# Prototype Design of IoT-Based Real-time Monitoring and Security System for University Server Room

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***Abstract***

*The server rooms consist of computing devices hosting essential data which is critical for the operation of universities. Ensuring server room environmental stability and security is vital to prevent data loss and service disruptions. This study presents the design of an IoT-based real-time monitoring and security system for university server rooms to help the IT staff monitor the conditions of the server room. The system aims to enhance server room management efficiency while mitigating risks associated with server room issues and unauthorized access. The research is conducted based on a prototyping model which integrates hardware and software. The main focus is on the construction of the prototype device as a monitoring tool to monitor the server room environment based on the sensor parameters. The prototype has sensors to detect temperature, humidity, smoke, flame, dust, and motion as well as a real-time camera to provide continuous environmental monitoring and intrusion detection. On the software side, the functional design is presented using Unified Modeling Language. Data collected by the sensors are transmitted to IoT platforms for further analysis and visualization, enabling remote monitoring and instant notifications. The research result is a hardware prototype designed with an IoT system that is potentially used to monitor the server room environment.*

***Keywords***— sensors, microcontrollers, alarm, internet, IoT platforms.

## 1. INTRODUCTION

The Internet of Things (IoT) has become a unique research subject since the development of human needs and technology. Researchers are developing IoT by optimizing sensor devices, wireless sensor networks, and other objects so that they can interact with equipment that has an internet network. IoT devices can transmit data over the internet network and then can be analyzed to generate or make the right decisions [1]. The IoT technology can be applied in areas related to environmental monitoring specifically in a server room.

The server room is an important asset for an institution. Universitas Klabat has a server that contains important data such as student data and other data that continues to grow, and at any time the data will be used and valuable to the university [2]. The server room at Universitas Klabat functions as a database storage center. However, server rooms also present challenges in terms of management, monitoring, and security. Factors such as unstable temperatures, high or low humidity, and threats from smoke, fire, dust, and unauthorized access into the server room can disrupt the operation of the hardware and software inside. If not handled properly, this can lead to serious damage to the devices, data loss, as well as significant operational disruptions.

In the face of these challenges, Internet of Things (IoT) technology offers innovative solutions that can support real-time monitoring and management of server rooms. IoT allows various devices such as sensors and microcontrollers to be connected via an internet network, resulting in data that can be accessed, analyzed and managed remotely. This technology provides the ability to detect changes in environmental conditions and provide immediate notifications in case of potential problems.

There was research literature on hardware design integrated with IoT. For example, research [3] focused on temperature, humidity, and motion detection in server rooms. Research [4] built a system to monitor gases and detect fire as an early warning system. Research [5], built a system to monitor the dust and temperature inside the room with the use of Telegram and IoT.

Besides the research discussed previously, the researcher has also built several IoT-based monitoring systems using different sensors and microcontrollers integrated with the IoT platforms in different scopes and implementations [6-10]. Previous research [2] built a prototype and implemented it inside the server room of Universitas Klabat. However, the system needs improvement in terms of the scope of parameter monitoring, especially when it will be applied for real-time monitoring and security access for the server room. The gaps are related to the improvement of sensing dust, smoke, flame, motion detection, pop-up notification messages, LED indicators, LCD, and alarms as well as visual monitoring with a camera. Those parameters have not been included and need to be added to extend the functionalities of the system.

This research aims to overcome these limitations by adding smoke sensors, fire sensors, dust sensors, motion detection sensors, LCD, LED light indicators, alarms, and ESP-Cam32 for real-time monitoring to visualize the server room remotely. The system provides direct alarms and pop-up notifications about critical issues in the server room that need attention and handling. The data obtained from the sensors is processed by a microcontroller and then designed to be sent to Blynk 2.0 and ThingSpeak as the IoT platforms for remote monitoring and graphical data visualization. The configurations of IoT platforms with Blynk and ThingSpeak with its data analysis will be described in a future paper. In this research, the main focus is the design of the prototype device and how the prototype can be integrated with an IoT-based monitoring system.

This research presents and refers to several aspects including:

1. Server Room

Servers, network equipment, storage devices, etc., are placed inside a server room to support the information technology operations of a business. To guarantee stable and secure operations the server room needs to be designed and built with specific technical standards such as a cooling system, environment monitoring, security system, fire suppression system, remote monitoring, and management [11]. A good server room can provide an environment where computer equipment can operate safely in one place, which allows networking and other activities to run more efficiently and effectively [12].

2. Detectors and Monitoring Systems

Detectors in server rooms are security devices installed to detect conditions that could jeopardize equipment and data inside the server room, such as fire, smoke, excess humidity, or significant temperature changes. These detectors serve as an early warning system to prevent damage to the IT infrastructure and ensure the operational continuity of the server [13]. A monitoring system functions to collect data in real time and perform remote monitoring of assets or processes [14]. A monitoring system is a piece of hardware or software used to oversee system performance and resources. A system that monitors and recognizes failures, providing alerts when components are not functioning as they should [15].

3. Internet of Things

The Internet of Things is a concept about devices that can transmit data over Wi-Fi networks without the need for human-to-human or human-to-computer interaction, and everything is done automatically through the programs installed in them. Kevin Ashton first used the term "Internet of Things" at a Proctor & Gamble presentation in 1999 [16]. The goal of the Internet of Things (IoT) is to increase the benefits of continuous Internet connectivity [17].

4. Temperature and humidity sensor (DHT21)

DHT21 is a sensor that collects digital signal data and outputs a digital signal calibrated with temperature to detect air temperature and humidity. When the sensor detects these two conditions, the data received will be adjusted to the calibration coefficient in memory [18].

Specifications of the DHT21:

- Works on 3.5V to 5.5V voltage,
- The temperature and humidity sensor uses a serial 1-wire interface,
- Measurement current ranges from 1-1.5mA,
- Humidity can be measured from 0-100% RH,
- The temperature range that can be measured is from -40 to 80ºC (degrees Celsius).

Table 1. shows the recommendations for temperature and humidity in the server room which is considered as the baseline. Based on the references, the prototype device baseline used in this research suggests the recommended range value of 18 - 27ºC. The 27ºC is the maximum temperature threshold for the server room which means that when the temperature is higher than 27ºC the IoT system triggers the alarm, and LED indicators, and sends a pop-up notification to the user via Blynk 2.0, to notify the user about the high-temperature level. For the humidity, the recommended value for the server room is 40 - 60%. The humidity threshold is 60% RH. When the humidity sensor senses the value is above 60% RH, the system sends a pop-up notification to the user via Blynk 2.0, indicating that the humidity is at a high level.

*Table 1. Server Room Temperature and Humidity Recommendations*

| References | Temperature (°Celsius) | Humidity (% RH) |
|---|---|---|
| [19] | 19º - 25º C | 40% - 60% |
| [20] | 21º - 23º C | 45% - 60% |
| [21] | 20º - 23º C | 45% - 60% |
| [22] | 20º - 25º C | 40% - 55% |
| [23] | 18º - 27º C | 45% - 55% |

5. Smoke Sensor (MQ-2)

Smoke is the gaseous product of burning materials, especially of organic origin made visible by the presence of small particles of carbon [24]. It contains gases such as carbon monoxide, carbon dioxide, nitrogen oxides, and water vapor. The MQ2 Sensor Module can detect smoke or combustible gases at concentrations between 200 ppm and 10,000 ppm including LPG, Alcohol, Smoke, Propane, Hydrogen, Methane, and Carbon Monoxide. Its application can prevent fires by detecting LPG gas leaks and smoke [25].

6. Flame Sensor

Fire is a rapid chemical reaction (oxidation) consisting of three elements: heat, oxygen, and combustible material that produces heat and light. A flame sensor is an electronic component that can detect flames with a wavelength of 760nm-1100nm [26].

7. Dust Sensor (GP2Y1010AU0F)

Dust consists of small solid particles, with a diameter of less than 500 micrometers. Infrared-based dust sensors work by the photodiode converting light reflected on the particle surface into a voltage. To read the change, the voltage must be amplified. The analog voltage produced by the sensor is equal to the measured dust density. The voltage increases by 0.5V every 0.1 mg/m3 of dust density, with a sensitivity of 0.5V/0.1 mg/m3 [27].

8. Passive Infrared (PIR) Sensor

A PIR sensor (Passive Infrared Sensor) is a device that measures changes in the level of infrared radiation emitted by surrounding objects to detect motion. PIR sensors are passive, meaning they only receive and do not emit infrared rays. As the name suggests, this sensor only responds to energy from passive infrared rays emitted by the detected object. [28]. PIR sensors detecting object motion can also be used as a home security system with the Internet of Things platform [6].

9. Microcontroller
The microcontroller in the Arduino Uno R4 Wi-Fi is the RA4M1 series based on the 32-bit microcontroller RA4M1 R7FA4M1AB3CFM#AA0 from Renesas. This microcontroller uses a 48 MHz Arm® Cortex®-M4 processor with a floating point unit (FPU). The operational voltage for this RA4M1 remains at 5V for hardware compatibility with shields, accessories, as well as circuits based on previous versions of the Arduino UNO board [29].

10. ESP32-CAM
ESP32Cam is a platform that enables real-time monitoring through the integration of a camera and Wi-Fi module inside [30]. The highly competitive small camera module can serve as a minimum system. With a footprint size of only 27*40.5*4.5 mm and a deep sleep current of up to 6mA, it can be used for various IoT applications, such as wireless positioning system signaling, industrial wireless control, wireless monitoring, wireless QR identification, and smart home devices.

11. Liquid Crystal Display (LCD)
Liquid Crystal Display (LCD) is an electronic component that can display data, such as characters, letters, symbols, or graphics. LCDs are usually paired with microcontrollers because of their small size. LCDs are available in the form of modules that have pins for data, power control, and contrast control, making them easier to use [31].

12. Buzzer
A buzzer is an electronic device that can convert electrical signals into sound. The sound is produced from the vibration of a membrane that has a coil in it. Buzzers are often used in security systems, such as in anti-theft circuits or as an early warning to notify others [32] In the prototype, the Buzzer is used to sound the alarm and it is also connected to the Push Button so that users can disable the Buzzer immediately when handling the problem which may occur in the server room.

13. UML
The Unified Modeling Language (UML) is often used in application or system development due to its focus on object modeling, which enables simplification of the problem and increased understanding of the system being developed. UML is one of the industry's most popular language standards for the analysis, design, and definition of requirements in object-oriented programming [33].

## 2. RESEARCH METHODS

This research uses the prototyping method as shown in Figure 1, which allows system development to be carried out in stages through repeated iterations to ensure the system can meet user needs properly [34]. In this research, the iterations conducted in the construction of the hardware prototype, mainly related to the several testing of the functionalities of the system whether it is well-function or not matching the requirements of the server room standard and user needs. The main stages in this method include:

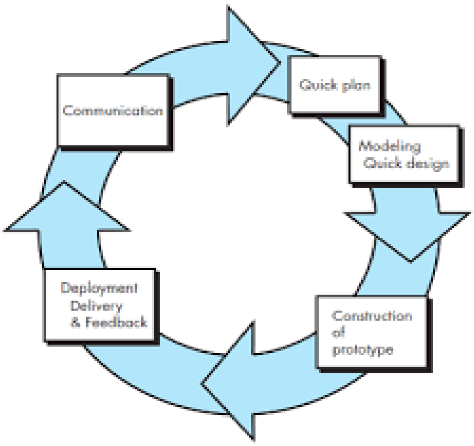


*Figure 1. Prototype Model [34]*

1. Communication
During the project initiation and requirement gathering, the researchers identified the problems faced by the Universitas Klabat server room, specifically related to monitoring environmental conditions. Information was collected through observation, interviews with IT staff, and literature studies on IoT-based monitoring systems.

2. Quick Plan
Planning was done by determining hardware and software requirements, such as Arduino Uno R4 Wi-Fi, DHT21 sensor, MQ-2, Flame Sensor, GP2Y1010AU0F, PIR, ESP32-CAM, as well as Blynk 2.0 and ThingSpeak software. Researchers also designed the initial requirements and system functionalities by using UML.

3. Modeling Quick Design
Researchers created a system design of hardware schematic that includes inter-sensor relationships, microcontrollers, and other supporting components using an electronic schematic diagram called Fritzing. The software side uses two IoT platforms namely Blynk 2.0 and ThingSpeak, but the details of implementation will be discussed in further research.

4. Construction of Prototype
This stage involves building a prototype system by integrating all hardware and software components. The Arduino Uno R4 Wi-Fi is programmed using the Arduino IDE to read data from the sensors and send it to IoT platforms via an internet connection. The first focus of this research is to build the hardware prototype. After the prototype is built and ready, the second focus will shift to the advancement and implementation of the system which is integrated with the IoT Platforms using Blynk 2.0 and ThingSpeak with its data analysis.

5. Deployment, Delivery, and Feedback
The prototype will be installed in the Universitas Klabat server room to ensure the system functions as designed. Data from the sensors was tested under various environmental conditions to verify measurement accuracy, notification functions, and data visualization.

## 3. RESULT AND DISCUSSION

This research produces a prototype of an IoT-based monitoring system designed to monitor server room conditions in real-time. The system detects environmental parameters such as temperature, humidity, smoke, fire, dust, and motion, and provides automatic notifications through the IoT platform.

*3.1. System Design*

Figure 2 describes the use case diagram in the development of an IoT-based detector and monitoring system in the Universitas Klabat server room using Arduino Uno R4 Wi-Fi, ESP-32 Cam, temperature and humidity sensor (DHT21), smoke sensor (MQ-2), fire sensor, dust sensor (GP2Y1010AU0F), and movement sensor (PIR). The use case consists of functions such as detecting sensor value, real-time data processing, value checking, getting pop-up notifications, alarm activation, access data, and live video monitoring.

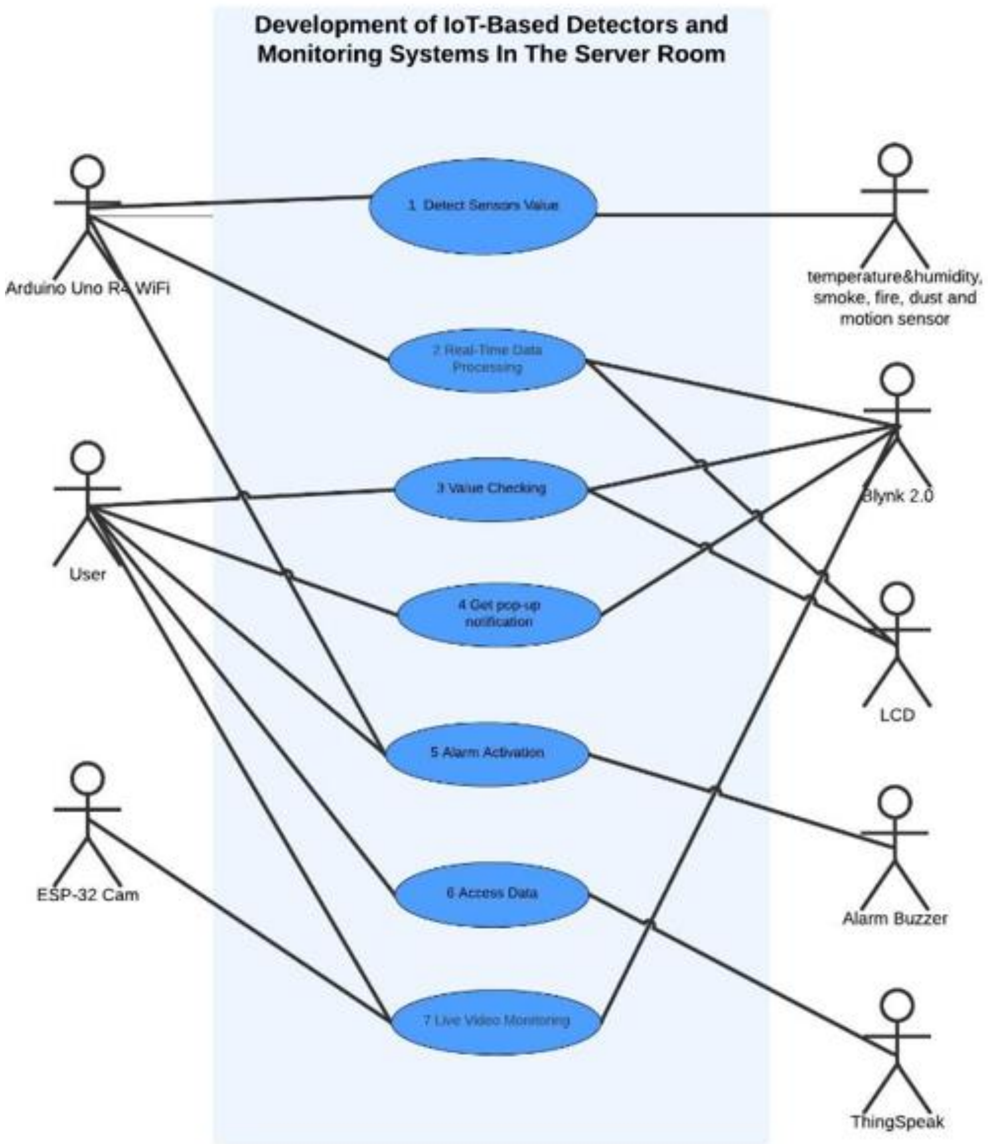


*Figure 2. Use Case Diagram*

Figure 3 displays the system design with hardware and software to provide a visual representation of the stages of the process between sensors and other components connected to the IoT.
The explanation of the system design with the hardware and software integration is as follows:

1. Power Supply functions to channel or provide power for the board Arduino UNO R4 Wi-Fi, DHT21 sensor, MQ-2 sensor, 5 channel Flame sensor, GP2Y1010AU0F dust sensor, pear sensor, Buzzer, LCD, and ESP32-CAM. DHT21 sensor, MQ-2 sensor, 5 channel Flame sensor, GP2Y1010AU0F dust sensor, and pear sensor to measure temperature and humidity data, smoke, fire, dust, and movement in the server room. As well as ESP32-Cam for virtual monitoring.
2. Sensors monitor data on temperature and humidity, smoke, fire, dust, and movement in the server room.
3. The data sent by the sensor is received by the Arduino Uno R4 Wi-Fi then processed and sends back a command for the Buzzer alarm if a problem occurs in the server room.
4. The data processed by the Arduino Uno R4 Wi-Fi into information that can be displayed on the 16x2 LCD.
5. For any changes related to predefined parameters, it can trigger the LED indicator to signal a problem has occurred in the server room.
6. The data processed by the Arduino Uno R4 Wi-Fi is sent to the platform via the Internet so that it can be accessed online.
7. ThingSpeak accesses information from the Arduino Uno R4 Wi-Fi via the internet and displays it in graphical form.
8. Information on ThingSpeak can be accessed by users (IT staff) using computers and smartphones. Access through the computer allows users to view and analyse data in more detail on a larger screen. The smartphone can also be used as a device that can provide direct information about the server room anytime and anywhere.
9. Blynk 2.0 accesses information from the Arduino Uno R4 Wi-Fi via the internet and then displays it.
10. Information on Blynk 2.0 can be accessed by users using computers and smartphones. The access by the computer allows users to view the data in the Blynk dashboard. For smartphones, it can provide quick and easy access to Blynk from anywhere and can control devices through smartphones.
11. The ESP32-Cam functions as a real-time monitoring camera which is set up to be connected to Blynk 2.0 and can be accessed via smartphone to display the server room and its surroundings. This is to monitor the access inside the server room.
12. Users access Blynk 2.0, ThingSpeak, and video via smartphone/computer.
13. Users can find out the conditions in the server room indicated by the LED lights for each sensor. The blue color LED acts as an indicator for the temperature and humidity sensor, the green color LED for the Smoke sensor, the red color LED for the Fire sensor, the yellow color LED for the Dust sensor, and the white color for the PIR sensor.
14. While inside the room, the user can directly view sensor information about the server room conditions which are displayed through the Liquid-Crystal Display (LCD).
15. When the Buzzer Alarm sounds, the user can turn off the Buzzer Alarm either with the Blynk application or also by pressing the Push Button in the prototype.

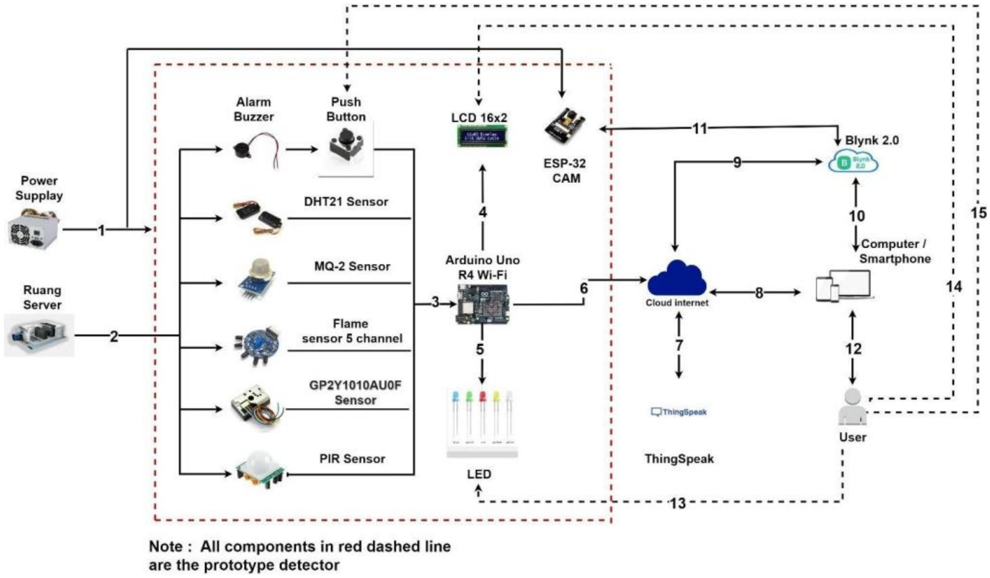

Figure 3. System design with hardware and software integration

## *3.2. Schematic and Hardware Implementation*

Figure 4 shows a schematic of the design of an IoT-Based real-time monitoring and security system for university server rooms which consists of a temperature and humidity sensor (DHT21), MQ-2 sensor, fire sensor, PIR sensor, dust sensor (GP2Y1010AU0F), ESP32- Cam, LED, 16x2 LCD, Buzzer, Push Button, 220kΩ resistor, capacitor and Arduino Uno R4 Wi-Fi. The schematic was designed using a software called Fritzing.

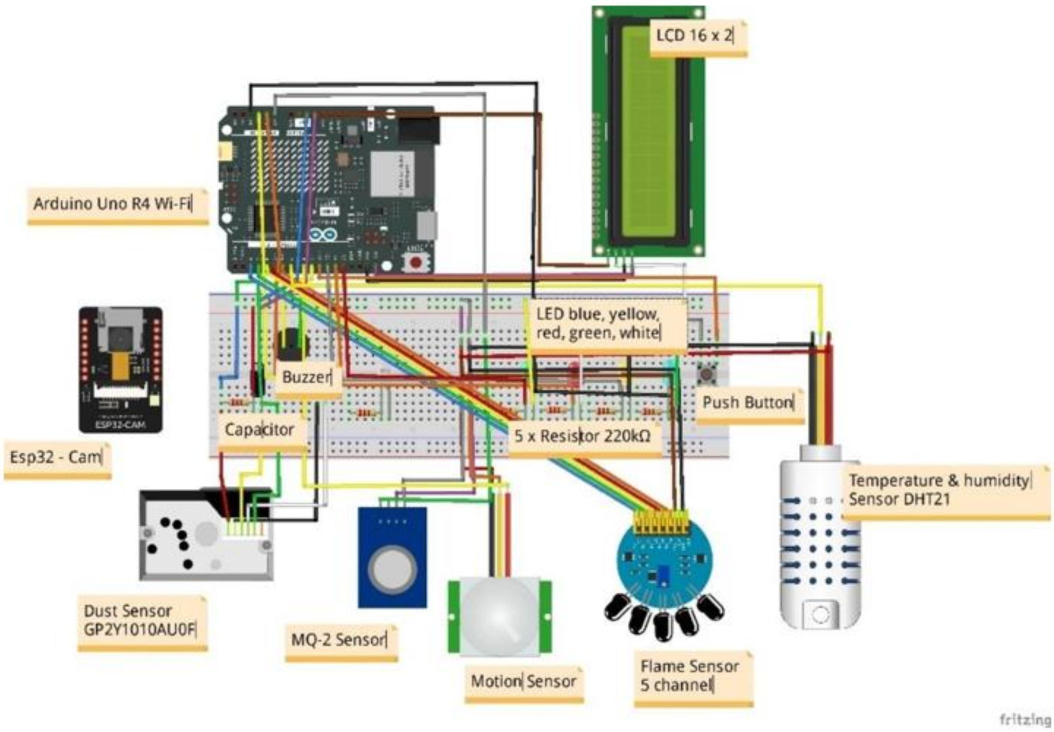

*Figure 4. Schematic of Detector and Monitoring System in Server Room*

Figure 5 shows hardware components consisting of LEDs, Arduino UNO R4 Wi-Fi microcontroller as a data processor, temperature and humidity sensors (DHT21), MQ-2 sensors, fire sensors, PIR sensors, dust sensors (GP2Y1010AU0F) as detectors and monitoring systems in the server room. 16x2 I2C LCD as a tool to display information that can be used to monitor the server room processed from the microcontroller; Buzzer and Push Button as an alarm system; and ESP32-Cam as a real-time camera monitoring.

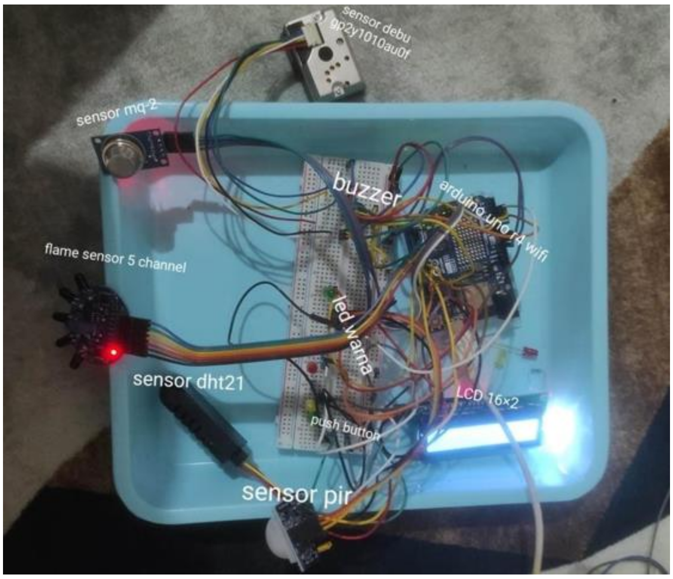


*Figure 5. Hardware Components*

### *3.3. Object Diagram*

Figure 6 is an image structure of the IoT-based Detector and Monitoring System for the university server room. Designed based on the analysis of the tools and methods used on each object that serves to run the detector and monitoring system in the server room.

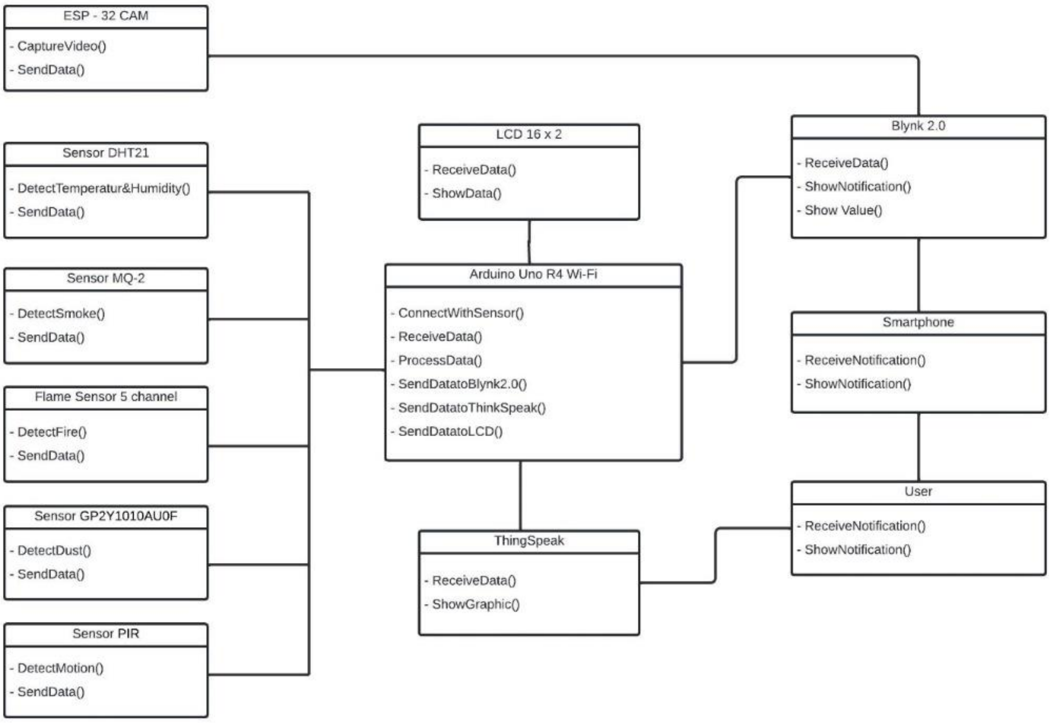


*Figure 6. Object Diagram*

### *3.4. Activity Diagram*

Activity diagrams describe the workflow of the detector and monitoring system created. An activity diagram is an advanced version of a flowchart that shows the flow from one activity to another.

The elements in the activity diagram are the start point, end point, activities, fork, joint, direction, and swim lane. The function of the activity diagram:

1. Describes the business process of the sequence and activities in a process.
2. Displays the sequence of process activities on the device.
3. Activity diagrams are made based on several use cases in the use case diagram.

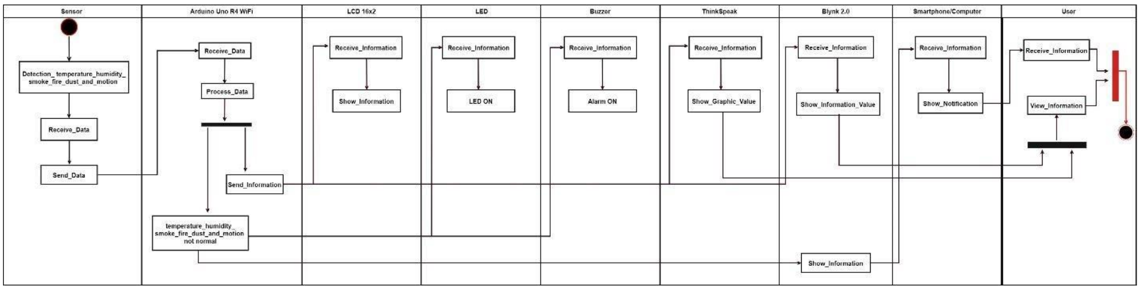


*Figure 7. Activity diagram of Server Room Detector and Monitoring System*

Figure 7 illustrates the process flow of the monitoring system where the sensor is ready to receive data from the server room, and then send data to the Arduino UNO R4 Wi-Fi for processing. Arduino UNO R4 Wi-Fi which receives data from the sensor and then performs data processing to generate information. Furthermore, the information is sent to the LCD, ThingSpeak, and Blynk 2.0. Abnormal conditions received by the LED, Buzzer, and Blynk 2.0 make the LED and Alarm light up to indicate that there are conditions that require action related to the condition of the server room. The transmitted information is received and displayed on the LCD. ThingSpeak receives the information analyzes it and converts it into graphical form and stores the data history for display. Blynk 2.0 receives information to be used to display information via smartphone in the form of pop-up notification to the user.

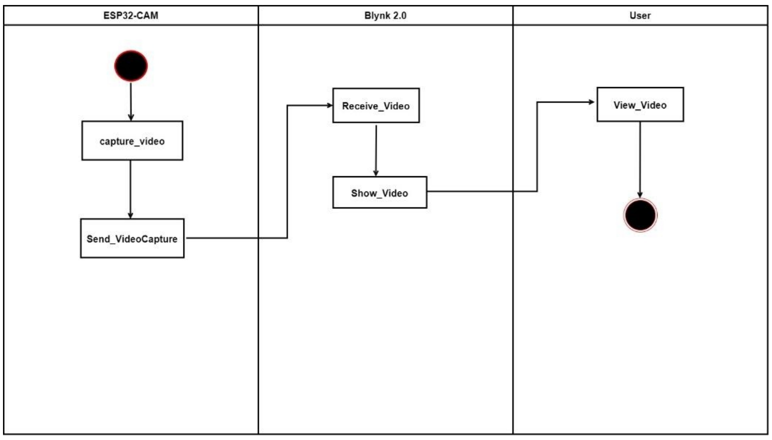


*Figure 8. Activity Diagram of Server Room Monitoring Video*

Figure 8 shows the functional flow of the Live Video Monitoring process which explains the interaction of the ESP32-Cam in recording conditions which then sends it to Blynk 2.0 to be displayed and users can monitor the condition of the server room virtually anytime anywhere.

### *3.5. System Testing*

Researchers conducted functional testing of the system which can be seen in Table 1. Testing is done to find out the test of each component runs well and carries out its functionality. The scenario to simulate the fire condition is done by making a fire source from a lighter or match surround the flame sensor and checking whether the flame sensor can respond and detect the fire. To simulate the smoke condition burning an object (i.e. paper, cigarette, etc) which then produces smoke to be detected by the smoke sensor MQ2. To test the functionalities of the dust sensor GP2Y1010AU0F is done by inserting the tip of a stick or something similar into the dust sensor reading hole [35]. To test the PIR sensor, simply make a motion around the sensor. When the sensors successfully detect the input parameters of the temperature, humidity, dust, and smoke it will display the output value in LCD. The input from motion and flame parameters will be triggered output to the LED indicator and sound buzzer as an alarm. These scenarios are conducted to resemble the real conditions that can happen, although it is still limited to the test of the functionalities of the hardware prototype since the prototype is not yet placed inside the environment of a server room. For future research it is planned, to put the hardware prototype inside the university server room within a specified time to assess and analyze how the whole system works for monitoring and security purposes in the server room.

*Table 2. Functionalities System Testing*

| Component | Conditions | Process | Result |
|---|---|---|---|
| DHT21 Sensor, MQ-2, Flame Sensor, GP2Y1010AU0F, PIR | Sensor in standby (active) state | The sensors detect temperature and humidity values, smoke, fire, dust and movement | The sensor successfully detects the temperature value in Celsius, Humidity in unit %, Smoke, Fire, Dust, and PIR. Then sends the result to Arduino Uno R4 Wi-Fi. |
| Arduino Uno R4 Wi-Fi | Arduino Uno R4 Wi-Fi is enabled and connected to the sensor | Analog and digital data from the sensors are received by the Arduino Uno R4 Wi-Fi and the data is processed according to the respective functions sensor | The Arduino Uno R4 Wi-Fi successfully processes the data and sends it to Blynk 2.0, ThingSpeak, and LCD. |
| LCD | The LCD is connected to the Arduino Uno R4 Wi-Fi. | Arduino Uno R4 Wi-Fi sends data from sensors that have been processed to the LCD. | Data of temperature and humidity values, smoke, and dust were successfully displayed on the LCD. |
| LED | The LED is connected to the Arduino Uno R4 Wi-Fi. | The value of the abnormal sensor makes the Arduino UNO R4 Wi-Fi send the signal to the LED so that can be turned on according to the conditions. | LED successfully lit up accordingly, with blue color for the temperature and humidity sensor, green color for the smoke sensor, red color for the fire sensor, color yellow for sensor dust, and white color for the PIR sensor |
| Buzzer | Connect with Arduino Uno R4 Wi-Fi | Abnormal conditions make the Arduino Uno R4 Wi-Fi send a signal to turn on the Buzzer. | The alarm successfully sounds when an abnormal condition is detected by the sensor. |

## 4. CONCLUSION

The design of an IoT-based prototype demonstrates the potential of IoT technology in enhancing the safety and efficiency of university server room management. By integrating real-time monitoring and automated alerts, the system could be implemented to minimize the risks associated with environmental instability and unauthorized access. The response time is considered real-time within the hardware itself. There is low latency with only a few seconds when the data gets processed to the IoT platforms, which relies on the support of internet access. When the internet is down, the prototype hardware still can process the monitoring through LCD, LED indicators, and alarm. Regarding the process in the IoT platforms, it needs internet support to display the data in Blynk 2.0 and ThingSpeak.

Future research will focus on expanding the system's scalability, assessing the accuracy of the sensors, and integrating predictive analytics for proactive maintenance. It will also focus on setting up IoT platforms namely Blynk 2.0 and ThingSpeak with their implementation and data analysis to provide insights into trends or issues related to the server room monitoring.

## 5. ACKNOWLEDGMENTS

The researchers would like to express gratitude to Universitas Klabat for providing access to the SIU server room and support in this research.

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