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CLOUD BASED REAL-TIME AIR QUALITY AND ENVIRONMENTAL PARAMETERS MONITORING AND LOGGING SYSTEM

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Abstract

Cloud based real-time air quality and environmental parameters monitoring and logging system is based on the internet of things (IoT) using the ESP32 board which can process sensor data and upload them to cloud via internet. The system is based on **MQTT protocol** using ESP32**, BME680 integrated environmental sensor,** BH1750 light intensity sensor and UV sensor. The readings from all sensors are processed by the ESP32 board and uploaded to the ThingSpeak cloud. The real-time parameters are also displayed on the TFT LCD as well as serial monitor. The data collected in ThingSpeak cloud can be exported in .csv format. This research highlights the benefits of the advanced cloud-based technology which effectively reduce time and energy waste for human labor.

Keyward: MQTT protocol, ThingSpeak cloud, .csv format

Introduction

In this cloud-based real-time air quality and environmental parameters monitoring and logging system, the air quality and environmental parameters from the surrounding environment or of a particular location is measured with the help of some sensors and then the collected data will be stored on a server after being processed by a microcontroller. The daily activities are inseparable from weather conditions and various environmental factors. The real-time data collected can be used in research and analysis and the results can be helpful in human life and for improving environmental conditions as well.

The application of this environmental parameters monitoring system can also play an important role in the field of agriculture to increase productivity, research application, and reducing manpower. Sometimes in a particular agricultural zone that is hazardous for a human being, it is quite difficult to manually monitor the environment or weather conditions. In such cases, this cloud-based environmental parameter monitoring and logging system can be of great importance. The functional block diagram of the system is shown in Figure 1.

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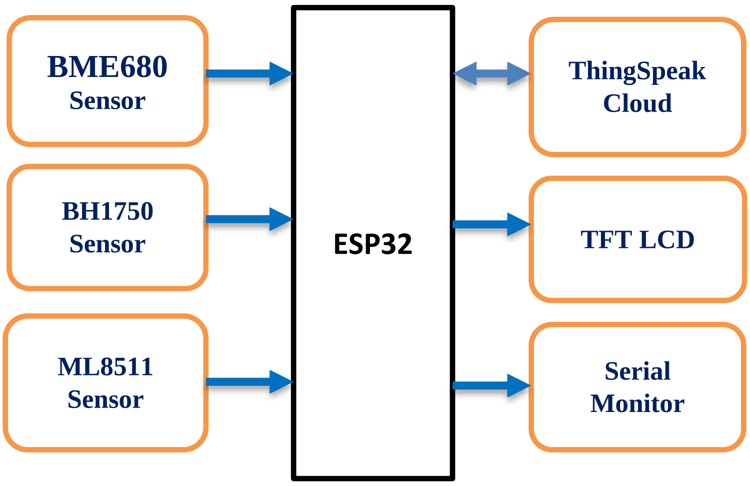

Figure 1. Functional block diagram of the system

Materials and Methods

Constructed system consists of the hardware and software sections. In hardware section, an ESP-WROOM 32 board, BME680 environmental parameter sensor, BH1750 light sensor, LM8511 UV sensor and TFT_LCD (thin-film transistor liquid crystal display) are used. The softwares are the Arduino IDE Software and ThingSpeak cloud.

ESP-WROOM 32

ESP-WROOM 32 microcontroller board composes of the high-speed dual core processor attached with Wi-Fi, Bluetooth classic and Bluetooth low energy (BLE). The cores are protocol CPU (PRO_CPU) and application CPU (APP_CPU). The CPU clock frequency is adjustable from 80 MHz to 240 MHz. The ESP32 also includes a variety of peripherals such as GPIO, I2C, SPI, UART, ADC, CAN, etc which makes it easy to interface with other devices. Photograph of ESP-WROOM 32 microcontroller board is shown in Figure 2.

Figure 2. Photograph of ESP-WROOM 32 microcontroller board

BME680 Environmental Data Sensor

BME680 is the environmental digital sensor which detects gas resistance, temperature, pressure and humidity. The altitude can be approximately determined by knowing atmospheric pressure. Similarly, dew point temperature can be measured using values of temperature and humidity. BME 680 also composes of metal oxide sensor which detects the volatile organic compounds (VOC) such as ethanol, alcohol and carbon monoxide. The resistance of the heated metal oxide sensor is changed due to the amount of VOC in air. Therefore, indoor air quality (IAQ) can be classified according to the quantitative performance of VOC in air. The Figure 3 shows the BME680 sensor module.

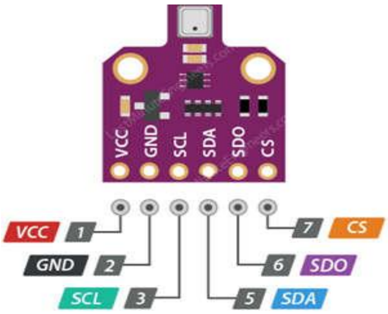

Figure 3. BME680 sensor module

ML8511 UV Sensor

The ML8511 is UV sensor is composed of an internal trans-impedance amplifier that converts photo-current flowing through photo-diode to voltage due to the amount of UV intensity. This unique feature is solution to measure the UV intensity. The relative responsibility of sensor is effective within the wavelength of 280nm and 400nm. The ML8511 UV sensor is shown in Figure 4.

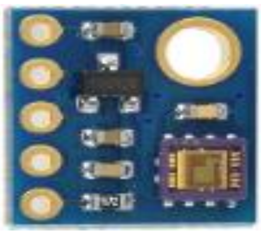

Figure 4. The ML8511 UV sensor

BH1750 Light Sensor

BH1750 is a digital ambient light sensor which can measure light intensity. It consists of photo-diode, amplifier and ADC. The photo-diode is effectively responsive in the visible region. When the ambient light is falling on it, photo-diode produces the current. This photo-current is converted to analog voltage by using the op-amp amplifier. The analog voltage signal is also converted to 16-bit digital data by means of ADC unit. Figure 5 shows the BH1750 light sensor.

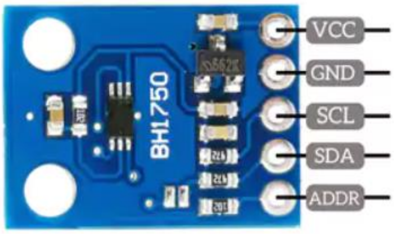

Figure 5. BH1750 Light intensity sensor

2.8″ TFT LCD - Thin Film Transistor Liquid Crystal Display

ELT240320ATP is a transmissive type color active matrix liquid crystal display (LCD) which uses amorphous thin film transistor (TFT) as switching devices. This product is composed of a TFT LCD panel, a drive IC, a FPC, and a WLED-backlight unit. The active display area is 2.8 inches diagonally measured and the native resolution is 240*RGB*320. Photograph of TFT LCD is shown in Figure 6.

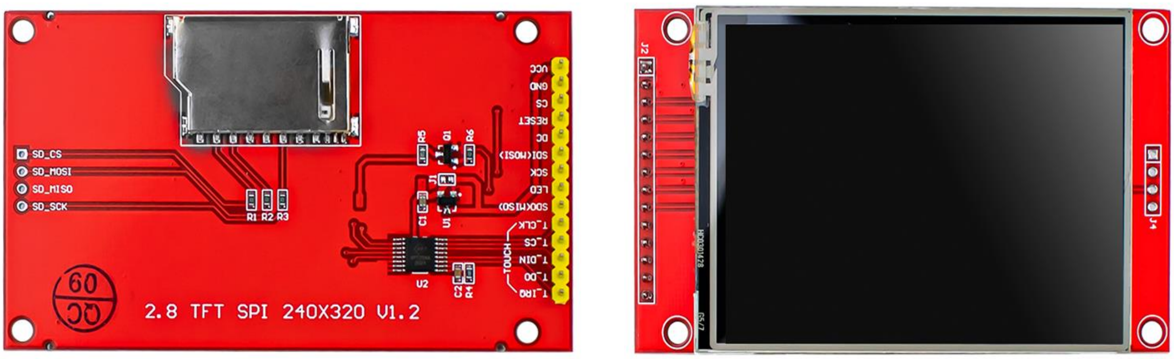

Figure 6. Photograph of TFT LCD

Arduino Integrated Development Environment (Arduino Software IDE)

The Arduino Integrated Development Environment or Arduino Software (IDE) contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

ThingSpeak Cloud

ThingSpeak cloud server is a place where one can store data online and can access that data at any time and from anywhere in the world. A real-time data is created with the help of a web-server. ThinSpeak web service provided by MathWorks which allows us to send sensor readings to the cloud. The ThingSpeak is an open-source data platform for the Internet of Things

(IoT) applications. We can also visualize and act on or access the data (calculate the data) sent to the ThingSpeak server from ESP32. ThingSpeak is frequently used for IoT prototyping and proof-of-concept systems that require analytics.

Hardware Preparation

This research is based on the environmental data acquisition system using internet of thing (IoT) technology. BH1750sensor, BME680 sensor and ML 8511 sensor are used in this research. ESP32 implements two functions; one is data detection and logging like a microcontroller and another is data uploaded to cloud via internet. The schematic circuit diagram is drawn by easyEDA software as shown in Figure 7.

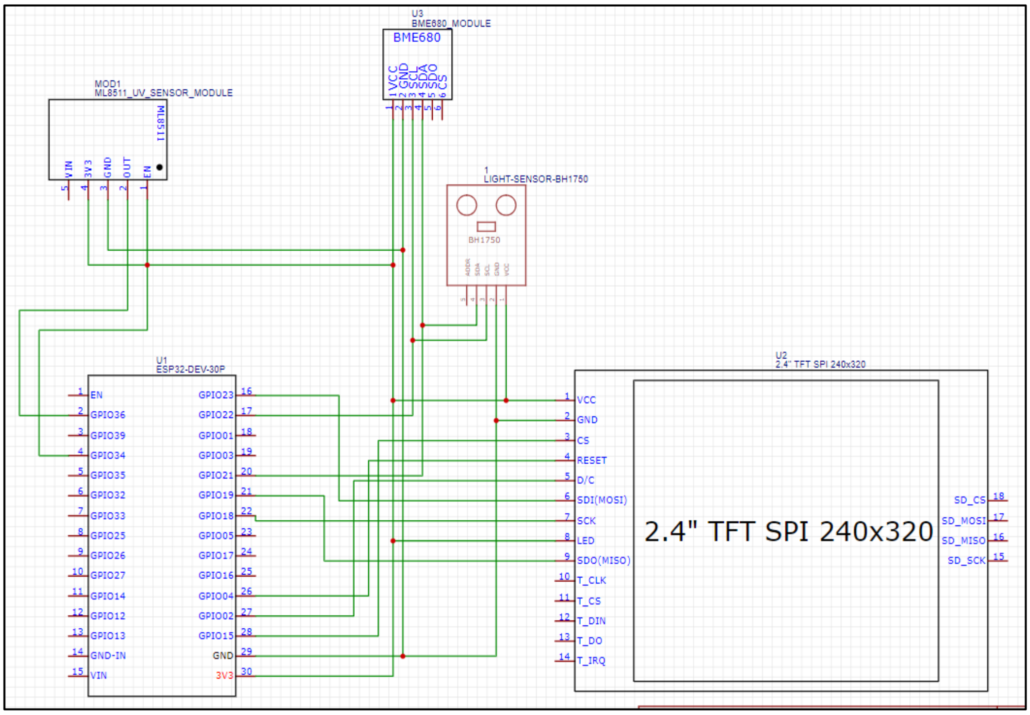

Figure 7. Circuit diagram of constructed system

Software Preparation

ESP32 is used because it composes of the microcontroller which is integrated with Wi-Fi module to communicate the cloud via internet. Although the Arduino IDE software is compatible for ESP32. The libraries of ThingSpeak, ESP32, BME680, BH1750 and TFT_LCD are included in Arduino IDE. The whole system of flow chart is illustrated in Figure 8.

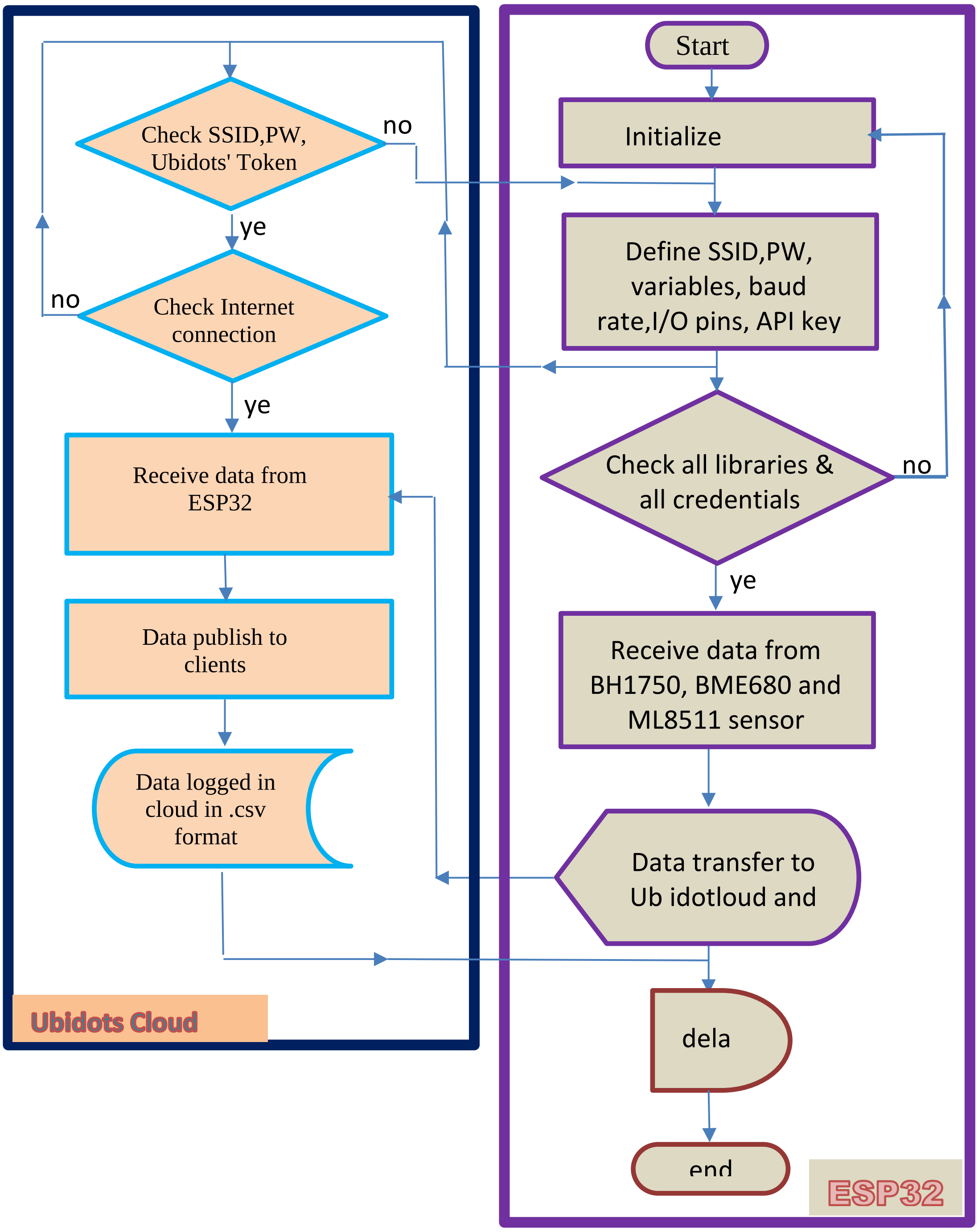

Figure 8. Software flow chart

Results

The eight different environmental conditions which include temperature, humidity, pressure, altitude, light intensity, UV index, gas resistance and IAQ (indoor air quality) were observed. The sensor data collected by ESP32 from BME680, BH1750 and LM8511 sensors is published to the ThingSpeak web server. A channel was created on ThingSpeak that contains eight fields to store eight different environmental parameters. Figure 9 shows the system location. The 'Field 1' which was containing the temperature readings published or communicated from the ESP32 module and saved on the ThingSpeak server as in Figure 10.

Similarly, fields 2, 3, 4,5,6,7 and 8 are displaying the humidity, pressure, altitude, light intensity, UV index, gas resistance and IAQ respectively were shown in Figure 11 to 17.

The serial monitor displayed the **temperature** in degree Celcius, **humidity** in percentage, atmospheric **pressure** in hPa, **altitude** in meters, **dew Point** in degree Celcius and **gas** as a **resistance value**. The sensor is used to obtain the so-called gas resistance and then calculate an **Index of Air Quality (IAQ)** from a combination of humidity and the gas content readings of the air. UV intensity and Light intensity were also displayed in $mWcm^{-2}$and lux respectively as in Figure 18. Complete circuit diagram with real-time results were displayed on TFT_LCD as in Figure 19. Live data from ThingSpeak cloud is shown in Table 1.

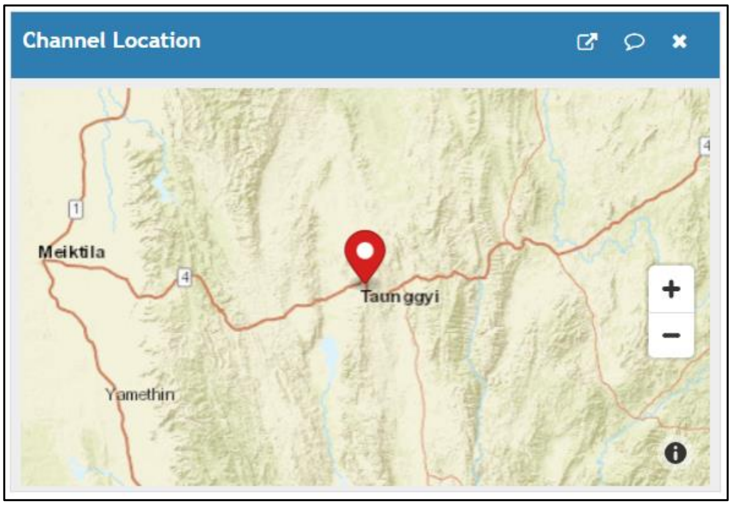

Figure 9. Sensor location

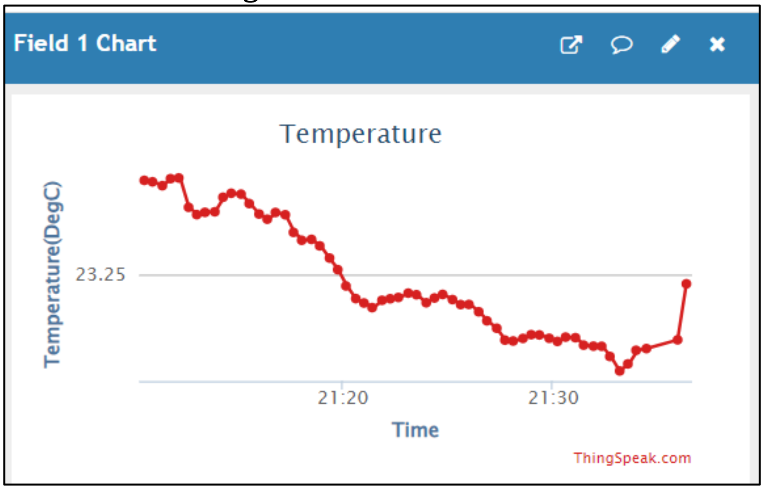

Figure 10. Live data of temperature (deg C)

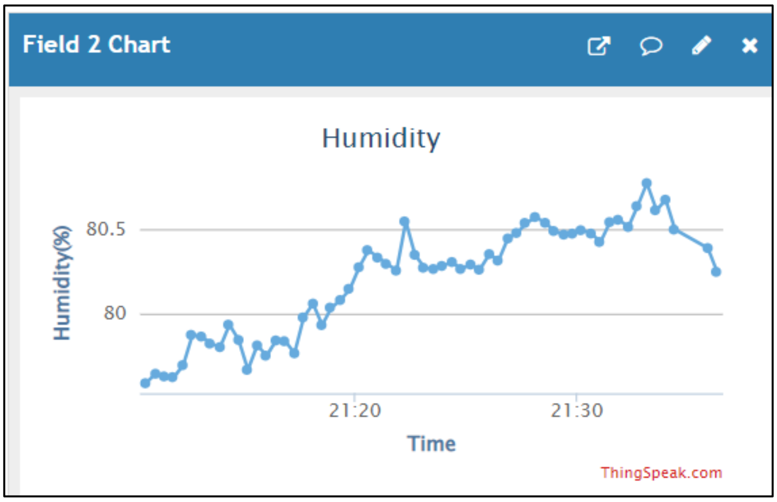

Figure 11. Live data of humidity (%)

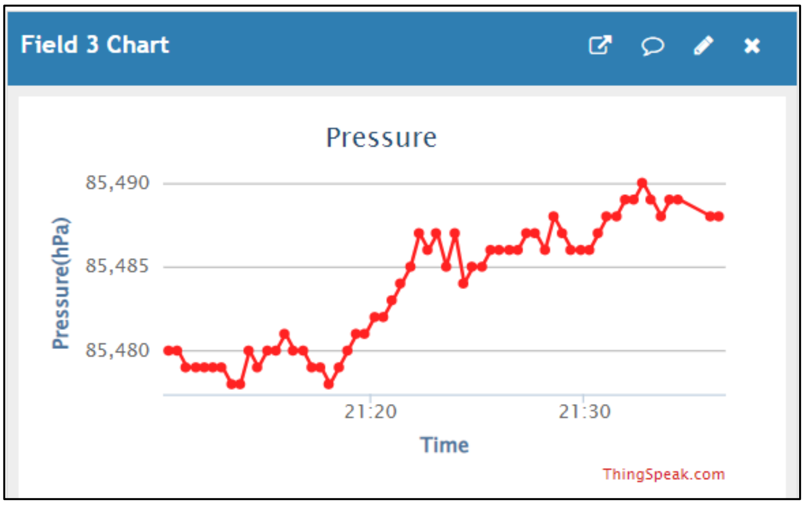

Figure 12. Live data of pressure (hPa)

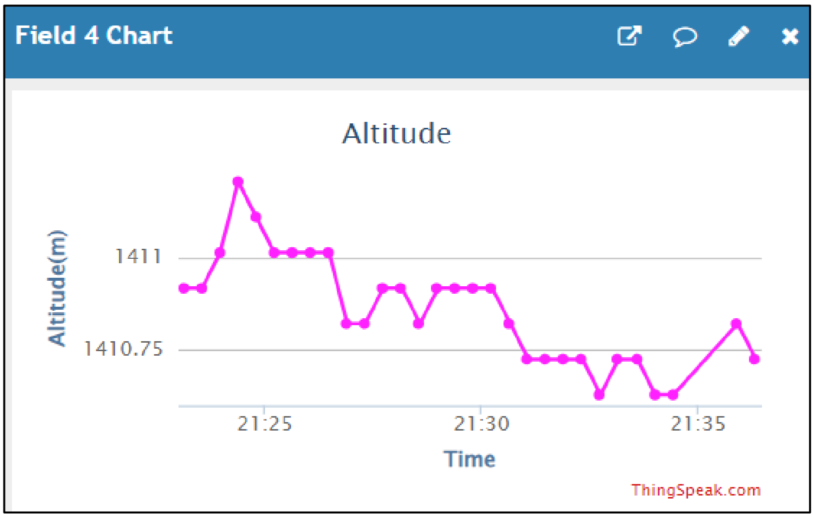

Figure 13. Live data of altitude (m)

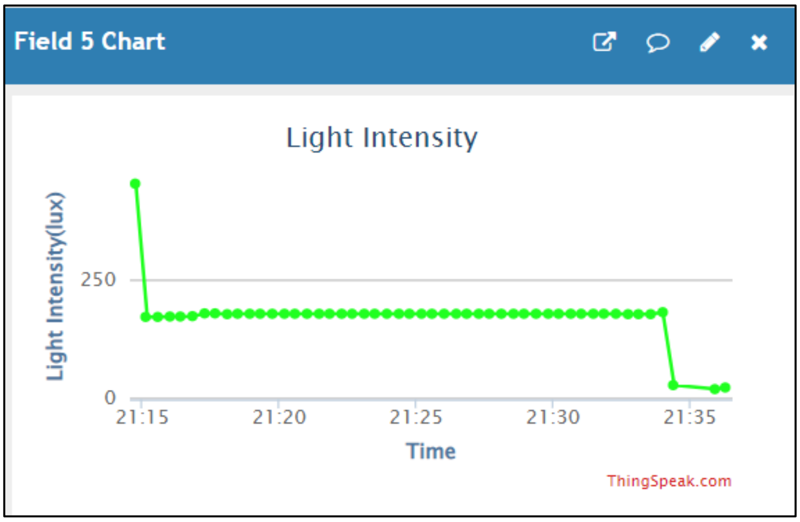

Figure 14. Live data of light intensity (lux)

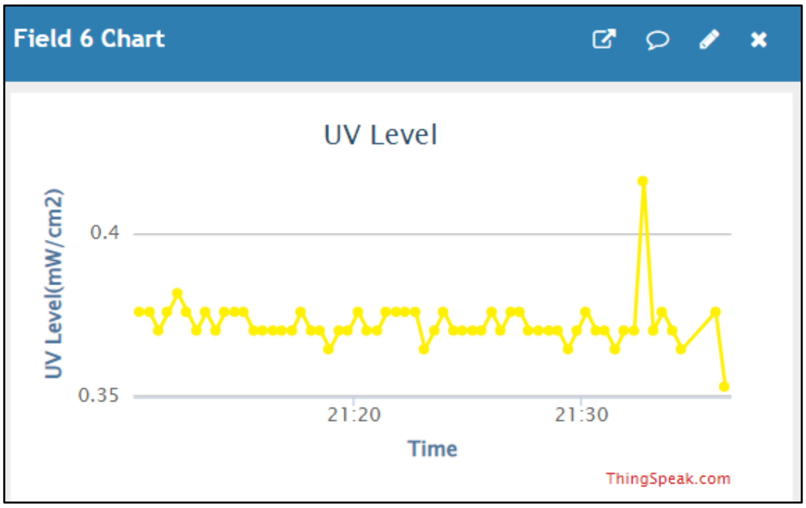

Figure 15. Live data of UV level (mW-cm^{-2})

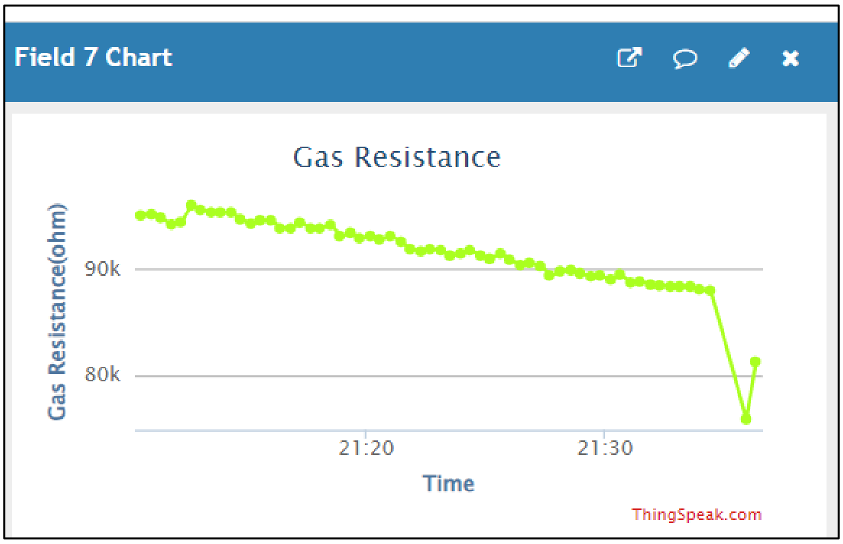

Figure 16. Live data of gas resistance (ohm)

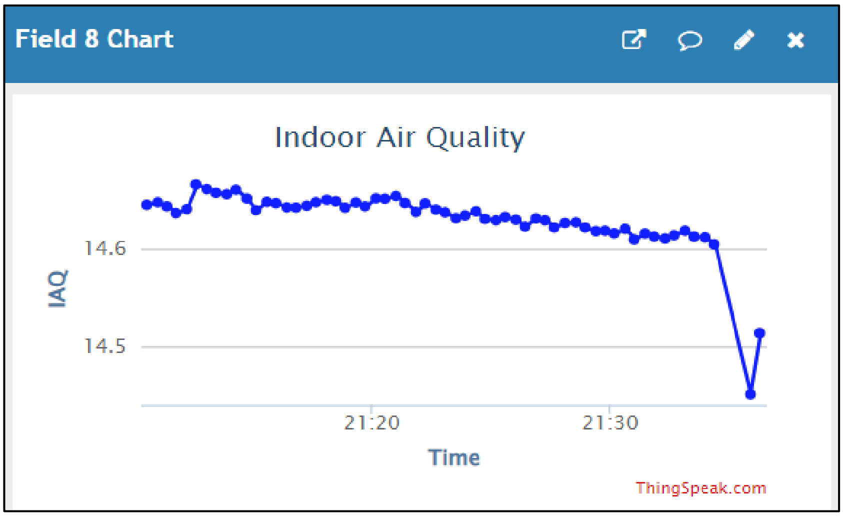

Figure 17. Live data of indoor air quality

```
COM7
21:40:40.321 -> IAQ = 14.62    IAQ: Good
21:40:40.321 ->
21:40:41.721 -> Channel updated successfully!
21:40:42.809 -> Temperature = 23.08 °C
21:40:42.809 -> Humidity = 80.08 %
21:40:42.809 -> Dew Point = 19.10 °C
21:40:42.809 -> Pressure = 854.89 hPa
21:40:42.809 -> Gas = 106.36 KOhms
21:40:42.809 -> Approx. Altitude = 1410.63 m
21:40:42.809 -> Light intensity =175.83lx
21:40:42.809 -> UV intensity =0.37 mW/cm^2
21:40:42.809 -> Gas Resistance =106.36 kOhms
21:40:42.854 -> IAQ = 14.78    IAQ: Good
```

Figure 18. Serial monitor display

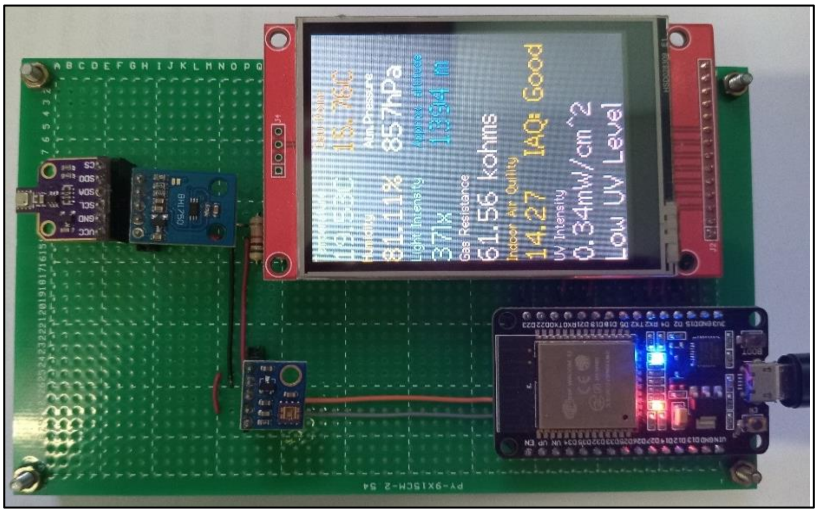

Figure 19. Complete circuit diagram with real-time data display on TFT_LCD.

Table 1. Live data (sample) from ThingSpeak cloud

created_at	entry id	Temp (degC)	Humidity (%)	Pressure (hPa)	Altitude (m)	Light Int(lux)	UV ($mWcm^{-2}$)	Gas res(Ω)	IAQ
2023-08-18 T15:58:04+06:30	1	26.36	73.79	84786	1478.02	153.33	0.46	22417	12.96
2023-08-18 T15:58:34+06:30	2	26.17	74.31	84790	1477.73	155.83	0.45	34298	13.41
2023-08-18 T15:58:59+06:30	3	26.09	74.37	84792	1477.54	126.67	0.45	46693	13.72
2023-08-18 T15:59:24+06:30	4	26.16	75.22	84790	1477.73	144.17	0.45	56456	13.95
2023-08-18 T15:59:50+06:30	5	26.20	74.14	84791	1477.73	140.83	0.45	65075	14.05
2023-12-12 T21:26:54+06:30	186	23.15	80.45	85486	1410.82	176.67	0.38	90613	14.63
2023-12-12T21:27:19+06:30	187	23.13	80.48	85487	1410.82	176.67	0.38	90317	14.63
2023-12-12T21:27:44+06:30	188	23.11	80.54	85487	1410.92	176.67	0.37	89443	14.62
2023-12-12T21:28:10+06:30	189	23.10	80.58	85486	1410.92	176.67	0.37	89829	14.63
2023-12-12T21:28:35+06:30	190	23.11	80.54	85488	1410.82	176.67	0.37	89927	14.63

Discussion

The benefits of using BME680, BH1750 and ML8511 sensor are as follows: (i) Air quality monitoring, (ii) Warning system for high temperature and low-humidity condition, (iii) Altitude tracking and calories expenditure for sports activities, (iv) Solar radiation monitoring, (v) UV index monitoring and (vi) Advanced-protecting the impact of UV radiation. BME680 sensor can sense the quantity of VOC gas but cannot distinguish what kind of gases contained.

ThingSpeak is a versatile platform that simplifies the process of collecting, storing, analyzing, and visualizing IoT data, making it a valuable tool for IoT developers and businesses. Its ease of use, customization options, and integration capabilities contribute to its popularity in the IoT community.

Conclusion

The adoption of cloud-based real-time air quality and environmental parameters monitoring and logging systems has brought about significant advancements in the field of environmental data collection and analysis. These systems have demonstrated their ability to efficiently gather real-time data from diverse sources, offering unprecedented insights into our surroundings. By leveraging cloud technology, these solutions have overcome traditional limitations, enabling seamless data storage, analysis, and remote access. As technology continues to evolve, this system can anticipate further enhancements in these systems, leading to even more accurate, accessible, and actionable environmental data.

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