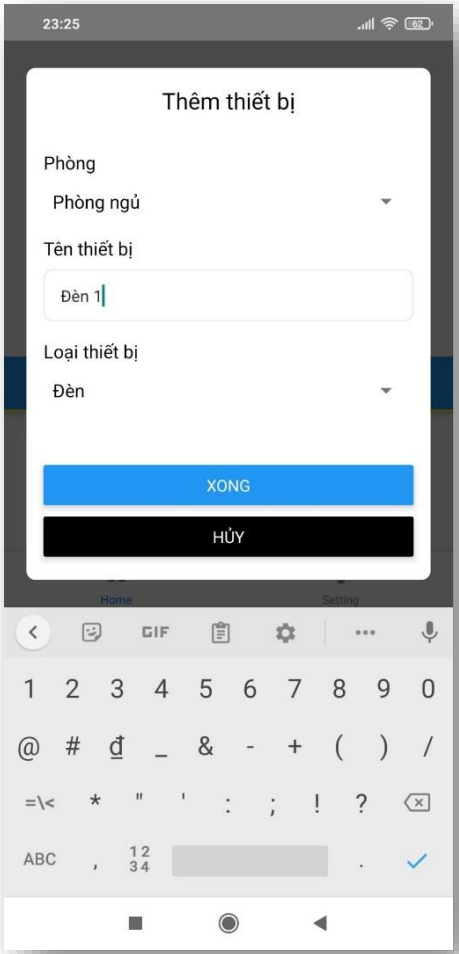
Project 2. Smart home

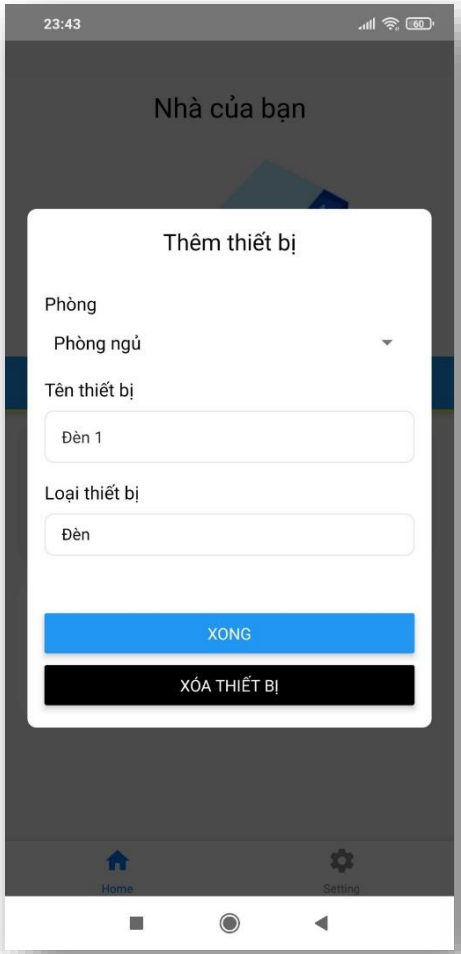
- Mobile app:
  - Home/Rooms Management (Add/Edit)

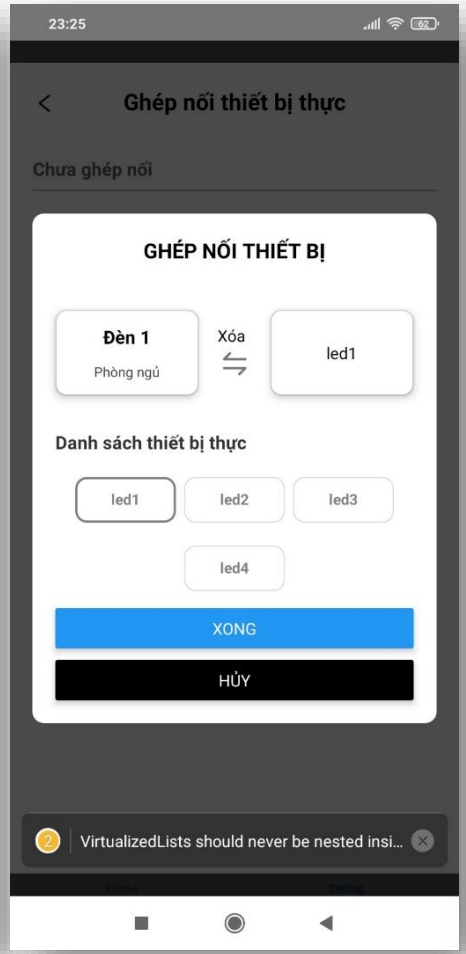


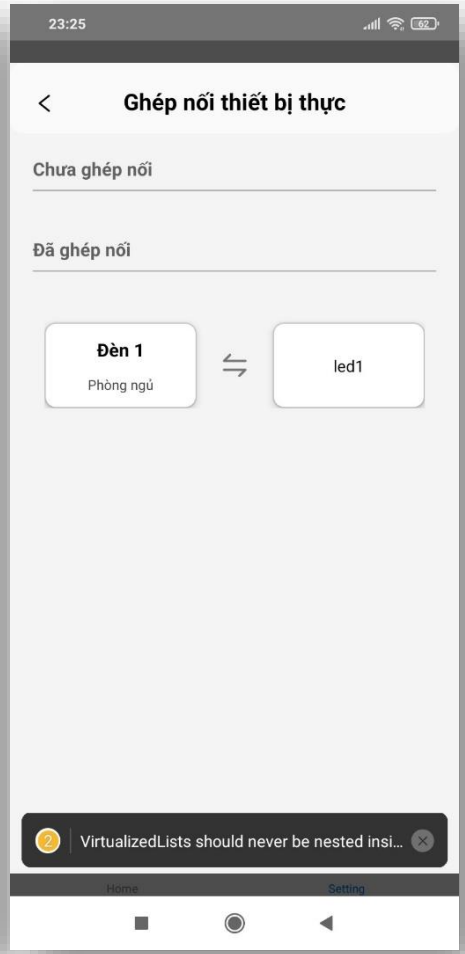
Project 2. Smart home

- Mobile app:
  - Add Device, Connect Physical Devices



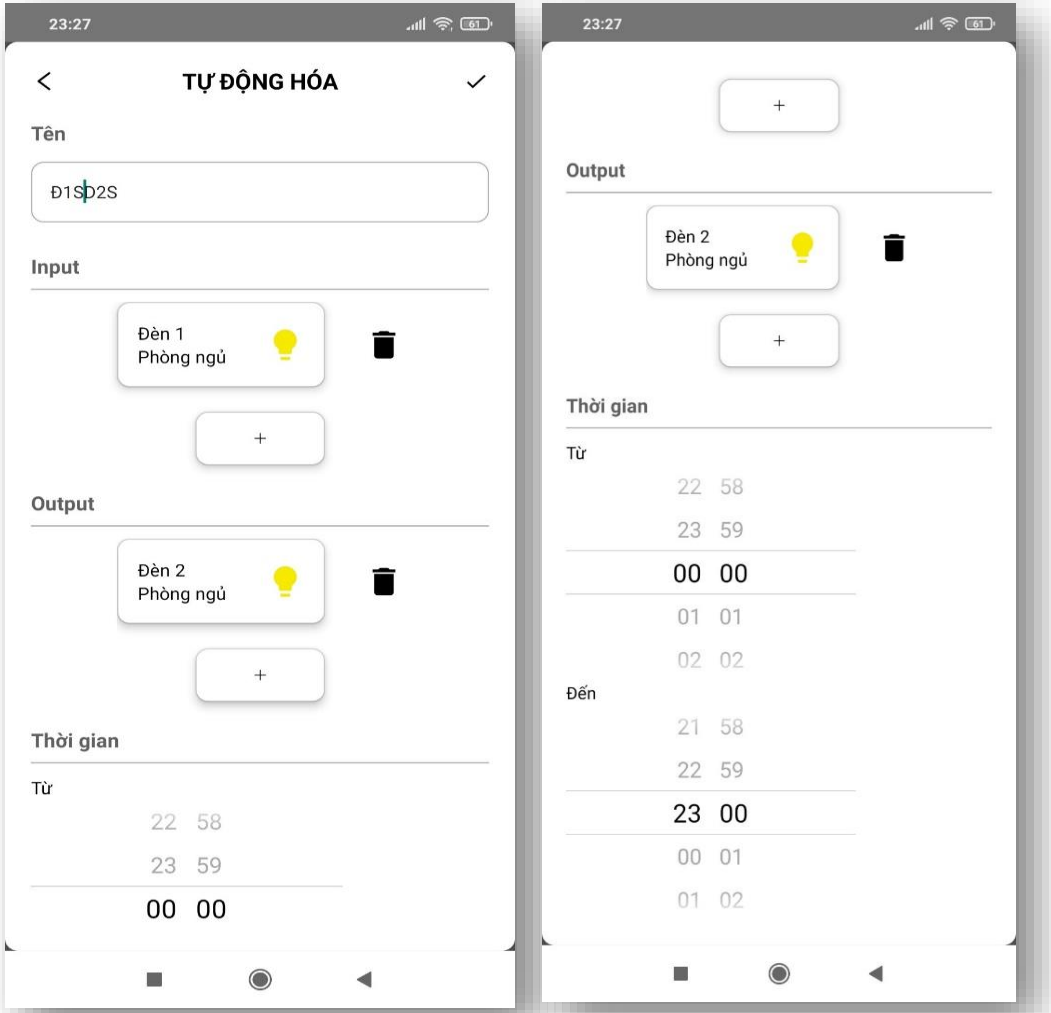






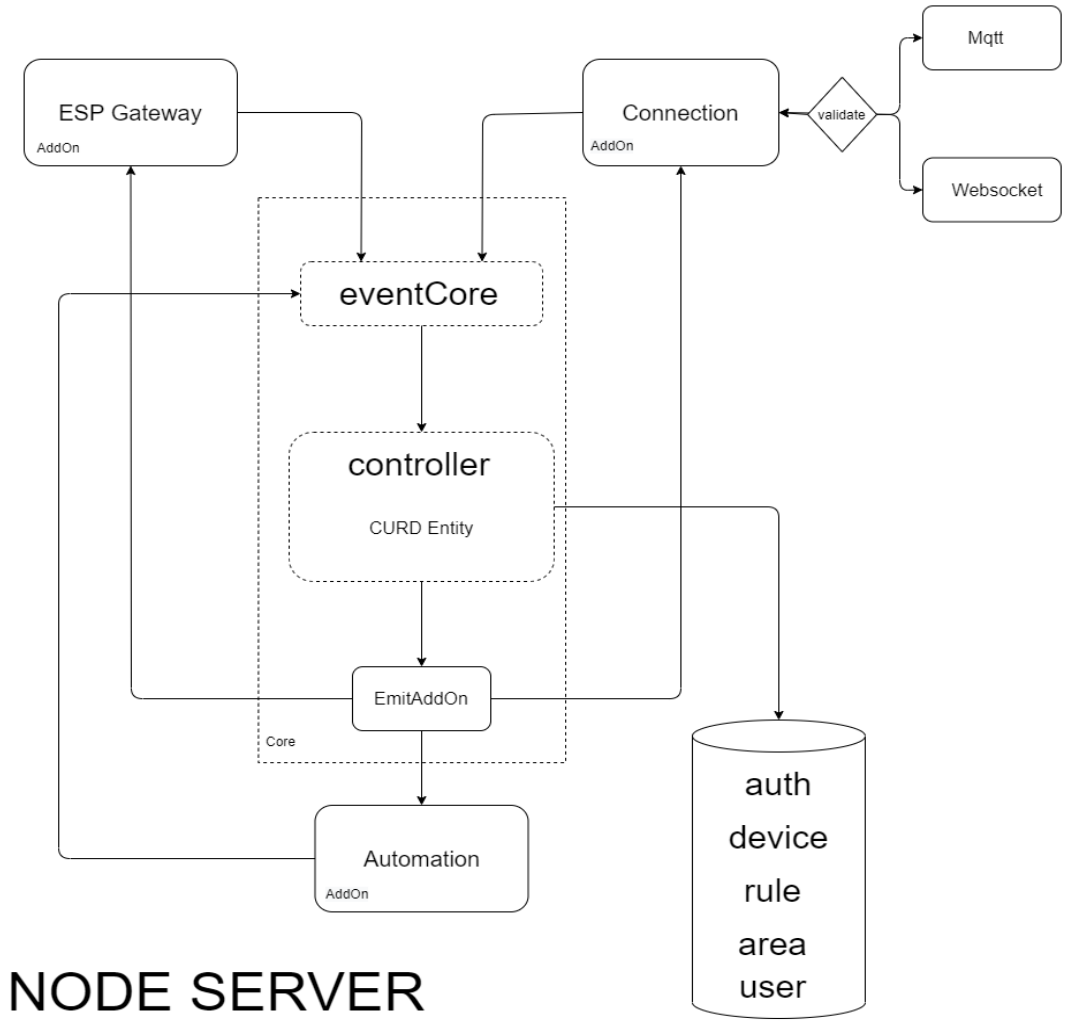
Project 2. Smart home

- Mobile app:
  - Automation



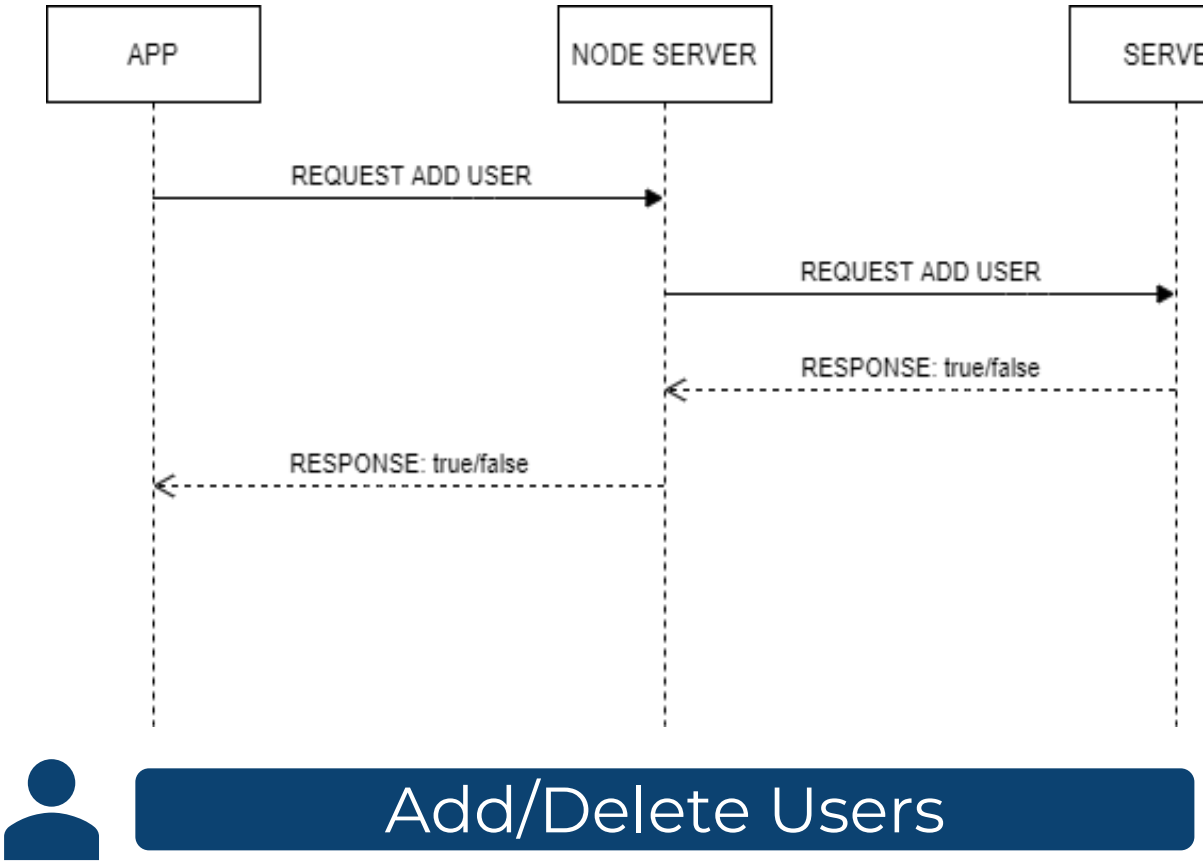
Project 2. Smart home

- Server design:



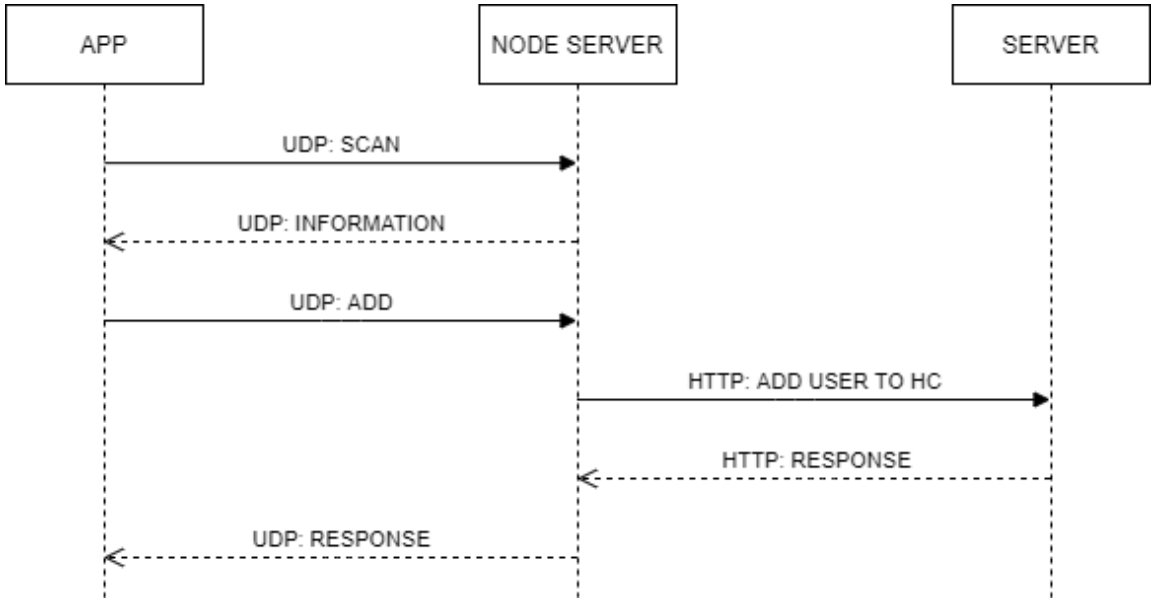
Project 2. Smart home

- Server design:
  - User Management Workflow for Adding/Removing Users



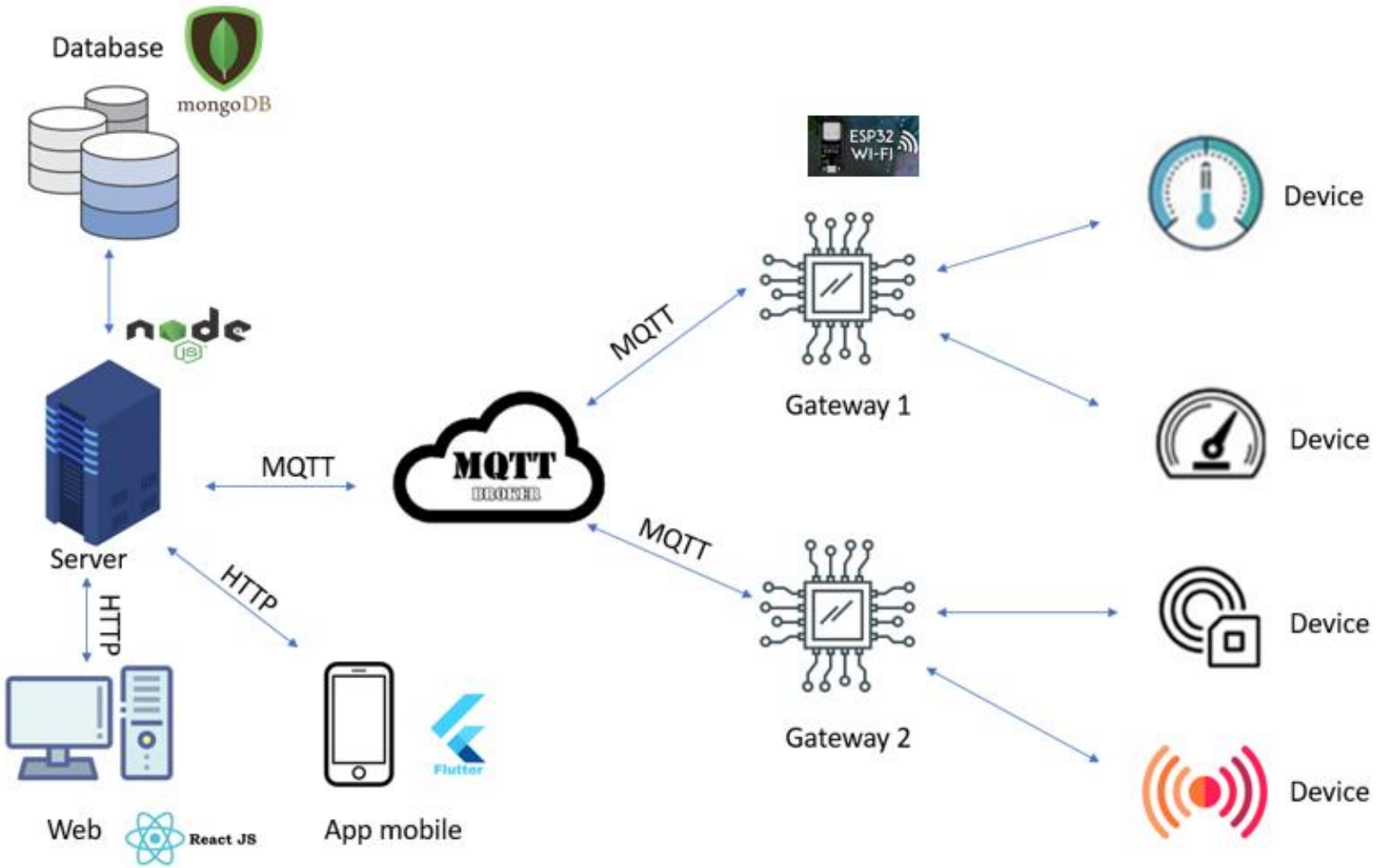
Project 2. Smart home

- Server design:
  - Workflow for Adding a House



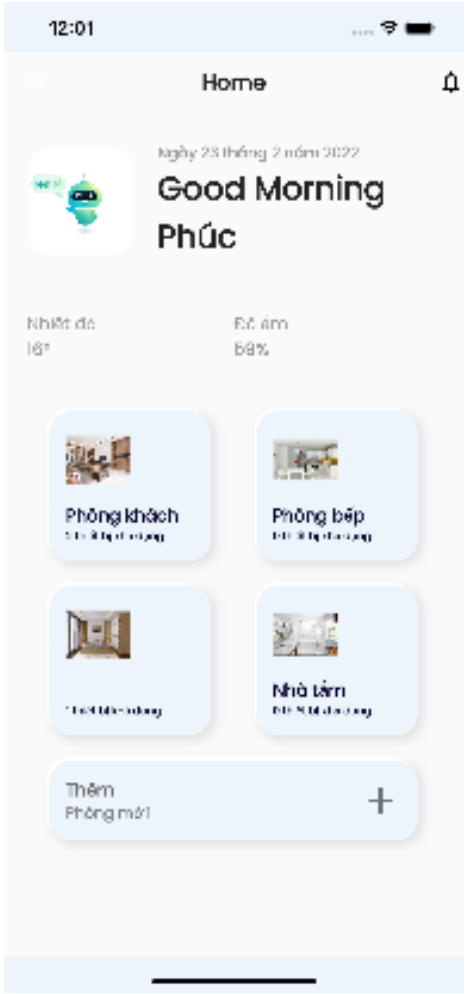
Project 3. Smart home

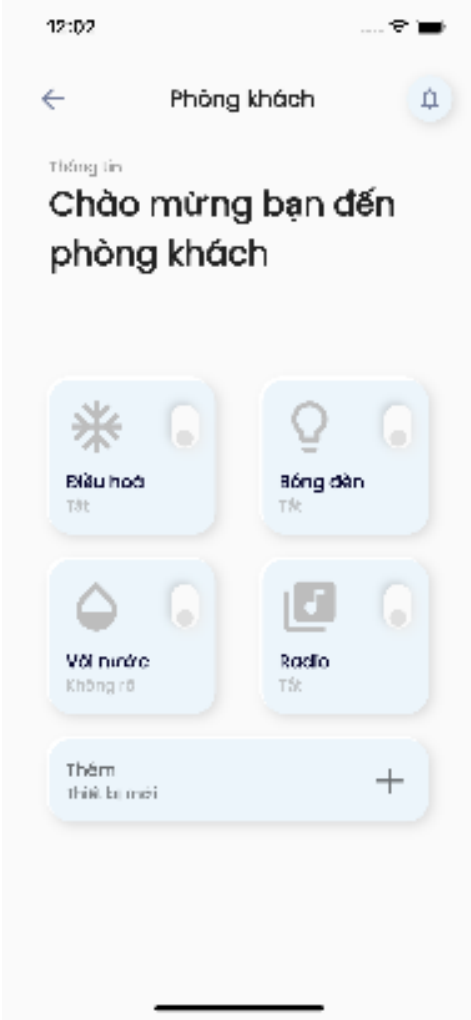
- System design



Project 3. Smart home

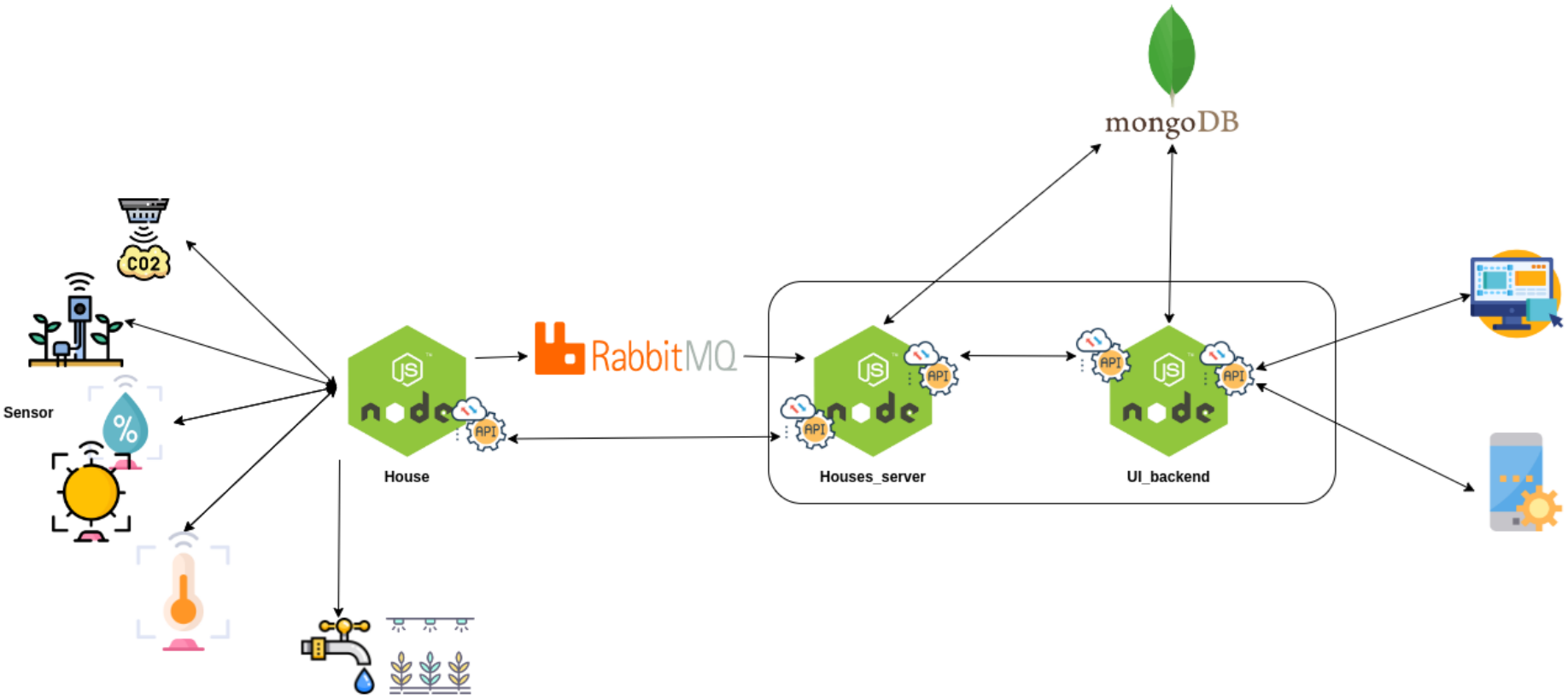
- Mobile app





Project 4. Smart garden

- System architecture

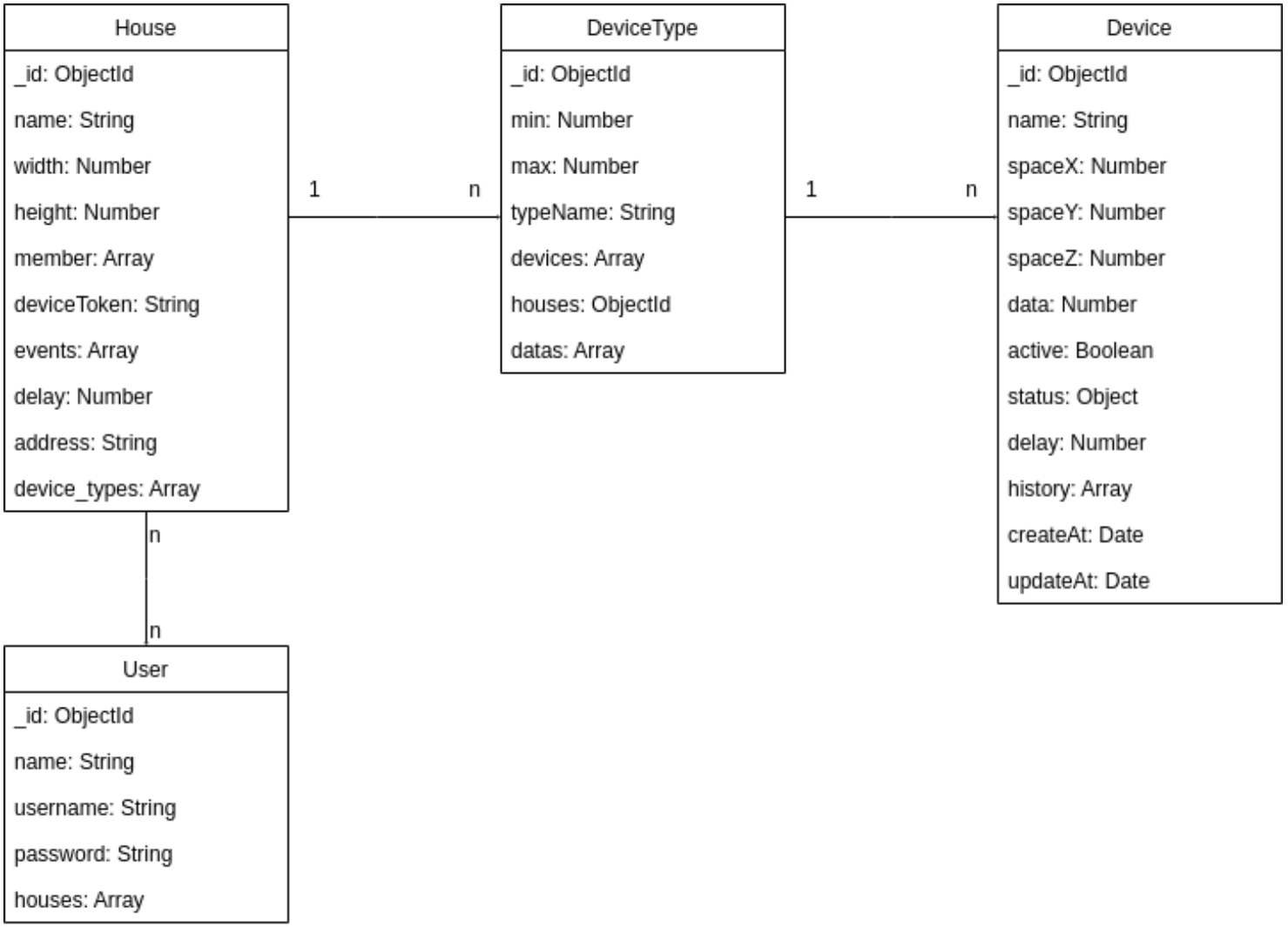


Project 4. Smart garden

- Technologies:
  - Using Synthetic Data for Sensor Devices
  - Server: NodeJS, ExpressJS.
  - Database: MongoDB.
  - Website: React JS.
  - Mobile App: React Native.

Project 4. Smart garden

- Database desgin



Project 4. Smart garden

- Building APIs
  - Register: POST /v1/auth/register
  - Login: POST /v1/auth/login
  - Get list of devices for a specific house:GET /v1/device/{houseId}
  - Update device information: PUT /v1/device/{deviceId}
  - Get statistical data: GET /v1/data/{houseId}
  - Get list of warning/events for a specific house: GET /v1/house/events/{houseId}
  - Get information for a house: GET /v1/house
  - Add new house: POST /v1/house
  - Update house's information: PUT /v1/house/update-house/{houseId}
  - Add new member: PUT /v1/house/update-member/{houseId}
  - Delete a member: PUT /v1/house/delete-member/{houseId}/{userId}

Project 4. Smart garden

- Example API for Get list of devices for a specific house

GET http://localhost:9000/v1/device/63e8a7ab1d624a76b5d91255 Send

Params Authorization Headers (8) Body Pre-request Script Tests Settings Cookies

Body Cookies Headers (8) Test Results Status: 200 OK Time: 233 ms Size: 81.27 KB Save Response

Pretty Raw Preview Visualize JSON


```
{
    "success": true,
    "devices": [
        {
            "_id": "63de1380dd8742bc1ba5390a",
            "name": "ND-01",
            "active": true,
            "spaceX": 100,
            "spaceY": 0,
            "spaceZ": 0,
            "data": 21.8,
            "created_at": "2023-02-04T08:12:48.776Z",
            "__v": 0,
            "delay": 2,
            "status": {…
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            "history": […
            ],
            "max": 30,
            "min": 15,
            "type_name": "Temp"
        },
        {
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```
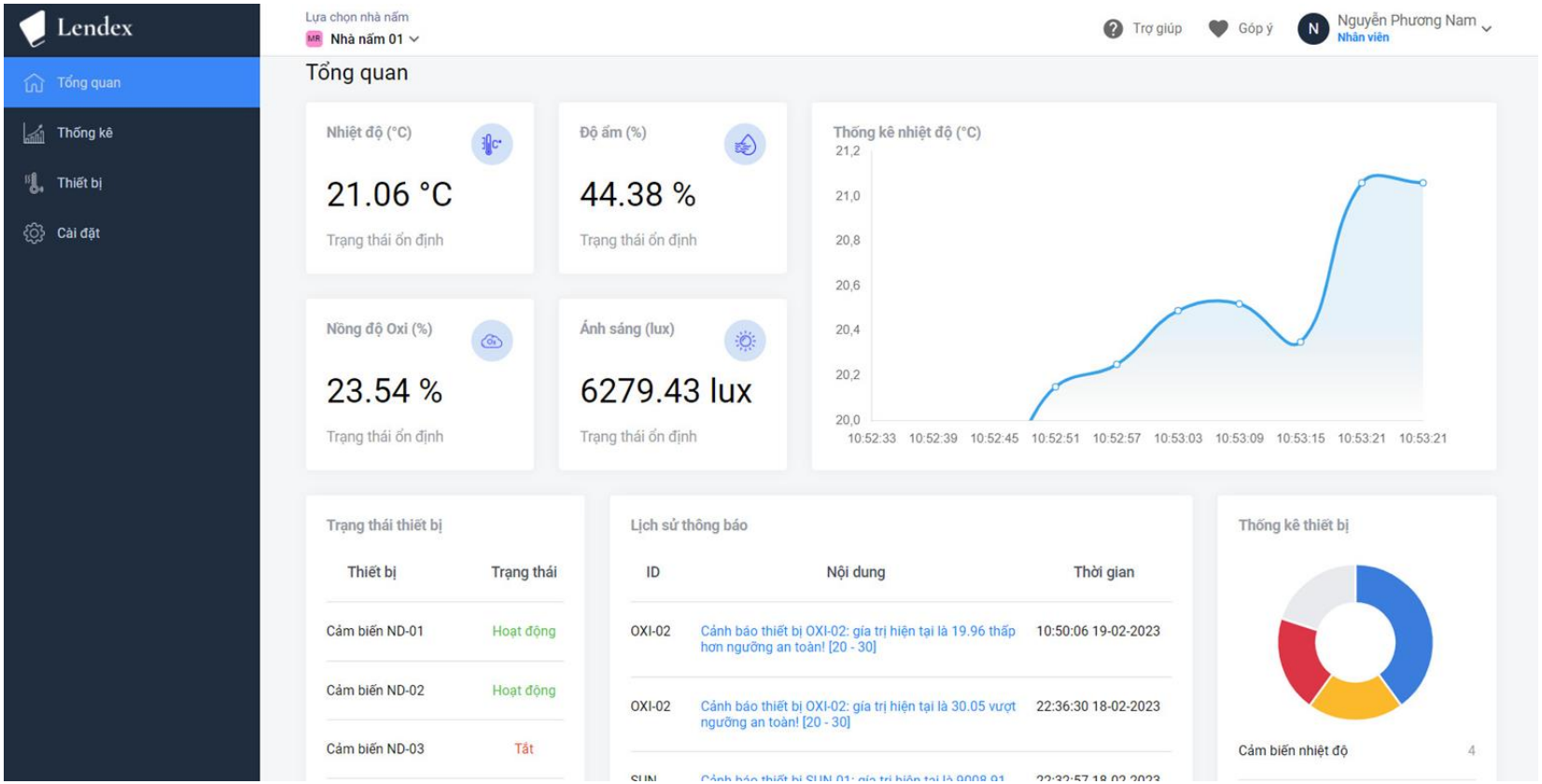
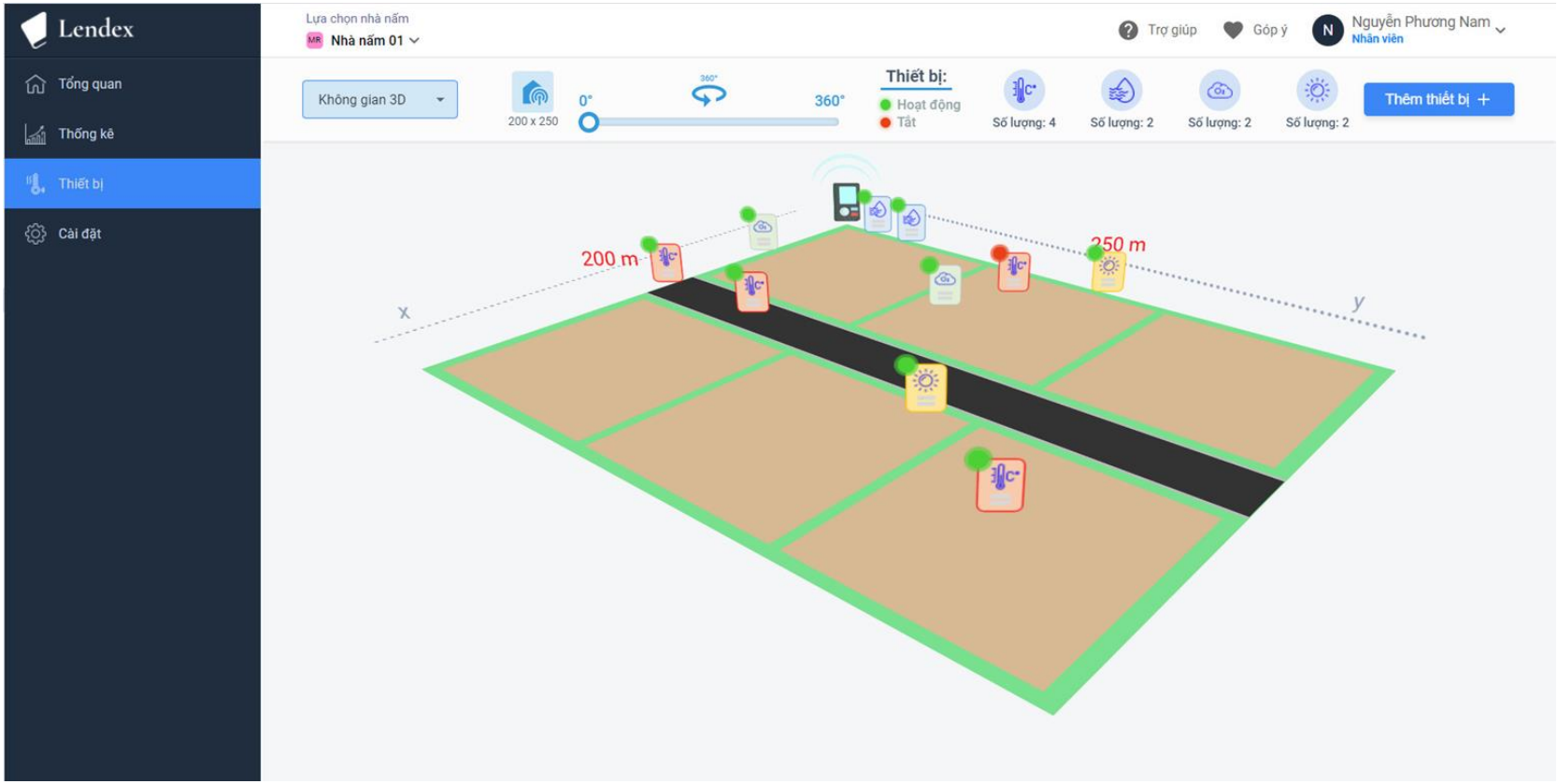

Project 4. Smart garden

- Admin dashboard Web app



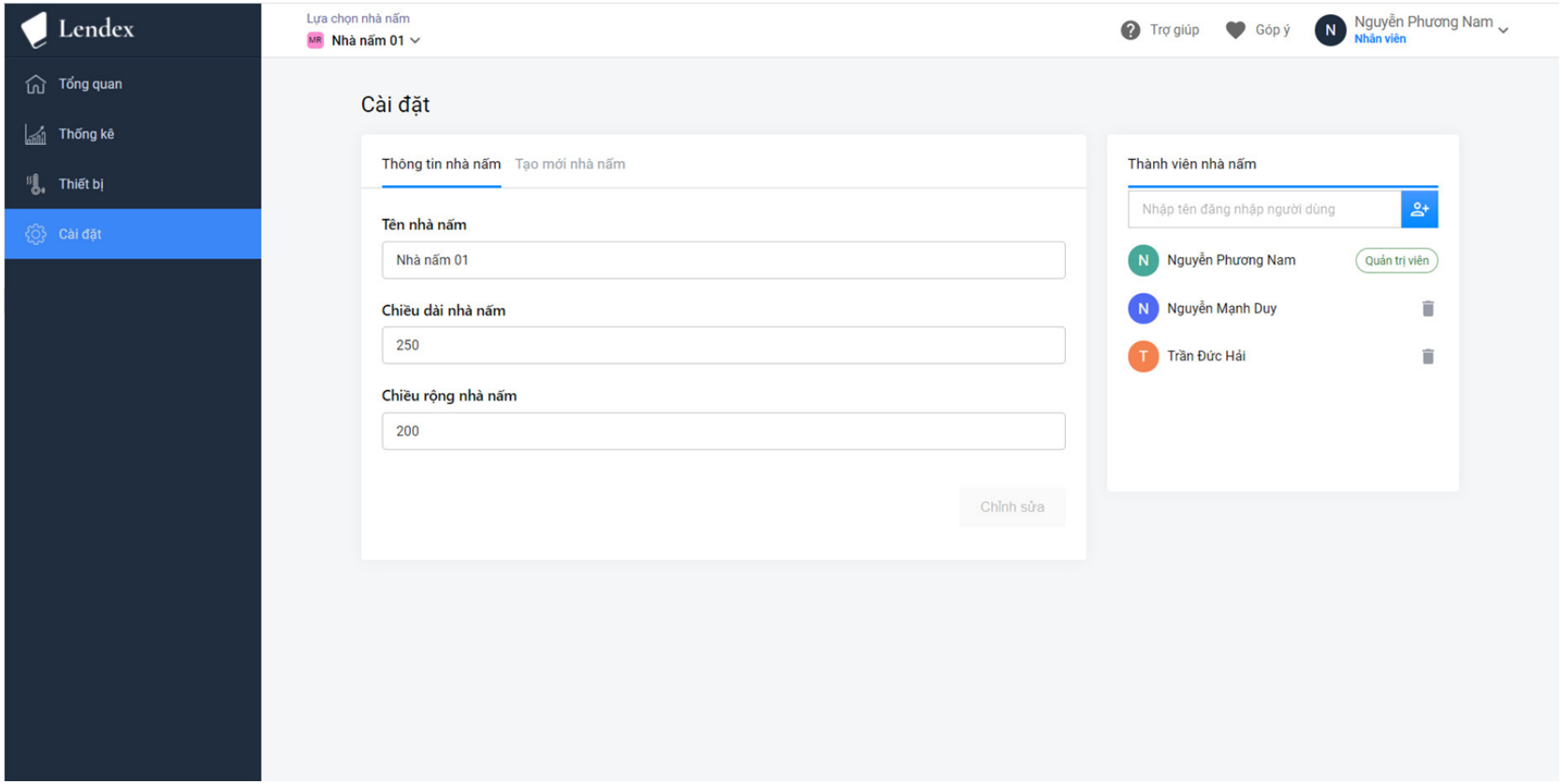
Project 4. Smart garden

- Admin dashboard Web app:



Project 4. Smart garden

- Admin dashboard Web app:



Project 4. Smart garden

- Mobile app