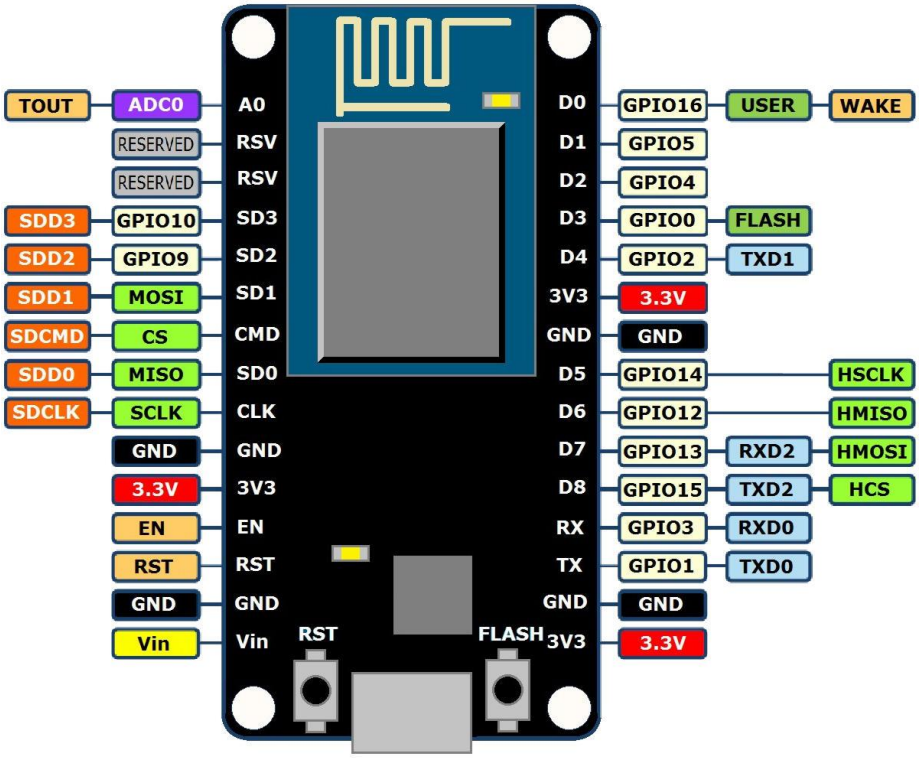
IoT Workshop

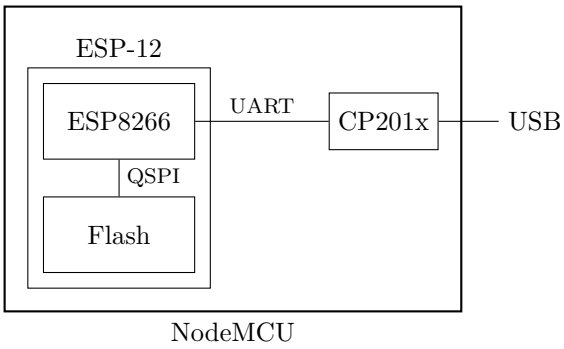
Trygve Laugstøl <trygvis@trygvis.io>

NodeMCU

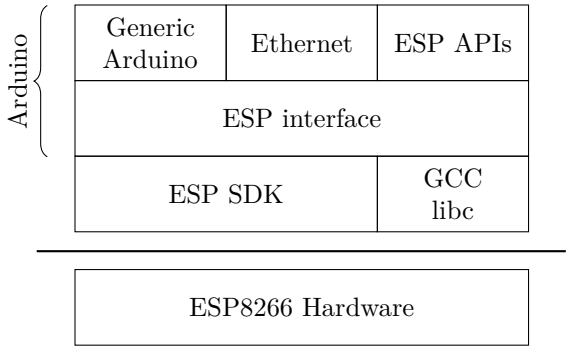
NodeMCU hardware



NodeMCU hardware



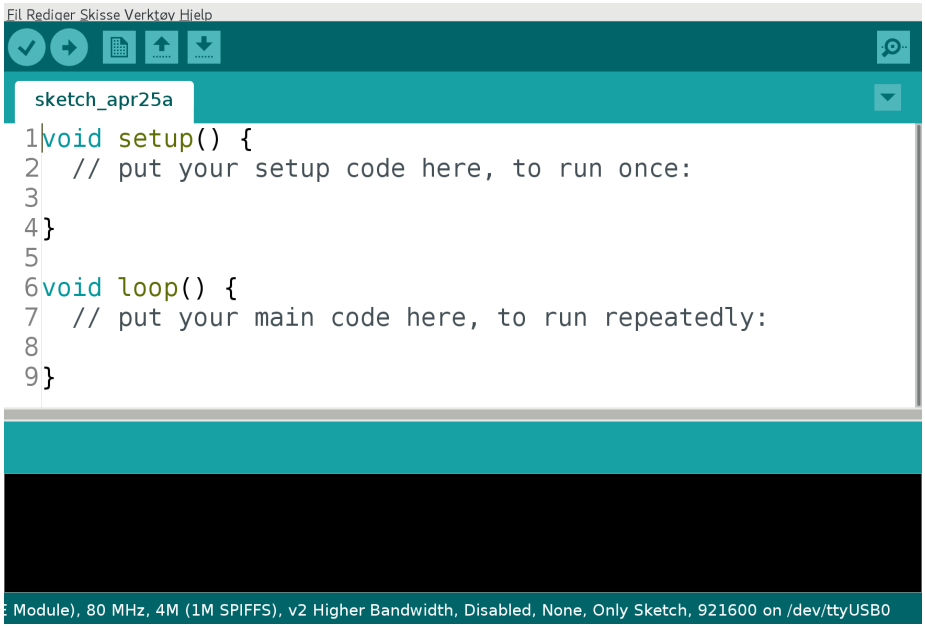
ESP8266 software layers



ESP8266 + Arduino

- Standard Arduino IDE
- ESP8266 Arduino core
  - https://github.com/esp8266/Arduino

Arduino IDE



Arduino code structure

```
void setup() {
    // Called once
}

void loop() {
    // Called repeatedly
}
```

MCU programming is often structured into:

- Configure
  - CPU
  - GPIO ports
  - MCU's peripherals
  - The rest of the board
  - Configure application and callbacks.
- Sleep

Arduino chooses to run the cpu at 100% instead of the sleep step..

Arduino file structure

```
foo/
  foo.ino
  config.h
```

`foo.ino` must always be in a `foo` directory.

config.h is created by "new tab".

Generic Arduino APIs

```
// Pin: D0, D1, etc.
// Mode: OUTPUT, INPUT, INPUT_PULLUP
void pinMode(uint8_t pin, uint8_t mode);

// State: HIGH, LOW, true/false, 1/0
void digitalWrite(uint8_t pin, uint8_t state);
int digitalRead(uint8_t pin);

unsigned long now millis();
unsigned long now micros();
```

ESP Arduino APIs

```
class {
    void restart();
    uint32_t getFreeHeap();
    uint32_t getChipId();

    ...
} ESP;

// Usage
ESP.restart();
```

ESP

```
// Top of file
#include <ESP8266WiFi.h>

// In setup()
WiFi.mode(WIFI_STA);
WiFi.begin(ssid, password);
```

```
while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
}

Serial.println("");
Serial.println("WiFi connected");
Serial.println("IP address: ");
Serial.println(WiFi.localIP());
```

ESP Arduino APIs

```
class {
    String macAddress();

    wl_status_t status();
    int32_t RSSI();

    IPAddress localIP();
    IPAddress subnetMask();
    IPAddress gatewayIP();
    IPAddress dnsIP(uint8_t dns_no = 0);

    ...
} WiFi;

// Usage:

Serial.println(WiFi.localIP().toString());
```

http://arduino-esp8266.readthedocs.io/en/latest/libraries.html

What is IoT

What is IoT

- Not “a computer connected to the internet”
  - Then it is really just another computer connected to the internet
- Must be something else
  - It is simply devices that are resource constrained
    - Usually in more than one way
- Autonomous operation, the connection might not be permanent

IoT is just a concept

- *The Internet of Things (IoT) is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect and exchange data.*[1]

What is an IoT Device?

As for their definition.

What differentiates a computer from an IoT device?

What is an IoT Device?

- Constrained in (one or more of):
  - Memory
  - CPU
  - Network bandwidth and/or latency
  - Storage
- Has connectivity
  - Bluetooth
  - Wi-Fi
  - NB-IoT
  - LTE Cat-M
  - LoRa
  - Proprietary radio

Might not have:

- RTC

Extra features:

- IR
- UART
- CAN

Sparkfun and Adafruit etc sell modules with all of these technologies.

IoT Devices - Example chips

Protocol	Chip	Specs
Bluetooth 4/5	nRF52x	32-64 MHz, Cortex-M0/M4F,

[1] Wikipedia "Internet of Things"

Protocol	Chip	Specs
		24-256k RAM, 192-1024 k Flash, $1.88-$3.85
WiFi	ESP8266/ESP32	80MHz-160MHz, 1-2 cores, ~80k RAM, < $1 - $4.53
LoRa	Semtech	$3.23 - $4.74

BT and Wi-Fi has many, many more chips. Technologies based on open/accessible standards. LoRa is much more closed and driven by a single company.

4.53 is quantity=10

LoRa chips are just trancievers, an MCU with LoRa stack is required.

ESP8266 details - Power usage

State	Current usage
Off	0.5 µA
Deep sleep with RTC	20 µA
Light sleep (with Wi-Fi)	1 mA
Sleep with peripherials	15 mA
TX	170 mA

Datasheet page 18

Lecture: MQTT

MQTT

- *Message Queuing Telemetry Transport*
- Wikipedia: MQTT

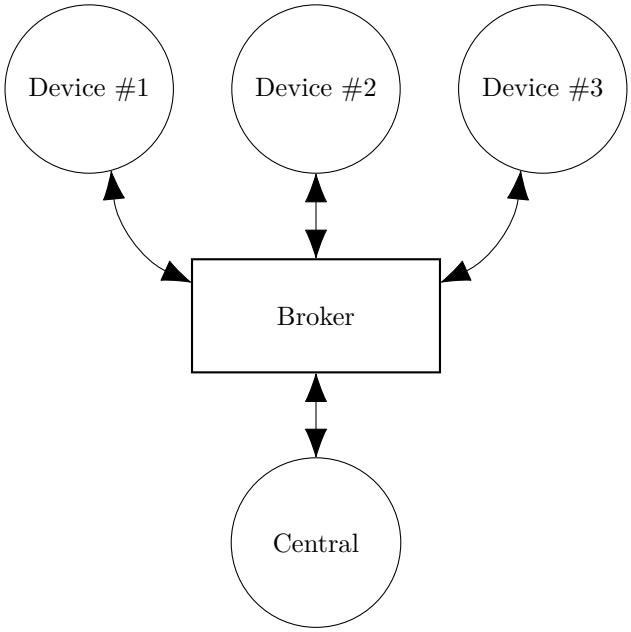
MQTT is *the* standard for IoT applications (and lots of other useful stuff to). Using HTTP is just silly.

Supports SSL, and requires TCP.

Has UDP-like semantics with "fire and forget" but on a higher level (the message always have to be delivered and ACKed by the broker, not it's final recipient.

Version 3.1.1 er den som gjelder, V 3.1 er rar, de andre finnes ikke (før standardisering).

Device and application architecture with MQTT



MQTT Topic

The temperature sensor:

- Publishes on:
  - `myapp/$device-id/temperature`
  - `myapp/$device-id/humidity`
  - `myapp/$device-id/altert`
- Subscribes to:
  - `myapp/$device-id/command`

The central application:

- Subscribes to:
  - `myapp/#/temperature`
  - `myapp/#/humidity`
- Publishes on:
  - `myapp/$device-id/command`

Typical first round of implementation.

Commands can be: * load new firmware (maybe an URL and firmware signature). * Set new calibration values * Change reading interval, altert levels (autonomous operation)

MQTT - Implementations

- Mosquitto
- Eclipse Paho
- RabbitMQ
- ActiveMQ

RabbitMQ has a separate connector that must be installed Not sure about ActiveMQ but it is at least a part of the project so it is releases at the same time.

MQTT Cloud Connectors

- Cloud
  - Amazon IoT
  - Google Cloud IoT
  - Microsoft Azure IoT
  - CloudMQTT (at Heroku)
- DIY
  - ThingMQ
  - HiveMQ

In between are:

- self hosted
- Generic bridges

MQTT - The protocol

Agents have one of two roles:

- *Client*
  - Publishes *messages*
  - Subscribes / unsubscribes to *topics*
  - Keep alive
- *Broker* (aka Server)
  - Handles network connections
  - Keeps subscriptions
  - Manages client
    - Timeouts and disconnects
    - *(last) will*
  - Persistence of retained messages

network connections: this includes removing closed sockets, client's that doesn't respons to timeouts and duplicate clients.

http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/mqtt-v3.1.1.html

Subscriptions are not permanent. The connection is (unlike HTTP) stateful.

Some messages may be persistent, but only one per topic. You will often end up with a "proper" mq on the backend if queuing is needed.

Push vs pull, central applications can push to clients

MQTT - The protocol - MQTT Topic

- Topic name: `foo/bar/baz`
- Topic filter
  - `foo/bar/?`
  - `foo/#`

MQTT - The protocol - Retained message

Message is kept by the server even after disconnect

- `CONNECT`
- `PUBLISH`
  - `RETAIN`
  - `$app/$device/temperature`
  - `22.3`
- `DISCONNECT`

Later on:

- `SUBSCRIBE`
  - `$app/#/temperature`
- `PUBLISH`
  - `$app/$device/temperature`
  - `22.3`

The last PUBLISH is an incoming message

MQTT - The protocol - Will message

Message sent when you disconnect

Client #1:

1. `CONNECT`
   - `WILL TOPIC: $app/$device/online`
   - `WILL PAYLOAD: 0`
2. `PUBLISH`
   - `$app/$device/online`
   - `1`

3. `DISCONNECT`

Broker

1. *To all subscribers* `PUBLISH`
   - `$app/$device/online`
   - `0`

MQTT on Arduino

PubSubClient is our MQTT client implementation.

```
#include <PubSubClient.h>

WiFiClient wifiClient;
PubSubClient mqtt(wifiClient);

void callback(char* topic,
              byte* payload,
              unsigned int length);

void setup() {
    // Configure WiFi
    mqtt.setServer(mqtt_server, 1883);
    mqtt.setCallback(callback);
}
```

MQTT on Arduino

```
void loop() {
    if (!mqtt.connected()) {
        reconnect();
    }
    else {
        mqtt.loop();
    }

    // Do work
}

void reconnect() {
    do {
        Serial.println("Connecting to MQTT");
    } while (!mqtt.connect(client_id));
    Serial.println("Connected to MQTT server");
```

```
    // Subscribe to any topics you need
    mqtt.subscribe(topic_pattern);
}
```

This is blocking!

Assignment

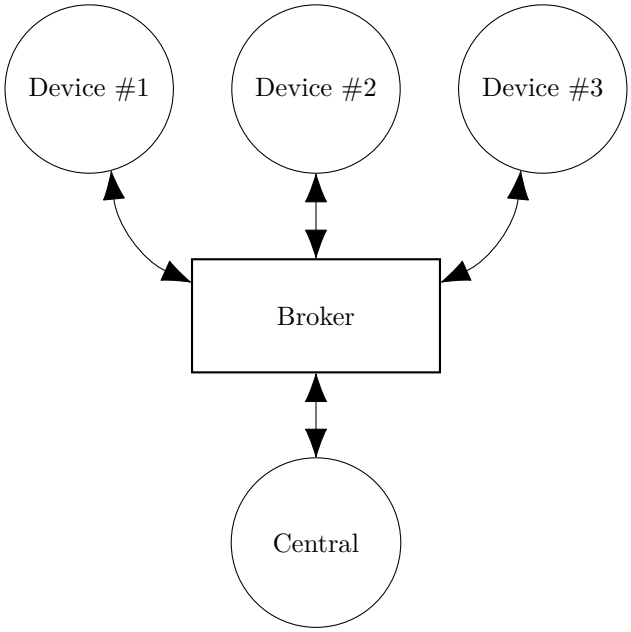
- `mqtt`

MQTT topic architecture

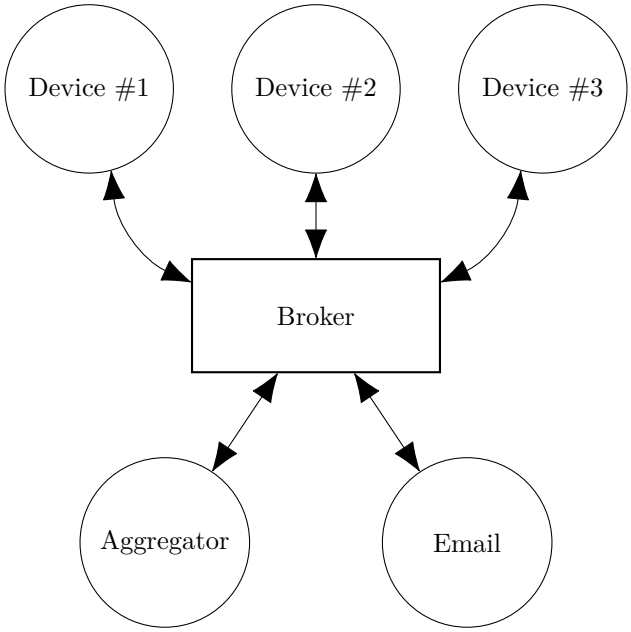
The central application is split:

- An aggregating agent:
  - `myapp/#/temperature`
  - `myapp/#/humidity`
- Emailing agent
  - `myapp/$device-id/altert`
- Publishes on:
  - `myapp/$device-id/command`

MQTT topic architecture



MQTT topic architecture



MQTT - Patterns

- Combining MQTT and HTTP
- Using web sockets transport

Assignment

- `mqtt2`

Assignment

- `mqtt3`

discussion: how to connect these two devices?