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IOT-enabled Anti-poaching System for Protecting Wildlife and Forests Through Advanced Monitoring and Alert Mechanisms

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Abstract

Forests are essential for preserving the intricate ecological harmony of our planet, serving as critical habitats for numerous animal species. Unfortunately, this equilibrium is increasingly jeopardized not only by illegal logging but also by the scourge of animal poaching the global demand for exotic animal parts and products fuels poaching, which presents a major menace to wildlife populations across the globe. The repercussions of poaching extend far beyond individual animals. It disrupts entire ecosystems, destabilizing predator-prey dynamics and leading to imbalances that can have cascading effects throughout the food chain. Additionally, the depletion of keystone species resulting from poaching can cause significant and enduring impacts on the general well-being and adaptability of ecosystems. To address the menace of poaching, our proposed IoT-enabled Anti-poaching system offers a multifaceted approach. While it primarily focuses on detecting and deterring illegal logging activities, it also serves as a powerful tool in combating wildlife crime. By deploying a network of sensors and employing artificial intelligence algorithms, the system can detect and respond to suspicious activities in real-time, thereby providing enhanced protection for vulnerable animal populations. The data collected by the Anti-poaching system can be invaluable for law enforcement agencies and conservation organizations in their efforts to combat wildlife trafficking networks. By leveraging technology to disrupt poaching operations and protect endangered species, we can work towards ensuring a more secure future for wildlife and the ecosystems they inhabit. In addition to its primary focus on combating illegal logging and poaching, our proposed IoT-enabled Anti-poaching system offers comprehensive protection for wildlife and their habitats. Continuously observing forested regions enables the system to identify and address various threats, including habitat encroachment, conflicts between humans and wildlife, and the introduction of invasive species. Furthermore, by utilizing advanced tracking and identification technologies, it can aid in the conservation efforts of endangered species, allowing for targeted interventions such as habitat restoration and captive breeding programs. By implementing these strategies, our Anti-poaching system plays a role in conserving biodiversity and protecting our planet's invaluable natural heritage.

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INTRODUCTION

Forests cover approximately 75% of Earth's biosphere and contain over 80% of the total plant biomass. India, along with eight other countries,

collectively contributes to 67% of the global forest area [1]. According to the Indian State of Forest Report (ISFR) published in 2019, dense forests cover 3% of India's land, while both dense and open forests collectively occupy 18% of the country's area, as shown in (Figure 1). However, there is a pressing issue of illegal logging in protected areas, driven by the lure of profits in various markets. The escalating demand for commodities such as palm oil, timber, and paper products is fueling illicit activities, posing a grave threat to the delicate balance within these ecosystems [2].

Forests serve as crucial habitats for a diverse array of animal species and provide shelter, sustenance, and breeding grounds. This sustains the vibrancy and health of ecosystems. Although forest fires have historically been part of natural cycles, human activities have exacerbated their frequency and intensity. Factors such as strong winds and abundant fuel sources, such as fallen leaves and old wood, contribute to the severity of these fires, causing extensive damage to ecosystems and triggering complex changes in forests. Understanding the interplay between natural fire patterns and human impacts is essential for devising effective strategies to manage fires and safeguard forest ecosystems. [3, 4].

Wireless Sensor Networks (WSNs) have emerged as transformative technologies that have revolutionized various aspects of daily life. By combining sensor-equipped nodes with communication modules and low-power microprocessors, WSNs offer compact, affordable, and energy-efficient solutions suitable for diverse applications. From monitoring and maintenance to security and control systems, WSNs actively contribute to numerous fields. This project specifically focuses on leveraging WSNs to address the critical issue of detecting the illegal logging of economically valuable trees. Furthermore, this research proposes a comprehensive approach for monitoring and conserving wild animals within forest reserves.

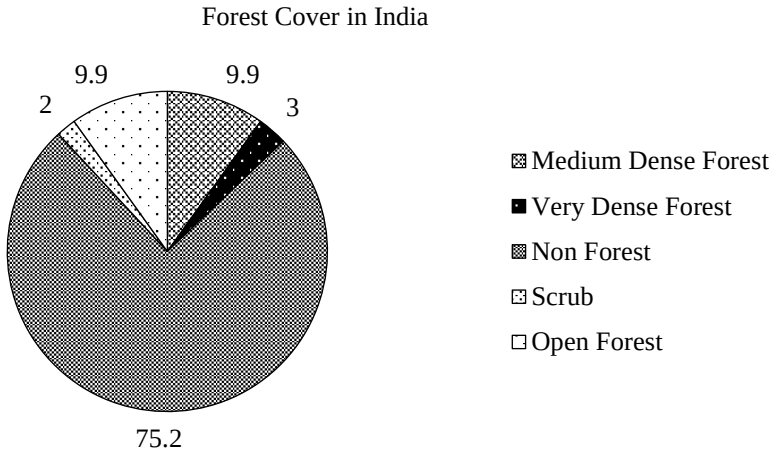

Figure 1. Forest cover in India.

By integrating biotelemetry, sensor networks, and data analysis, this project aims to gain unprecedented insights into animal health and guide conservation efforts [5]. Non-invasive containment strategies, such as bioacoustic deterrents, have been explored to prevent animal encroachment and ensure the well-being of forest fauna. By harnessing technology and fostering collaboration, this research endeavors to revolutionize the management of wild animal health within protected areas [10].

In the face of escalating pressure due to global economic growth and urbanization, forests demand vigilant monitoring of conservation, production, and protection endeavors. Forest conservation, crucial for combating climate change through carbon sequestration, necessitates stringent oversight, which is challenging because manual monitoring is required [10]. Forest reserves, which serve as dedicated conservation areas, play a pivotal role in safeguarding biodiversity, facilitating research, and providing controlled environments for studying ecosystems. However, monitoring these vast reserves of

unauthorized activities poses significant logistical challenges. Integration of technologies such as satellites and artificial intelligence (AI) aids in real-time surveillance, strengthens conservation efforts, and ensures the sustainable management of these critical natural resources [15].

RELATED WORKS

[1] The research work Titled "The Smart Solar Powered System for Unauthorized Logging" presents a comprehensive solution utilizing a network of diverse sensors—such as infrared, vibration, tilt, and flame sensors—to effectively identify human presence involved in unauthorized tree felling and forest fires. The collected sensor data are transmitted to a centralized server for analysis and programmed to promptly trigger alarms in cases of logging or fire outbreaks. A critical facet of this system is its reliance on solar power, ensuring sustainability and minimizing its environmental impact. The utilization of these sensors not only improves accuracy but also enables swift intervention while minimizing false alarms. Real-time data analysis empowers forest management by providing timely insights and allows proactive measures to counter potential threats. The reliance of this innovative system on renewable solar power aligns with sustainability goals, reducing its ecological footprint while efficiently safeguarding forests. Its ability to integrate diverse sensors coupled with real-time analysis is a promising tool in the ongoing battle against unauthorized logging and forest fires, offering a proactive and technologically advanced approach to forest conservation and protection.

[2] The research work titled "Solar Operated IoT based Smart System to Monitor Illegal Logging" presents a comprehensive approach to forest surveillance. The utilization of vibration and tilt sensors for logging and tree fall detection shows a proactive stance against unauthorized activities within forested areas. Moreover, the incorporation of infrared (IR) and flame sensors serves as a preventive measure against potential wildlife threats and forest fires, thereby ensuring a holistic protection mechanism. By harnessing solar power and employing the IoT technology, this system demonstrates a sustainable and efficient monitoring solution. The autonomous nature of the system, powered by solar energy, not only reduces operational costs, but also minimizes the environmental footprint. It is imperative to acknowledge the potential limitations and challenges of this system. The occurrence of false alarms triggered by natural phenomena, such as storms causing vibrations, underscores the necessity for refining sensor sensitivity to distinguish between intentional logging and environmental disturbances. The constraint of the Wi-Fi communication range owing to line-of-sight restrictions poses a challenge in ensuring comprehensive coverage across vast forested areas.

[3] The research work Titled "GreenSoal: Illegal Tree Logging Detection System Using IoT" presents a sophisticated approach to combat illegal logging by leveraging advanced technology. The strategic placement of microphones further enhances the system's accuracy in detecting and pinpointing the source of the detected sounds, enabling swift and targeted intervention by forest authorities. The utilization of Forest Sentinels' hop-to-hop network addresses communication challenges often encountered in densely forested regions, ensuring seamless data transmission and real-time alerts. This comprehensive solution not only contributes significantly to forest conservation efforts but also boasts versatility and cost-effectiveness in its deployment across diverse forest environments. The implementation of such a system necessitates substantial initial investment, both in infrastructure and in ensuring robust cybersecurity measures to safeguard the sensitive data collected by the system. Despite the impressive performance of the system in field tests, certain limitations must be considered for optimal functionality. The system's long-range communication capabilities solidify its position as a key asset in the conservation arsenal, enabling proactive measures to combat illegal logging and protect invaluable forest ecosystems.

[4] The research work titled "Fully Smart Fire Detection and Prevention in Authorized Forests" introduces a comprehensive system designed to proactively identify and mitigate forest fires. This intricate system amalgamates temperature, smoke, and color sensors strategically positioned within forests, offering a multifaceted approach for fire detection. By assimilating data from these sensors and incorporating satellite imagery, the system achieves a nuanced understanding of the potential fire risks. The determination of fire intensity is facilitated through the application of Byram's formula, which provides a quantitative measure for prompt and effective responses. Upon confirming the presence of a

fire, unmanned aerial vehicles (UAVs) were swiftly deployed using the Dijkstra algorithm to navigate to the nearest water source. These UAVs are equipped with water balloons, enabling rapid and targeted water delivery to extinguish flames and curtail the spread of fires. Addressing these concerns is paramount to ensuring the sustained efficacy of the system in safeguarding forested areas. Although investment hurdles and cybersecurity considerations are intrinsic to the implementation of such advanced technologies, the system has demonstrated remarkable capabilities in simulated scenarios, boasting an impressive fire detection accuracy rate exceeding 90%. This validation underscores the system's potential to revolutionize forest fire management, offering a proactive and technologically advanced solution for safeguarding vital ecosystems.

[5] The research work titled "Real-Time Forest Anti-Smuggling Monitoring System based on IoT using GSM" introduces a comprehensive setup involving tree and server units, aiming to revolutionize forest monitoring and protection. The sensor-based monitoring of tree health by the tree unit, coupled with data transmission to the server unit, marks a proactive approach to forest surveillance. Despite its advantages, the implementation of this system presents multifaceted challenges. The upfront costs associated with setting up and maintaining such a sophisticated monitoring network pose considerable hurdles. Concerns regarding cybersecurity are large and require robust measures to safeguard sensitive data transmitted between units. Furthermore, limitations in remote areas, particularly the range of communication via the GSM, could hinder the effectiveness of the system in certain regions. Addressing these challenges requires meticulous planning and strategic measures to ensure the efficiency and reliability of the system. While simulations exhibit impressive accuracy levels exceeding 90% in detecting simulated instances of tree cutting or potential threats, the estimated response time of less than 20 min from detection to alert generation shows the system's ability to initiate timely interventions. However, practical implementation and real-world scenarios may introduce additional complexities that necessitate the continuous refinement and adaptation of the system to ensure optimal performance. Collaborative research and development efforts are imperative to address these challenges and elevate the system's effectiveness in combating forest smuggling and preserving natural ecosystems.

[6] The research work titled "Protocol Implementation for Wireless Sensor Network for Anti-Poaching of Trees" introduces a novel approach to combat poaching activities within forested areas. By strategically deploying low-cost sensor nodes throughout the forest, this system aims to detect and track vibrations associated with poaching incidents, effectively communicating these events to a centralized base station. The segmentation of nodes into ordinary nodes and area-based nodes enhances the capability of the system to comprehensively monitor and identify poaching activities within designated areas. One of the primary advantages of this system lies in its efficient use of a wireless sensor network, leveraging accelerometers within nodes to swiftly detect and respond to instances of poaching. The system's strengths include wide coverage, minimal power consumption, self-sustainability through solar power, and overall cost-effectiveness. The system's range and security measures require stringent assessments to ensure reliable and secure data transmission between nodes and the central base station. Environmental factors may also affect node performance and signal transmission, necessitating adaptability to varying conditions. Nevertheless, the commendable attributes of the system, including high efficiency and low power consumption facilitated by solar energy, enable prolonged operation and reduce the need for frequent maintenance.

[7] The research work Titled "Design and Development of Wireless Sensor Node for Anti-Poaching" introduces an innovative system leveraging sensor nodes equipped with accelerometers to detect and respond to vibrations associated with illegal tree felling. These sensor nodes function by wirelessly communicating with a central base station and utilizing an area-based routing protocol to relay alerts in real time. This proactive approach aims to trigger alarms or notify authorities promptly upon detecting suspicious activities, thereby enabling swift intervention against poaching incidents within forested areas. However, inherent limitations, such as range constraints, security vulnerabilities, and potential environmental factors, require careful consideration for the system's effective deployment and sustained performance. Notwithstanding these challenges, the system demonstrates significant

advantages, notably in power consumption optimization, enabling prolonged operation through efficient energy utilization. The scalability of the system is a key attribute that allows seamless adaptation to different plantation sizes without compromising its cost-effectiveness, facilitated by the integration of affordable sensor nodes. The emphasis on energy efficiency not only ensures long-term functionality but also aligns with sustainable practices by reducing the environmental footprint of the system. However, the limitations of the system, particularly concerning its range and security, demand robust solutions to guarantee reliable and secure data transmission between sensor nodes and the base station, thereby fortifying its efficacy in combating poaching activities.

[8] The research work Titled "Design WSN Node for Protection of Forest Trees Against Poaching Based on ZigBee" presents a cutting-edge system designed to employ technology for combating poaching in forested areas. The system integrates a range of sensors, including a gyro, thermistor, Wi-Fi, and GSM modules, to monitor and protect trees from illicit activities. By focusing on the real-time measurement of temperature and tilt angles of trees, the system can effectively detect suspicious activities, such as unauthorized tree cutting or potential fire incidents. In the event of such anomalies, the system ensures swift response mechanisms by alerting officials through SMS notifications and cloud-based dashboards, thus enabling timely intervention to mitigate potential threats. A notable feature of this system is its capacity for cost effective monitoring. However, this research acknowledges the potential for false alerts arising from natural tree tilting, emphasizing the need for a nuanced approach to data interpretation and response strategies. Additionally, concerns have been raised regarding the reliance on batteries for power and the ongoing maintenance requirements of deployed sensor nodes. Despite these considerations, the proposed system represents a promising technological advancement in leveraging wireless sensor networks to protect forest trees against poaching, contributing to global conservation efforts and fostering the sustainable management of precious natural resources.

[9] The research work Titled "IoT-based Anti-Poaching Alarm System for Trees and Wildlife Monitoring System in Remote Area" puts forth a comprehensive system designed to combat poaching and monitor wildlife in remote and often inaccessible areas. The system harnesses the power of the Internet of Things (IoT) by deploying wireless sensors to conduct real-time monitoring of forest cover and identify and thwart illegal activities. The primary objective was to achieve heightened accuracy in forest monitoring by strategically placing sensor-equipped nodes throughout the forest, thereby facilitating seamless communication among them. Overcoming connectivity challenges is imperative for the successful implementation of the anti-poaching alarm system, as disruptions in communication could compromise the effectiveness of the monitoring network. As the system endeavors to safeguard not only trees but also wildlife, it becomes crucial to strike a balance between the deployment scale and the associated costs, thereby optimizing the efficacy of the system in conserving biodiversity and preserving the delicate ecosystems in remote regions. Despite the inherent challenges, this research showcases a pioneering step towards leveraging IoT for anti-poaching efforts, reflecting a commitment to innovative solutions for the protection of our invaluable natural resources.

[10] The research work titled "Anti-Poaching of Trees in Forest-Based on IoT" introduces an innovative IoT-based system aimed at curbing unauthorized tree-cutting incidents and forest fires. The system utilizes a combination of tilt, sound, and temperature sensors strategically placed to detect anomalies in the forest environment. Upon the breach of predefined thresholds in the sensor data, the system triggers the activation of buzzers and water pumps, providing an immediate response mechanism to mitigate potential threats. The strength of this solution lies in its simplicity and cost-effectiveness, which are attributed to the straightforward nature of the employed sensor modules. Communication range issues further compounded these challenges, restricting the reach of the IoT network, especially in vast and remote forested areas. This study recognizes the possibility of frequent false alerts arising from the system's sensitive triggering mechanism, prompting the need for a refined approach to data interpretation and response protocols. Despite these challenges, the proposed IoT-based anti-poaching system represents a commendable effort to address critical issues related to unauthorized tree cutting

and forest fires. By leveraging technology to create a responsive and cost-effective solution, this research contributes to the ongoing global efforts to preserve and protect forests, underscoring the importance of continued innovation and refinement in environmental monitoring systems.

[11] The research work Titled “IoT-based Anti- Poaching Alarm System for Valuable Trees” introduces a pioneering system designed to counter poaching activities through the integration of a microcontroller and Wireless Sensor Network (WSN) technology. The system employs a sophisticated approach involving the detection of vibrations caused by tree cutting facilitated by a 3-axis MEMS accelerometer. Upon detection, warnings are promptly transmitted using Xbee RF modules, adhering to the Zigbee protocol. This strategy enabled the system to effectively monitor and safeguard valuable trees in remote forested areas. Despite its effectiveness, this study acknowledged a significant limitation in the communication range of the system. The Zigbee protocol, with a data rate of 250 Kbps, can cover a maximum distance of approximately 30 m. Although this range may be suitable for certain applications, it poses challenges in monitoring expansive and often inaccessible forested regions. The constrained communication range restricts the scalability of the system, necessitating careful consideration of deployment strategies to achieve a comprehensive coverage. Although not extensively discussed in the research, the system power consumption remains a crucial factor in determining the overall sustainability and longevity of the deployed nodes. To address these limitations, future iterations of the system may explore enhancements in communication protocols or the incorporation of additional technologies to extend the monitoring range. Despite these considerations, this research marks a commendable effort in leveraging IoT technology to protect valuable trees, highlighting the ongoing need for technological advancements in conservation efforts to combat poaching and preserve biodiversity in diverse ecosystems.

[12] The research work Titled “A Design and Development of Smart Forest Alert Monitoring System using IoT” introduces a wireless sensor network system aimed at enhancing safety and monitoring capabilities in forests for both the environment and travelers. The system employs multiple sensor nodes strategically placed to collect crucial data, including temperature, humidity, and sound levels. These data are then transmitted to a central node for processing and analysis, enabling the system to detect various events, such as forest fires, human intrusion, or other potential risks in real time. The overarching goal is to establish an efficient energy system that continuously assesses the conditions in forested areas, contributing to the proactive management and preservation of these vital ecosystems. Despite its innovative approach, this study acknowledges the challenges that may arise in the deployment of such a system. Providing power to dispersed sensors scattered across vast geographical regions poses a significant challenge and requires careful consideration of energy-efficient solutions and alternative power sources. Additionally, ensuring reliable data transmission over wide areas introduces complexities, as factors such as signal degradation and environmental obstacles may impact the effectiveness of the wireless sensor network. Addressing these challenges is crucial for the successful implementation and scalability of smart forest-alert monitoring systems. Strategies to optimize power consumption, explore renewable energy sources, and improve data transmission reliability are instrumental in overcoming these hurdles. This study contributes to the growing field of IoT-based environmental monitoring, emphasizing the importance of technological advancements in safeguarding forests and facilitating informed decision-making for sustainable forest management and conservation.

[13] The research work Titled “IOT Based Anti-Poaching Sensor System for Trees in Forest” proposes an anti poaching system based on the Internet of Things that has been developed to protect trees by utilizing sensors of detecting tree cutting activities, forest fires and other unauthorized actions. The system incorporates various types of sensors, including tilt sensors, flame sensors, and vibration sensors, among others, to monitor trees. When illegal poaching activities are detected, SMS alerts are triggered to notify officials so that appropriate actions can be taken. Cloud dashboards also provide monitoring capabilities. The primary goal of this system is to mitigate threats related to tree poaching and deforestation, which may pose challenges when integrating module types across forest areas.

[14] The research work Titled "Smart Forest: An IoT Based Forest Safety And Conservation System" proposes an Developed system to ensure safety in forests by utilizing technology, for comprehensive monitoring. This system incorporates sensors that can detect logging activity, fires, human presence, soil moisture levels, and temperature. All collected data were then transmitted to a platform where they were analyzed and processed using Python. If any threats are identified, such as dangers or risks, SMS alerts are sent to forest rangers and relevant authorities. This system enables data analysis to inform conservation policies and support e-initiatives. However, there are challenges related to powering sensing modules and ensuring reliable data transmission from densely forested areas.

[15] The research work Titled "IOT Based Wildlife Monitoring System" proposes A wildlife monitoring system that utilizes technology with virtual fencing and deforestation monitoring capabilities. The virtual fencing aspect employs sensors. The GPS technology is used to create boundaries around specific areas to monitor animal movements and prevent them from entering dangerous zones. In contrast, deforestation monitoring utilizes sensing techniques along with satellite imagery to detect changes in forest cover and promptly alert authorities about any threats posed to ecosystems. The primary goal of this system is to gain insights into animal behavior while mitigating the impact of human activities on natural habitats through the integration of advanced technology. We acknowledge the challenges related to costs and implementation difficulties that may arise during the process. Table 1 compares the data from different published papers.

Table 1. Comparison Table.

Reference Number	Author	Detecting anti-smuggling of tress	Detects Forest fires	Detection of Wildlife Intrusion	Detecting Wildlife Health	Detecting the location of illegal logging
[1]	S. Mathumitha Murali	✓	✓	×	×	×
[2]	M. Ashok Kumar	✓	✓	×	×	×
[3]	H.M.K.S.Bandaranayake	✓	×	×	×	×
[4]	Venkata ramana	×	✓	×	×	×
[5]	Darshini M.S	✓	×	×	×	×
[6]	Pratiksha Bhuta	✓	×	×	×	×
[7]	Akshay D. Sonwane	✓	×	×	×	×
[8]	Smita Gaikwad	✓	×	×	×	×
[9]	Kavya S	✓	✓	×	✓	×
[10]	S. Sanjay Kumar	✓	×	×	×	×
[11]	Pooja Baraddi	✓	×	×	×	×
[12]	Pooja Baraddi	✓	✓	×	×	×
[13]	Darshan U	×	×	×	×	✓
[14]	Parthiban .M	✓	✓	×	×	×
[15]	Purushottam Rohidas Patil	✓	✓	×	×	×

METHODOLOGY

The central component of our system is the Arduino Uno Microcontroller, which effectively orchestrates and integrates sensors and devices [1]. This plays a crucial role in ensuring the smooth operation and coordination of our anti-poaching system. To provide real-time data and alerts, we incorporated a user LCD display [4], [5]. This display serves as an interface, empowering on-site personnel to respond promptly to detected threats and to facilitate communication and decision-making. MEMS sensors, as outlined in references [7] and [9], are employed to detect irregularities in tree movements or vibrations, significantly contributing to measures against illegal tree felling and enhancing forest resource protection.

Fire sensors have been integrated into our system [10]. These sensors serve as warning systems, enabling rapid responses to prevent damage to the forest ecosystem and aligning with our commitment to forest preservation. In our dedication to wildlife health monitoring, we have included a heartbeat sensor [1] that detects signs of stress or distress among animals, serving as an indicator for poaching

incidents or health issues within the wildlife population. Temperature sensors, labeled in References [4] and [10], play a crucial role in detecting environmental situations such as fires or sudden temperature shifts, which are essential for responding to poaching measures. The alarm system implemented in our system [1] promptly alerts on-site personnel, thereby enhancing the effectiveness of our poaching prevention efforts by facilitating swift action against any threat.

To enable communication between devices and the central server, a Wi-Fi module inspired by References [2] and [3] was integrated, allowing for data transfer and establishing a network that supports real-time monitoring and response. Additionally, incorporating a water pump [7] aids in fire suppression by automatically triggering the spraying of water upon fire detection, minimizing damage, and prioritizing sustainability. The use of rechargeable batteries [5] ensures reliable power supply, guarantees system operation, and extends monitoring capabilities. Positioned cameras, referenced in [2] and [3], act as vigilant eyes to capture evidence and provide insights into animal behavior, thus aiding in identifying threats to the forest environment.

For data processing, storage, and visualization, our system interfaces with a laptop [9], which serves as our command center for wildlife and forest monitoring. The incorporation of Zigbee technology [9] enhances the connectivity capabilities of our system, allowing efficient data transfer between sensor nodes and devices, ultimately improving the efficiency and responsiveness of our communication infrastructure. This interconnected network of nodes forms a mesh that significantly enhances the effectiveness of the proposed poaching prevention system. By synergistically integrating all components, we collect and analyze data promptly to generate alerts effectively and combat threats comprehensively. This holistic solution serves the purpose of preventing poaching activities and monitoring environmental conditions.

CONCLUSIONS

The intended system seeks to address the issue of unauthorized tree felling by employing a range of sensors. These sensors will swiftly alert forest officials whenever a tree is illegally harvested or when it tilts unexpectedly. Additionally, our system includes forest fire detection capabilities, which can promptly notify authorities and potentially activate a water pump to extinguish any detected fires. Furthermore, our system will actively monitor the health and whereabouts of wildlife, alerting authorities if an animal strays beyond the boundaries of wildlife reserves.

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