Wildfire detection based on IoT technology

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***Abstract*— Wildfires are a global concern due to their increasing severity and frequency, resulting in economic, environmental, and human losses. These events primarily affect rural areas with high organic matter accumulation and inadequate surveillance. Traditional fire detection methods rely on sensors that detect heat, smoke particles, specific gases, and radiative emissions. Internet of Things (IoT) technology offers a promising solution for remote wildfire detection by providing long-lasting, low-power sensors that operate autonomously. Despite challenges in ensuring connectivity in remote areas, technologies like LoRaWAN enable energy-efficient, long-range communication at a low cost. By leveraging IoT and LoRaWAN technologies, a wildfire monitoring system can be developed to provide real-time surveillance and early warnings to authorities, improving response time capabilities. This paper aims to conceptualize, design, and develop a cost-effective, energy-efficient IoT-based system for early wildfire detection.**

Keywords—IoT, Wildfire, Node-RED, LoRa, LoRaWAN, Fire Detection

I. INTRODUCTION

Wildfires have become a concerning global issue with their increase in severity and frequency. These global events not only ruin our landscapes but also lead to massive economic and environmental impacts. Tragically, they often lead to the destruction of people's properties and the loss of lives, be the property owners or the authorities combating the flames [1]. These occurrences are most common in countryside with high accumulation of organic matter areas where surveillance is insufficient or nonexistent [2].

Traditionally fires have been detected by heat, presence of smoke particles and certain gases, and radiative emissions such as Infrared light [3]. The sensors used in these detectors are mainly used in residential and commercial areas where electricity is easily accessible, and communication infrastructure is present.

Internet of Things (IoT) technology can provide a solution to remote sensor challenges by offering devices, sensors capable of long longevity with relative low power necessities and capable of long-range communication. IoT technology can be described as a network of smart devices that share information without human interaction. IoT has proven effective in various applications such as home automation, healthcare, transportation, agriculture and most relevant to this project, environment monitoring. This technology can be powered by small batteries and is extremely power efficient, allowing the deployment to remote locations [4, 5].

Some challenges still arise with connectivity. Remote areas have difficult access and might not have the necessary network infrastructure. Connectivity through mobile networks might be unreliable or nonexistent, its power requirements and service costs are high. LoRaWan is used to combat these problems, devices are energy efficient, capable of long-range communication and of low acquisition cost. [5]

By leveraging these technologies, a wildfire system could potentially monitor large areas in real-time and provide early warnings by assessing environmental conditions to the respective authorities.

While some investigations have been conducted on this topic, it's still a relevant area to study [4, 6]. Sensor technology is continuously advancing and more cost-effective, enabling further research.

This paper's aim is to conceptualize, design and develop an IoT system with relative low cost and energy efficient to improve early fire detection.

II. METHODOLOGY

This project adopts a hybrid research methodology that integrates a Systematic Literature Review (SLR) with Experimental Research (ER) to study and develop an IoT solution for wildfire detection.

The research starts with the SLR to gather, analyze and synthesize existing literature on IoT technology, sensors, LoRa technology, wildfire emissions, IoT middleware platforms and energy efficiency.

With the comprehension derived from the SLR phase, a Prototype Design phase will start with the design of an IoT Device and a dashboard to report its data.

A. Research Questions

Two research questions arise with this research project and were identified as follows:

RQ1 – How can IoT Technology be used to improve the detection of wildfires?

RQ2 – How would the connectivity and communication between IoT devices be accomplished?

B. Hypotheses

The following hypotheses are proposed to the previous questions.

RQ1_H1 – The creation of a self-sustainable and low-cost IoT device with various sensors to assess wildfire occurrences will prove the concept and ensure the project longevity.

RQ1_H2 – The creation of a mesh network of such IoT devices will triangulate precise fire location.

RQ2_H1 – Usage of LoRaWan Gateways to connect IoT devices (Nodes) will ensure continuous communication.

RQ2_H2 – The Creation of a dashboard to report devices data will increase awareness on the state of the connected IoT devices.

III. STATE OF ART

This project involves different fields of expertise. The current section reviews relevant studies published in fields such as wildfires emissions and behavior, traditional fire detection, IoT and Sensors, Middleware platforms and Lora Technology.

A. Wildfires

By definition, a wildfire is (Cambridge Dictionary, n.d.) "a fire that is burning strongly and out of control on an area of grass or bushes in the countryside".

The impacts of this phenomenon are vast, and it's most felt on biodiversity degradation, destruction of natural resources and agriculture structures, and the negative impact on climate change through the emissions of greenhouse gases like CO2 (Carbon dioxide), CO (Carbon monoxide) and CH4 (Methane). The destruction of residential, agriculture areas and firefighting efforts lead to large economic impacts. In the year of 2023, Portugal incurred a cost of 377.2 million euros due to wildfires [7].

Wildfires are generated by a combination of factors, those being ignition, drought, continuous fuels and suitable weather. The conclusions of [2] indicate that fire occurrence is determined by the frequency of which of these thresholds are crossed and its effects are largely influenced by climate change and human activity.

1) Atmospheric composition and climate

Fires, particularly those resulting from biomass burning, are sources of gas emissions that impact air quality. The primary gaseous emissions include Carbon Dioxide (CO2), Carbon Monoxide (CO), and Volatile Organic Compounds (VOCs), with their concentrations varying from most to least abundant. CO2 is the most abundant gas, typically comprising about 90% to 95% of the emissions, followed by CO, which makes up approximately 5% to 10% [8].

Although these gases are indicative of an active fire, ambient temperature and relative humidity are crucial factors in assessing fire-prone conditions. Higher temperatures reduce the moisture content in vegetation, improving its flammability, while lower relative humidity accelerates the drying process of vegetation. These two variables are essential for predicting the risk of fire occurrence [2, 8].

B. Traditional Methods of Wildfire Detection

1) Early warning Systems

Early warning systems are important resources to provide timely response and mitigation to fire occurrences. These systems typically use a combination of technologies, including satellite imaging, ground sensors, and aerial surveillance, to detect and monitor wildfires in real-time.

Advanced systems integrate machine learning algorithms to enhance detection accuracy, reduce false alarms, and provide predictive analytics for potential fire outbreaks. Key components of these systems include the collection of environmental data, real-time analysis, and dissemination of alerts to relevant authorities and the public. The effectiveness of early warning systems is largely dependent on the integration of multiple data sources and the rapid processing of information to trigger alerts [9].

2) Satellite Imaging

Satellite imaging has been used for wildfire detection due to its ability to cover large geographic areas. Satellite systems like MODIS and VIIRS provide data for detecting and monitoring wildfires. MODIS, aboard NASA's Terra and Aqua satellites, offers a revisit time of 1-2 days and captures data in multiple spectral bands, which identifies thermal deviations associated with wildfires.

Geostationary satellites like GOES-16 offer high temporal resolution, providing updates every 15 minutes, but with lower spatial resolution compared to polar-orbiting satellites. Recent advances include the use of CubeSats, which provide improved temporal resolution and cost-effectiveness. However, their limited data transmission capabilities remain a challenge [9, 10].

3) Lookout Towers and Human Patrols

Lookout towers and human patrols are among the oldest methods for wildfire detection. These methods rely on human observers stationed at strategic points, typically in elevated locations, to visually scan for signs of smoke or fire. While cost-effective and providing real-time data, these methods are limited by human error, the physical range of visibility, and the inability to operate effectively during night or in adverse weather conditions. Despite these limitations, lookout towers and human patrols remain an important component of wildfire detection, especially in remote areas where modern technology may not be available [4, 9].

4) Aerial Surveillance

Aerial surveillance involves the use of manned or unmanned aircraft equipped with cameras and other sensors to detect wildfires. Early aerial detection efforts began in the 1920s and have evolved significantly with the introduction of infrared imaging, which allows for the detection of fires even through thick smoke.

Modern aerial surveillance often employs Unmanned Aerial Vehicles (UAVs), which provide flexibility and can cover areas that are difficult or dangerous for manned aircraft. However, UAVs are limited by weather conditions and flight time. Aerial surveillance is particularly valuable for detecting fires in their early stages, especially in remote or inaccessible areas [4, 9].

5) Ground Sensors

Thermal cameras and gas sensors are increasingly being used for wildfire detection. These sensors can detect the thermal signatures of fires or the presence of smoke and other combustion-related gases. Ground sensors are highly effective in providing localized data with high accuracy and can be deployed in large networks to cover extensive areas. However, the effectiveness of ground sensors is limited by the need for a dense network to ensure comprehensive coverage, which can be costly and logistically challenging. Despite this, ground sensors play a crucial role in early detection, especially when integrated into larger, multi-modal detection systems [3, 4, 9].

C. IoT Technology and Its Applications

1) Definition and Scope of IoT

The Internet of Things (IoT) is characterized by the interconnectivity of various devices, sensors, and systems through private or public networks, enabling them to collect, exchange, and act on data without human intervention. The architecture of IoT systems generally includes layers such as the physical layer (sensors and devices), the middle layer (cloud infrastructure for services like storage and event management), and the application layer (user interfaces and applications). These systems are designed to operate autonomously, performing tasks like data collection and communication with minimal human input [4,11].

2) *Air Quality Monitoring*

IoT-based air quality monitoring systems are commonly used to measure and manage air pollution in urban areas. These systems typically consist of low-cost sensors that monitor pollutants such as particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), carbon monoxide (CO), and carbon dioxide (CO2). The data collected by these sensors is transmitted to a central platform where it is analyzed and compared against air quality standards [12].

For instance, PM2.5 sensors can detect fine particulate matter with diameters of 2.5 micrometers or smaller, which can pose significant health risks. Thresholds for PM2.5 often follow guidelines from organizations like the World Health Organization (WHO), where a 24-hour average concentration of 15 $\mu g/m^3$ is considered the recommended limit for safe air quality [13].

D. *IoT-based Wildfire Detection Systems*

1) *Wireless Sensor Networks (WSNs)*

Wireless Sensor Networks (WSNs) are integral to IoT-based wildfire detection systems. These networks consist of distributed sensor nodes that communicate wirelessly to monitor environmental conditions such as temperature, humidity, and gas concentrations. WSNs can detect early signs of wildfires and provide real-time data to authorities. The typical communication range for WSN nodes is 100 to 300 meters in dense forests, and up to 1 kilometer in open areas [6].

2) *LoRa Technology*

LoRa (Long Range) technology is particularly well-suited for IoT applications in wildfire detection due to its long-range communication capabilities and low power consumption. LoRa operates in the sub-GHz frequency bands (typically 868 MHz in Europe) and can achieve communication ranges. A study achieved up to ~30 km, although only 62% of the packets sent were received from the station 30km away [5].

LoRa's low data rate (0.3 to 50 kbps) is sufficient for transmitting sensor data, making it ideal for large-scale deployments where power efficiency and range are critical. The technology supports a star-of-stars topology, where end devices communicate with gateways that relay the data to a central server. This architecture reduces the energy consumption of sensor nodes, prolonging their battery life [14].

3) *CO2 and CO Emission Monitoring*

Gas sensors are important components of IoT-based wildfire detection systems, helping the remote monitoring of fire-prone areas and providing real-time data for the detection of early fire. By measuring specific gases released during combustion, such as carbon dioxide (CO2) and carbon monoxide (CO), the two most abundant gases, these sensors identify and respond to wildfires before they escalate [8].

CO2 sensors are particularly useful in detecting active fires. They measure CO2 concentrations in parts per million (ppm), typically within a range of 350 to 10,000 ppm. During combustion of combustible forest materials, CO2 levels from the first ~300 seconds may vary from 20 to 220 ppm, which could trigger alerts and provides valuable data for further analysis and decision-making [16].

Similarly, CO sensors can detect carbon monoxide concentrations within a range of 0 to 1,000 ppm. Alarm thresholds are usually set at 10 ppm to initiate early warning alerts, allowing for a swift response to potential fire hazards [3].

In addition to their role in fire detection, monitoring CO2 and CO emissions during wildfires is essential for assessing the environmental impact.

4) *Node-RED and Middleware Platforms*

Middleware platforms in IoT provide the necessary infrastructure to connect and manage communication between IoT devices and applications. These platforms support device integration, data processing, and protocol management, making it easier to deploy and manage IoT systems [15].

Node-RED is widely used in IoT-based wildfire detection systems for its ability to integrate various sensors and communication protocols into a cohesive system. Middleware platforms like Node-RED allow for the rapid development of data flows, enabling the real-time processing and visualization of sensor data. In a wildfire detection system, Node-RED can be used to manage the data streams from multiple sensor nodes, apply threshold-based logic to detect anomalies, and trigger alerts that notify authorities [14, 17].

5) *Similar Projects*

Similar projects have demonstrated the effectiveness of IoT-based wildfire detection systems. For instance, a project in Portugal involved the deployment of a wireless sensor network for forest fire detection, using IEEE 802.15.4 standard-compliant devices. The system utilized Contiki OS and the RPL routing protocol to ensure robust communication in a forested environment. The project demonstrated that early detection and real-time data collection could improve the response time to wildfires [6].

Another project focused on the deployment of LoRa-based gas sensors for wildfire detection. The study showed that LoRa's long-range communication capabilities made it possible to cover a radius of 1.1km with relatively few sensor nodes, reducing costs and complexity. The system was able to detect peak CO2 concentrations corresponding to work communal hours, indicative that it could detect presence of fire.[18].

IV. Proposed Solution

The proposed solution for this project leverages IoT technology to create an efficient, low-cost, and sustainable system. The core of this system involves building a sensor array composed of various low-cost sensors capable of detecting critical environmental parameters, including CO, CO2, relative humidity, temperature, and particulate matter (PM2.5). These sensors will be deployed in strategic locations and connected via a LoRaWAN network for its long-range capabilities and low-power requirements. The Things Network (TTN) will be used for data transmission.

To ensure continuous operation in off-grid areas, the sensor nodes will be powered by a solar panel and rechargeable Li-Po battery, allowing for self-sustainability.

The collected data will be processed and visualized using Node-RED, which will also be used to set up real-time alarms when any parameter reaches a predefined threshold indicating potential fire. A LoRaWAN gateway will serve as the communication hub, connecting the sensor devices to the cloud where the data can be monitored and analyzed.

A. *Solution Architecture*

The architecture proposed for this project is organized into four layers, as illustrated in Fig. 1. The foundational layer is the Sensor Layer, where the IoT device, equipped with chosen sensors and development board, collects data from the surrounding environment. Above this is the Communication Layer, which consists of a LoRaWAN gateway. This gateway transmits sensor data from the IoT device to the Middleware Layer. Within the Middleware Layer, Node-Red processes the incoming data from the LoRaWAN gateway and subsequently stores it in a PostgreSQL database. Finally, the Application Layer is responsible for data visualization and alert generation. Here, the Node-Red Dashboard displays the processed data and triggers alerts in response to any detected hazardous conditions.

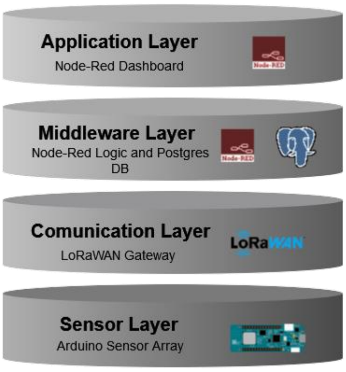

Fig. 1. Proposed architecture

B. *IoT Device Achitecture*

1) *Development Board*

The development board chosen for this project was the Arduino MKR WAN 1310 which is a microcontroller board designed for Internet of Things (IoT) applications, particularly focusing on LoRa and LoRaWAN connectivity. It features a SAMD21 Cortex®-M0 32-bit ARM® MCU and an onboard Murata CMWX1ZZABZ LoRa® module, making it capable of long-range communication with low power consumption.

The board comes with several GPIO pins, analog and digital interfaces, an I2C interface for connecting sensors and an 868MHz antenna. The MKR WAN 1310 is suitable for applications that require remote data collection, environmental monitoring, and other IoT projects that benefit from the LoRa® protocol's range and low power characteristics.

Active Power Consumption: ~ 100mW

Sleep Power Consumption: ~0.1551mW

2) *CO2, Relative Humidity and Temperature Sensor*

The Grove SCD30 is a high-precision carbon dioxide (CO2) sensor module that also measures temperature and relative humidity. It is based on the Sensirion SCD30 sensor and is designed for easy integration with various microcontroller platforms, including Arduino and Raspberry Pi, using the Grove connector system. However, for this project a basic I2C connection will be used.

The SCD30 uses non-dispersive infrared (NDIR) technology to accurately measure CO2 concentrations from 0 ppm to 10,000 ppm, making it ideal for indoor air quality monitoring, HVAC systems, and other environmental sensing applications.

Active Power Consumption: ~ 375mW

3) *PM2.5 Sensor*

The Grove HM3301 is a high-precision laser particulate matter (PM) sensor module, designed to measure the concentration of particulate matter in the air, specifically PM1.0, PM2.5, and PM10. It uses laser scattering technology to detect particles as small as 0.3 micrometers, providing accurate real-time data on air quality.

The HM3301 is equipped with a fan to draw in ambient air, ensuring consistent sampling, and outputs data via I2C, making it compatible with a wide range of microcontroller platforms, including Arduino and Raspberry Pi. This sensor is particularly useful for indoor air quality monitoring, pollution detection, and environmental sensing applications.

Active Power Consumption: ~ 375mW

4) *CO Sensor*

The CO Senser used in this project is the Grove MQ-9, a gas sensor module designed to detect carbon monoxide (CO) and other combustible gases such as methane and LPG. It is based on the MQ-9 sensor, which uses a tin dioxide (SnO2) semiconductor to detect gas concentrations in the air. The sensor provides an analog output, which reflects the concentration of the gases.

The MQ-9 is particularly sensitive to carbon monoxide and is commonly used in applications like gas leak detection, air quality monitoring, and safety systems.

Active Power Consumption: ~ 750mW

5) *Solar Power Management Board*

The DFRobot 5V Solar Power Manager v1.1 is a power management module designed to efficiently manage solar energy for powering small electronics projects. It can manage the input from a solar panel and regulate it to provide a stable 5V output, suitable for powering microcontrollers, sensors, and other low-power devices.

The module includes a built-in lithium battery management system, allowing it to charge a connected Li-Po using solar energy while providing protection features such as overcharge, over-discharge, and short-circuit protection. It also has multiple power outputs to support various devices and can automatically switch between solar, battery, and USB power sources depending on availability.

6) *Sensor Array Diagram*

Fig. 2 illustrates a simplified circuit diagram of the proposed IoT device. The system is managed by an Arduino MKR1310 microcontroller, which is powered by an 8000mAh, 3.7V Li-Po battery. The battery is rechargeable via a solar-powered system consisting of a 5V solar power management unit and a 6V, 3.5-watt rated solar panel.

To optimize energy consumption, the SCD30 and HM3301 sensors are controlled by a MOSFET circuit, which is managed by the Arduino to selectively power these components on and off as needed. In contrast, the MQ-9 sensor, which has the highest energy consumption among the components, must remain continuously powered due to its 24-hour pre-heating requirement,

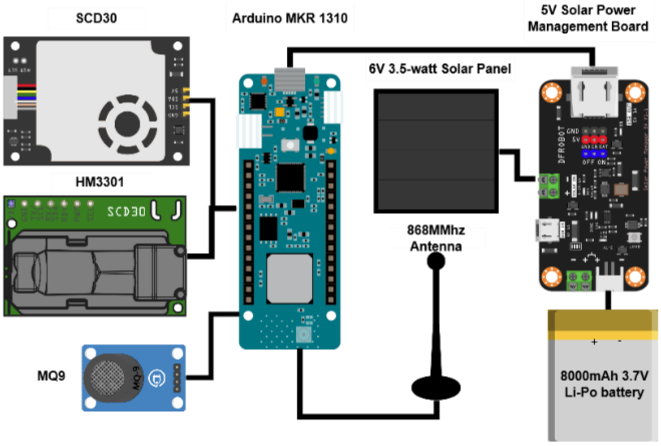

Fig. 2. Sensor Array Diagram

7) Power Consumption

a) Full Power Mode – Cosntant Reading and Transmission

In full power operation, all components of the system are actively reading, leading to a constant power draw. This mode, while acquiring real-time data and transmitting it, results in the highest possible energy consumption. For the system under consideration, which includes the Arduino MKR 1310, Grove HM3301, Grove SCD30, and Grove MQ9:

$$P_{total}=100+375+375+750=1600\text{mW}=1.6\text{W} \quad (1)$$

$$\text{DPC}=1.6\text{W}\times 24\text{h}=38.4\text{Wh/day} \quad (2)$$

$$\text{SPI}=3.5\text{W}\times 5\text{h}=17.5\text{Wh/day} \quad (3)$$

$$\text{ED}=38.4-17.5=20.9\text{Wh/day} \quad (4)$$

$$\text{BL}=\frac{29.6\text{Wh}}{20.9\text{Wh/day}}\approx 1.42\text{ days} \quad (5)$$

Equation (1) demonstrates that the total power consumption of the system (P_{total}) is 1.6 watts, corresponding to a daily power consumption (DPC) of 38.4Wh (2). When powered by an 8000mAh, 3.7V Li-Po battery, which provides 29.6Wh of energy storage, the system can operate autonomously for approximately 1.42 days with a full battery life (BL). The BL duration is extended with the inclusion of a daily solar power input (SPI) of 17.5 Wh. The energy deficit (ED), representing the shortfall between energy consumption and energy supply, is also considered in the system's overall energy management (4).

b) Efficiency mode – Intermittent Readings and Transmission

To optimize energy consumption and extend battery life, the system can be configured to operate in intermittent mode. In this configuration, the Arduino MKR 1310 and selected sensors (HM3301 and SCD30) remain in a low-power sleep state for most of the time, waking only every 15 minutes to take readings and transmit data. However, the Grove MQ9 sensor, due to its requirement of a 24-hour preheating period, remains continuously active.

The duty cycle for the active components is defined as:

$$\text{Duty Cycle}=\frac{\text{Active Time}}{\text{Total Time}}=\frac{30\text{s}}{900\text{s}}=0.0333 \quad (6)$$

The total average power consumption of the system is given by:

$$P_{total}=3.48+12.49+12.49+750=778.46\text{mW} \quad (7)$$

Thus, the daily power consumption (DPC) is:

$$\text{DPC}=0.778\text{W}\times 24\text{h}=18.67\text{Wh/day} \quad (8)$$

The energy deficit (ED), representing the shortfall between energy consumption and solar power input (SPI), is calculated as:

$$\text{ED}=18.67-17.5=1.17\text{Wh/day} \quad (9)$$

The battery life (BL), assuming the same additional solar input if full power mode, can be estimated by:

$$\text{BL}=\frac{29.6\text{Wh}}{1.17\text{Wh/day}}\approx 25.3\text{ days} \quad (10)$$

On average, the system consumes 0.778 W (7), resulting in an energy deficit of 1.17Wh/day (8). Under these conditions, the battery would last approximately 25.3 days (10), making this setup viable for long-term operation in areas with moderate sunlight (approximately 5 hours of sunlight per day).

To achieve full system sustainability, the required power input (RPI) is:

$$RPI=\frac{18.67Wh/day}{5h}=3.73W \quad (11)$$

For complete self-sufficiency, a solar panel capable of providing at least 3.73 W is required. However, to account for periods of insufficient sunlight, it is advisable to use a solar panel with a higher power output. For example, a 10 W solar panel, under the same sunlight conditions, would provide 50Wh/day, resulting in a surplus of 11.6Wh/day. This excess energy would be ideal for extended periods of low sunlight, improving the system's reliability and long-term viability as well for a self-sustainable solution.

C. Node-Red Dashboard Design

Fig. 3 presents a map displaying icons with the precise locations of IoT devices. This visualization enables users to identify the exact position of each device and access the sensor data being transmitted in real-time.

Fig. 3. Mesh map showing sensor location on Node-Red Dashboard

Fig. 4 demonstrates the user's ability to view sensor data and obtain a fire risk assessment based on the collected information. Additionally, users can request a new data reading from the IoT device to ensure the most recent and accurate data is available for analysis.

Fig. 4. IoT device with Sensor Data on Node-Red Dashboard

V. Conclusions

This paper presented an IoT-based wildfire detection system designed to provide early warnings and real-time monitoring in remote areas. The system utilizes LoRaWAN for long-range, low-power communication, coupled with a variety of environmental sensors to detect conditions that indicate wildfire risks. The integration of solar panels for energy supply ensures that the system can operate autonomously in off-grid locations. Through initial testing, the system has shown promising results in terms of energy efficiency and data accuracy. However, further refinements are necessary to optimize its performance in real-world scenarios.

The validation of the hypotheses produced varied outcomes. Hypothesis 1 (RQ1), proposing the development of a self-sustaining, low-cost IoT device, was mostly validated, though solar power optimization remains necessary. Hypothesis 2 (RQ1), concerning the triangulation of fire events using a mesh network, could not be fully achieved due to acquisition constraints. For Hypothesis 1 (RQ2), the system successfully communicated with the LoRaWAN gateway, validating the use of LoRaWAN for long-range communication. Finally, Hypothesis 2 (RQ2), which aimed to create a dashboard for real-time data visualization, was fully validated with an effective implementation.

A. Limitations and Future Work

While the proposed system offers an approach to wildfire detection, certain limitations were identified that must be addressed in future iterations.

One key limitation is the need for more concrete functionality and efficiency tests in real-world scenarios While controlled experiments have provided valuable insights, field tests are necessary to evaluate the system's reliability and performance under varying environmental factors such as signal interference, terrain, and weather conditions.

Another limitation is the current solar power setup. Although the system is designed to be energy-efficient, the solar panel used in this project does not provide sufficient energy during periods of moderate sunlight. Future work must use a more powerful solar panel and make the system fully self-sustaining. Additionally, upgrading the solar power manager to a version capable of charging the battery with higher currents will ensure continuous operation, even in less ideal weather conditions.

Finally, the system currently uses the MQ9 CO sensor, which requires a 24-hour stabilization period before it can provide reliable data. This long pre-heating time challenges the system efficiency. Future work will involve identifying a more efficient CO sensor that not only consumes less energy but also has a shorter stabilization time.

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