UNIVERSITY OF PISA

MSc in Artificial Intelligence and Data Engineering

Internet of Things

CottonNet

Project Documentation

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Contents

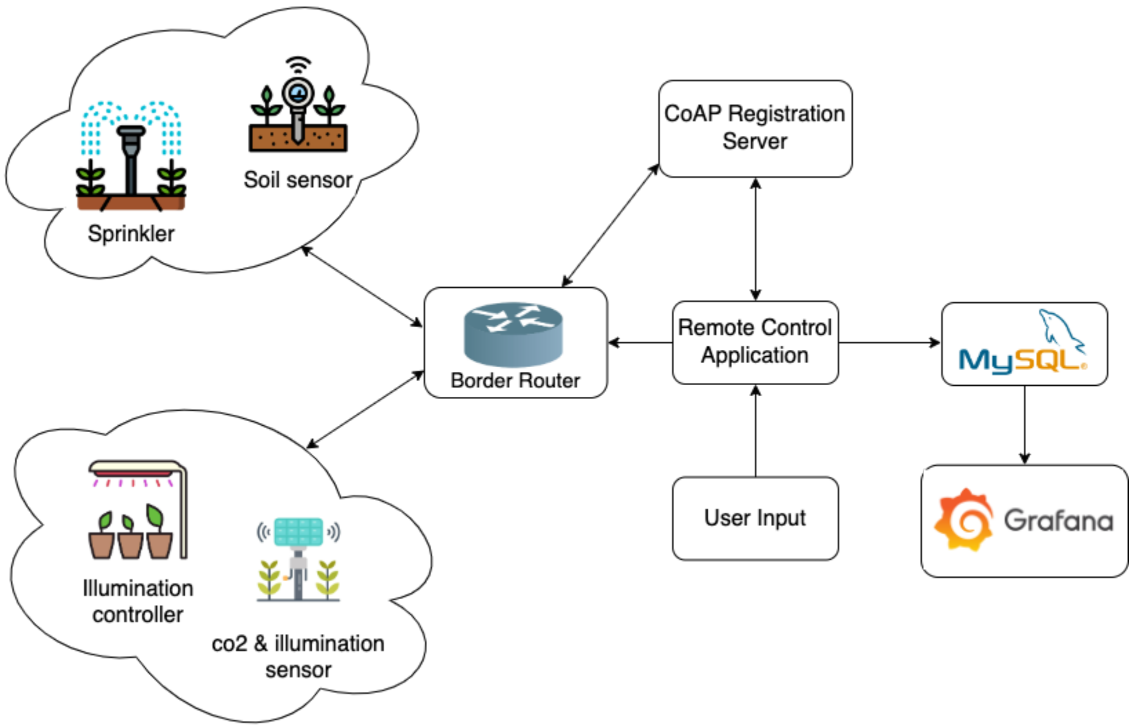
Introduction

CottonNet is a smart environment which purpose is to provide automatic control of cotton farms. The system has a wireless sensor network for real-time sensing and control of an irrigation and illumination system. This system provides required levels of water to void water wastage, and a light controller to reduce energy consumption:

- an irrigation mechanism that turns off the pumping motor ON and OFF, based on a Machine Learning algorithm to find dryness of the soul and predict water requirement
- an illumination controller that changes the state of its LEDs in case of inadequate light conditions or CO2 levels

Hence, the aim of CottonNet is to mainly reduce human work and both save resources and optimize the growth of the farm.

Architecture



CoAP Network

The CoAP network consists of 5 nodes:

- a border router
- two sensor nodes: the first measures moisture and temperature, and the second one, for the illumination system, measures the CO2 level, the light phase (day/night) and the farming phase (germination or flowering)
- two actuators, each one coupled with one of the sensors, which are a sprinkler for the irrigation system and a lighting controller for the illumination system

Cloud Application

The following components are exploited:

- The Registration Server registers the nodes of the CoAP network in the database. Both sensors and actuators sens a registration message upon joining the network, used to retrieve the IP address and other information to be stored in database.
- The CoAP Observer implements the observation features for the illumination system: every time the sensor detects a new measure within the periodical sampling, a notification is provided and the new measures are properly inserted into the dedicated table in the dataset.

Remote Control Application

Multiple functions are performed:

- **Show registered devices**: retrieves and displays information about all registered devices, both sensors and actuators, fetching the relative names, addresses, type (sensor or actuator), and sample timing from the database.
- **Set new sample timing for the illumination/soil sensor**: allows the user to input a new value, then a CoAP POST request is sent to the illumination/soil sensor to update the value.
- **Show real-time measures from the illumination/soil sensor**: retrieves all measures and registers new ones from the illumination sensor (CO2, light, farm phase) or the soil sensor (moisture, temperature) and prints them along with their timestamps to the console.
- **Turn off all devices**: deactivates all connected devices in the network by sending a CoAP request to each device and removes its record from the database.

Database

A MySQL database **CottonNet** is used to store data among the following tables:

- **devices** stores the registered devices (both sensors and actuators)

Field	Type	Null	Key	Default	Extra
name	varchar(255)	NO	PRI	NULL	
address	varchar(255)	NO		NULL	
type	varchar(255)	NO		NULL	
sampling	int	YES		NULL	

- **illumination** stores all the data changes detected by the illumination sensor

Field	Type	Null	Key	Default	Extra
id	int	NO	PRI	NULL	auto_increment
co2	int	NO		NULL	
light	int	NO		NULL	
phase	int	NO		NULL	
timestamp	timestamp	YES		CURRENT_TIMESTAMP	DEFAULT_GENERATED

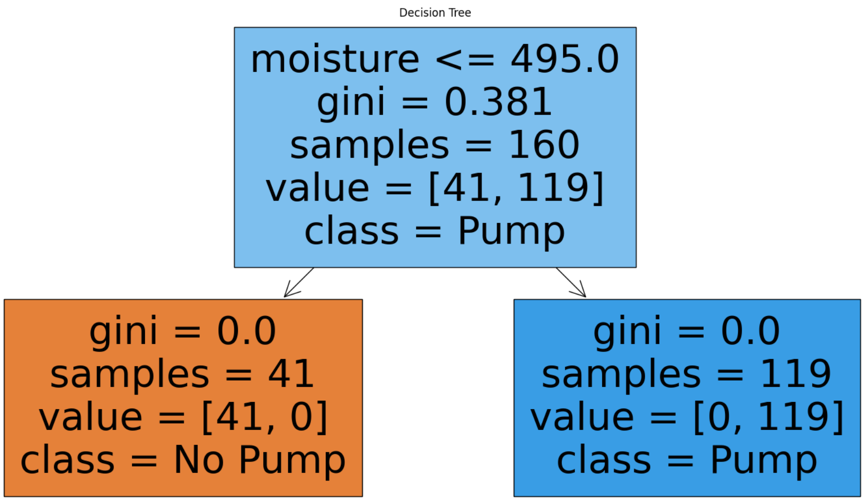
- **soil** stores all the data changes detected by the sensor of the irrigation system

Field	Type	Null	Key	Default	Extra
id	int	NO	PRI	NULL	auto_increment
moisture	int	NO		NULL	
temperature	int	NO		NULL	
timestamp	timestamp	YES		CURRENT_TIMESTAMP	DEFAULT_GENERATED

Machine Learning model

In order to check the dryness of the soil, the irrigation system incorporates a Machine Learning model based on the Decision Tree algorithm to determine when to irrigate the crops. The Decision Tree algorithm is used for classification tasks: it splits data into branches based on feature values, leading to a decision at each leaf node. In the specific case of the irrigation actuator, the model uses moisture and temperature as features to decide whether irrigation is needed.

The decision rule has been created as follows:



- The decision node is based on the **moisture** feature
- The decision rule is '**moisture** $\leq$ **495**'
- if so, it is classified as 'No Pump', then **no irrigation is needed**
- if **moisture** $>$ **495**, it is classified as 'Pump', then **irrigation is needed**

Data Encoding

For the forwarding of the measurements, JSON messages are used, since JSON allows to simply insert multiple fields as name-value pairs. Also, this structure is consistent with the MySQL table structures.

Deployment

All the nodes start the registration process by pressing the respective button (it is appropriate to switch the sensors on before actuators to ensure a successful message exchange)

Illumination system

The **illumination sensor** register with a CoAP Server and periodically sends sensed data (CO2, light and farm phase) within a sampling interval. The process:

- initializes a CoAP POST message setting its payload with the sensor attributes (name 'sensor0', type 'sensor' and sampling interval).
- activates the CoAP Resources **res_co2**, **res_light**, **res_phase** and **res_sampling**
- enters a loop where it waits for timer events and sends sensed data at the specified sampling intervals.

After the registration of the **illumination actuator** through the CoAP Server, it is also registered for observing notification from CO2, light and farm phase resources. Based on this data, its LED state is updated accordingly:

Light phase	CO2	Farm phase	LED
1	$400<x<1500$	0	OFF
1	$400<x<1500$	1	OFF
1	$x<400$ or $x>1500$	0	YELLOW
0	$400<x<1500$	1	YELLOW
0	$400<x<1500$	0	RED
0	$x<400$ or $x>1500$	0	RED
1	$x<400$ or $x>1500$	1	GREEN
0	$x<400$ or $x>1500$	1	GREEN

Irrigation system

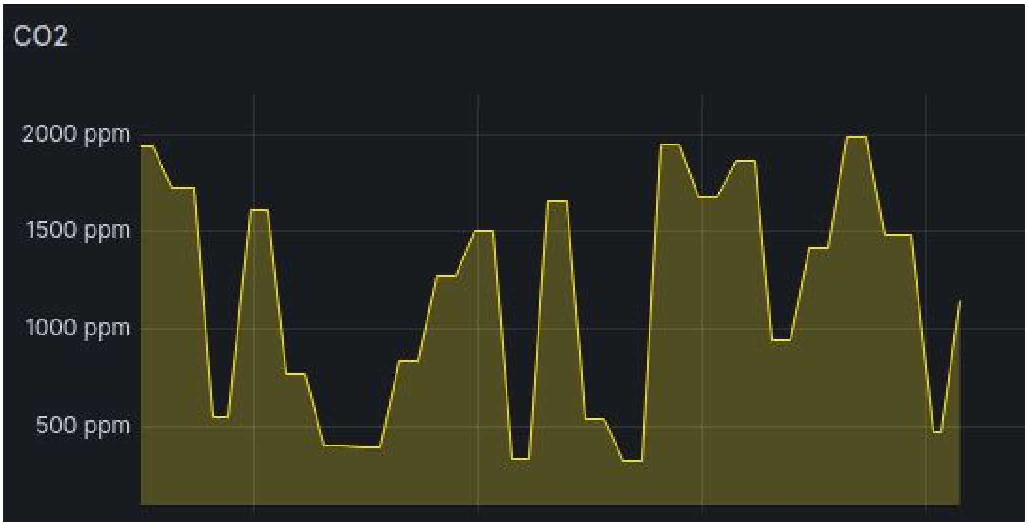
The **soil sensor** register with a CoAP Server and periodically sends sensed data (moisture and temperature) within a sampling interval. The process:

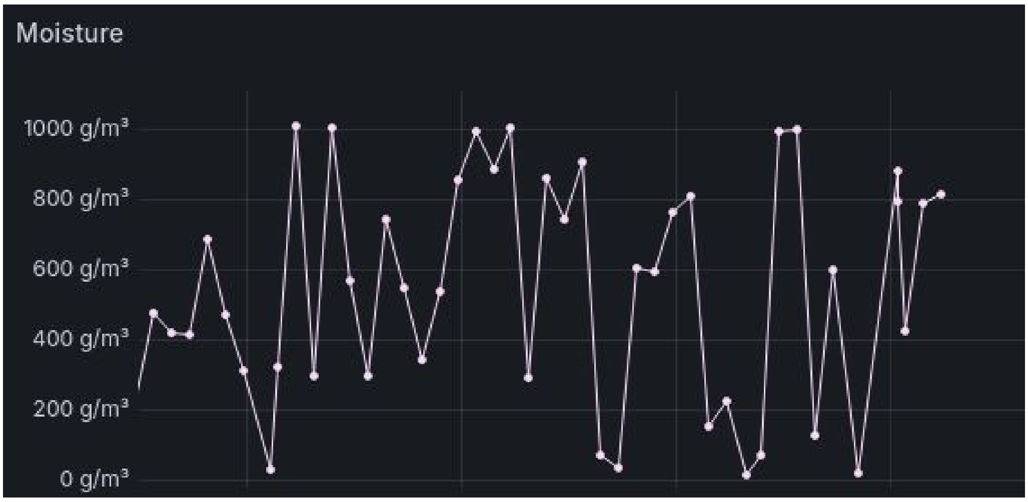
- initializes a CoAP POST message setting its payload with the sensor attributes (name 'sensor1', type 'sensor' and sampling interval).
- activates the CoAP Resource **res_soil**
- enters a loop where it waits for timer events and sends sensed data at the specified sampling intervals.

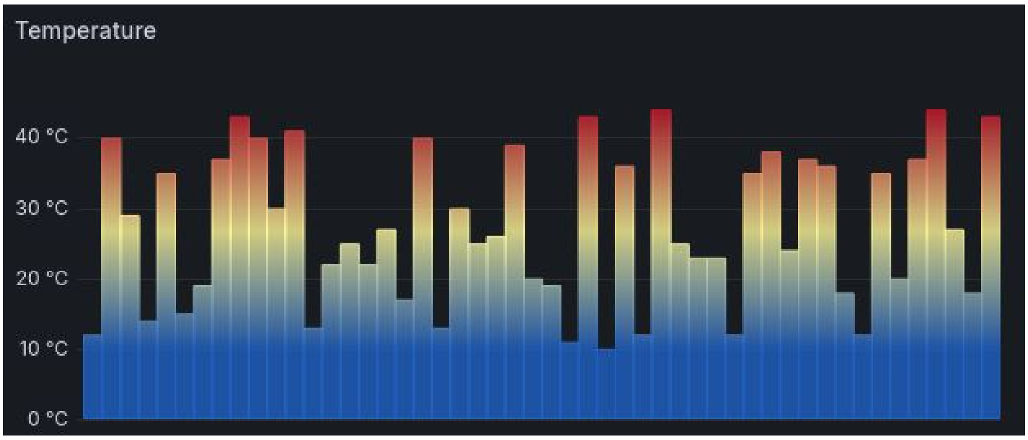
The **sprinkler** retrieves data from the soil sensor and uses the **Machine Learning** model to determine if irrigation is needed.

Grafana

Grafana has been used to provide a dashboard that shows the fluctuations of the measurements registered by the sensors over time.







Use case

The **illumination system** is designed to monitor environmental conditions of the cotton farm and it adjusts the illumination accordingly. The sensor is installed in the farm environment and responsible for continuous monitoring of CO2 levels, light and current phase of the farming process. The illumination controller adjusts its LED indicators according to the incoming data:

- if the CO2 levels and light conditions are optimal (between 400 and 1500 ppms), the LEDs remain off
- if there are issues, such as CO2 levels being too high or too low, or inadequate light conditions, the LEDs change state.

This configuration ensures that the farm illumination is dynamically adjusted to improve plant health and reducing energy consumption.

The **irrigation system** has the purpose of providing an automatic water supply, the sprinkler retrieves the moisture and temperature sensed by the sensor in order to assess the soil condition. It incorporates a Machine Learning model to decide whether the irrigation is needed based on the combination of the moisture and temperature conditions and consequently activates relay motor. This automation helps crops to receive the right amount of water, reducing waste and optimal growth conditions for the farm.

In conclusion, the usage of both the illumination and irrigation system creates a smart environment where conditions are constantly monitored and adjusted to ensure the crop health and an efficient usage of resources.