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Design and Built a Prototype Kit for Fire Detection in a Peat Swamp Forest: A Preliminary Results

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Abstract: Peat forest fire detectors need to be developed immediately due to the frequency of peat forest fires in Malaysia during the summer is very high. This can affect the life in the forest and the health of the surrounding population. Among them is the Ayer Hitam Muar Forest Reserve, Johor which is almost 50,000 acres in size and experiences fires every year. However, fire monitoring management methods still need to be improved in terms of speed, accuracy and systematic channeling fire alerts. Apart from location and area factors, the main challenge of the early fire detection process is the lack of manpower to monitor and notify fires. The conventional method through patrols and phone calls from farmers who see a fire is less effective because of the delay in the notification received by the authorities. Initially, the work of identifying the location of the fire and measuring the signal strength of the telco service in the Forest Reserve was done with the help of rangers from the Muar district forestry department. This article proposes a prototype for detecting peat forest fires capable of monitoring and sending early fire notifications using a smartphone. The prototype uses an ESP32 microcontroller, GSM/GPRS modem and industry-standard sensors incluing smoke, temperature, humidity and motion detectors. A total of five prototype units were developed as sensor nodes (SN) 1 to 5 with unique IDs that can send information to UTHM web servers simultaneously. Data from each SN is displayed in real-time while notifications of smoke detection and motion alerts are sent to the authorities via the Telegram application. Solar panels are used as a source of electricity supply while the authorities can access information via smartphones. This prototype was tested to see its stability and operational accuracy while the data obtained were recorded. The developed system can help the authorities detect fires at an early stage and the location of the fire can be known based on the SN information received on the smartphone screen.

Keywords: Prototype kit, fire detection, peat swamp forest

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1. Introduction

The year 2021 marks an exciting development in terms of the advancement of industry 4.0 and the internet of things (IoT) resulting in smart automation systems that attract society's attention. This technology allows humans to monitor and control things over the internet network. In other words, humans and things can communicate by sending and receiving information despite being far apart from each other. Today, IoT technology is widely used in forestry to improve the efficiency of forest management, especially for the early detection of fires. In [1], reviews on the types of forest fire detection systems such as satellite systems, optical cameras, human observation and node sensor networks are made in detail with the final findings that the use of sensor node network is the best solution. In [2] an IoT-based forest monitoring and fire occurrence notification system was developed. Sensors used include temperature, gas, humidity, sound sensors (microphones) while fire, pollution and forest trespassing notification systems are also developed. The developed prototype allows the authorities to monitor the forest at a distance more systematically. It uses a Rasberry Pi microcontroller and a configured wifi module to connect sensors and smartphones. In [3], a temperature, pressure and rainfall monitoring system to detect early forest fires was developed. The system is based on a PC web server that uses a network of node sensors. It uses an AMTmega 164A microcontroller and a Zigbee module to control and link data from Labview software sensors and GUI displays. In [4], an IoT-based peat forest monitoring system was developed to monitor peatland temperature, humidity and water level. It involves three main components namely sensor node, gateway and user. LoRa module and GSM modem were used in the developed system. In [5], the researcher used the findings of the water level value in the peatland as an early indicator of the occurrence of fire along with the proposed early warning system of peat forest fires. Other projects such as in [6] share the information regarding peat forest in fire obstruction and prevention. Various suggestions were made by researchers around the country regarding the peat forest monitoring system. Among the proposed innovations of peat forest monitoring systems in Malaysia include the use of sensor node networks and satellite systems reported in [6] - [13]. Table 1 depicts the universities involved, methods and findings of the study.

Table 1 - Selected forest fire detection system technique

No	Author	Method	Research location	Microcontroller/ sensor/RF Comm.	Research Focus
1 [6]	A. Sali *et al.* (2021) (Univiersiti Putra Malaysia)	Sensor node network	Selangor	- microcontroller - temperature, moisture, piezometer - LoRa modul	- the study is based on the water level, temperature and the humidity of the peat with a good result are obtained - high cost and no security system
2 [7]	T. Listyorini *et al.* (2018) (Universiti Malaysia Perlis)	Sensor node network	No information	- WEMOS ESP8266 - fire sensors, temperature sensors, servo motors, buzzers and surveillance cameras - No information on RF comm.	- the study is based the fire sensors, temperature, servo motor etc with good results are obtained by using IoT and Fuzzy logic - no information of the real testing and security issue
3 [8]	E. Abdul Kadir *et al.* (2019) (Universiti Teknologi Malaysia)	Sensor node network	No information	- Arduino - temperature, humidity, CO_2, haze, smoke - no information on RF comm.	- the study is based on the temperature, humidity, CO_2, haze and smoke level with good results are obtained - no information of the real testing and security issue

4 [9]	Z Sa'adi *et al.* (2016) (Universiti Teknologi Malaysia)	Sensor node network	Sarawak	- rain gauge	- the study is based on the rain fall data for peat fire index (PFI)
5 [10]	A. N. Othman et al. (2019) (Universiti Teknologi Mara)	Satellite system	Selangor	- remote sensing and GIS technique	- the study is based on the land use, temperature, pH value and soil type to predict the peat fire potential area
6 [11]	M. D. H Suliman et al. (2014) (Universiti Kebangsaan Malaysia)	Satellite system	Selangor	- remote sensing and GIS technique	- geospatial technology and mathematical modeling used in this study for identifying, classifying and mapping the potential area for burning
7 [12]	M. H. Phua et al. (2007) (Universiti Malaysia Sabah)	Satellite system	Sabah	- remote sensing and GIS technique	- the study is based on the image differencing technique and object oriented classification approach to detect and analyze the burn area, respectively.
8 [13]	A. H. Mohd Hassan (2008) (Universiti Teknologi Malaysia)	Satellite system	No information	- remote sensing and GIS technique	- the study is based on the detecting of the fire hot spots, computing the fire risk index and generating spatial analysis for detected fire.
9	Proposed in this work (Universiti Tun Hussein Onn Malaysia)	Sensor nodes network	Johor	- ESP32 - smoke, temperature, humidity and motion	- develop a low cost prototype kit to detect the smoke, temperature and humidity

Innovations such as in [6] can help the authorities monitor peat forests condition using smartphones systematically. The system measured and monitored readings of soil temperature, moisture and water level in real-time using two sensor nodes. It also records and stores sensor data readings and authorities can easily access this information. Optimization of fire monitoring systems using artificial intelligent (AI) technology was also proposed in [7].

Early monitoring and detection of fires in peat forests is a complex task to perform as it involves large and remote areas. An attempt by the authorities to detect fires through regular forest patrols is less effective due to manpower limitations for very wide coverage area of the forest. This is further compounded if the authorities are outside the area and have certainly failed to detect if a fire occurs in the remote location. In this case, they need a kit that can detect fires remotely using a smartphone. Therefore, the prototype developed in this project is expected to help the authorities monitor temperature, humidity and receive fire notifications if smoke is detected. This kit will be installed in the areas at risk of fire. The developed system is easy to use with correct readings. The integration of sensor nodes and GSM/GPRS modems produce node-gateway sensors enabling remote communication to be made while fire notification can be sent to the authorities automatically and quickly. This prototype kit uses solar panels as a source of electricity supply while Internet of things (IoT) technology can help authorities to access information via smartphones or laptops.

All data from the node-gateway sensors will be sent, received and stored in a database in the web server while notifications regarding fires will be made using Telegram. Thus, this prototype will help the authorities detect fires at an early stage by detecting smoke and the location of the fire can be known based on the sensor node information received on the smartphone screen. These are illustrated in Fig. 1 and Fig. 2.

A stand-alone picture of a wireless sensor node using a GSM modem is illustrated in Fig. 2. The system is capable of collecting temperature, humidity, smoke and movement data using an ESP32 microcontroller. The 4G network is used to send this data to the UTHM web server as preliminary work. Five node-gateway sensors were developed that can collect data from the sensors and send it to the server in real-time. This configuration was chosen because it does not require a LoRa module, is independent, cheaper and its operation has no distance limitation.

Peat forest fire monitoring requires a system of high accuracy, high cost and high commitment from the authorities [14]. Today, the authorities know about the fire manually through the patrols and information from villagers or farmers who saw the fire and without prior monitoring. Therefore, peat forest fires occur for a large area due to delays in firefighters and authorities arriving to put out the fire. Nowadays, there are many peat forest fire monitoring systems proposed, but they involve considerable costs. In addition, most systems involve the construction of a towel lookout which requires substantial costs and is limited in its functionality. The project in this article involves developing sensor-getaway nodes and IoT applications that meet user's needs at a reasonable and practical cost. It can measure temperature, humidity, smoke and motion-based on IoT which can detect early fires in peat forests. The prototype kit was tested and the readings obtained were recorded and verified.

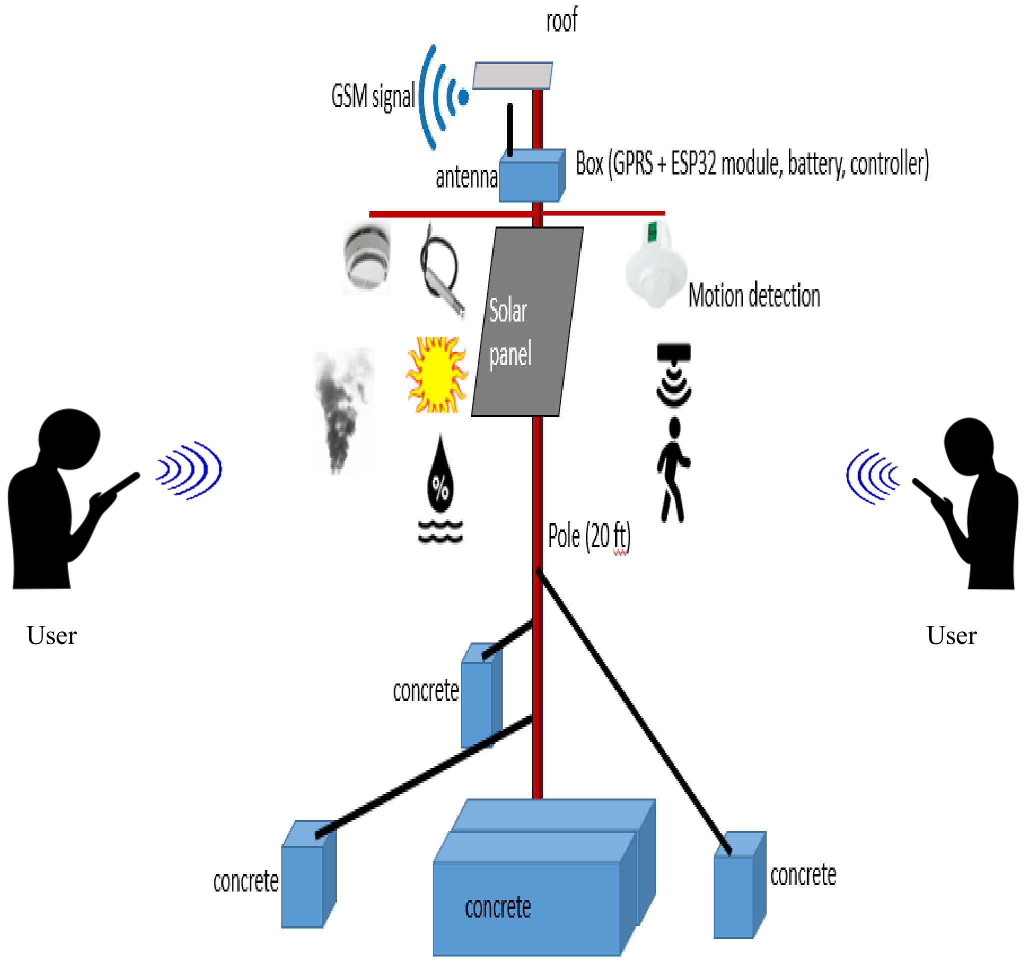


Fig. 1 - Sensor node-gateway installation

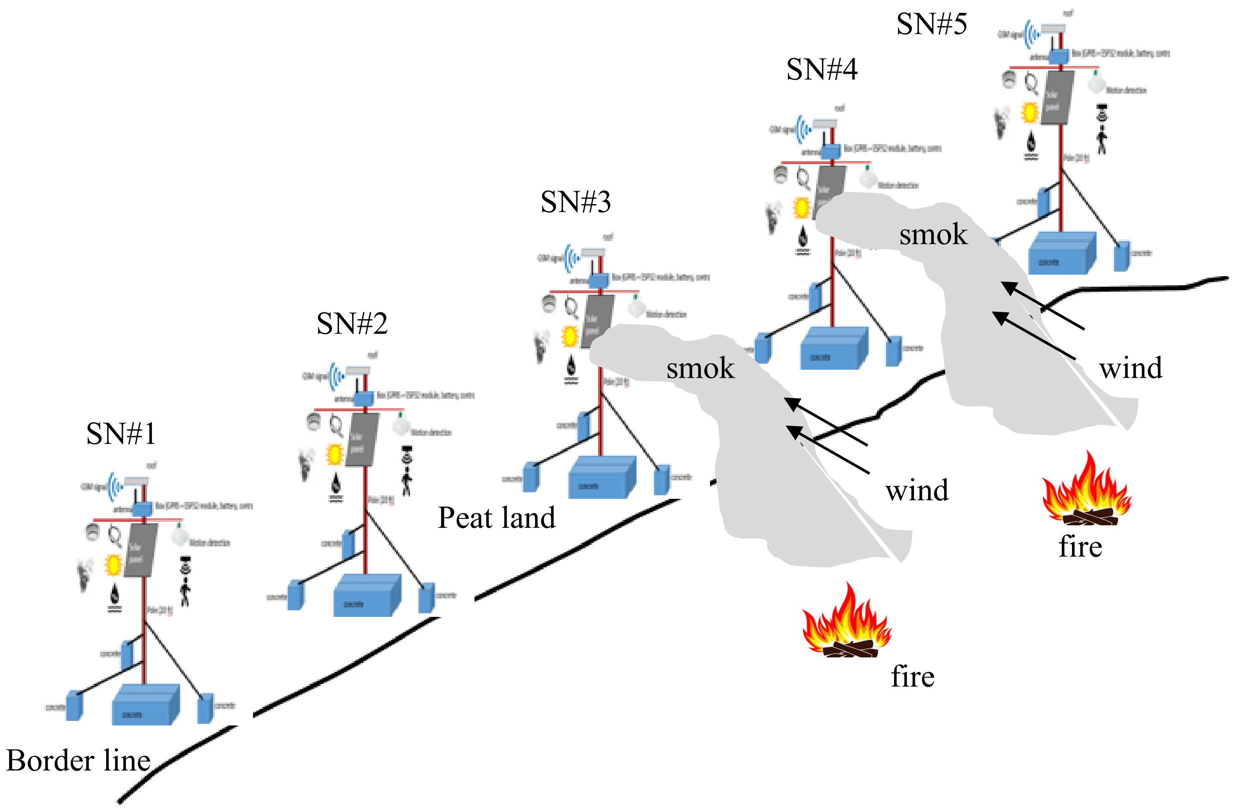


Fig. 2 - Illustration of the sensor node-gateway detects the smoke

1. Proposed system design

1.1 Hardware development

The IoT-based peat forest fire notification and monitoring system developed consists of a combination of hardware, software and IoT parts that can fulfil the purpose of this research study. The microcontroller used is the ESP32 module while the GSM/GPRS modem is the RF communication. The feature of SN is an independent node that can send data from the sensor and directly send it to the webserver. In the SN, the smoke sensor and motion detector are connected directly to the ESP32 microcontroller while the temperature and humidity sensors are connected to the unit Modbus as an intermediary with the microcontroller. Interestingly, the sensors used in this project are used in industry and outdoor applications. The data readings from these sensors are accurate and durable in rainy and hot weather. The output of the smoke detector is connected to pin 0 on the ESP32 microcontroller. The other three parts are the 12V power supply and earthing, respectively. The output of the temperature/humidity sensor is connected via a modbus where it uses pins A and B. Pins 12, 14, 32 and 33 on the ESP32 are connected to the Modbus. The motion sensor output is connected to pin 34 on the ESP32 board. The 3V3 and 5V pins on the ESP32 are the alternating current (AC) power supply to the Modbus, temperature/humidity, and motion sensors. This project uses the UTHM cloud server located at iot.uthm.edu.my to store all data in the database and users can log in using any device such as smartphones and laptops. When the smoke sensor detects smoke, the system will activate by sending the smoke effect status equal to 1 and the server will send a notification to the user via Telegram. Users registered on the Telegram account will receive the notification. It includes SN alerts that have detected smoke. In addition, they can look at the monitoring data such as the pattern of changes in temperature and humidity to confirm the occurrence of an increase in heat due to fire in the vicinity. Fig. 3 and 4 are fire detection system suggestion and wiring diagram, respectively.

1.2 Software development

In this project, the software development is divided into two parts: programming Onboard ESP32 and configuring the webserver system. Two types of software are used in this work, Node-RED and Grafana software. Node-RED software is used to store data in the database and send notifications of smoke and movement effects. Grafana software is used to monitor all data from sensors on the GUI display. Inside the ESP32 board, a program code is developed to read temperature, humidity, smoke and motion. The Modbus unit is used as the interface unit between the sensor and the microcontroller. Thus, the program code involving the operation of sensors, Modbus and microcontrollers was developed. Later, a program to connect ESP32 with a GSM modem to allow data to be sent to a web server (UTHM server) is also developed. The microcontroller will send data to the cloud server via GSM modem using the MQTT protocol. Here, the data from all sensors are stored in the database. The web server also can trigger the presence of smoke and motion by sending a notification via Telegram if smoke and motion are detected. Initially, users need to build a cloud account on the URL link http://iot.uthm.edu.my/monitoring/login. The user can login to monitor the data from the sensors which is sent by the microcontroller and stored in the database in real-time.

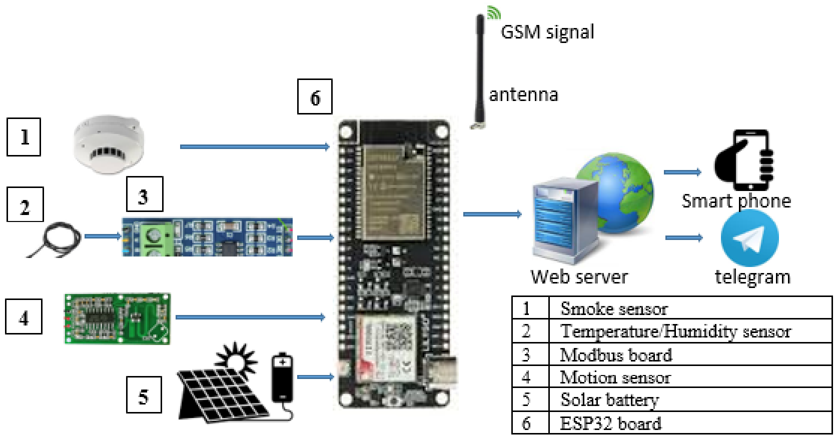


Fig. 3 - Proposed prototype kit for fire detection system

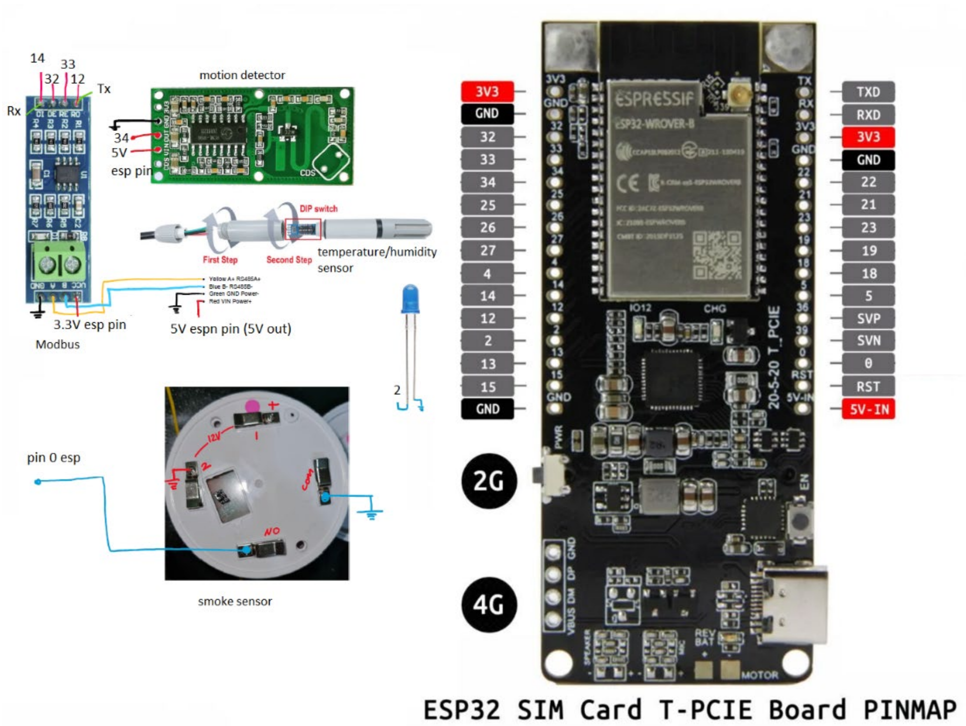


Fig. 4 - Wiring diagram for the sensor node –gateway

2. Implementation of the Proposed Prototype Kit

Fig. 5 and 6 show some parts of the developed prototype kit. Initially, SN reads data for temperature, humidity, motion and smoke to identify weather, humidity, smoke detection and the presence of objects in the area where SN is installed. Temperature and humidity data will be sent to the webserver within 1 minute while smoke and motion data will be sent to the server at digits 1 and 0 indicating that smoke is detected and SN is approached by an object or vice versa. SN will send all the information via GSM modem to the cloud server and the server will store the data in the built-in database. SN 1 to 5 operates by sending data simultaneously to a server using a unique ID. The proposed prototype operates independently and uses a GSM line without an intermediary unit which is more economical and easy to develop. Users can monitor the information of each SN through the developed GUI display while fire information (via smoke detection) and intrusion (via motion detection) are obtained via Telegram. In addition, this web-based IoT system is developed with an easy-to-use interface (GUI). The overall flow chart of the prototype kit process is shown in Fig. 7.

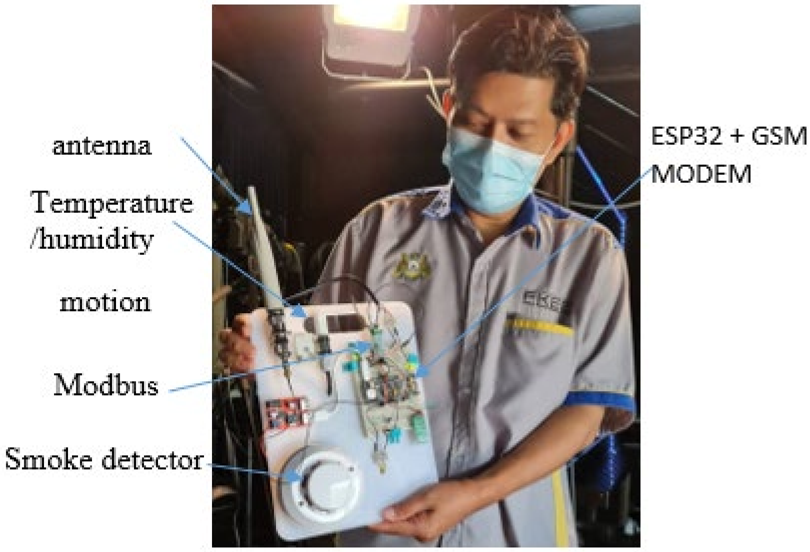


Fig. 5 - Proposed prototype kit

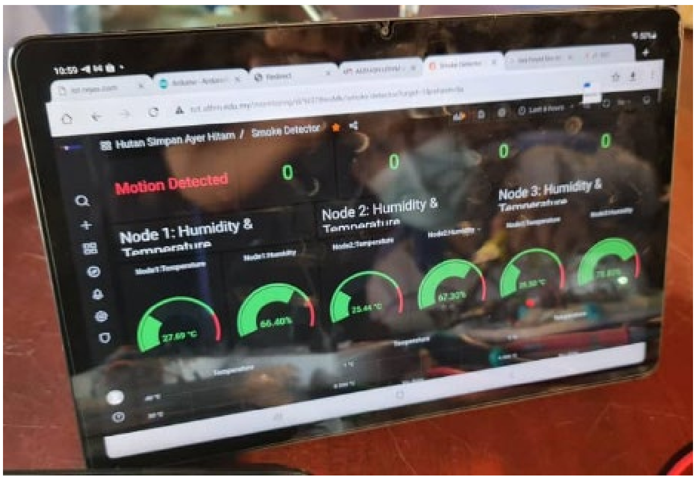


Fig. 6 - Display on the smart phone screen

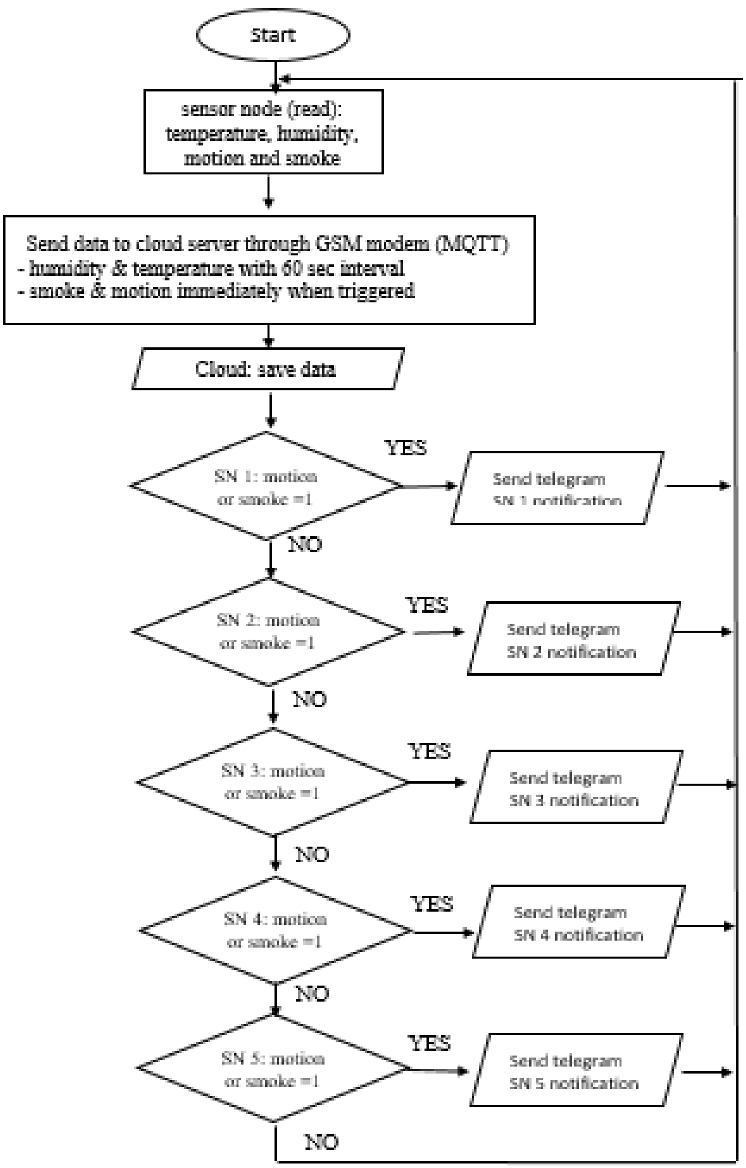


Fig. 7 - The overall flow chart of the prototype kit process

Two new methods are proposed and developed in this system:
- Sensor node with unique ID
- Monitoring the fire detection process and the notification system by using Grafana software and Node-RED software

These methods are discussed in the next subtopic.

Method 1: Sensor node with unique ID

In this project, SN uses a unique ID to allow the server to identify data received from different nodes. The IDs are 1, 2, 3, 4 and 5 representing SN1, SN2, SN3, SN4 and SN5 respectively. Figs. 8 and 9 show a flow-based programming tool using Node-RED software. In Figure 8, SN1 sends data from the sensor to the cloud server via the MQTT protocol. Node-RED's MQTT SN1 will receive the data and store this data in a database. Each SN will send data via Node-RED using MQTT-specific node names. This condition allows the server to differentiate the received data of each sensor as shown in Fig. 9. Firstly, the MQTT channel "smoke/cp1/node1" receive the data from SN1. Secondly, the received data is converted to JSON format. Thirdly, JSON format data is filtered to detect the high-level status of motion and smoke. From here, a function is created to send the smoke and motion data to the Telegram bot channel. Next, the SQL query function is created to update and insert the data into the database. Then, the return value from the functions is obtained and sent to "/smoke/telegram" MQTT's channel for the Telegram message. Lastly, the node is connected to the database. The developed database is shown in Table 2.

Fig. 8 - Flow-based programming tool using Node-RED software for SN1

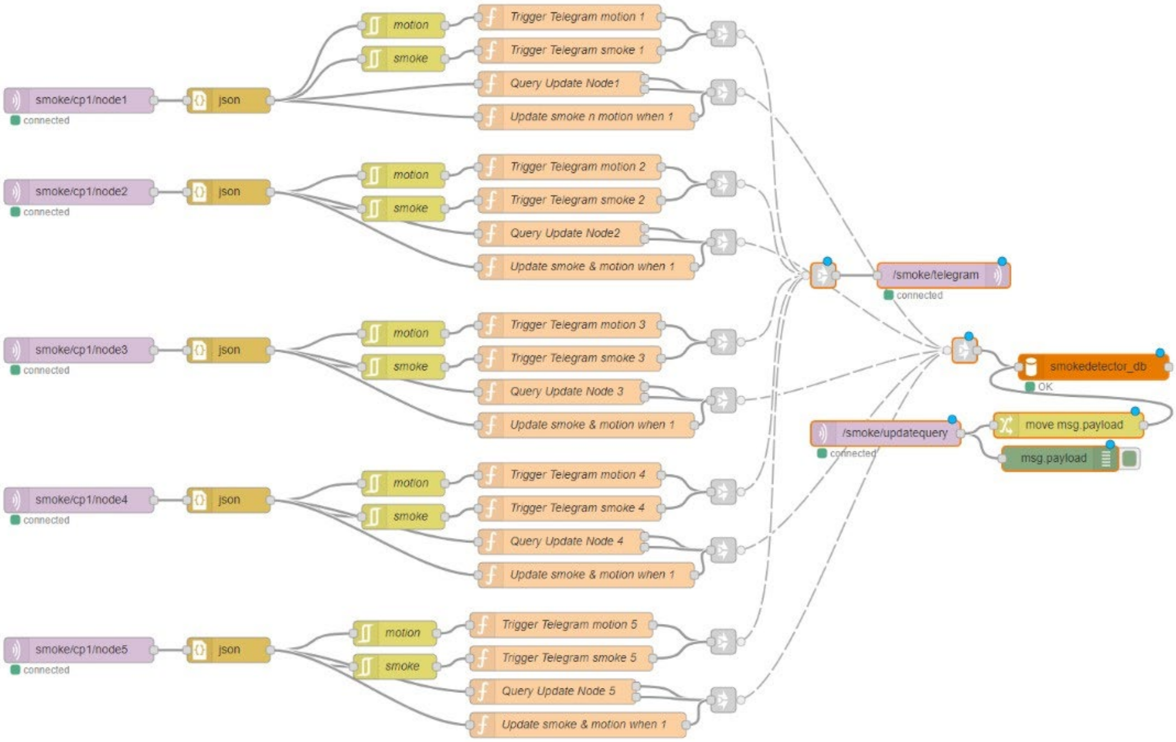


Fig. 9 - Flow-based programming tool using Node-RED software for all SN

Table 2 - The developed database

id	nodeid	temperature	humidity	motion	smoke	dateadd
1	1	24.41	56.65	1	0	2021-05-07 02:03:33
2	1	24.41	56.65	1	0	2021-05-07 02:03:47
3	1	24.41	56.65	1	0	2021-05-07 02:04:03
4	1	24.33	56.07	0	0	2021-05-07 02:04:16
5	1	24.33	56.07	1	0	2021-05-07 02:04:16
6	1	24.33	56.07	1	0	2021-05-07 02:04:33
7	1	24.33	56.07	1	0	2021-05-07 02:04:49
8	1	24.33	56.07	1	0	2021-05-07 02:05:05
9	1	24.27	55.58	0	0	2021-05-07 02:05:16
10	1	24.27	55.58	1	0	2021-05-07 02:05:16
11	1	24.27	55.58	1	0	2021-05-07 02:05:35
12	1	24.27	55.58	1	0	2021-05-07 02:05:50
13	1	24.27	55.58	1	0	2021-05-07 02:06:05
14	1	24.24	55.06	0	0	2021-05-07 02:06:16
15	1	24.24	55.06	1	0	2021-05-07 02:06:16
16	1	24.24	55.06	1	0	2021-05-07 02:06:22
17	1	24.24	55.06	1	0	2021-05-07 02:06:41
18	1	24.24	55.06	1	0	2021-05-07 02:06:52
19	1	24.24	55.06	1	0	2021-05-07 02:07:07
20	1	24.24	55.84	0	0	2021-05-07 02:07:16

Method 2: Monitoring the fire detection process by using Grafana and Node-RED software

Grafana software is used to monitor the temperature, humidity, smoke and motion data of each SN as shown in Fig. 10. Through this GUI display, users can get information on critical temperature and humidity levels at specific locations. Apart from smoke detection notification, this system also has security features to prevent theft of SN components, especially solar panels and batteries. Node-RED software is used to send motion detection notifications via Telegram. The issue of theft is also emphasized in this research work. Many cases have been reported in [15] regarding missing and stolen sensor node components due to the remote position of the nodes in the peat forest. Also, the devices used are expensive as it involves the use of solar batteries. Apart from efforts to prevent theft such by installing fences, warning signs and using high poles with concrete, they added the value to the developed system through movement detectors if there are intruders approaching it. The monitoring system is installed in fire-prone locations as described in the identification section. Users need to connect the smartphone line with the internet to access the information. In addition, users will obtain information via Telegram regarding smoke detection as shown in Fig. 11. Fig. 12 shows the GUI display for the user to reset the smoke sensor and motion sensor readings for SN1.

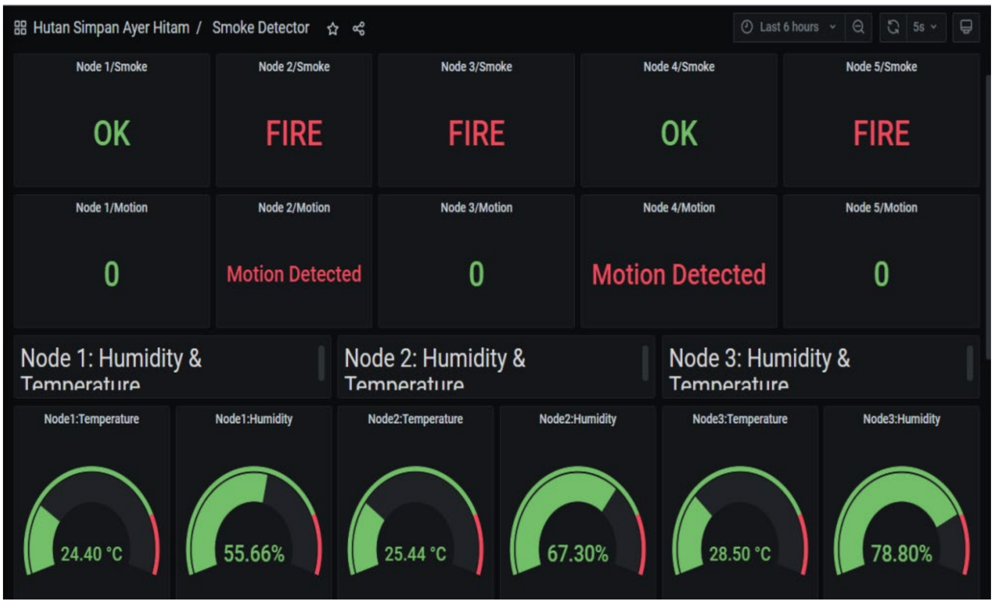


Fig. 10 - GUI for the prototype kit using Grafana software

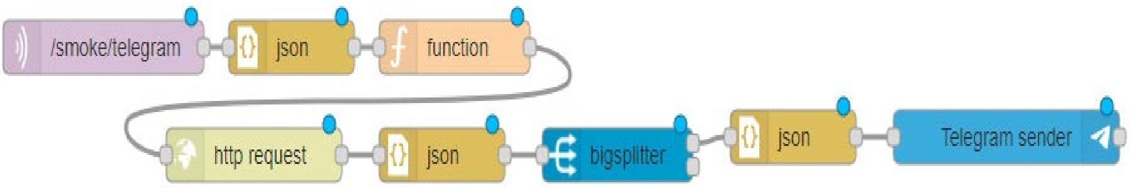


Fig. 11 - Flow-based programming tool using Node-RED software for notification purpose

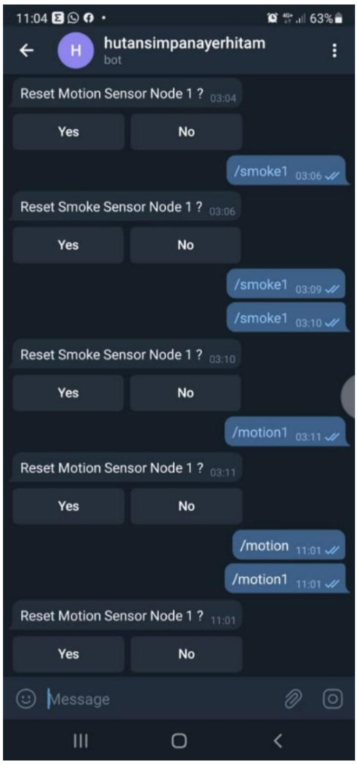
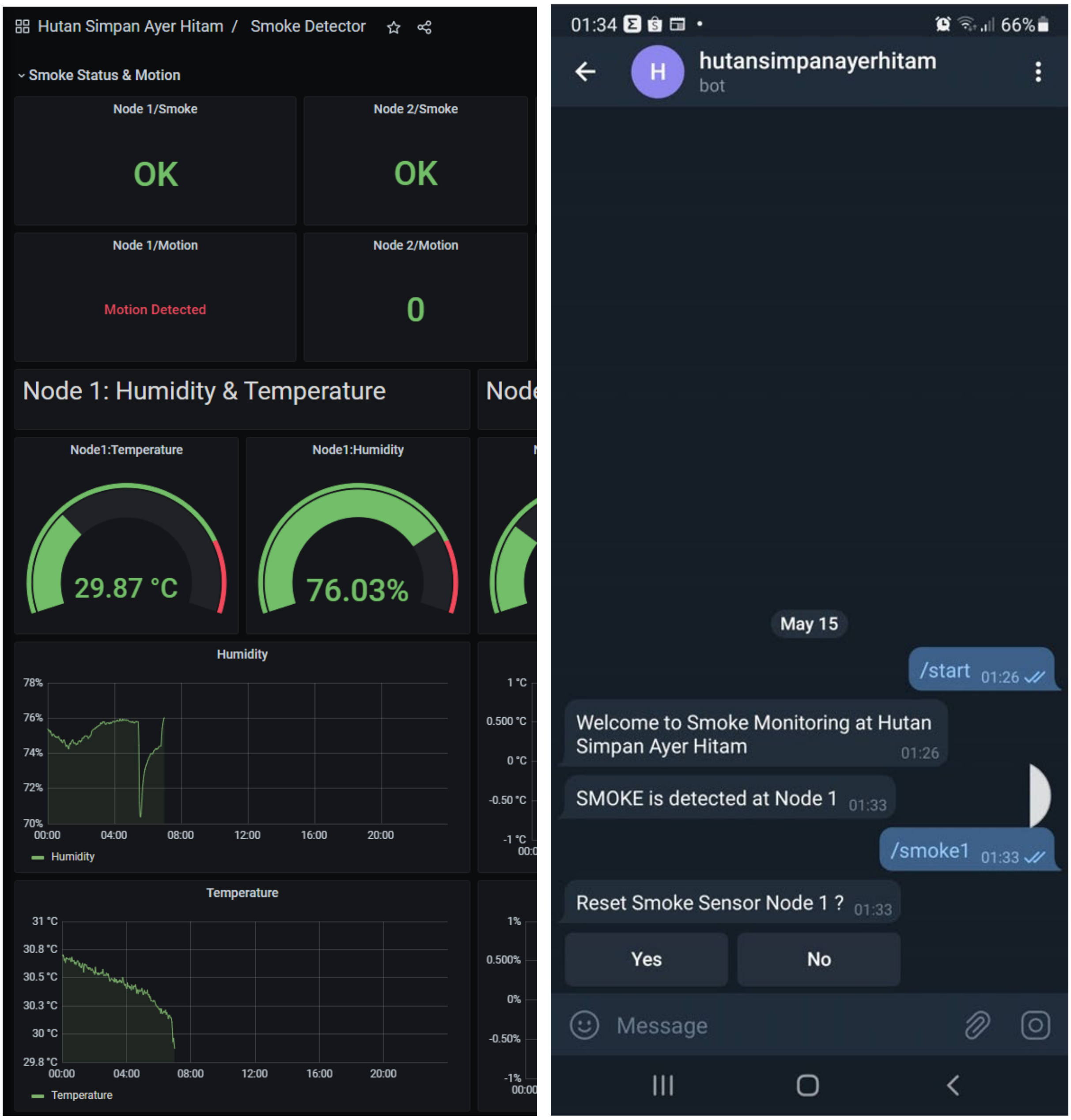


Fig. 12 - GUI for resetting the smoke sensor and motion sensor of SN1

3. Results and Discussion

Temperature, humidity, smoke and motion readings from the sensors are stored in a web server database. Authorities can access the data using a smartphone or laptop. In this work, all sensor nodes, SN 1 to 5 can operate very well. Fig. 13(a) shows the GUI display values for smoke, motion, temperature and humidity SN1. Smoke reading "OK" means no smoke is detected. Motion reading "motion detected" means the sensor detects the presence of objects near the prototype. Temperature and humidity are two parameters that can be used as a reference by the authorities to detect early fires. The temperature and humidity measurements are processed in this prototype kit by the ESP32 microcontroller module. The readings are displayed in the form of real-time numbers and graphs as in the diagram. Temperature and humidity readings are 29.87°C and 76.03%, respectively. The data is also recorded and displayed in real-time. At 12:00 pm, 4:00 am and 7:00 am, the temperature readings are 30.7°C, 30.35°C and 29.9°C, respectively. The equivalent humidity readings are 75.5%, 75.9% and 76%, respectively. Changes in these readings indicate that the temperature and humidity sensors are working properly. The smoke detection notification on SN1 is shown in Fig. 13(b) using a Telegram application. The sensor readings of this prototype kit are tested several times at the RF Laboratory UTHM Parit Raja Campus to measure the changes in temperature, humidity, presence of smoke and motion. This is to ensure the prototype kit operates with correct readings. The good performance of the monitoring system provides a strong justification that it can be used as a fire detector in peat forests. Therefore, the authorities can monitor the peat forest by using this prototype kit in their daily work.



(a) (b)

Fig. 13 - (a) GUI display using Grafana software; (b) message display in Telegram applications

4. Conclusion

The prototype kit developed in this research project successfully works to detect smoke, motion, measure temperature and humidity readings that meet the study's objective in detecting early peat forest fires using automation features equipped in the system. The test results show the presence of smoke and objects under good supervision because it is proven that the prototype kit can send notification messages to the users through Telegram applications. At the same time, data readings from the sensors can be displayed on the GUI in real-time. Moreover, the temperature and humidity readings obtained are accurate, stable and easy to read. Therefore, the developed system can be used as an early detection tool for peat forest fires. The system also successfully implements several methods such as sensor node (SN) with a unique ID which allows the webserver to differentiate the reception of the data from each SN.

Furthermore, wireless communication between SN and web server occurs in real-time and automatically without distance limitation. The proposed prototype kit in this work is expected to help the authorities monitor early peat forest fires more systematically. The current research work paves the way to installation and testing the prototype kit in Ayer Hitam Forest Reserve, Muar, Johor in the future.

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