Remote Data Acquisition and Internet of Things

Introduction to Computer Engineering

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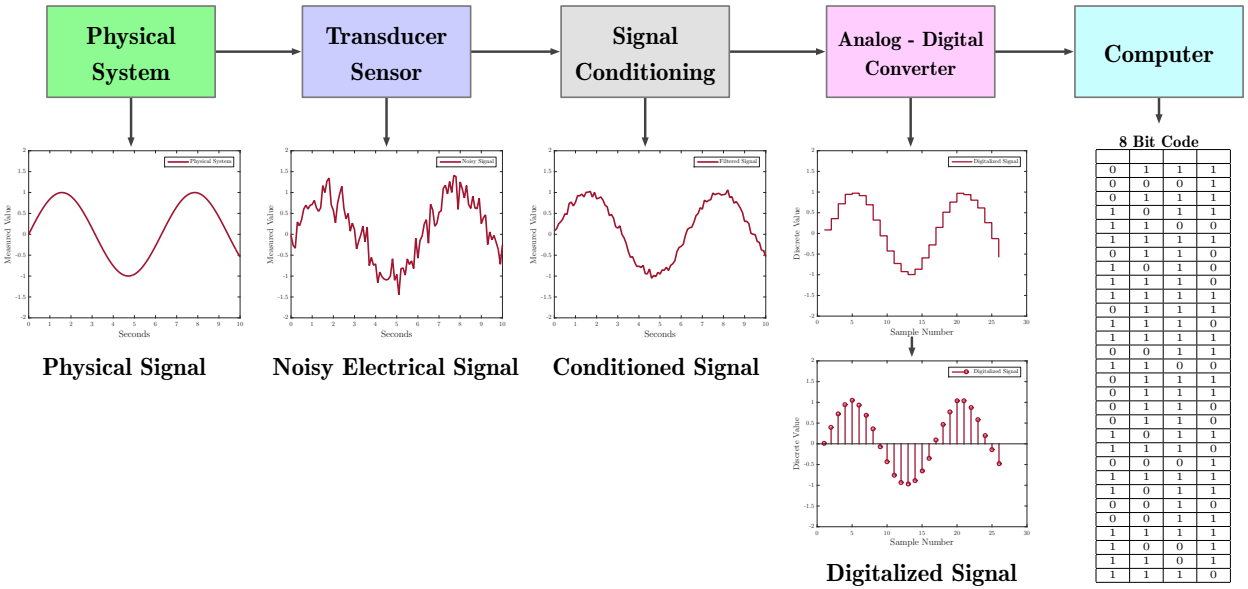
Data Acquisition

The process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer.

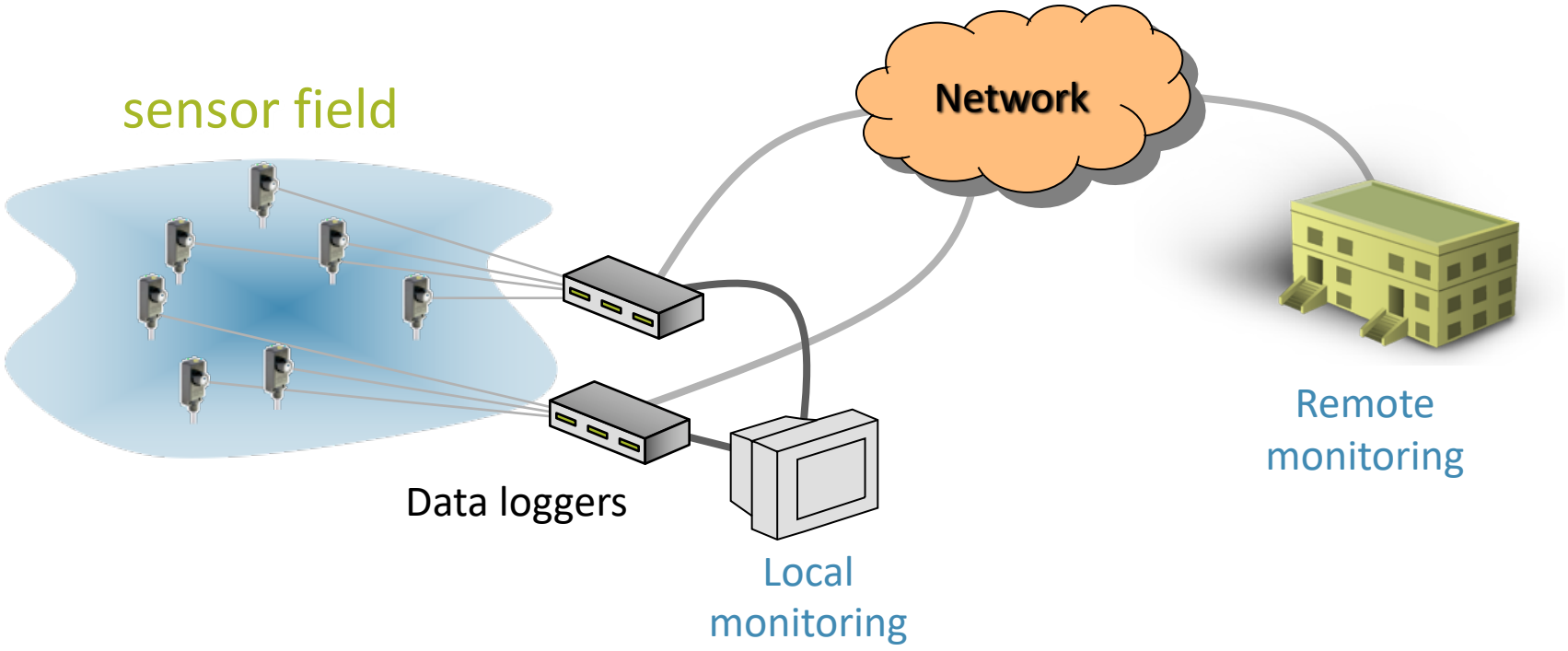
- **Data acquisition system**, also known as **DAS** or **DAQ**, is a system that performs the above process



https://en.wikipedia.org/wiki/Data_acquisition

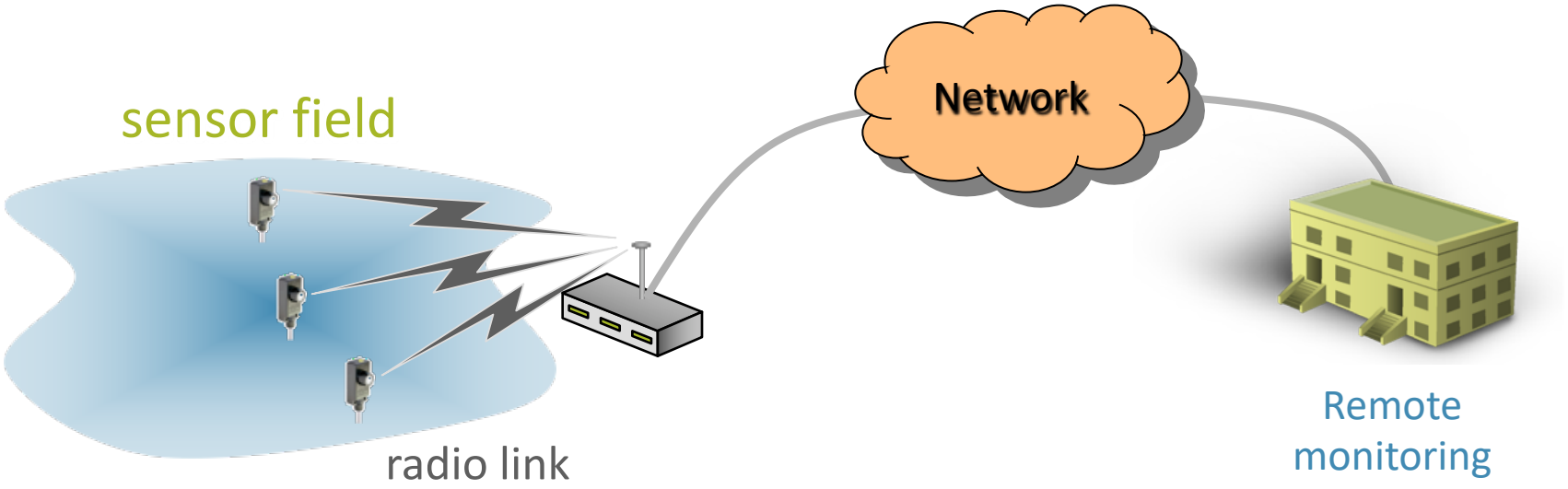
Remote Data Acquisition

- Traditional, wired sensors



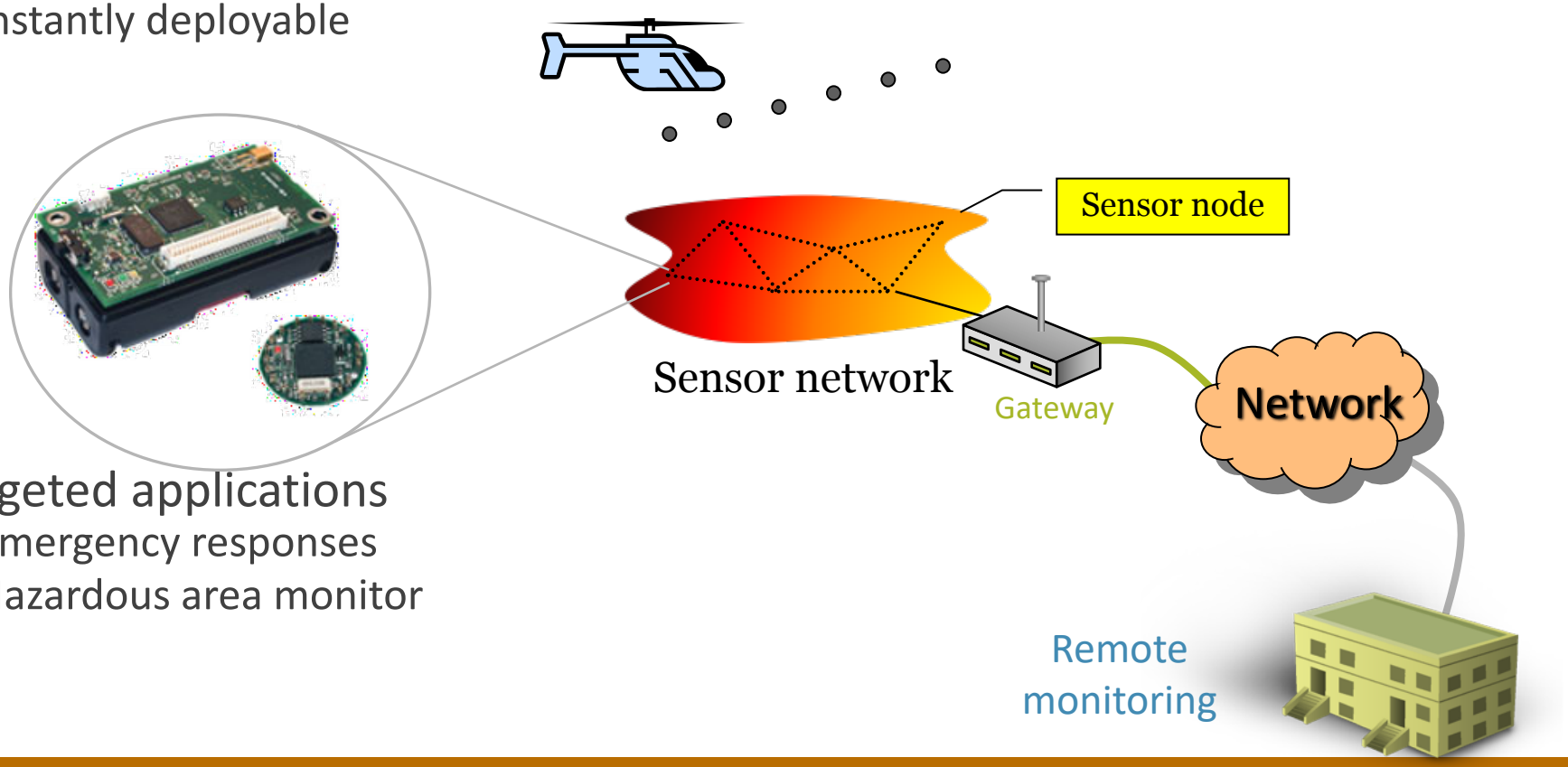
Remote Data Acquisition

- Wireless sensors
- Sensors communicate with data logger via radio links



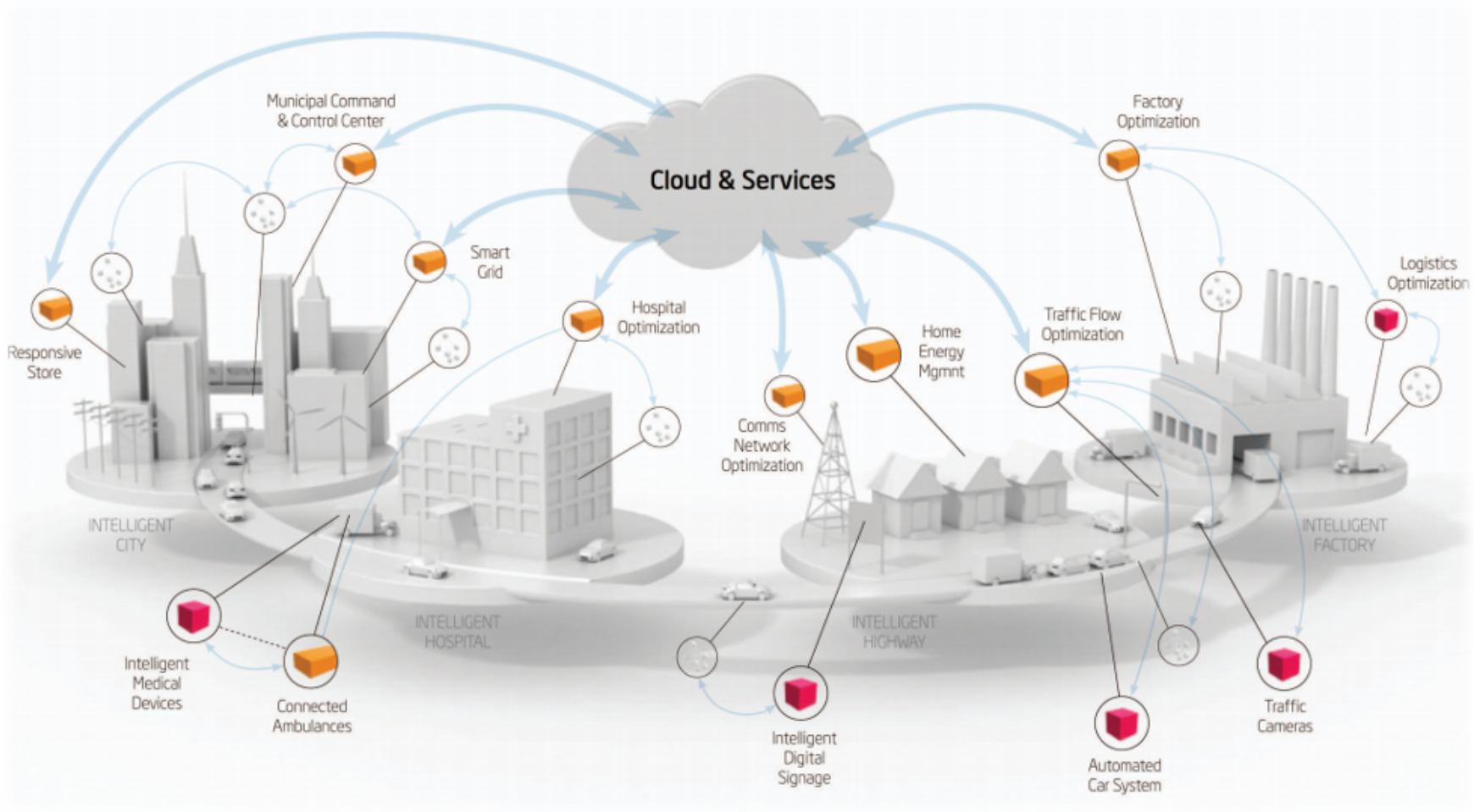
Remote Data Acquisition

- **W**ireless **S**ensor **N**etworks – WSN
- Sensor nodes deployed and forming an ad hoc network
  - Requires no hubs, access points
  - Instantly deployable



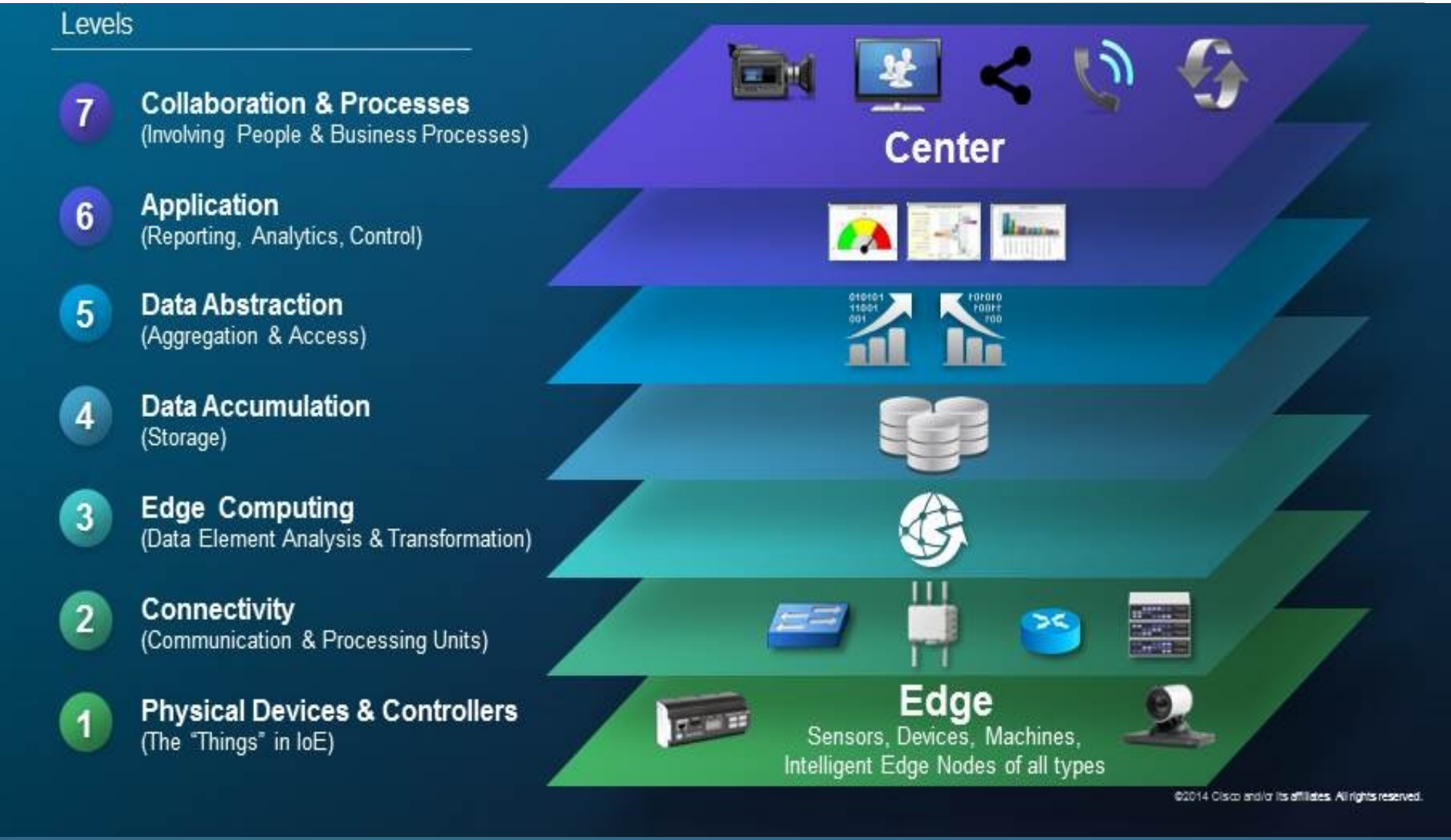
- Targeted applications
  - Emergency responses
  - Hazardous area monitor

Internet of Things (IoT)



http://www.opinno.com/en/content/internet-things-0

IoT Reference Model



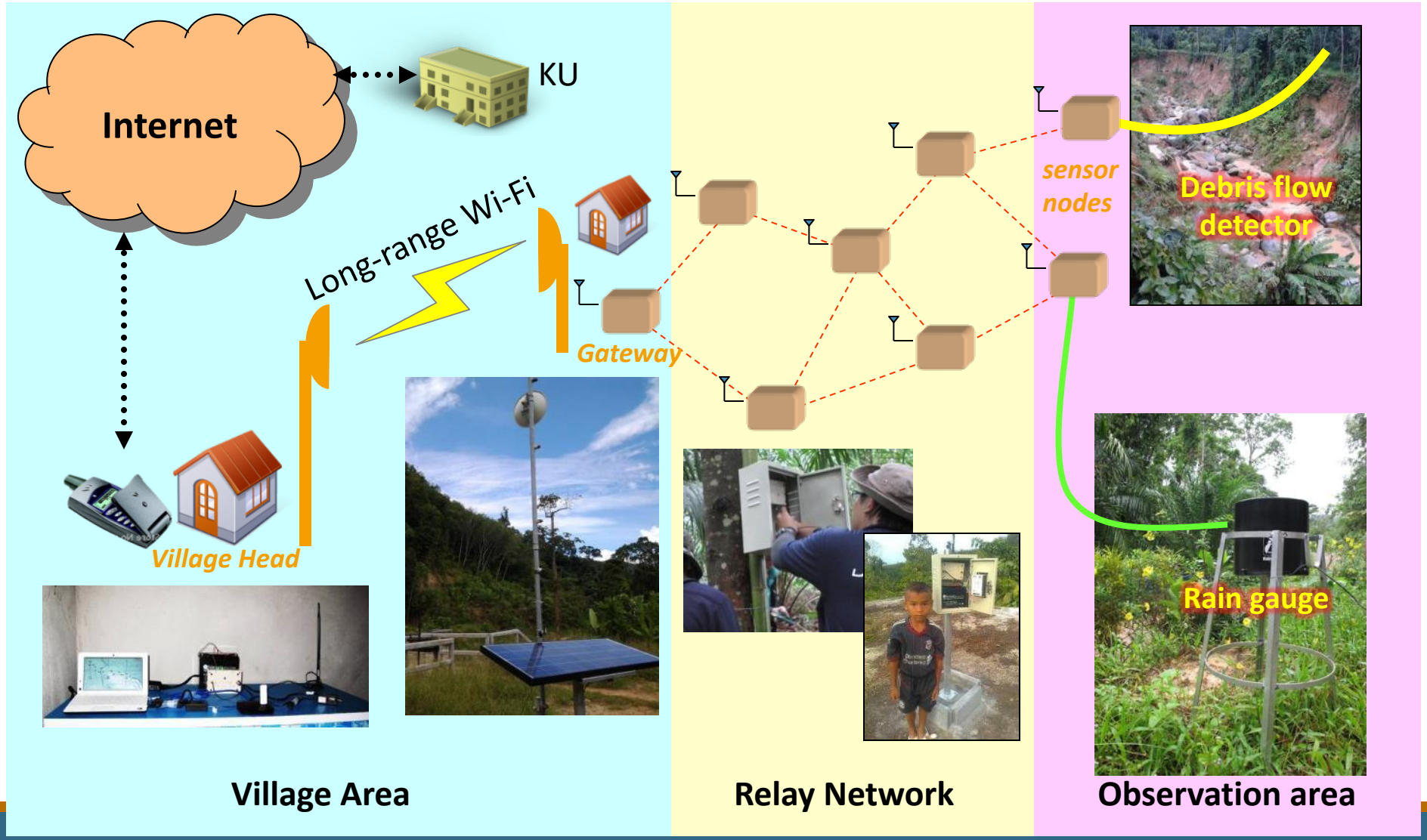
https://insightaas.com/new-iot-reference-model-creates-common-tongue/

Project: Landslide Monitor

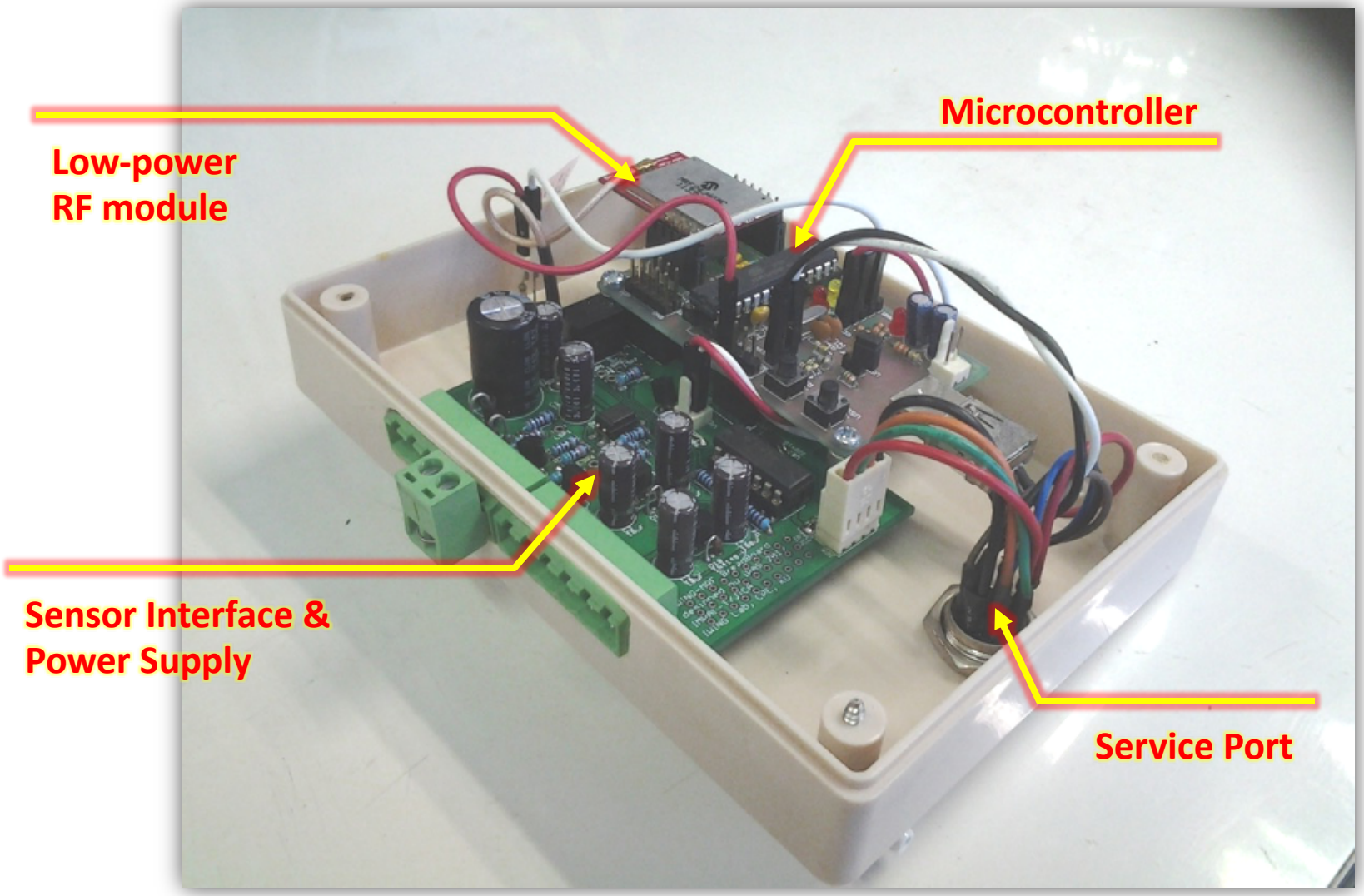
- Location: Khao Panom, Krabi
- Period: 2011 – 2013
- Communication technologies
  - IEEE 802.15.4
  - Ubiquiti's airMAX® TDMA
  - 2G/3G
- Purpose
  - Measure rainfalls and detect landslide on the mountain

Khao Phanom, Krabi Province, Southern Thailand

Landslide Monitor: System Overview



Sensor Nodes: *Internals*



Landslide Monitor: Observation Areas

- Rain gauge installation



- Debris flow detector installation


Landslide Monitor: Relay Nodes

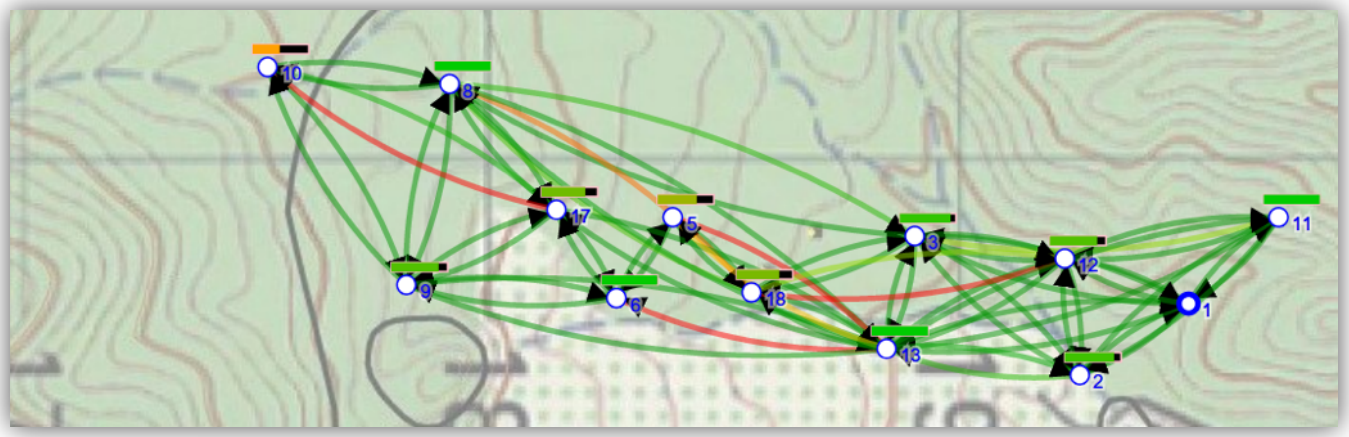
Landslide Monitor: Deployment






Network Status Monitor

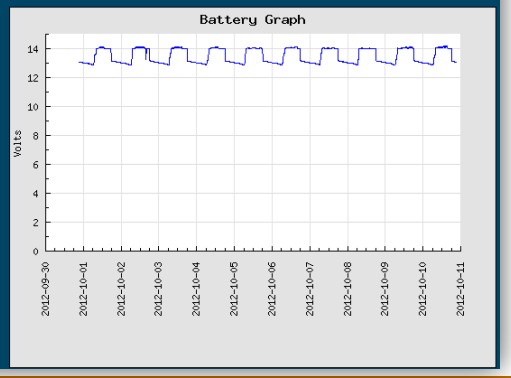
- User-friendly interface for the villagers



PAN: Huay Nam Kaew, Krabi (1282)
Node ID: 8

Battery: 13.06 V
Last updated: 2012-10-10 21:00:32

hear_from	RSSI	LR	datetime
18	2.75	30.2	2012-10-10 21:00:32
9	47.84	97.65	2012-10-10 21:00:31
3	0.78	97.65	2012-10-10 21:00:30
10	47.45	97.65	2012-10-10 21:00:30
13	10.98	97.65	2012-10-10 21:00:30
17	21.18	97.65	2012-10-10 21:00:30
6	0	81.57	2012-10-10 20:53:29



Project: Cattle/Dog Tracking

- Locations: Kanchanaburi, Nan, and Vietnam
- Period: 2018 – 2019
- Communication technologies
  - LoRa
  - 3G/4G
- Purpose
  - Track animals and their interaction in the field for up to 1-3 months

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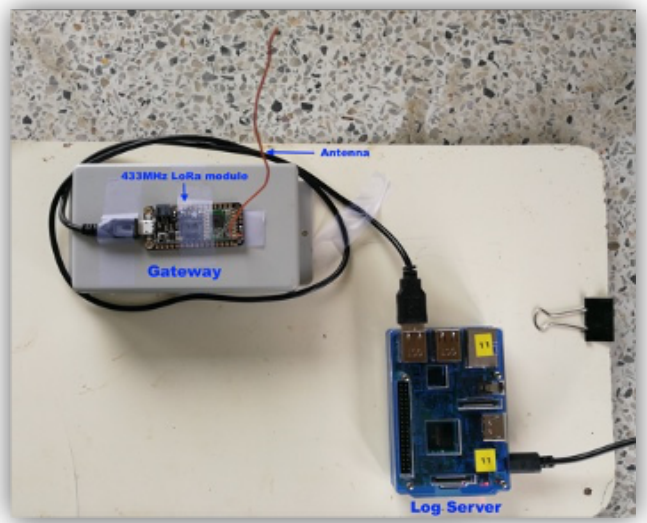
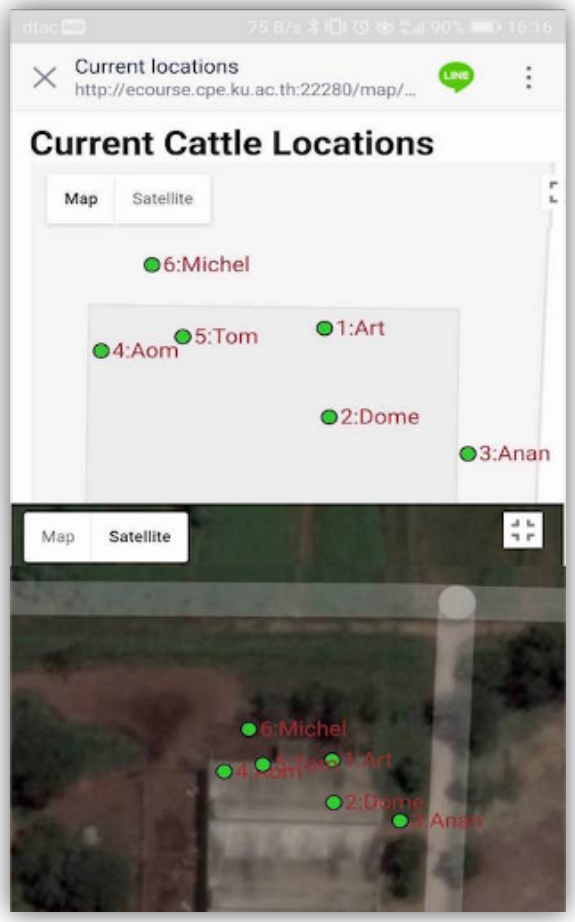
Cattle/Dog Tracking

- Tracks and records cattle movements with GPS receiver





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Power Management

https://www.cpe.ku.ac.th/~cpj/cattrack/kps.2018-06-11.html

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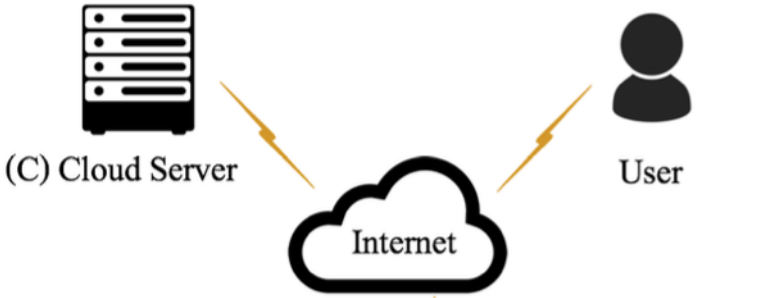
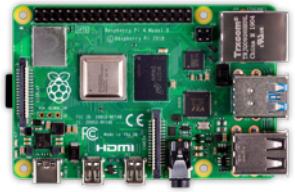
Growth Chamber Control

- Locations: Department of Biochemistry, Faculty of Science, KU
- Period: 2018 – 2020
- Communication technologies
  - Wi-Fi
- Purpose
  - To monitor and control environment inside a growth chamber

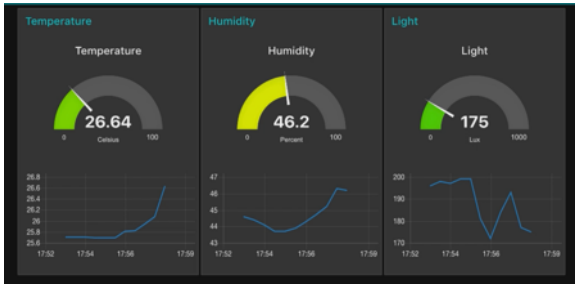
Growth Chamber Monitoring

- Monitors and controls light, temperature and humidity in a chamber for plant growth and tissue culture





Growth Chamber Monitoring



A

Humidity & Temperature Sensor

Light Sensor

GPIO

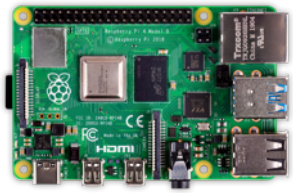
GPIO

Microcontroller

GPIO

MQTT Client

Wi-Fi



B

Local Server

Database

MQTT Broker

Wi-Fi

Ethernet

Internet

C

Cloud Server

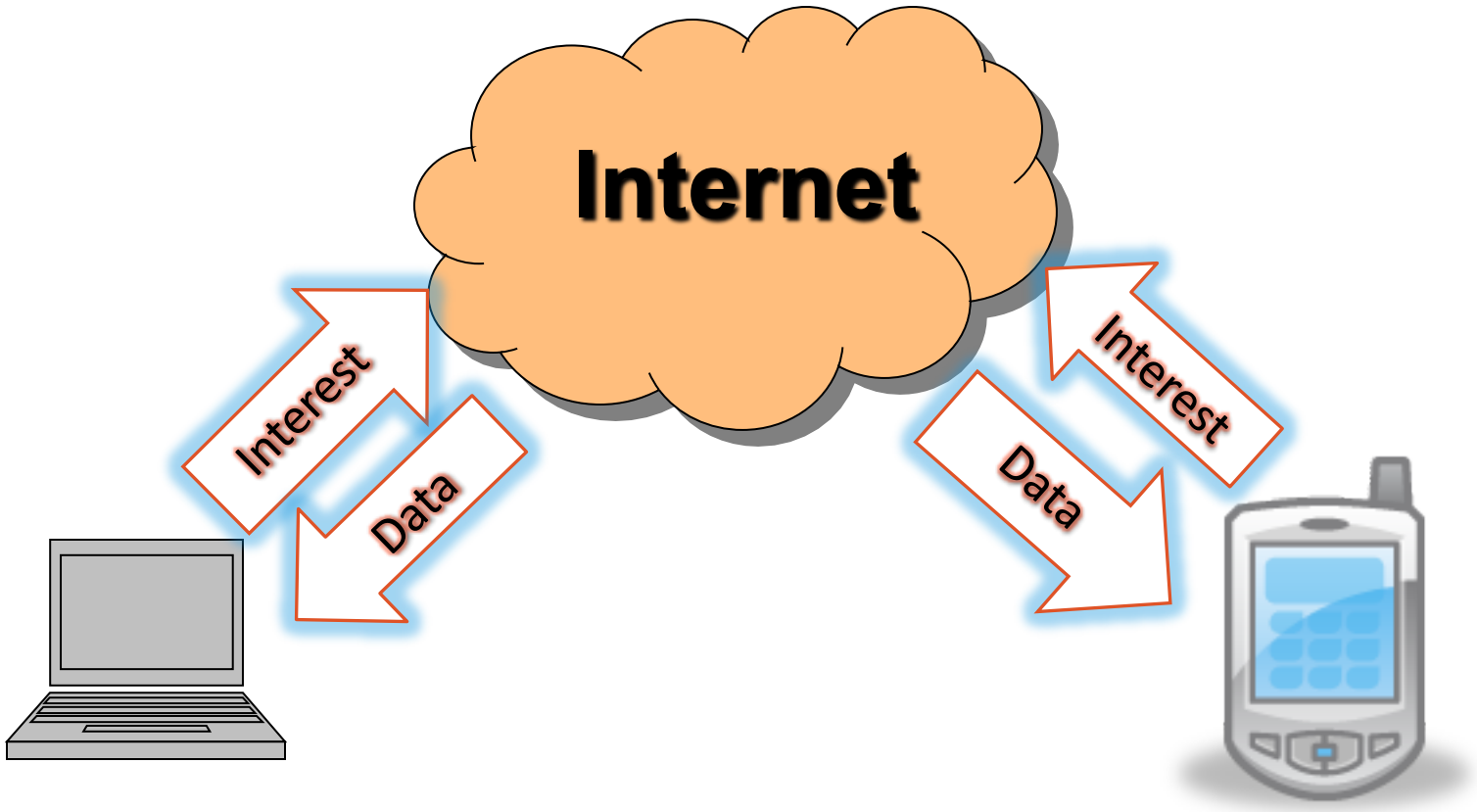
Database

Server

MQTT Client

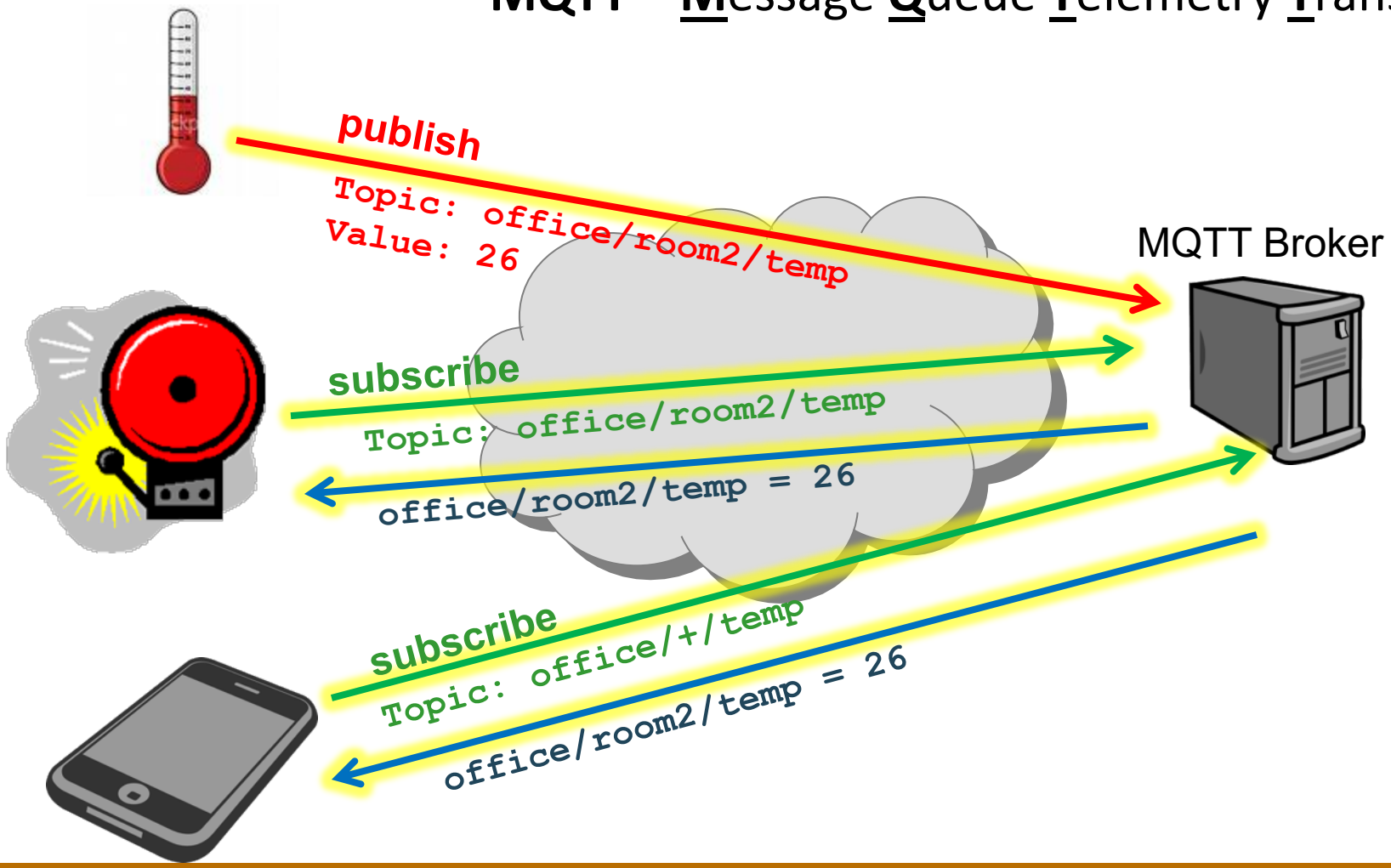
Ethernet

Content-Centric Networking Model



MQTT Protocol

MQTT – **M**essage **Q**ueue **T**elemetry **T**ransport

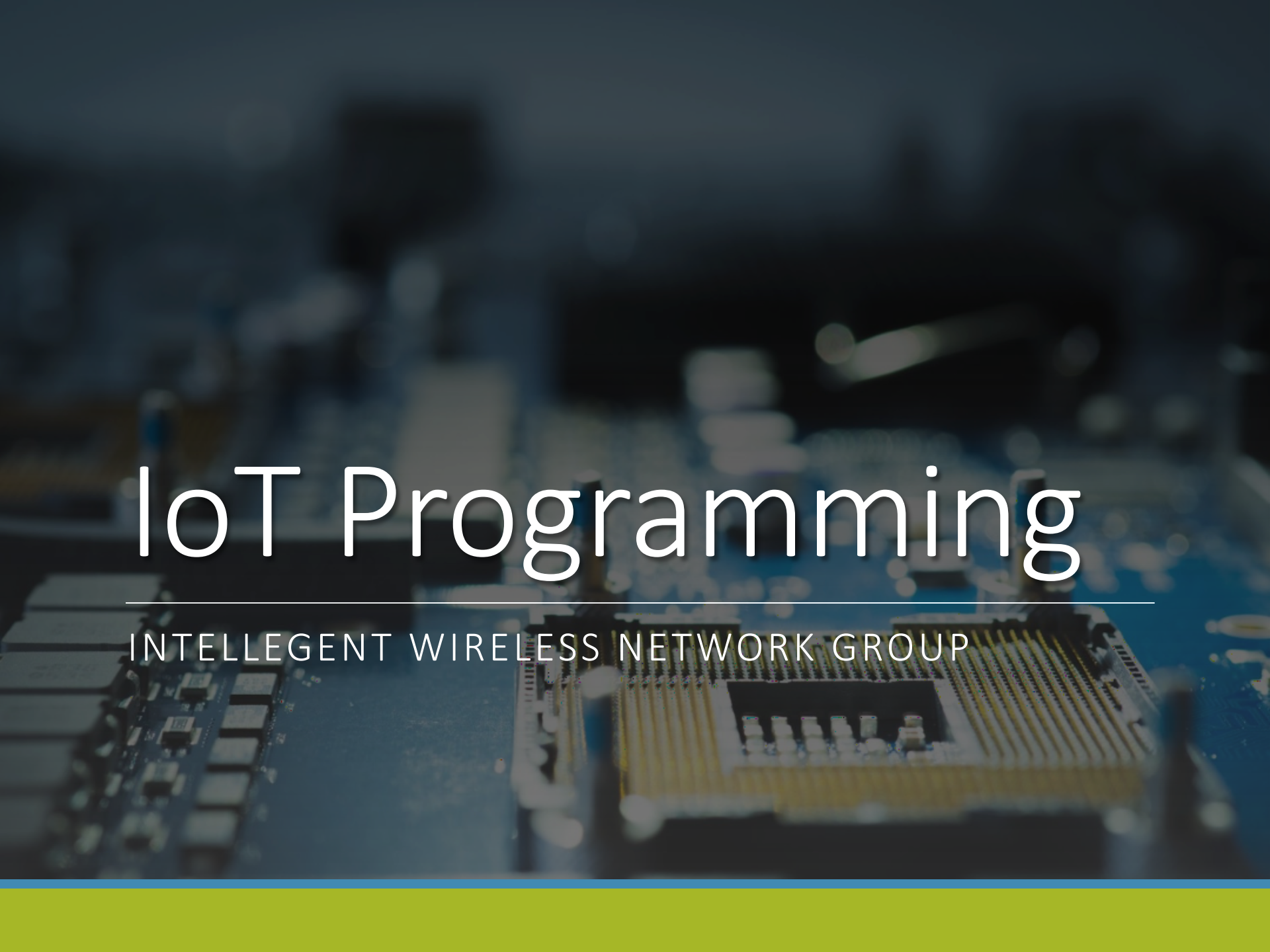


Demonstration: MQTT

- Install MQTT software on your mobile devices

MyMQTT (for Android)

MQTTool (for iOS)



IoT Programming

INTELLEGENT WIRELESS NETWORK GROUP

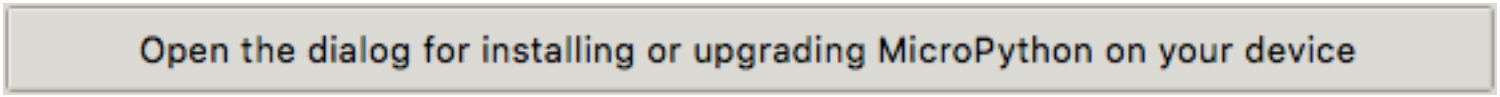
MicroPython IDE Installation

- Download and install **Thonny** from https://thonny.org
- Update Thonny and install ESPTool
  - Go to Tools → Open system shell…
  - At the shell/command prompt, enter

```
pip3 install --upgrade esptool thonny
```

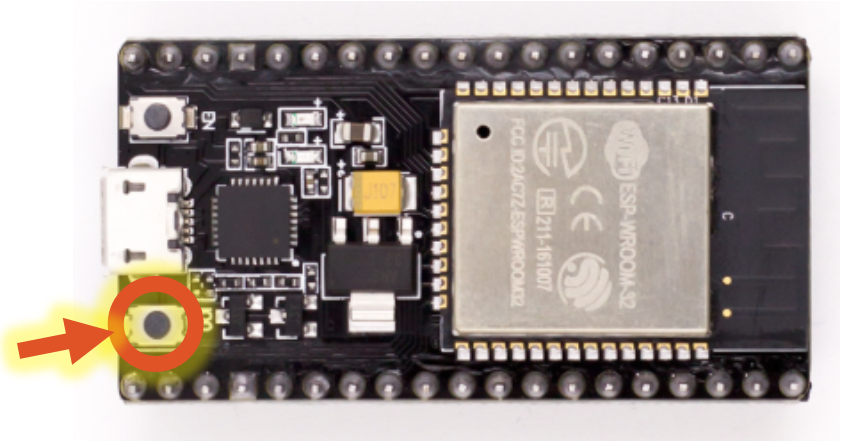
  - Exit the shell and restart Thonny

Flashing MicroPython Firmware

- Download MicroPython firmware from https://ecourse.cpe.ku.ac.th/intro-cpe/iwing/
- Plug in an NodeMCU-32S/ESP32 module
- In Thonny, go to Run → Select interpreter…
- Select **MicroPython (ESP32)** as the interpreter
- Choose the port the ESP32 module is attached to
- Click 

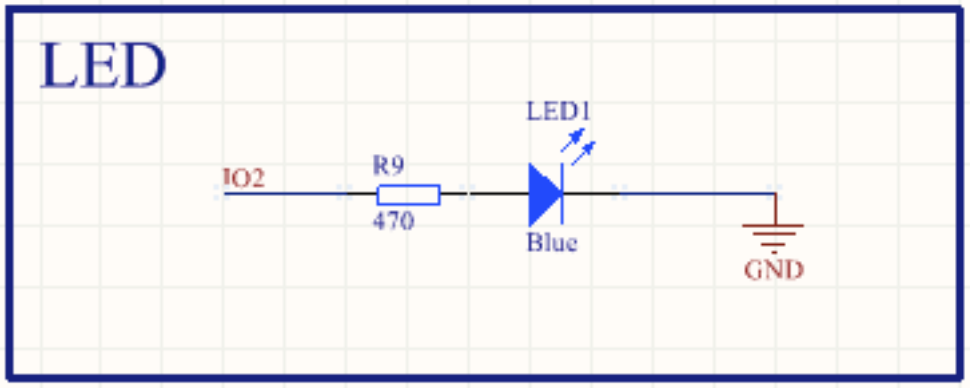
Flashing MicroPython Firmware

- Choose the firmware micropython-1.12.cpe-ku.bin
- Make sure **Erase flash before installing** is checked
- Hold down the IO0 button to force device into boot loader mode after reset, then click Install



Setting Up Built-in LED

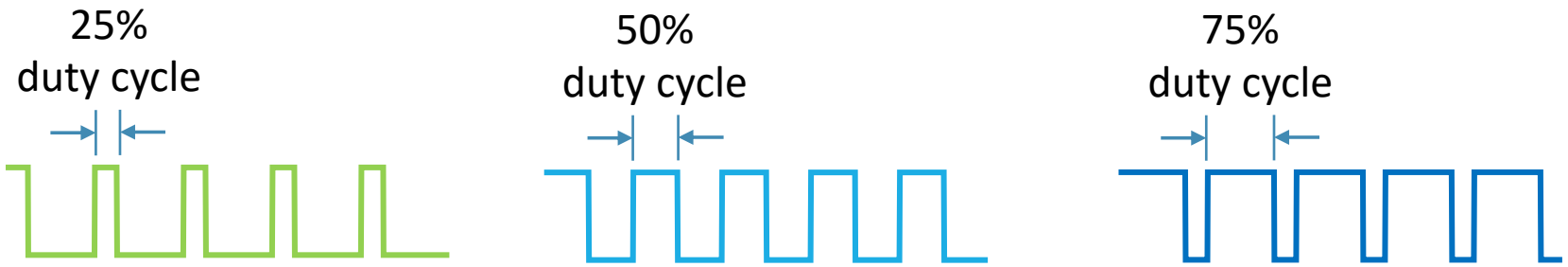
- On-board LED attached to GPIO2




```
from machine import Pin
led = Pin(2, Pin.OUT)
led.value(1)  # turn LED on
led.value(0)  # turn LED off
```

Analog Control for LED

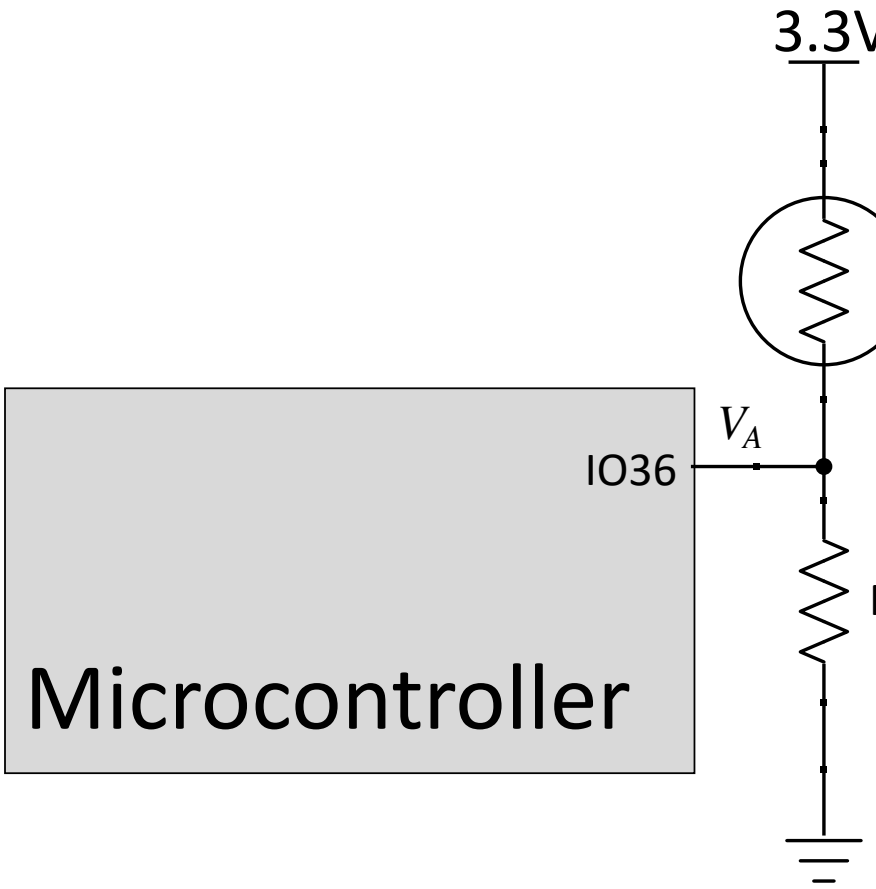
- LED can be used as an analog output using PWM (pulse-width modulation)



- Examples:

```
from machine import PWM
pwm = PWM(led)
pwm.freq(1000)

pwm.duty(0)     # LED off
pwm.duty(1023)  # LED on with full brightness
pwm.duty(512)   # LED on with 50% brightness
```

Light Sensing Circuit



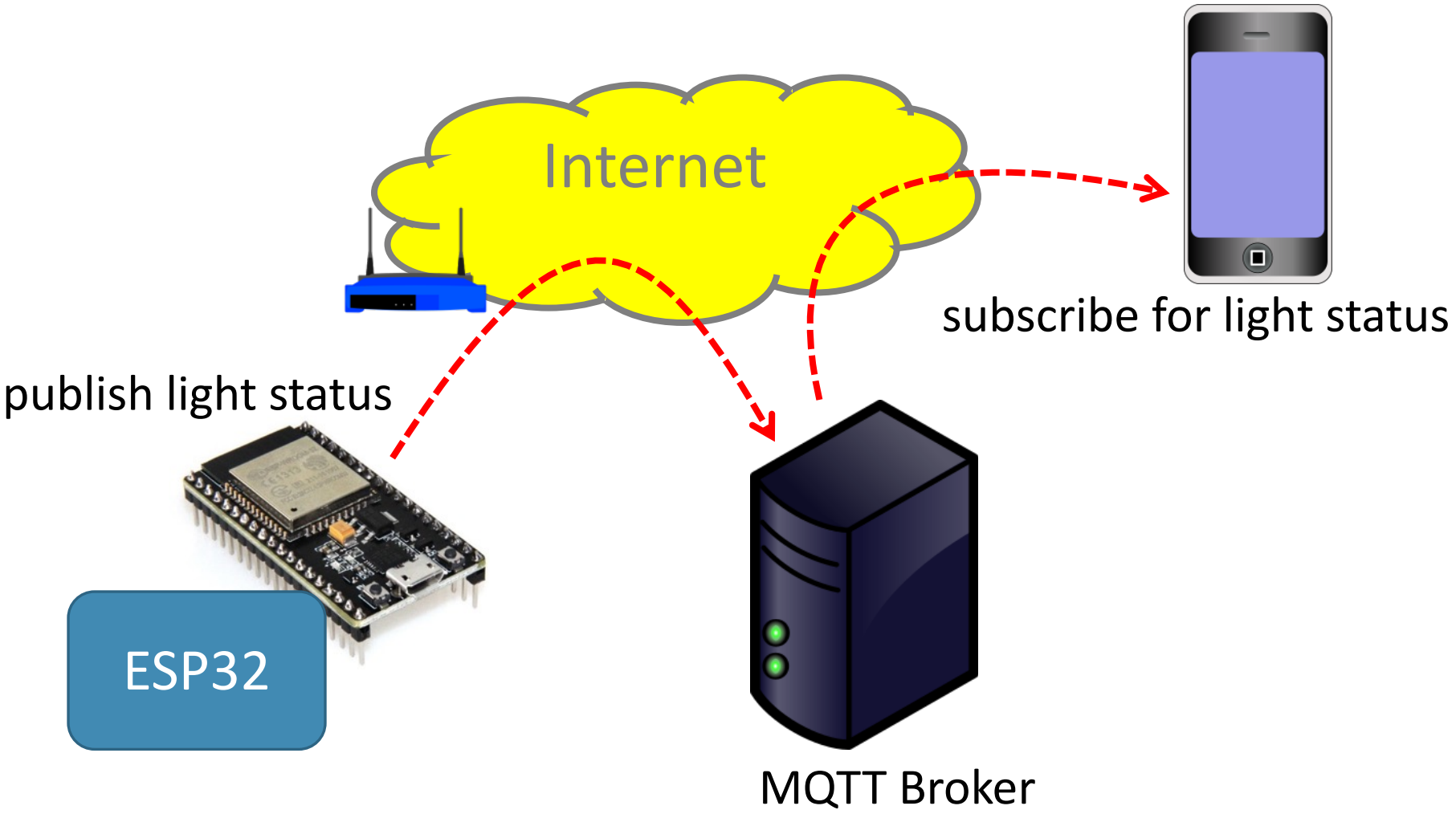
By Ohm's Law,

$$V_A = 3.3 \times \frac{R_2}{R_2 + R_{LDR}}$$

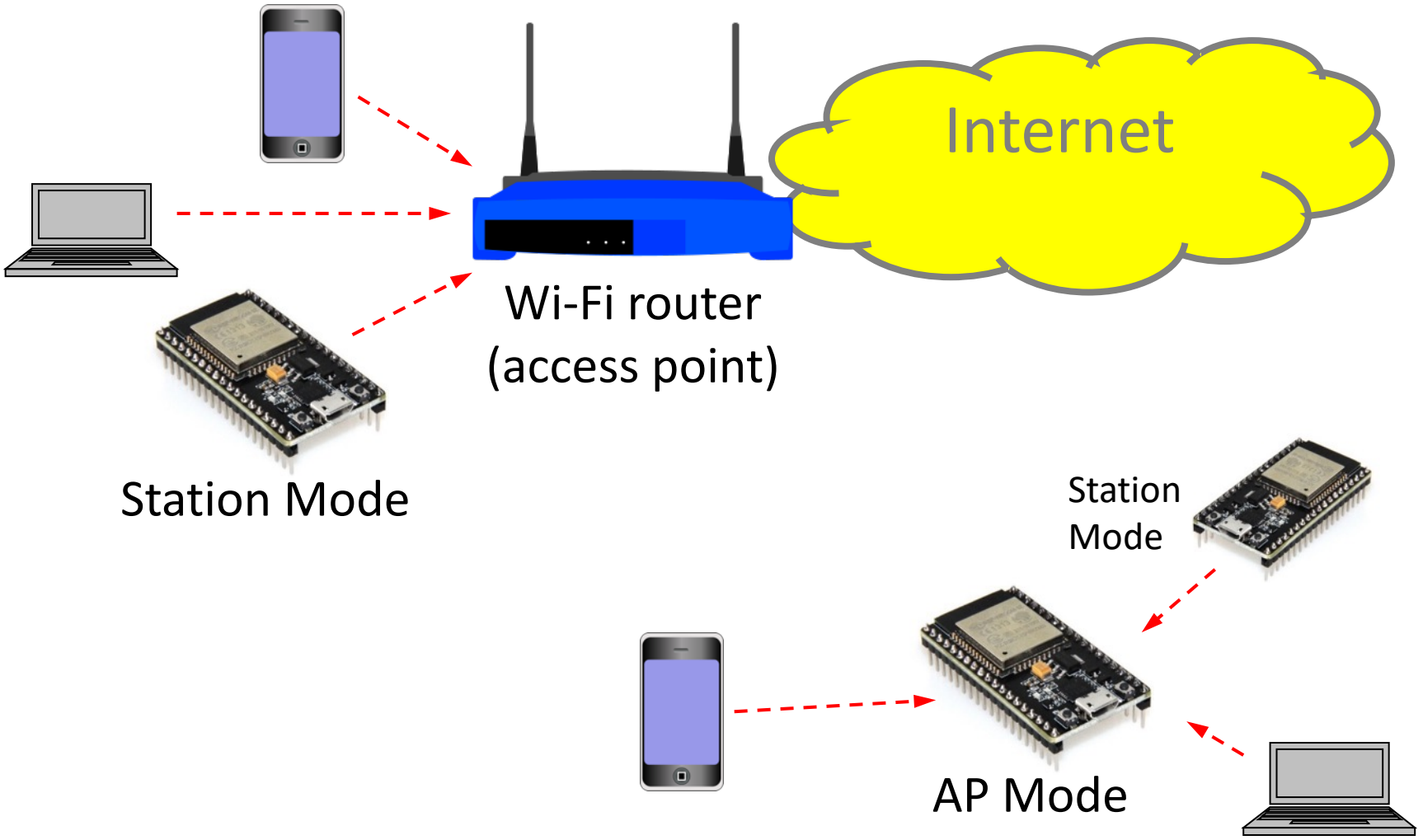
LDR Setup

```
from machine import Pin, ADC

# attach LDR to Pin 36
ldr = ADC(Pin(36))

# set measurement range of 150-2450 mV
ldr.atten(ADC.ATTN_11DB)

print(ldr.read())
```

Scenario 1 – Publishing Data



ESP32 Networking Modes



Connecting to WiFi

```
import time
import network

wifi = network.WLAN(network.STA_IF)
wifi.active(True)
wifi.connect("SSID","PASS")
while not wifi.isconnected():
    time.sleep(0.5)
print('WiFi connected')
```

Connecting to MQTT Broker

```
from umqtt.simple import MQTTClient

mqtt = MQTTClient("UNIQUE-ID","BROKER")
mqtt.connect()
print("MQTT Connected")
```

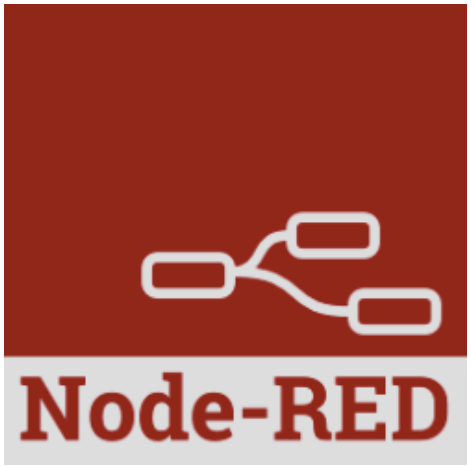
Publishing Data

- The following publishes the knob's value to the topic `ku/cpe/XXXXXX/light` every 5 seconds

```
while True:
   value = ldr.read()
   mqtt.publish("ku/cpe/XXXXXX/light",str(value))
   time.sleep(2)
```

Node-RED

- Flow-based programming tool for wiring together:
  - Hardware (e.g., IoT) devices
  - Files/databases connectivity
  - APIs
  - Online services
  - UI dashboard
- Originally developed by IBM
- Built on Node.js
- Additional nodes can be installed, created, and shared with other developers

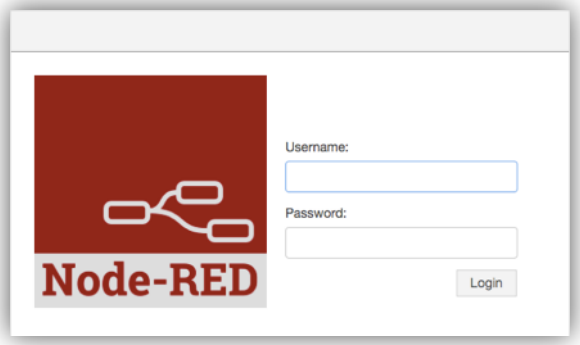


Accessing Your Node-RED Instance

- Each of you has access to a personal Node-RED instance running inside a Docker container
- Point your browser to

  https://158.108.34.31/red/*<ku-account>*

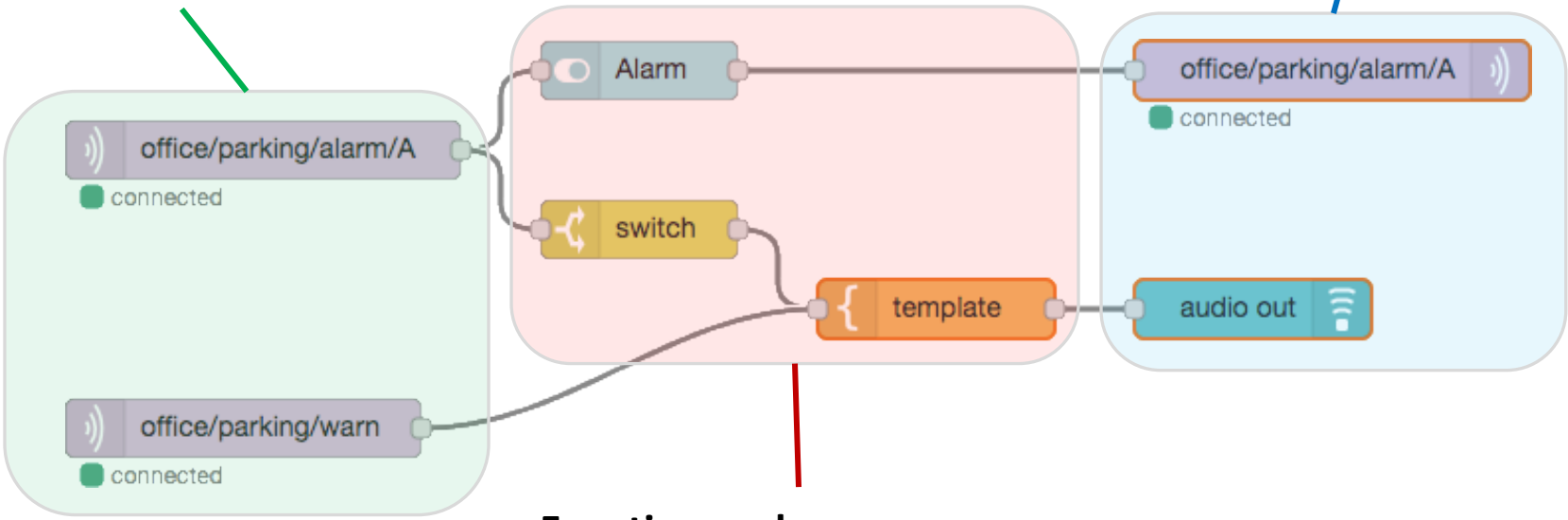
- The site's security certificate is self-signed, so please accept the warning and continue
- The password is the same as your KU account's password



Typical Node-RED Flows

Input nodes
accept input from outside and generate messages

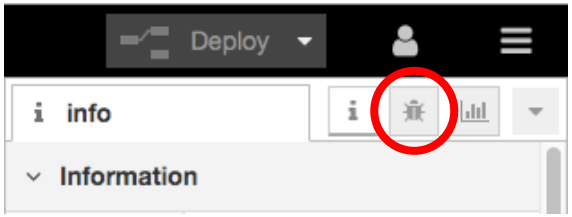
Output nodes
send messages' data to outside



Function nodes
process/manipulate messages

Your First Flow: Hello, World!

- Add an **inject** node and a **debug** node
- Wire the Inject node's output to Debug node's input
- Double-click the Inject node to change the payload type and content
- Save and run the flow by clicking 

- Switch to the Debug tab 

- Click the Inject node's button and observe the result

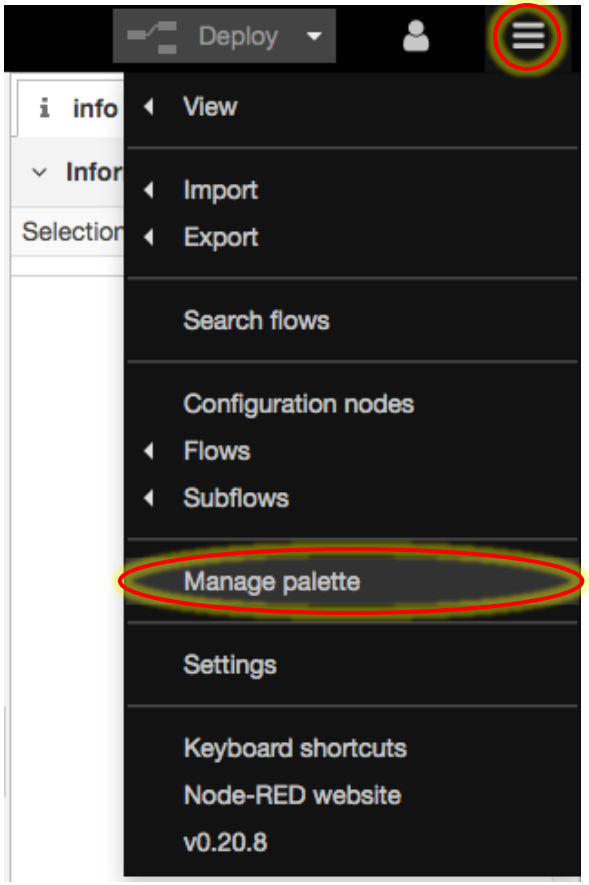
MQTT Interaction

- Node-RED comes with two built-in MQTT nodes
  - MQTT subscribe node (input)

  - MQTT publish node (output)

Installing More Nodes

- Use the menu Manage palette to manage and install your nodes



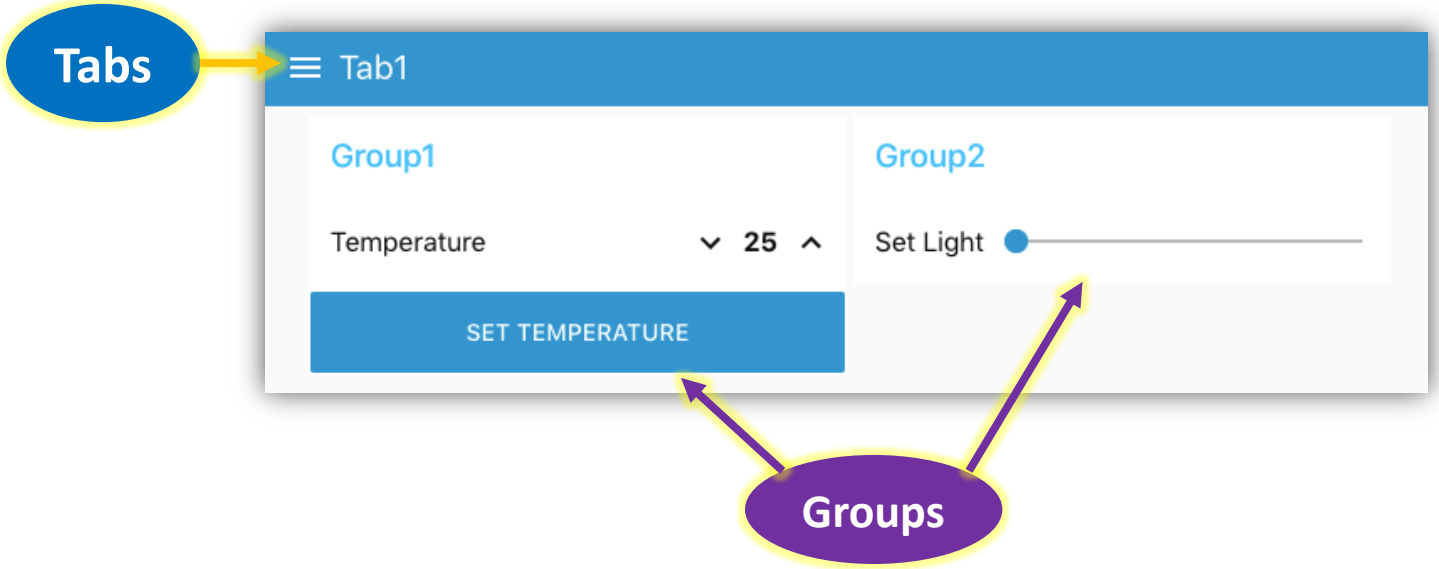
Node-RED Dashboard

- Installed with **node-red-dashboard** package
- Allows simple, yet highly customizable UI based on Angular and Material Design

https://flows.nodered.org/node/node-red-dashboard

UI Groups and Tabs

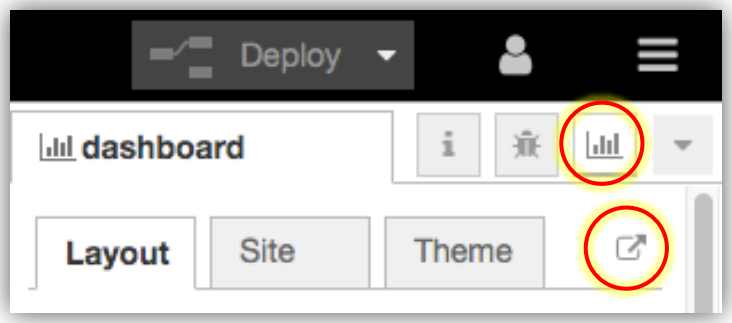
- UI dashboard consists of one or more tabs
- Each dashboard tab consists of one or more groups



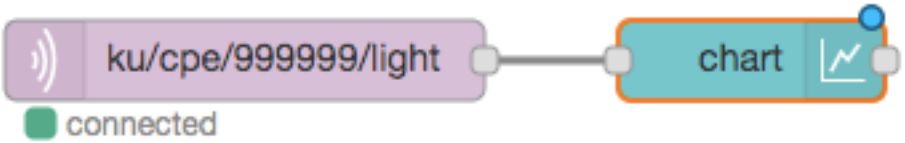
- When adding the very first UI widget, you will need to create a new UI group and tab for it

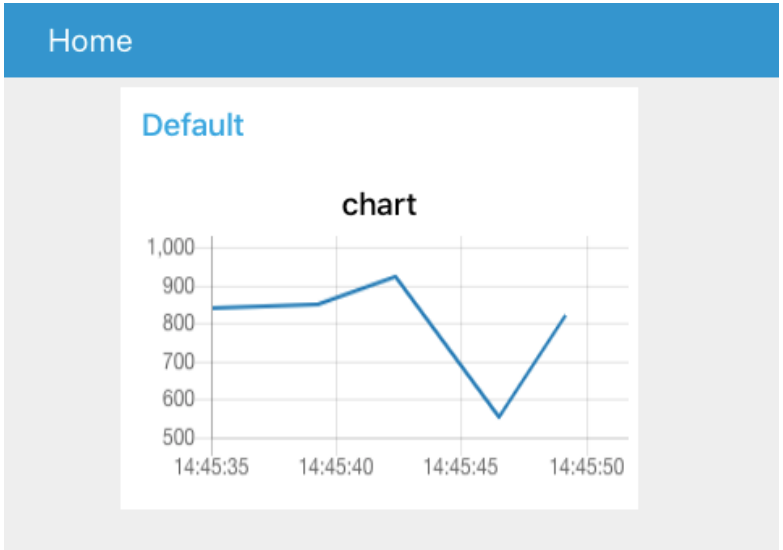
Dashboard Page

- To open the dashboard page, select the dashboard tab and click the link icon

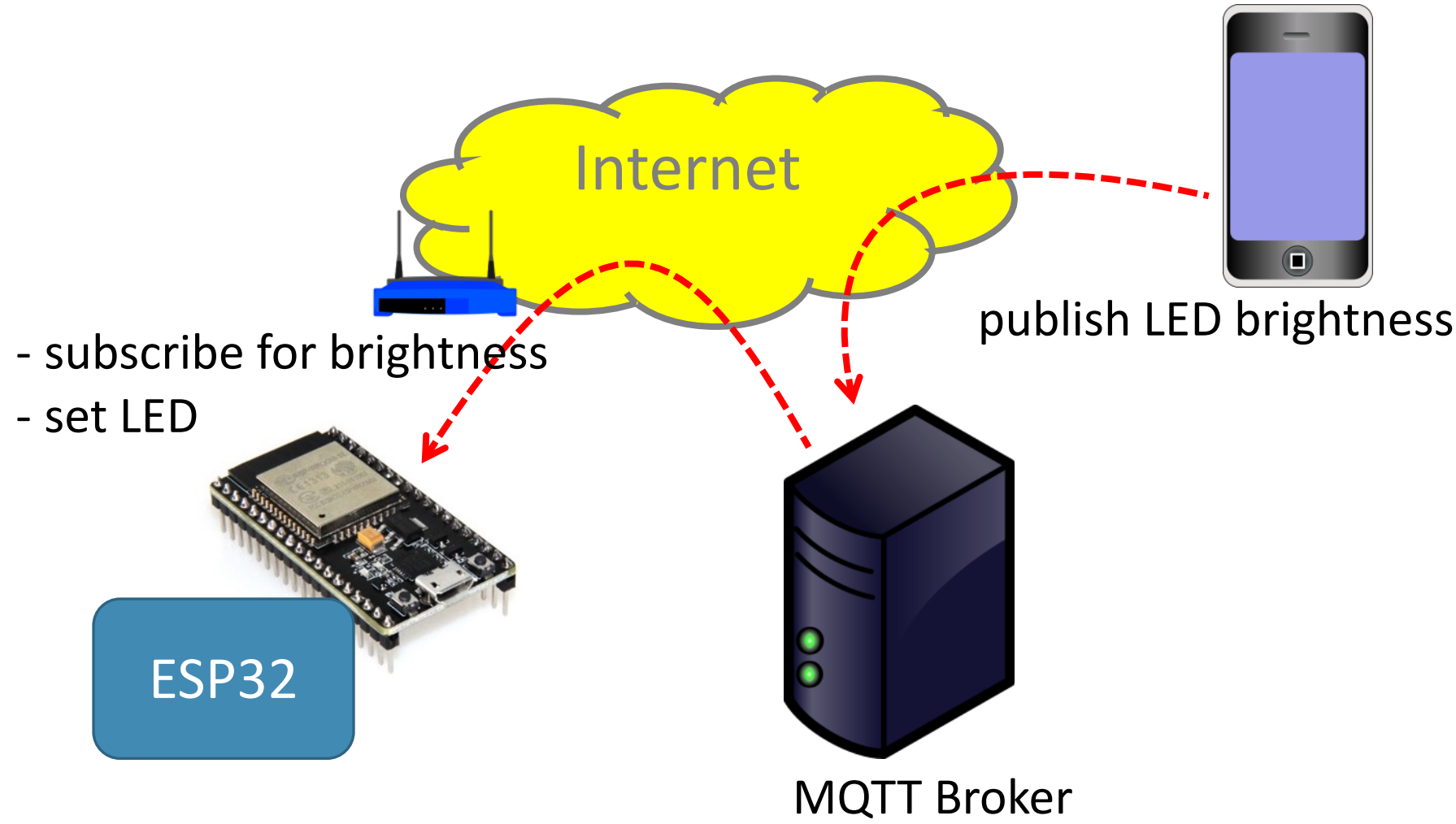


Example: Light Chart





Scenario 2 – Subscribing



Subscribing to a Topic

```
def sub_cb(topic,msg):
   if topic == b"ku/cpe/XXXXXX/led":
      value = int(msg)
      pwm.duty(value)

mqtt.set_callback(sub_cb)
mqtt.subscribe("ku/cpe/XXXXXX/led")
while True:
      mqtt.check_msg()
      time.sleep(0.2)
```