Internet of Things
Data Acquisition to Machine Learning.

Ciira wa Maina
cwamaina.dekut@gmail.com

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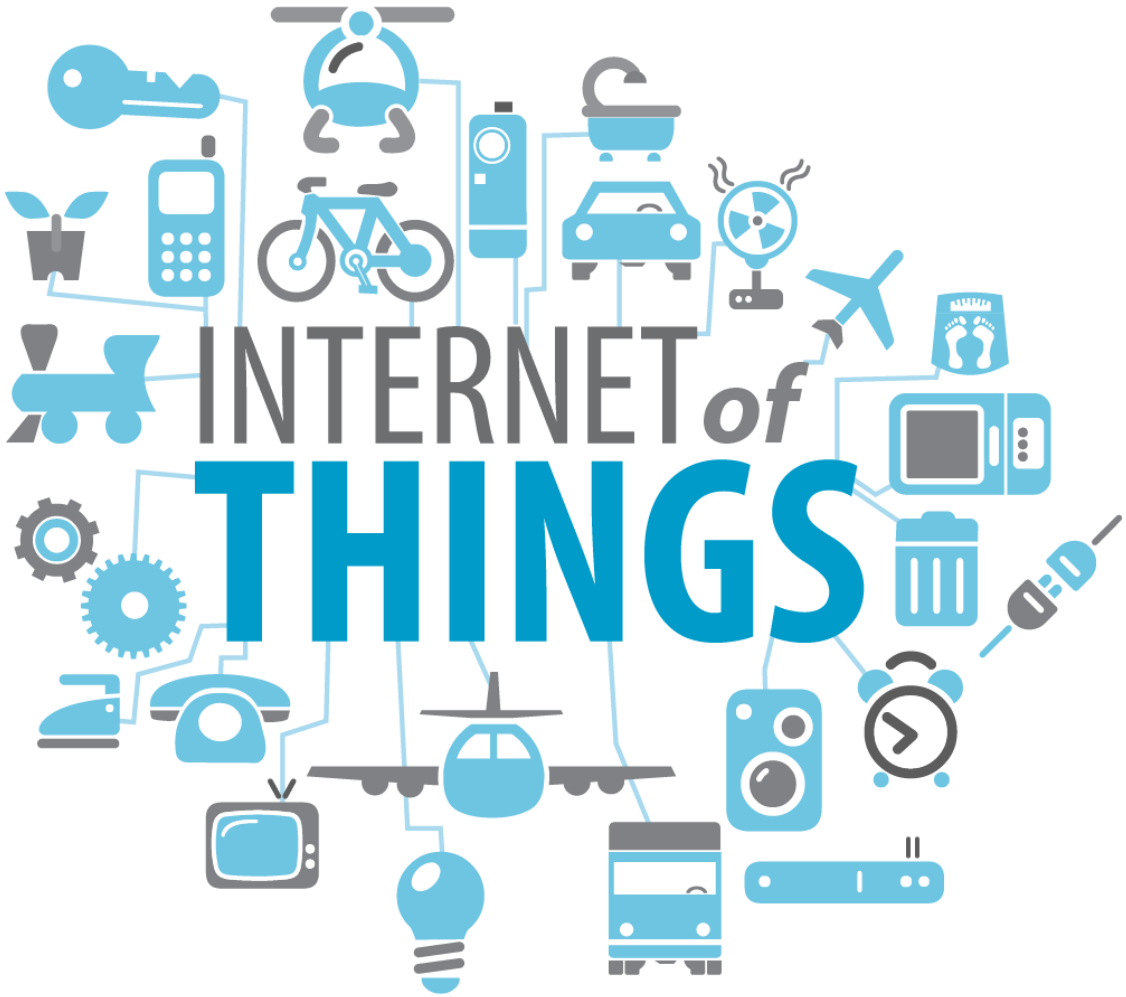
The Internet of Things

- Connecting things over the internet
- We can measure physical states and use this information to guide actions



Internet of Things

Adding digital inputs/outputs to physical things - Jan Jongboom

Use Cases Closer Home

- Agriculture, Environmental Monitoring, ...

Getting the Data

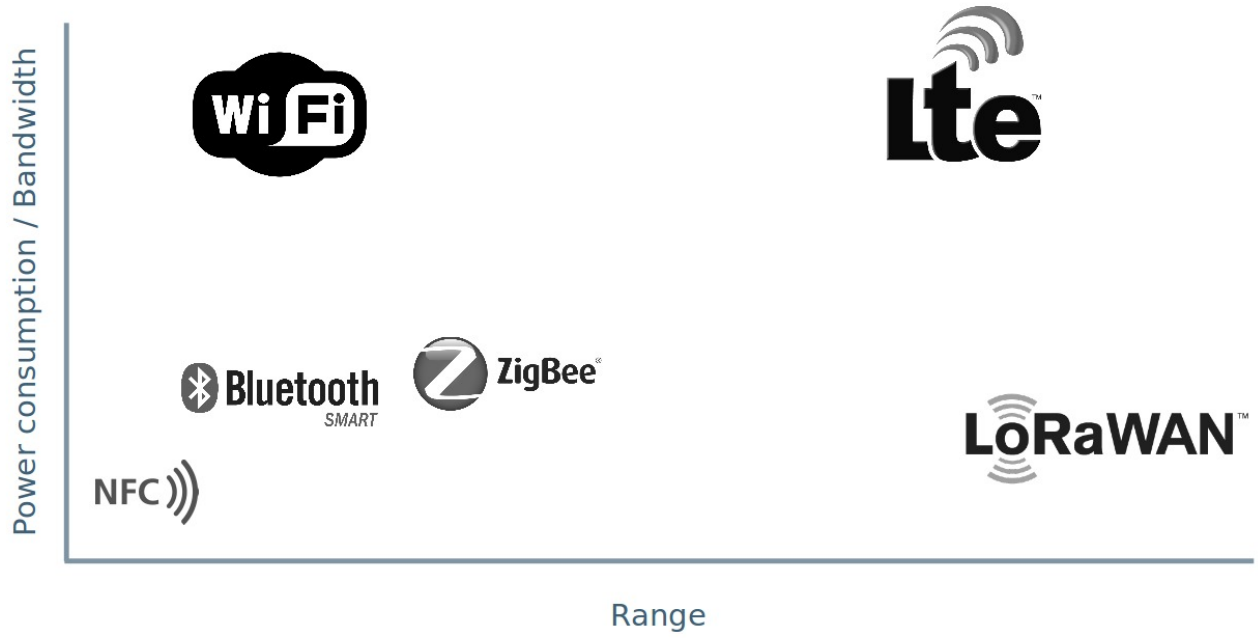
- Before data scientists can work their magic on data, it must be acquired
- Sensor systems provide a rich data source
- But data acquisition is not always easy...

Getting the Data

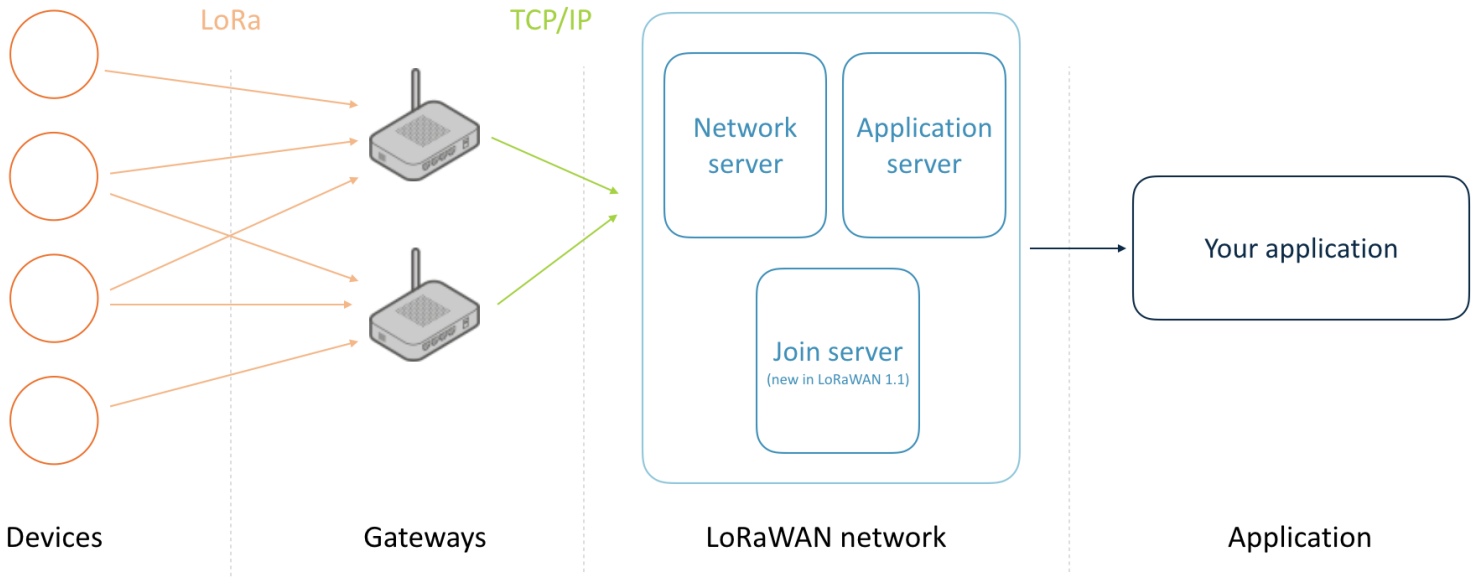
- It may also require armed escort!

LoRa

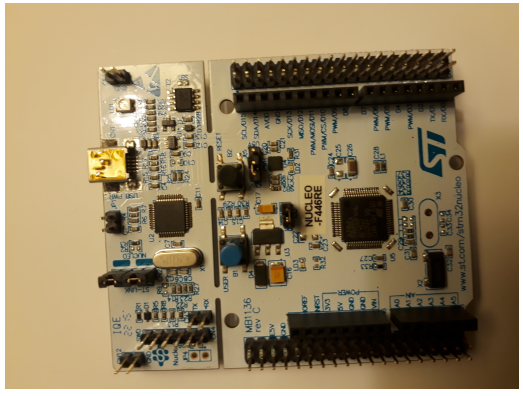
- Low power, long range network
- Ideal for low bandwidth situations such as sending sensor data

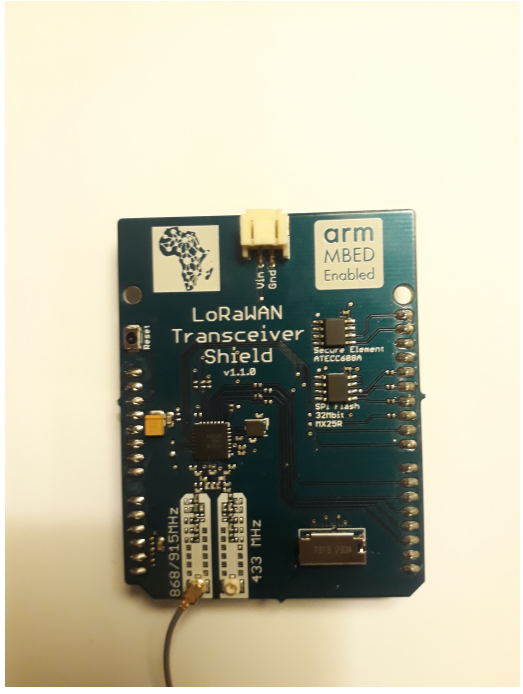


LoRa Networks



Devices


NUCLEO
-F446RE


arm
MBED
Enabled
LoRaWAN
Transceiver
Shield
v1.1.0
868/915MHz
433 MHz

Mbed OS

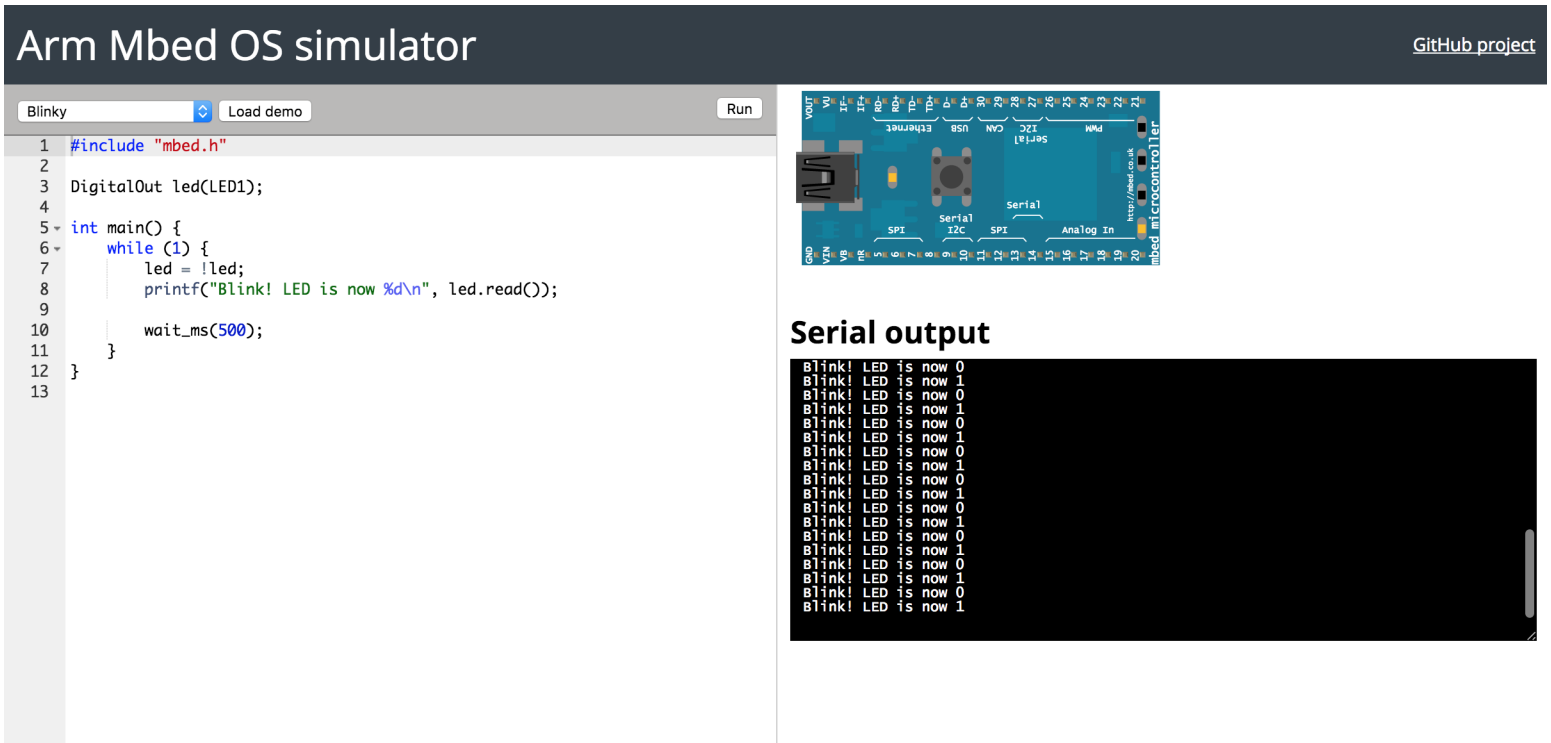
- A free, open-source operating system for embedded devices
- Ideal for IoT
- Allows development of applications in C/C++

Mbed OS

- Mbed OS implements
  - Radio drivers
  - Networking
  - Hardware drivers
  - Storage
- Allows rapid prototyping

Mbed OS Code Development

- Online compiler `https://os.mbed.com/compiler`
- Offline CLI
- Try things out on the online simulator `https://labs.mbed.com/simulator`



Built with Mbed mbed.com/built-with-mbed/

- Babbler: A device to monitor cargo on transit

Built with Mbed

- A device to monitor tilting of power poles

Gateways


kerlink


MULTITECH
MultiConnect Conduit


THE THINGS NETWORK
THE THINGS GATEWAY
THE THINGS GATEWAY

Gateways

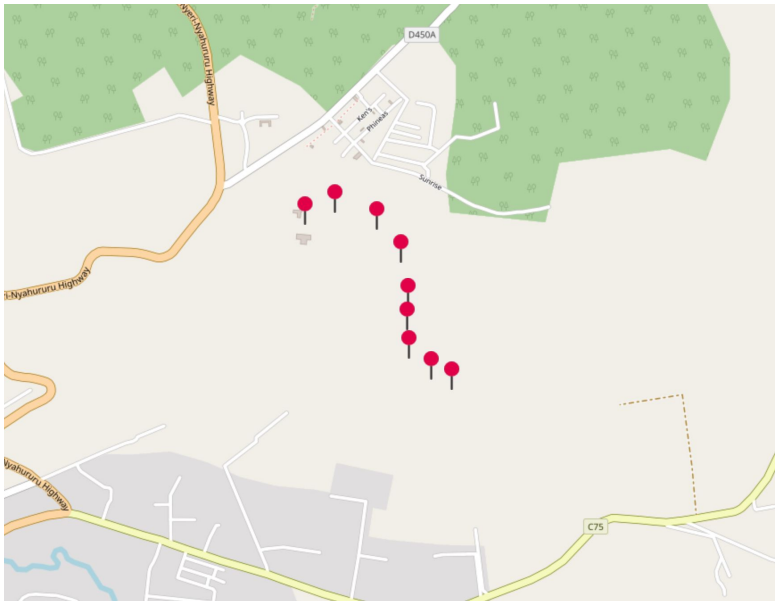
- Gateway placement is important! The higher the better

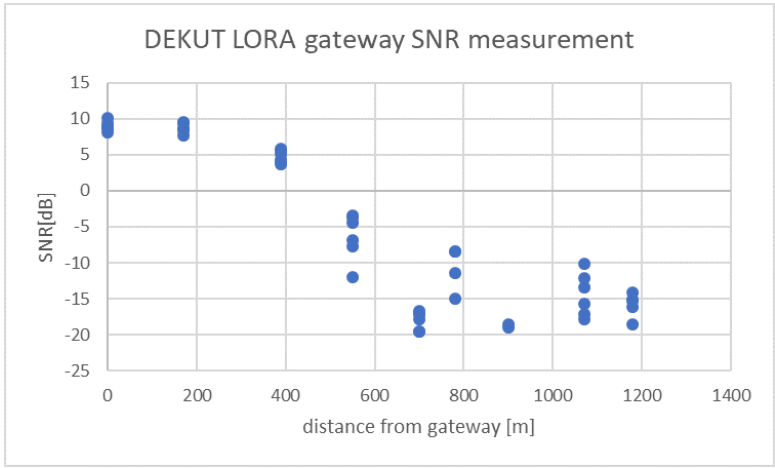
Gateways

- Jared and Stephen taking the gateway to new heights.

Gateways

Gateways


D450A
C75

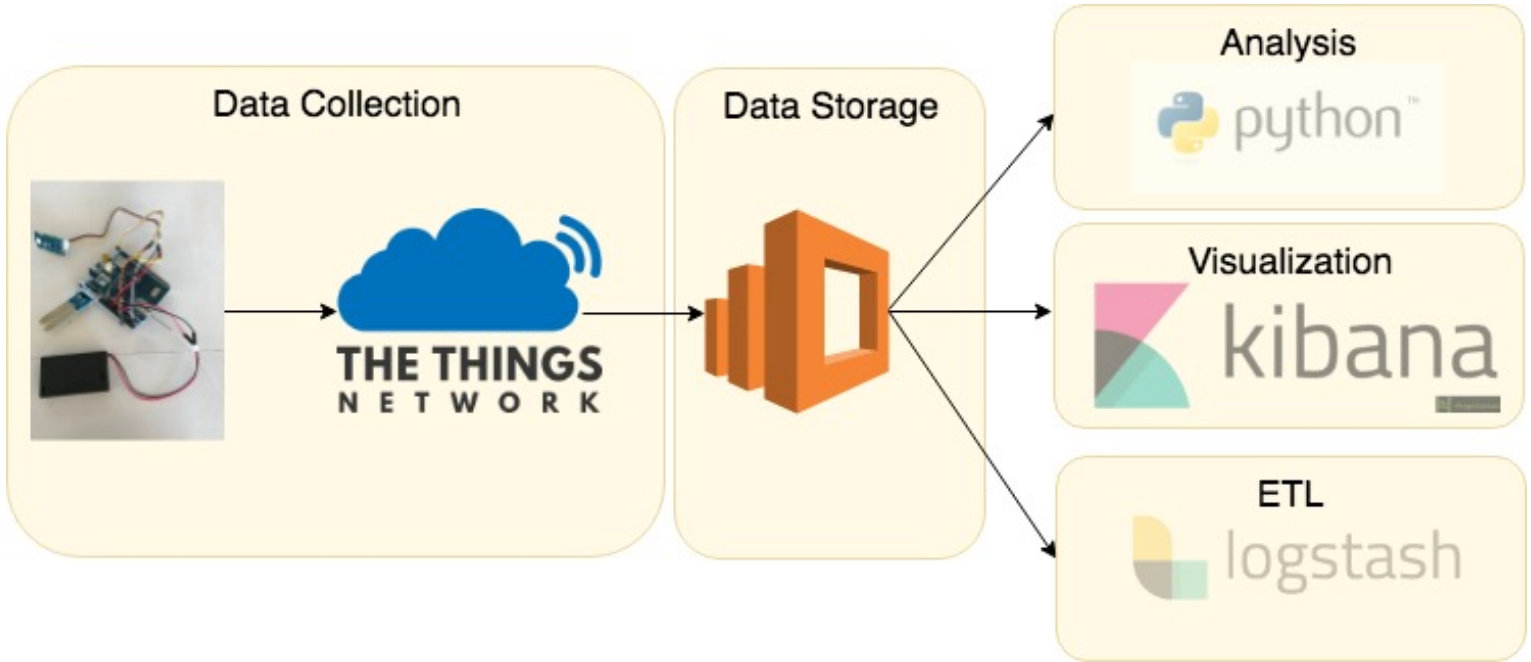

DEKUT LORA gateway SNR measurement
SNR[dB]
15
10
5
0
-5
-10
-15
-20
-25
0
200
400
600
800
1000
1200
1400
distance from gateway [m]

Network Servers

- Servers that understand the LoRa protocol
- Companies offer this as a service

Applications

- The network server forwards data to database
- Database could be from any cloud provider or local host
- Applications query data and use it to guide decisions

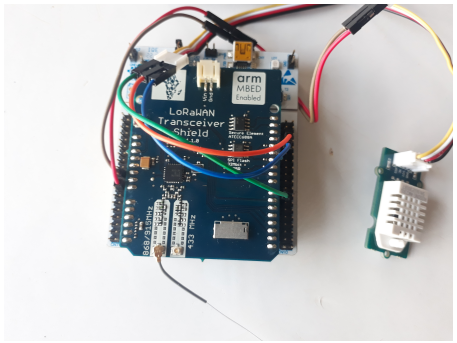


Demo Application

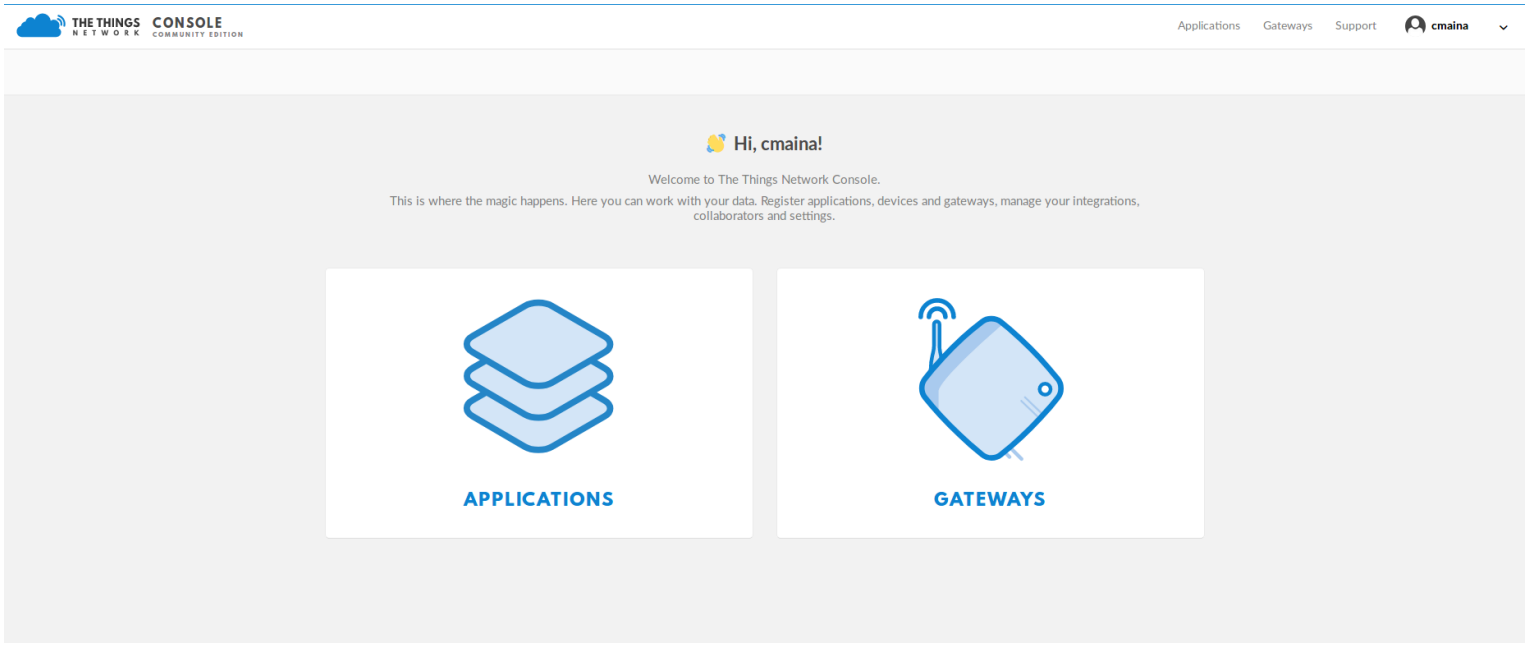
- Temperature and humidity measurement
- Smart office motion detection
- Data transmitted to the Things Network
- Data stored on Amazon Web Services or Cayenne

Sense the Environment

```
56 // Send a message over LoRaWAN
57 static void send_message() {
58     CayenneLPP payload(50);
59     int attempt = 0;
60
61     float temperature = 0.0f;
62     float humidity = 0.0f;
63     int error_code;
64
65     while (attempt++ < SENSOR_READ_ATTEMPTS) {
66       error_code = temperature_humidity_sensor.readData();
67       if (error_code != ERROR_NONE) {
68         printf("Error = %d\n", error_code);
69         wait_ms(SENSOR_WAIT_TIME_MS);
70         continue;
71       } else {
72         temperature = temperature_humidity_sensor.ReadTemperature(CELCIUS);
73         humidity = temperature_humidity_sensor.ReadHumidity();
74         break;
75       }
76     }
```



Set Up Devices on The Things Network



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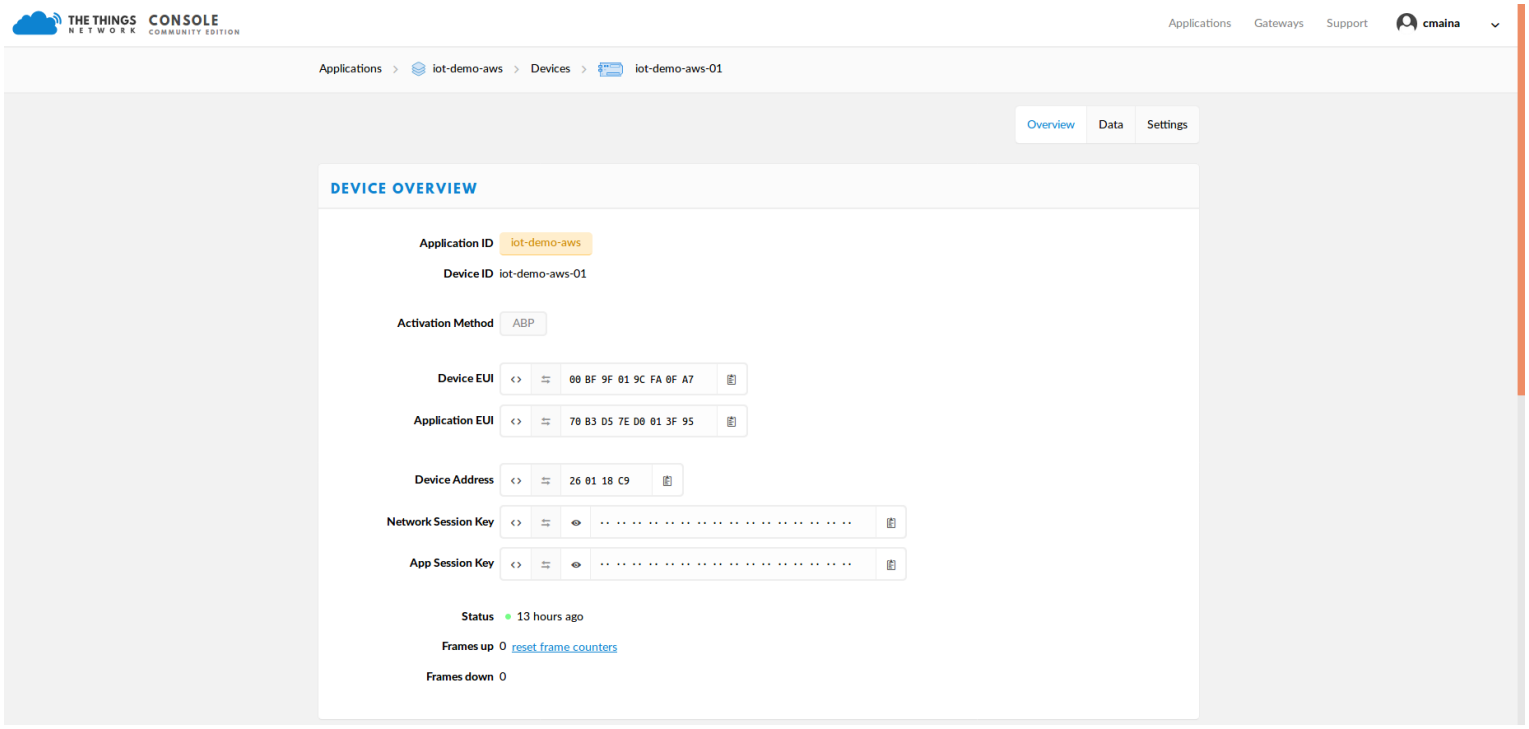
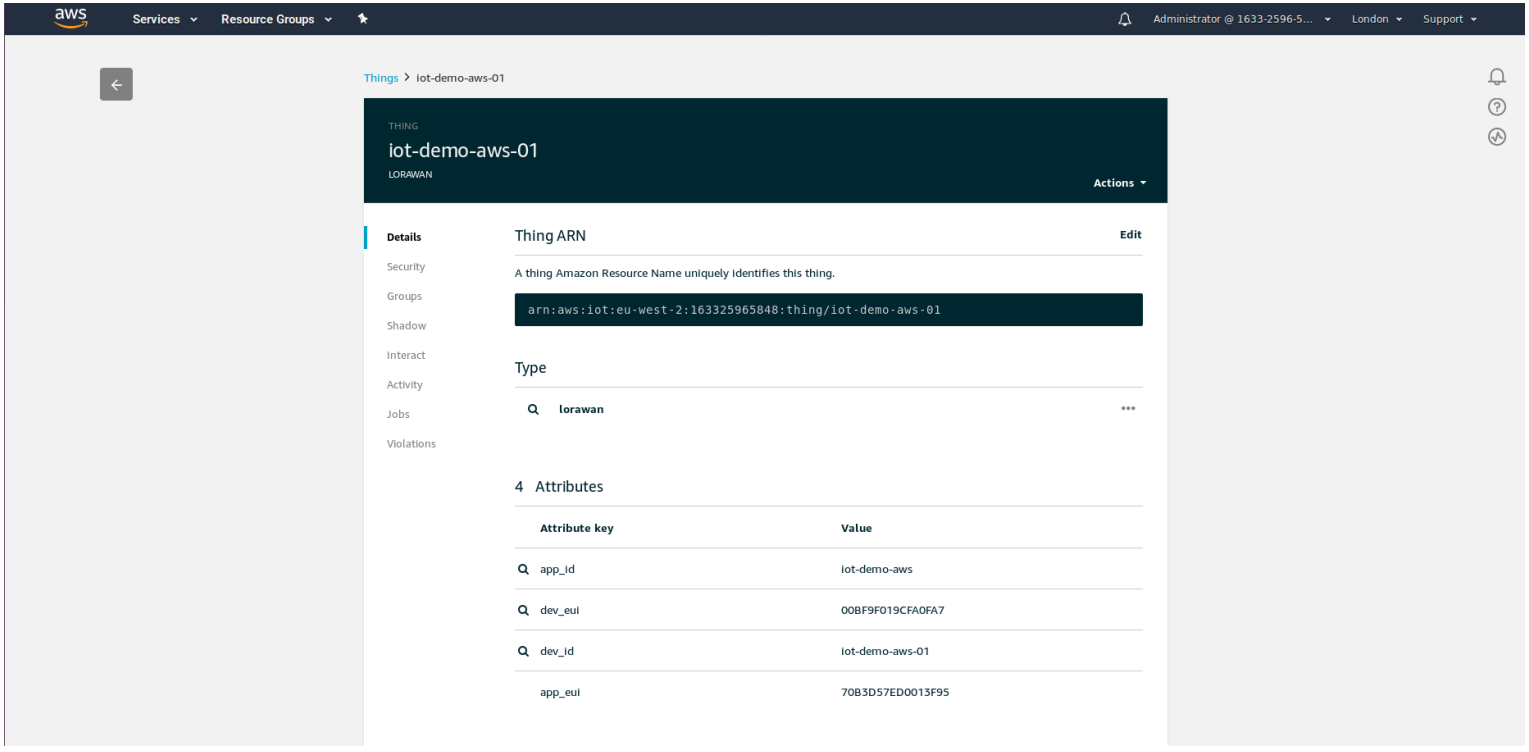
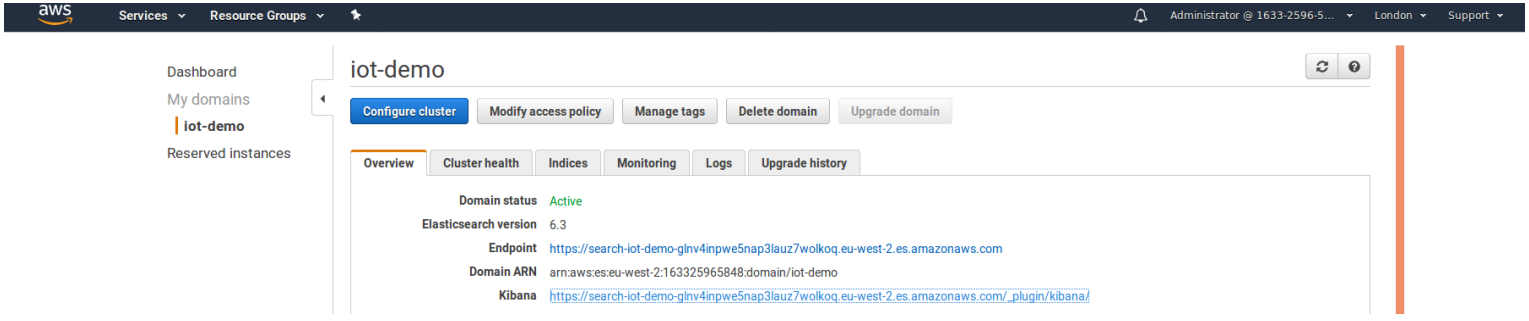


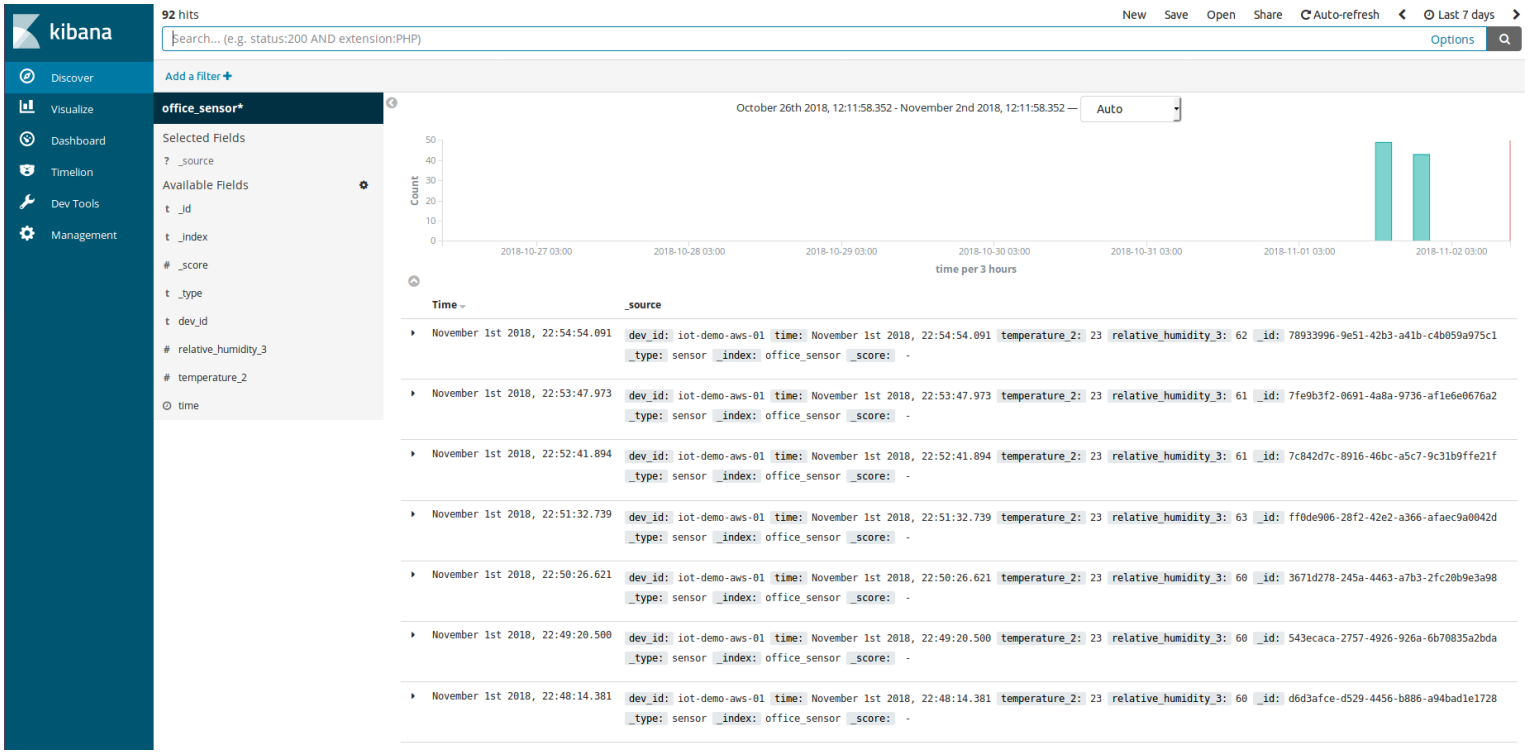
Amazon Web Services Integration



Amazon Web Services Integration - Database

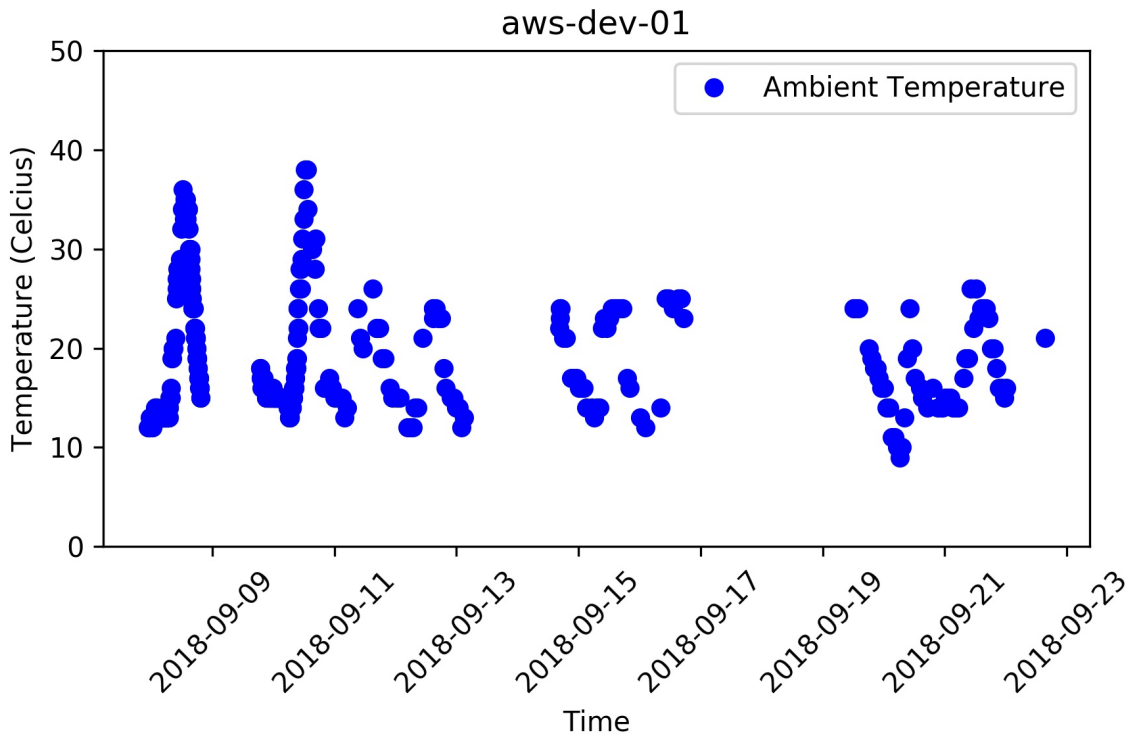


Amazon Web Services Integration - Database



Act on Data

- Visualization
- Monitor variables and guide actions

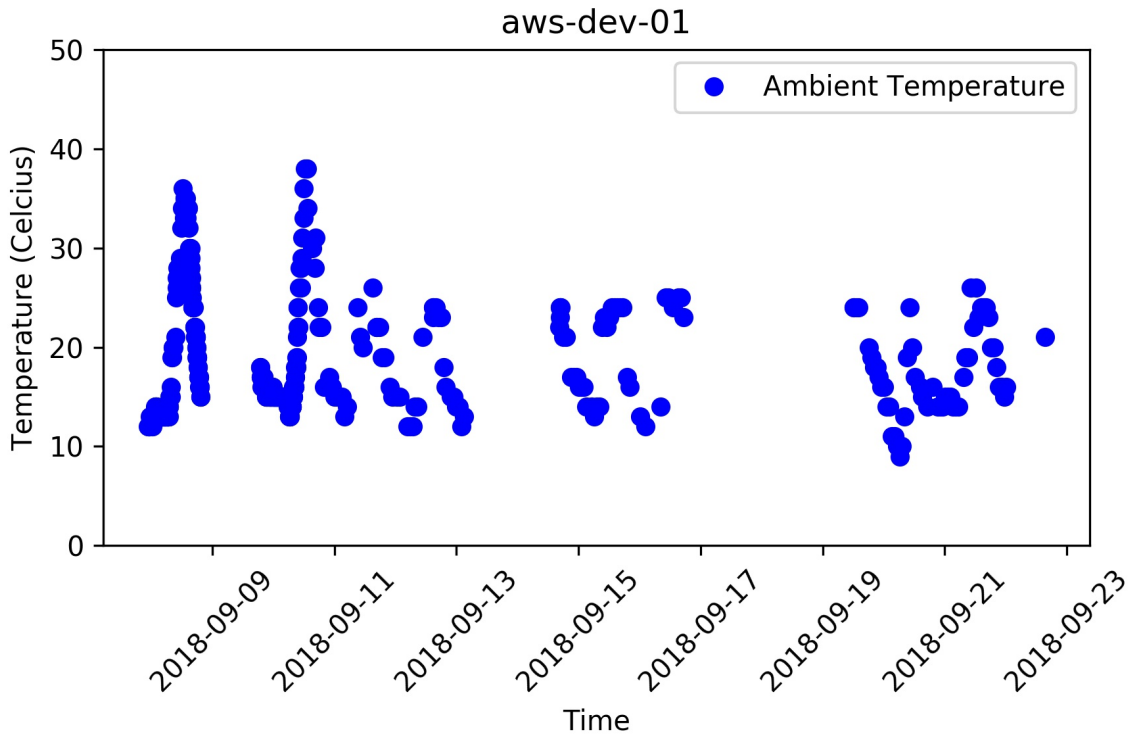


Machine Learning Example

- Temperature data from the coffee farm at DeKUT
- Temperature influences susceptibility to fungal disease
- Current monitoring is manual

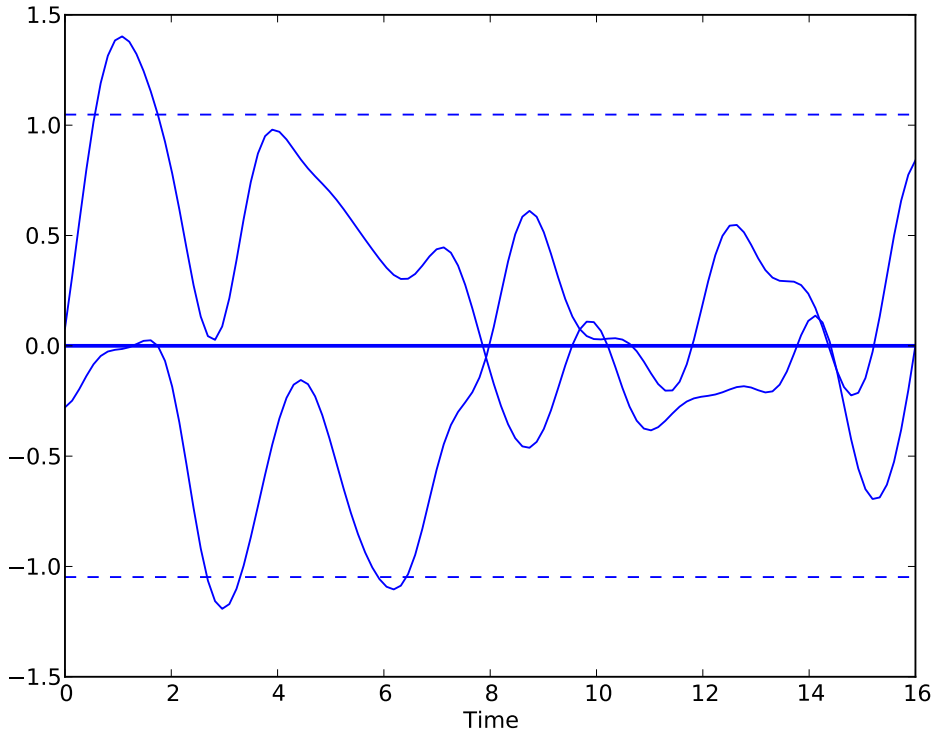
Machine Learning Example

- Gaussian Process regression to fill missing values



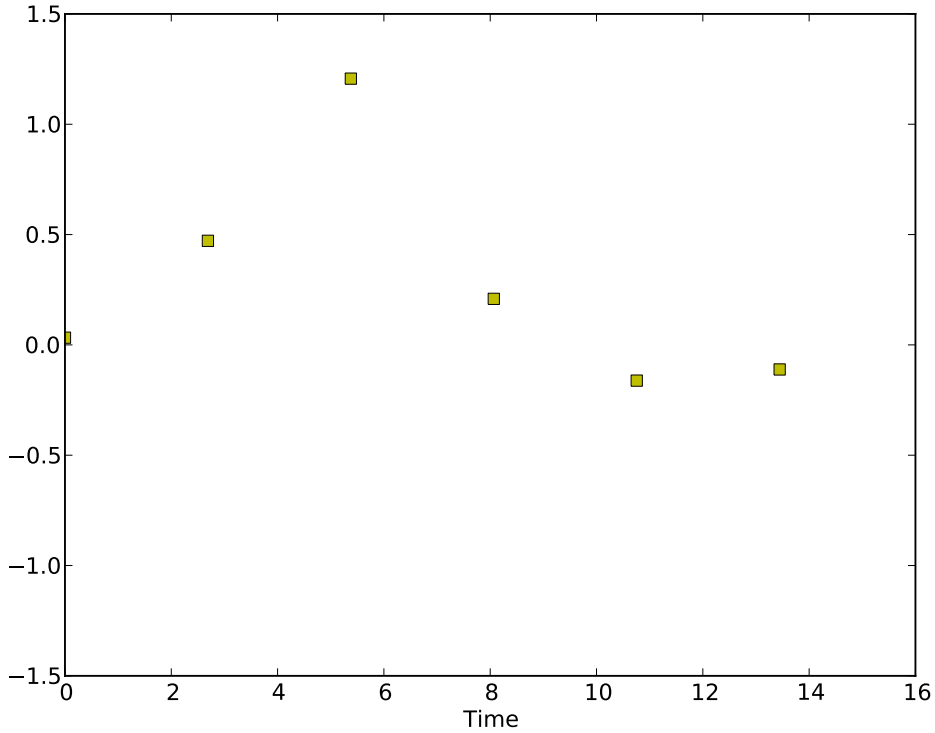
Gaussian Processes

- A Gaussian process (GP) is a distribution over the space of functions.
- This distribution is completely specified by a mean function $m(t)$ and a covariance function $k(t, t')$.
- $f(t) \sim \mathcal{GP}(m(t), k(t, t'))$



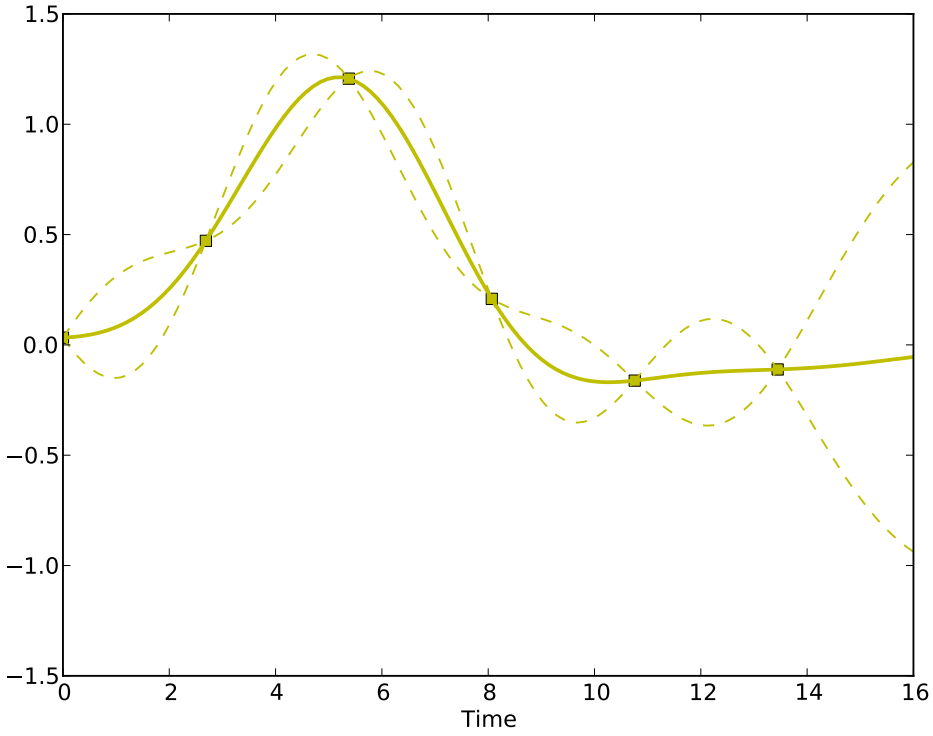
Gaussian Processes cont

- Given observations we would like to infer an interpolant



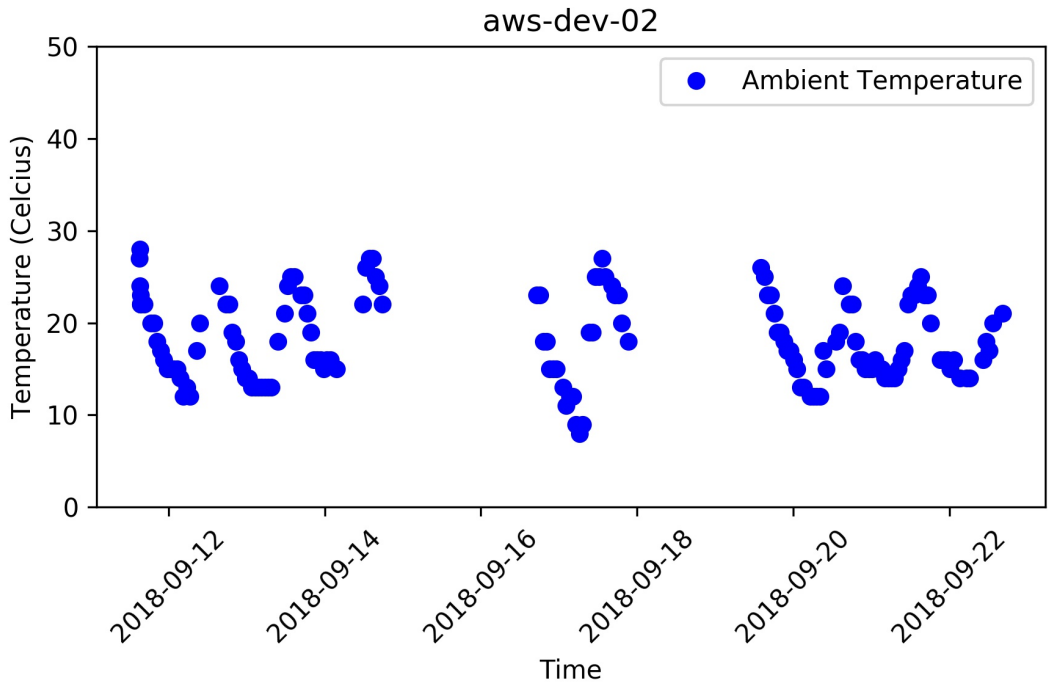
Gaussian Processes cont.

- Posterior distribution of functions given observations



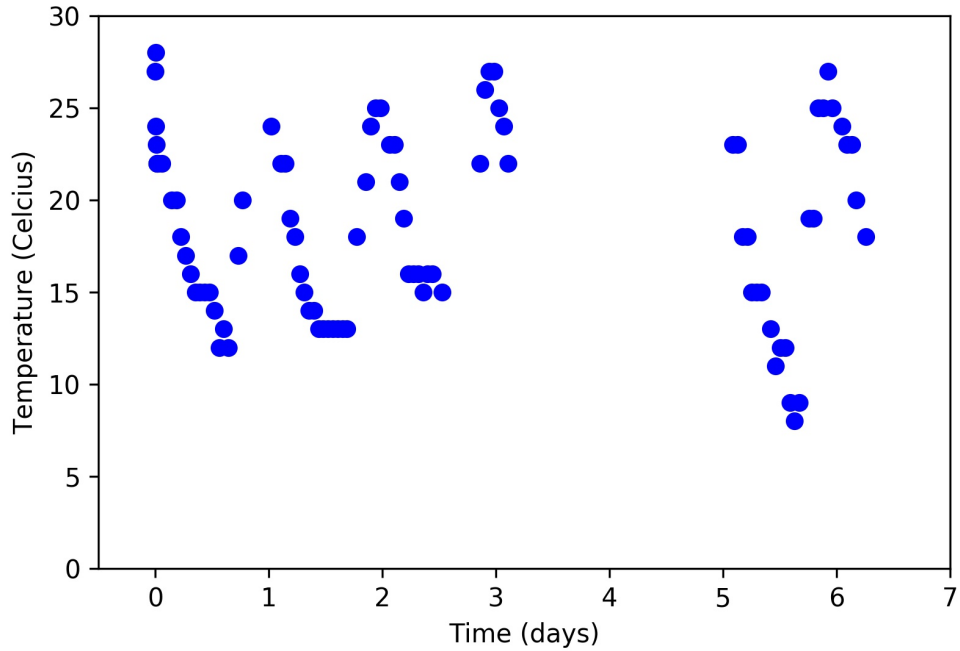
Gaussian Processes cont.

- Original temperature data collected at the DeKUT coffee farm between 11th and 22nd September 2018.



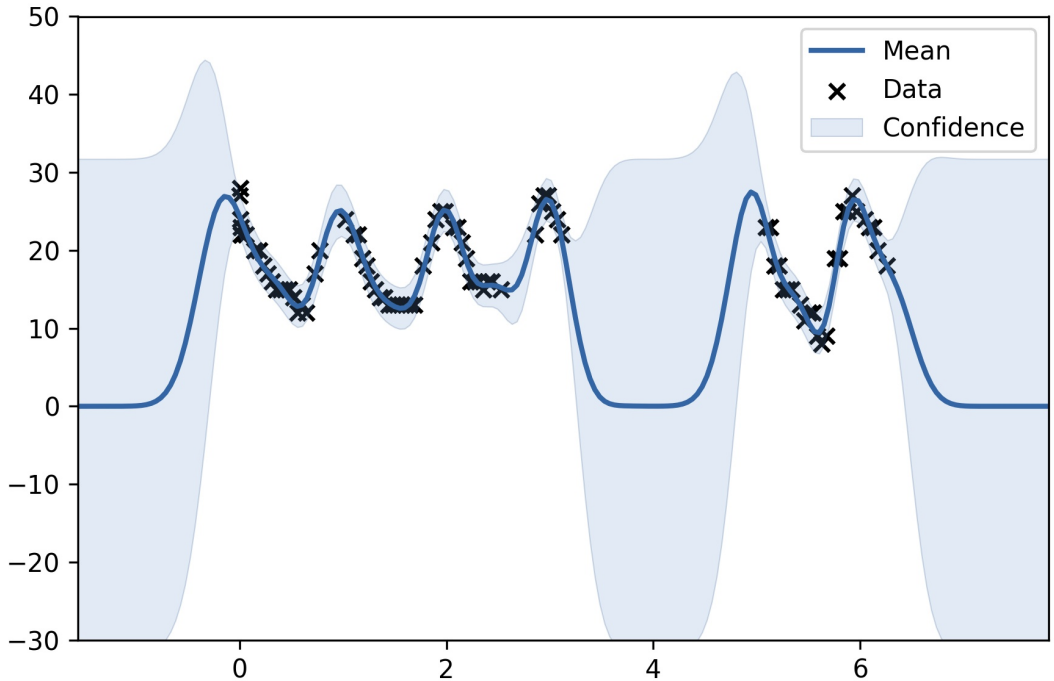
Gaussian Processes cont.

- Same data with time axis normalized in terms of days (first 7 days)
- Missing data from the 3rd and 4th day



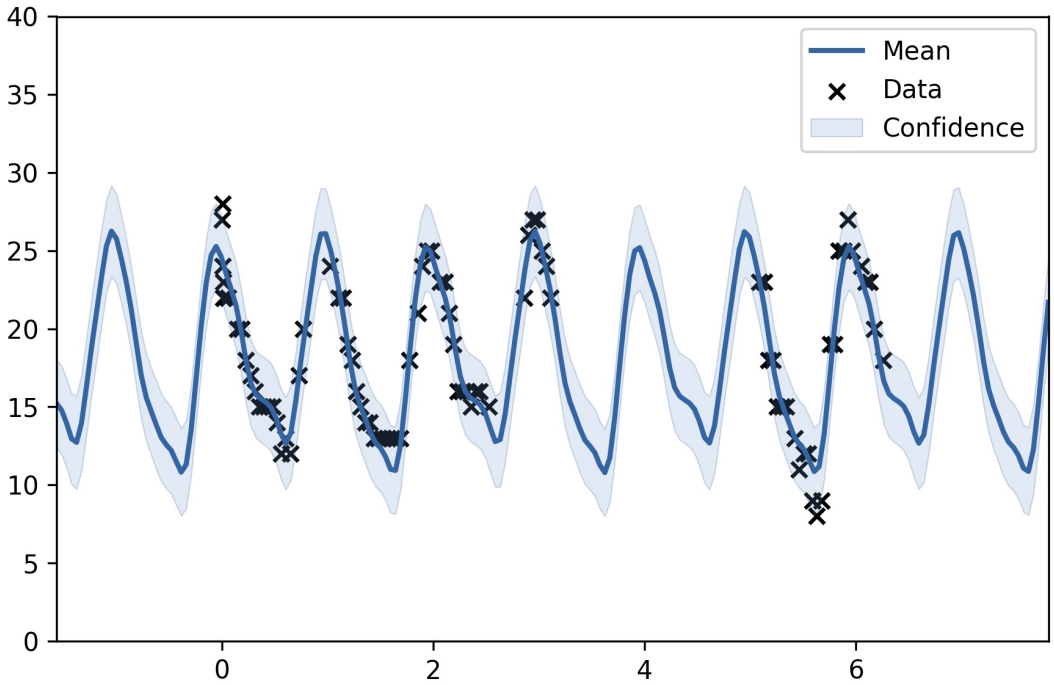
Gaussian Processes cont.

- Gaussian process fit with radial basis function kernel
- Fit using GPy from SheffieldML (`sheffieldml.github.io/GPy/`).



Gaussian Processes cont.

- Gaussian process fit with periodic kernel



Conclusion

- Data acquisition is an important step in data science
- LoRa is ideal for IoT applications requiring low power and long range
- Rapid prototyping is achievable for proof-of-concept
- Finding the ideal use cases is important

Hands on work

- This repo describes the process of programming the Nucleo boards.
  `https://github.com/ciiram/dsa-abuja-mbed-demo`
- This repo reproduces the analysis of the coffee data using Gaussian processes.`https://github.com/ciiram/dsa-abuja-demo`

Thank You