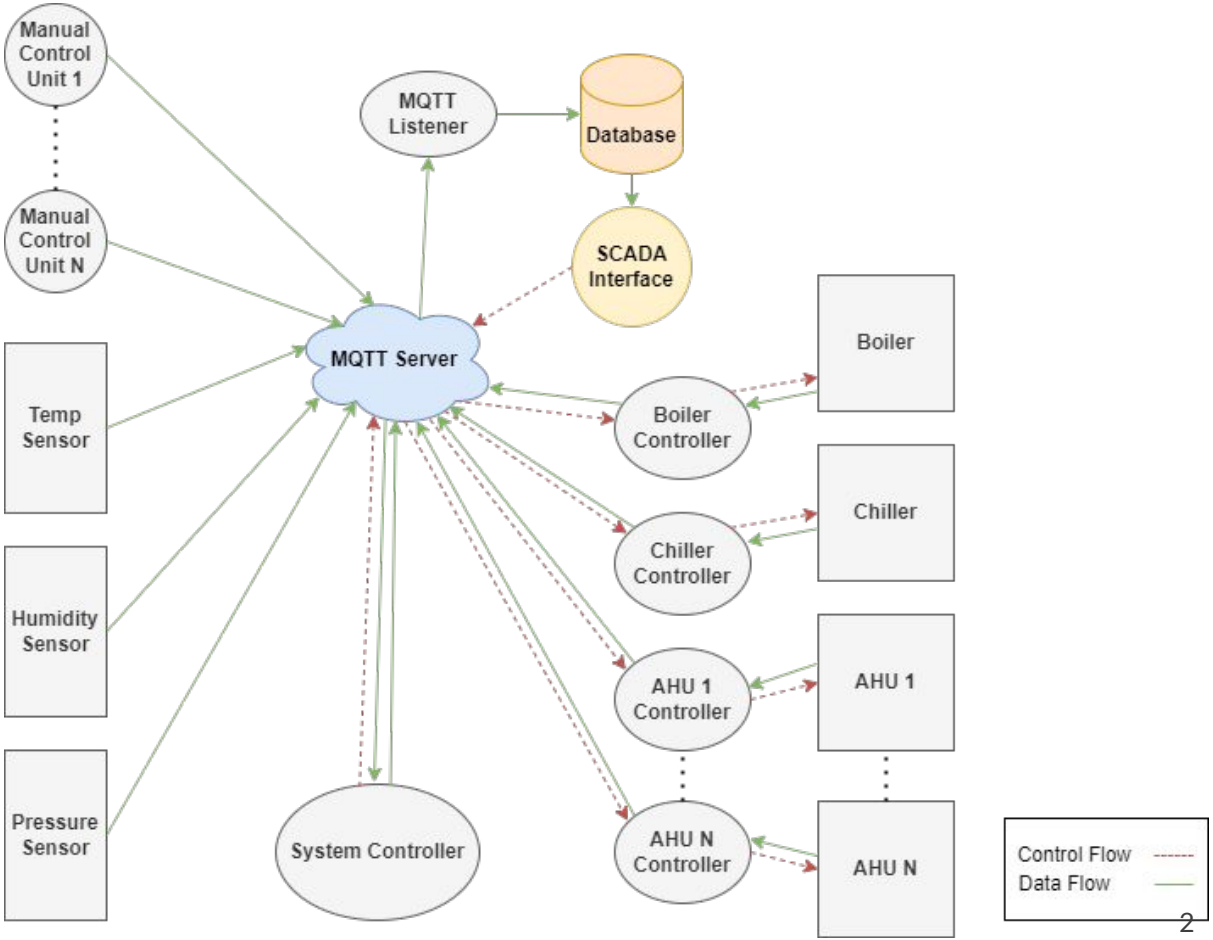
CO326 Project

Smart Building

Group A

HVAC

The HVAC control system allows for energy-efficient **heating, ventilation, and air conditioning control**. The controller adapts to the desired temperature, regardless of whether it is set by the user, automatically based on room usage, or centrally by facility management. It simply, accurately, and cost-effectively **creates the desired room atmosphere**.

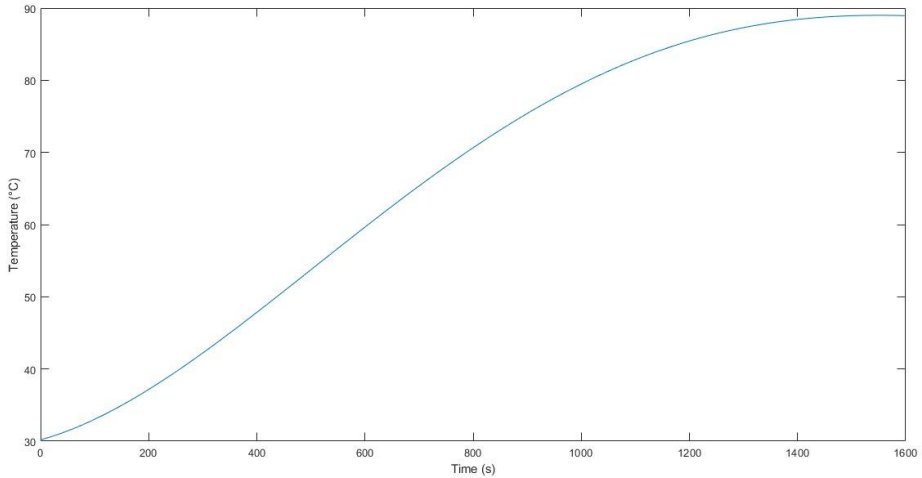


Topics

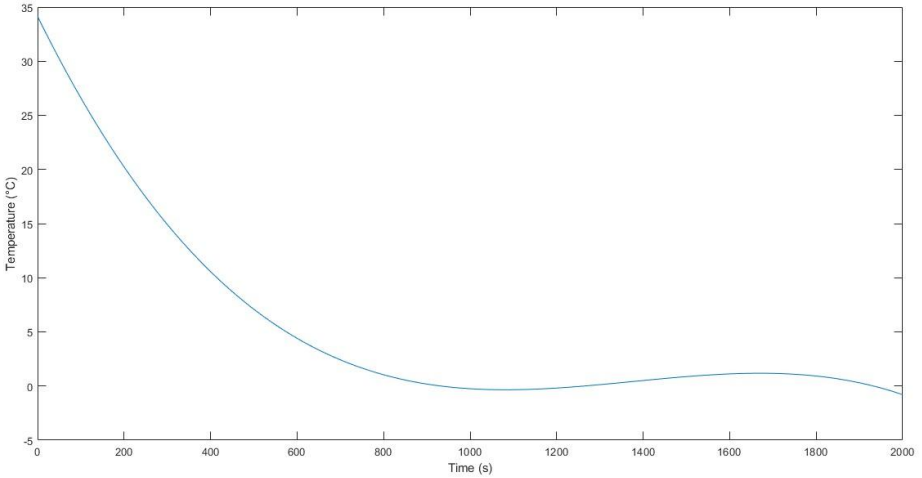
- Sensors
- Actuators
- MQTT Server
- SCADA
- Database
- System Controller
- Data Analytics
- Demonstration

Sensors

The behavior of the boiler and chiller were modeled using MATLAB and their characteristic polynomial curves were used to obtain sets of data points (elapsed time and temperature at the air duct) as a lookup table for the Python scripts that are running continuously.



Boiler Characteristic Curve



Chiller Characteristic Curve

Sensors

```
room_temp + (temp - room_temp)*exp(-t/12000)
```

```
target_pres = 0.012 * speed
new_pres = target_pres + (current_pres - target_pres) * exp(-t / 100)
```

Temperature sensor

The behaviour of the boiler and chiller were **modelled using MATLAB**.
For both the boiler and the chiller, the behaviour when the actuator is off was modelled following **Newton's law of cooling**.

AHU modelling

The temperature sensor within the room was modelled such that it adjusts its temperature according to the **hot/cold air mix ratio**.
Additionally, the **blower speed** is taken into account.

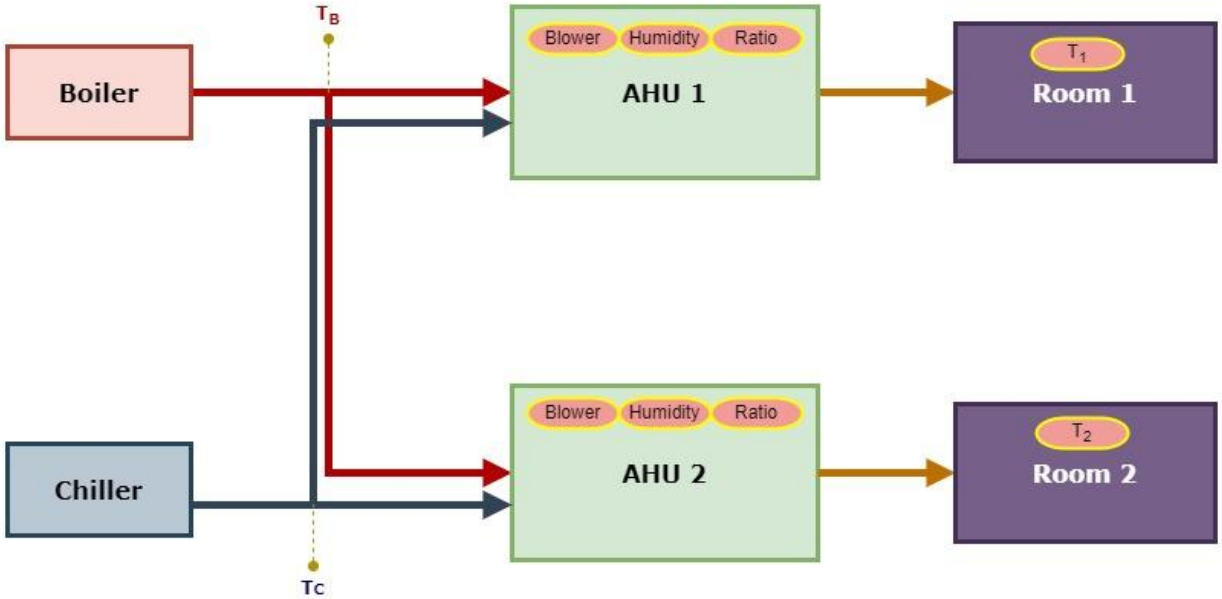
Pressure sensor

The differential pressure sensor was modeled considering the **blower speed** and the elapsed time.

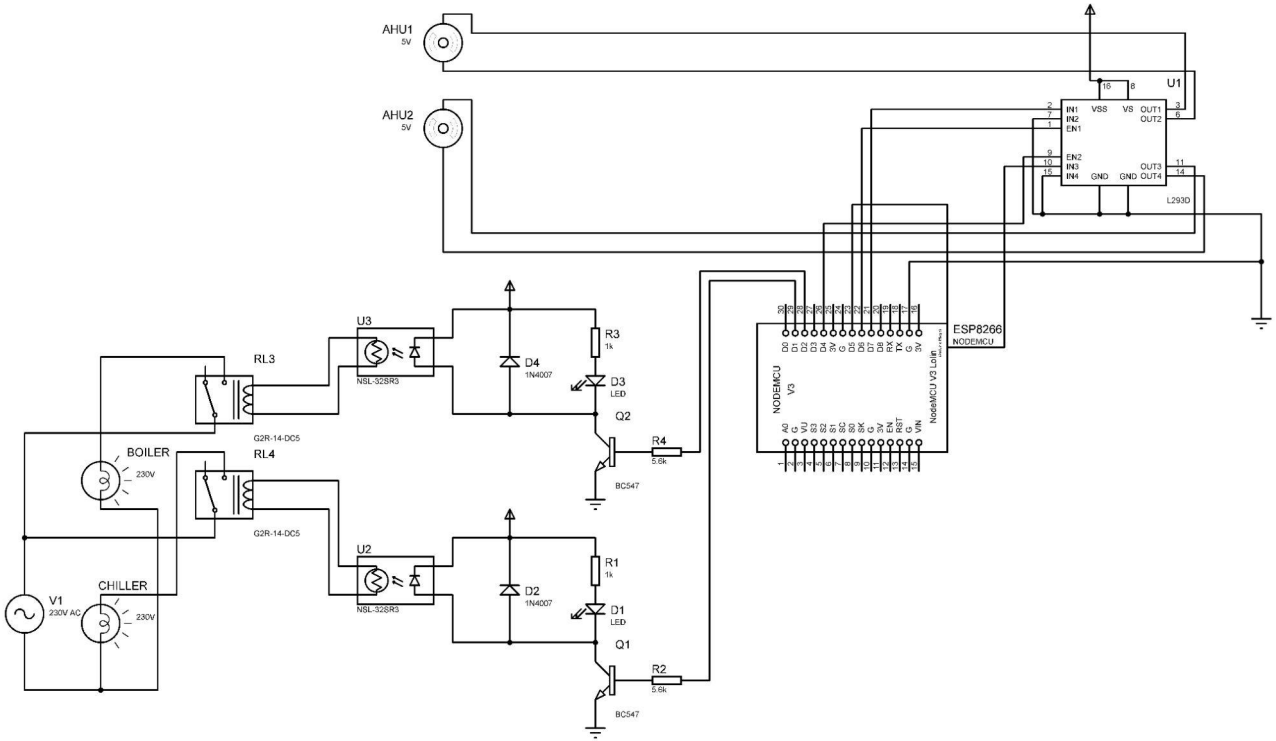
```
target_temp = (ratio * Tb  +  (1-ratio) * Tc
new_temp = target_temp + (current_temp - target_temp)*exp(-t/ (4000*speed))
```

Actuators

The **boiler**, while on, will continue to increase the temperature of the air duct connected to it whereas the **chiller** will provide cool air through its air duct.
The AHU controls the temperature for each room by **mixing the hot and cold air to produce air of the required temperature** for the room. The **AHU** contains dampers on each of the air ducts to control the mix ratio between the hot air and cold air.



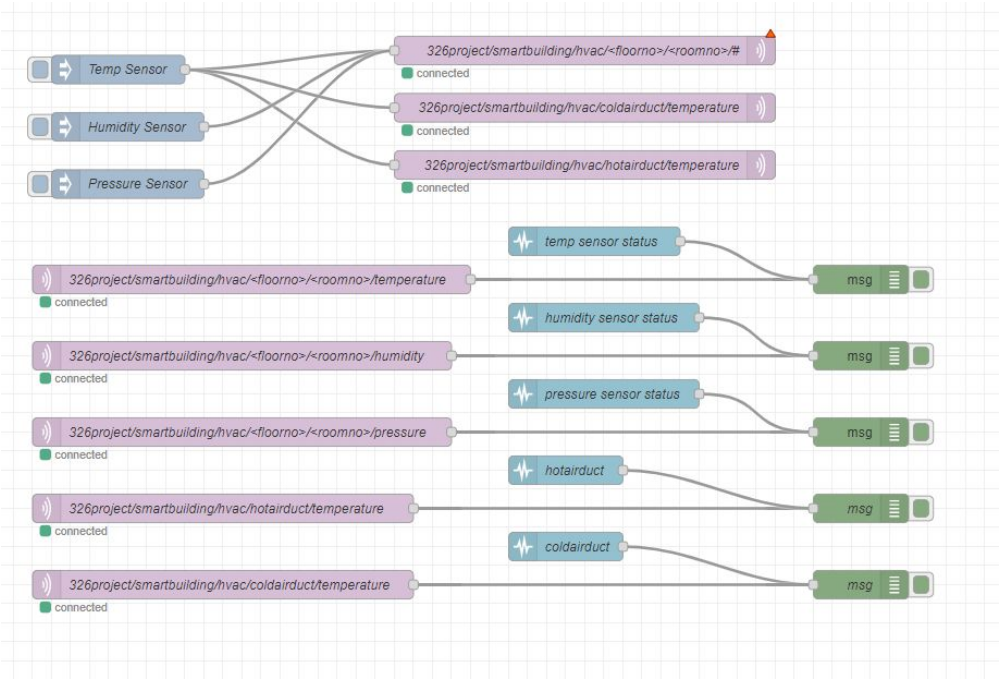
Actuators



The schematic diagram for the designed hardware model

MQTT

Sensor Data

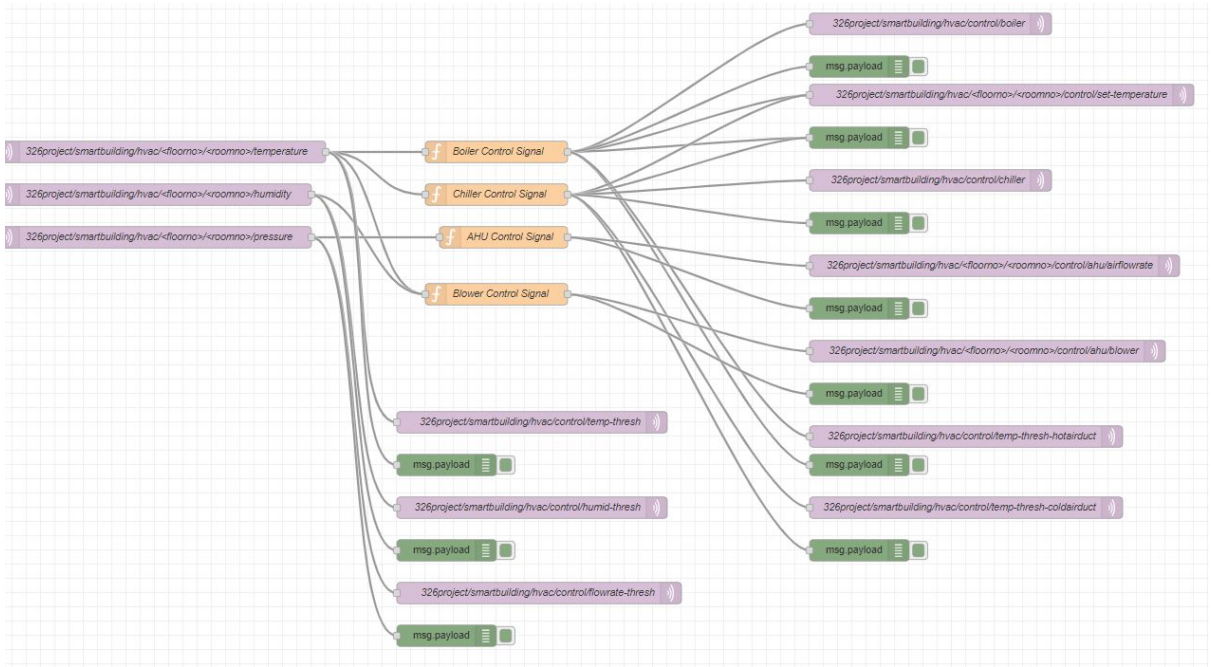



```
Boiler/chiller and main control/acquisitions
      326project/smartbuilding/hvac/coldairduct/temperature
      326project/smartbuilding/hvac/hotairduct/temperature
```

```
Ventilation control in rooms
 Sensing
  326project/smartbuilding/hvac/<floorno>/<roomno>/temperature
  326project/smartbuilding/hvac/<floorno>/<roomno>/humidity
  326project/smartbuilding/hvac/<floorno>/<roomno>/pressure
  326project/smartbuilding/occupancy/<floorno>/<roomno>/count
```

MQTT

Control Data

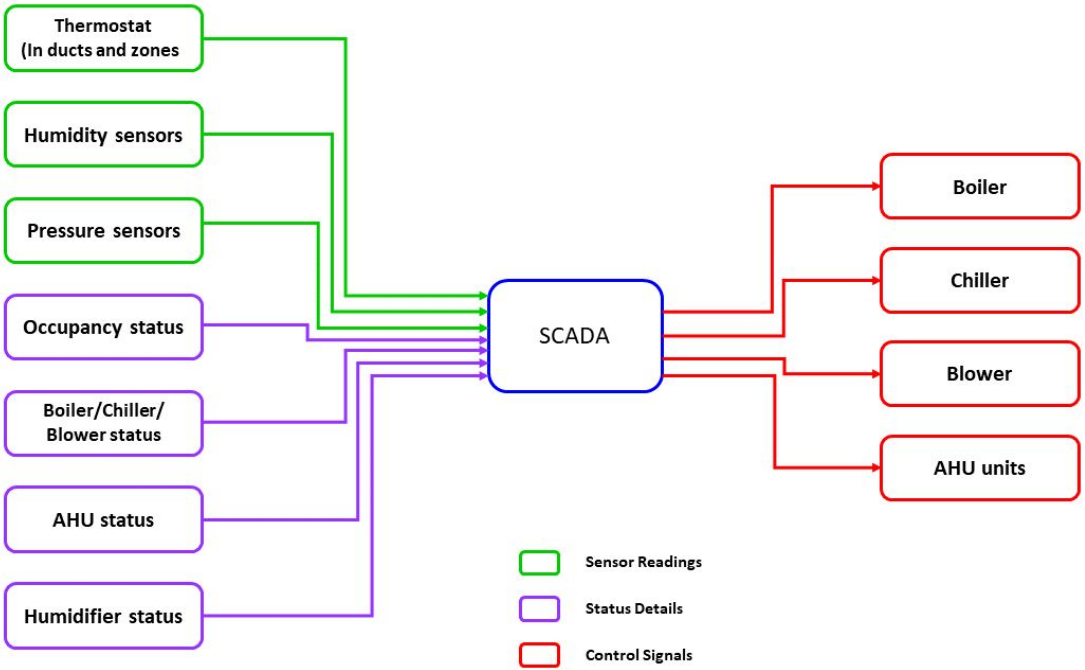



```
Boiler/chiller and main control/acquisitions
    Control
      326project/smartbuilding/hvac/control/boiler
      326project/smartbuilding/hvac/control/chiller
```

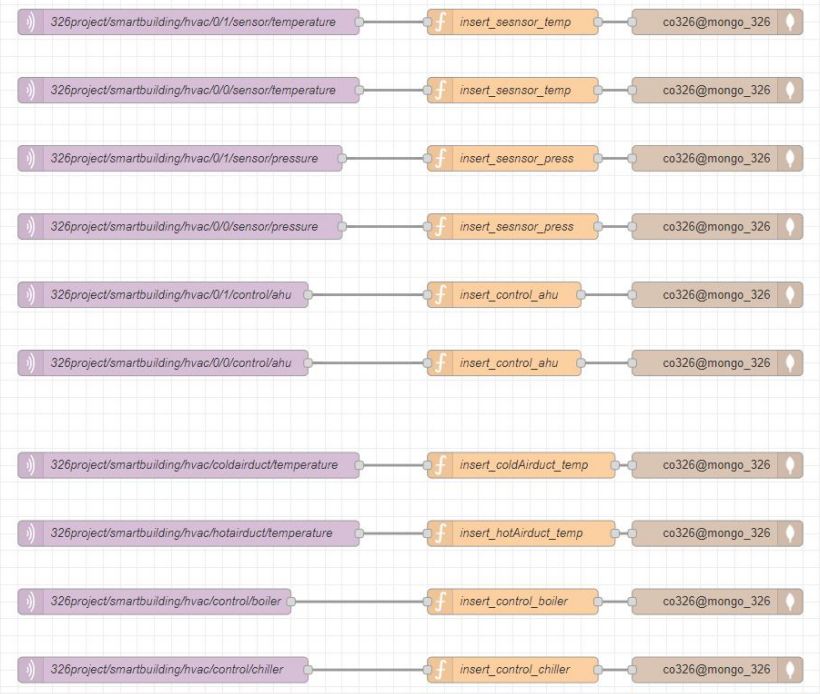
```
Ventilation control in rooms
 Control
 *326project/smartbuilding/hvac/<floorno>/<roomno>/control/set-temperature
  326project/smartbuilding/hvac/<floorno>/<roomno>/control/ahu/blower
 *326project/smartbuilding/hvac/<floorno>/<roomno>/control/ahu/airflowrate
```

```
set thresholds
      326project/smartbuilding/hvac/control/temp-thresh
      326project/smartbuilding/hvac/control/temp-thresh-coldairduct
      326project/smartbuilding/hvac/control/temp-thresh-hotairduct
      326project/smartbuilding/hvac/control/humid-thresh
      326project/smartbuilding/hvac/control/flowrate-thresh
```

SCADA


Thermostat
(In ducts and zones
Humidity sensors
Pressure sensors
Occupancy status
Boiler/Chiller/
Blower status
AHU status
Humidifier status
SCADA
Boiler
Chiller
Blower
AHU units
Sensor Readings
Status Details
Control Signals

Database



Complete Node-RED workflow

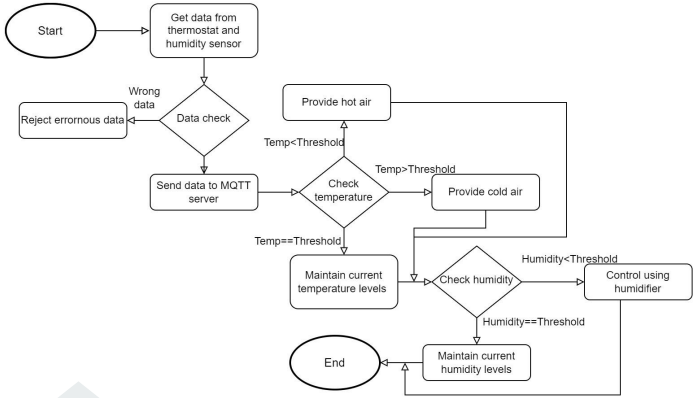
Necessary MQTT data, commands and events are stored in the database. Python scripts are used to enter the published data into the database.

```
let str = msg.topic;
str = str.substring(30, str.length);

let floor = str.substring(0, 1);
let room = str.substring(2, 3);
let description = str.substring(4, str.length);
let data = msg.payload;
let time = new Date().toLocaleString();

msg.payload = {
    "floor": floor,
    "room": room,
    "description": description,
    "data": data,
    "time": time
};

msg.collection = "co326_hvac_sensor_temp_floor0/room1";

return msg
```

MongoDB Collections

- co326_hvac_ahu_floor0/room0
- co326_hvac_ahu_floor0/room1
- co326_hvac_temp_floor0/room0
- co326_hvac_temp_floor0/room1
- co326_hvac_press_floor0/room0
- co326_hvac_press_floor0/room1
- co326_hvac_coldAirduct_temp
- co326_hvac_hotAirduct_temp
- co326_hvac_control_chiller
- co326_hvac_control_boiler

System Controller

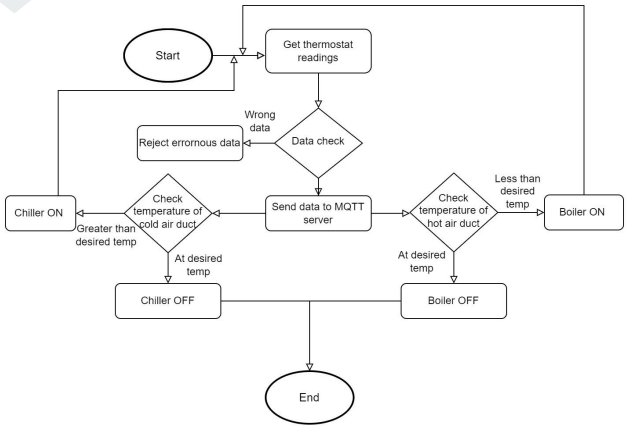


Boiler/Chiller Control

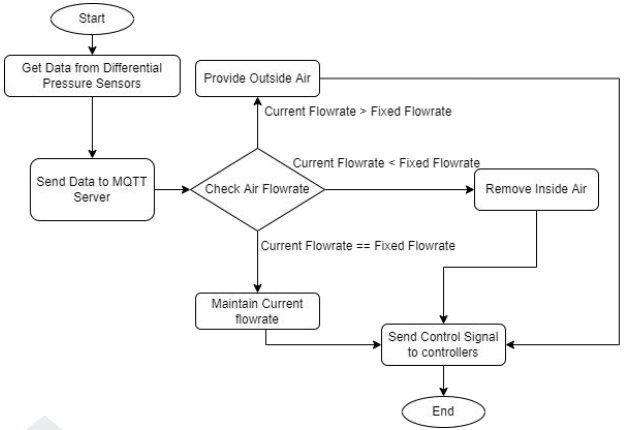
Thermostat readings are sent using MQTT and the main controller receives these data, then the controller should take necessary decisions.

Temperature/Humidity Control

The readings of the thermostat and the humidity sensor should be sent to the MQTT server continuously, such that the controller can make necessary decisions.



System Controller

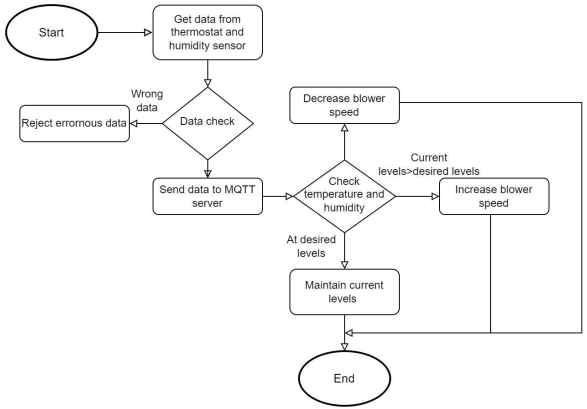


Blower Control

The thermostat/humidity sensor readings are sent using MQTT to the main controller that receives these data, then the controller should take decisions and send the control signal to the blower controller using MQTT.

Ventilation Control

The readings of the pressure sensor should be sent to the MQTT server. Then the controller should take necessary decisions and send the control signal to the AHU controller to speedup/ slowdown the air flow rate.



System Controller

Boiler/Chiller and Main Control

To obtain temperatures of cold-air duct and hot-air duct.	`326project/smartbuilding/hvac/coldairduct/temperature` `326project/smartbuilding/hvac/hotairduct/temperature`
If the temperature from the cold-air duct is greater than the desired temperature range, turn on the chiller.	`326project/smartbuilding/hvac/control/chiller`
If the temperature from the hot-air duct is greater than the desired temperature range, turn off the boiler.	`326project/smartbuilding/hvac/control/boiler`

We have subscribed to the following topics to change the threshold values.	`326project/smartbuilding/hvac/control/temp-thresh`
	`326project/smartbuilding/hvac/control/temp-thresh-coldairduct`
	`326project/smartbuilding/hvac/control/temp-thresh-hotairduct`

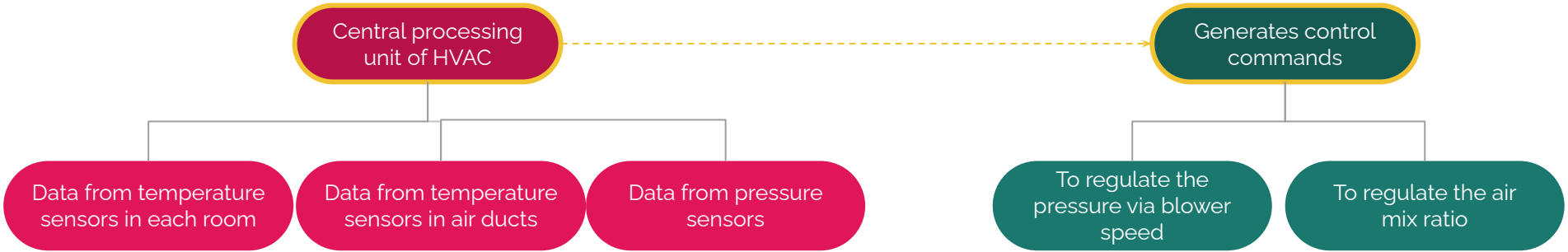
System Controller

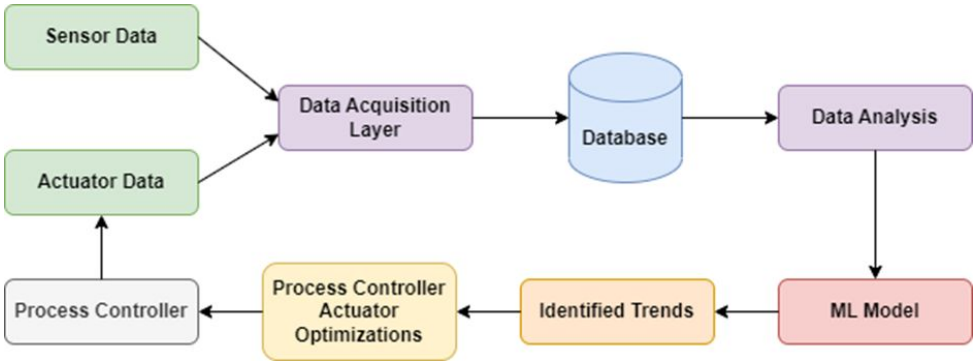
Ventilation Control in Rooms

Get the temperature, humidity, pressure and occupancy count in a room.	`326project/smartbuilding/hvac/<floorno>/<roomno>/temperature` `326project/smartbuilding/hvac/<floorno>/<roomno>/pressure`
If the incoming temperature and the humidity are greater than the desired range, increase the speed of the blower.	`326project/smartbuilding/hvac/<floorno>/<roomno>/control/ahu/blower`
Get the current flow rate and check whether it is greater than the desired range. If so, publish a control command to provide outside air.	`326project/smartbuilding/hvac/<floorno>/<roomno>/control/ahu/airflowrate`

We have subscribed to the following topics to change the threshold values.	`326project/smartbuilding/hvac/control/temp-thresh`
	`326project/smartbuilding/hvac/control/humid-thresh`
	`326project/smartbuilding/hvac/control/flowrate-thresh`

Data Analytics





Generated control commands that are stored in the database can be used to create ML models and increase the efficiency of the HVAC. **For example**, **training an ML model on historical data over a long period of time** will allow us to identify trends in HVAC utilization such as peak times and idle times to optimize the control algorithm for greater efficiency.

Demonstration

Thank you