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Role of Environmental Engineers in Minimizing Wildfire Damages

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Abstract

The impact of forest fires is a significant concern when it comes to the loss of our natural atmosphere. These fires are often sparked by human activity, as well as by natural elements like wood, stone, and plants. To reduce the risk of forest fire disasters while promoting economic development, we need to consider the ecological changes that come with it. This framework model aims to process data and develop new techniques to keep firefighters updated. In this research, we focus on monitoring flames, humidity, temperature, and smoke detection. We'll evaluate forecasts using innovative IoT platforms to create a software solution that leverages data gathered through sensing and networking capabilities, all supported by cloud computing in Wireless Sensor Networks (WSNs). The main goal of this study is to detect fires in various locations, identify wildfire incidents, and prevent them before they escalate into serious threats. By planning the infrastructure of sensor networks for wildfire detection systems, we can spot fires early on, before they spread across large areas. The device will be equipped with multiple sensors to monitor flames and movement, and it will be strategically placed after thorough surveys. The data collected by these sensors will be sent to devices located in various areas. The system will then process this information and simultaneously relay it using a GSM module to the nearest fire service station, pinpointing the fire's location with the help of a GPS module. Some of the sensors used in this system include humidity sensors, temperature sensors, smoke sensors, fire sensors, and ultrasonic sensors.

Keywords: Environmental Engineers, Wildlife Damages, Sensor Network (SN)

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Introduction

In the past, changes in the environment, along with human activities, significantly impacted atmospheric conditions. These events include extreme heat, droughts, sandstorms, floods, hurricanes, and wildfires. These fires have had a profound effect on both local and global ecosystems, leading to destruction of infrastructure, injuries, and disasters in habitats. Consequently, identifying fire locations and accurately assessing the type, size, and impact of these incidents over large areas is becoming increasingly crucial. Governments and regulatory bodies often struggle to predict large-scale fire incidents, whether they stem from natural causes or human actions, resulting in substantial losses of money, property, and wildlife (Corona et al., 2015). To mitigate these issues, it's essential to anticipate conditions by understanding the causes of disasters beforehand and providing swift recovery plans after a tragedy strikes. Sensor networks (SN) act like a remote control, playing a vital role in data communication and proving beneficial in these situations. Wireless sensor networks (WSN) utilize technologies that emphasize the need for rapid rescue efforts during disasters. SN is a self-governing decentralized network of sensors that monitors environmental and physical variables. It consists of interconnected sensor nodes that share data and information with one another. These nodes collect information about the environment, such as weather conditions, pressure, and humidity, and then send it to a central base station. Depending on the type and severity of the data collected, the entry node either forwards the information to a network or triggers an alert or action. Potential applications include weather and forest monitoring, combat surveillance, environmental monitoring, and tracking the movements of both humans and wildlife in forests and borders. In WLANs, researchers use the air as a neutral broadcast medium for wireless communication. However, other standards struggle to connect with WSNs, which is essential for terminals in a native zone network (NZN) to communicate effectively. The main difference is that, unlike devices in Local Area Networks, sensors operate on a very small amount of energy (National Academies of Sciences et al., 2019). This creates a need for innovative, energy-responsive MAC protocols. The Internet of Things (IoT) is a high-level automation and analysis framework that encompasses ordering, discovery, big data, and sensor technology to create comprehensive systems for products or services. When applied to the design of any transaction or platform, these systems enhance simplicity, management, and functionality. Thanks to their unique adaptability and ability to fit into any environment, IoT systems have applications worldwide. Through smart devices and well-regulated technologies, they improve data collection, automation, tasks, and much more. In today's rapidly changing global economic, demographic, social, and environmental landscape, governments, local authorities, researchers, businesses, and individuals need to recognize the value of the resources found in forests—not just from a biodiversity perspective, but also considering the economic benefits that forests provide. Therefore, any significant threats to these vital environmental assets must be identified, planned for, and addressed using the most effective and modern economic strategies and technological means. One of the biggest threats to our forests comes from wildfires. These fires can be sparked by both natural causes and human activities (Calkin et al., 2014). For instance, many forest fires start naturally, often due to lightning strikes that ignite the trees. While rain can help put out these fires, it can also cause significant damage beforehand. High temperatures and dry conditions create the perfect environment for a fire to start. On the other hand, human-caused fires can be triggered by sources of heat like campfires, cigarettes, or electrical sparks coming into contact with flammable materials. In India, forests have been particularly affected by fires, a situation worsened by the growing population of people and livestock, which increases the demand for forest products. The causes of forest fires can be broadly categorized into two groups: natural and human-related. Natural causes are typically linked to weather conditions such as heat, wind, and humidity levels, as well as the duration of dry spells. Other natural factors include bamboo erosion due to strong winds and sparks from debris that can ignite dry leaves on the forest floor. Human-related causes often stem from activities and practices related to forest management (Arab et al., 2021).

Literature review

Advancements in Remote Sensor Networks can help prevent disasters, but they also play a crucial role in disaster preparedness, such as in prediction and early warning systems. This means that the Internet of Things (IoT) can compensate for a lack of infrastructure, especially in developing and vulnerable regions. For instance, consider how we monitor forest fires: sensors placed on trees can gather data to alert us when a fire breaks out or when there's a significant risk, based on factors like temperature, humidity, and CO2 levels. If these indicators reach a critical threshold, early warning systems can notify nearby residents and request assistance. When firefighters arrive, they already have important information about the fire's location and spread. Additionally, various IoT technologies are being developed for different types of disasters, such as microwave sensors that can detect ground movements before and during earthquakes, or infrared sensors that can monitor floods and track people's movements. IoT advancements should not only enhance disaster preparedness but also improve resilience in the face of calamities. The extensive network of IoT-enabled devices—often battery-powered and capable of remote operation—can significantly

contribute to community resilience when disasters strike (Rigolot et al., 2009). IoT devices should allow for limited communication options, like emergency text messaging, when traditional communication systems are down. While disaster resilience isn't their primary purpose, this ability to provide an alternative means of verbal exchange is incredibly valuable in areas where conventional infrastructure is weak, vulnerable, or completely absent, as illustrated by the following example. Wildfires are a common issue that significantly impacts terrestrial, aquatic, and various ecosystem systems around the globe. Every year, the world faces devastating wildfires that consume thousands of hectares of forest, leading to negative effects on biodiversity, land use, and landscape stability. Therefore, we need to examine the theoretical connections between fires using a scientific approach to find ways to integrate applications and service providers. This involves understanding forest vegetation dynamics in relation to fire regimes, the role fire plays in the provision of services, and the social context surrounding fire applications. This knowledge can help the country understand the behavior of local forest inhabitants and plan for landscape-level management accordingly. However, climatic patterns will complicate fire events by altering the conditions within that framework. The most frequent threat in forests is, without a doubt, wildfires. These fires are as much a part of the forest as the trees themselves. They pose a risk not only to the wealth of forested areas but also to the overall picture of fauna and flora, significantly threatening biodiversity and the environmental health of a region (Finney, 2021).

Methodology

We're excited to introduce an innovative architectural framework aimed at tackling forest fires by utilizing various parameters to gather sensor data from devices. This framework is designed to pinpoint the best platform and pathway for communicating and transferring data to the IoT data center via a wireless network. Each parameter is monitored regularly, and if the readings meet or exceed the predetermined values, they are logged in the database and sent to the network. This system is incredibly useful for detecting fires through a range of sensor devices and comparing their readings to established thresholds. When a value hits the mark, it checks against another parameter, and if both conditions are met, the data is swiftly communicated to the IoT center. The main goal of this project is to create a system that can effectively monitor and predict forest fires. The framework is built for processing data from sensors that are integrated into the architectural model. This model collects data and manages it through devices, allowing for real-time viewing on an IoT platform and secure storage in the cloud (Kaloudis et al., 2010). Additionally, when sensor data hits a critical threshold, it triggers an alarm to alert authorized personnel to take preventive measures.

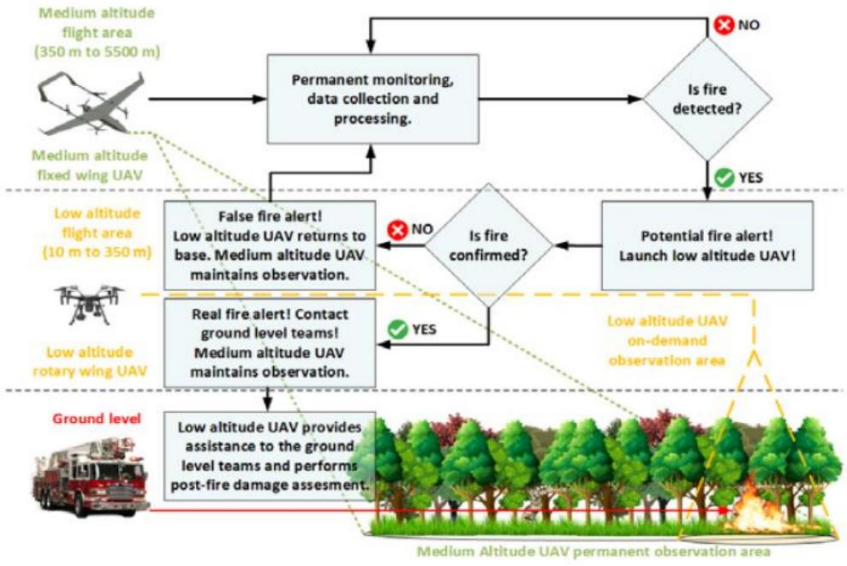


Fig. 1: Unmanned Aerial Vehicles Detecting Forest Fire

The system we've developed has a lot of potential for improvement, especially when it comes to analyzing different data strategies and enhancing performance. It uses three sensors to monitor conditions that could predict forest fires, alerting the appropriate authorities to help protect our natural environment. The Forest Fire Prevention Algorithm (FFPA) plays a crucial role in this process, utilizing various parameters to determine when action is needed. If the readings from the sensors hit a certain threshold, the system triggers a response to prevent a fire at a specific location in the forest. The steps in this algorithm are designed to predict where a fire is likely to occur based on the surrounding

area of a given node. By identifying the node, we can pinpoint the exact location in the forest that may be at risk, allowing us to take proactive measures to avert a disaster. The FFPA processes sensor data, comparing it against both independent and dependent parameters, such as temperature (t), humidity (h), smoke (s), flame (f), and various threshold values (v1, v2, v3). When the conditions are met, the system quickly relays information through the sink node to the IoT Center.

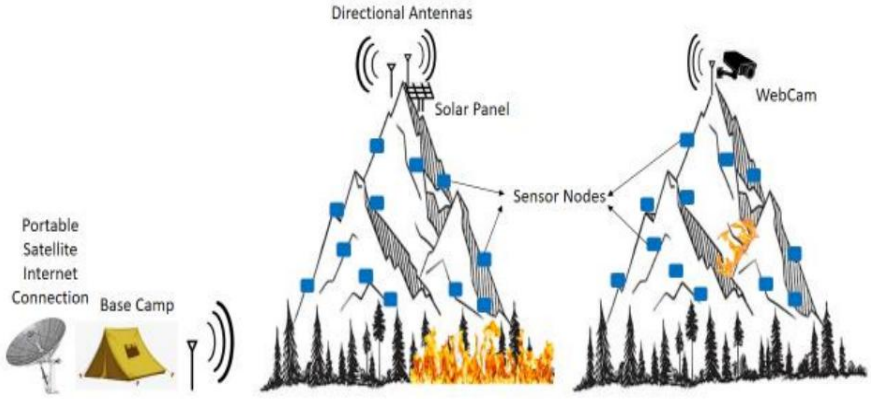


Fig. 2: FireWXnet

Let's talk about how we can keep an eye on fire accidents in forested areas and take proactive steps to prevent these disasters. We need to check each parameter against a threshold value (TH). If everything checks out, we send the information through the network and trigger an alarm based on the EDTA method, which helps us act quickly to prevent and control fires in the forest. Each monitoring node looks at four key parameters against the TH value, focusing on detecting forest fires through data verification and established fire detection rules, while also considering changes over time with the help of the EDTA algorithm (Jazebi et al.,2019). Fires are identified by processing the node parameter values using the EDTA algorithm, which categorizes the risk into three levels: Low, Medium, and High. Depending on the level of risk, we take steps to alert the appropriate authorities if all the sensing criteria are met, ensuring a swift response to any potential fire threat.

Results and Discussion

Wildfires can typically be categorized into three types: natural wildfires and managed wildfires. Natural wildfires occur when heat generated from debris and various ecosystems during the summer months is exacerbated by human negligence. On the other hand, managed wildfires are intentionally set by local residents.

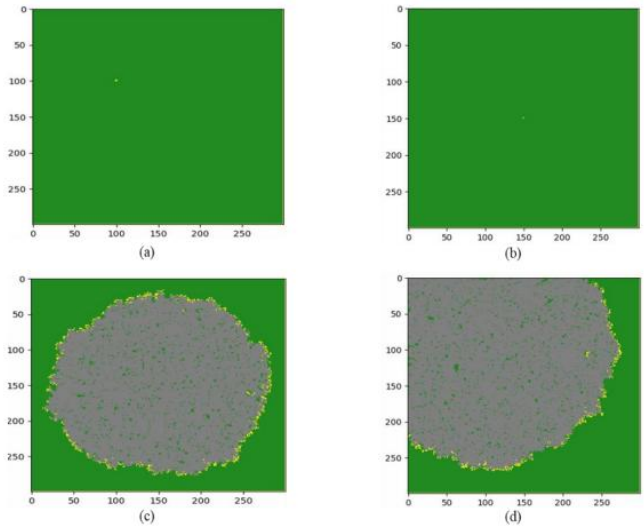


Fig.3: Fire Spread with Different Conditions

A coronet heater can be particularly dangerous in evergreen areas due to the fact that its resinous texture can ignite logs quite aggressively. On sloped surfaces, if the flue points downward, the heat can quickly rise, causing warm air to flow up the slope and spread flames. If the fire starts to climb, there's a much lower chance of it spreading downward. Fires are a serious cause of forest degradation and have far-reaching negative impacts on the environment, economy, and society, including: the loss of valuable timber resources, degradation of catchment areas, destruction of biodiversity, and the extinction of plants and animals. Additionally, there's the loss of wildlife habitats and the consumption of wildlife, a decrease in natural regeneration, and a reduction in forest cover. Climate change is exacerbated, carbon sink resources are diminished, and carbon dioxide levels in the atmosphere rise. This can alter the microclimate of the planet, leading to undesirable living conditions. Soil erosion can affect soil productivity and agricultural output, while the depletion of the ozone layer poses health risks that can lead to diseases. Furthermore, the loss of livelihoods for indigenous peoples and rural communities is significant, as around 300 million people directly depend on various non-wood forest products from forested areas for their livelihoods.

Conclusion

The number of wildfires in the country is on the rise, with more land being scorched each year. The main reason for this troubling trend is the fragmented approach to tackling the issue. There's a lack of both national focus and the technical resources needed to support a comprehensive fire management program. Key elements of effective fire management—like establishing fire centers, coordinating among various ministries, securing funding, developing human resources, conducting fire research, controlling fires, and implementing outreach programs—are sorely missing. Given the seriousness of the situation, it's crucial to make significant improvements to the country's fire management strategy. The Ministry of Environment and Forests in the Indian Government has drafted a national policy for fire management. This policy aims to introduce a well-structured and coordinated fire management program that includes: preventing man-made fires through education and environmental changes. It will involve activities, engineering projects, community engagement, and training and enforcement. The plan emphasizes increasing community involvement through collaborative fire control efforts for fire prevention.

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