# Real-time Forest Fire Detection and Alert System Using Wireless Sensor Networks and Solar Energy

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## I. Abstract

This work proposes the design and implementation of a real-time forest fire detection and alert system utilizing wireless sensor networks (WSN) and solar energy. The system utilizes ESP-NOW protocol for wireless communication among the sensor nodes, which are strategically placed in the forest to detect any potential fire hazards. The sensor nodes are powered by renewable energy sources, specifically solar panels, to ensure sustainable and long-term operation. The collected data is then transmitted to a central control unit for analysis and decision-making. In the event of a fire, the system will trigger an alert to notify relevant authorities for immediate action. The proposed system aims to provide an efficient and eco-friendly solution for the early detection and prevention of forest fires.

## II. Introduction

Forest fires are a major concern worldwide, causing significant damage to both nature and human life. Early detection and prompt action are crucial to minimizing the impact of these fires. Wireless sensor networks (WSN) have been proposed as a potential solution for forest fire detection due to their ability to monitor large areas and provide real-time data. However, the deployment and maintenance of WSN in remote and inaccessible areas can be challenging.

One potential solution to this problem is to utilize renewable energy sources, specifically solar energy, to power the sensor nodes. This approach not only addresses the energy needs of the system but also provides a sustainable and eco-friendly solution. The ESP-NOW protocol is used for wireless communication among the sensor nodes, allowing for efficient and fast data transmission.

Research into the effectiveness of WSN for spotting forest fires is growing. Many diverse approaches, involving a wide range of sensor technologies, network architectures, and power supplies, have been proposed in [1,15]. Some work proposes utilizing infrared sensors and the ZigBee protocol to detect fires, while other work proposes using thermal imaging and the LoRa network for the same purpose [1, 2]. [3] presented an efficient routing protocol for energy management systems. A machine learning algorithm-based system for fire detection was proposed in [4]. An image processing-based fire detection system was proposed in [5]. A system based on AI algorithms and wireless sensor networks was presented in [6]. [7] presented a fire-detection system that makes use of wireless sensor networks and the internet of things. A the system for detecting fires utilizing wireless sensor networks and cloud computing was suggested in [8]. An approach to fire detection based on wireless sensor networks and big data analytics was suggested in [9]. A system integrating wireless sensor networks and blockchain technology was presented for fire detection in [10]. Wireless sensor networks and edge computing were presented in [11] as a method for fire detection. In [12], the authors presented a fire detection system based on wireless sensor networks and 5G connectivity. In [13], the authors suggest a fire detection system that makes use of wireless sensor networks and satellite communication. According to [14], a method was presented employing cellular connectivity and wireless sensor networks to detect fires. An approach based on wireless sensor networks and mesh networks for fire detection was proposed in [15].

In this project, we propose the design and implementation of a real-time forest fire detection and alert system utilizing WSN and solar energy. The proposed system aims to provide an efficient and eco-friendly solution for the early detection and prevention of forest fires.

## III. Methodology

### A. Architecture

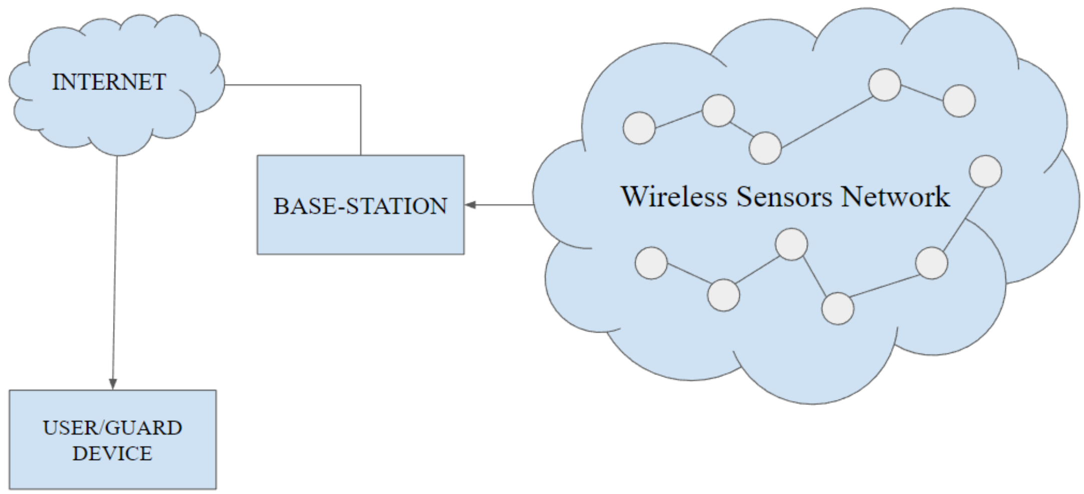


Figure 1. Architecture of the system

The above diagram gives a representation of the architecture of the system. Wireless Sensor Networks (WSN) consist of sensor nodes that are low-power, compact devices that are deliberately positioned throughout the forest to monitor for any potential fire threats. Their primary function is to prevent forest fires. They typically consist of sensors such as infrared, thermal, or gas sensors, which may detect changes in temperature as well as smoke and other phenomena associated with fires.

The base station acts as a hub for the sensor nodes and is responsible for collecting, processing, and transferring data from the sensor nodes. In addition, the base station serves as a storage location for the data. It is often connected to a power source, such as solar panels or batteries, in order to ensure that it will continue to function in a sustainable manner over time.

As the base station is connected to the internet, it is able to communicate the fire detection warning as well as the Node ID to the user or guard who is monitoring the network over the internet.

The user or the guard is the one who receives the fire detection warning and the Node ID via the internet, which enables them to take the necessary precautions.

The sensor nodes are distributed across the forest area, and in the event that a fire is detected, the sensor nodes will transmit the data to the base station. In the event that a fire is detected, the base station is responsible for receiving the data, processing it, and sending an alert. The user or the guard will then receive an internet transmission from the base station containing the fire detection warning as well as the Node ID. The alert is received by the user or guard, who then takes the appropriate action.

B. Block Diagram

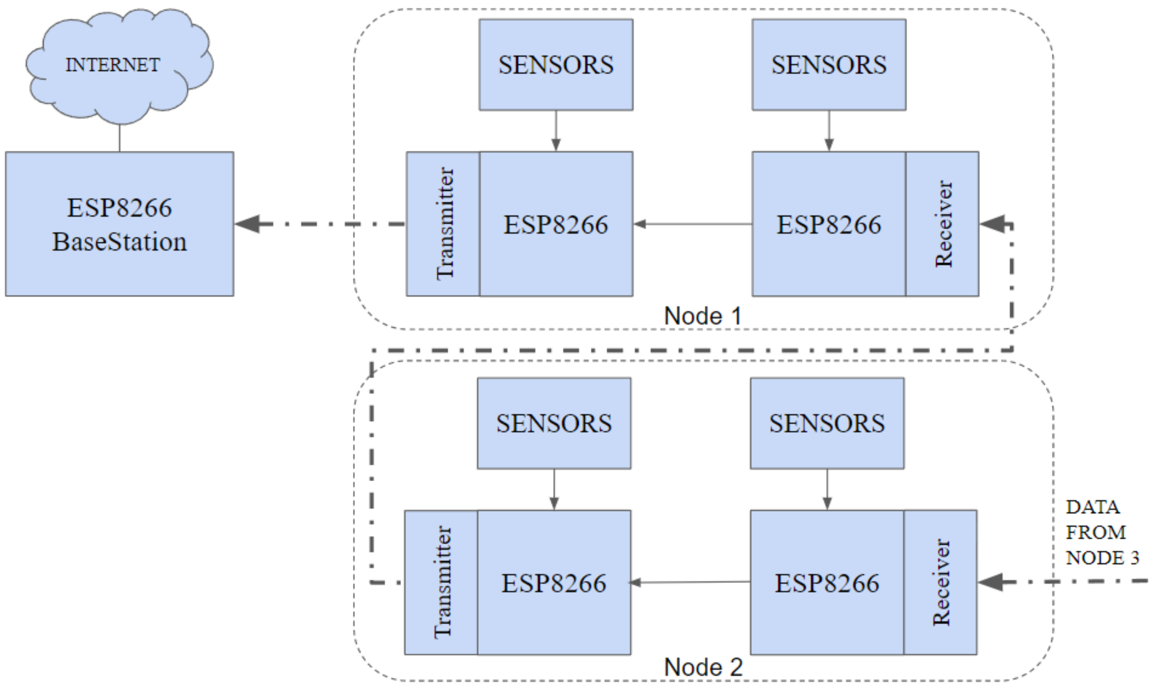


Figure 2. Block Diagram

The block diagram (Figure 2.) of the system may be seen above, and it provides a concise explanation of the system. Each node is made up of two esp8266 MCUs that are connected to one another via the UART protocol. The reason behind using 2 MCUs in a single node is because at a time ESP8266 can act as a transmitter or receiver. With this configuration although we are using two MCUs, but the number of sensors that can be connected if we used only MCU in a node will remain unchanged as both can be used to connect the sensors through digital pins. One of the esp8266 MCUs serves as the transmitter section of the node, while the other serves as the receiver section. Through the use of the ESPNOW protocol, the nodes are wirelessly connected to one another. This is represented by the dashed lines. The first node, referred to as

Node1, is connected to the base station, which possesses internet access. It is through this connection that the base station will alert the user or the guard.

C. Flow Diagram

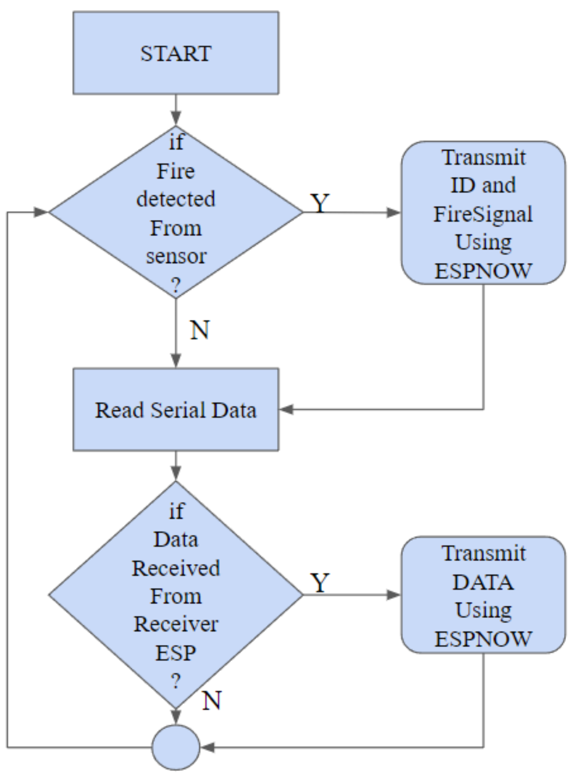


Figure 3(a). Transmitter Flow

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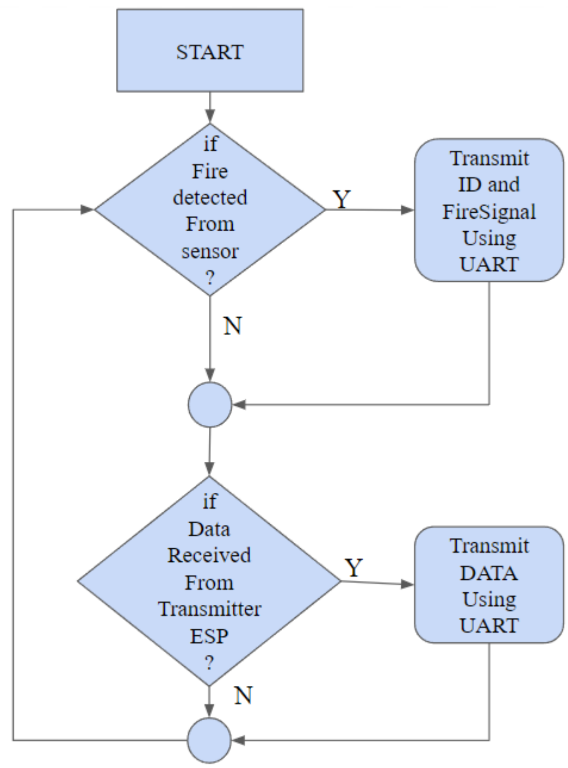


Figure 3(b). Receiver Flow

Figure 3(a). Shows the transmitter flow for a wireless sensor network (WSN) that uses the ESP-NOW protocol to detect forest fires. The sensors connected to the transmitter section are performing a constant scan of the environment to look for any potential sources of fire dangers. In the event that a fire is discovered, the sensor node will send out a warning signal. When a fire signal is triggered, the sensor node will send its unique ID together with the fire signal to the base station via the ESP-NOW protocol. This will occur once the fire signal has been triggered. If the sensor node does not detect any fire, it will continue to read serial data from the UART for any data from the receiver section of the node. This data includes sensor data from other ESP nodes and the receiver section of the same node. If there is any fire alert data available (node ID) it will transmit to other nodes using the ESPNOW protocol.

Figure 3(b). Shows the receiver flow, where if the sensor connected to it detects any fire, the node ID of the current node will be transmitted via UART communication to the transmitter section of the node. Else it will keep scanning for any data from other nodes as it is acting as the receiver section of the node. As soon as any data is received from the other nodes (Node ID), the data will be transmitted to the transmitter section of the node via UART communication. Here the WSN configuration is peer-to-peer and one-way communication, which means each node can transmit to a single node, and the end node will transmit the data to the base station.

Solar panels can charge batteries by converting the sun's energy into electricity through the process of photovoltaics. The electricity generated by the solar panels is sent to a charge controller, which regulates the amount of electricity going into the battery. The charge controller ensures that the battery is not overcharged or undercharged, which can damage the battery or reduce its overall lifespan. The electricity is stored in the battery and can be used to power devices or systems when sunlight is not available.

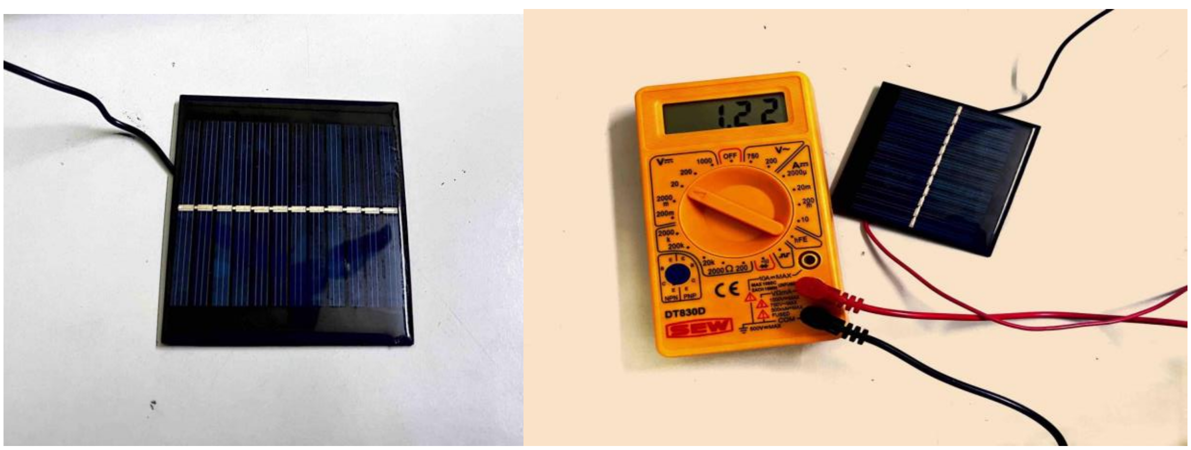


Figure 4. Solar panel

Connected the Solar panel of dimension 6.5cm * 5.2 cm with a rated voltage of 5v output as in figure 4(a). The output of the solar depends upon the intensity of sunlight and the angle.The solar panel's output voltage and current (in volts and amps) using a digital multimeter as in figure 4(b).

To calculate the required solar panel capacity using a 5V solar panel with dimensions of 6.5 cm by 5.2 cm, we can follow this approach:

**Determination of the average daily solar energy availability:**

$$Area\ of\ solar\ panel = 6.5cm\ x\ 5.2cm$$
$$Area\ of\ solar\ panel = 33.8cm^2$$

$$Average\ daily\ solar\ energy\ availability = Solar\ Radiation\ x\ Area\ of\ Solar\ Panel$$

The typical Solar Radiation in India lies between 4-7kWh/m$^2$/day. Assuming the worst-case scenario of 4kWh/m$^2$/day, we calculate the average daily solar energy

$$Average\ daily\ solar\ energy\ availability = \frac{\frac{4kWh}{m^2}}{day} x\ 0.00338\ m^2$$
$$Average\ daily\ solar\ energy\ availability = 13.52Wh$$

**Required solar panel capacity:**

$$\text{Required solar panel capacity} = \frac{(Adjusted\ total\ energy\ consumption)}{Average\ daily\ solar\ enerygy\ availability}$$

$$\text{Required solar panel capacity} = \frac{3\ Ah}{13.52\ Wh}$$
$$\text{Required solar panel capacity} = 0.221\ kW$$

According to these calculations, in order to power our system with a solar panel that operates at 5 volts and has dimensions of 6.5 cm by 5.2 cm, we need a solar panel that has a capacity of around 221 Watts. This calculation is based on the assumption that conditions are perfect and does not take into account any losses in efficiency, shadowing, or other factors that may impair the performance of solar panels.

## IV. Results and discussion

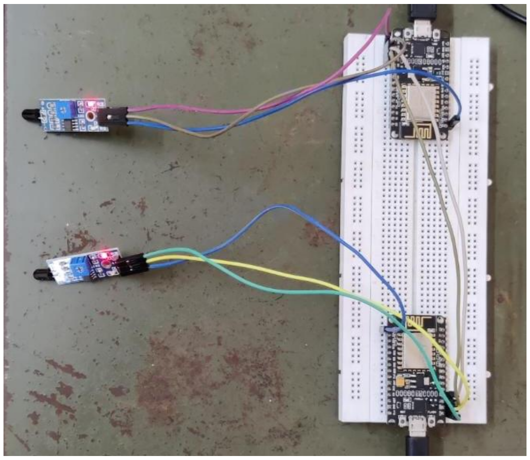

Figure 4(a). Node with flame sensor

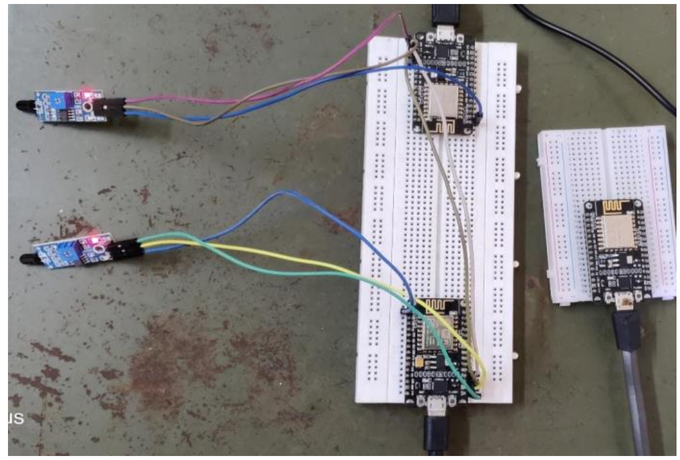

Figure 4(b). End node with Base station ECU

In figure 4(a) the system contains two ESP8266 connected via UART acting as a node. One MCU is acting as a transmitting section while the other one is acting a receiver section. Each MCU's digital pin can be connected to one flame sensor. So, in all, we can connect up to 20 sensors to a single node. In figure 4(b). The system contains a node closer to the base station (Node 1).

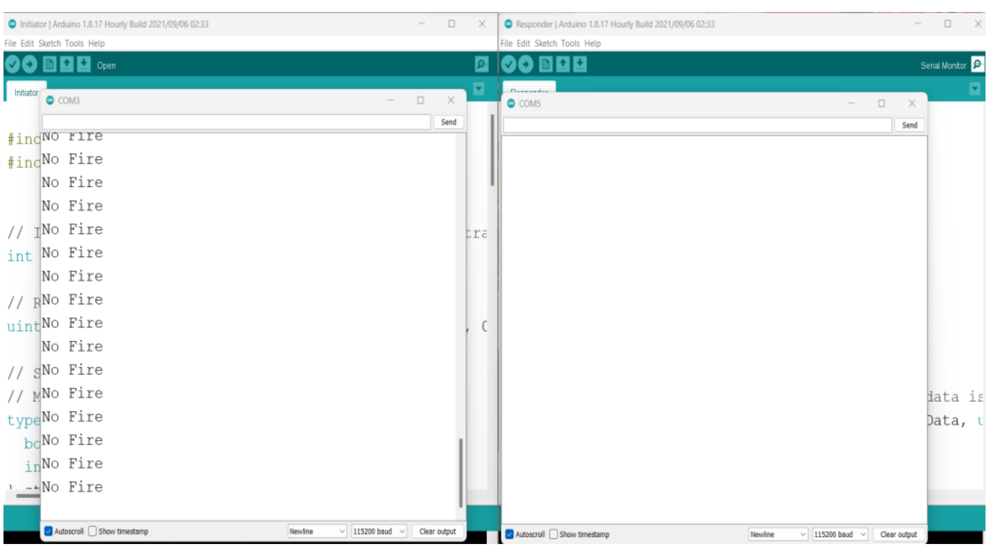


Figure 5(a). No fire Signal

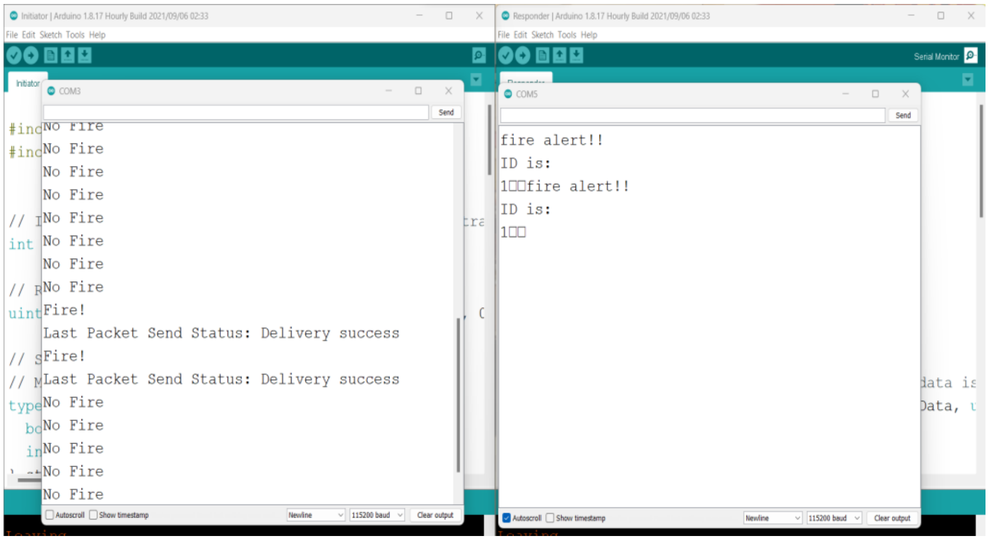


Figure 5(b). Fire Signal Detected at one node

The serial monitor for the transmitter section of one node is connected to COM 3 and the receiver section of the other node which is connected to the previous node via ESPNOW is connected to COM 5 (figure 5(a) and figure 5(b)).

Figure 5(a) states when there is no fire detected thus, no alert signal is transmitted the to next node COM 5. As soon as the fire is detected the corresponding node ID and fire alert message is transmitted through ESPNOW and as shown in figure 5(b).

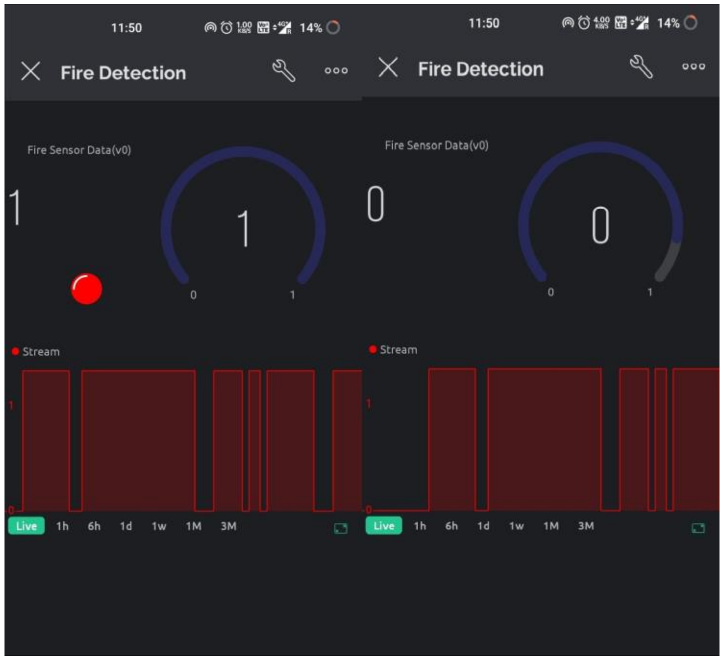


Figure 6. Blynk output at Base-station

Figure 6. Depicts the output of Blynk which is used to indicate presence of fire to the user/guard through the base station which is provided by the internet. It shows the alert signal and Node ID where the fire is present so that user/guard can easily go to that location corresponding to the ID.

## V. Conclusion

In conclusion, there are several benefits associated with using an ESP-NOW protocol and solar energy to power a wireless sensor network (WSN) designed to detect forest fires. To begin, the utilization of the ESP-NOW protocol for wireless communication among the sensor nodes makes it possible for effective and rapid data transfer. This ensures that the forest can be monitored in real time for potential fire dangers. Second, the use of solar energy as a source of power for the sensor nodes guarantees the system's ability to operate reliably and for an extended period of time. This cuts down on the amount of maintenance that is required and reduces the system's negative effects on the environment. Thirdly, the system that has been described offers an effective method that is also kind to the environment for the early identification and prevention of forest fires. The system is able to monitor wide regions and offer real-time data thanks to the utilization of sensor nodes that have been carefully positioned throughout the forest. This enables the system to take rapid action in the event that a fire breaks out. Finally, connecting the base station to the internet enables the system to send the fire detection alert as well as the Node ID to the user/guard. This information assists the user/guard in taking the appropriate actions in the event that a fire is detected. Thus, the system that has been described provides a reliable, sustainable, and effective solution for the detection and monitoring of forest fires. This, in turn, can help to reduce the negative effects that forest fires have on both the natural world and human life.