Solar Panel Powered Forest Fire Early Warning System

Tole Sutikno[1], Tosan Aji Bayusuta[2], Hendril Satrian Purnama[3]

[1,2]Department of Electrical Engineering, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[1,3]Embedded Systems and Power Electronics Research Group, Yogyakarta, Indonesia

- Abstract

Forest and land fires in Indonesia become the government's main concern when entering the dry season. To overcome the related problems, the development of early detection technology based on Wireless Sensor Network (WSN) and Internet of Things (IoT) is one of the effective solutions. This research combines Arduino UNO and ESP8266 NodeMCU with sensor nodes consisting of smoke sensors, fire sensors, temperature, and humidity to detect potential forest fires. These nodes are placed at fire-prone points in the forest. The gateway node uses the XBee-PRO S2C RF module, ESP8266 NodeMCU, DS3231 RTC, and 20x4 LCD. The received data will be processed by ESP8266 NodeMCU and sent to Thinger.io database for real-time report display on computer and 20x4 LCD. The test results of the developed system show that the system can display and transmit data in real-time to the Thinger.io platform via an internet connection. In addition, the information is also displayed on the physical screen of the 20x4 I2C LCD on the base station. The forest fire early warning system functions well and the test results show good detection capability.

Keywords: forest fire, mitigation system, IoT, WSN, Zigbee

- Introduction

Forest and peatland fires in Indonesia are mostly caused by human and natural factors. One example of human factors is land clearing activities for industry and agriculture, as well as illegal or negligent burning and logging of forests. On the other hand, natural factors include hot weather during the long dry season, causing drought and increased temperatures. These high temperature conditions can trigger fires.

Based on data reported by the Ministry of Environment and Forestry (MoEF) in 2019, there is information that the area of forest fires in September reached 857,756 hectares. Of this area, 630,451 hectares were on mineral land, while 227,304 hectares were on peatland. This is a 160% increase compared to the previous August, which covered an area of around 328,724 hectares. This data was obtained through Landsat satellite imagery. The total burnt area consists of 66,000 hectares in industrial plantation forests (HTI), 18,465 hectares in natural forests, 7,545 hectares in ecosystem restoration (RE) efforts, and 7,312 hectares in forest release areas. The areas with the most burned areas are those that have been issued by the Ministry of ATR/BPN and have certificates, with an area of 110,476 hectares (Nugroho, 2019).

Forest fires are a common occurrence around the world, and this is a major problem, as the occurrence of forest fires will cause many problems such as increased carbon dioxide (CO2) and carbon monoxide (CO) emissions released into the air due to forest fires. In addition, forest fires cause even greater damage to nature as many habitats in the forest are affected, including indirect impacts such as floods and landslides due to the destruction of trees in the forest.

Forest fires have become a crucial issue lately, hence the need for technological innovation to prevent forest fires from occurring more frequently. Forest fire monitoring systems generally involve satellite imagery, although this is not real-time and requires manual analysis by authorities. This approach has several drawbacks, especially its inability to detect forest fires quickly and assess fire risk in vulnerable areas [7], [8]. Satellite-based monitoring is further compromised by adverse weather conditions, making it relatively inaccurate and unreliable due to its dependence on weather patterns. In addition, high spatial resolution satellite imagery is costly. In addition, cloudy conditions significantly hinder the accurate capture of forest images

. In the modern era, technology has made significant advances, enabling the development of highly effective fire monitoring systems [9], [10]. Various research approaches have been employed to create these systems, including image processing [11]-[13], airborne technologies [14]-[16], and fuzzy logic-based approaches [17], [18]. On the other hand, many researchers have endeavored to develop early warning technologies to prevent IoT-based forest fires. IoT-based monitoring technology has become a widely researched topic recently, due to its easy access and rapid development in recent years. With IoT technology, real-time and remote monitoring and early warning systems can be realized. In addition, problems that become obstacles and limitations in satellite-based monitoring can also be resolved. This is certainly an important point in efforts to prevent forest fires.

In this paper, a device that can detect early forest fires is developed by utilizing sensor technology integrated with IoT. By utilizing IoT technology, it is expected to minimize the limitations of existing detection systems. But on the other hand, the use of IoT-based devices also has special challenges, especially related to the limited availability of electricity resources and internet access in forest areas. Finally, an in-depth analysis of the monitoring system's performance, encompassing parameters such as temperature, humidity, and CO2 concentration, is a crucial component of this project. The rest of this work is organized as follows: Section 2 discusses the process of developing a real-time forest fire detection, monitoring and alert system. Meanwhile, section 3 presents the results collected from the experiments. All collected results are displayed and analyzed. Lastly, section 4 concludes the present work.

- Research System Design

The design of the forest fire early detection system begins with creating a block diagram to determine the system architecture and the components needed to design the system. Fig. 1 show the block diagram of entire system designed in this work. Arduino UNO R3 and NodeMCU ESP8266 used as main controller of both Node Gateway and Node Sensor respectively. RF-Xbee used as a transmitter from node sensor to node gateway, this mechanism act as wireless sensor network (WSN). This project used several sensors to detect a fire, which are; a) flame sensor, b) DHT-22, and c) MQ-7 sensor. The output of the system is LCD display on base station, and Website dashboard that can be accessed anywhere through IoT interface.

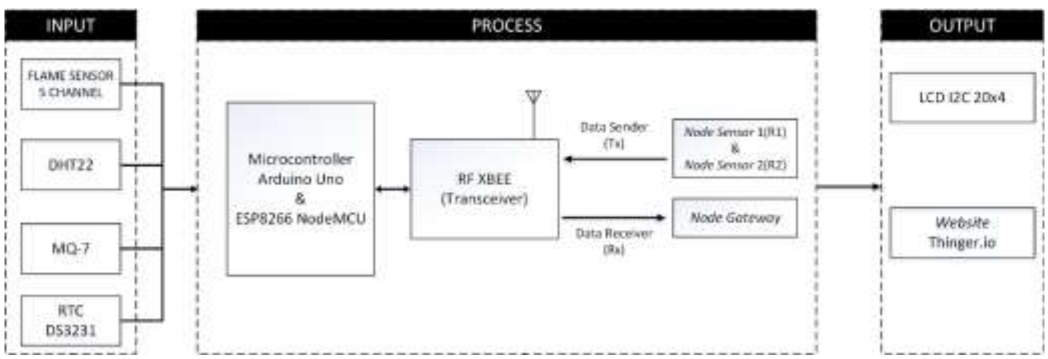


Figure 1. System Block Diagram

Figure 2 shows the details of the components and their connectivity in the designed system. The sensor node device consists of several sensors including: 5 channel fire sensor, MQ-7 sensor, & DHT-22 sensor which are used as sensing devices from the environment to be monitored, the three sensors will be input data parameters such as gas levels, temperature condition data, and fire detection. Then the XBee RF module is used as a data sender, Arduino Uno is used as the core brain of the system that regulates the work of all hardware, and battery batteries as a support for system power supply. As for the whole device, it will be placed at points in areas prone to forest fires so that it also functions to collect data information in the area.

The Gateway Node, which can also be referred to as a sink node, is a device responsible for connecting a wireless sensor network to a wider network, such as the internet or a local network. The gateway node acts as a gateway or interface between distributed sensors and a larger communication infrastructure.

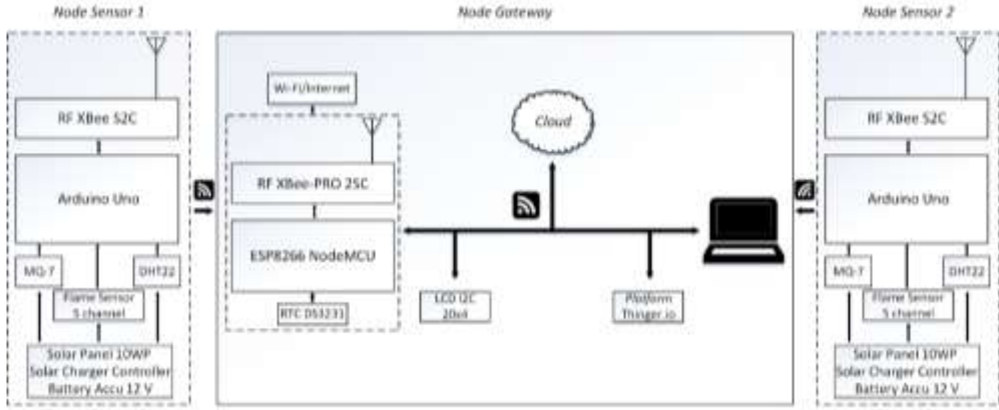


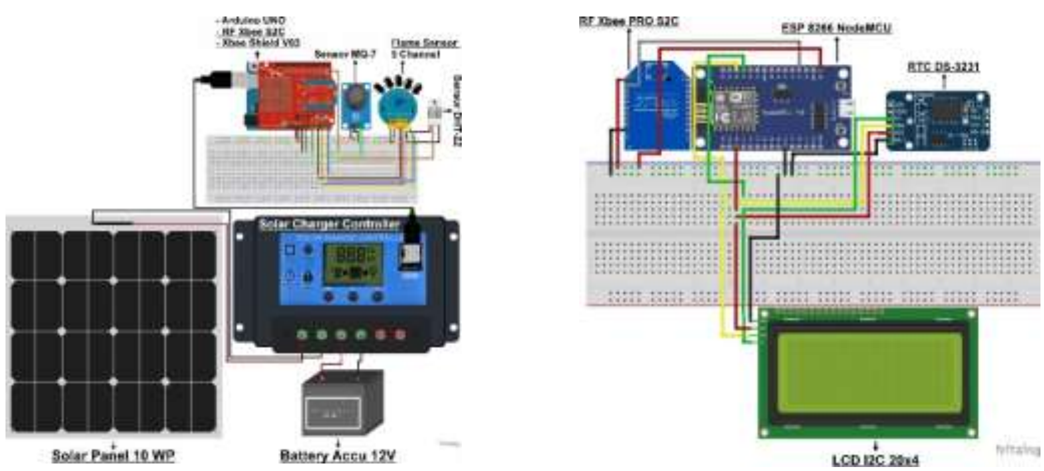
Figure 2. System design

- **Experimental Setup**

In this research, there are 2 main parts that support each other to create an effective monitoring system. The first part is a sensor node that can consist of 2 or more nodes, which will be placed at points prone to forest fires. While the second part is a gateway node consisting of 1 system that will receive all data from sensor nodes, the gateway node is used as a data collection device or can be referred to as a base station which will then process and send all data that has been collected to the internet network via NodeMCU ESP8266.

a. Hardware Design

Figure 3.a. shows the wiring diagram for the proposed system's main board. The key components of the device are the NodeMCU ESP8266, various sensors, the ADC module, the RTC, and the SD card module. Table 1. shows the complete data and usability of each device.



(a) (b)

Figure 3. Schematic circuit on: a) Sensor Nodes (router 1 and router 2), b) Gateway Nodes

Table 1. Component List

Node Sensor		Node Gateway	
Component Name	Usability	Component Name	Usability
Solar PV System	System power supply	NodeMCU ESP8266	Main processor
Arduino UNO	Main processor	Xbee Pro S2C	Wireless data Receiver
RF Xbee S2C + Shield	Wireless data transmitter	RTC Ds3231	Time generator

MQ-7 Sensor	Smoke sensor	LCD I2C 20x4	Node Physical display
5 Channel flame sensor	Flame sensor		
DHT 22 sensor	Temperature & Humidity Sensor		

b. Software Design

1). Monitoring Software Platform

The monitoring software platform used in this work is "Thinger.io". Thinger.io is a cloud IoT Platform that provides every needed tool to prototype, scale and manage connected products in a very simple way. The used of thinger.io is because the simplicity and open source, so engineer can easily create and manage monitoring plan as they needed. Fig. 4 shown the dashboard monitoring of this project on thinger.io

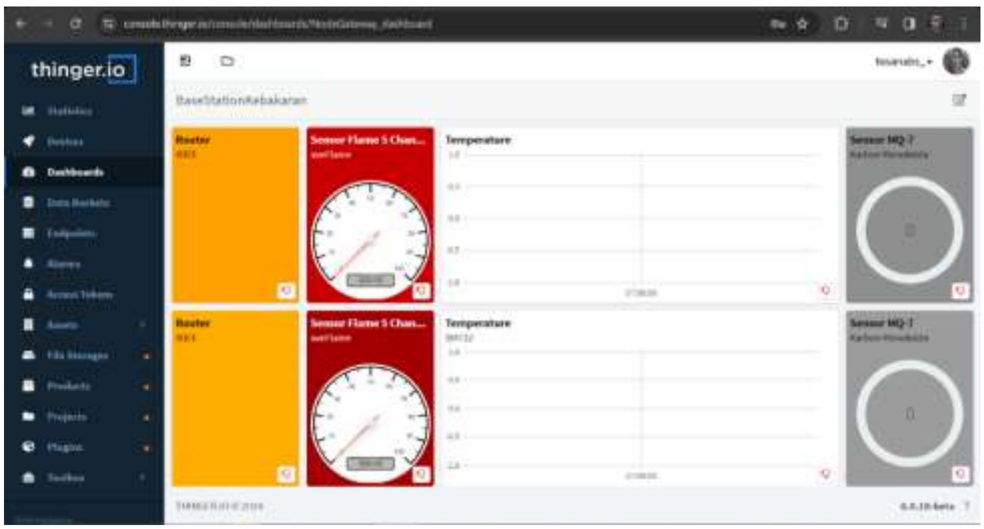


Figure 4. Dashboard view of thinger.io website

2). Monitoring and Alerting Algorithm

Fig. 5 shows the flowchart of the monitoring and alerting algorithm used in this project. The proposed system starts by initializing node sensor (R1 & R2), then sensor data from each node is read and collect by the Arduino UNO. After that, collected data from sensor will send from node sensor through Xbee transmitter to the node gateway using Zegbee protocol. In the node gateway, collected data will be processed and conclude the status of the fire, then the data and status will send to the internet through NodeMCU ESP8266. Monitoring flatform that used in this project is Thinger.io, because its open source and easy to access.

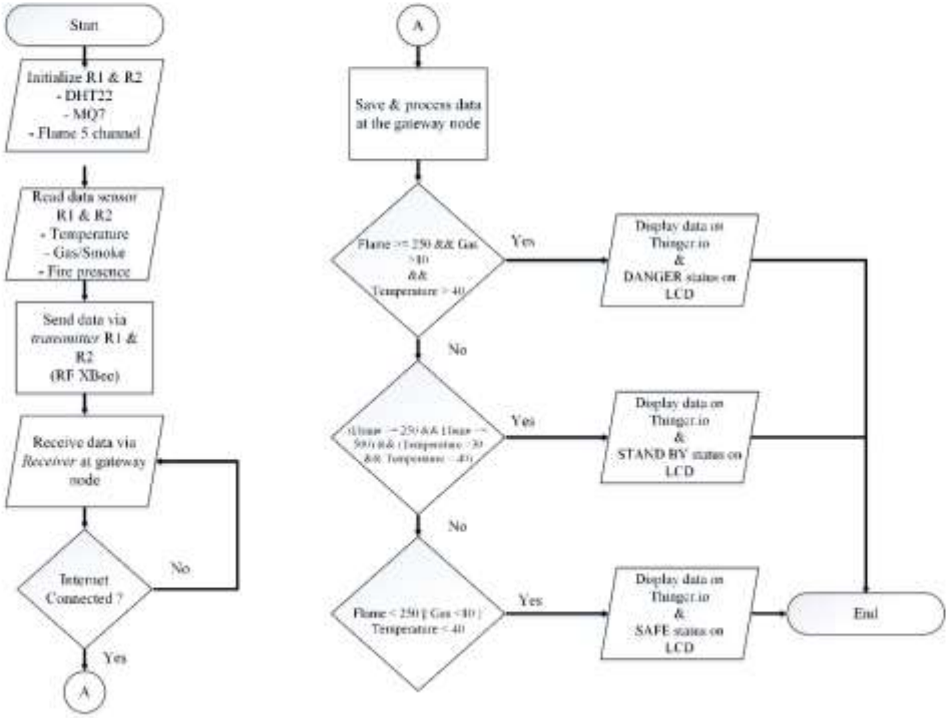
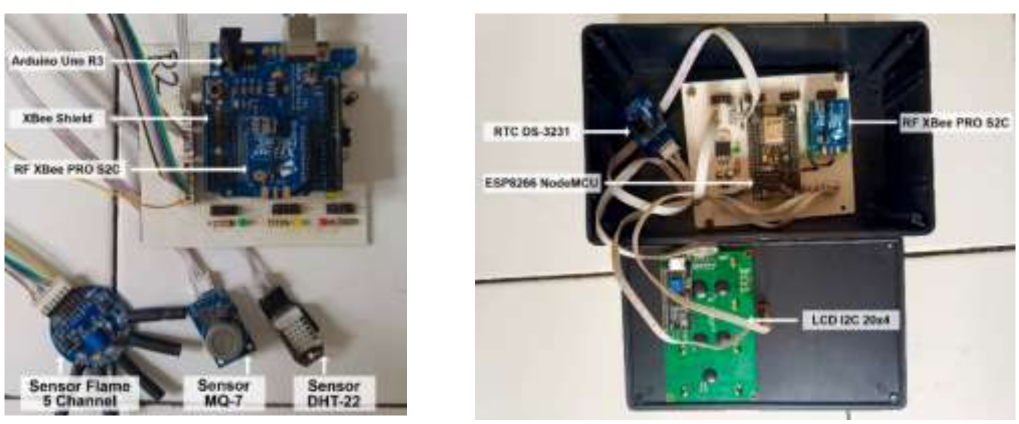


Figure 5. Flowchart of the entire system

- **Result and Discussion**

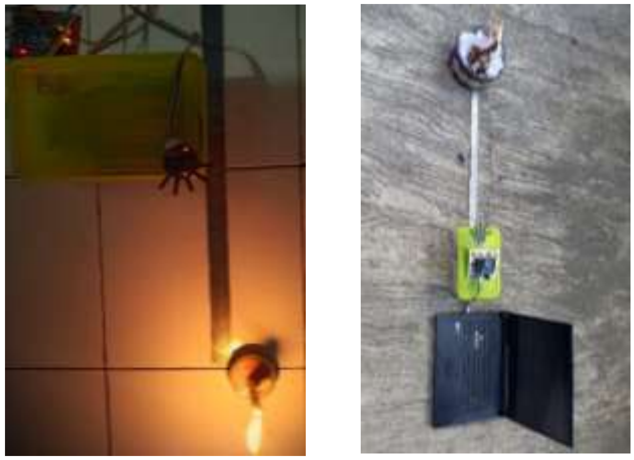
Fig. 6 shows the photograph of the hardware system developed in this research. Fig 6.a is the system hardware for node sensor which is include of Arduino UNO R3, RF XBee Pro S2C and shield, 5 channel flame sensors, MQ7 sensor, and DHT22 sensor. Fig 6.b is the system hardware for node gateway which is include of NodeMCU ESP8266, RTC DS-3231, RF XBee Pro S2C and LDC I2C 20X4. The hardware was developed to test the system performance and accuracy.

Fig. 7 shows the experimental setup for testing the accuracy of flame sensor in the day and night. The night scene was simulated by conducting the test indoor, so the sun light was not exposed during the test.



(a) (b)

Fig 6. Photograph of: a) board system Node sensor 1 and Node sensor 2, b) board system Node Gateway



(a) (b)

Fig 7. 5-channel fire sensor data capture display when: (a) indoor condition, (b) outdoor condition

Table 2. Testing results of XBee sending data when LOS conditions

Jarak (m)	Pengiriman & Penerimaan Data XBee							
	Node 1 (R1)	Waktu kirim	Waktu terima (Gateway)	Delay (s)	Node 2 (R2)	Waktu kirim	Waktu terima (Gateway)	Delay (s)
10	Mengirim	13:10:05	13:10:08	3	Mengirim	13:30:00	13:30:03	3
20	Mengirim	13:10:09	13:10:12	3	Mengirim	13:30:04	13:30:07	3
30	Mengirim	13:10:13	13:10:16	3	Mengirim	13:30:08	13:30:11	3
40	Mengirim	13:10:17	13:10:20	3	Mengirim	13:30:12	13:30:15	3
50	Mengirim	13:10:21	13:10:24	3	Mengirim	13:30:16	13:30:19	3
60	Mengirim	13:10:25	13:10:28	3	Mengirim	13:30:20	13:30:23	3
70	Mengirim	13:10:29	13:10:32	3	Mengirim	13:30:24	13:30:27	3
80	Mengirim	13:10:33	13:10:36	3	Mengirim	13:30:28	13:30:31	3
90	Mengirim	13:10:37	13:10:40	3	Mengirim	13:30:32	13:30:35	3
100	Mengirim	13:10:41	13:10:44	3	Mengirim	13:30:36	13:30:39	3
110	Mengirim	13:10:45	13:10:48	3	Mengirim	13:30:40	13:30:43	3
120	Mengirim	13:10:49	13:10:52	3	Mengirim	13:30:44	13:30:47	3
130	Mengirim	13:10:53	13:10:56	3	Mengirim	13:30:48	13:30:51	3
140	Mengirim ada delay	13:11:03	13:11:08	5	Mengirim ada delay	13:31:58	13:31:03	5
150	Tidak Terkirim	-	Terputus	-	Tidak Terkirim	-	Terputus	-

Table 3. Overall system test results

Nilai Pengukuran Node Sensor 1			Tampilan Kondisi LCD	Nilai Pengukuran Node Sensor 2			Tampilan Kondisi LCD
Sensor Flame 5 Channel	Sensor DHT-22	Sensor MQ-7	Router 1	Sensor Flame 5 Channel	Sensor DHT-22	Sensor MQ-7	Router 2
365.00	42.60	32.73	BAHAYA	243.00	28.80	9.20	AMAN
310.00	42.50	25.25	BAHAYA	230.00	28.80	8.00	AMAN
357.00	42.50	27.48	BAHAYA	219.00	28.70	7.10	AMAN
365.00	42.40	18.39	BAHAYA	231.00	28.60	8.06	AMAN
452.00	42.30	16.10	BAHAYA	225.00	28.60	7.70	AMAN
458.00	35.70	9.29	SIAGA	193.00	28.60	7.32	AMAN
371.00	35.40	8.80	SIAGA	179.00	28.50	7.20	AMAN
469.00	35.20	8.44	SIAGA	187.00	28.40	7.11	AMAN
347.00	35.10	8.00	SIAGA	235.00	28.30	8.25	AMAN
295.00	34.90	7.83	SIAGA	216.00	28.20	8.39	AMAN
243.00	29.90	9.54	AMAN	187.00	28.20	7.91	AMAN
258.00	29.70	8.47	AMAN	261.00	28.00	7.45	AMAN
231.00	29.60	8.03	AMAN	194.00	27.90	7.39	AMAN
220.00	29.40	8.35	AMAN	175.00	27.90	8.12	AMAN

209.00	29.10	7.90	AMAN	157.00	27.80	8.16	AMAN
197.00	29.00	8.15	AMAN	440.00	38.20	49.34	BAHAYA
201.00	29.80	8.89	AMAN	377.00	38.00	40.75	BAHAYA
180.00	29.70	7.65	AMAN	415.00	38.10	37.25	BAHAYA
174.00	29.60	7.23	AMAN	339.00	37.90	27.72	BAHAYA
208.00	29.60	9.10	AMAN	260.00	37.90	19.14	BAHAYA
195.00	29.00	8.22	AMAN	289.00	34.30	9.23	SIAGA
187.00	28.90	7.80	AMAN	265.00	34.20	8.81	SIAGA
169.00	28.90	7.68	AMAN	270.00	34.20	8.43	SIAGA
153.00	28.80	8.10	AMAN	263.00	33.00	8.03	SIAGA
128.00	28.80	8.00	AMAN	278.00	32.90	8.67	SIAGA
111.00	28.70	7.94	AMAN	197.00	30.00	8.57	AMAN
91.00	28.70	8.03	AMAN	212.00	29.90	8.23	AMAN
80.00	28.80	8.06	AMAN	181.00	29.90	7.70	AMAN
99.00	28.90	8.12	AMAN	163.00	29.80	8.51	AMAN
76.00	29.10	8.16	AMAN	152.00	29.80	8.00	AMAN

- **Conclusion**

1. Forest and land fires are large-scale fires that can occur naturally or as a result of human activity. They can have negative impacts on society, the environment, and the economy, including air pollution, health issues, and economic losses. In Indonesia, efforts to prevent fires are not yet optimal, and information about fires is often received only after they have grown. This emphasizes the importance of preserving forests as crucial ecosystems. Therefore, it is essential to optimize and improve prevention and control measures.
2. This monitoring system is designed using the Wireless Sensor Network (WSN) and Internet of Things (IoT) methods and using solar panels, so as to increase real-time data transmission and independently have its own energy backup in the system in detecting fires.
3. Based on experiments and tests separately and the entire system that has been carried out, each of the sensors used can work in detecting and sending data properly without any errors in each parameter, and can display the results of the condition parameters on the 20x4 I2C LCD physical display and sending data output on the thinger.io web monitoring dashboard located at the user base station.

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