Long Range Low Power Sensor Networks for Agricultural Monitoring - A Case Study in Kenya

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kenya

Motivation, problem area

Tomatoes grown in DeKUT greenhouse

- Manual monitoring of greenhouse parameters affects most farmers in Kenya.
- Its ineffectiveness leads to prevalence of pests and diseases, low crop yields, increased labor costs and wastage of resources.
- Lack of data storage services for future inferences.

- Measurements based on individuals feeling and comfort
- Regular manual checking of greenhouse parameters.
- This system gives real-time data analysis, visualization and feedback.
- Saves water, pests and crop diseases mitigation hence optimum crop conditions.

Soil moisture measuring

Greenhouse sensor deployment

General Research Objectives

- To collect, store, analyze and visualize greenhouse data on;

  Ambient temperature.

  Soil moisture.

  Soil temperature.

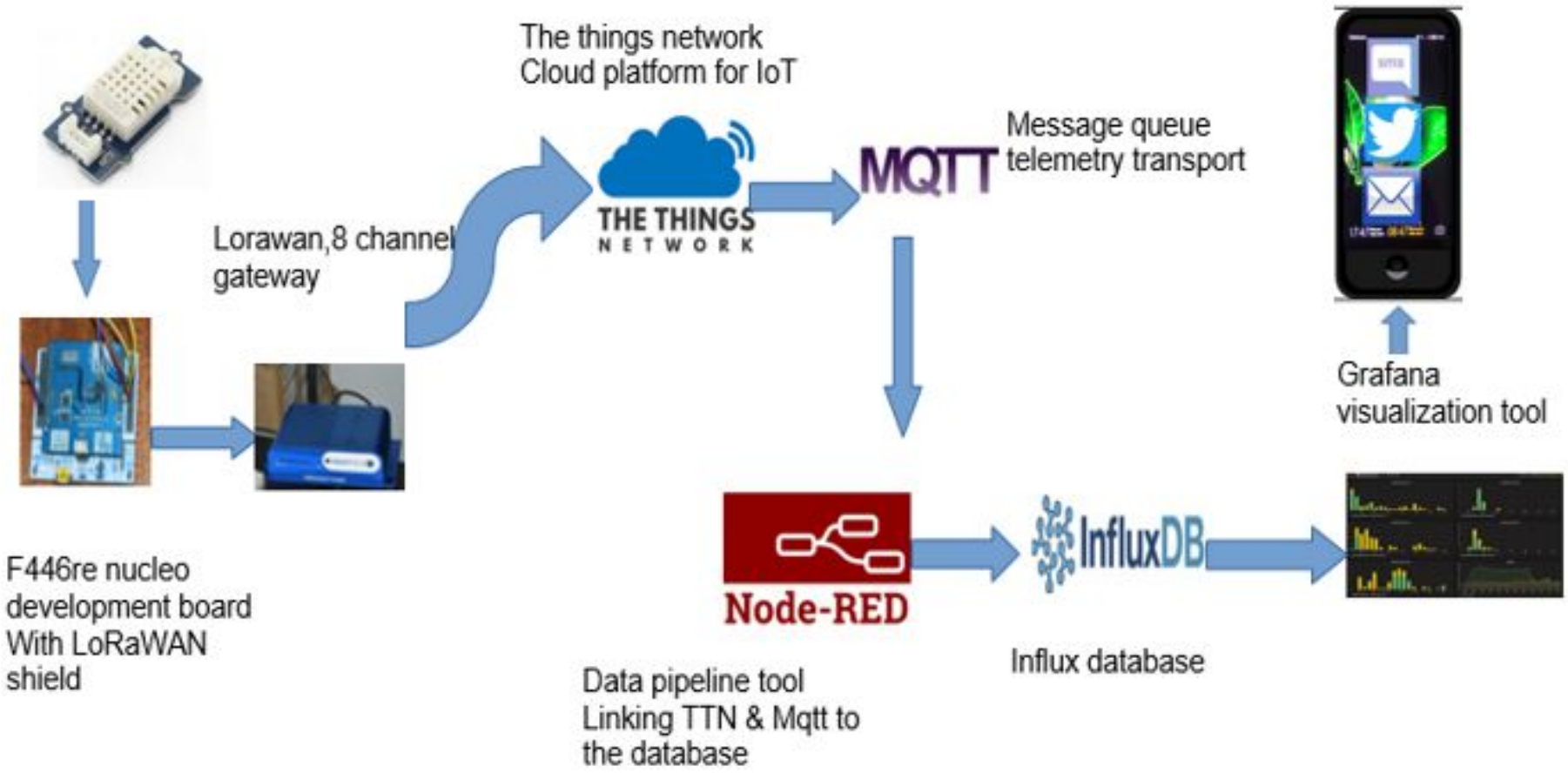
  Relative humidity.

  Light intensity and

  Air quality.

- Give feedback, insights to the farmer via SMS, email or a tweet using open source tools.

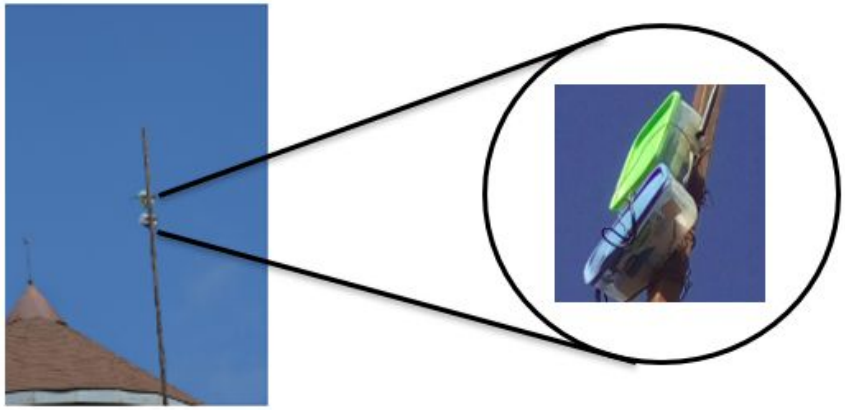
Research approach, Methodology

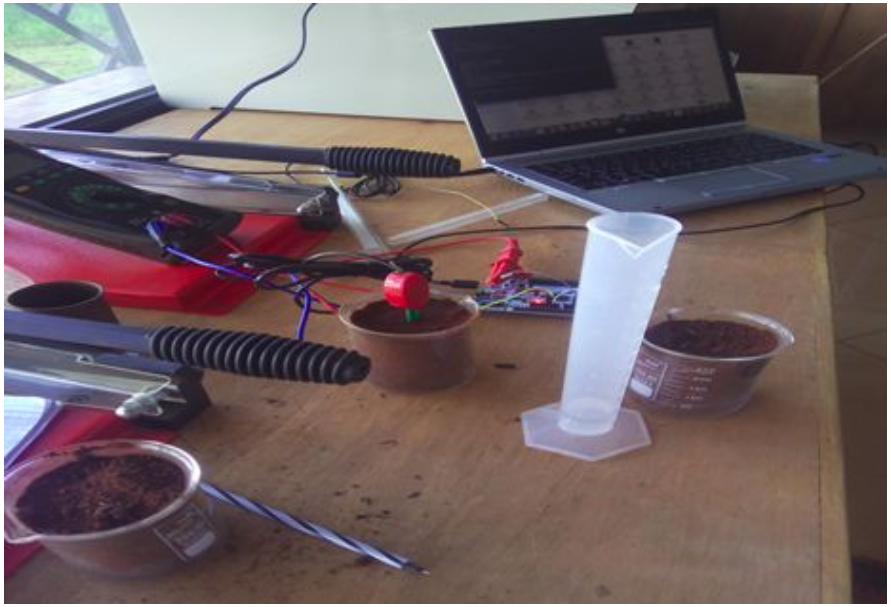


Lora Technology

Ref: Fundamentals of IoT - Data Science Africa 2018 presentation by janjongboom

Lora gateway and sensor calibration





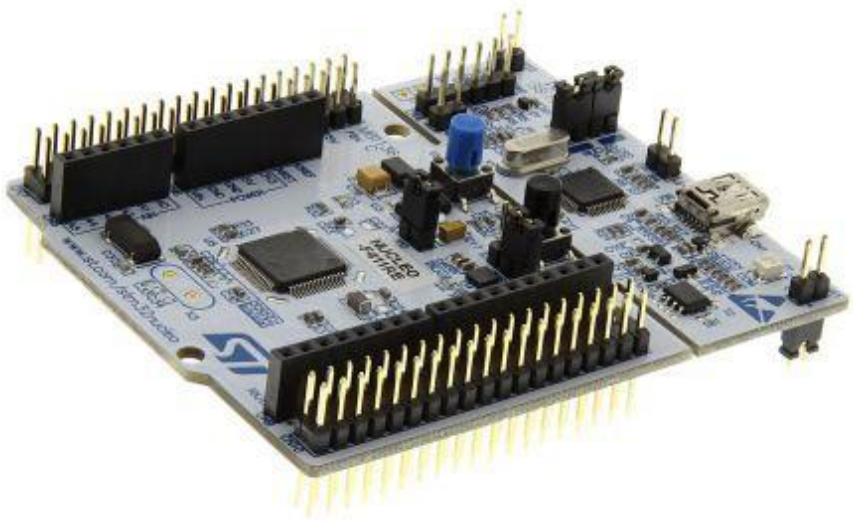
Sensors

Grove DHT Humidity & temperature sensor.

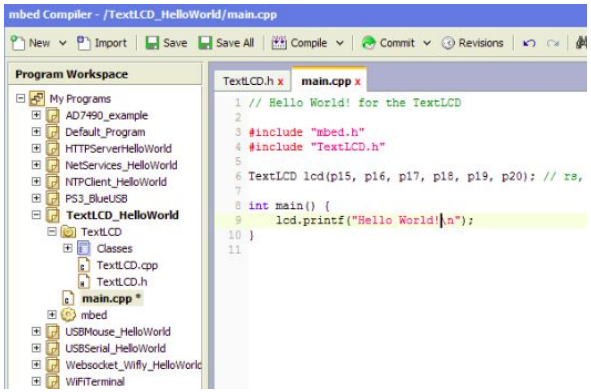
Vegetronix H400 soil moisture sensor.

Vegetronix soil temperature sensor THERM200-

Mbed NUCLEO-F44RE



Mbed on line compiler



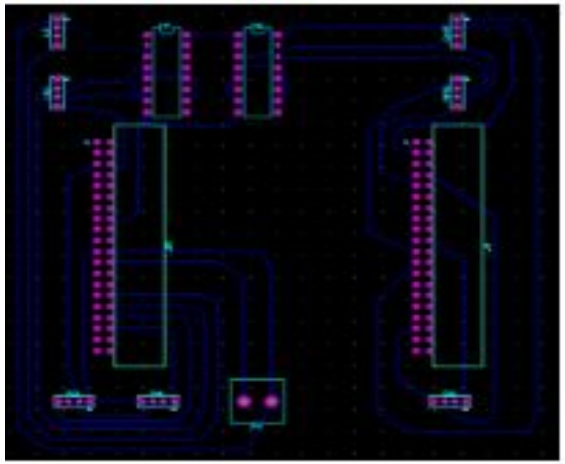
Mbed commandline (cli)

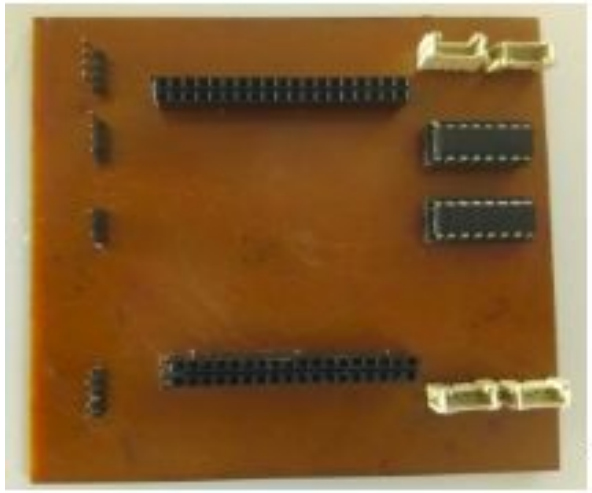
```
Compile [ 99.7%]: trng_api.c
Compile [ 99.9%]: stm_spi_api.c
Compile [100.0%]: us_ticker.c
Link: mbed-os-example-blinky
Elf2Bin: mbed-os-example-blinky
| Module              |          .text |       .data |        .bss |
|---------------------|----------------|-------------|--------------|
| [fill]              |      132(+132) |       4(+4) |      38(+38) |
| [lib]/c.a           | 25039(+25039) | 2472(+2472) |      56(+56) |
| [lib]/gcc.a         |     3176(+3176) |       0(+0) |       0(+0) |
| [lib]/misc          |      236(+236) |     16(+16) |      28(+28) |
| main.o              |      922(+922) |       4(+4) |      36(+36) |
| mbed-os/cmsis       |     1021(+1021) |       0(+0) |       0(+0) |
| mbed-os/components  |      152(+152) |       0(+0) |       0(+0) |
| mbed-os/drivers     |      915(+915) |       4(+4) |    100(+100) |
| mbed-os/features    |      172(+172) |       4(+4) |    192(+192) |
| mbed-os/hal         |     3695(+3695) |       8(+8) |    269(+269) |
| mbed-os/platform    |     4289(+4289) |    260(+260) |    235(+235) |
| mbed-os/rtos        |     8298(+8298) |    168(+168) | 5969(+5969) |
| mbed-os/targets     |     8867(+8867) |       4(+4) |    397(+397) |
| Subtotals           | 56914(+56914) | 2944(+2944) | 7320(+7320) |
Total Static RAM memory (data + bss): 10264(+10264) bytes
Total Flash memory (text + data): 59858(+59858) bytes

Image: ./BUILD/NUCLEO_F411RE/GCC_ARM/mbed-os-example-blinky.bin
jared@jared-HP-EliteBook-8470p:~/ready/mbed-os-example-blinky$
```

Programming and circuit fabrication

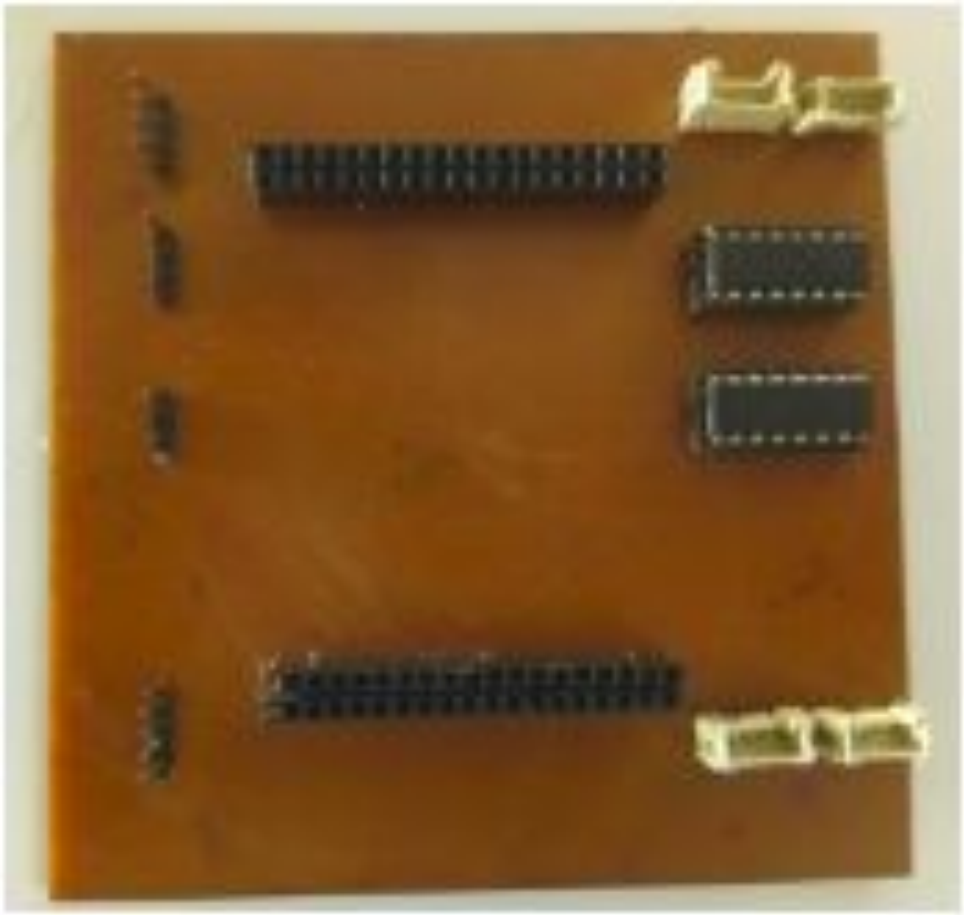
The_code.cpp

```
92
93    }
94
95    if (SOIL_SENSORS) {
96      payload.addAnalogInput(4, soil_temperature);
97      payload.addAnalogInput(5, soil_moisture);
98      payload.addAnalogInput(6, Rsensor);
99
100     printf("Ambient Temp=%f Ambient Humi=%f Soil temp=%f Soil moist=%f  light=%f\n", temperature, humidity,
101
102
103   }
104
105
106   if (dust_updated) {
107       dust_updated = false;
108       printf("Measured concentration = %.2f pcs/0.01cf\n", dust_concentration);
109       payload.addAnalogInput(1, dust_concentration / 100.0f); // save space
110
111
```



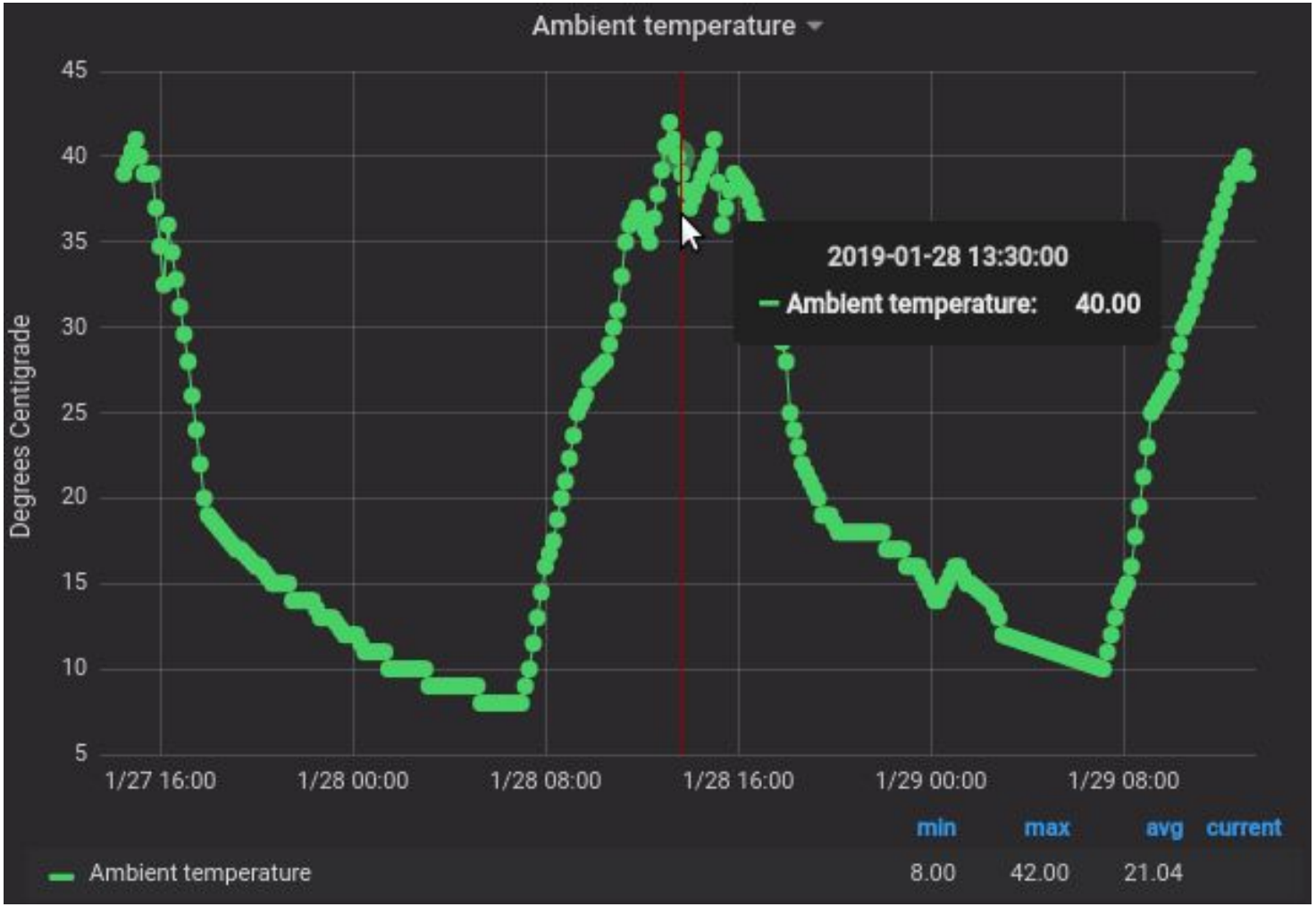


Power management scheme

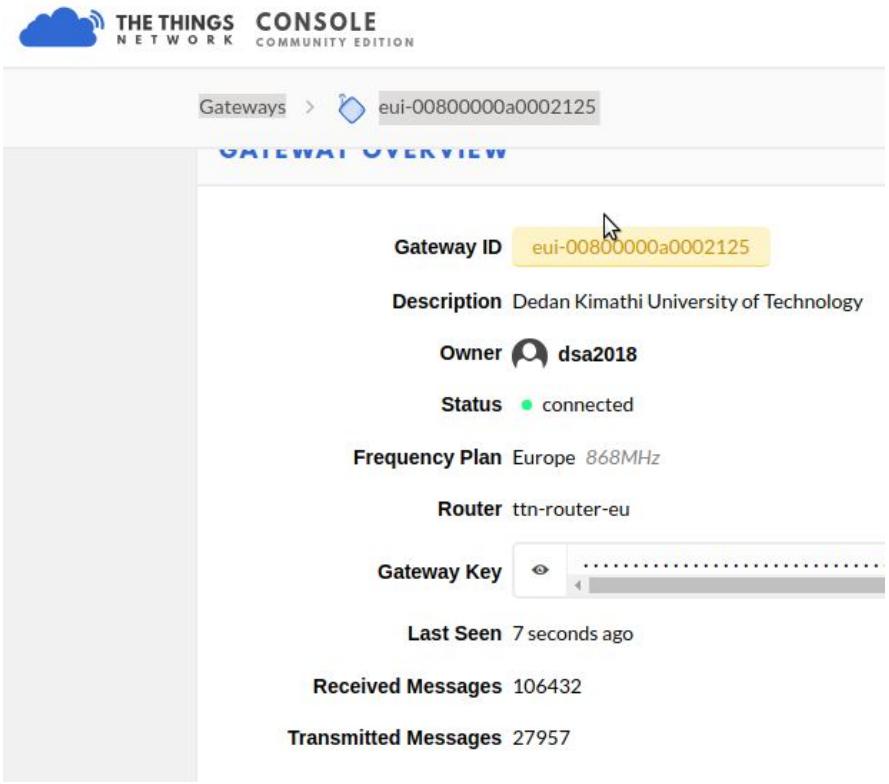


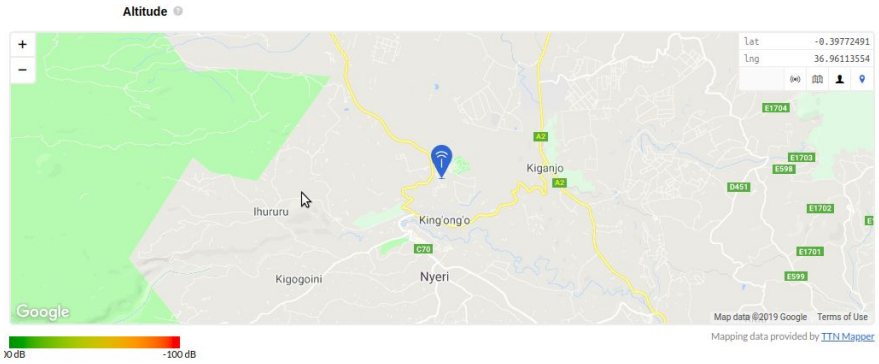
Solar powering and deployment

Major Outcomes/Results



Major Outcomes/Results





Data pipeline

MQTT Protocol

```
Received uplink from  dev-01
{'time': '2019-08-13T09:44:17.171780715Z', 'fields': {'data_rate': 'SF12BW125', 'rssi': -103.0, 'snr': 4.2
```

Payload viewed on the command line

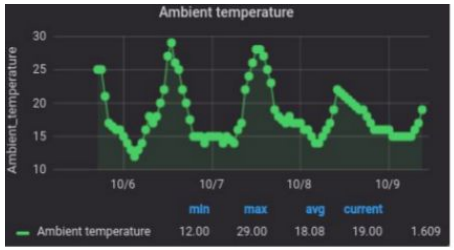
time	Relative Humidity	Temperature	data_rate	rssi	sensor	snr
1565950018720947968	65	18	SF12BW125	-109	dev_01	2.5
1565950158977933824	65	18	SF12BW125	-107	dev_01	2.8
1565950225094799104	65	18	SF12BW125	-107	dev_01	3.2
1565950439476345088	65	18	SF12BW125	-109	dev_01	2.8
1565950508554321152	65	18	SF12BW125	-109	dev_01	3
1565950574635691776	65	18	SF12BW125	-107	dev_01	3
1565950643778501888	65	18	SF12BW125	-109	dev_01	2.2
1565950778991041792	65	18	SF12BW125	-109	dev_01	1.5
1565950845106201856	65	18	SF12BW125	-109	dev_01	2.5

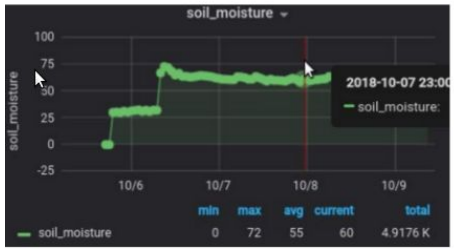
Data stored in Influx database

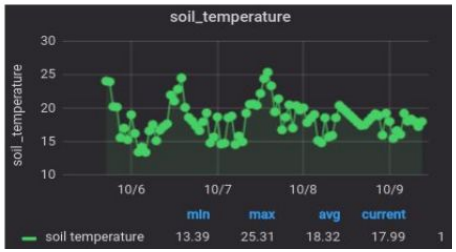
Influxdb Database

time	analog_in_1	analog_in_4	analog_in_5	analog_in_6	relative_humidity_3	temperature_2
1551163723407630783	0	-21.06	0.9	10.25		
1551163852111239166	0	-20.85	0.96	9.89		
1551164028203573477	0	-20.65	0.91	9.57		
1551164204323009175	0	-20.79	1.06	10.32		
1551164418936531915	0	-21.76	0.94	10.03		
1551164496963771786	0	-18.97	1.04	10.74		
1551166474713760357	12.87	20.71	49.78	87.13		
1551167423797082261	17.88	20.81	49.5	86.34		
1551167482540765452	17.88	20.31	49.27	87.1	42	29
1551168440770261829	17.57	20.1	50.6	86.2	38	30
1551169401843720371	18.13	20.37	51.61	87.17	40	30
1551170362902021599	23.6	21.31	51.05	86.76		
1551170406655839779	20.1	20.81	49.84	86.88	38	31
1551171374703283987	12.72	21.58	49.9	86.71	32	31
1551172327829020242	23.56	21.11	49.69	87.22	33	33
1551173275037032610	17.98	22.55	49.01	86.61	33	34
1551174223117741109	23.68	22.59	49.99	87.35	28	36
1551175179121818411	18.01	21.88	48.99	86.98		
1551176140677686835	18.31	22.12	49.27	87.2	27	38
1551176188986639698	12.92	21.85	49.16	87.49		
1551177142260012682	23.84	22.35	49.61	87.66		
1551178093965693951	29.45	22.02	48.78	87.39	26	38
1551179044110950688	23.79	22.15	49.67	87.1	22	38
1551179984105927065	23.41	23.36	49.08	87.05	23	38
1551180937313083670	18.15	23.83	48.25	87.76	20	40
1551181882253524017	13.01	22.42	49.86	86.88		
1551182834890971164	23.33	23.09	48.88	86.42	25	38
1551183805946144146	27.58	22.19	48.67	86.56	28	34
1551184784006940488	23.5	23.76	49.39	86.61	33	33
1551185755239952486	12.66	23.86	48.4	86.61	48	32
1551186702451124405	23.49	23.23	49.25	87.05	30	31

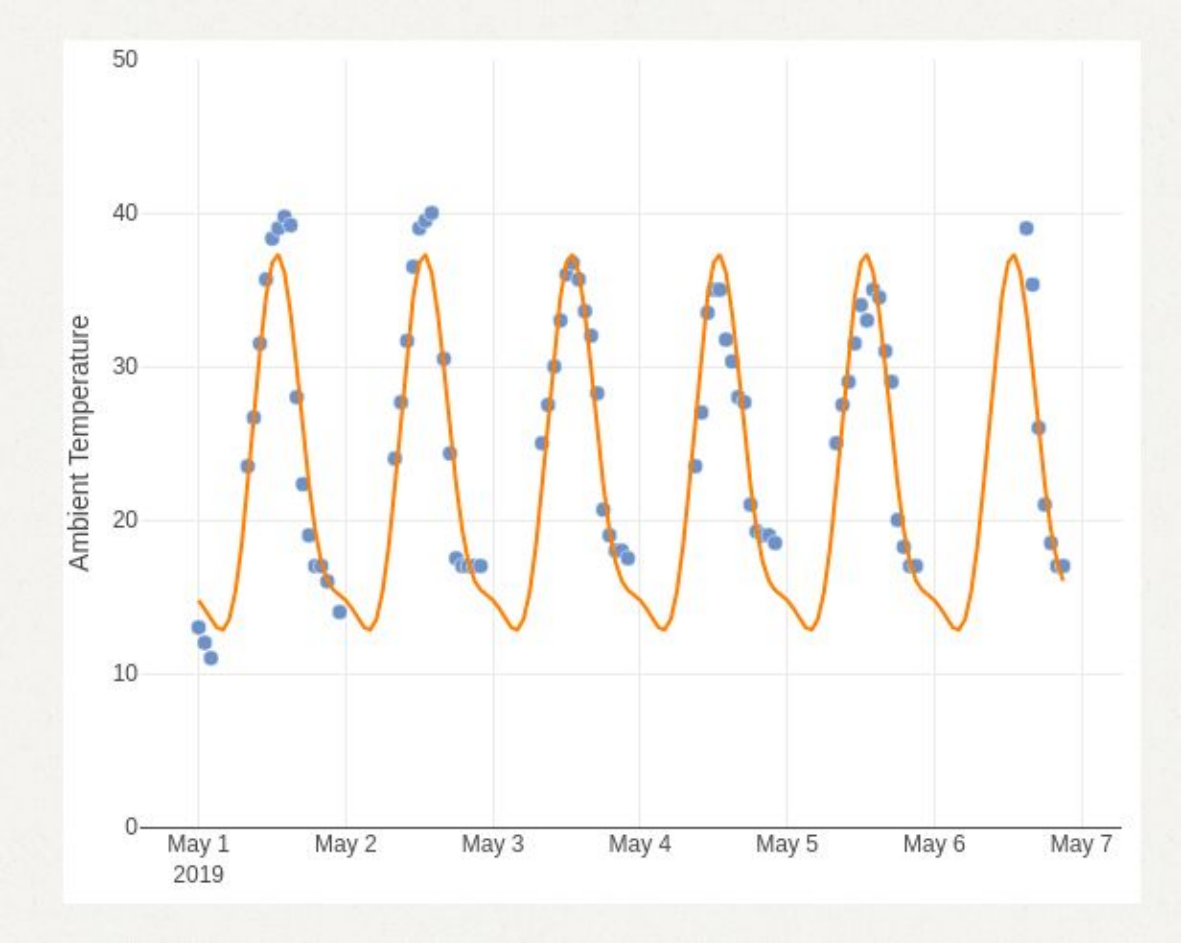
Grafana visualization





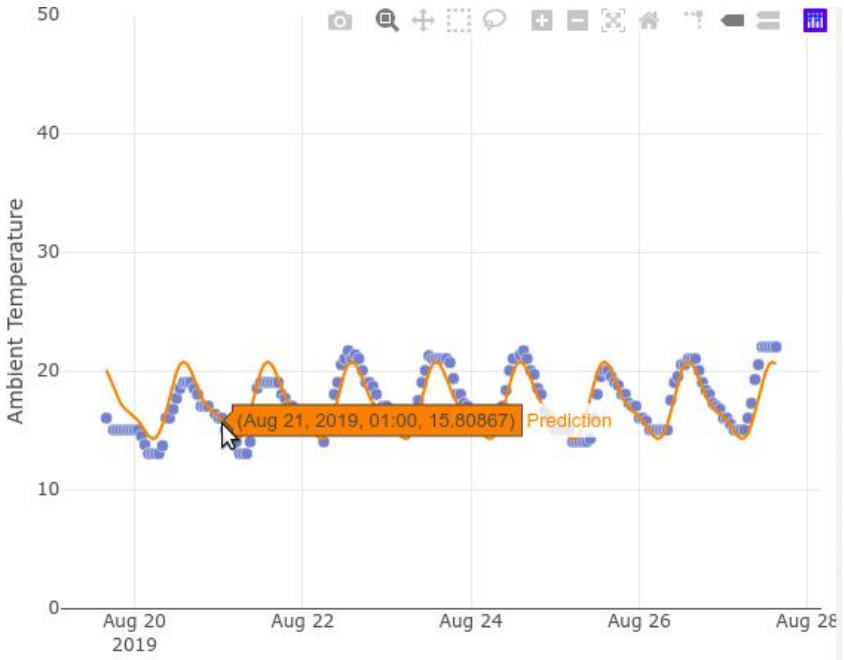


Dash application and plotly



Regression to fill in the missing data

Cont ..



Predictions on parameters
Watering events
Email alerts when gateway or device is down

greenhoxx@gmail.com
to me

Hi,
I hope you are well. The last time data was written was:

21.5 Minutes ago. Check the gateway

Best regards

Jared

Feedback

SMS

greenhoxx@gmail.com

to me

Hi,

I hope you are well. The last time data was written was:

21.5 Minutes ago. Check the gateway

Best regards

Jared

Conclusion and outlook

- This paper has demonstrated real time monitoring of greenhouses and field conditions at a coffee firm buy use of lora radio networks (LoRaWAN).
- We have used Nucleo-F446RE development boards and sensors, cloud computing, such as TTN, MQTT protocol with python SDK, solar power and databases.
- The system is able to collect temperature, relative humidity, soil temperature and moisture from greenhouse and open field, transmit to a cloud server, visualize and give alerts seamlessly and in real time.
- Future work will focus on analysis of the data collected to provide meaningful insights and alerts to farmers. We also intend to develop web and android applications interfaced with cloud services for efficiency.

Thank you