The '*Humble Roots'* Project

Homegrown Process Control

Applied To

Medical Cannabis Cultivation.

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Introduction

The 'Humble Roots' project is an example of a successful system developed by a medical cannabis patient aiming to grow his own medicine within the strict bounds of Washington State's laws.

This project combines horticulture, open hardware and software with consumer appliances and blends them together into an inexpensive, easy to build, automated gardening system, fostering re-use of existing parts, materials and commonly available supplies.

While the focus of the project is on medical cannabis cultivation, it's important to note that the 'Humble Roots' project is not limited by any means to cannabis cultivation or horticulture: it is applicable to many other problems where process control and automation through sensors, actuators, data and rules is beneficial.

The 'Humble Roots' project does not attempt to be a comprehensive cannabis horticulture guide. Several excellent books have been written on that subject by experts such as Ed Rosenthal and Jorge Cervantes. However, smart farming technologies were hardly discussed when these books were written and remained the domain of 'big agriculture' for way too long.

Now, with the ubiquitous availability of inexpensive 'system on a chip' computers, micro-controllers and sensors, combining sound horticulture practices with the right technology can produce amazing results while fostering sustainability.

Why do this?

The 'Humble Roots' project was born in 2013 out of a need to grow medical cannabis indoors for personal use, using sustainable, organic, pesticide-free cultivation methods capable of producing consistent yields, in both quality and quantity. To date, this project has produced four beautiful harvests, starting with the very first one.

It may seem odd that anyone would consider undertaking such a project in Washington State where medical and recreational cannabis have been legalized. After all, why go through the trouble of building an automated growing system when cannabis is readily available from state-licensed outlets?

The reality is that the laudable recreational cannabis legalization efforts in Washington State have had unfortunate consequences for patients: medical cannabis dispensaries are being eliminated and merged into the recreational market, forcing patients into a heavily-taxed marketplace, where only the most popular strains are available and where the use of pesticides is allowed. Furthermore, access to state-licensed outlets can be difficult, and in some areas, it is simply unavailable. Finally, Washington State strongly encourages medical cannabis patients to enter a registry accessible by law enforcement and government agencies.

For those of us who value our privacy, or who are unable to afford sourcing our medicine from the recreational market, or who are no longer able to find the specific strains that we need or who are unwilling to ingest pesticides, the only sensible alternative is growing our own medicine within the

rules imposed by the state.

Medical cannabis patients and caretakers who have realized that investing in their own garden is viable are still facing several challenges: cannabis can be tricky to grow and requires a well-controlled environment to thrive into a bountiful harvest. By automating the control of key processes, and following best practices, a grower can greatly reduce or even eliminate certain classes of risks while saving precious resources such as water and power.

Finally, in an attempt to mitigate the steep learning curve associated with cannabis cultivation, the 'Humble Roots' project provides recipes meant to educate and guide the budding gardener. A master grower might also appreciate the consistency of yields produced through recipe-driven automation and crafting her own recipes.

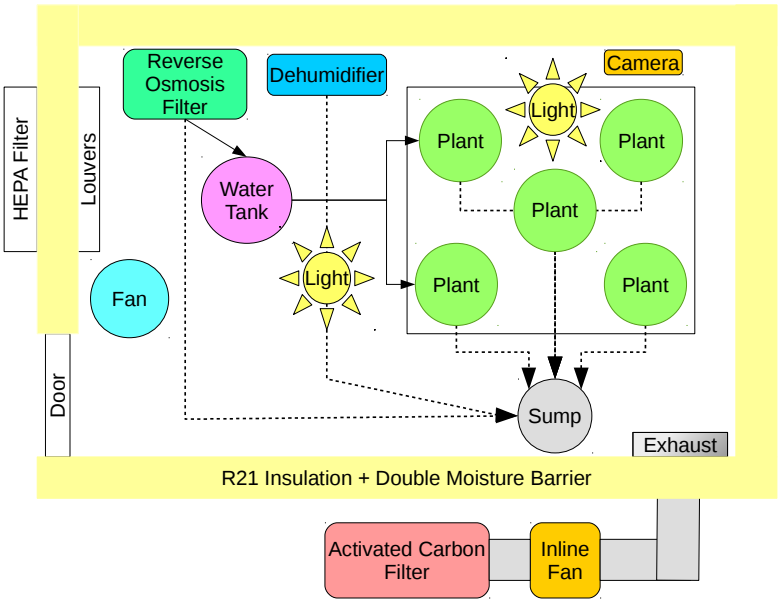
To Do: add links and references to WA's cannabis laws, articles about I-502 and subsequent bills, articles about the difficulties faced by commercial growers.

The Garden

In the context of the 'Humble Roots' project, the garden is composed of several cannabis plants inside of a secure, insulated space keeping moisture, heat and cold, pests (insects and humans) and unfiltered air out. Of course, moisture, heat and air trapped within the garden must be managed appropriately and we'll cover why and how in the sections below.

The Floor Plan

The following diagram provides a simplified view of the garden space as it is organized today. It will be referenced when discussing the integration of the environment with the devices, hardware and software used to control it.



Overhead view of the garden space.

Sustainable by Design

Sustainability has been the principle guiding the project since its inception: many design choices supporting this goal were made based on debates with seasoned growers, experiments and data gained over two years of testing with different growing mediums, different strains, various plant counts and iterating over hardware and software components. The efficiency of the current design is excellent but there's always room for improvement. Hopefully, fellow gardeners will be inspired to contribute ideas and their own experience to help push the efficiency of the system even further.

Thermal efficiency

The garden is located in a room elevated above ground to prevent the floor from getting too cold during the winter months. The floor, the walls and the ceiling are filled with R21 insulation material. The insulated material is sandwiched between two plastic moisture barriers. The door is made of metal, can be locked and seals tightly with its frame.

Because the room is well-insulated, it allows for semi-passive cooling and saves a great deal of energy in the process since an air conditioning units is not required. Passive cooling relies on a temperature differential between cooler outside air and the warmer air inside of the room. A fan is used to draw cool air inside the room while sucking warm air out.

Running the system at night ensures that the temperature difference between the two zones is adequate for passive cooling. It also makes it much cheaper to operate since the cost of grid power drops dramatically during these off-peak hours. Louvers automatically open when air needs to enter and leave the space and shut themselves off afterward.

Louvers play an important role in preventing light, air and smells from leaking in or out of the garden.

We will see later how software contributes to achieving a climate equilibrium and further contributes to saving energy. Not everyone can dedicate a room to grow indoors. Fortunately, it's possible to achieve great results with grow tents using the same principles.

Lighting efficiency

Two LED lamps, representing 885 Watts in total, illuminate the ~4.5' x 4.5' area where the plants are located from above and from one side. The room is painted flat white, from floor to ceiling, making for a very bright environment, maximizing the lamps' output.

LED lights were chosen for their energy efficiency: they're engineered to only emit light in the blue, red, IR and Ultraviolet (A) parts of the spectrum, which plants thrive on. Nearly all of the green portion of the spectrum is eliminated by these LED lamps as it is useless for photosynthesis and therefore, saves energy and heat.

LED lamps tend to penetrate through foliage deeper that other light types, which promotes heavier growth of lower buds on the plant, making for higher quality yields.

LED lamps produce little heat, which is advantageous in a passively cooled environment.

Finally, LED lamps do not require electronic ballasts, making for simpler electrical connections and fewer potential failure points.

To make the most of the light available to them, each plant is potted in a 3.5 gallon bucket, each inserted in another water collection bucket, allowing for a healthy root system and foliage to develop but not so large that competition for light resources becomes an issue.

A soft mesh screen helps with training the plants to grow uniformly wherever light is available. It also helps with supporting stems once the plants enter their flowering cycle.

Water treatment and conservation

A copper pipe brings cold city water into the space. Another PVC pipe leading to the sewers is used to drain out waste water temporarily stored into a sump.

City water quality varies greatly depending on where you live but even good quality city water invariably contains additives, such as Chlorine or Chloramine as well as other minerals that can negatively impact sensitive cannabis plants by interfering with nutrient solutions and the composition of the soil. Left unchecked, such mineral and metal build-ups can lead to nutrient toxicity or nutrient deficiencies for the plants. Therefore, it is strongly advised to cleanse city water with a carbon filter or a reverse-osmosis system before using it in a cannabis garden.

There are efficiency trade-offs to consider with different water treatment methods: for instance, a reverse-osmosis system produces 'waste water' as well as clean water and carbon filters eventually need to be replaced. While Chlorine just evaporates when left to air out for a few days, Chloramine takes much longer to dissipate and that water might be problematic to store in the meantime.

Carbon filtering and reverse-osmosis systems have both been used successfully as part of the 'Humble Roots' project. Currently, a reverse-osmosis system is used. It is controlled by a solenoid valve and an ultrasonic distance sensor tracking the water level inside of the tank. This fresh water is used for irrigating the plants with a pump. The water is kept aerated at all times thanks to an air pump and two air stones.

Assuming that water has been properly conditioned, it still must be applied with care: too much water will prevent the root system from accessing oxygen, stunting and eventually killing the plant. Too little water and the plant will starve, dry out and die as well. Accurately tracking and maintaining an optimal moisture level in the growing medium is not only beneficial to the plants, it is also beneficial to our drought-stricken environment: as you will see, by using smart irrigation techniques, it is achievable to grow a very healthy patch of cannabis plants with less water per day than is required to flush an average toilet once. A custom irrigation system was built to meet this goal using a soil moisture probe buried root-deep in one of the pots and a water distribution network going to each plant. Software determines when to irrigate and how much.

Some growing techniques consume larger amounts of water than others: for instance, hydroponic systems require far more water than growing in soil, regardless of scale. For this reason, the 'Humble Roots' project favors soil as its growing medium. A good soil mix retains just the right amount of moisture, is well oxygenated and provides a strong buffer against sudden pH fluctuations. Soil can also be re-used when cared for and amended properly.

The run-off water coming from irrigating the plants, as well as the water coming from the reverse-osmosis system and the dehumidifier drain into a 'sump', made from three 5 gallon buckets, through gravity. When the water reaches a certain level, as measured by another ultrasonic distance sensor, it is automatically pumped out to the sewer. Note that the water being pumped out is quite clean and close to being pH neutral.




Finally, the pH balance of the water, once combined with nutrients, is extremely important to measure and adjust, regardless of the growing medium, as it affects the availability of nutrients to the plant's root system and the plant's ability to uptake water. This is addressed in the grow recipes driving the automation.

Air Treatment

Maintaining good air quality is vital to grow a healthy garden: filtering out contaminants such as spores, pollens, dust, mites, is key to preventing a host of problems that can quickly destroy a crop. For that reason, all the air entering the garden is filtered through a MERV 12 filter.

Similarly, it is also critical to maintain an optimal range for air temperature, relative humidity and CO2 levels as they impact the growth of the plants, the quality and the amount of resin produced by cannabis flowers. Here, air temperature within the room is controlled through a powerful in-line fan exhausting hot air through an activated carbon filter, which scrubs the air and removes odors in the process.

A constant air flow is also maintained in the room thanks to a fan circulating air around the plants.

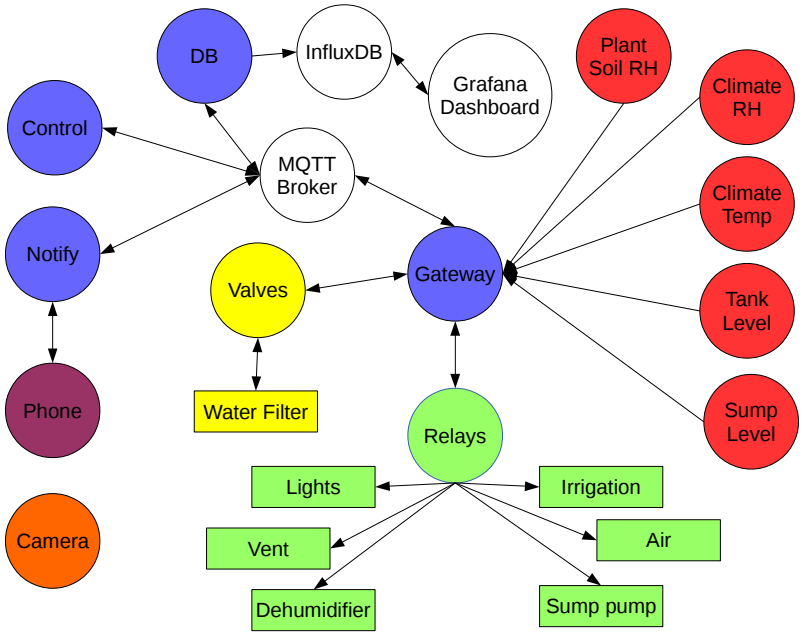
The relative humidity within the room is controlled through a small dehumidifier unit, keeping molds, such as Botrytis, from being able to develop.

It's worth noting that relative humidity sensors built into consumer-grade appliances often lack in accuracy.

The 'Humble Roots' project takes this issue into account by using separate climate sensors so that inexpensive consumer appliances can be controlled accurately and reliably.

The Control System

High-level Diagram



High-level diagram of the control system

Sensors

Soil Moisture

Climate

Water Levels

Camera

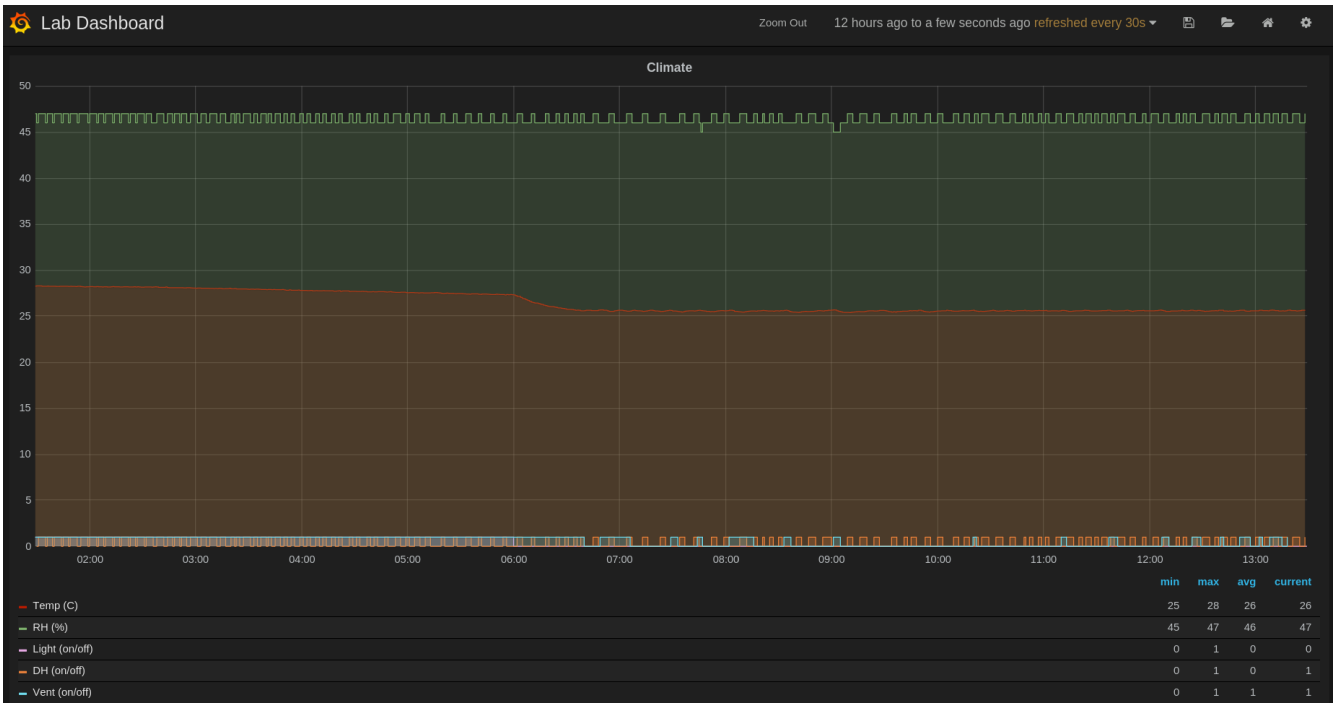
Actuators

Relays

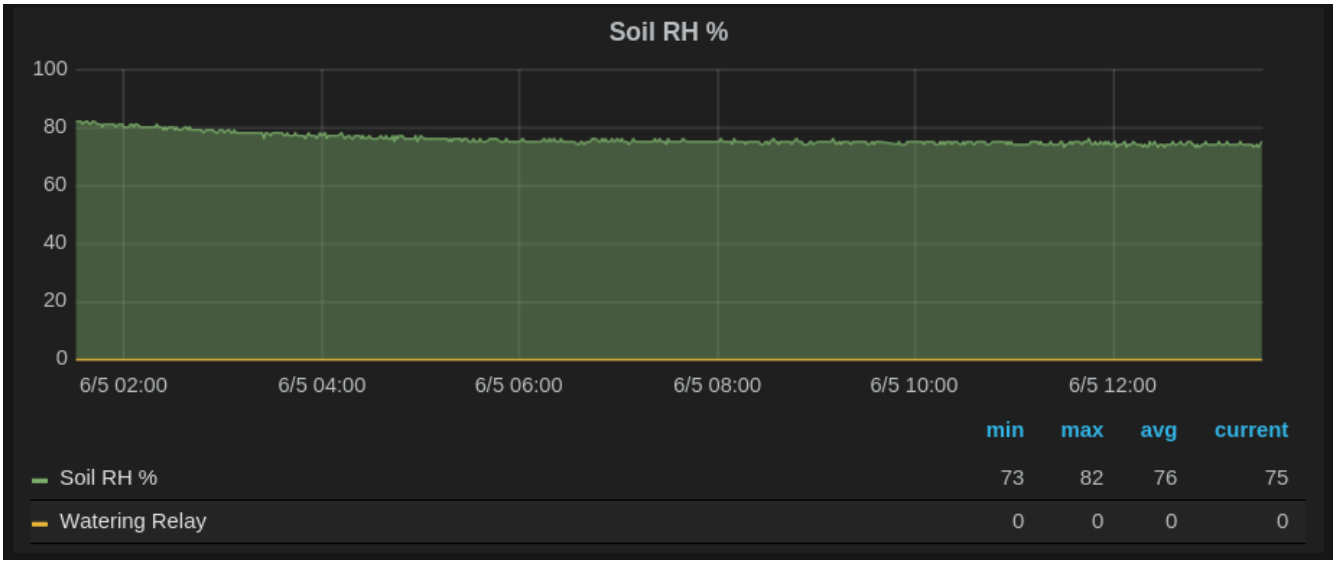
Valves

The Dashboard

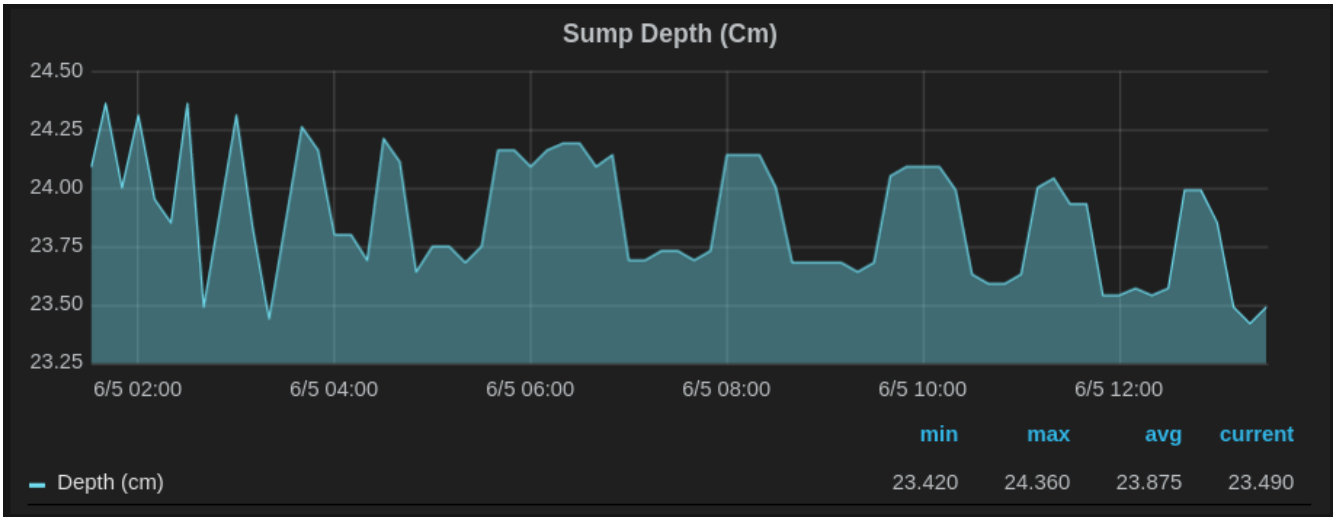
Climate



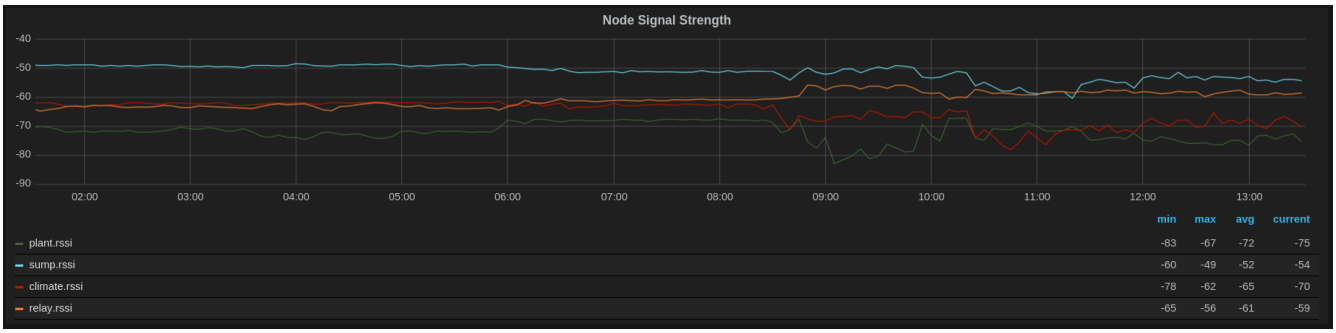
Soil Relative Humidity



Sump Depth Level

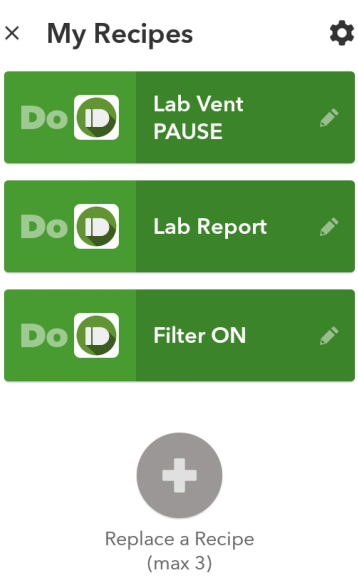


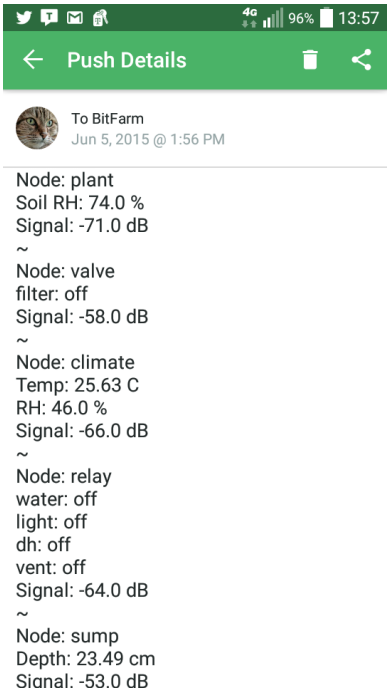
Node Signal Strength



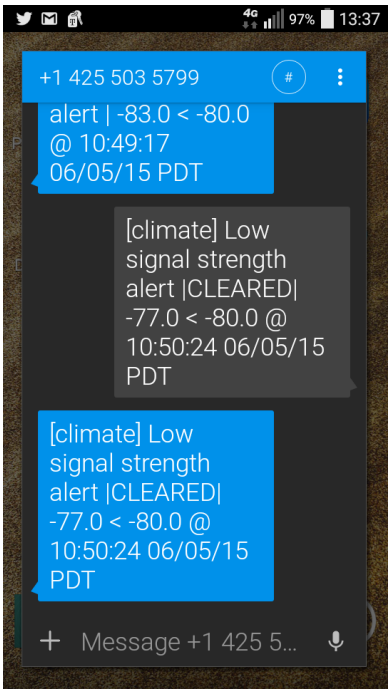
Mobile Interface

Basic Controls, Reporting, Alerting





SMS Alerts


97% 13:37
+1 425 503 5799
alert | -83.0 < -80.0 @ 10:49:17 06/05/15 PDT
[climate] Low signal strength alert |CLEARED| -77.0 < -80.0 @ 10:50:24 06/05/15 PDT
[climate] Low signal strength alert |CLEARED| -77.0 < -80.0 @ 10:50:24 06/05/15 PDT
Message +1 425 5...

Source Code

git clone https://github.com/fabienroyer/humble-roots

Required Dependencies

Install the Mosquitto MQTT broker from http://mosquitto.org/

sudo apt-get install mosquitto

Install the Python MQTT client from https://www.eclipse.org/paho/clients/python/

git clone http://git.eclipse.org/gitroot/paho/org.eclipse.paho.mqtt.python.git

cd org*

sudo python setup.py install

Install the PySerial package from https://pypi.python.org/pypi/pyserial

wget https://pypi.python.org/packages/source/p/pyserial/pyserial-2.7.tar.gz#md5=794506184df83ef2290de0d18803dd11

gunzip pyserial-2.7.tar.gz

tar xvf pyserial-2.7.tar

cd pyserial-2.7

sudo python setup.py install

Install the Hashids package from http://hashids.org/python/

git clone https://github.com/davidaurelio/hashids-python.git

cd hashids-python

sudo python setup.py install

Optional Dependencies

Install the Python development tools, if not present

sudo apt-get install python-dev

Install Python pip, if not present

sudo apt-get install python-pip

Install libffi-dev if not present so that PyOpenSSL builds w/o errors

sudo apt-get install libffi-dev

Install and build PyOpenSSL and its dependencies, if not present.

sudo pip install pyopenssl ndg-httpsclient pyasn1

Install the PushBullet Python client from https://github.com/Azelphur/pyPushBullet

git clone https://github.com/Azelphur/pyPushBullet.git

cd pyPushBullet

sudo python setup.py install

Install InfluxDB from http://influxdb.com/

If installing on the Raspberry Pi, check here

Install Grafana from http://grafana.org/

The Recipes

Bill Of Materials

References