Project Documentation

Indoor Air Monitoring System
Embedded Systems Workshop 2019

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Indoor Air Quality Monitoring System

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***Abstract*—Indoor air pollution due to household cooking is a hidden public health problem especially in developing countries. Cooking practices have an influence on the amount of pollution. Higher prevalence of respiratory infections is associated with cooking smoke especially among children. Most documented literature points toward a higher prevalence of respiratory symptoms, lung cancer and impaired lung functions with cooking smoke. Cleaner fuels seemingly cause less pollution though the literature is rare on kerosene. Identifying household air pollutants and their health implications helps us prepare for various health-related issues. However, the real challenge is adopting changes to reduce the health effects of household air pollution and designing innovative interventions to minimize the risk of further exposure. We present you a sophisticated model of air quality monitoring system which sense the presence of different of various air pollutants and send them to cloud for easy analysis.**

***Index Terms*—Air Monitoring System,Kitchen,Air Pollution,Pollutants**

I. Introduction

In the words of Rosalynn Carter, "There is nothing more important than a good, safe and secure home". It is believed that a house is the most secure and healthy environment for any individual. However, the house can also be a source of various air pollutants that can have a significant adverse impact on health.

Indoor air pollution within households is one of the main contributors of mortality and disability globally. Emission due to household cooking fuels is found to be one of the main factors affecting indoor air pollution. In most parts of the developing world, traditional devices are used for cooking. The incomplete com bustion of these give rise to many pollutants including carbon monoxide, aldehydes, nitrogen oxides, polycyclic aromatic hydrocarbons, etc. . Indoor cooking is also a primary source of particle pollution, which is also called 'particulate matter' (PM). This consists of solid and liquid particles in the air . In a study on PM, it was found that 29-48% of source- wise attribution was from solid fuels . An Indian study revealed that 50-80% of the total suspended particulate emissions of cooking stoves using biomass and coal, were respirable being less than 2 μm in size. According to a Chinese study, PM levels during winter were significantly correlated with the usage of solid fuel. Incomplete combustion is influenced by poor ventilation and the poor quality of cooking devices used in lower-income countries . Improved cooking devices are associated with less pollution. Furthermore, factors such as higher education is associated with the usage of improved cooking devices than traditional ones . In return, negative respiratory effects are less when improved cooking devices are used .

A. Problem Definition

Monitor the Air Quality Standards in Kitchens.
Using the NodeMCU and air pollutants sensors like Particulate sensors, Humidity and Temperature sensor,Multi-channel gas sensors and VOC and CO2 sensors, collect the amount of various air pollutants and send them to ONEM2M server and IOT cloud for easy further analysis.

B. Purpose of System

Food production area are prone much air pollution as they will be using

- Inflammable fuels
- Burning coal
- Organic matter

Despite this pollution these areas should be kept clear of other air pollutants and gases. The air pollutants's concentration should be monitored to ensure the safety of the workers and the quality of the food.

C. Overview of System

In this project we monitor the air pollutants and standards such as

- Particulates
- Volatile organic compounds
- Carbon dioxide
- Nitrogen dioxide
- Ammonia
- Carbon monoxide
- Temperature and Humidity

The data which is collected is then sent to the ONEM2M server and Thingspeak cloud for easy monitoring and analytic.

II. System Requirements

A. Hardware Requirements

•Should use a processing unit to collect data from different sensors.
•Sensors should be used to collect the following data.
•Temperature and Humidity.
•Concentration of Particulates.
•Concentration of Volatile Organic Compounds in air.
•Concentration of gases like CO2,NO,CO,NH3
•Use a portable WiFi router to connect to the Internet.
•Use a power bank to act as an uninterruptible power supply.

B. Software Requirements

•Processing unit should be capable of sending data using WiFi to a cloud software.
•Should use ONEM2M as a service layer and send data to ONEM2M servers.
•Should send data to IOT platform like Thingspeak for easy analytic.

III. System Specifications

A. Hardware part

List of controllers,sensors and other devices:

- NodeMCU
  We use NodeMCU as our central processing unit connecting air pollutants sensors
  - NodeMCU is an open source LUA based firmware developed for ESP8266 wifi chip.
  - The ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems with TCP/IP protocol.
  - NodeMCU Dev Kit has Arduino like Analog (i.e. A0) and Digital (D0-D8) pins on its board.
  - It supports serial communication protocols i.e. UART, SPI, I2C etc.

NodeMCU	Programmable IOT Development Board
Input Voltage	5v
Operating Votage	3.3V
WiFi type	11 b/g/n Wi-Fi Direct (P2P), soft-AP
Protocol	Integrated TCP/IP protocol stack
Programming Chip	CP2102 Serial / USB Chip
Output Power	+19.5dBm in 802.11b mode
Memory	4MB Flash Memory
CPU	Integrated low power 32-bit CPU
Interface	SDIO 1.1 / 2.0, SPI, UART
Output Power	+19.5dBm in 802.11b mode
Output Power	+19.5dBm in 802.11b mode
Dimensions	49mm x 24.5mm x 13mm
Weight	Approx. 12g

Fig. 1. NodeMCU specifications [1]

- Nova PM2.5-PM10 Particulate Sensor(SDS011)
  We use Nova particulate sensor to sense particulates with size under 2.5nm and more than 10nm in diameter.
  - The SDS011 using principle of laser scattering,can get the particle concentration between 0.3 to 10μm in the air.
  - It gives direct digital output via serial protocol at 9600bps and also over 2 PWM channels.
  - There is a built-in fan for stable and reliable operations.

Item	Specification
Measurement parameters	$PM_{2.5}$, PM_{10}
Measuring range	0.0–999.9 $\mu g/m^3$
Input voltage	5 V
Related current	70 mA ± 10 mA
Sleep current	< 4 mA (lase and fan sleep)
Response time	1 s
Serial data output frequency	1 Hz (1 time/s)
Minimum resolution of particle	0.3 µm
Counting yield	70% @ 0.3 µm; 98% @ 0. n5 µm
Relative error	Maximum of ± 15% and ±10 $\mu g/m^3$
Temperature range	Storage environment: −20–+60 °C; work environment: −10–+50 °C
Humidity range	Storage environment: max. 90%; work environment: max. 70%
Air pressure	86 KPa–110 KPa
Product Size	L × W × H = 71 × 70 × 23 mm
Appropriate price	€16/piece
Appropriate weight	50 g
Service life	Up to 8000 h
Certification	CE/FCC/RoHS

Fig. 2. Nova PM2.5-PM10 sensor specifications [2]

- Digital Humidity and Temperature Sensor(DHT22)
  - It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed).
  - Its fairly simple to use, but requires careful timing to grab data.
  - The only real downside of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old.
  - DHT22 specifications [3]:
    * Low cost
    * 3 to 5V power and I/O
    * 2.5mA max current use during conversion (while requesting data)
    * Good for 0-100
    * Good for -40 to 80 ◦ C temperature readings 0.5 ◦ C accuracy
    * No more than 0.5 Hz sampling rate (once every 2 seconds)
    * Body size 15.1mm x 25mm x 7.7mm

- Grove Multi-channel sensor(MiCS-6814)
  - Grove Multi-channel Gas sensor is a environment detecting sensor with a built in MiCS-6814 which can detect many unhealthful gases, and three gases can be measured simultaneously due to its multi channels,

Specification

Parameter	Signal	Values
Working Voltage	3.3V/5V	
Output range	TVOC	0 ppb to 60000ppb
	CO_2eq	400 ppm to 60000 ppm
Sampling rate	TVOC	1HZ
	CO_2eq	1HZ
Resolution	TVOC	0 - 2008 ppb / 1 ppb
		2008 - 11110 ppb / 6 ppb
		11110 - 60000 ppb / 32 ppb
	CO_2eq	400 - 1479 ppm / 1 ppm
		1479 -5144 ppm / 3 ppm
		5144 - 17597 ppm / 9 ppm
		17597 - 60000 ppm / 31 ppm
Default I2C address	0X58	

Fig. 3. SGP-30 specifications [5]

so it can help you to monitor the concentration which more than one gas.

- Multi-channel gas sensor specifications [4]:

  * Three fully independent sensing elements on one package
  * Built with ATmega168PA
  * I2C interface with programmable address
  * Heating power can be shut down for low power
  * Detectable gases
  * Carbon monoxide CO 1 to 1000ppm
  * Nitrogen dioxide NO2 0.05 to 10ppm
  * Ethanol C2H6OH 10 to 500ppm
  * Hydrogen H2 1 to 1000ppm
  * Ammonia NH3 1 to 500ppm
  * Methane CH4 ¿1000ppm
  * Propane C3H8 ¿1000ppm
  * Iso-butane C4H10 ¿1000ppm

• Grove VOC and CO2 Gas sensor(SGP-30)
  - The Grove-VOC and eCO2 Gas Sensor(SGP30) is an air quality detection sensor.
  - This grove module is based on SGP30, provided TVOC(Total Volatile Organic Compounds) and CO2eq output for this module.

• JioFi(JMR1040)
  - We use JioFi to get internet access to post the data obtained from sensors in an ONEM2M server and IOT cloud to store them and for easy further analysis

• Zinq power bank
  - We use a power bank to provide an uninterruptible power service for the whole device.

Model	JMR1040
No of Devices supported	Recommended 10 (Wi-Fi) + 1 (USB tethering)
Standard	WAN: LTE (2300/1800/850MHz) IEEE 802.11b/g/n 2.4G only
Power Supply	AC: 100-240V; DC: 5V&1A
Dimensions	74 X 74 X 20 mm
External Interface	Micro-SD Card, Micro-USB Port, Nano SIM
Battery Capacity	3000mAh

Fig. 4. JioFi specifications [6]

Brand	Zinq Technologies
Model	Z5KP_RED
Model Name	Z5KP
Item Weight	99.8 g
Product Dimensions	9.9 x 6.4 x 1.4 cm
Batteries:	1 Lithium Polymer batteries required. (included)
Item model number	Z5KP_RED
Compatible Devices	iPhone
Included Components	Power Bank, Micro USB Cable and Thank You Card
Batteries Included	Yes
Batteries Required	Yes
Battery Capacity	5000 milliampere_hour
Battery Cell Composition	Lithium Polymer
Battery Power	5000 milliamp_hours

Fig. 5. Zinq power bank specifications [7]

  - Ultra small and powerful: Smallest size for its capacity of 5000 mAh is very portable and easy to carry
  - Input-output versatility: The power bank has Single input charging options of micro USB and has dual output ports with 2.0A fast charging
  - 6-level protection: Built using the highest quality Li-polymer battery and protection from short circuits, current and voltage overloads overheating and wrong insertion
  - Led indicator: A led indicators to find the status of charge ensuring you exactly know so that you don't run into surprises
  - Compatibility: Charge your iPhone, all Android devices, tablets, cameras and iPod, headphones

B. *Software part*

1) Arduino: We use Arduino IDE [8] for flashing the code in NodeMCU.Code is mentioned in the github repository given at last.
Arduino is an open-source physical computing platform based on a simple I/O board and a development environment that implements the Processing/Wiring language. Arduino can be used to develop stand-alone interactive objects or can be connected to software on your computer (e.g. Flash, Processing and MaxMSP). The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free at https://arduino.cc

2) ONEM2M: We added ONEM2M [9] service layer to our model to make it easy for machine to machine communication

and security. We use ONEM2M API to send data to ONEM2M server.
The purpose and goal of oneM2M is to develop technical specifications which address the need for a common M2M Service Layer that can be readily embedded within various hardware and software, and relied upon to connect the myriad of devices in the field with M2M application servers worldwide. A critical objective of oneM2M is to attract and actively involve organizations from M2M-related business domains such as: telematics and intelligent transportation, healthcare, utilities, industrial automation, smart homes, etc.

3) Thingspeak: We also use Thingspeak [10] for IOT cloud to store data and do further analytic with MATLAB(integrated with Thingspeak).
our MATLAB functions used to analyze the air quality data collected by ThingSpeak. The MATLAB code helps preprocess the sensor data, provides functions to classify the data, and provides functions for visualizing the processed air quality data. The MATLAB visualizations are added to a ThingSpeak channel dashboard so you can see the current air quality near you. The MATLAB analysis code calculates the AQI using the definitions from the United States Environmental Protection Agency (EPA).

4) Dashboard: We built a data analysis dashboard on ThingSpeak using our available data and MATLAB. This project it makes it easy to explore IoT data analysis using MATLAB to preprocess and visualize data without having IoT hardware.

IV. Stake Holders

This device affects all the people working in mess or kitchens. It also affects the food quality.

V. Design Details

A. Conceptual Flow

The working of the device go as follows

- Firstly the processing unit,NodeMCU take power from the power bank and run the code flashed into it.
- NodeMCU, using its esp8266 WiFi module connects to the JioFi through the given SSID and password.
- Now NodeMCU collects data from each sensor and store them in variables.The NodeMCU collects data every 30 seconds.
- The data stored in variables is sent to different Thingspeak channels by using thingspeak API in Arduino IDE.
- For every 15 minutes, The NodeMCU post recent data to ONEM2M server by a certain CSE IP ,here it is onem2m.iiit.ac.in with port 80.

B. Entity Interaction

We have entities interacting in many different ways.

- NodeMCU - SDS011
This interaction uses UART communication.Rx pin of NodeMCU is connected to Tx pin of SDS011 and Tx pin of NodeMCU is connected to Rx pin of SDS011.

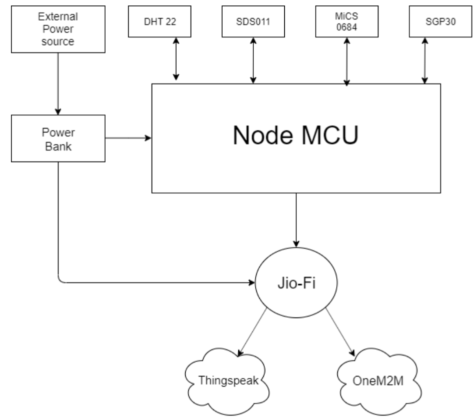

Fig. 6. Block diagram representation of the flow

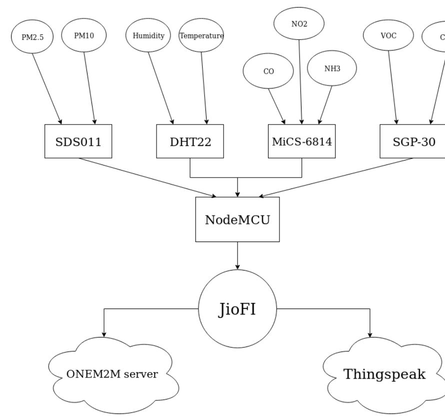

Fig. 7. Entities Interacting

- NodeMCU - DHT22
This interaction uses GPIO communication.D3 pin of NodeMCU is connected to DHT22.
- NodeMCU - MiCS-6814
This interaction uses I2C communication.D0 and D1 pins of NodeMCU are connected to SCK and SDA pins of Mics-6814.
- NodeMCU - SGP-30
This interaction uses I2C communication.D0 and D1 pins of NodeMCU are connected to SCK and SDA pins of SGP-30.
- NodeMCU - JioFi
This interaction uses WiFi communication.NodeMCU uses esp 8266 module to communicate to JioFi through WiFi.
- JioFi - ONEM2M or Thingspeak
Here the data is sent through post requests to both the servers and is stored there.

VI. Operational Requirements

A. System Needs

- Although power bank serves as the uninterruptible power source for both NodeMCU and JioFi,Power bank should

be connected to a power source like a power socket all the time even when power bank is fully charged.
- The device should be hanged in open space in kitchen.It should be at a suitable height to get affected by pollutants.
- Since we need internet to post data to cloud, we need of consistent network signal for JioFi in the kitchen.

B. UI design

The device is cleanly,compactly enclosed in 3D-enclosure with two sides with grid walls to let free passage of air.
We can check the working condition by the led lights provided by JioFi to verify whether NodeMCU is connected to it or not. The power source can be verified by checking the led lights on power bank.

C. Analytical System

- ThingSpeak support functions let you use desktop MATLAB to analyze and visualize data stored on ThingSpeak.com or on private installations of ThingSpeak.
  With the MATLAB engine built into ThingSpeak, you can perform calibrations, develop analytics, and transform your IoT data.
  Operationalize your analytics using the Time Control and React apps. With the Time Control app, you can schedule a computation to run once a day, once an hour, or as quickly as once every 5 minutes. The React App is used for condition monitoring. You can monitor the data coming in from your devices and set up an alert when the data indicates something may need attention.
- The data in ONEM2M server is stored in containers with time stamps,So, We know the date and time when the air pollutant levels are breached.

Acknowledgment

The work described in this project was conducted within IIIT Hyderabad and also funded by IIIT Hyderabad under Embedded Systems Workshop 2019.We sincerely thank Dr.Sachin Chaudhari and Tanmai Mukku for their support and guidance through the whole project.

References

[1] https://veerobot.com/store/CB-MCU-IOTB-12
[2] https://cdn-reichelt.de/documents/datenblatt/X200/SDS011-DATASHEET.pdf
[3] https://www.adafruit.com/product/385
[4] http://wiki.seeedstudio.com/Grove-Multichannel_Gas_Sensor/
[5] http://wiki.seeedstudio.com/Grove-VOC_and_eCO2_Gas_Sensor-SGP30/
[6] https://www.jio.com/shop/en-in/router-jmr1040-white/p/491193523
[7] https://www.amazon.in/Zinq-Technologies-Z10KI-10000mAH-Lithium/dp/B07MHCFRW5
[8] https://www.arduino.cc/en/main/software
[9] http://www.onem2m.org/about-onem2m/why-onem2m
[10] https://thingspeak.com/

User Document

***Abstract*—We present you a sophisticated model of air quality monitoring system which sense the presence of different of various air pollutants and send them to cloud for easy analysis.**

***Index Terms*—Air Monitoring System,Kitchen,Air Pollution,Pollutants**

I. Introduction

Indoor air pollution within households is one of the main contributors of mortality and disability globally. Emission due to household cooking fuels is found to be one of the main factors affecting indoor air pollution. In most parts of the developing world, traditional devices are used for cooking. The incomplete com bustion of these give rise to many pollutants including carbon monoxide, aldehydes, nitrogen oxides, polycyclic aromatic hydrocarbons, etc. . Indoor cooking is also a primary source of particle pollution, which is also called 'particulate matter' (PM). This consists of solid and liquid particles in the air . In a study on PM, it was found that 29-48% of source- wise attribution was from solid fuels

A. Objective

Monitor the Air Quality Standards in Kitchens.
With this device we should monitor the air pollutants and standards such as
•Particulates
•Volatile organic compounds
•Carbon dioxide
•Nitrogen dioxide
•Ammonia
•Carbon monoxide
•Temperature and Humidity
The data which is collected is then sent to the ONEM2M server and Thingspeak cloud for easy monitoring and analytic.

B. Scope

Food production area are prone much air pollution as they will be using
• Inflammable fuels
• Burning coal
• Organic matter
Despite this pollution these areas should be kept clear of other air pollutants and gases. The air pollutants's concentration should be monitored to ensure the safety of the workers and the quality of the food.

II. Product Operational Requirements

A. Operating Environment

- This device is focused on but not constrained to kitchens and other food production areas.
- The device must be kept in an open space to let be affected by air pollutants.
- The device should be hanged at an appropriate height to the wall.
- The device should not get into contact with any liquid.
- The device shouldn't kept directly above stove or below an exhaust fan.
- The device should be connected to a 220V socket.
- The device should have proper network signal to post data to cloud.
- The JioFi data card should have an active internet package to get access to internet.

III. System Working Model

A. Base State

The first prototype is designed for testing and calibration with no physical enclosure.
It was designed on a breadboard.Then it was upgraded to a perforated circuit board.
It doesn't include JioFi and power bank.
It has a power socket as it's power source,since it is not an uninterruptible power source,the device is not a steady state device.
It was only integrated with Thingspeak.
Testing and Calibrating was done in a lab for a week and proper adjustments were made.

B. Working State

The working model is an advanced model of Base state.
It was enclosed in a physical enclosure with some walls replaced by grills to have free passage of air.
The working state include JioFi and power bank which were absent in the Base state.
The working system has an uninterruptible power source unlike Base state.
The working state is designed on Printed Circuit Board which improve compactness to a great extent.
It is integrated with both Thingspeak and ONEM2M.The data can be accessed by ONEM2M dashboard and Thingspeak dashboard.It is even accessible in mobile through various mobile applications like Thingsview etc.

Acknowledgment

The work described in this project was conducted within IIIT Hyderabad and also funded by IIIT Hyderabad under Embedded Systems Workshop 2019.We sincerely thank Dr.Sachin Chaudhari and Tanmai Mukku for their support and guidance through the whole project.We also like to thank the Embedded Systems Workshop Professors for their guidance in various aspects and fields.

3 IOT Project Components

3.1 Hardware Specifications

- NodeMCU
  NodeMCU is an open source LUA based firmware developed for ESP8266 wifi chip.The ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems with TCP/IP protocol. NodeMCU Dev Kit has Arduino like Analog (i.e. A0) and Digital (D0-D8) pins on its board.It supports serial communication protocols i.e. UART, SPI, I2C etc

- SDS011
  The SDS011 using principle of laser scattering,can get the particle concentration between 0.3 to 10Îijm in the air. It gives direct digital output via serial protocol at 9600bps and also over 2 PWM channels. There is a built-in fan for stable and reliable operations

- DHT22
  It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). Its fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old.

- MiCS-6814 Grove Multichannel Gas sensor is a environment detecting sensor with a built in MiCS-6814 which can detect many unhealthful gases, and three gases can be measured simultaneously due to its multi channels, so it can help you to monitor the concentration which more than one gas.

- SGP-30
  The Grove-VOC and eCO2 Gas Sensor(SGP30) is an air quality detection sensor. This grove module is based on SGP30, provided TVOC(Total Volatile Organic Compounds) and CO2eq output for this module.

3.2 Communication

OneM2M is used for communication between the Node and Server. It has the following uses:

- Security and privacy aspects(authentication, encryption, integrity verification).
- Identification and naming of devices(for differentiating different devices).
- Data aggregation, buffering in case of missing connectivity and synchronisation upon connectivity re-establishment
- Group management and application and data discovery functions

Other forms of communications like UART and I2C are also used for the interacting components but are not used in the communication between the server and the node.

3.3 Software specifications

- Arduino IDE is used to program the microcontroller.
- Eagle Cad is used to design the printed circuit board.
- Fusion 360 is used to design the 3D printed box.
- Microsoft Excel is used to draw graphs for the collected data and for analysis.
- EasyEDA is used to draw the schematic representation of the circuit in the node.

3.4 Data References

Thingspeak

- https://thingspeak.com/channels/864652
- https://thingspeak.com/channels/864651
- https://thingspeak.com/channels/864650
- https://thingspeak.com/channels/864649
- https://thingspeak.com/channels/906528
- https://thingspeak.com/channels/907653
- https://thingspeak.com/channels/907654
- https://thingspeak.com/channels/907655

Github
https://github.com/SachinKumar105/Embedded-Systems-Workshop
OneM2M
http://onem2m.iiit.ac.in/webpage/welcome/index.html?context=/~&cseId=in-cse

3.5 Data Handling/Visualization

The data from the server is pulled by web-scraping. The data is also sent to Thingspeak server from where the data can be retrieved in an .xlsx format. The data from both are converted to the excel form and are further filtered and sorted according to date and time to provide better view of the results. These results are then represented as graphs.For Each of the sensors the average is taken for each day and for a particular day where the values are closest to these averages , the values are taken for each hour to see the change in the concentration of the gases across different times of the day. The obtained graphs for various sensors are as follows:

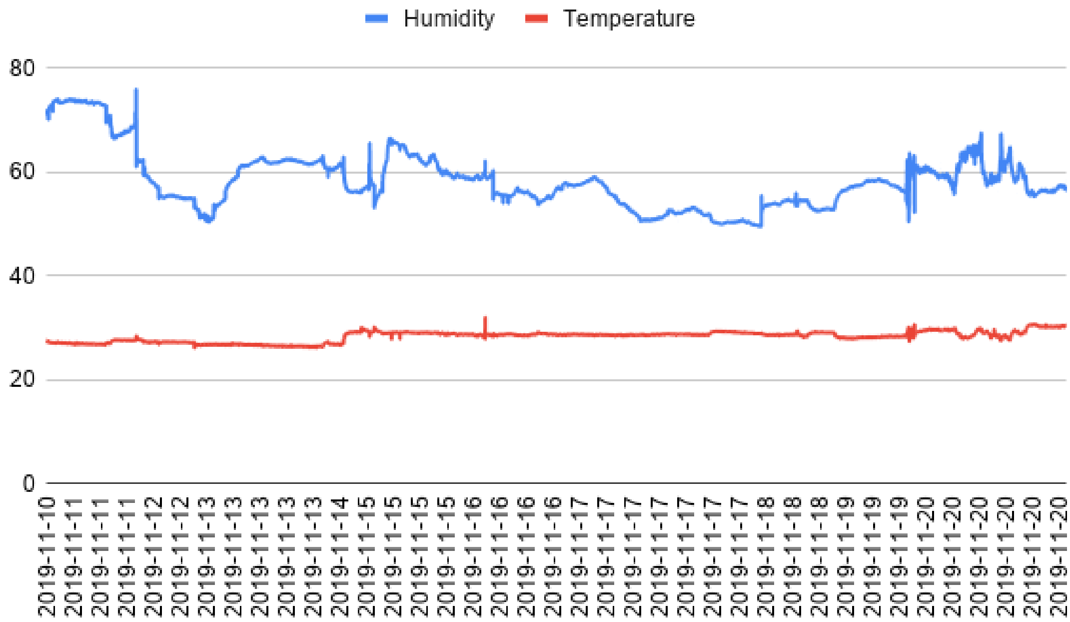

Figure 1: data from DHT22

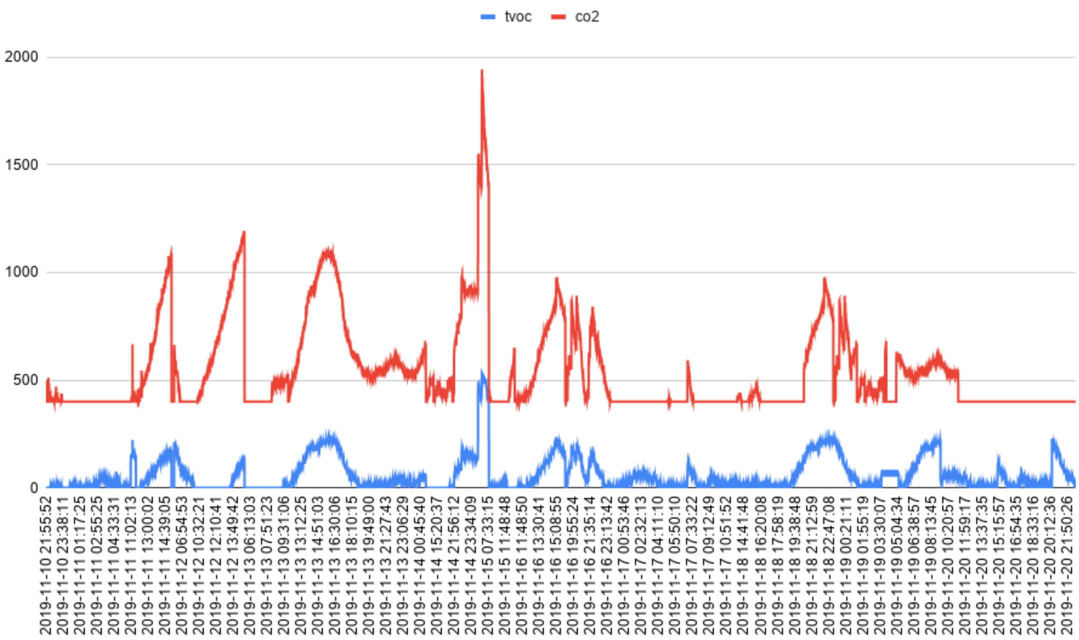

Figure 2: data from SGP30

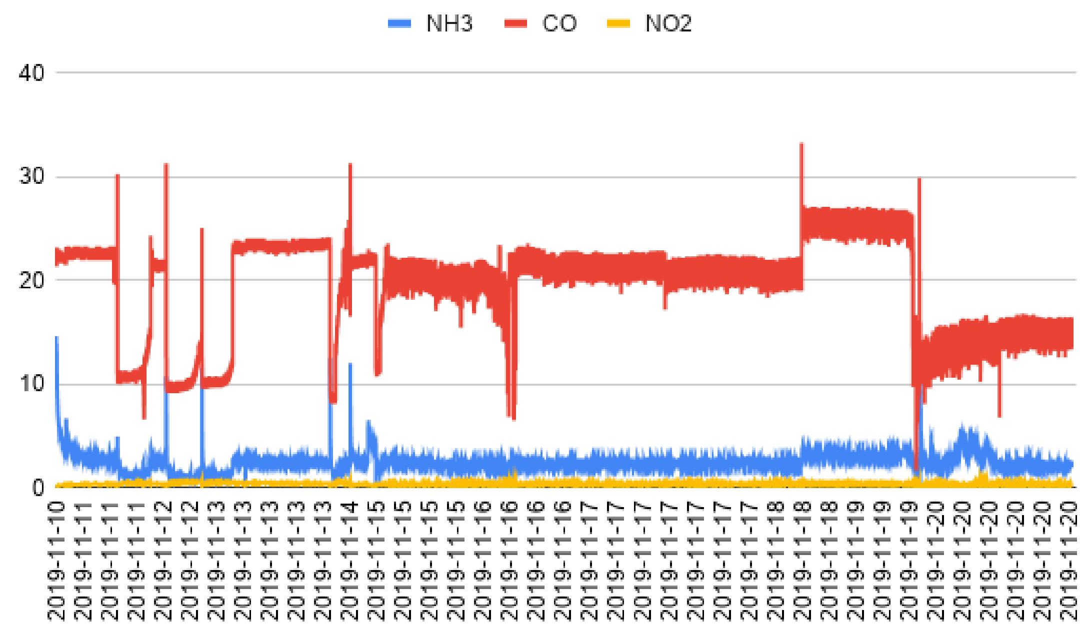

Figure 3: data from MiCS-6814

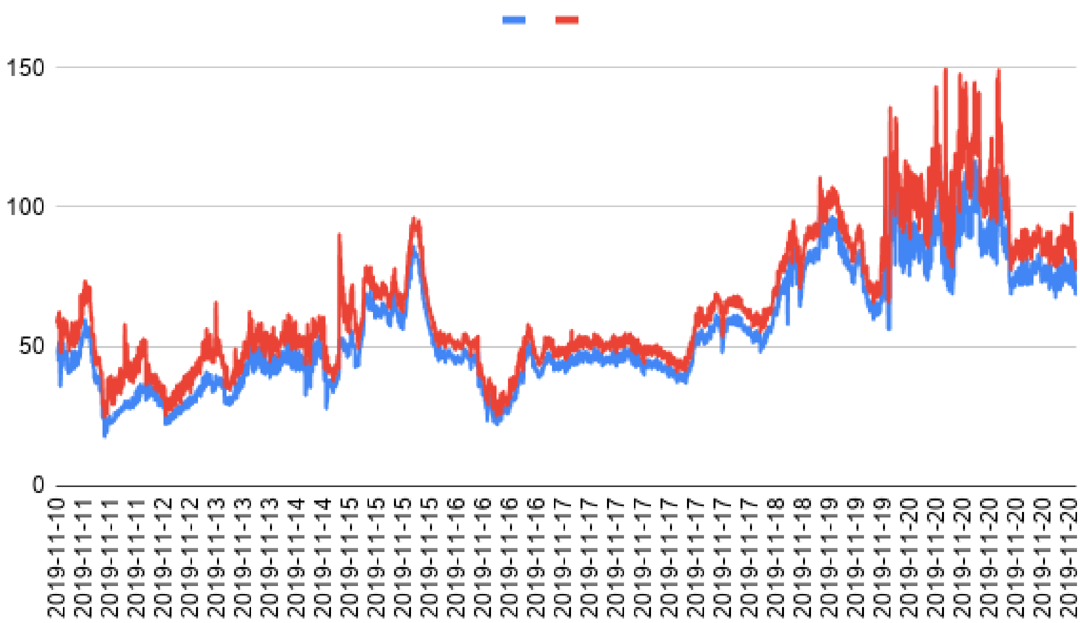

Figure 4: data from SDS011