Smart System to Prevent Forest Fire Based on Internet of Things

Poltak Sihombing, Herriyance, and M. Rizki Syaputra

Abstract—**Forest fires that have occurred in Indonesia recently caused enormous impacts and losses for human life and other living things. The problem of forest fires can cause smog, exposure to disease and human death. One of the causes of forest fires is inadequate early warning, and it is difficult for firefighters to reach hotspots. This paper aims to offer a prototype of an early warning system for forest fire monitoring and control. In this research, we have proposed an automated monitoring system that can monitor fire, humidity, and gas in real-time by using Internet of Things (IoT) and Blynk Cloud network. Several sensors are installed such as the DHT-22 sensor to control temperature and humidity, the LM393 fire sensor to detect fire, and the MQ-2 gas sensor to detect levels of liquefied petroleum gas (LPG) in forest areas. A water pump is also installed to spray water automatically when the temperature is >40 0C. The system resulted an early warning by turning on the "BUZZER ON" and "WARNING" lights, if the gas level is > 35% or the temperature, is >40 0C. In the simulation, the system can provide information and the location of hotspots by google maps and messages on smartphones, such as "temperature >40 0C detected, the hot temperature detected in A-SECTOR forest area". In the second test, the system can detect gas in the A-SECTOR forest area with a level of 35%.**

***Index Terms*— Smart System, Arduino, Sensor, IoT, GPS.**

I. Introduction

THE problem of forest fires that have occurred in Indonesia recently has caused enormous impacts and losses not only for human life but also for animals that live in the forest. These forest fires can also cause smog, disrupt aircraft departure schedules, and paralyze human activities. Based on data compiled from the "National Disaster Management Agency (BNPB)", the total area of forest and land burned throughout Indonesia during January - August 2019 reached 328,724 hectares.

This incident was caused by the lack of early prevention leading to forest fires. There is also no monitoring of temperature conditions in forest areas so far. Likewise, gas monitors that can cause fires have not been monitored. So that forest fires occur continuously every year. In addition to the lack of early prevention, forest fires are also caused by officers in the field finding it difficult to find and reach the hotspots. This study aims to develop a monitoring system for temperature and gas components in the forest area and establish a safety classification in the forest area.

Current technological developments, especially in sensors, microcontrollers, and the Internet of Things (IoT) have touched various fields, including forest automation and control systems. Utilizing sensors as a means of detecting temperature, fire, and gas, can help to prevent forest fires early. The development of sensors is also very rapid they can be used for various purposes to detect an object. The current sensor can detect symptoms or signals from an object around the sensor. Many tasks can be done by utilizing the capabilities of sensors, including remote monitoring of forest areas.

Today's cellular communication technology is a part of communication that cannot be separated from human life. Whether communication uses social media applications such as chat, video calls, voice calls, and SMS and telephone media, communication via SMS is the minimum communication owned by mobile devices at this time. This technology can be connected to the Internet of Things (IoT) to optimize forest fire prevention.

Based on the brief description above, it is possible to develop intelligent systems to detect and monitor forest conditions using various sensors and microcontrollers. With the development of various computer network topologies and the IoT, it is possible to monitor forest conditions remotely in real-time as we propose in this study. An automated monitoring system that is carried out continuously will reduce the risk of forest fires and living things around the forest.

II. Related Work

The study of IoT in forest fire detection systems and early warnings has been discussed by Trinath Basu et.al [1]. They use a variety of temperature sensors, smoke sensors, and signals connected to a microcontroller. Their system provides immediate early warning in case of a fire. Their approach is to avoid the accident caused by overheating in the forest area.

Another study described a survey the use of IoT and intelligent systems to improve the quality of human life by Sathish and S. Smys [2]. They mentioned that with IoT, it is possible to communicate with each other both physically and virtually. With the help of IoT, objects can be connected more

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intelligently with any device at any time. It was further stated that nowadays, people want to communicate with inanimate objects via IoT. IoT is used to collect and analyze data from various actuators and sensors and then pass it through the smartphone via wireless connection.

Another IoT application study was carried out by Sayed A Elmustafa, and EY Mujtaba [3]. They provide a brief conceptual review of the field of environmental studies based on IoT technology and discuss the justification behind the use of IoT in environmental studies. Moreover, they investigate various proposed environmental research applications based on IoT. They further reviewed the impact of environmental phenomena on human life. They review intelligent environmental sensors integrated with 'Internet of Things (IoT) technology which can provide new concepts in tracking, sensing, and monitoring environmental objects.

Another study describes an intelligent and sustainable environment using the IoT by Tyagi and Amit Kumar [4]. They write that the government in India has initiated a plan to develop 100 smart cities, including maintaining an intelligent environment using IoT. They explained a clear view of IoT integration and its effects on available resources.

The study on Environmental phenomena, described by Elmustafa and Mujtaba Yousef [5], this study explains the significant impact of environmental phenomena on daily human life. They provide a brief concept of studying intelligent environments using IoT technologies and their applications.

In another discussion, Wajahat et al [6], conducted experiments in real-time to monitor the forest environment [6]. They propose monitoring from several points in the forest area, and the data will be sent to the control center. They use various sensors at various points around the forest such as sensors to detect fire, sensors to detect smoke, sensors to detect light intensity, temperature sensors, and forest humidity.

The next study is a smart fire detection and deterrent system for a human savior by using IoT proposed by Abdul Rehman, et al [7]. This paper described a system that can detect fire and be an intelligent solution. The results of data detection from the sensor are then analyzed with a rule-set using a fuzzy logic algorithm. The results of this analysis provide a decision to give a warning if it is at a dangerous level. This processing simulation work is carried out using MATLAB.

The next paper is to create a forest fire monitoring network system involving all critical players in forest fire operations by Molina-Pico A et al [8]. The network is built with a hierarchical command system and has been simulated in dealing with forest fires. They described several important fire risk points by placing various wireless sensors at these points. Air conditions are also monitored from several points in the forest area and reported to the central control station. They successfully tested this integrated command configuration simulation with fire detection and built a communication network system.

The next paper proposes a low-cost LoRa-based network for forest fire detection by Roberto Vega, et al [9]. They outline a low-cost Long Range (LoRa) based network. This system can evaluate the level of fire risk and the presence of forests. The system is composed of LoRa nodes, and a set of sensors is used to measure temperature, humidity, wind speed, and CO 2. Users can view the parameters measured by the nodes in real-time through the website.

In another discussion, Rajesh et al [10] have proposed an intelligent system technological in forests to improve forest ecosystems. They create intelligent systems for sensing and monitoring to anticipate incidents of forest fires, illegal felling of trees, poaching, etc. They said that intelligent systems could be used directly in the future for advances in research and development related to data collection and processing applications such as flora analysis and forest fire prediction.

Furthermore, Ravi Tomar et al [11] have proposed an information delivery system and related algorithms using various parameters, wireless technology, sensors, and the Internet of Things. They also involve cloud computing to provide real-time information about forest fire events. The results can show the probability of a fire occurring and transmitted to system users through interactive graphs and images, along with the latitude and longitude of the location in the forest. The system built can send information to local authorities and forest fire management centres.

III. The Methodology

This section describes our proposed methodology to control and prevent forest fire hazards. The sensors and microcontroller are installed in the artificial forest. The sensor's function is to detect the forest area's gas, temperature, and humidity. The data detection is monitored by smartphone in real-time and recorded by an Internet of Things (IoT) network.

To support this research, we created C programming language platform software embedded in the microcontroller with the Arduino IDE compiler. The function of this program is to connect the microcontroller to all sensors planted in a miniature forest.

IoT function is connected to every component of the system in a network. This device is used to communicate with humans and provide sensors and data storage in cloud storage by Blynk software. The data in the cloud is processed to obtain the required information. The connection of the microcontroller to IoT system on Blynk Cloud is shown in Fig. 1.

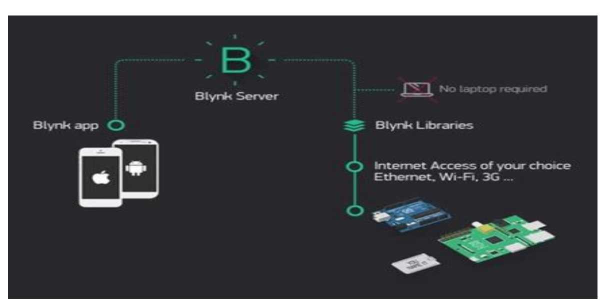

Fig. 1. The connection of microcontroller to IoT on Blynk Cloud.

A. Sensor and Data Processing Diagram

An overview of the sensors connection and other components to the microcontroller and smartphone are shown in the Fig.2. Briefly, this picture describes the sensor connection and data processing diagram, consisting of the flow between input, output, and the main components as used. The system work starts with the main power of PLN 220 Volt AC (Alternating Current) 50/60 Hz. This power is converted into two devices of DC (Direct Current) outputs, 12 Volt DC which is used to supply the power of the Arduino microcontroller and cooling fan. The other components such as sensors, SIM900 shield module, and LCD monitor use 5 Volt DC to supply the power from the Arduino. The buzzer warning component uses 12 Volt DC power, and the pump uses 220 Volt AC power.

The data in the forest area detected by the sensor is forwarded to the microcontroller and sent to the smartphone in real-time, if there is a temperature received above the standard value, then the fun and the water pump are turned ON automatically to neutralize the forest area temperature. We can also turn the fan and water pump off directly through the smartphone.

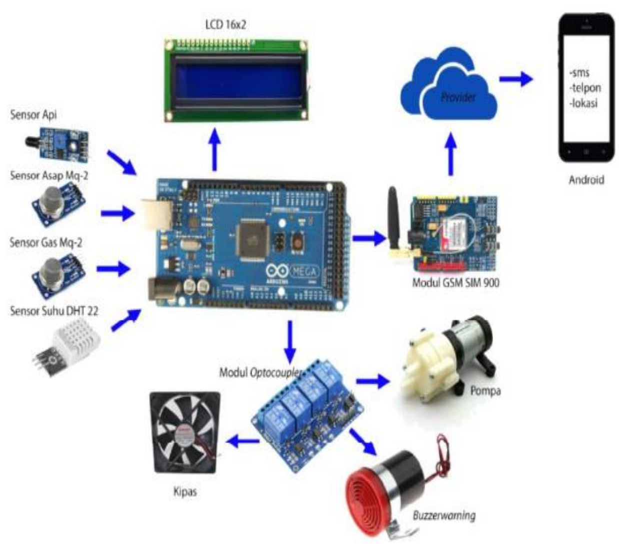

Fig. 2. Sensors and Data Processing Diagram

B. Power Suplly Unit (PSU)

The PSU divides the electrical voltage from PLN and converts it into several DC voltage sections according to what is required by the electrical components used in this study. The Arduino uses 12 VDC from the PSU, and the sensors get 5 VDC voltage. Besides that, we can also use the external power supply with AC/DC adapter or battery. PSU is made to replace batteries to make it easier, more economical, and last longer when used.

C. Sensors and Other Components

A sensor is a component that detects data from forest areas. The kind of data may be electrical signals, gas, fire, humidity, chemical, mechanical energy, etc. Sensors and other components used in this study are as follows:

1) LM393-Fire Sensor

The fire sensor detects fire and radiation; this sensor can also detect light sources with wavelengths of 760 mm to 1100 mm. The required voltage source is 3.3 Volts – 5 Volts. The results of the fire sensor detection are forwarded to the microcontroller and smartphone as shown in Fig.2.

1) MQ-2 Sensor

The MQ-2 sensor can detect gas content such as H2 liquefied petroleum gas (LPG), CH4, CO, alcohol, and propane. The working principle of the MQ-2 sensor is that when it detects gas, the sensor then converts it into an analogue voltage. The sensitivity of the MQ-2 sensor can be adjusted according to the gas you want to detect by turning the trim pot as needed. The MQ-2 sensor can detect other gases such as i-butane, methane, alcohol, and hydrogen. The results of the gas sensor detection are forwarded to the microcontroller and smartphone as shown in Fig. 2.

2) DHT-22 - Sensor

The DHT-22 sensor is a temperature and humidity sensor consisting of a capacitive humidity sensor and a transmitter. This sensor works even though there is no signal control circuit and ADC because this sensor uses a micro-chip controller with a digital signal output. The results of the detection of the DHT-22 sensor are forwarded to the microcontroller and smartphone, as shown in Fig. 2.

3) GSM SIM Shield 900

The GSM SIM 900 module is an intermediary microcontroller for sending SMS/telephone. The GSM SIM 900 module is a Quad-band GSM/GPRS module that uses a single-chip LPC 2148 processor. The GSM SIM 900 can transmit SMS and voice data. The GSM SIM 900 module is enabled with the "AT-Command" (AT=Attention). AT Command is a standard command usually used to communicate between a computer and a cell phone via a serial port. Through AT Command, the data on the cell phone can be known as signal strength, message reading, message delivery, and others. The connection between the Microcontroller with GSM SIM Shield 900 and Blynk Cloud is shown in Fig.2.

4) Optocoupler

An optocoupler is an electronic device that functions as a separator between the system's power and control circuits. Opto means optic or light, and coupler means to trigger. The optocoupler works using light as the on/off trigger. The optocoupler is a sensor consisting of two parts, the transmitter and receiver. The connection between the Microcontroller with the Optocoupler module and other components is shown in Fig.2.

Transmitters are generally made of infrared LEDs because they have much better signal resistance than ordinary LEDs, and the naked eye cannot see the light rays emitted by the LEDs.

The receiver generally uses a photodiode which is very sensitive to light. Moreover, the light received from the LED is getting better. In this control system, the optocoupler module controls the water pump, buzzer warning, and lights installed in the forest area. The working principle depends on the intensity of light the photodiode receives on the optocoupler.

2) Arduino ATMEGA 2560 Microcontroller

This study uses the Arduino Mega 2560 Microcontroller equipped with input or output pins. Digital 14 pins are used as PWM (Pulse Width Modulation) outputs, 16 pins are used as analogue pins, and four pins are used for UART. The microcontroller uses a 16 MHz crystal isolator, a USB connection, an ICSP (In-Circuit Serial Prog.) header power jack, and a reset button. This microcontroller module also has a USB port for programming the microcontroller, a power source via an adapter supply, and a battery. All of these modules are used to support the Arduino microcontroller, with the programming language used being the C programming language platform. The connection between Arduino ATMEGA 2560 Microcontroller and other components is shown in Fig.2.

D. *The Forest Miniature*

Fig. 3 illustrates the monitored and controlled forest prototype for simulation testing of our project.

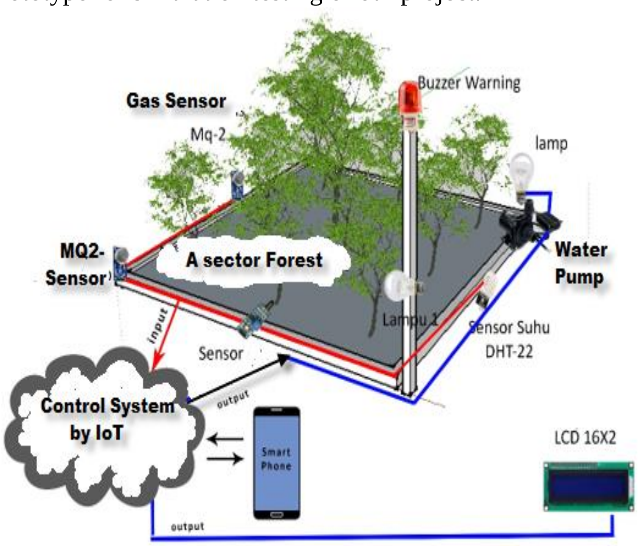

Fig. 3. The Forest Monitoring System

E. *Buzzer Warning*

The buzzer is an electronic component that converts electrical vibrations into sound vibrations. The buzzer works is almost the same as a loudspeaker, where the buzzer is made of a coil mounted on a diaphragm. If the diaphragm coil is energized, it will form electromagnetic waves. The electromagnetic waves will change the diaphragm coil pulled out in the direction of the current around it. Furthermore, the coil mounted on the diaphragm will move the diaphragm back and forth, causing the air to vibrate and produce sound. The buzzer warning function in this study is used as an indicator to show an early warning of the danger of forest fires.

IV. Experimental Result

We have tested this system in a miniature the artificial forest in the campus area of the Universitas Sumatera Utara (USU), Medan, and the results are described below.

A. *The Smart System Monitoring*

We have tested the supporting components, including the Optocoupler Module, SIM900 module, Buzzer Warning, LCD, and Pump. The initial test is to send an SMS command to the system. Then the system will respond and display the status of the command on the LCD. SMS commands can control ON/OFF all channels on the Optocoupler Module, such as Buzzer Warning, lights 1, 2, and Pump lines. The SMS command for testing all components is running well as shown in Table I.

TABLE I
The Smart System Monitoring

SMS Command	Function	Component				System Perfor mance
		Pump	Buzzer warning	Lamp	LCD	
Pump ON and OFF	To start the pump	Active			Active	Good
Buzzer ON and OFF	To turn on the buzzer warning		Active		Active	Good
Lamp 1 ,2 ON	To turn on the light			Active	Active	Good

B. *System Sensor Testing*

The sensor function testing aims to test the quality and standard capabilities of the sensor. The sensors tested are the MQ-2 gas sensor, the MQ-2 gas sensor, and the DHT-22 temperature sensor.

1) MQ-2 gas sensor testing

Testing the MQ-2 sensor is to find out whether it can detect a gas within the threshold limit, send the gas conditions via SMS, and display it on the LCD. The function of the MQ-2 gas sensor is to detect gas from burning dry leaves. The results show that the sensor can detect gas well.

Testing the MQ-2 sensor is to find out whether it can detect a gas within the threshold limit, send the gas conditions via SMS, and display it on the LCD. We have tested the function of the MQ-2 gas sensor to detect the gas from burning dry leaves of the forest prototype. The results show that the sensor can detect gas well, as shown in table II.

TABLE II
MQ-2 Gas Sensor Monitoring

No	Range of MQ-2 gas	Gas Detected	Category	Action
1.	30-100 %	30 %	safe	monitor
2.	30-100 %	32 %	safe	monitor
3.	30-100 %	35 %	warning	turn on the fan
4.	30-100 %	35 %	warning	turn on the fan
5.	30-100 %	40 %	dangerous	turn on the buzzer

Table 2 shows that the MQ-2 gas sensor works well, as expected. In this simulation, we tested the MQ-2 gas sensor by spraying liquefied petroleum gas (LPG) in the artificial forest area. When the gas increases up to 35%, the system warns and sends a message via Smartphone: "Gas detected in the forest of A-SECTOR area with Level 35%". The system also sends the incident location link via Google Maps.

The gas sensor response is tested by simulating the burning of the forest miniature as shown in Fig..11. Simulations for other sensors have also been carried out on a forest miniature, which will be described in the next discussion.

Fig. 4. shows a miniature forest made for the simulation of testing the components assembled in this study. We have carried out simulations for forest fire prevention by trying to get the smoke and gas closer to a miniature forest location, and it turns out that the system responds quickly. The system responds immediately by sounding a buzzer warning and turning on lights 1 & 2 as an early warning.

Fig. 4. The fire simulation in a miniature forest at the USU campus area

2). DHT22 - sensor

The DHT22 sensor testing detects the temperature by using the burning of dry leaves and tree branches as a trigger for the hot temperature. The experimental results are shown in Table III.

TABLE III
DHT22 – SENSOR MONITORING

No	Range of DHT 22 Temperature	Temperature Detected	Category	Action
1.	35-100 ^{0}C	35 ^{0}C	safe	monitor
2.	35-100 ^{0}C	36 ^{0}C	safe	monitor
3.	35-100 ^{0}C	40 ^{0}C	warning	turn on the water pump
4.	35-100 ^{0}C	40 ^{0}C	warning	turn on the water pump
5.	35-100 ^{0}C	45 ^{0}C	dangerous	turn on the buzzer

Table III shows the test results of the DHT-22 sensor working well, as expected. The system sends the data, and the message to the Smartphone "Temperature >40 0C is detected, Heat temperature over is detected in A-SECTOR forest area". The system will send the message to the fire centre department and automatically send The Google Map location by Smartphone.

3). Fire sensor testing (flame detector)

The fire sensor test determines the sensor's ability to detect fire. Tests were carried out on several hotspots at a certain distance from the sensor, and the result is shown in Table IV.

TABLE IV
FIRE SENSOR TESTING

No	Fire Distance (cm)	Status	Sensor Response
1	20	Detected	Respond Well
2	40	Detected	Respond Well
3	60	Detected	Respond Well
4	80	Detected	Respond Well
5	100	Detected	Respond Well

All sensors placed in a miniature forest area can work well. The system can be controlled remotely by using the SIM900 module in the form of SMS to control the optocoupler, buzzer warning, pump, and lamp modules. To turn on/off the pump can be done from a smartphone with the "PUMP ON" command to deactivate it and the "PUMP OFF" command to turn it off. Likewise, turning on/off the buzzer warning can be done remotely using a smartphone with the "BUZZER ON" and "BUZZER OFF" commands.

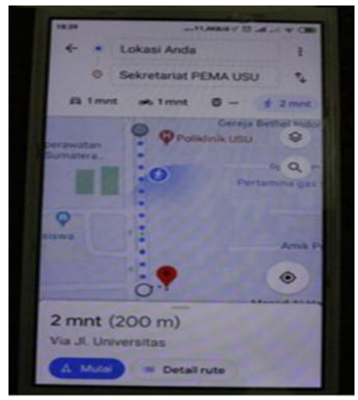

Fig. 5. The location of the incident is monitored from a smartphone

Fig. 5 shows the incident location link on google Maps resulting from the simulation burning of leaves and thick smoke. The system will automatically send the location to the disaster management center and the forestry police station. Fig. 5 is an example of a google map location sent to the disaster management centre and the forestry police.

The contribution of this paper is to make the early warning and can help fire disaster control officers to prevent the incident forest fires early. With the results of the monitoring system, we contribute to making a disaster hazard classification of forest fires. We have divided some forest sectors, and we classify them into three levels, namely safe, medium, and dangerous or prone to fire disasters.

V. CONCLUSION

Based on the experiments, the prototype of an IoT-based forest fire detection system has been successful, and all sensors are running well. The first experiment was carried out to detect temperature using the LM393 fire sensor. The test is done by trying to burn the artificial forest. The system can provide information and early warning. When it reaches 40 0C, the water pump automatically turns on to spray water into the forest area. It sends a message to the smartphone: "temperature >40 0C detected, more heat detected in A-SECTOR" forest area. The system also sends a link to the incident location via Google Maps.

We tested the MQ-2 gas sensor in the second simulation by spraying liquefied petroleum gas (LPG) in an artificial forest area. When the gas level increases to 35%, the system warns and sends a message via Smartphone: "Gas detected in A-SECTOR forest area with Level 35%". The system also sends a link to the incident location via Google Maps. The system can also remotely control the optocoupler module, buzzer warning, water pump, and warning light using SMS on the SIM900 module.

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