

# Internet of Things Monitoring System of a Modeled Cleanroom

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**Abstract:** The development of a cleanroom monitoring system needs more concentrated consideration consistently. There is a challenge to prove that the cleanroom operates following the specifications, in other words, users do not see the software error, they see failures in execution. This paper aims to design a smart monitoring system to monitor important parameters inside the cleanroom, i.e. temperature, humidity, and pressure to produce a good quality of work or experiment inside the cleanroom. The observing framework utilizes Arduino Mega as a microcontroller, ESP 8266 Wi-Fi module, DHT 11 as an integrated temperature and humidity sensor, HX710B as a pressure sensor, and Blynk application as a monitoring system to record and show information including provide fault notification. The project is tested on a modeled cleanroom to monitor important parameters via smartphone anytime and anywhere. From the experimental results, the Cleanroom IoT Monitoring System successfully read all parameters based on the system requirements and displays data of parameters in real-time and stored historical data. This system is also successful to provide failures notification of humidity, temperature, and pressure in real-time if any of the parameters are out of range from the system requirements. Lastly, users can monitor the condition of the cleanroom anytime and anywhere including receiving real-time failures notifications. This concept can avoid or reduce cleanroom working out of the criteria that can cause testing or experiment inside the cleanroom to be inaccurate. By observing and controlling the prerequisite development for IoT monitoring systems, great nature and better quality of performance of operational cleanrooms can be delivered..

**Keywords:** Internet of Things, Modeled Cleanroom, Monitoring System.

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## 1. INTRODUCTION

Defined by International Organization for Standardization (ISO) 14644-1:2015, a cleanroom is a room which the number of concentration of airborne particles is controlled and classified, and which is designed, constructed, and operated in a manner to control the introduction, generation, and retention of particles inside the room [1]. The level of cleanliness inside the cleanroom is based on the concentration of airborne particles including the sizes of particles. Other relevant physical parameters might also be controlled as required such as temperature, humidity, pressure, vibration, and electrostatic.

The usage of a cleanroom is very important in industrial fields such as electronics manufacturing, food manufacturing, medical equipment, and pharmaceutical. The cleanroom needs a keen smart monitoring environment system to maintain the operation of the cleanroom follows standards. So that activity in the cleanroom is not disrupted.

This project aims to design a smart monitoring system to produce a good quality of work or experiment inside the modeled cleanroom. The expected result of the research is to make sure the cleanroom operates per the specifications at all times. Then, if any failures occur in the cleanroom, users will be notified to take early action. The objective of this project is to control parameters of temperature,

humidity, and differential pressure in ideal conditions inside the cleanroom.

This project proposes Cleanroom IoT Monitoring System to monitor optimal environmental conditions such as temperature, humidity, and differential pressure using sensors. Using the Blynk application as an IoT platform, the sensors sense parameters inside the cleanroom, and data is sent into the Blynk server by the microcontroller via a Wi-Fi internet connection. All parameters will be displayed on the Blynk application via smartphone and will provide notification if any parameters are out of range.

## 2. LITERATURE REVIEW

According to [2], the internal environment of the cleanroom is monitored by using several sensors to monitor parameters of temperature, pressure, humidity, luminance, and gas concentration. The information inside the cleanroom can be monitored by a smartphone through an interface between the wireless sensor network and the android device.

Authors in [3] use temperature and humidity sensors to collect parameters information for monitoring air quality in the Angstrom cleanroom laboratory. This project identified conditions of parameters at all service facilities. Sensors collect the data by using an Arduino microcontroller through SX1278 radio frequency

transceiver chips. The information of the parameters is shown in graphs displaying through web page via computer with local area network (LAN) internet connection.

Furthermore, research in [4] introduces a cleanroom control system and method. This project implements a heating, ventilation and air conditioning (HVAC) system for controlling and maintaining the parameters of the cleanroom comprises filtration, ventilation, heating, cooling, humidification, and pressurization. The parameters of the airborne contaminations, i.e. temperature, humidity, pressure, and airflow inside the cleanroom are monitored in real-time or near real-time. Data from sensors transmit via an open platform communication (OPC) server in an existing building management system (BMS). HVAC system automatically controlled based on the comparison of the sensors by using model predictive control (MPC).

Research in [5] proposed an IoT-based smart agriculture monitoring system. Their works focused on devices and tools to manage and monitor temperature, humidity, soil moisture, atmospheric moisture, and intruders by using a wireless sensor network (WSN) system. The monitoring system is performed by two methods which are via hardware by using the LCD and android application. Any parameters exceed the threshold value, an alert system will send a message to the user via GSM.

Authors in [6] introduced a monitoring system and monitoring method for a cleanroom regulating system. Parameters that are monitored inside the cleanroom for this project are particle, temperature, humidity, pressure, and airflow rate. A local area network (LAN) is used as a communication channel to transmit data from the sensors to the host computer. Information of parameters is shown in real-time and as historical data. This project also used a host computer for comparing the physical properties of parameters and generating an alarm signal if any failures occur.

According to the existing solutions, the research gap that can be concluded is users have limited access to the monitoring system to monitor parameters inside the cleanroom at any time and anywhere. While monitoring systems that use LAN connections require a high cost to build it. Few monitoring systems used an LCD including a web page by using a host computer to show data of parameters that are only achieved on-site.

Some projects only show information of parameters in real-time but lack historical data. Without historical data, it is difficult for the user to investigate in the event of any failures occur while carrying out work. Fault notification showing what kind of parameters and value of parameters is also important for the user to be noticed because they can take earlier action if the failure occurs in the cleanroom. But, most monitoring systems only provide fault alarms without indicates the type of parameters including the value of the parameters.

**3. PROJECT METHODOLOGY**

**3.1 Overall Framework of IoT Monitoring System of a Modeled Cleanroom**

Figure 1 shows a block diagram of the proposed solution and Figure 2 determines the all-purpose flowchart of the proposed monitoring system. Two sorts of sensors are connected to acquire a few parameters expected to observe the temperature, humidity, and pressure inside the modeled cleanroom. For equipment usage, all sensors are associated with Arduino Mega [33] independently to get the involvement from numerous sorts of sensors. ESP8266 Wi-Fi module is associated with Arduino Mega at pin TX1 and RX1 for communicating information employing the Blynk application.

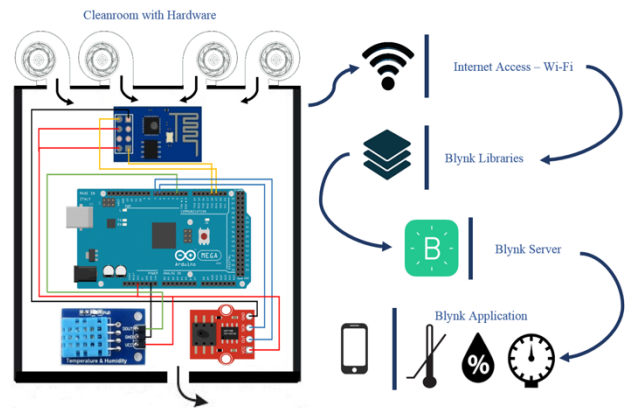


Figure 1. Block Diagram of Proposed Solution

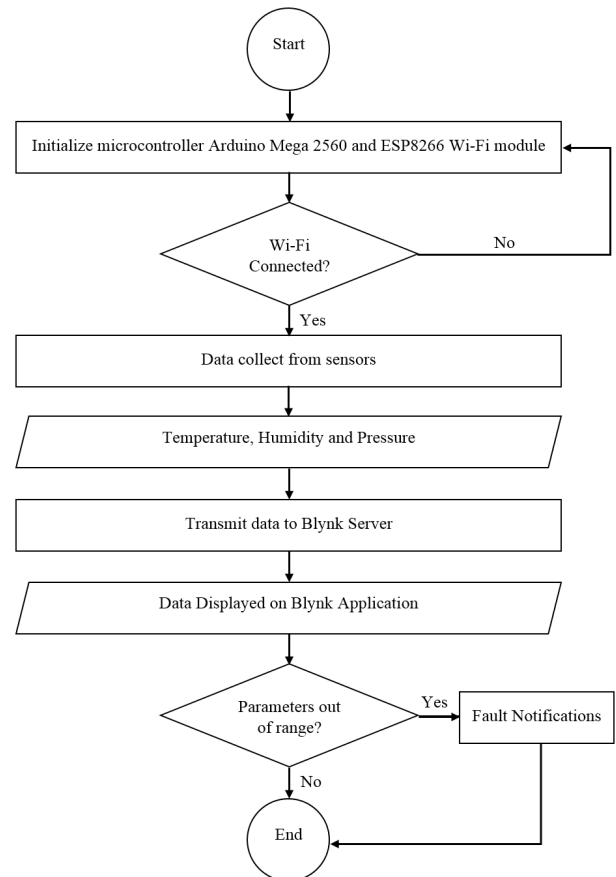


Figure 2. Process of the Monitoring System

ESP8266 Wi-Fi module is a component which has the capacity to interface with Wi-Fi link henceforth enabling information to be spread to a cloud application structure.

### 3.2 Data Attainment

The cleanroom is based on a prototype of the modeled cleanroom. The modeled cleanroom prototype is made from a PVC2 box with the size of 37 cm x 29 cm x 19 cm. Two kinds of sensors to gather a few parameters from the cleanroom and four units mini blower 12 V DC supply to provide positive pressure inside the cleanroom. Figure 3 and Figure 4 reveal the arrangement of the considerable of sensors in the prototype of the model mini cleanroom.

DHT11 [31] is utilized to inspect the temperature, and humidity of the cleanroom constantly. DHT11 sensors are located in the middle, inside the cleanroom to observe these parameters. The importance of temperature inside the cleanroom is to maintain the ideal temperature to maintain the performance of equipment operation such as incubator and to provide user comfort during working inside the room, while humidity is to reduce the growth of bacteria inside the cleanroom. Besides, these parameters also need to be controlled in a specific range to protect sample that located or stored inside the cleanroom. Figure 5 below demonstrates the DHT11 and HX710B sensors.

The sensor module of HX710B [32] is located outside the cleanroom and connected in the cleanroom via tubing to get information of pressure inside the cleanroom. The cleanroom needs positive pressure to perform cleanliness of the room and prevent contaminated air from enters the room. The humidity is measured in percentage while temperature and pressure are measured in the SI unit. DHT11 and HX710B give values from 0 to 1023 in analog. The ADC (Analog to Digital Converter) that converts analog voltage to the digital value has been built in the sensor itself.

### 3.3 Data Transmission by Internet

ESP 8266 [30] Wi-Fi module as shown in Figure 6 is a low-cost chip incorporated with a TCP/IP protocol stack that can send information to the cloud. The ESP 8266 is prepared to do either facilitating an application or offloading all Wi-Fi organizing capacities from another application processor. ESP 8266 is chosen since it is compatible with the Arduino board because of the accessibility of the Arduino shield which takes into account the handsets to be specifically mounted to the Arduino board. Wi-Fi module needs to be set up for ace and slave to permit communication among Arduino and Cloud. When communication is established, information can be transmitted through the Blynk application.

Data in the database can be manipulated through programming to be shown by the Blynk application in several monitored data, various forms of graphs, or spreadsheets.

### 3.4 Blynk Application Development

Figure 7 shows a user interface for the IoT Monitoring System of a Modeled Cleanroom by using the Blynk Application. Users can monitor parameters of temperature, humidity, and pressure in real-time and as historical data in a graph. All parameters provide failures notifications in real-time if any reading of the parameters is out of range as shown in Figure 8 including if the system operation is disconnected from the internet connection.

To develop a smart monitoring system, the information stored in the Blynk database is presented in the smartphone application entirely for the cleanroom. Users can access the application to analyze the data acquired.

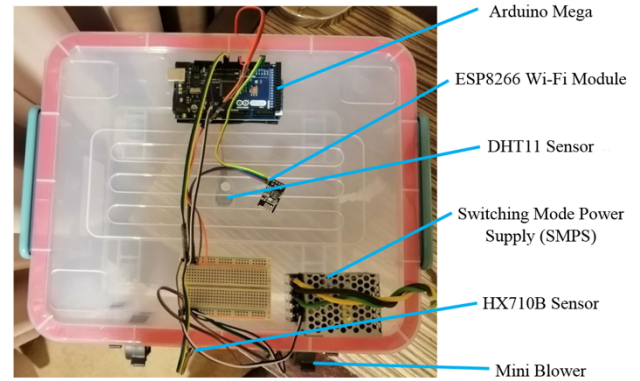


Figure 3. Prototype of Model Mini Cleanroom

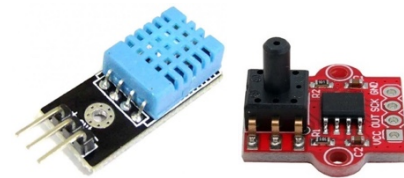


Figure 5. Sensors of DHT11 and HX710B



Figure 6. ESP8266 Wi-Fi Module

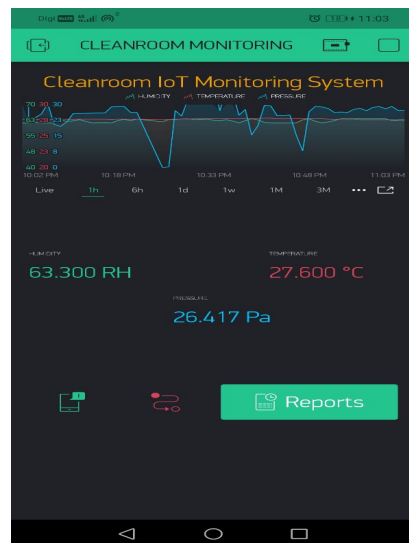


Figure 7. User Interface of the Monitoring System

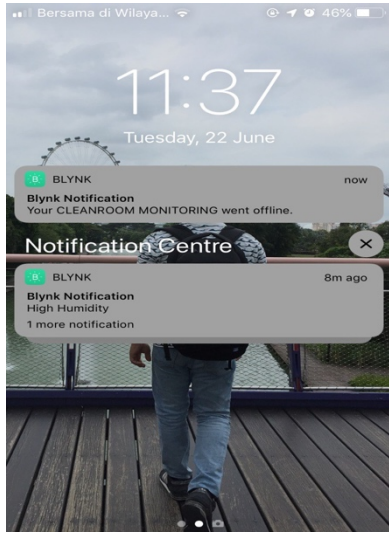


Figure 8. List of Failures Notifications of the System

**4. RESULTS AND DISCUSSIONS**

**4.1 Calibration**

Calibration defines the accuracy, and quality of measurements recorded using a calibrated equipment. Over time there is a tendency for results and accuracy to ‘drift’ particularly when using technologies or measuring parameters such as an application on this project. The objectives of this calibration are to measure the accuracy of the instrument and determines the traceability of the measurement [36]. Calibration also minimizes any measurement uncertainty by ensuring the accuracy of the unit under test (UUT).

Sensors that used in the development of this project were calibrated before applying them to the actual condition. In practice, calibration also includes adjustment of the value that given by the sensors.

DHT 11 sensor for measuring temperature, and humidity was calibrated by using calibrated test equipment. Figure 9 shows the calibration process by comparing the value that given by DHT11 and Anemometer [34]. Details of the test equipment are mentioned below:

- Test Equipment: Anemometer
- Brand / Model: TSI / TSI 9545
- Serial Number: T95452008001
- Calibration Due Date: 22nd April 2022

HX710B sensor for measuring pressure was calibrated by using calibrated test equipment. Figure 10 shows the calibration process by comparing the value that given by HX710B and Air Data Balometer [35]. Details of the test equipment as mentioned below:

- Test Equipment: Air Data Balometer
- Brand / Model: TSI / Alnor
- Serial Number: EBT731903018
- Calibration Due Date: 12th August 2021

After finish the calibration process of the DHT11 and the HX710B sensors, the next process is functioning test at various temperatures, humidity, and pressure. Location of testing at a normal room with a volume size of 21.6 m3. Sampling time is 60 minutes with time intervals of 1 minute. So, the total sampling data is 60 data.

Figures 11-13 show the result of the comparison reading between project sensor and test equipment. Based on the

pattern graph, the sensor sent data of the parameters correctly.



Figure 9. Calibration of DHT11 Sensor. Anemometer device is shown next to the smartphone.

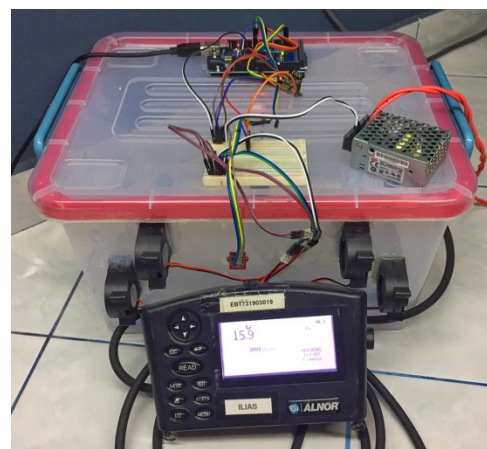


Figure 10. Calibration HX710B Sensor. Air Data Balometer is shown next to the modeled cleanroom.

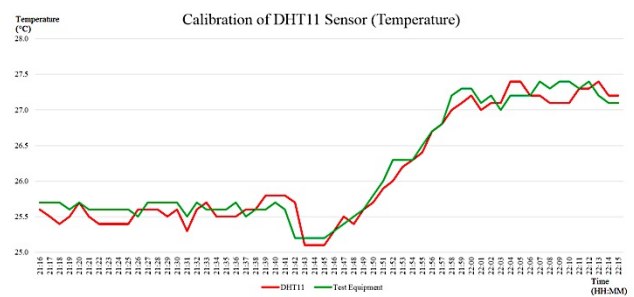


Figure 11. Reading of Temperature in Functioning Test

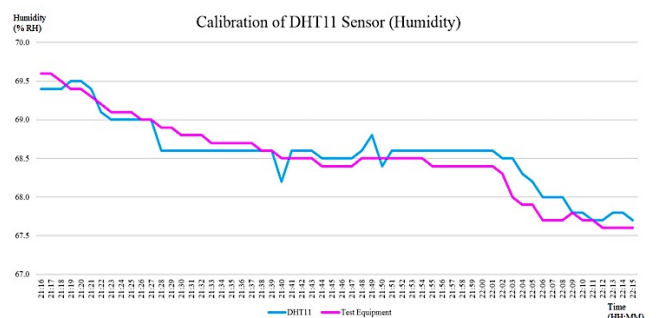


Figure 12. Reading of Temperature in Functioning Test



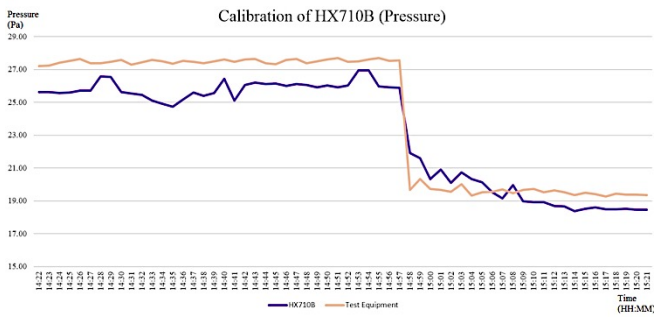


Figure 13. Reading of Temperature in Functioning Test

#### 4.2 Case Study

The objectives of this case study are to test the performance of the Cleanroom IoT Monitoring System. It is included to see the response of the sensor while parameters were changed. Next, to prove the failures notifications in real-time if any parameters out of range. The method that used in this case study is the same during the functioning test of the sensor. Case study 1, test project at normal room condition without turn ON the air conditioner. After several minutes, the dehumidifier will turn ON to reduce humidity and increase the temperature inside the room. Figure 14 shows the visual setup of this case study. While Figure 15 shows the result of the parameters of this case study in 1 hour. This system provides notification of low humidity and high ambient temperature results of dehumidifier use. From this case study, the system can read parameters of humidity and pressure starts from the normal condition until humidity becomes low and temperature becomes high.

In case study 2, the test project was at normal room condition. After several minutes, the air conditioner and nebulizer or humidifier were turned ON and placed near the blower to suck smoke from the humidifier to the inside model of the cleanroom to increase humidity and decrease temperature. Figure 16 shows the visual setup of this case study. While Figure 17 shows the result of the parameters of this case study in 1 hour. This system provides notification of high humidity and low ambient temperature results of air conditioner and humidifier or nebulizer use. From this case study, the system can read parameters of humidity and pressure starts from the normal condition until humidity becomes high and temperature becomes low.

In case study 3, without turn ON and OFF electrical appliances that can affect the humidity and temperature, this project test with turned ON 4 units blower. In several times, the number of blowers turns OFF one by one until all blowers turn OFF. Figure 18 shows the visual setup of this case study.

While Figure 19 showed the result of the parameters of this case study in 1 hour. Circle 4 represents the reading of pressure during 4 blowers turn ON, circle 3 represents during 3 blowers turn ON, circle 2 represents during 2 blowers turn ON, circle 1 represents during 1 blower turns ON and circle 0 represents all blowers turn OFF. This system provides notification of low-pressure results of only 2 blowers were ON. From this case study, the system can read differences in pressure values during blower turn ON and turn OFF.

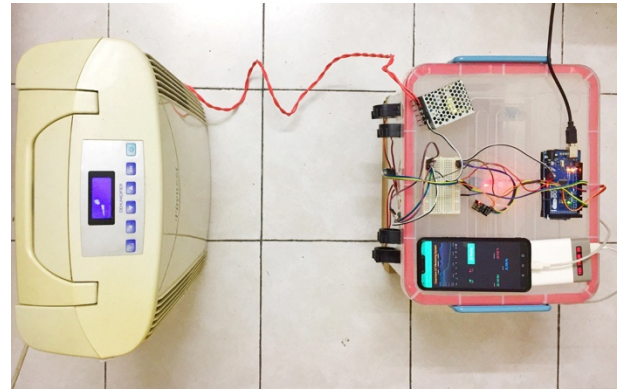


Figure 14. Visual Setup of Case Study 1

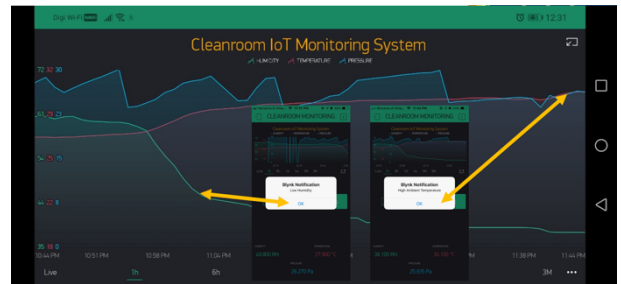


Figure 15. Result of Case Study 1

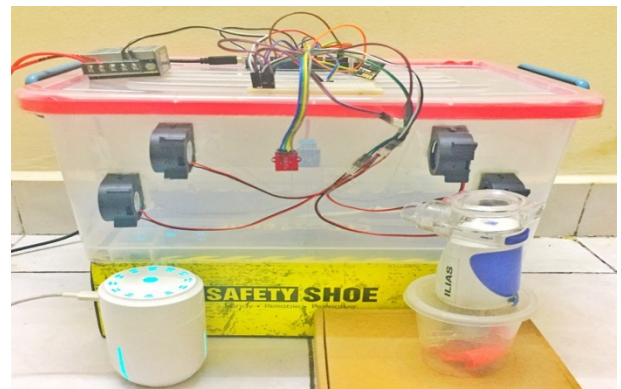


Figure 16. Visual Setup of Case Study 2

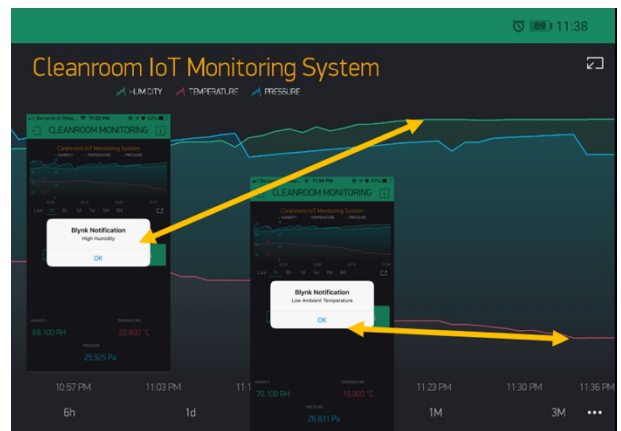


Figure 17. Result of Case Study 2

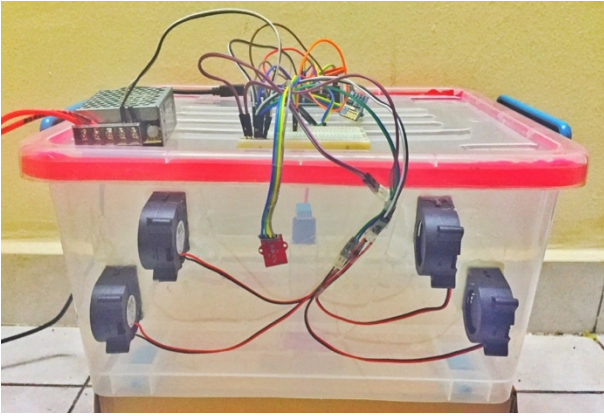


Figure 18. Visual Setup of Case Study 3

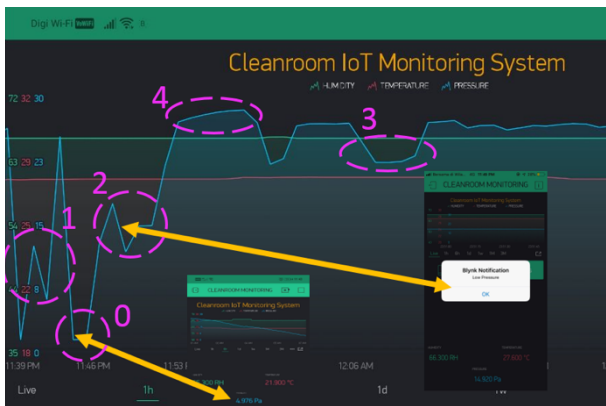


Figure 19. Result of Case Study 3

#### 4.3 Summary

Cleanroom IoT Monitoring System consists of hardware and software to achieve the objectives of the project. All components and electronic parts for hardware have been identified including the design of the circuit diagram. For the software, Blynk Application is an IoT platform and used to displays the reading of parameters inside a cleanroom in real-time and historical data including providing failures notifications if any parameters are out of range.

Based on all case studies, the Cleanroom IoT Monitoring System successfully read all parameters based on the system requirements and displays data of parameters in real-time and stored historical data. This system is also successful to provide failures notification of humidity, temperature, and pressure in real-time if any of the parameters are out of range from the system requirements. Lastly, users can monitor the condition of the cleanroom anytime and anywhere including receiving real-time failures notifications.

#### 5. CONCLUSION

In conclusion, the problem statement and objectives have been identified. Then, research of each concept of the project has been done in detail. From that, the focus of this project which is to produce a Cleanroom IoT Monitoring System was completed. This project helps the users to monitor important parameters such as temperature, humidity, and pressure inside the cleanroom including provide real-time notification to the users. The monitoring

system also provides real-time data and historical data as a reference for users. The proposed IoT monitoring system can be monitored via smartphone at anytime and anywhere.

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