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# Integrated IoT-Based Fire Prevention and Evacuation System for High-Rise Buildings

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## ABSTRACT

Conventional fire protection systems, characterized by low installation costs, often lack the sophistication to provide optimal protection, especially in high-rise buildings. This study aims to refine the operational productivity concerning fire prevention and evacuation by embracing a detailed fire safety framework that leverages Internet of Things (IoT) capabilities. This prototype integrates SMS and phone call alerts to facilitate timely response in case of fire detection. The system utilizes three key sensors: a KY-026 flame sensor module, an MQ-2 gas and gas sensor, and an LM35 temperature sensor. Testing results indicate significant sensor value variations between normal and fire conditions. The KY-026 flame sensor module, for instance, exhibited an average reading of 137.3 under normal conditions and 895.2 during fire detection. Similarly, the MQ-2 sensor recorded 1234.7 ppm and 4237.8 ppm, respectively. The LM35 temperature sensor measured 28.34°C and 48.46°C under normal and high-temperature conditions. Despite the sensors showcasing commendable efficacy, they displayed a minor error margin fluctuating between 0.04% and 1.08%.

**KEYWORDS:** *Fire protection, KY-026 flame sensor, MQ-2 Sensor, LM 35 temperature sensor.*

## NOMENCLATURE

| | |
|---|---|
| *SMS* | Short Message Service |
| *WiFi* | Wireless Fidelity |
| *LCD* | Liquid crystal display |
| *GSM* | Global System for Mobile Communications |
| *LED* | Light Emitting Diode |
| *ADC* | Analog Digital Converter |

## 1.0 INTRODUCTION

Fires often occur due to technical problems with electricity, gas, heating, mechanical problems, or human negligence so that they will be fatal and can cause huge material losses, economic disruption, injuries and even fatalities [1–3]. The victims of this fire are also inseparable from the unmeasured fire protection system and still use conventional systems [1], [4], [5]. This conventional system uses a single physical sensor such as a flame sensor or gas sensor that cannot detect actual fires, so it can trigger false alarms such as those caused by cigarette smoke [6–8].

The construction of buildings vertically along with the construction of large-scale buildings, the risk of fire is also increasing, so conventional fire protection systems are no longer effective [2], [8–10]. Therefore, it is important to minimize and prevent damage and losses in order to ensure safety due to fire by detecting fires accurately [2], [11]. Many researchers are currently conducting research to overcome fire protection problems with intelligent systems such as smart homes, smart buildings, and smart cities [12–15] The system is built with collaboration between machines and humans for early detection of fires that can work quickly and provide early warnings so that the evacuation and rescue process can be carried out faster and more effectively [16–18].

In the era of digital technology advancement, many fire protection systems are designed by integrating the Internet of Things (IoT) using microcontrollers as a fire protection system control tool [18–24]. Various studies and applications of fire protection systems using Arduino Uno [25], NodeMCU IDE or ESP 8266 connected to the DHT 11 sensor to monitor temperature and humidity levels [26–29] SP-12 modules that can be directly connected to WiFi, GSM modules connected to mobile phones [27], [28], [30], and various other technologies.

Based on this background, it is necessary to create a real-time fire protection monitoring system that can provide early warnings and instructions to building occupants, fire facilities, and authorities to evacuate so that fires can be prevented and damage can be reduced [19]. The fire protection system to be built is a monitoring system and early warning of fire in high-rise buildings using IoT based on microcontrollers by controlling three sensors in the form of a KY 026 flame sensor module [29][31], an MQ-2 gas sensor [32–34] and an LM 35 temperature sensor connected to an application on an Android smartphone [35][36]. This system will provide special notifications in the event of a fire wirelessly and connect it to the building authority, the local fire department via SMS using the GSM SIM 800L Module connected to the global GSM network.

## 2.0 RESEARCH METHOD

### 2.1 Fire Protection System Design

In this study, a fire protection system will be designed in a multi-storey building with a monitoring system using three types of sensors as fire detection devices. Arduino Mega 2560 integrated with KY-026 flame sensor module that can detect fire when the sensor reading value was > 500 [29][31][38]. The MQ-2 gas sensor will detect smoke or hazardous gas when the sensor reading value was > 3000 ppm. The LM 35 temperature sensor will detect that there is a high temperature when the temperature sensor reading value was > $40^0$C [24]. The microcontroller will process the data obtained from the sensor as a notification signal in the event of a fire. As a warning alarm for a fire, a buzzer and automatic command were also used to open the water sprinkle valve which is driven by a servo motor.

Based on Figure 1, the KY 026 flame sensor module [29][31], MQ-2 gas sensor [32–34] and LM 35 temperature sensor would work to provide reading data to the Arduino Mega 2560 [39]. Then, the data was processed to obtain reading parameters if the MQ-2 gas sensor in each room on the 1st and 2nd floors detects smoke or gas levels. Furthermore, the active buzzer as a warning alarm would work and the warning results was displayed on the 16 x 2 I2C LCD [40]. Then the microcontroller was also order the DC Micro Servo Motor to work to open the valve or water tap according to the results of the sensor readings in each room on each floor of the building to extinguish the fire. Liquid crystal display (LCD) as an evacuation route indicator can light up in each room. If no fire was detected as a sign, then the route was safe to pass during the evacuation or self-rescue process.

The data commands and indicators read on the sensors were also directly sent to the internet network via the ESP 8266 - 01 WiFi module. It was then displayed on the Blynk platform, so that authorities and security can monitor and also get notifications in real time directly to smart phones. And this system can also send fire location data to firefighters via short messages or SMS using the GSM SIM 800L Module connected to the global GSM network using 2G SIM (Telkomsel, Indosat, Three) and works on the GSM network frequency, namely QuadBand (850/900/1800/190 Mhz) [26][27]. Figure 2 shows a building fire early detection circuit. The implementing the circuit, a power supply with two outputs and an adjustable regulator were required to be connected to the fire early detection circuit.

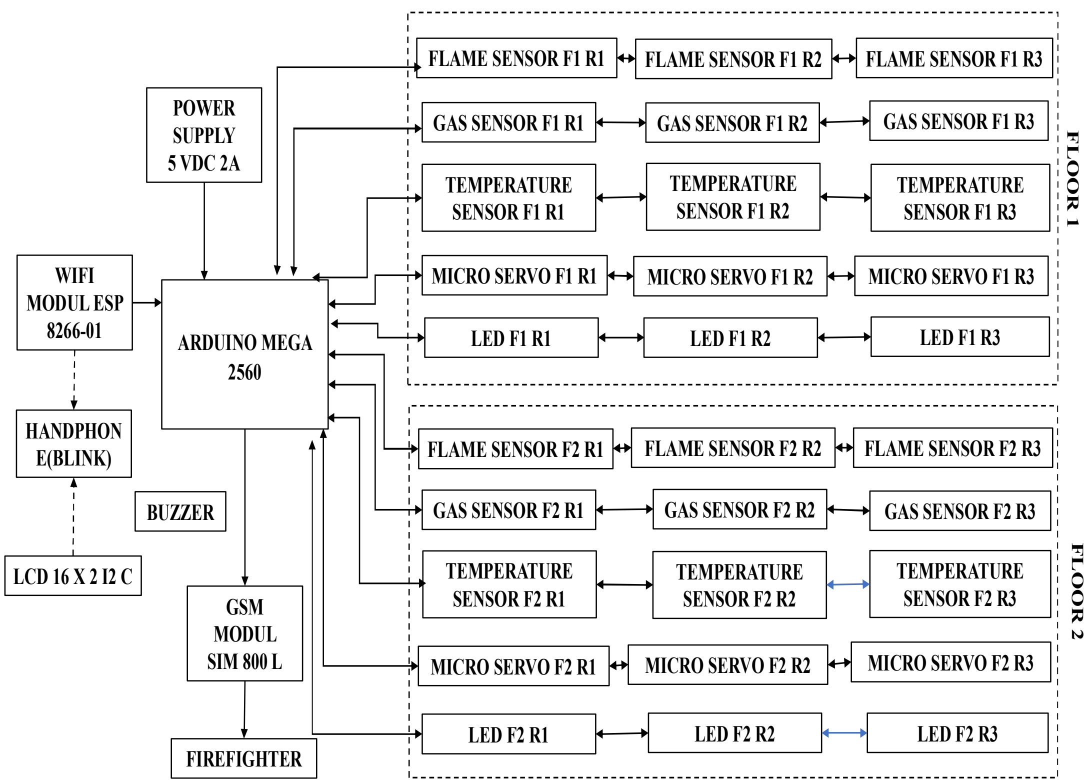


Figure 1: Block diagram of building fire early protection system


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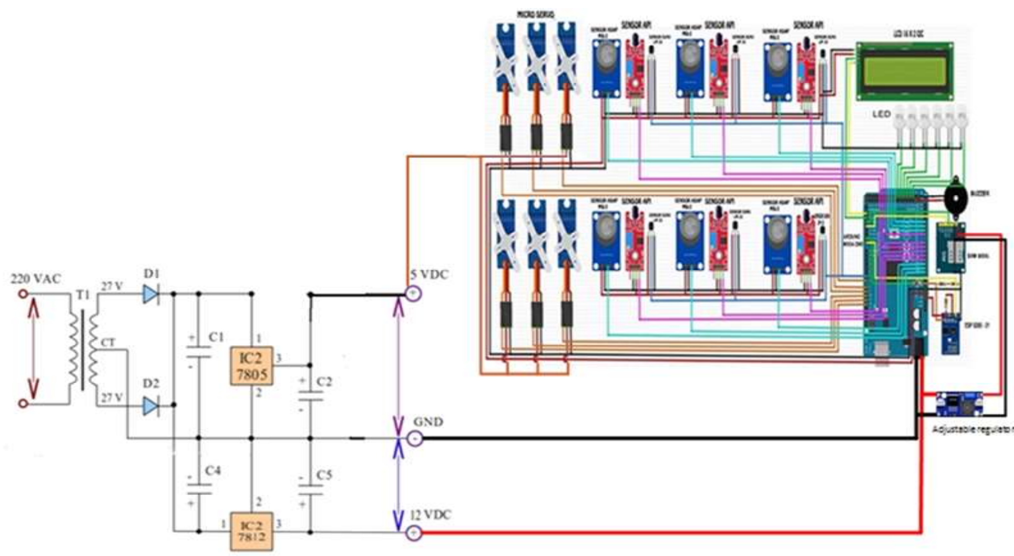


Figure 2: Building fire early detection circuit

Figure 3 illustrates the miniature scheme of the building to be made in this study, where there were six rooms with 2 floors and a sensor layout in each room. The sensors were placed in strategic places, and place LEDs as evacuation direction indicators on the building floor towards the stairs and exits.

## 2.2 Program Design

The program begins by initializing the sensors used, then the data read by the flame sensor module, gas sensor, and temperature of the sensor was sent to the Arduino Mega 2560. The data results were be displayed by the LCD. Then the WiFi module can provide data read from the Arduino to the Android User Interface with the Blynk Platform. If a fire, gas or smoke and a high temperature was detected, the buzzer can work as a notification alarm and at that time the micro servo would work. Then the Blynk application can display data from the sensor and can provide a special notification that a fire has occurred. If the fire did not go out, then, the SIM800L module would send the building location point to the firefighters via short message or SMS. The flowchart for designing the program on the building fire protection system can be seen in Figure 4.

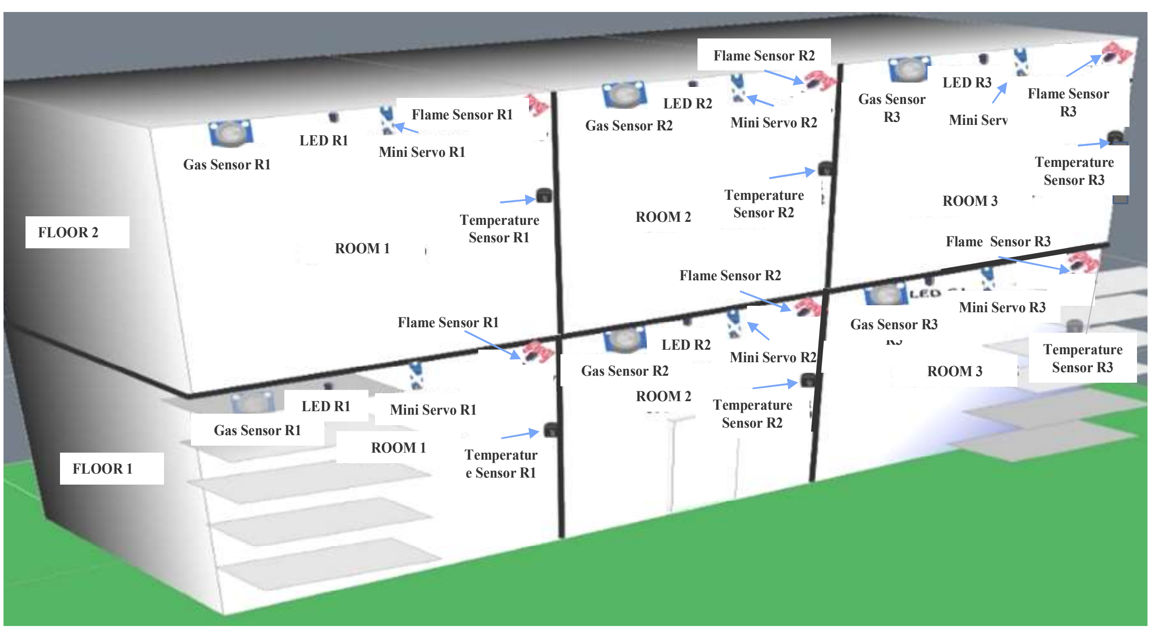


Figure 3: Miniature building schematic


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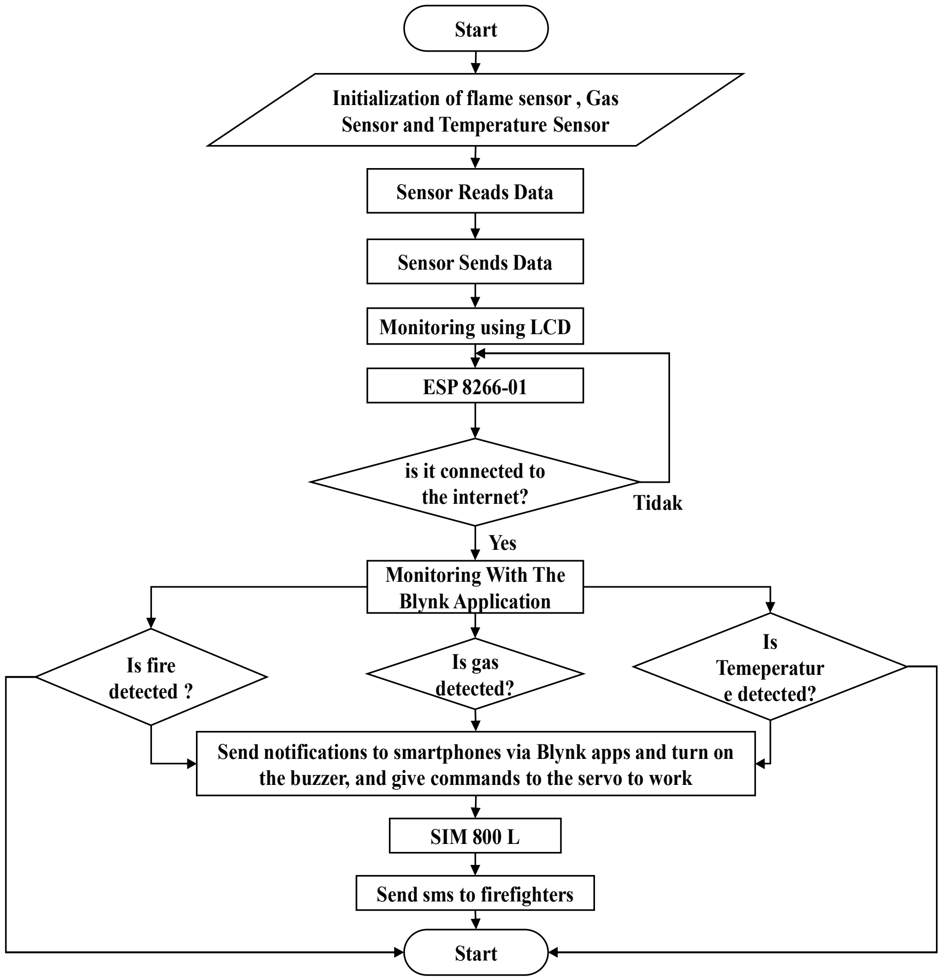

Figure 4: Program design flowchart

## 3.0 RESULT AND DISCUSSION

The results of the realization of the framework of building fire early protection system had been designed and tested the performance of each installed components. Then, it was continued by testing the entire system connected to the Arduino Mega 2560 microcontroller as a data processor from the sensors used, such as the KY-026 flame sensor module, MQ-2 gas sensor, LM 35 temperature sensor. In addition, the microcontroller also processed the data from the ESP 8266-01 WiFi module, Micro Servo SG-90, Buzzer and LED as indicators.

### 3.1 KY 026 Flame Sensor Module Testing

Testing on the KY 026 flame sensor module was carried out by measuring based on distance and monitoring the condition of the fire being detected or not at a predetermined distance. Then, it was monitored by the sensor reading value and measuring its voltage. This test was aimed to ensure that the performance of the flame sensor module, which can run well. The Analog Digital Converter (ADC) value for the KY 026 flame sensor module reading range was 0-1023. The value of 1023 was obtained from the Arduino pin, which can receive values up to 10 bits and then converted to 210 = 1024 means the value of 1023 represented a voltage of 5 Volts. In the voltage reading, the addition of 5 Volts from the source voltage was set up. So, the higher voltage, then was the greater the reading value that was read. Therefore, the calculated voltage must be reduced by the source voltage, which was 5 Volts. The results of the KY 026 fire sensor module test can be seen in Table 1.

### 3.2 Testing on MQ-2 Gas Sensor

The MQ-2 gas sensor was an electronic component that functions to detect flammable gas content in the air and smoke. To obtain the PPM value on the MQ-2 sensor, the following calculation is required:

$$\text{Manual PPM Value} = 300 + (\text{ADC} \times 9.4819159335) \quad (1)$$

To ensure that the MQ-2 gas sensor works properly, several tests were carried out with different levels of smoke sensitivity. The test results can be seen in Table 2.


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Table 1: Results of the KY 026 flame sensor module test

| No | Distance (cm) | Condition | | Indicator LED | Reading Value | | Voltage (Volt) | Error (%) |
|---|---|---|---|---|---|---|---|---|
| | | Detected | Not detected | | Sensor | Manual | | |
| 1 | 5 | √ | | on | 974 | 967 | 0.26 | 0.41 |
| 2 | 20 | √ | | on | 966 | 959 | 0.31 | 0.72 |
| 3 | 40 | √ | | on | 955 | 951 | 0.35 | 0.42 |
| 4 | 60 | √ | | on | 842 | 838 | 0.92 | 0.48 |
| 5 | 80 | √ | | on | 733 | 726 | 1.45 | 0.96 |
| 6 | 100 | √ | | on | 598 | 593 | 2.10 | 0.84 |
| 7 | 120 | | √ | off | 465 | 460 | 2.75 | 1.08 |
| Average error value | | | | | | | | 0.71 |

Table 2: MQ-2 gas sensor test results

| No | Gas PPM Value | Manual PPM Value | Voltage (Volt) | ADC | Error (%) |
|---|---|---|---|---|---|
| 1 | 5 | on | 0.26 | 88.46 | 0.41 |
| 2 | 20 | on | 0.31 | 200.96 | 0.72 |
| 3 | 40 | on | 0.35 | 53.07 | 0.42 |
| Average error value | | | | | 0.60 |

Table 3: LM 35 temperature sensor test results

| No | Time Interval ( Minutes ) | Measurement with Room Thermometer ($^0$C) | Measured Temperature ($^0$C) | Error (%) |
|---|---|---|---|---|
| 1 | 5 | 27.10 | 27.14 | 0.15 |
| 2 | 10 | 27.18 | 27.25 | 0.25 |
| 3 | 15 | 27.38 | 27.41 | 0.11 |
| 4 | 20 | 27.21 | 27.27 | 0.22 |
| 5 | 25 | 27.89 | 27.94 | 0.18 |
| 6 | 30 | 27.76 | 27.77 | 0.04 |
| Average error value | | | | 0.16 |

Table 4: Sensor testing in condition for the no-fire and with the fire

| Sensor Testing (No Fire) | | | | | |
|---|---|---|---|---|---|
| KY 026 Flame sensor module | | MQ-2 Gas sensor | | LM 35 Temperature Sensor | |
| Sensor reading | Voltage (V) | Sensor reading | Voltage (V) | Sensor reading | Voltage (V) |
| 125 | 4.05 | 1170 | 0.12 | 27 | 3.02 |
| 128 | 3.92 | 1180 | 0.23 | 28 | 3.19 |
| 130 | 3.89 | 1190 | 0.29 | 28 | 3.18 |
| 132 | 3.76 | 2000 | 0.33 | 29 | 3.24 |
| Sensor Testing (With Fire ) | | | | | |
| KY 026 Flame sensor module | | MQ-2 Gas sensor | | Temperature Sensor LM 35 | |
| Sensor reading | Voltage (V) | Sensor reading | Voltage (V) | Sensor reading | Voltage (V) |
| 974 | 0.4 | 3050 | 1.42 | 45 | 0.44 |
| 966 | 1.6 | 3587 | 1.70 | 47 | 0.46 |
| 955 | 2.4 | 3259 | 1.53 | 48 | 0.48 |
| 842 | 3.2 | 3998 | 1.91 | 50 | 0.51 |

### 3.3 LM 35 Temperature Sensor Testing

The LM35 temperature sensor and conventional thermometer were tested. To ensure consistency and accuracy during the testing process, recording was carried out every 5 minutes. Furthermore, the data generated from the comparison between the LM35 temperature sensor and the conventional thermometer were summarized and presented in Table 3. In able 3, the results of performance and reliability of the LM35 sensor have the average error value of 0.16.

### 3.4 Sensor Testing on No Fire and With Fire

The sensor testing was carried out to determine the performance of each sensor, which was aimed to ensure no-errors occurred in the reading sensor data under normal conditions. As well as, there was a fire. Test results on reading the KY 026 flame sensor module, MQ-2 gas sensor and LM 35 temperature sensor is depicted in Table 4. It can be seen in Table 4, all the sensors testing results were working well.


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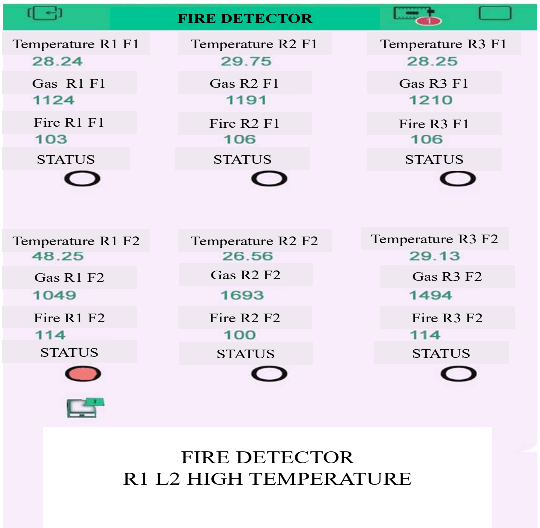


Figure 5: High temperature notification display on Blynk application

The Blynk application was designed to send notifications that clearly indicate the specific room and floor where a high temperature was detected. This feature enables precise identification of the location within a building where elevated temperatures occur. The system, integrated with the Blynk application, operates by providing real-time notifications that pinpoint the exact room and floor experiencing temperature irregularities. This functionality ensures accurate and timely alerts, facilitating prompt responses to potential issues. By leveraging the capabilities of the Blynk-based system, alerts were autonomously generated to specify the room and floor where temperature anomalies were detected. This automated process enhances the system's efficiency and reliability in monitoring environmental conditions. Testing on serial communication and response time between Arduino Mega 2560 and Blynk apps obtained a response time of 0-5 seconds, as well as serial communication between Arduino Mega 2560 and SIM800L. The serial communication assumes that the system works in real time and was well connected.

In Table 5 shows the several differences in the parameters read on each sensor displayed. This happens because the internet network used is not good. The poor internet network received by the ESP 8266-01 WiFi module causes the data reading process sent by the Arduino to be slower so that there are differences in the display values on the LCD and Blynk Apps for some time. If the internet network received by the ESP 8266-01 WiFi module is good and stable, the reading value will be the same between the sensor data readings on the LCD and on Blynk Apps

### 3.5 Testing and Simulation of the Tool's Working System During the Fire

Testing and simulation of the tool's working system during the fire was carried out to find out in detail the working principles and working systems of the tool that has been made when a fire occurs in one room. Fire simulations were carried out in each room to see if all systems were running well. Table 6 is one of the test results carried out in room R1 F2.

Table 5: Results of sensor testing, LCD with Blynk

| No | Sensor | Reading On LCD | | | | | | Reading On Blynk | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | F1 R1 | F1 R2 | F1 R3 | F2 R1 | F2 R2 | F3 R3 | F1 R1 | F1 R2 | F1 R3 | F2 R1 | F2 R2 | F3 R3 |
| 1 | KY 026 Flame Sensor | 130 | 121 | 115 | 149 | 121 | 130 | 130 | 121 | 114 | 134 | 121 | 127 |
| 2 | MQ-2 Smoke Sensor | 1134 | 1162 | 1418 | 1324 | 1836 | 1276 | 1134 | 1162 | 1826 | 1314 | 1921 | 1519 |
| 3 | LM 35 Temperature Sensor | 35 | 35 | 36 | 35 | 35 | 35 | 35.38 | 35.31 | 35.63 | 34.81 | 34.94 | 34.69 |

Table 6: Testing and simulation of the working system during a fire on R1 F2

| No | Room | Flame sensor module | Gas Sensor | Temperature Sensor | Buzzer | LED | Micro Servo | Blynk | Send SMS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | R1 F1 | 136 | 1224 | 27.12 | OFF | OFF | OFF | OFF | OFF |
| 2 | R2 F1 | 136 | 1230 | 27.62 | OFF | OFF | OFF | OFF | OFF |
| 3 | R3 F1 | 139 | 1232 | 27.49 | OFF | OFF | OFF | OFF | OFF |
| 4 | R1 F2 | 804 | 3687 | 47.99 | ON | ON | ON | ON | ON |
| 5 | R2 F2 | 139 | 1236 | 28.07 | OFF | OFF | OFF | OFF | OFF |
| 6 | R2 F2 | 144 | 1237 | 27.55 | OFF | OFF | OFF | OFF | OFF |

It can be seen in Table 6, that the room conditions indicate that if a fire occurs, the flame sensor module reading value is > 500, the gas sensor reading is > 3000 and the temperature sensor reading is > 400C. While the sensors in other rooms had been remain in normal conditions, if there was no indication of fire, the readings of each sensor did not exceed the specified limits. Then, the LED was light up as an indicator. The buzzer was light up as an alarm indicating that a fire has occurred, and the micro servo can open the water valve for early fire control. Furthermore, Blynk Application sent a notification in the form of a pop-up on the smart phone. Furthermore, the SIM800L sent an SMS notification that a


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fire had occurred accompanied by an incoming call as a fire warning marker to the building security officer's cell phone number.

The SMS contains a notification about a fire with a location point in the form of an address that can be accessed via Google Maps to make it easier to find the location of the fire when an indication of a fire was detected. If a fire was detected and shows signs of spreading to other rooms without being controlled, the SIM 800L module would promptly send an SMS and initiate a phone call to the fire department in real time. This immediate notification ensures that the fire department was alerted as quickly as possible, enabling them to respond to the fire location without delay and take necessary measures to contain and extinguish the fire.

## 4.0 CONCLUSION

This research was conducted on the fire protection system of high-rise buildings using IoT based on the Arduino Mega 2560 microcontroller integrated with the KY-026 flame sensor. The sensor can detect a fire when the value was >500, from the measurement results obtained the average reading of the fire sensor when normal conditions were 137.3 and when a fire was detected on value of 895.2. The MQ-2 gas sensor detected the smoke or hazardous gases when the reading value on the sensor was >3000 ppm. The testing was carried out the average value obtained in normal conditions, which were 1234.7 ppm. Then, the smoke and hazardous gases were detected the average reading of 4237.8 ppm. The LM 35 temperature sensor can detect a fire when the temperature was >$40^0$C. Based the result of testing under normal conditions the average value was $28.34^0$C and the average sensor reading when detecting high temperatures was $47.5^0$C. The error value in the reading of each sensor was 0.04% - 1.08%. The future work can be the early detection system for fires in high-rise buildings can also be developed by adding CCTV cameras to obtain valid data, information and conditions.

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