Exploring the Internet of Things for Agricultural Applications

Experiments at the Dedan Kimathi University of Technology.

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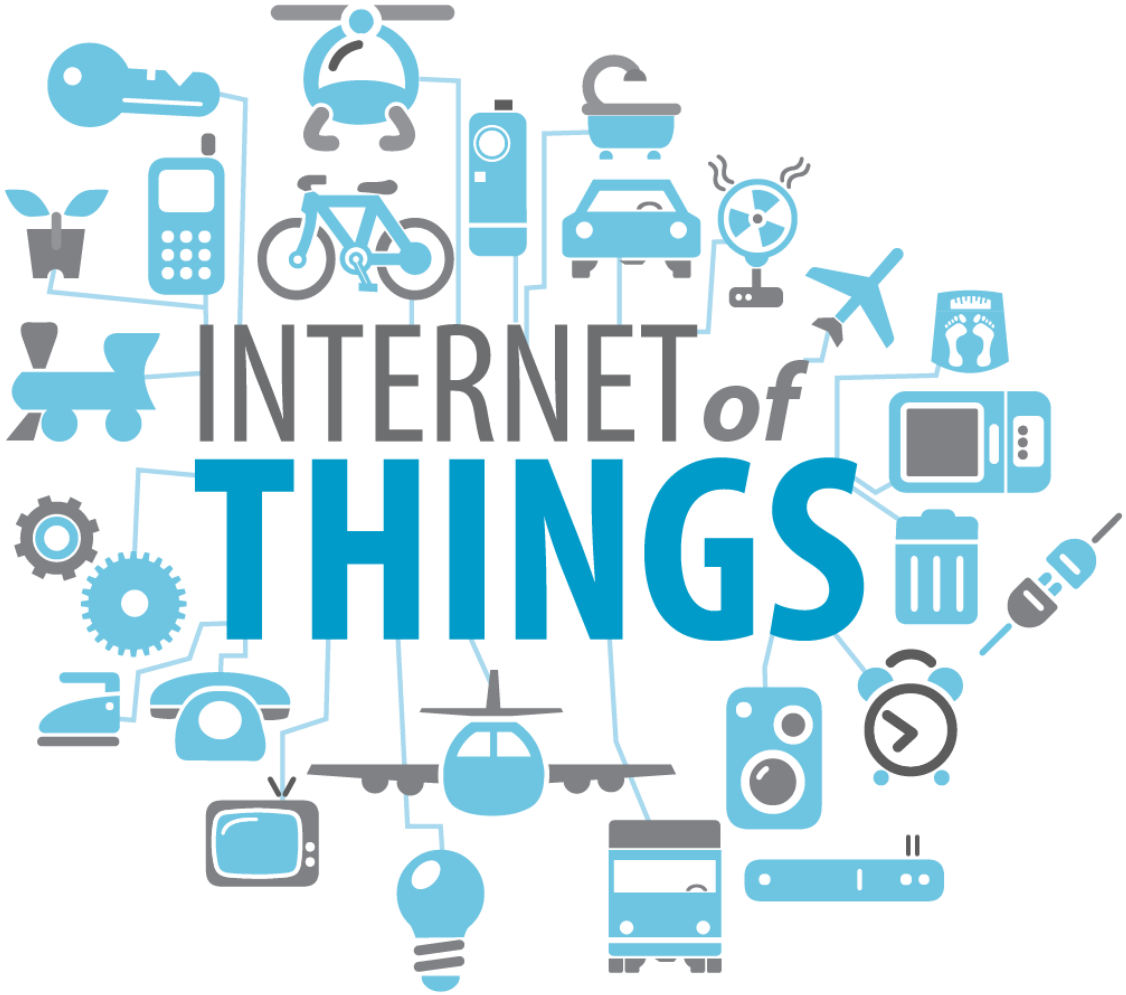
The Internet of Things

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



Use Cases Closer Home

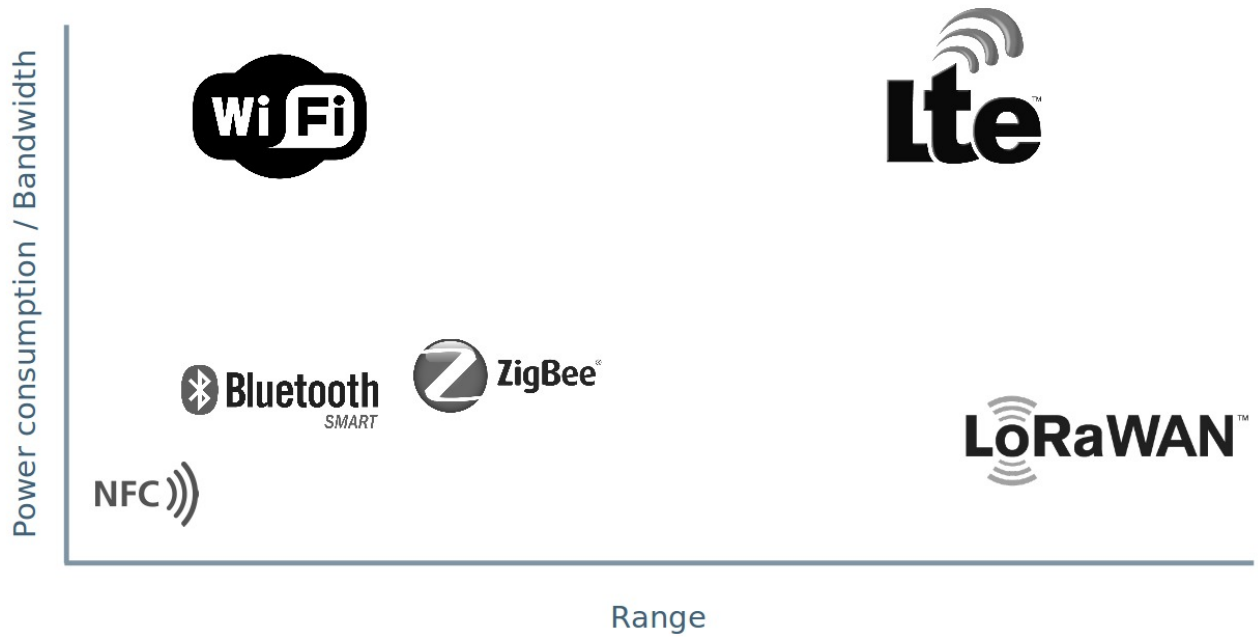
- Agriculture, Environmental Monitoring, ...

Getting the Data

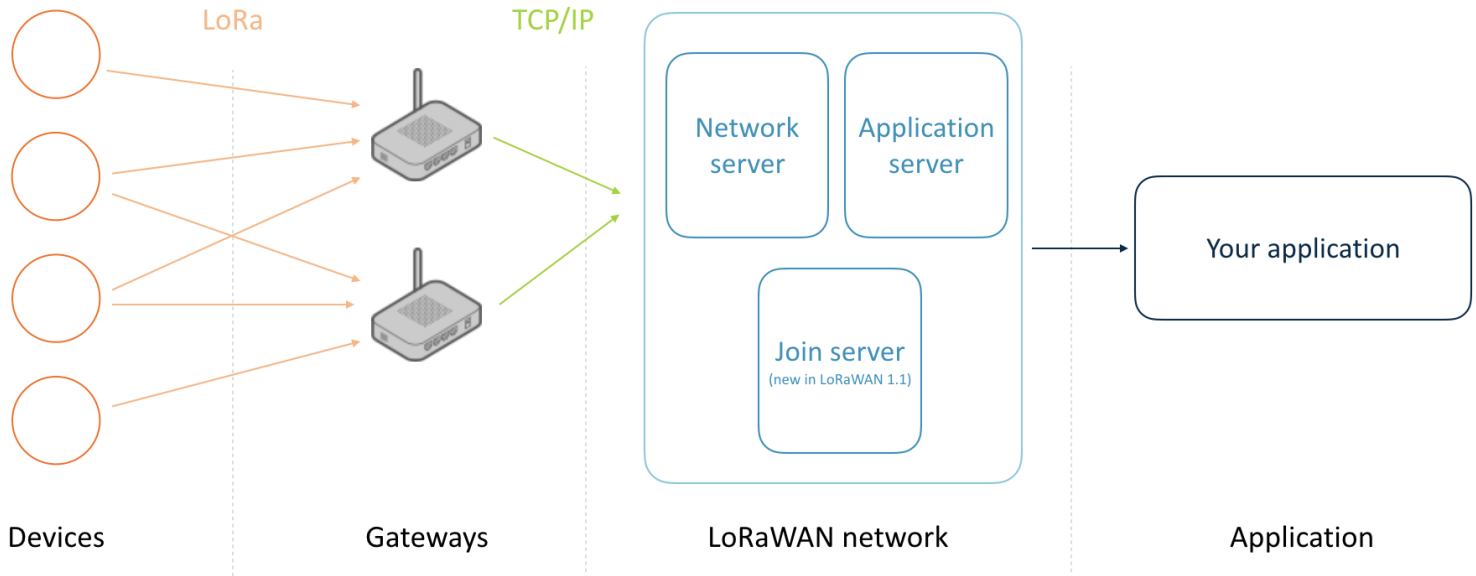
- Before data can be processed, it must be acquired
- Sensor systems provide a rich data source
- But data acquisition is not always easy...

LoRa

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

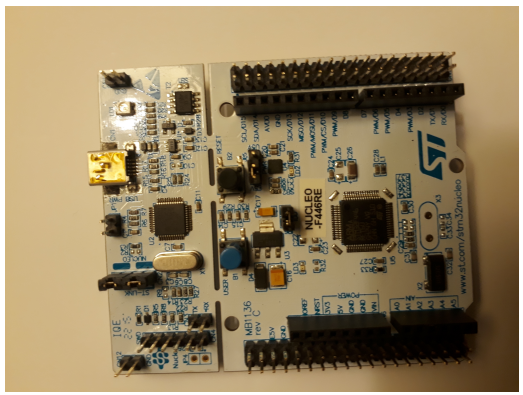


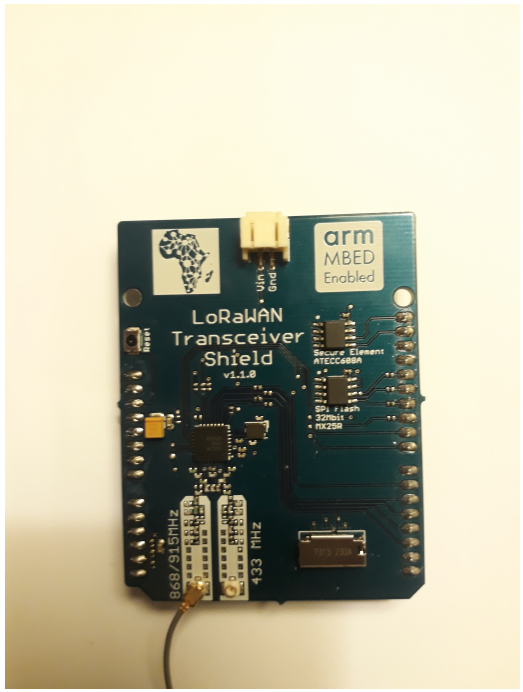
LoRa Networks



Devices

- STM32 Nucleo boards
- Custom LoRaWAN Shields
- Donated by ARM for Data Science Africa, Nyeri, 2018
  `http://www.datascienceafrica.org/dsa2018/`





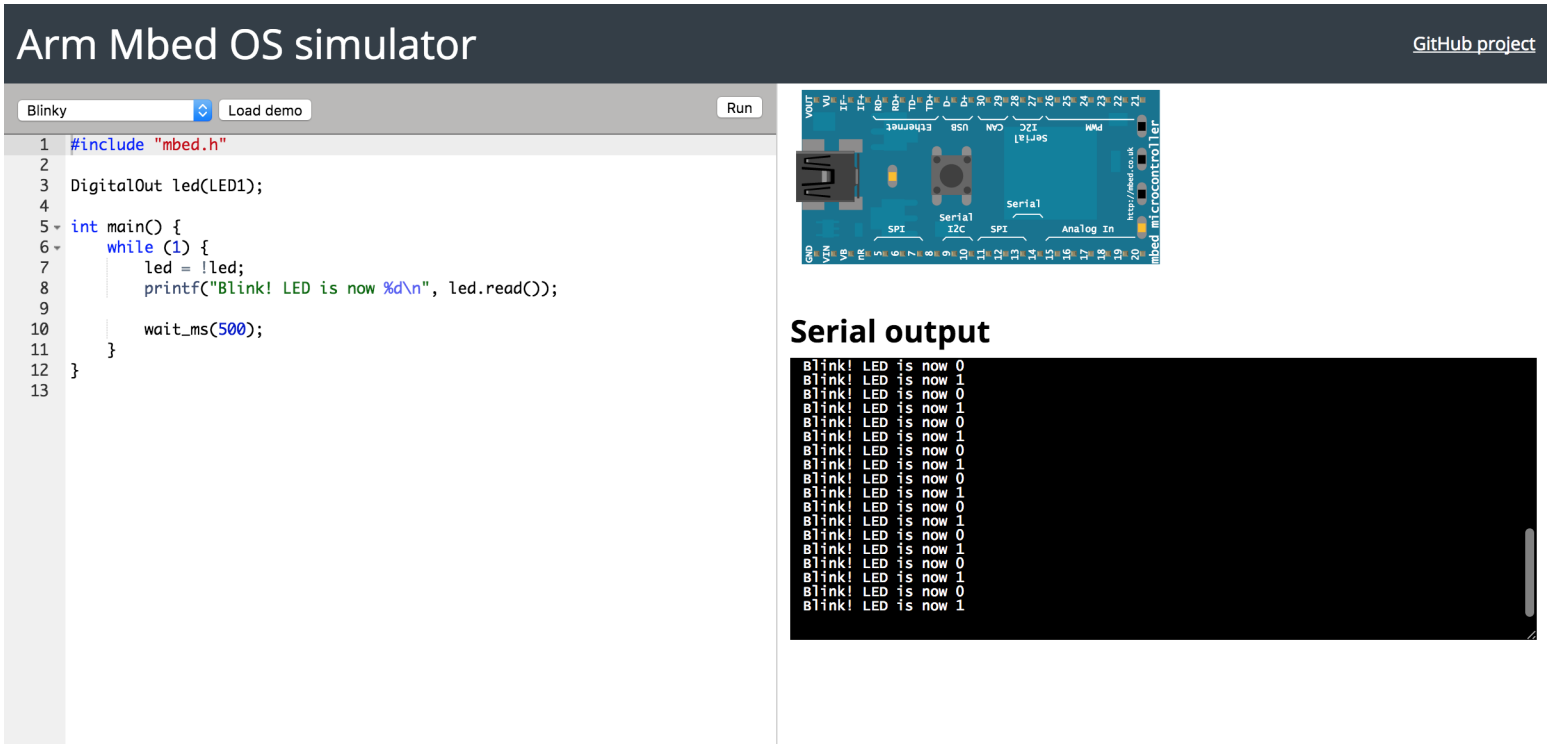
Mbed OS

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

arm
MBED

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`



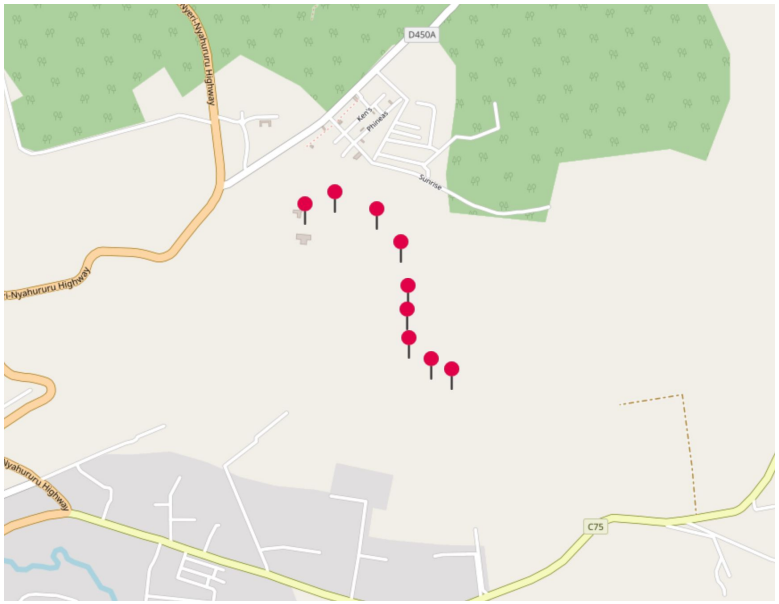
Built with Mbed mbed.com/built-with-mbed/

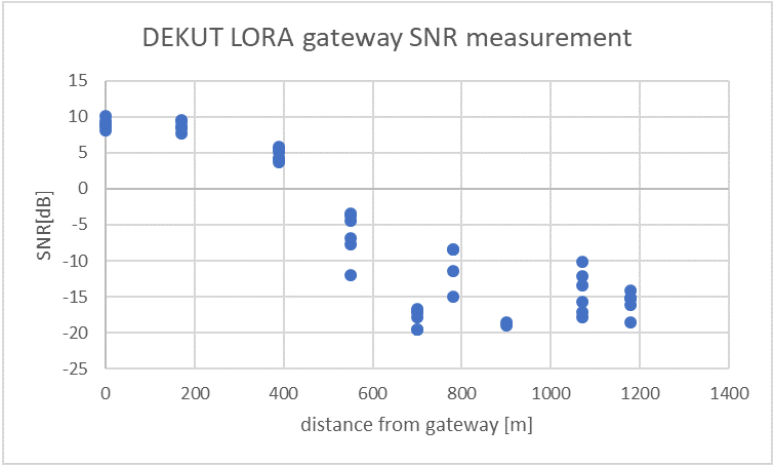
- Babbler: A device to monitor cargo on transit

Gateways

- Gateway placement is important! The higher the better

Gateways


D450A
C75

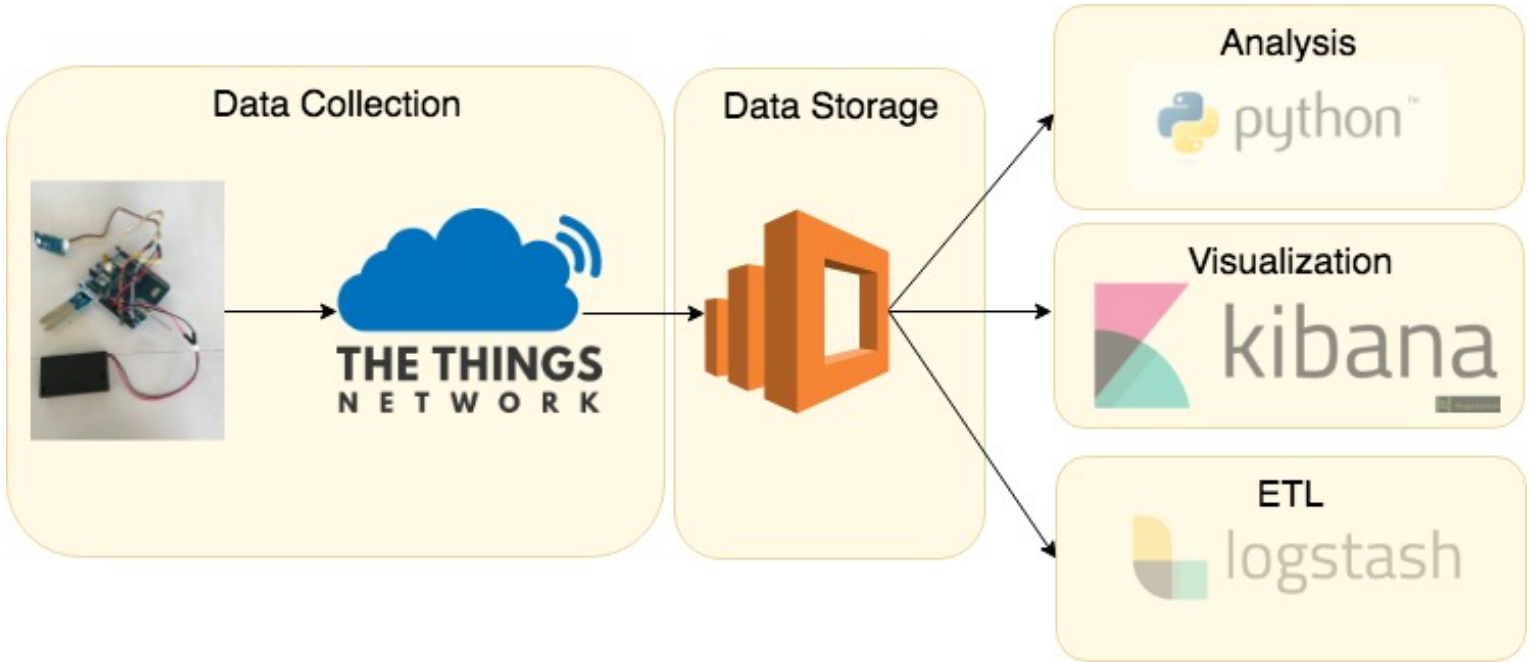

DEKUT LORA gateway SNR measurement
SNR[dB]
15
10
5
0
-5
-10
-15
-20
-25
0
200
400
600
800
1000
1200
1400
distance from gateway [m]

Network Servers

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

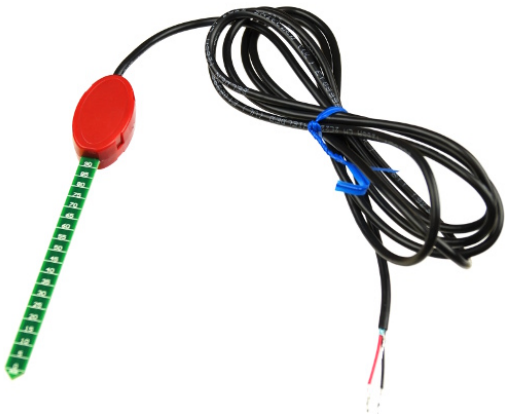
Applications

- 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



Agricultural Applications

- Temperature, soil moisture and humidity measurement
- Sensor interfaced to microcontroller and read using code
- Data transmitted to the Things Network
- Data stored on Amazon Web Services or Cayenne



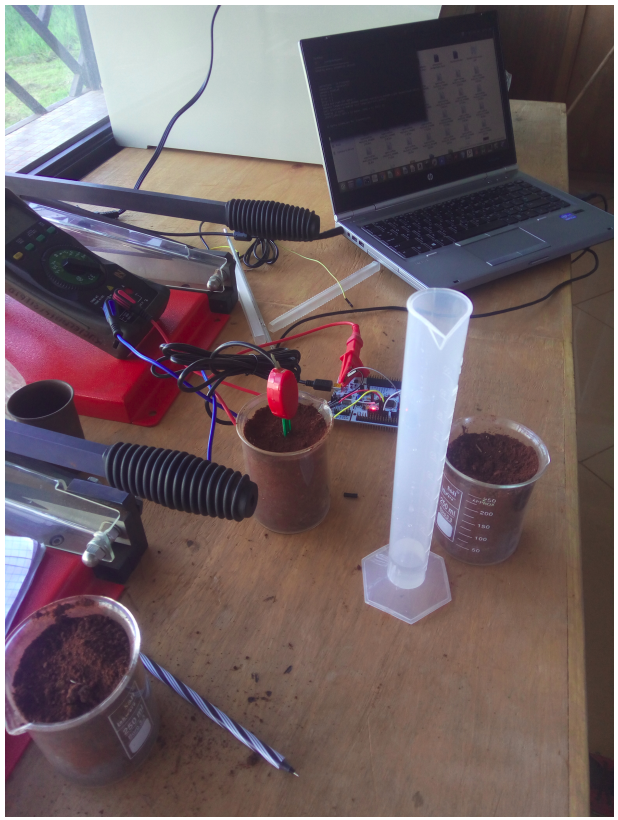
```
// Send a message over LoRaWAN
static void send_message() {
    CayenneLPP payload(50);
    int attempt = 0;

    float temperature = 0.0f;
    float humidity = 0.0f;
    int error_code;

    while (attempt++ < SENSOR_READ_ATTEMPTS) {
      error_code = temperature_humidity_sensor.readData();
      if (error_code != ERROR_NONE) {
        printf("Error = %d\n", error_code);
        wait_ms(SENSOR_WAIT_TIME_MS);
        continue;
      } else {
        temperature = temperature_humidity_sensor.ReadTemperature(CELCIUS);
        humidity = temperature_humidity_sensor.ReadHumidity();
        break;
```

Calibration

- Sensor calibration is important
- Soil sensors calibrated using soil from the farm
- Plots of volumetric water content to sensor output voltage determined

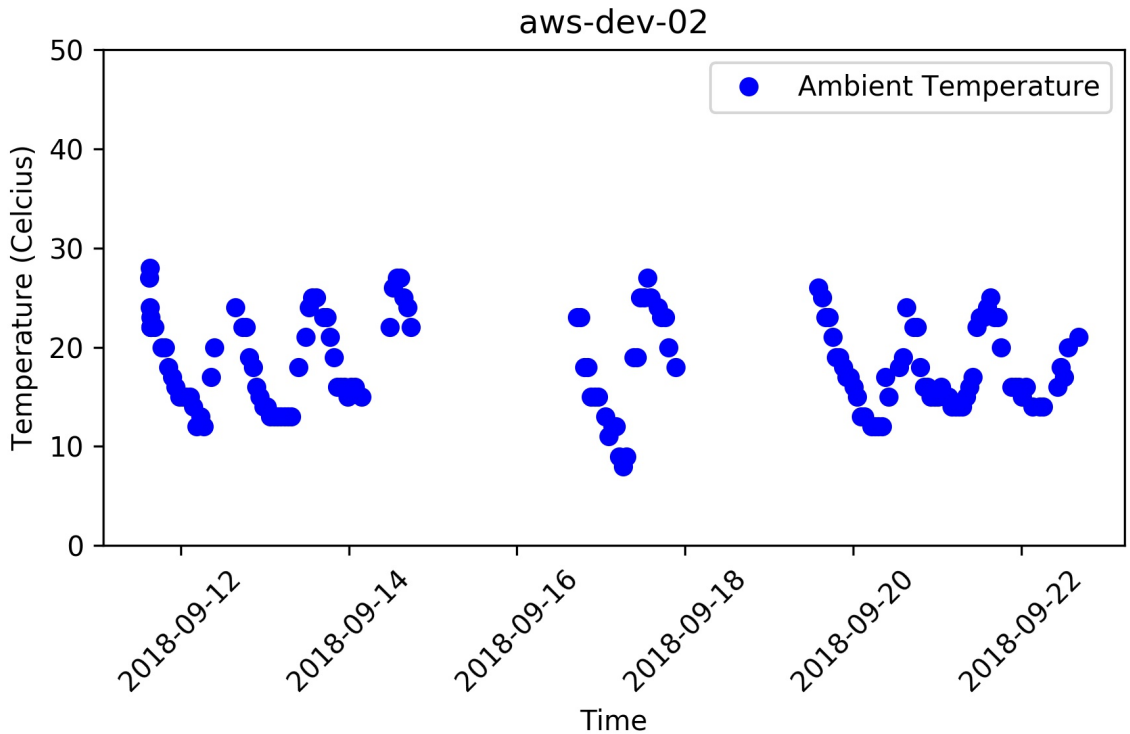


Coffee Data Analysis

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

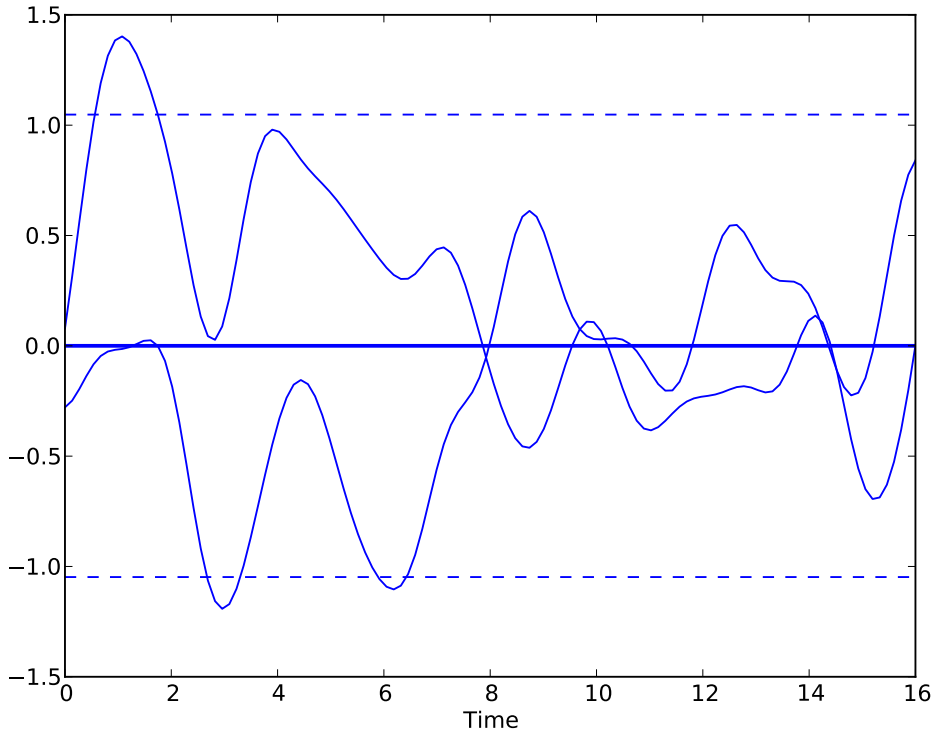
Machine Learning Example

- Gaussian Process regression to fill missing values



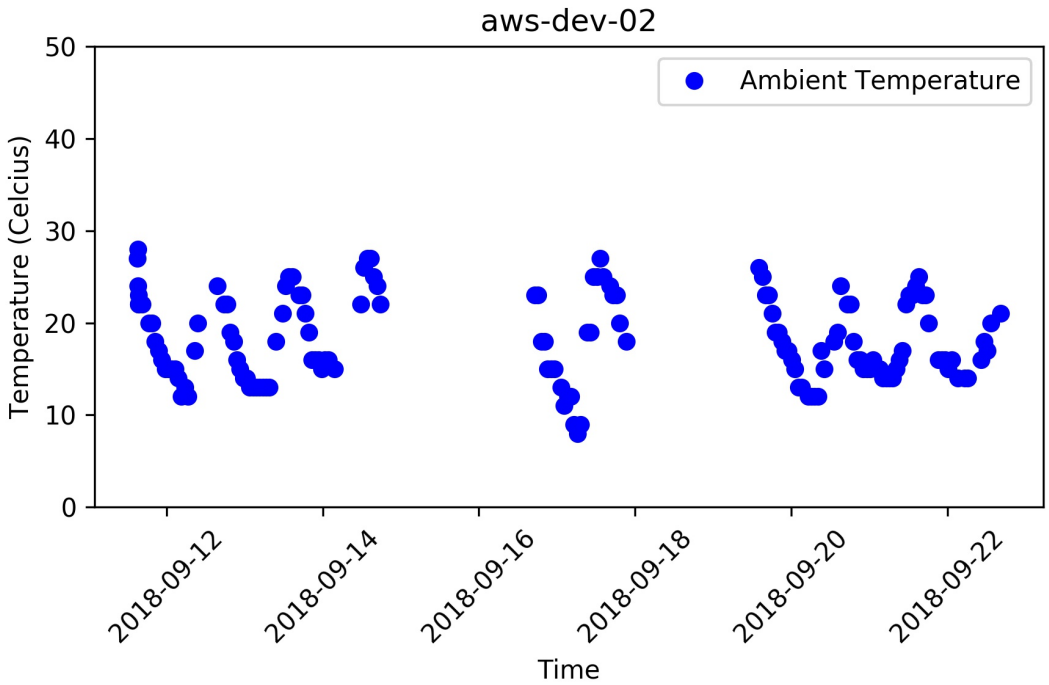
Gaussian Processes

- 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 $k(t, t')$.
- $f(t) \sim \mathcal{GP}(m(t), k(t, t'))$



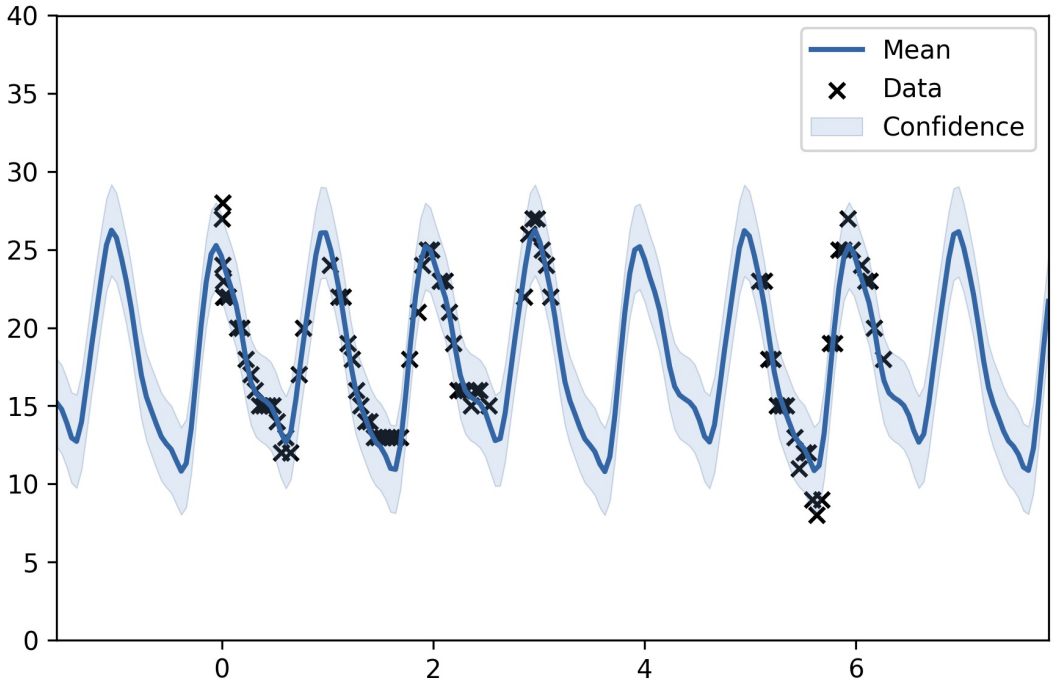
Gaussian Processes cont.

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



Gaussian Processes cont.

- Gaussian process fit with periodic kernel using GPy from SheffieldML (`sheffieldml.github.io/GPy/`)



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
- Power management and gateway placement are important challenges

Code Available

- Code for the coffee monitoring project
  `https://github.com/ciiram/nyeri-coffee`
- 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`
- More machine learning content at Data Science Africa
  `http://www.datascienceafrica.org/`

Thank You